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ROLLING RESISTANCE OF TIRES MEASURED [illegible] TRANSIENT AND EQUILIBRIUM CONDITIONS ON CALSPAN'S TIRE RESEARCH FACILITY

D.J. Schuring

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16. Abstract

Rolling loss tests were performed on 31 different passenger and 4 light truck tires on Calspan's Tire Research Facility (TIRF) under transient and equilibrium conditions. The tests were designed to determine the effects of load, speed, inflation pressure, tire temperature, slip angle, torque, tire construction, aspect ratio and wheel diameter. In addition, the influences of road curvature (flat roadway, drum) and trip length on rolling resistance were investigated. The results are presented in tables and graphs. They are expressed in terms of 12 power loss descriptors (for each tire), stating initial values, equilibrium values, and distances required to achieve equilibrium, for rolling resistance, contained air temperature, tread surface temperature, and inflation pressure.

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Tires, rolling resistance, power loss,
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PREFACE

One of the objectives of the Department of Transportation's Automotive Energy Efficiency Program (AEEP) is quantitatively to assess the impact of vehicle systems and components on vehicle fuel economy. Variations in tire-rolling resistance contributes to variations in vehicle fuel economy. This work defines these variations.

The work reported herein was performed by the Calspan Corporation for the Transportation Systems Center (TSC) under Contract No. DOT-HS-4-00923 during the period from 1 April 1975 to 31 January 1976. The TSC contract technical manager was Mr. Stephen N. Bobo. The project engineer was Dr. Dieterich J. Schuring of the TIRF Center of Calspan. The test program was performed under the direction of Mr. Ignaty Gusakov, Manager, TIRF Center.

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SYMBOLS AND BASIC EQUATIONS

TEMPERATURES

CAT	Contained air temperature[*]
ST or TST	Tread surface temperature.[*]

FORCES

FR	Rolling resistance of free – rolling tire (always positive) For flat roadway $\mathrm{FR} = \mathrm{FXO}$ For drum $\mathrm{FR} = \mathrm{FXO}\,(1 + \mathrm{RL}/\mathrm{R})$
FRT	Definition:[*] $\mathrm{FRT} = -\mathrm{FX}'$
FX	Longitudinal force, uncorrected for bearing friction torque and thermal drift[*]
FX'	Longitudinal force, corrected for bearing friction torque but not for thermal drift $\mathrm{FX}' = \mathrm{FX} - \mathrm{BFT}/\mathrm{RL}$
FX''	Longitudinal force, corrected for bearing friction torque and thermal drift $\mathrm{FX}'' = \mathrm{FX}' - \Delta\mathrm{FX}$
FXO	Definition: $\mathrm{FXO} = -\mathrm{FX}''$ (always positive)

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[*] Listed on TIRF data printouts (see Table 11).

ΔFX	Offset of FX caused by thermal drift of TIRF balance[*]
FY	Lateral tire force[*]
FZ	Vertical tire load.[*]

MOMENTS

BFT	Bearing friction torque of TIRF balance
MY	Moment of rolling resistance[*]
T	Driving/braking wheel torque.

RADII

R	Drum radius = 33.614 in.
RL	Loaded tire radius.[*]

---

[*] Listed on TIRF data printouts (see Table 11).

MISCELLANEOUS

N	Tire revolutions per minute
P	Tire power loss
	For flat roadway $P = FXO * V$
	For drum $P = FXO\,(1 + RL/R) * V$
P, p	Tire inflation pressure*
SR	Slip ratio $SR = (N * RL)/(168.07 * V) - 1$
TE	Time elapsed*
V	Road speed*
X	Distance traveled
Y	General independent variable
X_{99}	Distance at which state of equilibrium is (practically) achieved
	$X_{99} = 4.61/\lambda$
λ	Exponent in Equation (5), see Figure 18.

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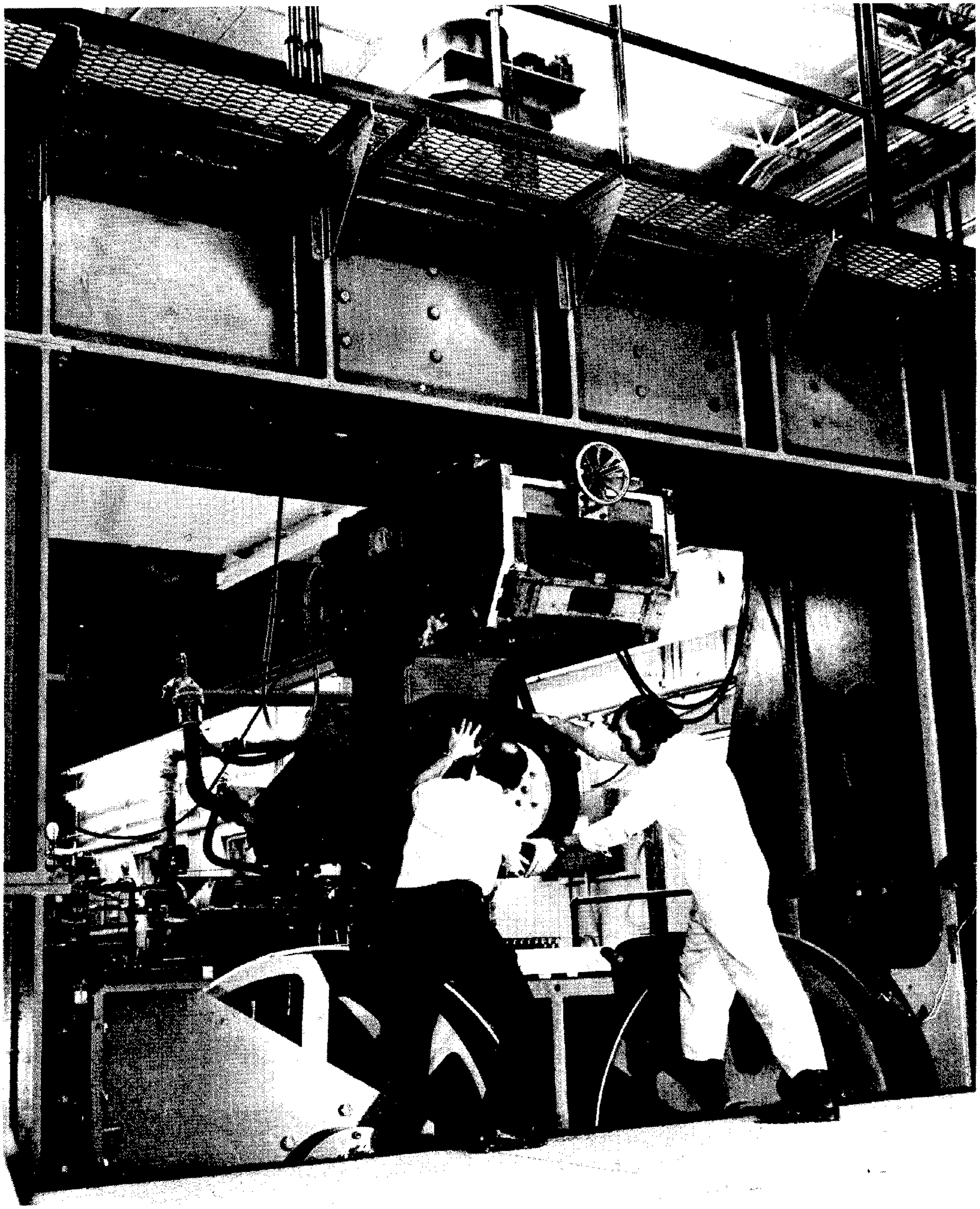
*Listed on TIRF data printouts (see Table 11).

SUBSCRIPTS

D	drum
F	flat roadway
o	initial
∞	equilibrium.



CALSPAN TIRE RESEARCH FACILITY (TIRF)

1. INTRODUCTION

The many studies on vehicle power consumption available in the literature (i.e., Refs. 1 and 2) all indicate that a rather large amount of the engine output is absorbed by the pneumatic tires. For instance, in the Federal Driving Cycle the rolling losses amount to nearly 25% of the total energy input (Ref. 1). This number includes the losses caused by the wheel bearings, but bearing losses are comparatively small. At constant speed without acceleration and deceleration, the rolling losses constitute 32% to 55% of the total energy provided by the engine. The same reference, and our own investigations (Ref. 3), indicate that a reduction in tire rolling losses of, say, 15% would result in fuel savings of 2% to 3%. Clearly, any reduction of the rolling losses would have a marked effect on fuel economy.

Rolling losses are influenced by many factors. For instance, tire rolling losses are strongly dependent on the distance traveled, particularly during the first ten miles or so. Since one third of the total mileage accumulated by automobiles in the USA, and nearly one half of the fuel consumed, is expended on trips under 10 miles of length (Ref. 4), the influence of trip length on tire losses has to be studied very carefully. Other factors of importance are inflation pressure, speed, load, braking/driving, slip angle, tire construction, and rubber compound. A systematic knowledge of all these relations would doubtlessly benefit the search for fuel savings, but although a large number of studies on tire rolling resistance are available (Clark and others compiled a bibliography with 90 references, Ref. 5), a comprehensive experimental research program performed on a large representative sample of contemporary tires is lacking. In addition, many experimental problems are still hampering the exact measurement of rolling resistance.

One problem arises from the temperature sensitivity of the visco-elastic tire material. The heat energy generated in the rolling tire raises its temperature which in turn results in three things -- it decreases the hysteretic losses, it increases the tire pressure, and it increases the heat exchange between tire and environment. As a consequence, the rolling losses decrease until a state of equilibrium is reached. The stabilization process takes about 30 minutes, provided the operating conditions are not changed during this time. In the past, the transient period has been largely ignored; but since a large amount of driving is accumulated on short trips, as noted, more experimentation was needed in this area. This would require rather sophisticated measuring systems and precise control of all pertinent factors -- requirements that are relatively difficult to meet.

Another problem is caused by the fact that a very small force, the longitudinal force F_x, has to be measured with good accuracy in the presence of a very large one, the vertical load F_z. If F_x is measured on the road, these difficulties are compounded by the additional presence of a high noise level caused by vibrations, wind forces, and other uncontrollable variables. On the other hand, measuring the rolling losses in the laboratory on a drum is not satisfactory either, because the curved surface leads to substantially smaller values of F_x (as discussed later).

All these problems are minimized on the Calspan Tire Research Facility (TIRF) (Ref. 6). TIRF provides a flat rigid surface, and it has a precise control and balance system that can measure all variables of interest with high accuracy. A photograph of TIRF is shown as frontispiece to this report; a detailed description is given in Section 5.

The following study is concerned with accurate measurements of the rolling losses -- transient and equilibrium -- of 35 tires (31 passenger tires and 4 light truck tires) representing contemporary distributions of the basic construction types and sizes. All tires were tested on the flat belt of TIRF, and a few on TIRF's driven drum (67.230 inches diameter). The drum tests were made by removing the steel belt and shifting the tire over to the driven drum (Fig. 1). Since the road temperature was considered of major importance, the drum surface was cooled down to the temperature of the belt surface (Fig. 2).

The main objective of this program was to generate a reliable, comprehensive body of rolling loss data from a representative sample of current tires -- data that would serve as a basis for further analytical work. Most of the analytical work was to be performed in an effort outside this contract. Nevertheless, a fair amount of data analysis has been attempted in this report, to facilitate conclusions as to the validity and consistency of the experimental results.

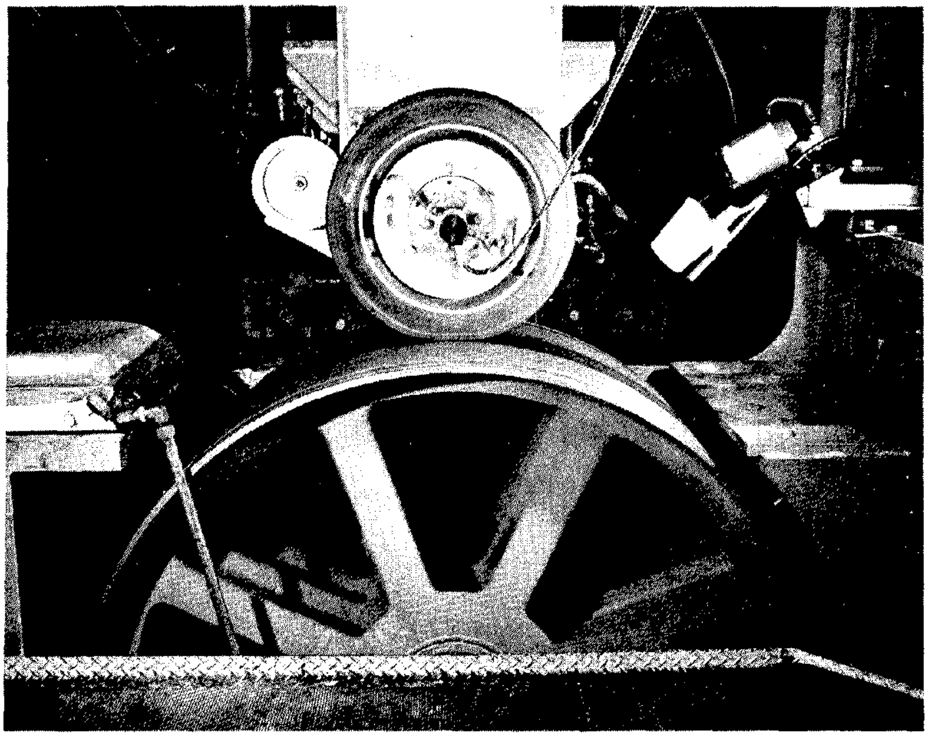


Figure 1 TIRE TESTING ON TIRF DRUM

NOTE THE TWO RADIOMETERS FOR MEASURING TREAD SURFACE AND DRUM SURFACE TEMPERATURES

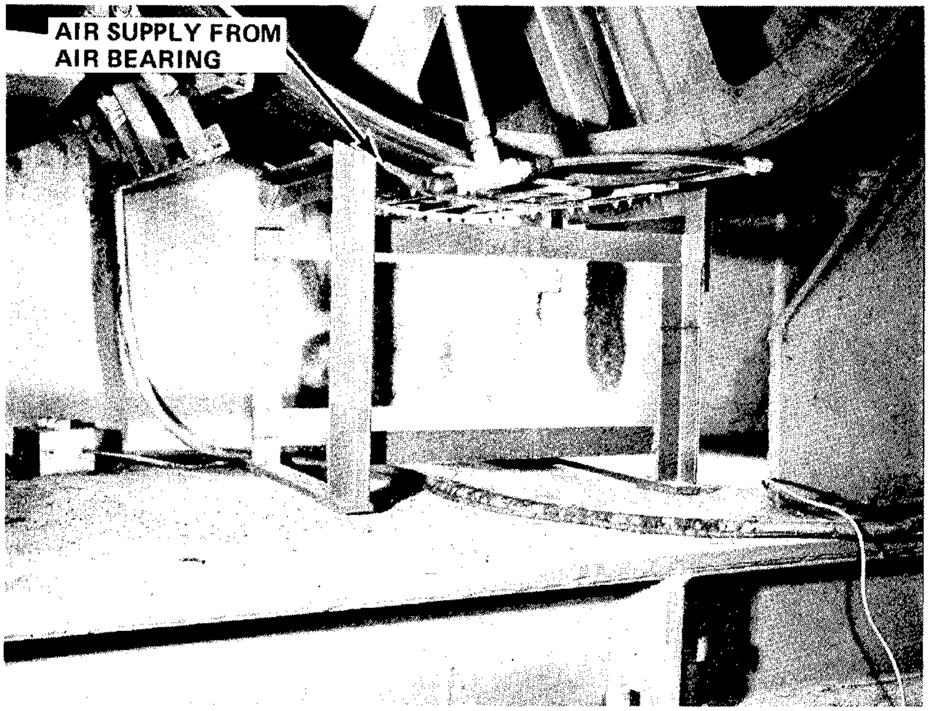


Figure 2 PNEUMATIC COOLING DEVICE (UNDERNEATH DRUM). VARIOUS LEVELS OF COOLING ACHIEVED BY VARYING THE AIR PRESSURE

2. DEFINITION OF ROLLING RESISTANCE

Basically, the rolling loss is that portion of the tire input energy that does not produce useful work; it is expended as heat due to hysteresis and friction. For the free-rolling tire (at zero steer and camber angles), hysteresis losses are dominant (Ref. 7); for the driven or braked tire, friction losses are more important.

We are not concerned here with the mechanism of rolling losses, however. Our concern is the definition of rolling loss in terms of the forces and moments acting on the tire. This definition is most easily found for the free-rolling tire where all input energy is lost, Fig. 3. For a flat surface, the rolling loss is then simply

$$P_F = FXO_F * V_F, \tag{1}$$

where FXO_F is the longitudinal force,* and V_F is the road speed. For a curved surface (drum), the rolling loss is

$$P_D = FXO_D (1 + RL_D/R) V_D, \tag{2}$$

where RL_D is the tire's loaded radius and R is the drum radius (here, 33.614 in.).

Note that the longitudinal forces FXO_F and FXO_D are not necessarily equal, and that both forces can only be known through tests, i.e. empirically. The ratio of rolling loss P and road speed V, i.e., P/V, is called

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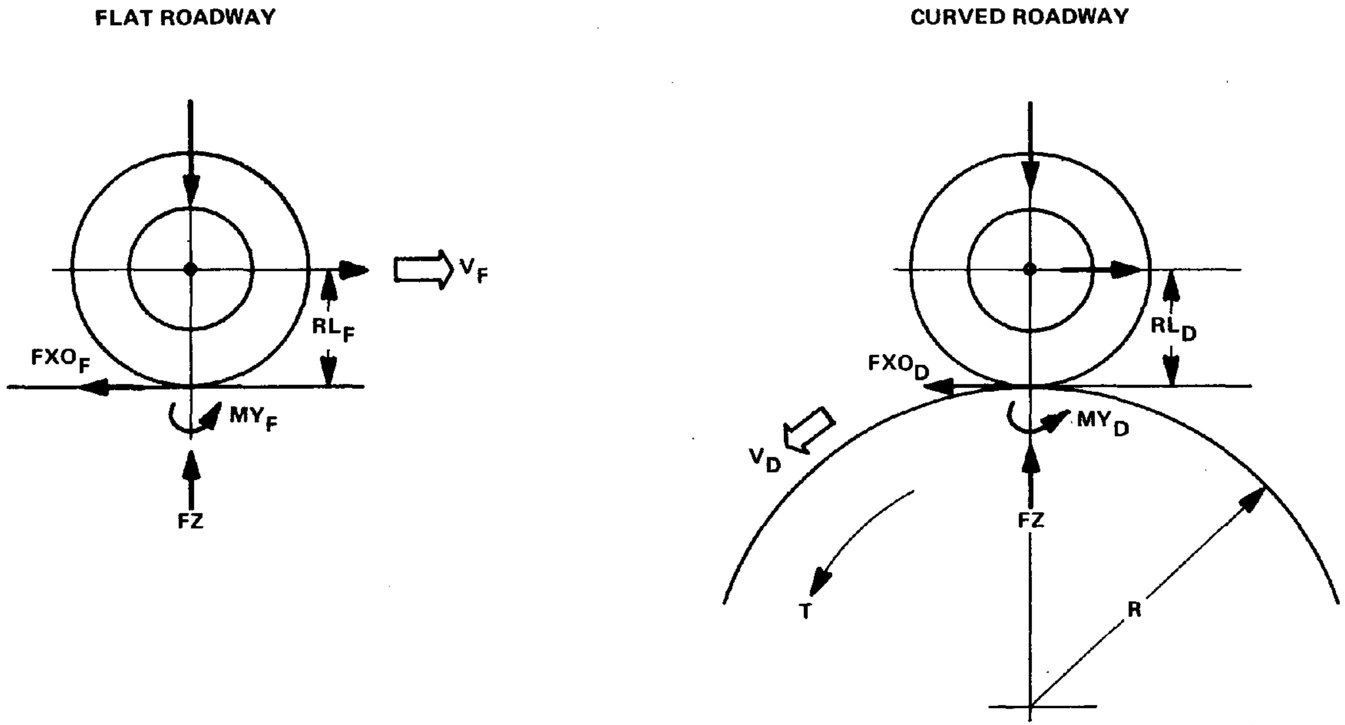
*The O in FXO signifies the absence of experimental errors caused by bearing friction torque and thermal drift, as discussed in Section 7.



POWER LOSS $P_F = FXO_F * V_F$

ROLLING RESISTANCE $FR_F = P_F/V_F = FXO_F$

POWER LOSS $P_D = FXO_D * V_D (1 + RL_D/R) = T_* V_D/R$

ROLLING RESISTANCE $FR_D = P_D/V_D = FXO_D (1 + RL_D/R)$

Figure 3 ROLLING RESISTANCE OF FREE—ROLLING TIRE MEASURED ON FLAT AND CURVED ROADWAYS rolling resistance; it is for the flat surface

$$FR_F = P_F/V_F = FXO_F, \tag{3}$$

and for the curved surface

$$FR_D = P_D/V_D = FXO_D\,(1 + RL_D/R). \tag{4}$$

For the braked and the driven tire, the expression for rolling loss is more complex because an additional quantity, the spin velocity of the tire, enters. In the following, we restrict ourselves to the free-rolling tire; the braked/driven tire will be discussed briefly at the end of the report.

3. TIRE SELECTION

The tires selected for testing were to reflect the present distribution of critical design and construction parameters. From publications of the Rubber Manufacturers Association and other sources, we estimated the distribution of basic tire construction types for passenger tires in 1976 (Ref. 8) as

19% for bias-ply tires
33% for bias-belted tires, and
48% for radial-ply tires.

The distribution of aspect ratios for passenger tires in 1976 was projected as

5% for balloon sizes
10% for metric sizes
1% for aspect ratio 60
22% for aspect ratio 70, and
62% for aspect ratio 78.

The distribution of wheel diameters of passenger cars for passenger tires in 1976 was estimated as

13% for 13 inches
37% for 14 inches, and
50% for 15 inches.

The distribution of carcass cord materials was estimated for 1976 as

78% polyester
9% nylon
10% rayon
2% high performance organic fiber, and
1% fiberglass.

The distribution of belt materials in 1976 was estimated as

8% rayon
43% fiberglass
45% steel, and
4% high performance organic fiber.

These distributions had to be approximated by a reasonably small number of tires, not more than 35. It was decided to include 5 tires used in an SAE round-robin rolling resistance test program, and 6 TPC tires donated by GM. In addition, one particular tire (No. 641) was to be included at the request of Mr. S. Bobo, TSC. The distribution of test tires that would accommodate all of these requirements is shown in Tables 1 and 2. Table 3 compares the distributions of design parameters actually achieved with those desired. In view of the many limitations imposed on the tire sample, agreement with the desired distributions must be considered satisfactory.

It was also estimated that 11% of all tires in 1976 would be light truck tires. The corresponding number in Table 1 is 4 light truck tires or 11.5%.

TABLE 1 DISTRIBUTION OF TEST TIRES
(Numbers are tire ID numbers)

		PASSENGER CAR								
		13"			14"			15"		
	ASPECT R →	60	70	78	60	70	78	60	70	78
BIAS-PLY (B)	A			(623)						
	B			603			600			
	C									
	D						604			
	E									
	F									
	G						601			602
	H									641
	J									
	L									
BIAS-BELTED (BB)	A		605	(624)						
	B									
	C									
	D		606			607	611			
	E									
	F									
	G				610	608	612		609	613
	H									
	J									
	L									(629)
RADIAL-PLY (R)	A		614							
	B			(631)						
	C									
	D					615	617			
	E									
	F						└638			└633
	G					616	618		└634	└640
	H								└639	└637
	J									
	L									(627)

LIGHT TRUCK (LT)	
7.00-15 (C)	622
7.50-16 (C)	619
7.50-16 (D)	620
7.50R-16 (D)	621

○ SAE ROUND ROBIN

└ GM TPC (19% OF PASSENGER TIRES)

TABLE 2 LIST OF TIRES TESTED

	TIRF Tire ID No.	
B 78-14	(600)	Goodyear Power Cushion Vytacord (4P)
G 78-14	(601)	
G 78-15	(602)	
B 78-13	(603)	Goodyear Power Cushion Polyester (2P)
D 78-14	(604)	
A 70-13	(605)	Goodyear Custom Wide Tread Polyglas (2P+2F/2P)
D 70-13	(606)	
D 70-14	(607)	
G 70-14	(608)	
G 70-13	(609)	
G 60-14	(610)	Goodyear Polyglas GT (2P+2F/2P)
D 78-14	(611)	Goodyear Custom Power Cushion Polyglas (2P+2F/2P)
G 78-14	(612)	
G 78-15	(613)	
AR 70-13	(614)	Goodyear Power Steel Radial W T (2P+4R+1S/2P)
DR 70-14	(615)	
GR 70-14	(616)	
DR 78-14	(617)	Goodyear Custom Polysteel Radial (2P+2S/2P)
GR 78-14	(618)	
7.00-15 C	(622)	Goodyear Custom Hi-Miler TT (N)
7.50-16 C	(619)	
7.50-16 D	(620)	
7.50R-16 D	(621)	Goodyear Custom Flexsteel LT Radial TT (P+S/P)

P = Polyester, F = Fiberglas, S = Steel, N = Nylon, R = Rayon

TABLE 2 (Cont'd.)

	TIRF Tire ID No.		
A 78-13	(623)	Firestone Deluxe Champion (2R)	SAE Round Robin
A 78-13	(624)	Firestone Deluxe Champion Sup-R-Belt (2P+2F/2P)	
L 78-15	(629)		
BR 78-13	(631)		
LR 78-15	(627)	Firestone Steel Radial 500 (2P+2S/2P)	
H 78-15	(641)	Firestone Deluxe Champion (4P)	S. Bobo
FR 78-15 (TPC 1010)	(633)	Goodyear Custom Tread Steel Belted Radial (2P+2S/2P)	GM TPC
GR 70-15 (TPC 1007)	(634)		
FR 78-14 (TPC 1004)	(638)	Goodyear Steel Belted Radial (2P+2S+1N/2P)	
HR 78-15 (TPC 1001)	(637)	.... (2P+2S+2N/2P)	
GR 78-15 (TPC 1003)	(640)	.... (2P+2S+1N/2P) Uniroyal PR 6 Steel Belted Radial	
HR 70-15 (TPC 1011)	(639)	..... (2P+2S/2P)	

P = Polyester, F = Fiberglas, S = Steel, N = Nylon, R = Rayon

TABLE 3 DISTRIBUTION OF TIRE DESIGN AND CONSTRUCTION PARAMETERS FOR 35 PASSENGER TIRES

Parameter		Distribution		
		Desired	Achieved	
		%	%	No. of tires
Construction	Bias Ply	19	23	7
	Bias Belted	33	35	11
	Radial Ply	48	42	13
Aspect Ratio	Balloon	5	--	--
	Metric	10	--	--
	60	1	3	1
	70	22	32	10
	78	62	65	20
Wheel Diameter	13"	13	23	7
	14"	37	42	13
	15"	50	35	11
Carcass Cords	Polyester	78	97	30
	Nylon	9	--	--
	Rayon	10	3	1
	HP Organic	2	--	--
	Fiberglas	1	--	--
Belt Cords	Rayon	8	--	--
	Fiberglas	43	46	14
	Steel	45	54	17
	HP Organic	4	--	--

4. TEST PROGRAM

The primary objectives of the program were to

- Measure rolling loss data of about 35 passenger and light truck tires of various constructions, sizes, and aspect ratios reflecting current distributions.
- Determine the basic relations between rolling resistance and load, speed, inflation pressure, temperature, slip angle, torque, tire construction, aspect ratio, and wheel diameter.
- Establish the influence of road curvature on rolling resistance.
- Examine the feasibility of a short-term procedure for measuring rolling resistance.
- Demonstrate the accuracy with which rolling resistance can be measured on TIRF.

To achieve these objectives, the test program was divided into transient tests, equilibrium tests, and special tests. The transient tests were intended to generate transient data (including equilibrium data) for all tires on the flat roadway and for a few tires, on the drum. In the equilibrium tests, equilibrium data for various loads, speeds, and pressures were to be originated on both flat and curved roadways. In the special tests, the influences of slip angle and torque (braking/driving) were to be probed.

Figure 4 shows the basic sequence of the transient tests. Starting at ambient temperature, the tires would be run at 50 mph and 100% T&RA load for 30 minutes. During this time, temperature and force data would be taken at 15 sec intervals. At the end of the 30 min runs, where the tires were

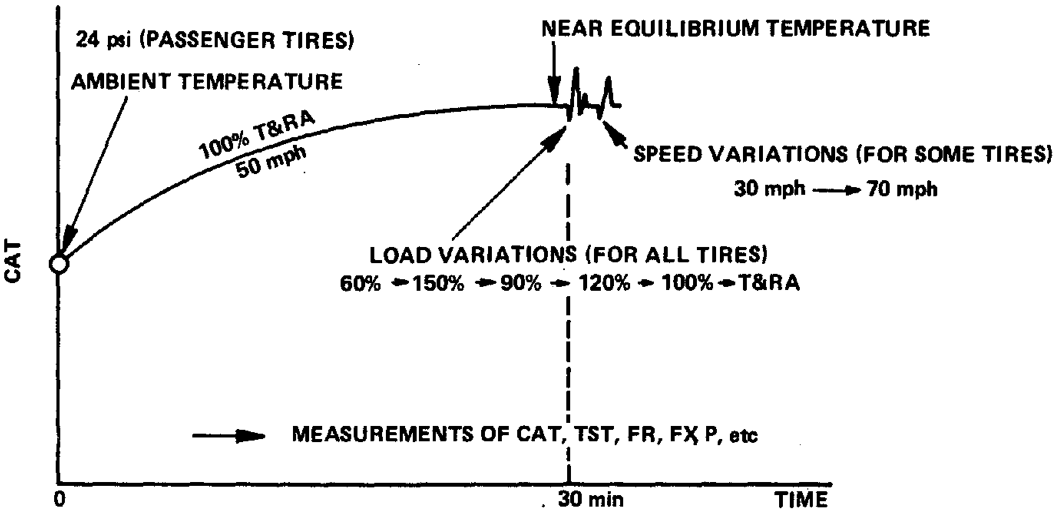


Figure 4 TEST SEQUENCE FOR TRANSIENT TESTS

expected to have approximated equilibrium conditions, the load would be varied rapidly to 60%, 150%, 90%, 120%, and back to 100% T&RA load. For some tires, the load variations would be followed by rapid speed changes to 30 and 60 mph. Load and speed variations would take about 2.5 min, in which time the average tire temperatures were anticipated to change very little.

Tables 4 through 6 give an overview of the general test conditions. All passenger and truck tires had to be subjected to general flat-roadway tests[*] (Tables 4 and 5). Nine tires, all of aspect ratio 78 and distributed evenly across the construction types, wheel diameters, and sizes, had to be tested on the drum (Table 6), so that the influence of road curvature could be evaluated.

Table 7 shows the basic test conditions of the equilibrium tests. One tire was selected (No. 640, size GR 78-15) to generate equilibrium data on drum and flat roadway at various speeds and loads (these tests were termed baseline tests); 6 tires were chosen to originate equilibrium data at various pressures on the flat roadway. In all these equilibrium tests, transient data were of interest only insofar as they helped establishing data at equilibrium temperatures. Figure 5 shows the run sequences designed to give the shortest total running time for the baseline tests. Figure 6 shows the basic test sequence for the equilibrium pressure tests.

In Table 8, the tires used for slip-angle and torque variations are identified. Since these tests were considered exploratory, only a few runs at (nearly) constant temperatures were contemplated.

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[*] With the exception of tire No. 640 (GR 78-15). This tire was set aside for baseline tests.

Figure 7 gives in graphic form an overview of the test program discussed so far. Before more details of the test procedures are given, a description of the test facility and its accuracy is in order.

TABLE 4 TRANSIENT TESTS OF PASSENGER TIRES ON FLAT ROADWAY

Numbers are run numbers. For tire numbers, see Table 1.

- Run Conditions: 24 psi cold (exceptions noted), 100% T&RA load, 50 mph (exceptions noted)
- Test Duration: 30 min
- At end of all runs: Load Variations (60, 90, 120, 150% T&RA)

At the end of some runs (v): Speed Variations (30, 70 mph)

◯ SAE Round Robin Tires └ GM TPC Tires

		Passenger Car						
		13"		14"			15"	
	Aspect R.→	70	78	60	70	78	70	78
Bias-Ply	A	(16 psi 30 mph)	⑲, ㊷					
	B		16			2		
	C							
	D					40		
	E							
	F							
	G					36, 29		13
	H					(16 psi)		9
	J							
	L							
Bias-Belted	A	15	⑱, ㊶					
	B	(16 psi, 30 mph)						
	C							
	D	17			1	38		
	E							
	F							
	G			32	30	27, 3	4	5
	H					(16 psi)		
	J							
	L							㊺ (v)
Radial-Ply	A	14 (16 psi, 30 mph)						
	B		⑳, ㊸					
	C		(v)					
	D				35	34		
	E							
	F					└33		└11
	G				31	37, 28	└6	
	H					(16 psi)	└8	└7
	J							
	L							㊹ (v)

TABLE 5 TRANSIENT TESTS OF LIGHT TRUCK TIRES ON FLAT ROADWAY

Run Conditions:	T&RA Load, 50 mph
Test Duration:	30 min
At end of runs:	Load variations (60, 90, 120, 150% T&RA)

LIGHT TRUCK (LT)			
Size	Run No.	Tire No.	Infl. press., psi
7.00 - 15 (C)	12	622	35
7.50 - 16 (C)	24	619	35
7.50 - 16 (D)	25	620	50
7.50R - 16 (D)	26	621	55

TABLE 6 TRANSIENT TESTS OF PASSENGER TIRES ON DRUM

Numbers are run numbers. For tire numbers, see Table 1.

- Run conditions: 24 psi cold, 100% T&RA load, 50 mph
- Test Duration: 30 min
- At end of all runs: Load variations (60, 90, 120, 150 T&RA)

  At end of some runs (v): Speed Variations (30, 70 mph)

◯. SAE Round Robin Tires

		Passenger Car						
		13"		14"			15"	
Aspect R.→		70	78	60	70	78	70	78
Bias-Ply	A		(55) (v)					
	B							
	C							
	D							
	E							
	F							
	G					48		
	H							54
	J							
	L							
Bias-Belted	A		(56) (v)					
	B							
	C							
	D							
	E							
	F							
	G					49		
	H							
	J							
	L							(53) (v)
Radial-Ply	A							
	B		(57) (v)					
	C							
	D							
	E							
	F							
	G					51		
	H							
	J							
	L							(52) (v)

TABLE 7 EQUILIBRIUM TESTS

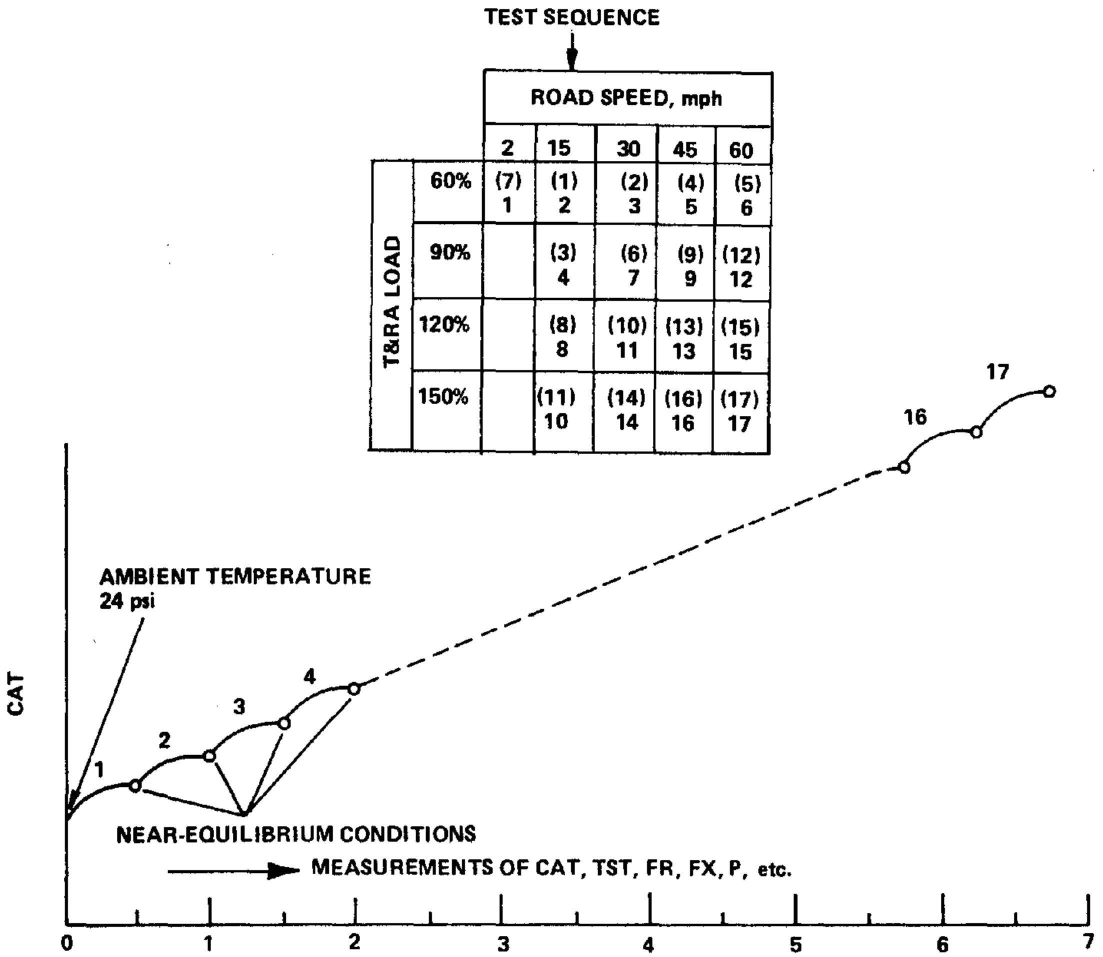
Numbers are run numbers. For tire numbers, see Table 1.

(P), at 3 pressures on flat roadway = Pressures Tests @ 50 mph and T&RA load (24 psi)

(B), at 5 speeds and 4 loads on flat roadway and drum = Baseline Tests

SAE Round Robin Tires
GM TPC Tires

		Passenger Car						
		13"		14"			15"	
	Aspect R.→	70	78	60	70	78	70	78
Bias-Ply	A		19, 42					
	B		(P)					
	C							
	D							
	E							
	F							
	G					36, 29		
	H					(P)		
	J							
	L							
Bias-Belted	A		18, 41					
	B		(P)					
	C							
	D							
	E							
	F							
	G					27, 3		
	H					(P)		
	J							
	L							
Radial Ply	A							
	B		20, 43					
	C		(P)					
	D							
	E							
	F							
	G					37, 28	39, 50	
	H					(P)		
	J						39 on Flat Bed	(B)
	L						50 on Drum	



TEST SEQUENCE

T&RA LOAD		ROAD SPEED, mph				
		2	15	30	45	60
	60%	(7) 1	(1) 2	(2) 3	(4) 5	(5) 6
	90%		(3) 4	(6) 7	(9) 9	(12) 12
	120%		(8) 8	(10) 11	(13) 13	(15) 15
	150%		(11) 10	(14) 14	(16) 16	(17) 17

Figure 5 TEST SEQUENCE FOR EQUILIBRIUM (BASELINE) TESTS; TIRE GR78-15 (NO. 640)

(7) = FLAT BED TESTS
7 = DRUM TESTS

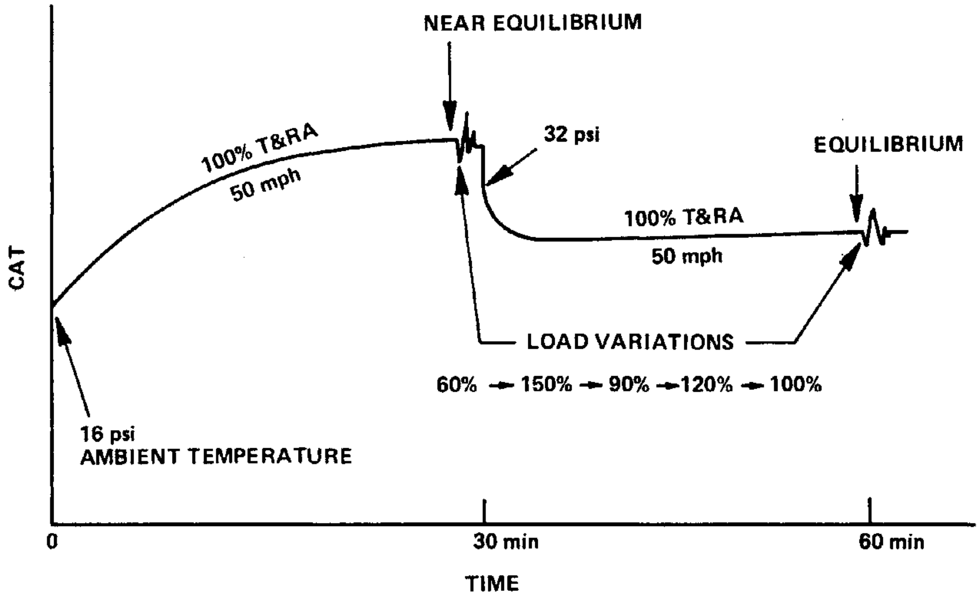


Figure 6 TEST SEQUENCE FOR TESTS AT DIFFERENT PRESSURES

TABLE 8 SPECIAL TESTS

Numbers are run numbers. For tire numbers, see Table 1.

(α) Slip angle variations on flat roadway

(T) Driving/braking torque variations on flat roadway

└── GM TPC Tires

		Passenger Car						
		13"		14"			15"	
	Aspect R.→	70	78	60	70	78	70	78
Bias-Ply	A							
	B							
	C							
	D							
	E							
	F							
	G					22		
	H					(α)		
	J							
	L							
Bias-Belted	A							
	B							
	C							
	D							
	E							
	F							
	G					21		
	H					(α)		
	J							
	L							
Radial-Ply	A							
	B							
	C							
	D							
	E							
	F							
	G					23		└47
	H					(α)		(T)
	J							
	L							

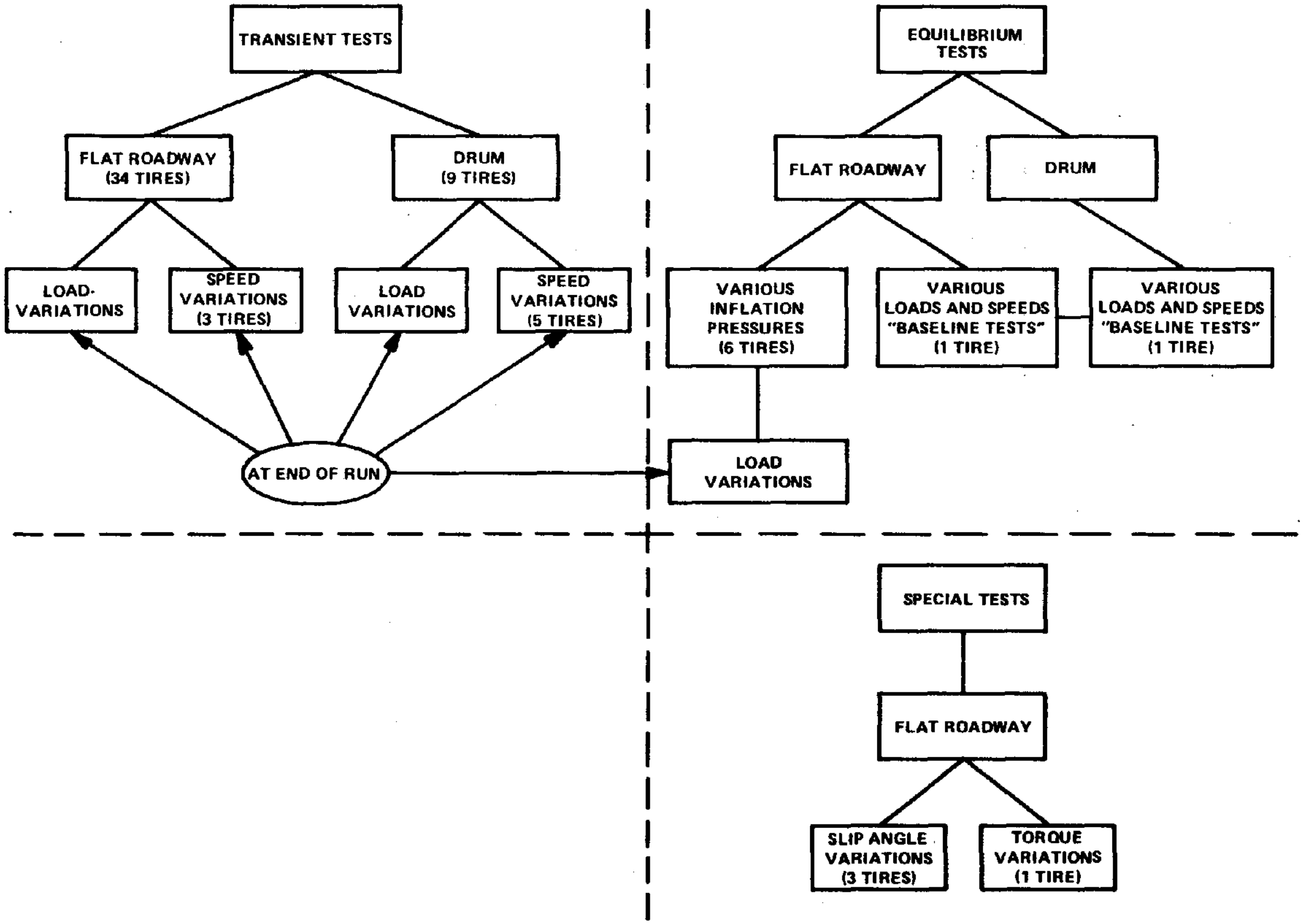


Figure 7 GENERAL TEST PROGRAM

5. TEST FACILITY

A photograph of the TIRF facility is shown as the frontispiece to this report; a dimensional view of the facility is shown in Figure 8. The primary features of the machine are:*

Tire Positioning System

The tire, wheel, force sensing balance and hydraulic motor to drive or brake the tire are mounted in the movable upper head. The head provides steer, camber and vertical motions to the tire. These motions (as well as vertical loading) are servo controlled and programmable for maximizing test efficiency. The ranges of the position variables, the rates at which they may be adjusted, and other information are shown in Table 9.

TABLE 9 **TIRF CAPABILITIES**

CHARACTERISTIC	RANGE
TIRE SLIP ANGLE (α)	±30°
TIRE CAMBER ANGLE (γ)	±30°
TIRE SLIP ANGLE, RATE ($\dot{\alpha}$)	10°/sec
TIRE CAMBER ANGLE RATE ($\dot{\gamma}$)	7°/sec
TIRE LOAD RATE (TYPICAL)	2000 lb/sec
TIRE VERTICAL POSITIONING	2"/sec
ROAD SPEED (V)	0-200 mph
TIRE OUTSIDE DIAMETER	18.5" to 46"
TIRE TREAD WIDTH	24" MAX.
BELT WIDTH	28"

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* A more complete description of this facility will be found in Ref. 6.

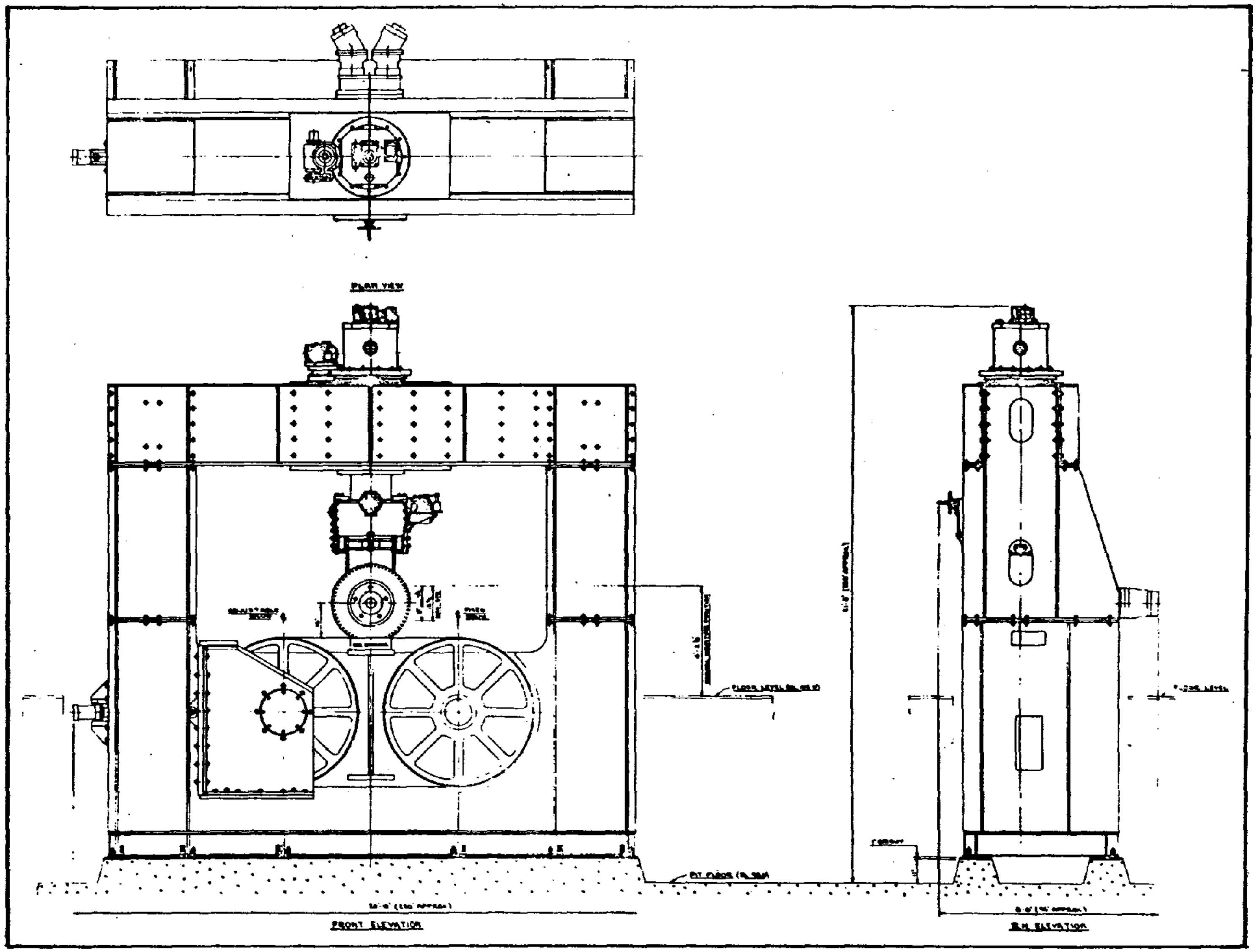

Figure 8 TIRE RESEARCH MACHINE

Roadway

The 28-inch wide roadway is made up of a stainless steel belt covered with material that simulates the frictional properties of actual road surfaces. The belt is maintained flat to within 1 to 2 mils under the tire patch by the restraint provided by an air bearing pad which is beneath the belt in the tire patch region. The roadway is driven by one of the two 67-inch diameter drums over which it runs. The road speed is servo controlled; it may be programmed to be constant or varied.

The surfaces usually used are "Safety Walk".[*] These surfaces have excellent microtexture giving a wet skid number[†] of about 60 in the untreated condition. The surfaces are honed to reduce the wet skid number to lower values (typically surfaces of skid number 50 and 30 are used).

A unique feature of TIRF is the ability to carry out tests under wet road conditions. A two-dimensional water nozzle spans the roadway. This nozzle has an adjustable throat which can be set to the desired water depth. The flow through the nozzle is then varied by controlling the water pressure. At each test condition the water film is laid on tangential to the belt at belt velocity. The film thickness may be varied from as low as 0.005 inches up to 0.5 inches.

Tire-Wheel Drive

A drive system which is independent of the roadway drive is attached to the tire-wheel shaft. This separate drive allows full variation of tire slip both in the braking and driving modes. The tire slip ratio, referenced to road speed, is under servo control.

---

[*] Manufactured by the 3M Company.

[†] At 40 mph and 0.020 in. water depth using the ASTM E-501 Standard Pavement Traction Tire.

Balance System[*]

A six-component strain gage balance surrounds the wheel drive shaft. Three orthogonal forces and three corresponding moments are measured through this system. A fourth moment, torque, is sensed by a torque link in the wheel drive shaft. The load ranges of the basic passenger car and truck tire balances are shown in Table 10. Transfer of forces and moments from the balance axis-system to the conventional SAE location at the tire roadway interface is in the data reduction computer program.

TABLE 10 **BALANCE SYSTEM CAPABILITY**

COMPONENT	PASSENGER CAR TIRE BALANCE	TRUCK TIRE BALANCE
TIRE LOAD	4000 lb	12,000 lb
TIRE TRACTIVE FORCE	±4000 lb	9000 lb
TIRE SIDE FORCE	±4000 lb	8000 lb
TIRE SELF ALIGNING TORQUE	±500 lb ft	1000 lb ft
TIRE OVERTURNING MOMENT	±1000 lb ft	2000 lb ft
TIRE ROLLING RESISTANCE MOMENT	±200 lb ft	400 lb ft

---

[*] More detailed information of the balance systems are their calibration may be found in Refs. 6 and 9.

Data Acquisition Program (DAP) Control

The data acquisition program (DAP) is a software system which controls machine operation and logs data during tests. DAP controls test operations by means of discrete setpoints which are generated in the computer by the program. These setpoints are sent to the machine servos which respond and establish tire test conditions. After the setpoints are sent to the servos, a delay time is provided which starts after the machine variables have reached a steady state value within predetermined tolerances. This allows the system to stabilize before data are taken. After data are taken, the next set of test conditions is established and testing continues.

One or two variables can be changed during DAP testing. The other test parameters are kept fixed throughout the test. Up to twenty data points can be used for each variable in a run.

A data reduction program is used to operate on the raw data collected during testing. These new data are reduced to forces and moments in the proper axis system and all variables are scaled to produce quantities with engineering units. Raw and reduced data are temporarily stored in a disc file. Both reduced and raw data can be transferred to magnetic tape and maintained as a permanent record.

Reduced data points can be listed, plotted and curves can be fitted to the points. All of the standard Calspan plots can be generated from DAP test data.

Data lists and plots are displayed on the oscilloscope screen of a CRT console. Hard copies of this information can be made off this display.

Continuous Sampling Program (CSP) Control

The continuous sampling program (CSP) is a software system which controls machine operation and continuously logs data during tests. Test variables can be constant or changed at rapid rates. One or all variables can be changed during a test. Data can be sampled at rates up to 100 samples per second. Pauses are used so that data can be logged during desired intervals of the test.

CSP testing can be conducted quickly which in turn reduces tire wear during severe tests. The high rate of data sampling also permits limited dynamic measurements to be made during testing.

Two parameter plots of data can be made. Carpet and family plots of test data cannot be made with this program at the present time. CSP data will also reflect time effects if tire characteristics are a function of the rate of change of testing variables.

Data reduction is accomplished in a manner similar to that employed in DAP testing.

Facility Validation

It has generally become accepted by industry and government that data taken on TIRF are valid, in the sense that forces, moments, power losses measured on the facility, are the same as would be experienced on the road under similar conditions. The facility has been used for over 30 clients representing US and foreign tire and vehicle manufacturers, materials suppliers, marketers, research organizations, government agencies, racing groups, etc. Many of these clients have used the facility for several programs. This extensive and repeated usage has come about because of general satisfaction with the results on the basis of usefulness and correctness.

On a more formal basis, a round robin validation program was sponsored by the Motor Vehicle Manufacturers Association and the Rubber Manufacturers Association in which identical bias belted and radial ply tires were run at various test conditions on the Calspan TIRF and eight other car and tire industry facilities. Three of these facilities were road testers (trailers or truck bed), two were circular drums (external) and three (in addition to TIRF) were flat bed laboratory machines. Typical results are shown on the following page (Fig. 9)*.

It may be seen that the road test data show significant spread, with the TIRF data falling near the center of this spread. The single drum data (120 in diameter) are in good agreement as are most of the flat bed data. One set of the outlying data from a flat bed plank machine was found to be too low due to insufficient rolling length to obviate tire relaxation effects; when the rolling distance was extended, agreement was improved. The remaining outlier data are also from a plank machine - shorter than the first-so these data are also suspect. Taking these features into account, the TIRF results have come to be accepted as representing the actual forces and moments produced under steady state operating conditions.

Further information on the general validity of TIRF data and the specific validation program may be found in References 6, 9 and 10.

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*One set of drum data were found to be invalid and are not shown.

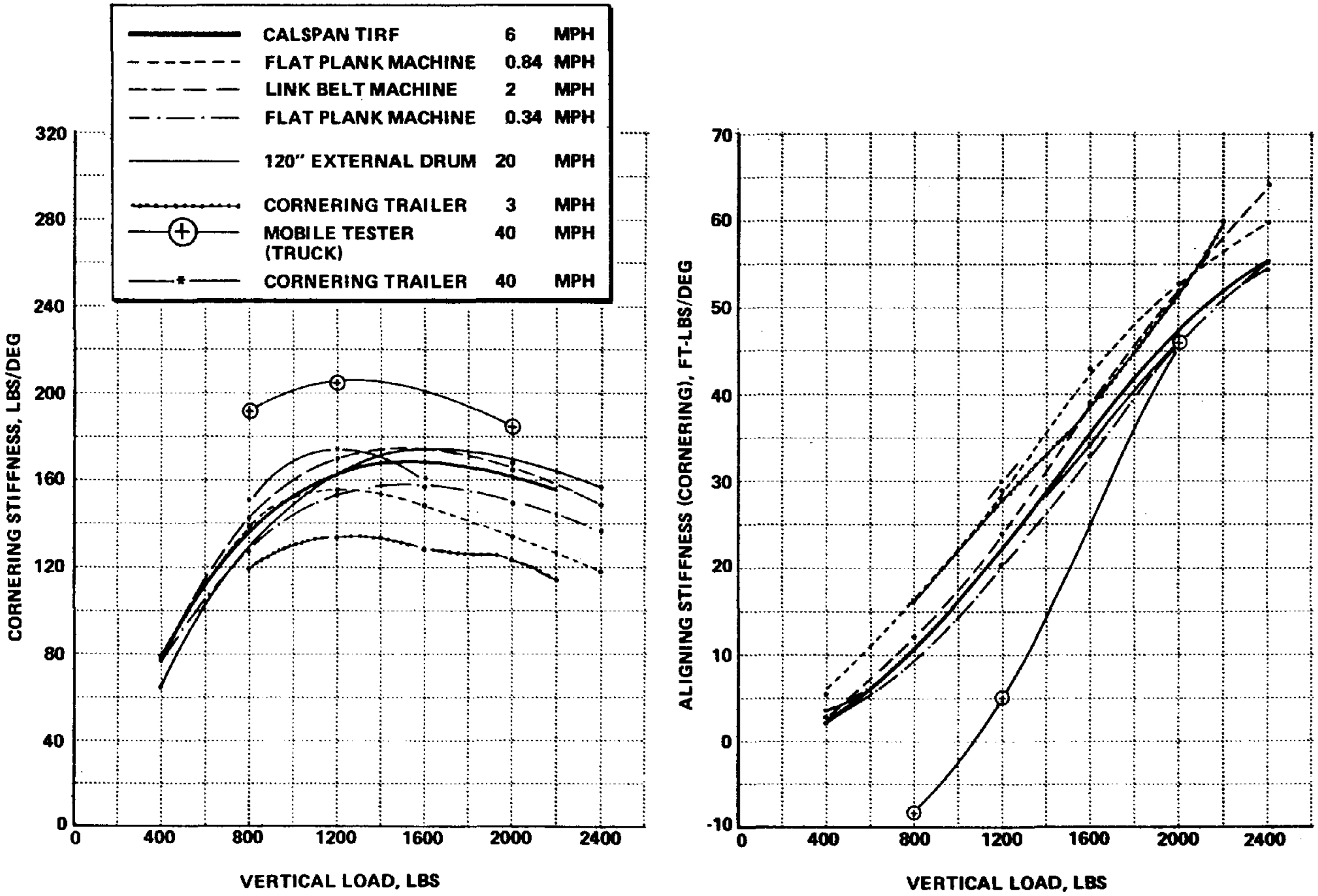

Figure 9 FACILITY VALIDATION RESULTS: CORNERING STIFFNESS AND ALIGNING TORQUE STIFFNESS VS VERTICAL LOAD FOR A G78-15 TIRE AT 28 PSI

ACCURACY

One of the difficulties in measuring rolling resistance arises from the fact that the resistance values are rather small, yet have to be determined with high accuracy (of the order of 0.1 lb) without interference from the simultaneously acting large vertical loads. In order to check the accuracy of longitudinal tire force measurements on TIRF under high vertical loads, the belt was replaced by a "floating plate" (size ≈ 1 x 1 ft) positioned between tire and air bearing. During a test, the plate was loaded to about 1000 lb and the in-plane force output recorded. The idea was that under perfect conditions, no in-plane plate forces should exist so that if such forces would be recorded they could be corrected as "errors". Unfortunately, it was discovered that physical forces between plate and air bearing could not be eliminated completely.

Initial tests revealed that the bearing was inclined by about 9 minutes in lateral direction and 1 minute in longitudinal direction. Although these errors were corrected, both accuracy and consistency of the test results were still deficient. It was detected that the air bearing would induce plate vibrations of high frequency which in turn would bring the plate into physical contact with the bearing and thus defeat the purpose of achieving a state of loading free of in-plane forces. Figure 10 shows some typical test results with longitudinal force recordings of about one pound; it was conjectured that these forces were caused by physical contact rather than by inaccurate calibration. A few tests were also performed with external forces FX of known magnitude imposed on the plate, Figure 11. Again, vibrations occurred and consistency and accuracy of the test results were poor. Nevertheless, despite the fact that accuracy determinations proved to be elusive, the tests did not invalidate the assumption that the balance was indeed suitable for measuring rolling resistance with good accuracy.

TEST NO.	STD. ERROR OF LINEAR REGRESSION, lb
1-6	1.31
7	0.20
8	0.16
9	0.16
10	0.37
13	0.31

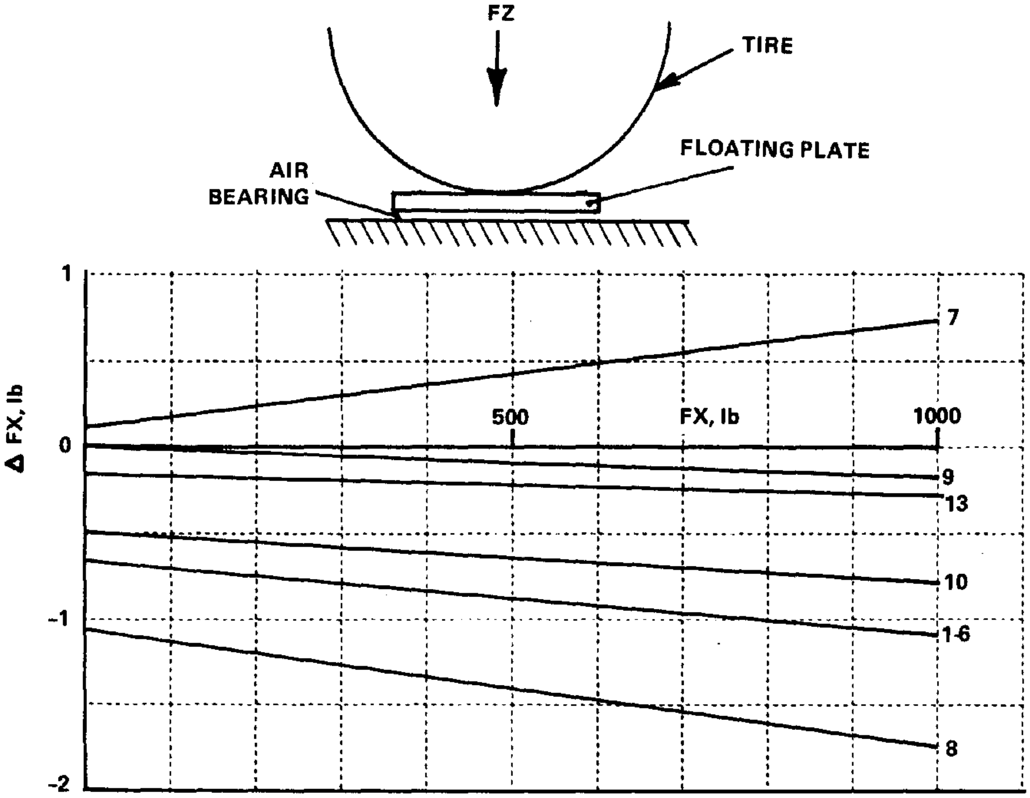

Figure 10 LINEAR REGRESSIONS OF VARIOUS FLOATING PLATE TESTS— WITH NO EXTERNAL FORCE FX

TEST NO.	FZ lb	STD. ERROR OF LINEAR REGRESSION, lb
1	530	0.17
2	1065	1.47
3	1060	1.11
4	1080	1.18
5	1080	1.31
6	1080	–

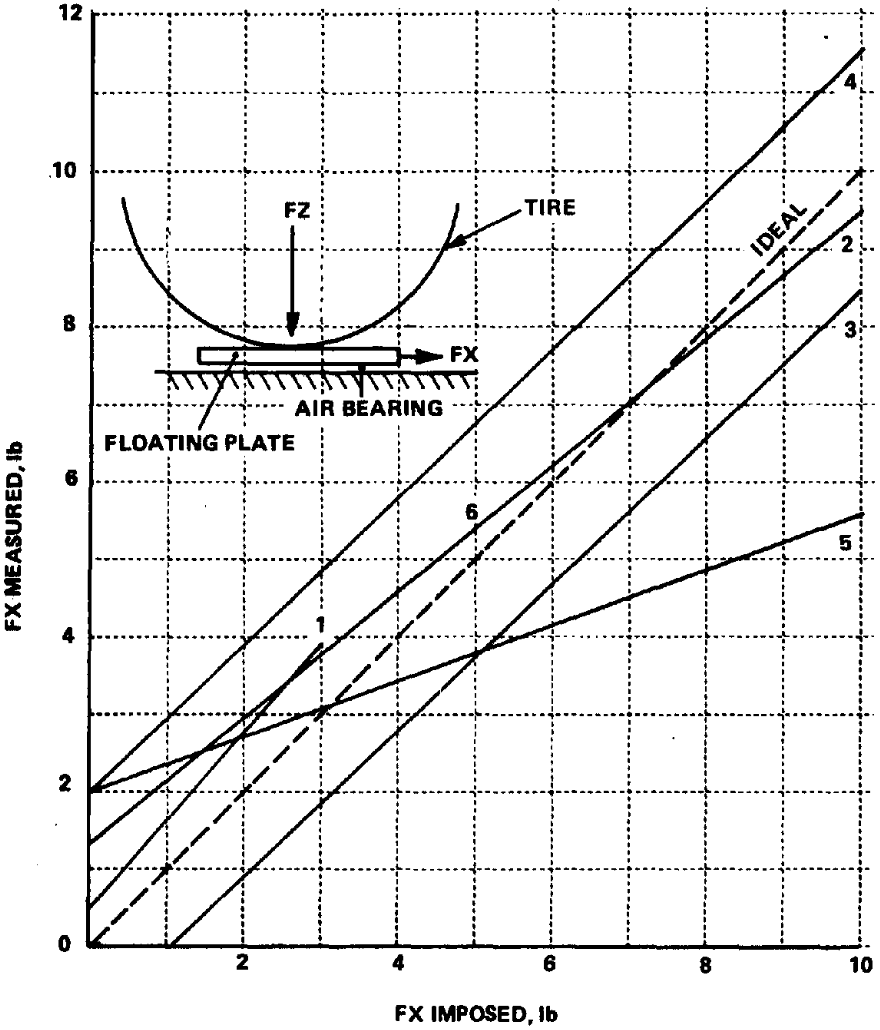

Figure 11 LINEAR REGRESSIONS OF VARIOUS FLOATING PLATE TESTS WITH EXTERNAL FORCE FX

During the first exploratory runs it was discovered that for running times of 15 min or longer the zero positions of the tire forces and moments recorded on TIRF would drift by small amounts, of the order of less than one pound for FX, FY, and FZ. Usually, for short term runs and large tire forces, the drifts are insignificant and can be neglected. For the long run times (up to 6 hours) and the small longitudinal forces of rolling resistance tests, however, they can significantly affect the test results. A number of tests established that the drifts were caused by a temperature rise of the balance of, typically, 30°F above room temperature. Along with the temperature rise, the zero position of FX would drift by $\Delta FX \approx 0.7$ lb within the first 15 min and then remain fairly constant. At the end of a test, as the balance cooled, ΔFX would decrease and go back to zero after about 10 min. Figure 12 shows a typical cycle. (See also Figure 19). Since a force of 0.7 lb constituted 3 to 7% of the rolling resistance, measures were taken to correct for the thermal drift, as described in the next section.

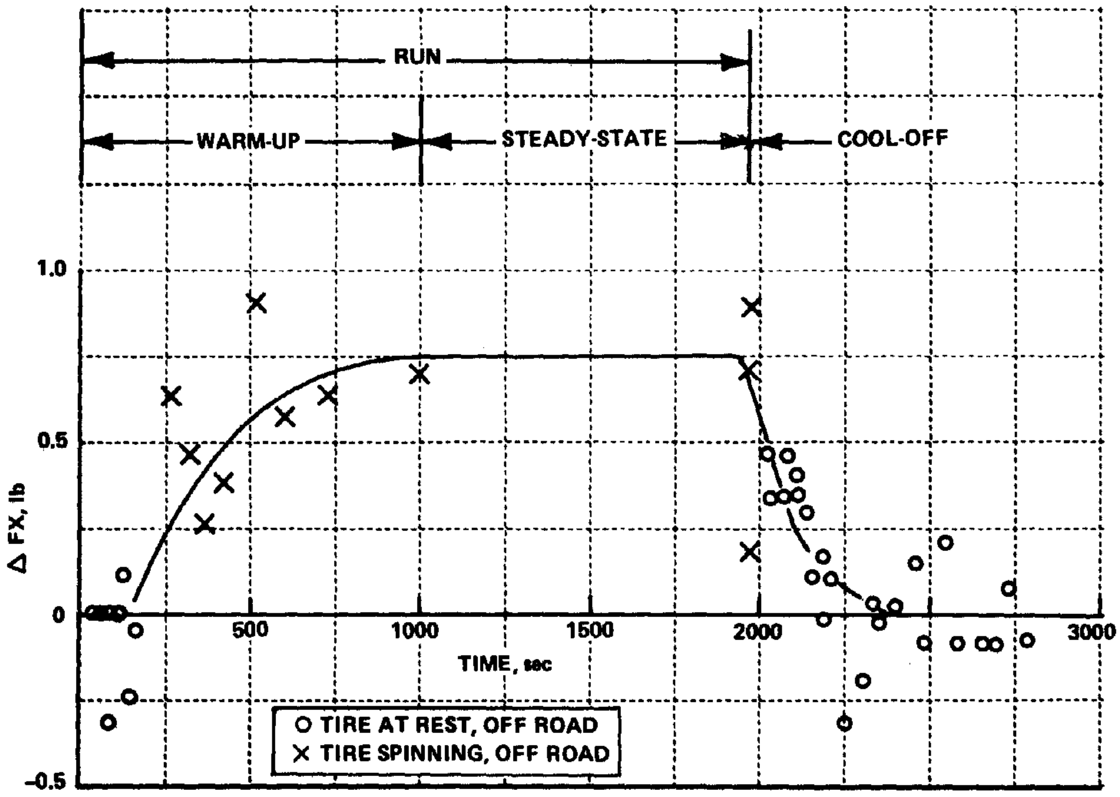

Figure 12 THERMAL DRIFT, ΔFX

6. TEST PROCEDURES

Break-in. Before actual testing, all tires (with the exception of the SAE Round Robin tires, which had been exclusively tested before) were run for two hours on a 48-inch road wheel at 50 mph and 80% T&RA design load.

Thermal Drift Corrections. Before each test, all channels of the TIRF balance system were set to zero, with the tire mounted and off the belt. During a run, the balance would warm up and cause the zero position to drift by small amounts, as discussed in Section 5. The zero drift of the longitudinal force was recorded at given time intervals (300, 600, 900, 1800, etc. sec) by lifting the tire briefly off the belt and measuring the longitudinal force, ΔFX. Since no external forces were acting on the tire during lift-off, the recorded longitudinal force, ΔFX, could be considered the thermal drift of FX.

Instrumentation. In addition to the instrumentation described in Section 5, an air temperature probe was used to measure the cavity tire temperature. The probe was inserted through the rim such that the temperature was picked up at the tire center plane 0.5 to 2 inches off the bottom of the rim well (depending on tire size and rim construction). Besides the cavity temperature, three more temperatures were recorded: the tread surface temperature at the forward portion of the tire, the road surface temperature in front of the tire, and the room temperature. The two surface temperatures were measured by two Barnes radiometers; the room temperature by a mercury thermometer. Both cavity and tread surface thermometers were integrated into the TIRF computer system.

Test Procedure. During a test, the values of 11 tire quantities were measured every 15 seconds, stored on magnetic tape and, after the test, printed out, as indicated in Table 11. Also, plots were made of FRT (= -FX', see Section 7),

TABLE 11 TIRF DATA PRINT-OUT (SAMPLE)

TIME ELAPSED	ROAD SPEED	VERTICAL LOAD	FRT = - FX'	CONTAINED AIR TEMPERATURE	TREAD SURFACE TEMPERATURE	INFLATION PRESSURE	
31-4-6	31-4-6	31-4-6	31-4-6	31-4-6	31-4-6	31-4-6	Run No
T.E.	U.	F.Z.	F.R.T.	C.A.T.	S.T.	P.	
SEC	MPH	LB	LB	DEG.C	DEG.C	PSI	
0.	50.	3.	-0.22	30.32	22.79	24.02	Tire Off Roadway
15.0.	50.	2.	-0.78	30.32	22.79	24.02	
30.0.	50.	2.	-0.78	30.32	23.03	24.02	
45.0..	50.	1.	-0.59	30.37	23.03	24.02	
60.0.	50.	1.	-0.35	30.37	23.26	24.02	
75.0.	50.	-1381.	27.8	30.09	26.51	24.32	
90.0	50.	-1380	26.6	30.28	26.74	24.46	
105.0	50.	-1380.	25.82	30.65	27.43	24.56	
120.0	50.	-1379.	25.19	31.22	27.89	24.71	
135.0	50	-1378	24.37	31.91	28.35	24.85	
150.0	50.	-1380.	23.58	32.61	28.57	24.95	
165.0	50.	-1381	23.21	33.39	28.8	25.15	
180.0	50.	-1381.	22.89	34.16	29.26	25.24	
195.0	50.	-1378	22.57	34.93	29.72	25.39	
210.0	50.	-1375.	22.2	35.69	30.17	25.44	
225.0	50.	-1377.	21.75	36.45	30.17	25.59	
240.0	50	-1381.	21.54	37.16	30.4	25.73	
255.0	50.	-1383.	21.46	37.91	30.63	25.83	
270.0	50.	-1379.	21.06	38.62	30.86	25.88	
285.0	50.	-1378.	20.94	39.32	31.08	26.03	
300.0	50.	3.	-2.26	38.92	27.2	25.68	← Tire Off Roadway
315.0	50.	-1377.	20.9	39.76	31.76	26.07	
330.0	50.	-1379.	20.36	40.46	31.54	26.17	
345.0	50.	-1380.	20.75	41.03	31.76	26.22	
360.0	50.	-1381.	20.12	41.6	31.54	26.32	
375.0	50.	-1376.	20.17	42.12	31.76	26.37	
390.0	50.	-1377.	19.54	42.69	32.	26.46	
405.0	50.	-1379.	19.59	43.22	32.22	26.51	
420.0	50.	-1378.	19.81	43.74	32.44	26.61	
435.0	50.	1379.	19.22	44.22	32.44	26.71	
450.0	50.	-1382.	19.18	44.7	32.67	26.71	

FRT = - FX + 12*BFT/RL

TABLE 11 Continued

TIME ELAPSED	LOADED RADIUS	LONGITUDINAL FORCE	LATERAL FORCE	ROLLING RESISISTANCE MOMENT	BEARING FRICTION TORQUE
31-4-6	31-4-6	31-4-6	31-4-6	31-4-6	31-4-6
T.E.	R.L.	F.X.	F.Y.	M.Y.	B.F.T.
SEC	IN	LB	LB	FT-LB	FT-LB
0.	23.49	0.27	19.	-0.43	0.1
15.01	23.5	0.61	0.	-1.52	-0.3
30.01	23.5	0.61	0.	-1.52	-0.3
45.01	23.5	0.55	0.	-1.16	-0.1
60.01	23.5	0.26	0.	-0.68	-0.2
75.01	12.02	-31.9	6.	27.83	-4.1
90.01	12.02	-30.91	6.	26.63	-4.3
105.0	12.02	-30.15	6.	25.85	-4.3
120.0	12.02	-30.	5.	25.22	-4.8
135.0	12.03	-29.16	4.	24.42	-4.8
150.0	12.03	-28.4	3.	23.63	-4.8
165.0	12.03	-28.23	3.	23.26	-5.
180.0	12.03	-27.77	3.	22.93	-4.9
195.0	12.04	-27.31	2.	22.63	-4.8
210.0	12.04	-26.78	2.	22.29	-4.6
225.0	12.04	-26.49	1.	21.83	-4.8
240.0	12.04	-26.2	1.	21.62	-4.7
255.0	12.04	-26.09	0.	21.53	-4.6
270.0	12.04	-25.5	-1.	21.13	-4.5
285.0	12.05	-25.34	-1.	21.04	-4.4
300.0	23.49	0.99	1.	-4.42	-2.5
315.0	12.06	-25.63	-2.	21.01	-4.8
330.0	12.05	-24.86	-2.	20.45	-4.5
345.0	12.06	-25.05	-2.	20.86	-4.3
360.0	12.06	-24.52	-2.	20.23	-4.4
375.0	12.07	-24.59	-2.	20.3	-4.4
390.0	12.06	-24.05	-3.	19.65	-4.5
405.0	12.07	-24.12	-3.	19.71	-4.6
420.0	12.07	-24.07	-3.	19.93	-4.3
435.0	12.07	-23.35	-4.	13.34	-4.8
450.0	12.07	-23.89	-4.	19.3	-4.7

Run No

Tire Off Roadway

Tire Off Roadway

ΔFX

the contained air temperature, the tread surface temperature, the inflation pressure, and other variables, to check the general quality of the run, see Figures 13 through 16.

Drum Cooling. As pointed out in the introduction and elsewhere, rolling resistance is a strong function of the tire temperature. The tire temperature, in turn, depends to a large degree on the temperature of the road. Therefore, rolling resistance data should only be compared if taken at the same road temperature.

Usually, when under tire load, a drum absorbs more heat and hence assumes higher surface temperatures than a thin steel belt cooled by an air bearing. To keep the drum surface temperatures down to the level of the steel belt, a pneumatic cooling device charged with air of the air bearing was installed underneath the drum, Figure 2. Figure 17 demonstrates that in this way good 1:1 correlation was achieved between corresponding drum and flat roadway surface temperatures.

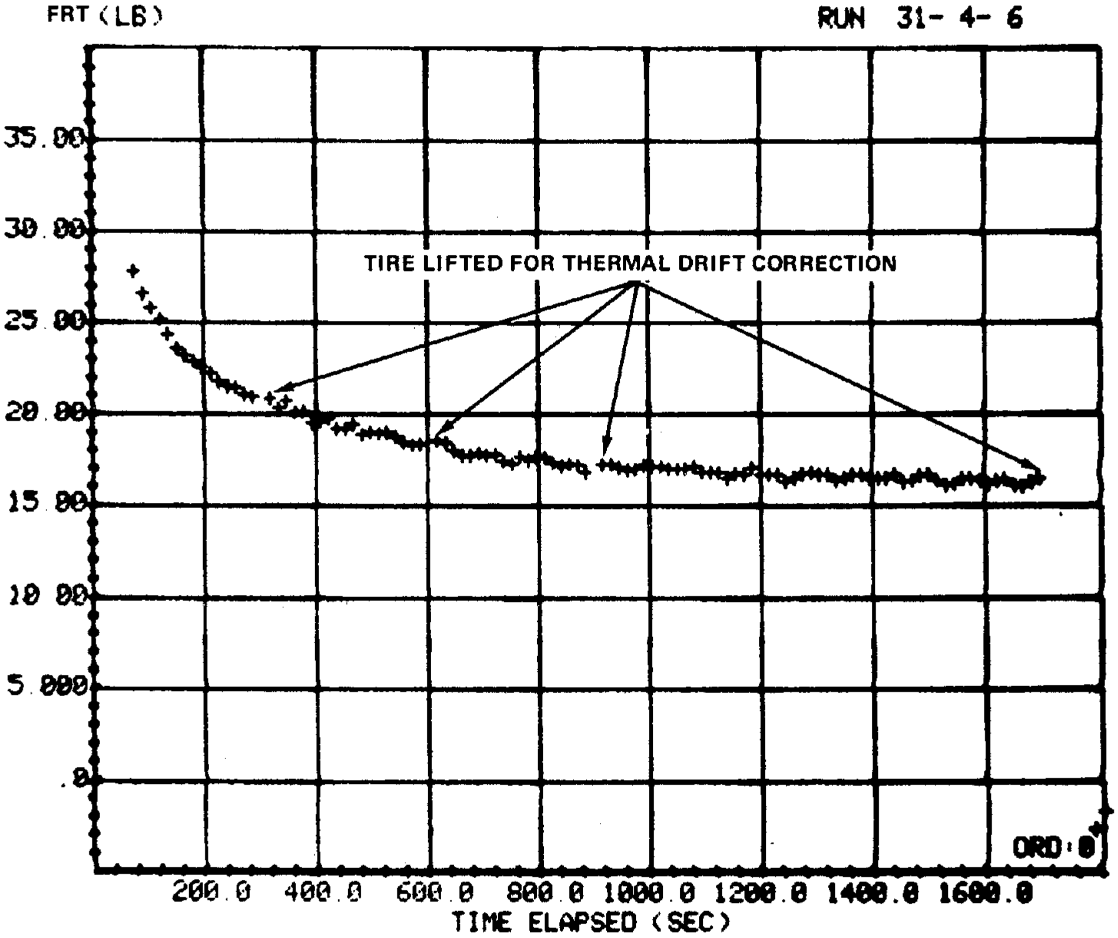

Figure 13 TYPICAL TIRF PLOT OF ROLLING RESISTANCE VERSUS TIME

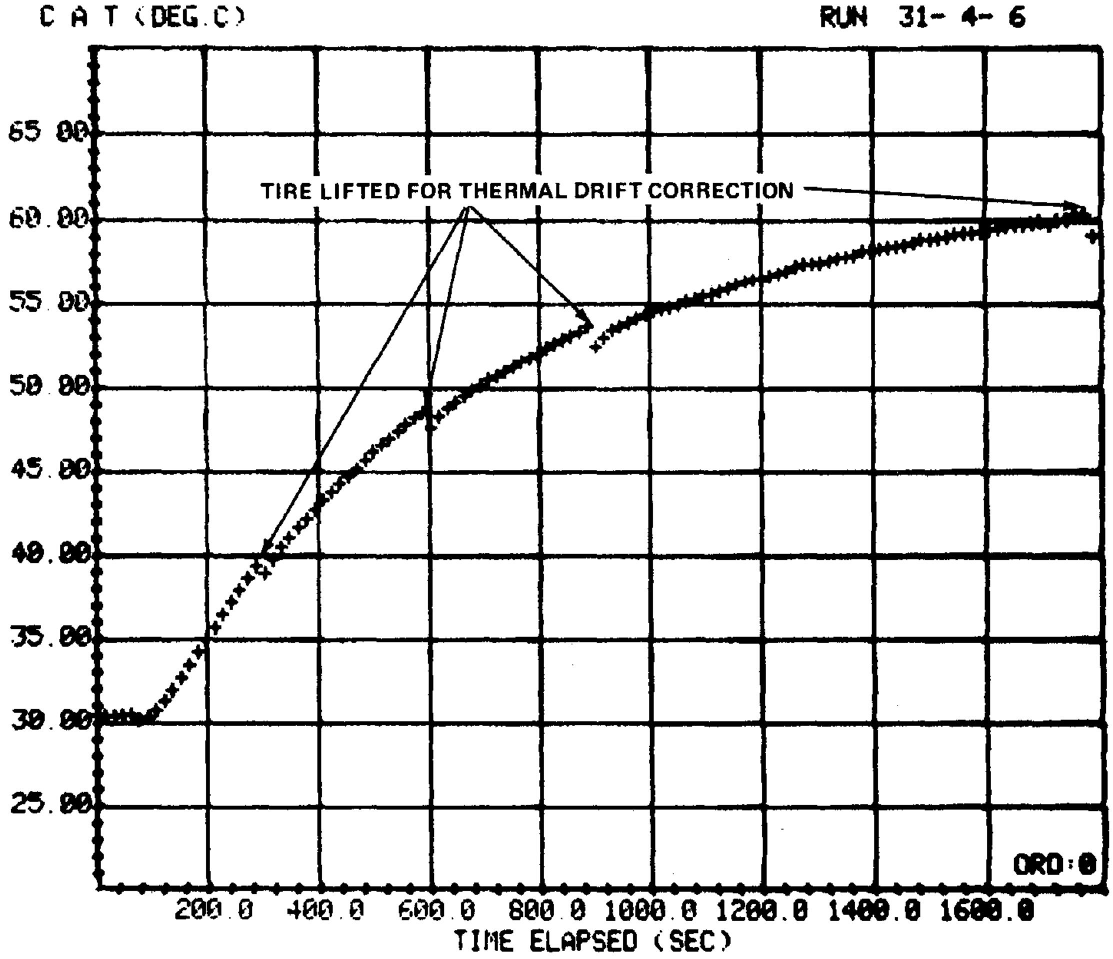

Figure 14 TYPICAL TIRF PLOT OF CONTAINED AIR TEMPERATURE VERSUS TIME

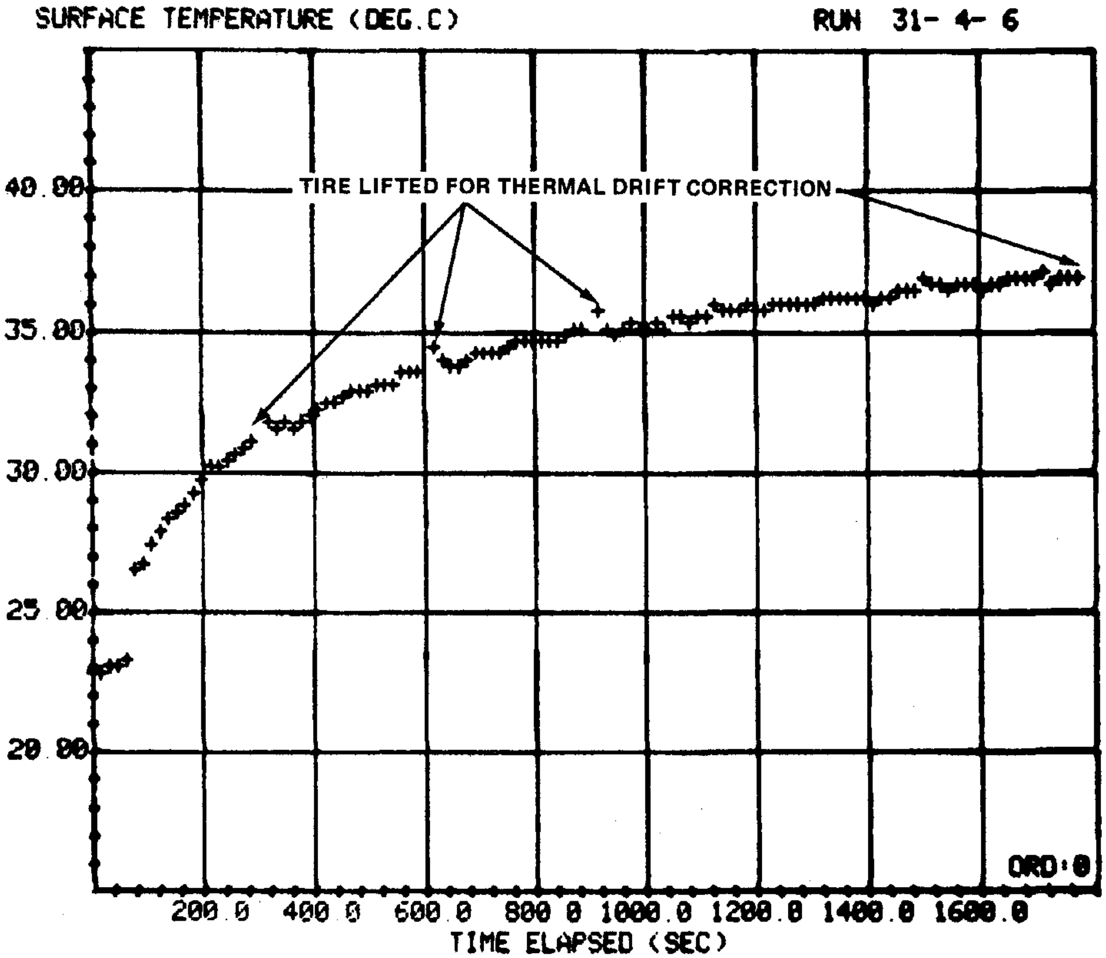

Figure 15 TYPICAL TIRF PLOT OF TREAD SURFACE TEMPERATURE VERSUS TIME

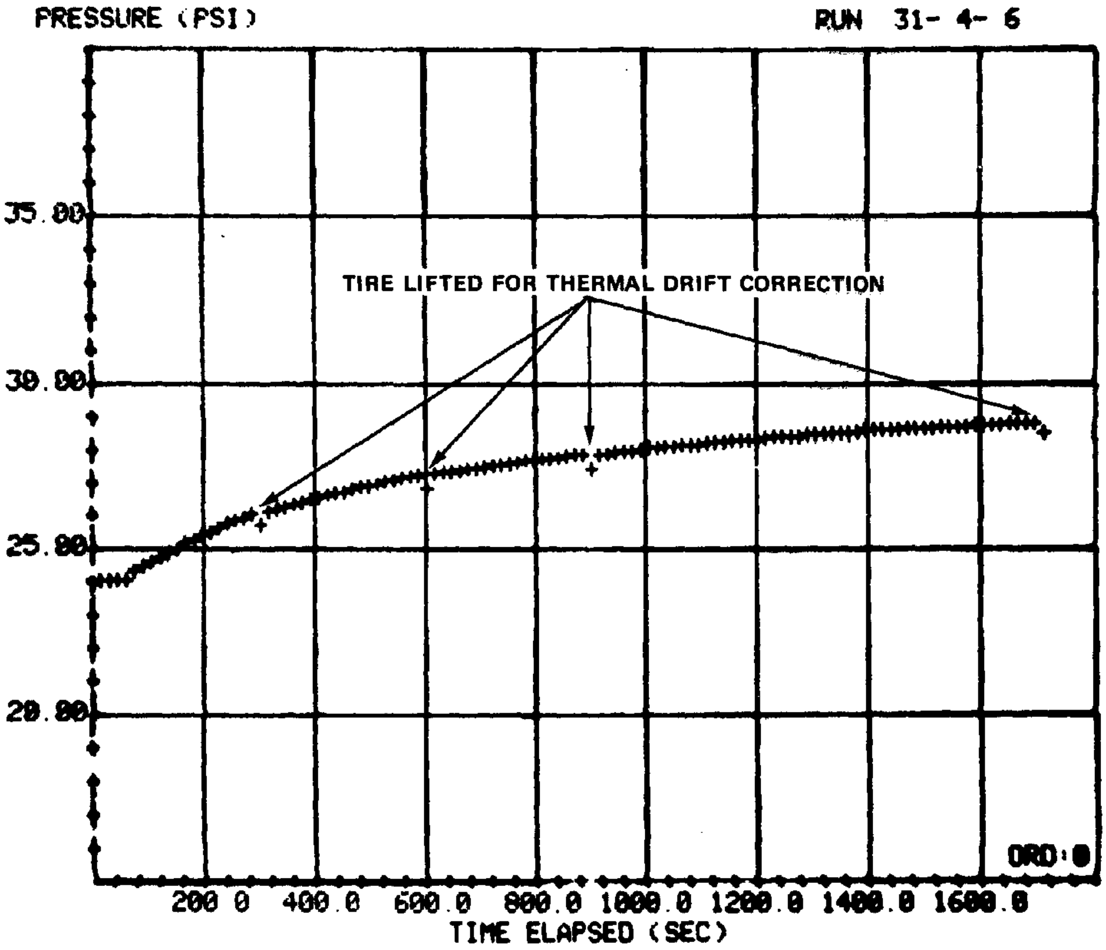

Figure 16 TYPICAL TIRF PLOT OF INFLATION PRESSURE VERSUS TIME

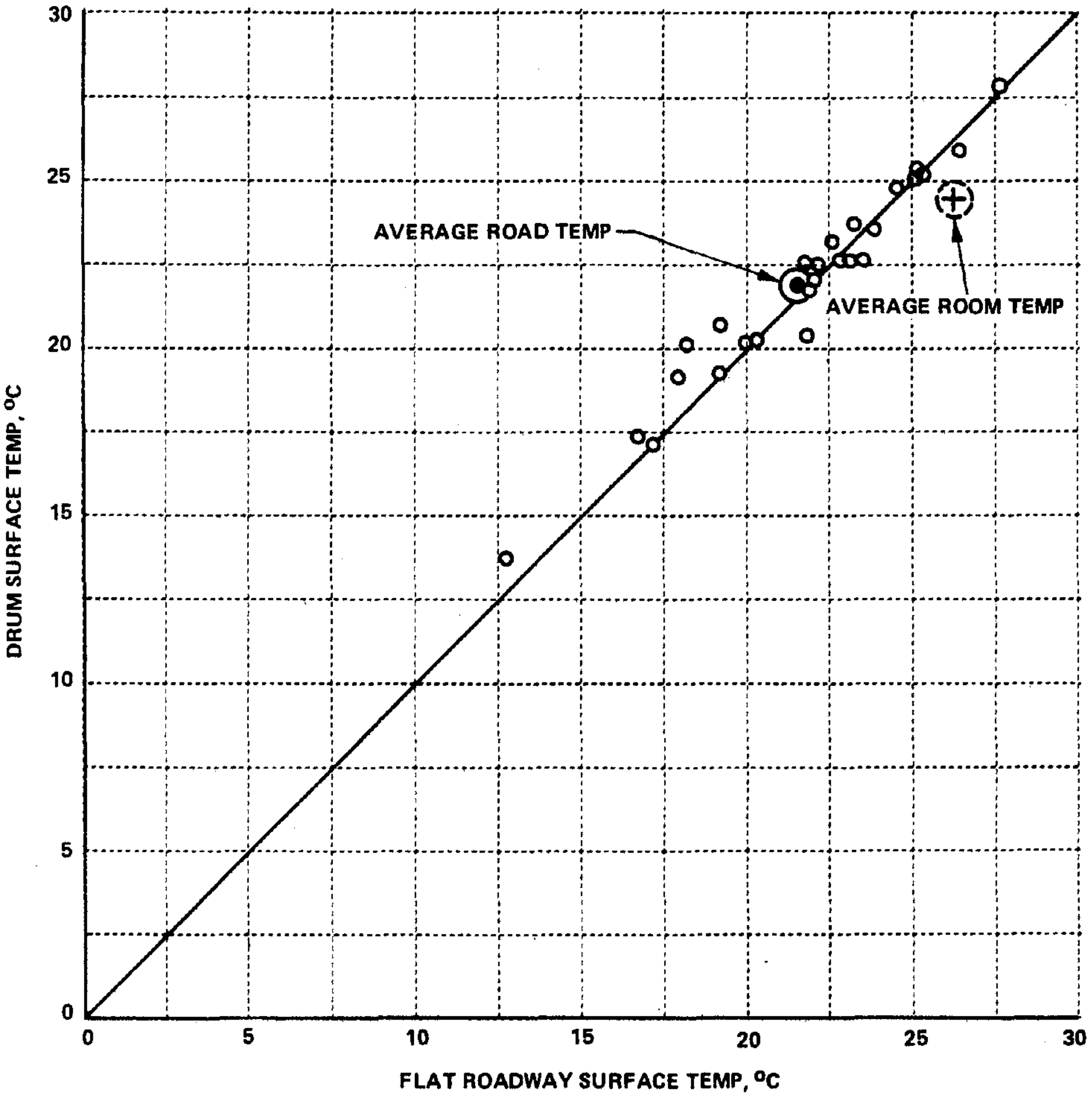

Figure 17 ROAD SURFACE TEMPERATURES OF CORRESPONDING TESTS ON FLAT ROADWAY AND DRUM

7. DATA PROCESSING

To condense the large amount of data measured for each tire into a few empirical constants, all transient data were curve-fitted by the least-square method. Upon inspection of TIRF-plotted curves such as shown in Figures 13 through 16, an exponential function of the kind

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}, \qquad (5)$$

appeared to be the "best" fit in terms of simplicity and accuracy. The variable X is the distance traveled (= time x speed), Y_o is the initial value of X =0 , Y_∞ is the equilibrium value at X = ∞, and λ represents the curvature. The curvature can be expressed in terms of the distance X_{99} at which the Y value has reached 99% (i.e. almost 100%) of its final value, Y_∞. That is, if

$$Y = Y_\infty + 0.01\,(Y_o - Y_\infty) \quad \text{(see Figure 18)},$$

then X = X_{99}, so that

$$Y_\infty + 0.01\,(Y_o - Y_\infty) = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X_{99}},$$

and, consequently,

$$\lambda = \frac{-\ln 0.01}{X_{99}} \,. \qquad (6)$$

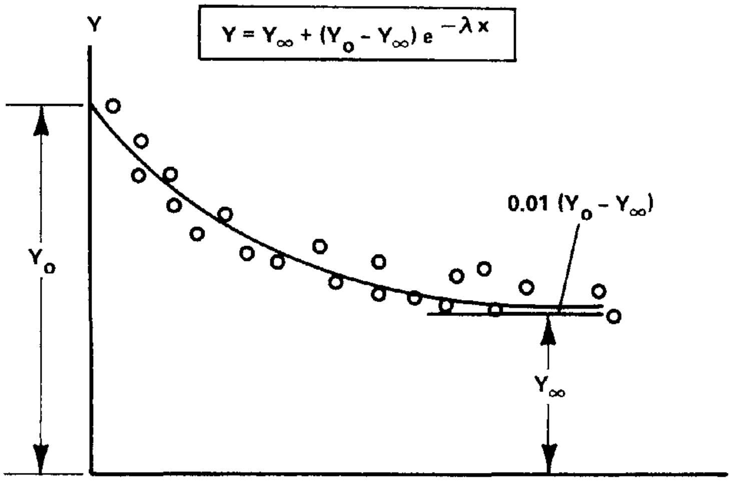

Figure 18 LEAST SQUARE EXPONENTIAL FIT OF EXPERIMENTAL TRANSIENT DATA

This expression substituted into (5) gives

$$Y = Y_{\infty} + (Y_{o} - Y_{\infty}) e^{-4.61\, X/X_{99}}. \qquad (7)$$

This expression was used to fit all transient test data including rolling resistance, contained air temperature, tread surface temperature, and inflation pressure. Fitting the FR data required two corrections of the raw data.

On TIRF, FX data are measured under the influence of the balance's bearing friction torque, BFT. To correct for BFT and thus obtain the longitudinal force for a tire without bearing friction, the correction formula

$$FX' = FX - BFT/RL, \qquad (8)$$

is applied, where RL is the loaded radius. The computation is performed on the TIRF computer and the result listed with a sign change as FRT (= - FX'), see Table 11.

The second correction is necessitated by the thermal drift of the balance. For each run, the experimental ΔFX data were fitted (with respect to distance traveled) by an exponential curve* and the curve data used to correct the TIRF measured FX data such that

$$FX'' = FX' - \Delta FX, \qquad (9)$$

or, since $-FX' = FRT$,

$$FX'' = -(FRT + \Delta FX). \qquad (10)$$

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*The corrections ΔFX averaged over 34 runs are plotted in Figure 19; the data clearly follow an exponential course. See also Figure 12.

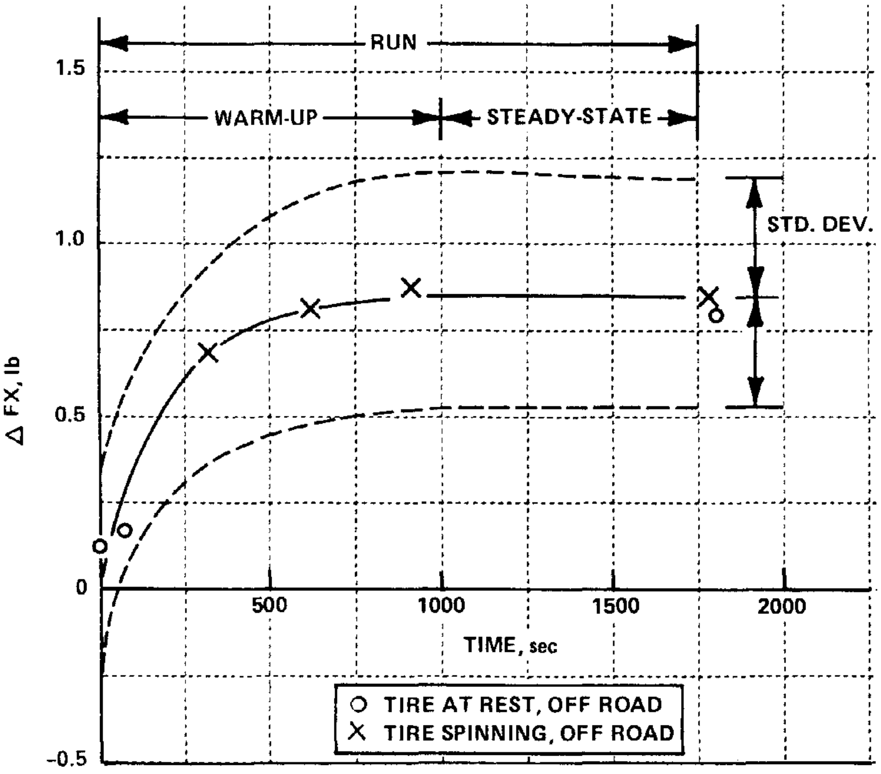

Figure 19 THERMAL DRIFT, ΔFX (AVERAGE OF 34 DIFFERENT RUNS)

To obtain positive signs, the negative values of FX" were defined as (positive) FXO.

$$FXO = -FX'' = FRT + \Delta FX. \qquad (11)$$

Note that FXO is the rolling resistance, FR_F, of the flat roadway.

$$FXO = FR_F . \qquad (12)$$

For the drum, a further correction is required, as shown by Equation (4) in Section 2.0.

The values of Y_∞, $Y_o - Y_\infty$, λ, and X_{99} computed for FXO, CAT, TST, and P were entered into tables, see Appendix A. The tables also contain the standard errors of the respective fits. They are very small. For the rolling resistance fits, the average standard error is 0.12 lb; for the contained air temperature fits, 0.21 °C; for the tread surface temperature fits, 0.04 °C; and for the pressure fits, 0.01 psi. These small errors demonstrate clearly the suitability of the exponential fits for the transient tire data of this program.

8. GENERAL PRESENTATION OF TEST RESULTS

All raw data were listed on TIRF data print-outs; a sample was shown in Table 11. The raw data were processed to yield

- For the transient tests (on flat bed and drum): Y_{∞}, $Y_o - Y_{\infty}$, λ , X_{99}; where Y stands for either FXO, CAT, TST, or P.
- For load and speed variation tests at constant temperatures: FXO, CAT, TST, P at various loads and speeds.

The results of the transient and the equilibrium pressure tests and of the load/speed variations test performed near equilibrium temperatures (see Figure 7) are listed in Appendix A for each tire tested, as mentioned, together with tire information (such as size, brand name, cord material) and run information (such as inflation pressure, load, speed). The results of the equilibrium baseline tests and the special tests are presented in Section 11 and 12, respectively.

9. FLAT ROADWAY TEST RESULTS

9.1 EFFECTS OF TIRE DESIGN AND CONSTRUCTION PARAMETERS

All 35 tires were subjected to transient tests of 30 min duration on the flat roadway, as specified in Tables 4, 5, and 6. In Figures 20 through 23, the average values of FR, CAT, TST, and P are plotted as functions of distance traveled. The curves exhibit rapid changes during the first ten miles and much slower changes thereafter, with steady-state condition achieved after 20 to 30 miles of travel. Table 12 shows that the bias ply tires reach equilibrium conditions a few miles earlier than both bias belted and radial tires -- for reasons not known at this time. Inflation pressure and contained air temperature reach equilibrium later than rolling resistance and tread surface temperature, at least for bias ply tires.

The figures suggest that there are significant differences between the three tire construction types regarding FR, CAT, TST, and P. It must be suspected, however, that the differences are strongly influenced by the fact that the distributions of tire sizes within each of the three types are not equal; for instance, the bias ply tires do not include an L size tire, the bias-belted tires include a tire of aspect ratio 60, etc., see Table 1. Therefore, a statistical analysis was made of the effect of basic tire constructions on rolling resistance involving only tires of equal size. Tables 13 and 14 show the differences of rolling resistance coefficients of pairs of tires; the tires of each pair are of equal size but of different construction. The average difference between bias ply and bias belted tires of 1.05 lb/klb is not significant, (Table 13). The average difference of 2.36 lb/klb between bias belted and radial ply tires, however, is significant (Table 14). This is not to say that a significant difference between the bias ply and bias belted tires would not exist; but our sample of four tires was too small to prove this.

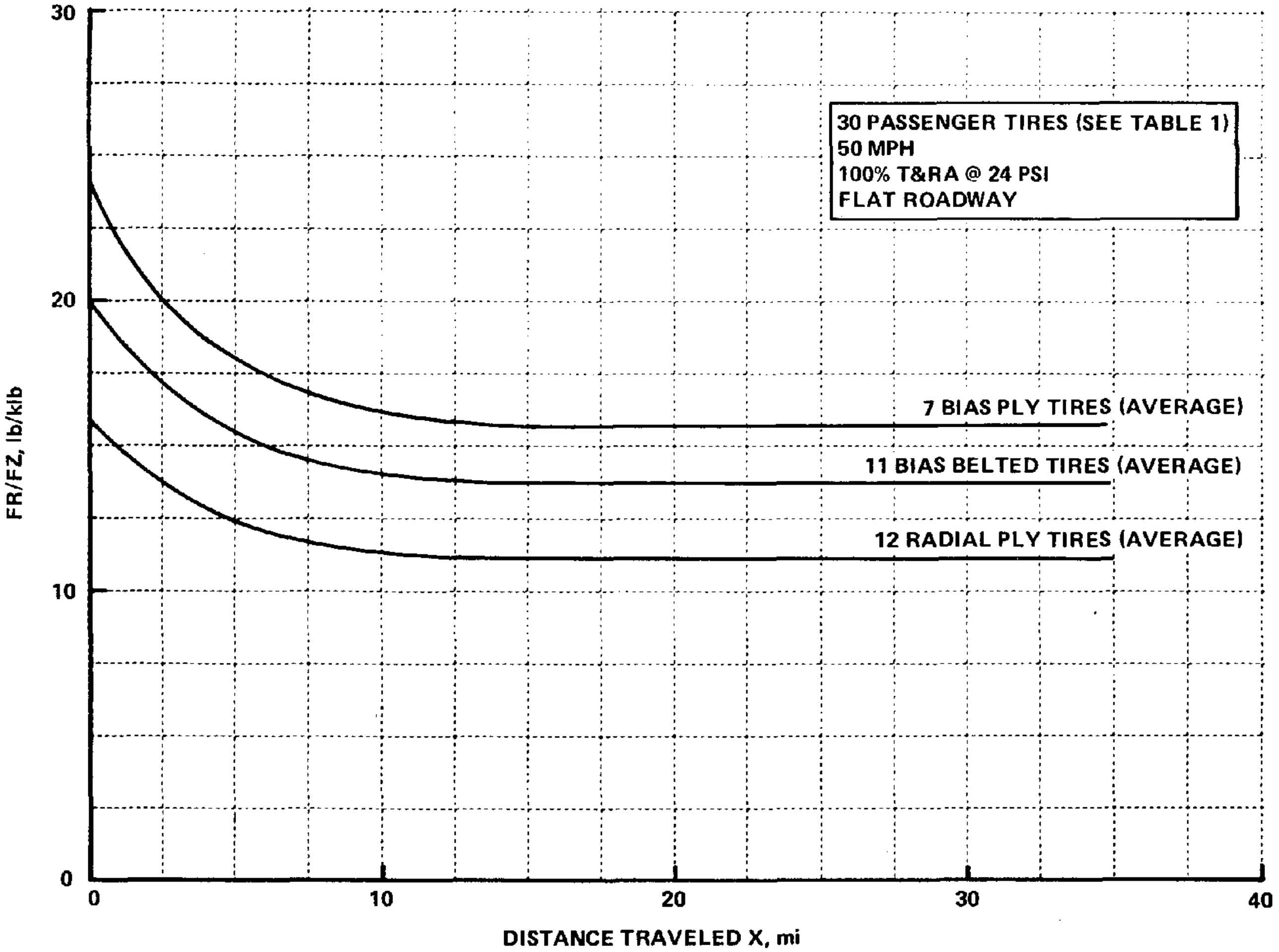

Figure 20 COEFFICIENT OF ROLLING RESISTANCE VS DISTANCE TRAVELED

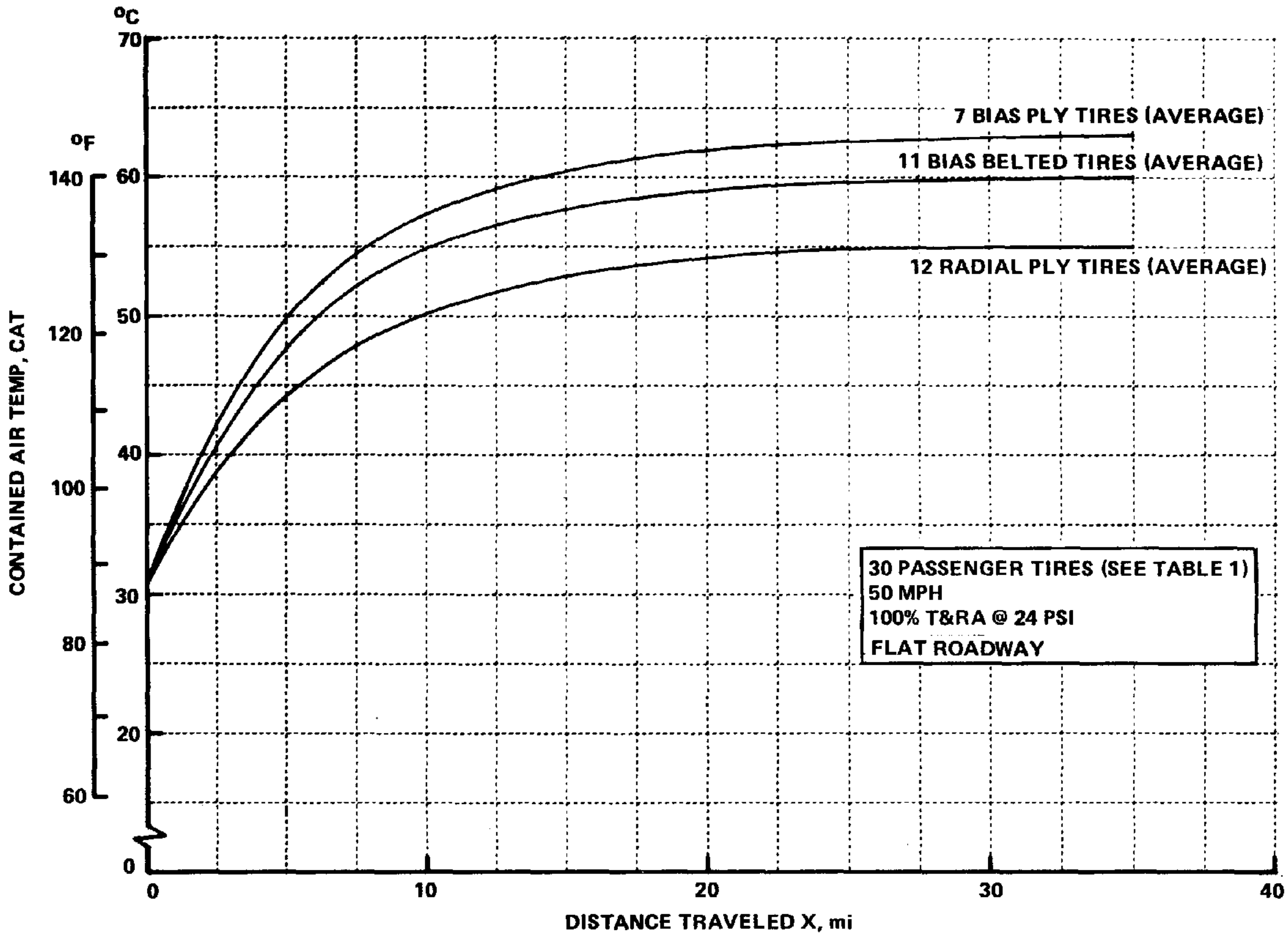

Figure 21 CONTAINED AIR TEMPERATURE VS DISTANCE TRAVELED

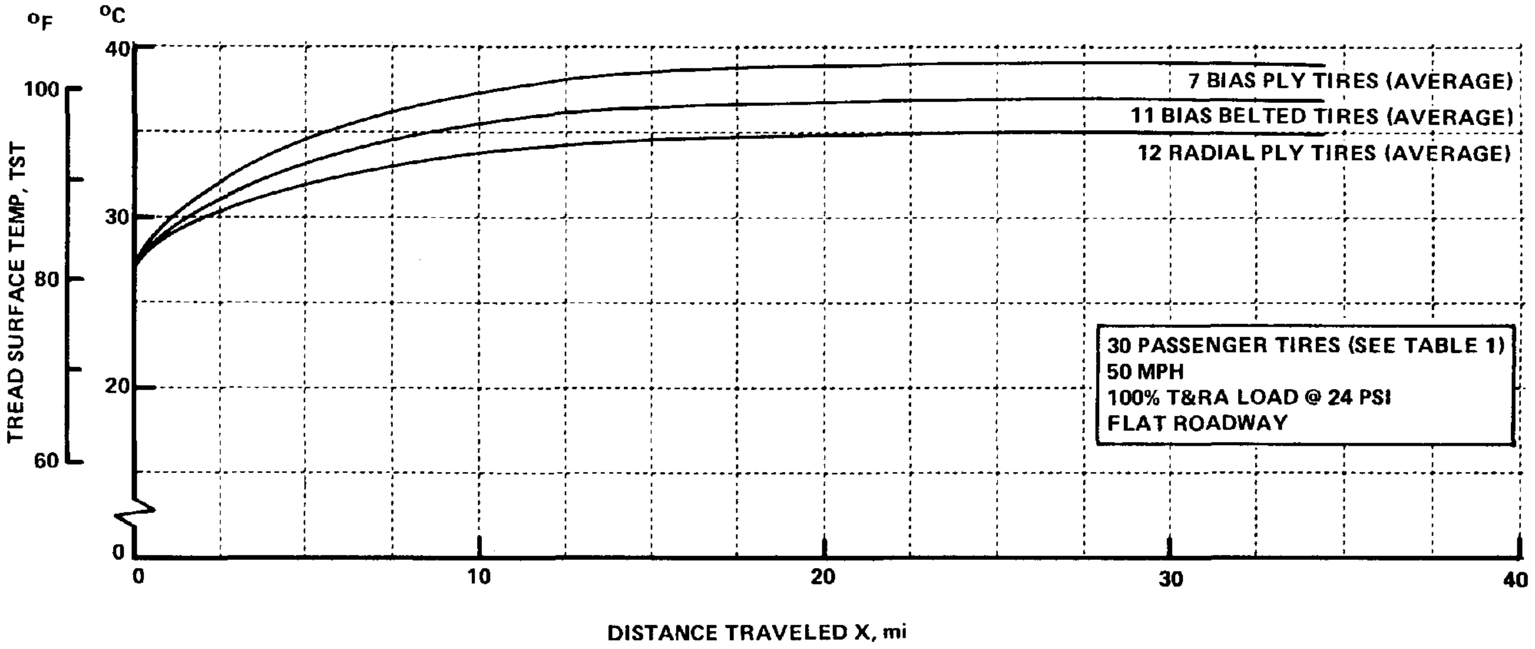

Figure 22 TREAD SURFACE TEMPERATURE VS DISTANCE TRAVELED

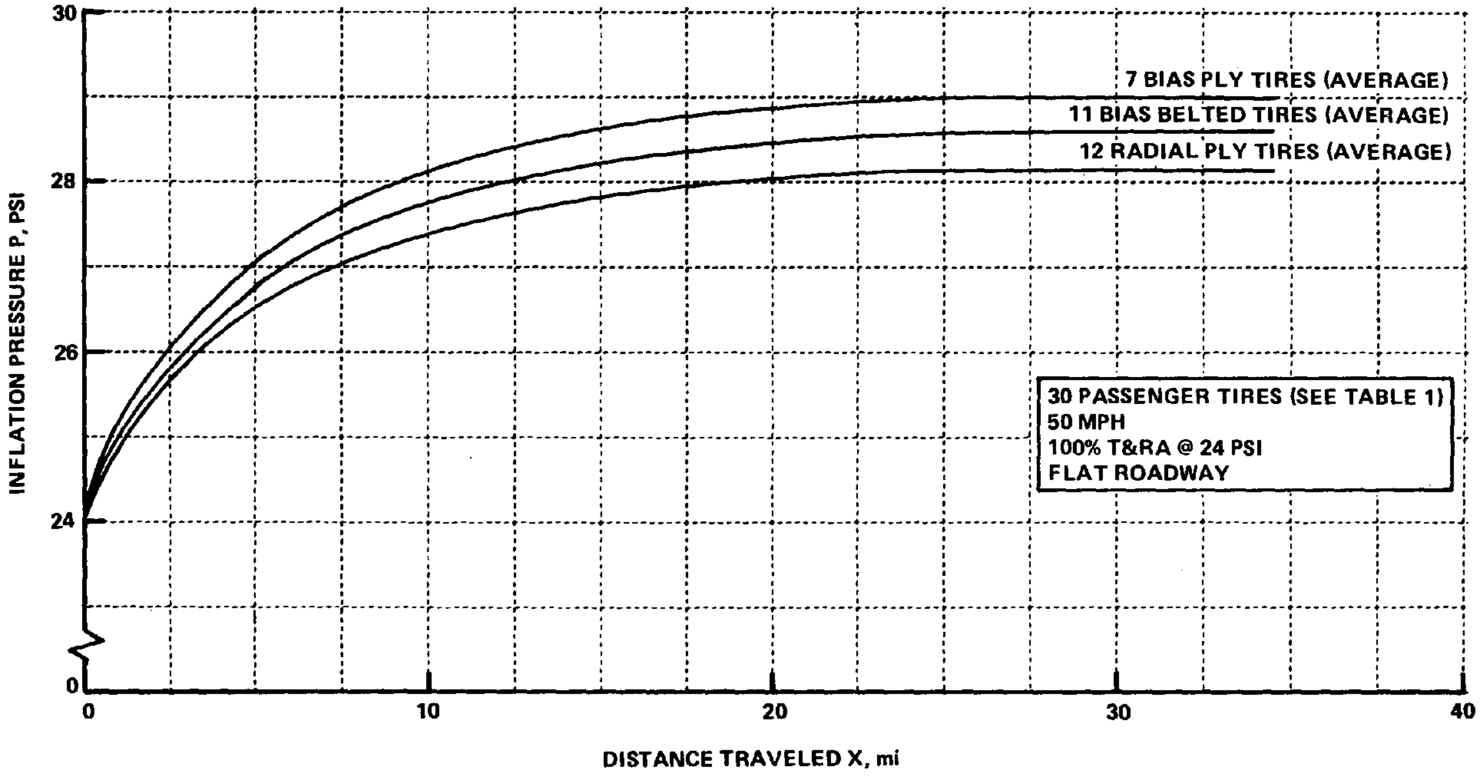

Figure 23 INFLATION PRESSURE VS DISTANCE TRAVELED

TABLE 12 DISTANCE REQUIRED TO REACH EQUILIBRIUM FOR FR, CAT, TST, P.

PASSENGER TIRES ON FLAT ROADWAY,
T&RA LOAD AT 24PSI COLD
50 MPH

	X_{99}, miles			
	FR	TST	CAT	P
Bias Ply	17	19	26	25
Bias Belted Radial Ply	20	28	32	29

TABLE 13 Effect of basic tire construction on equilibrium rolling resistance

NS = No significant difference between bias ply and bias belted

Bias Ply			Bias Belted			$\left.\frac{FR_\infty}{Fz}\right\|_B - \left.\frac{FR_\infty}{Fz}\right\|_{BB}$
Size	Run No	$\frac{FR_\infty}{FZ}$ lb/klb	Size	Run No	$\frac{FR_\infty}{FZ}$ lb/klb	
G78-15	13	14.40	G78-15	5	13.30	1.10
G78-14	29	16.35	G78-14	3	13.75	2.60
D78-14	40	14.95	D78-14	38	14.84	0.11
A78-13	42	16.24	A78-13	41	15.84	0.40
Average		15.49			14.43	1.05 (NS)
Std. Dev		0.96			1.14	1.11

$$t = \frac{1.05\sqrt{4}}{1.11} = 1.89 < t_{95}$$

$$t_{95} = 2.78$$

TABLE 14 Effect of basic tire construction on equilibrium rolling resistance

S = Significant difference between bias belted and radial ply

Bias Belted			Radial Ply			
Size	Run No	$\frac{FR_{\infty}}{F_Z}$ lb/klb	Size	Run No	$\frac{FR_{\infty}}{F_Z}$ lb/klb	$\frac{FR_{\infty}}{F_Z}\Big\|_{BB} - \frac{FR_{\infty}}{F_Z}\Big\|_{R}$
D70-14	1	14.07	DR70-14	35	11.84	2.23
G78-14	3	13.75	GR78-14	28	10.74	3.01
G70-15	4	12.88	GR70-15	6	10.11	2.77
A70-13	15	12.34	AR70-13	14	11.44	0.90
G70-14	30	12.78	GR70-14	31	13.05	-0.27
D78-14	38	14.84	DR78-14	34	11.07	3.77
L78-15	45	14.75	LR78-15	44	10.65	4.10
Average		13.63			11.27	2.36 (S)
Std. Dev		0.99			0.96	1.56

$$t = \frac{2.36\sqrt{7}}{1.56} = 4.00 > t_{99}$$

$$t_{99} = 3.71$$

In Table 15, the coefficients of rolling resistance of tire pairs with different aspect ratios are compared; the small average difference of 0.58 lb/klb is clearly accidental. The same is true for the influence of wheel size, Table 16.

The effects of tire size on equilibrium rolling resistance FR_{∞}, and on contained air temperature, CAT_{∞}, and tread surface temperature, TST_{∞}, are demonstrated in Figures 24, 25, and 26. Figure 24 indicates that FR_{∞} is a linear function of design load. Linear least-square fits resulted in the three values of 15.7, 13.8, and 11.2 lb/klb for FR_{∞}/FZ for bias ply, bias belted, and radial ply tires, respectively; but the difference between bias ply and bias belted tires may not be significant, as pointed out. The same figure shows rolling resistance data for the four light truck tires tested; general conclusions are not possible other than that due to the higher inflation pressures the coefficients of rolling resistance are much lower than those of passenger tires. The temperature data in Figures 25 and 26 indicate a weak increase of CAT_{∞} with design load, and no change of TST_{∞} (at least for bias tires; for radial tires, TST_{∞} appears to decrease with design load). The radial ply tires show a lower contained air temperature than the bias tires; Figure 25 indicates an average difference of about 10°F. The tread surface temperature data show too much scatter to permit a differentiation between bias and radial tires.

9.2 EFFECT OF TRIP LENGTH ON THE DETERMINATION OF EQUILIBRIUM ROLLING RESISTANCE

In the preceding section we showed that the equilibrium value of rolling resistance, FR_{∞}, is reached after a run length of about 20 miles. Since the experimental data can be fitted exponentially with excellent accuracy (the standard deviation of measured data from the fitted curves was about

*Estimated from Table 18

TABLE 15 Effect of aspect ratio on equilibrium rolling resistance

NS = Not significantly different from zero

A.R. 70			A.R. 78			
Size	Run No	$\frac{FR_\infty}{Fz}$ lb/klb	Size	Run No	$\frac{FR_\infty}{Fz}$ lb/klb	$\frac{F_{R\infty}}{Fz}\Big\rvert_{70} - \frac{FR_\infty}{Fz}\Big\rvert_{78}$
A70-13	15	12.34	A78-13	41	15.84	-3.50
D70-14	1	14.07	D78-14	38	14.84	-0.77
G70-14	30	12.78	G78-14	3	13.75	-0.97
DR70-14	35	11.84	DR78-14	34	11.07	0.77
GR70-14	31	13.05	GR78-14	28	10.74	2.31
G70-15	4	12.88	G78-15	5	13.30	-0.42
GR70-15	6	10.11	GR78-15	39	11.63*	-1.52
HR70-15	8	10.61	HR78-15	7	11.13	-0.52
Average		12.21			12.79	-0.58 (NS)
Std. Dev.		1.31			1.93	1.68

$$t = \frac{0.58\sqrt{8}}{1.68} = 0.98 < t_{95}$$

$$t_{95} = 2.37$$

TABLE 16 Effect of wheel diameter on equilibrium rolling resistance

NS = No significant difference between 14 and 15 inch wheels

W.D. 14"			W.D. 15"			$\frac{FR_\infty}{FZ}\Big\vert_{14} - \frac{FR_\infty}{FZ}\Big\vert_{15}$
Size	Run No	$\frac{FR_\infty}{FZ}$ lb/klb	Size	Run No	$\frac{FR_\infty}{FZ}$ lb/klb	
G78-14	3	13.75	G78-15	5	13.30	0,45
GR78-14	28	10.74	GR78-15	39	11.63*	- 0,89
G78-14	29	16.35	G78-15	13	14,40	1.95
G70-14	30	12.78	G70-15	4	12,88	-0.10
GR70-14	31	13.05	GR70-15	6	10.11	2.94
FR78-14	33	10.88	FR78-15	11	10.52	0.36
Average		12,93			12.14	0,79 (NS)
Std. Dev.		2.07			1.67	1.41

$$t = \frac{0.79 \cdot \sqrt{6}}{1.41} = 1.37 < t_{95}$$

$$t_{95} = 2.57$$

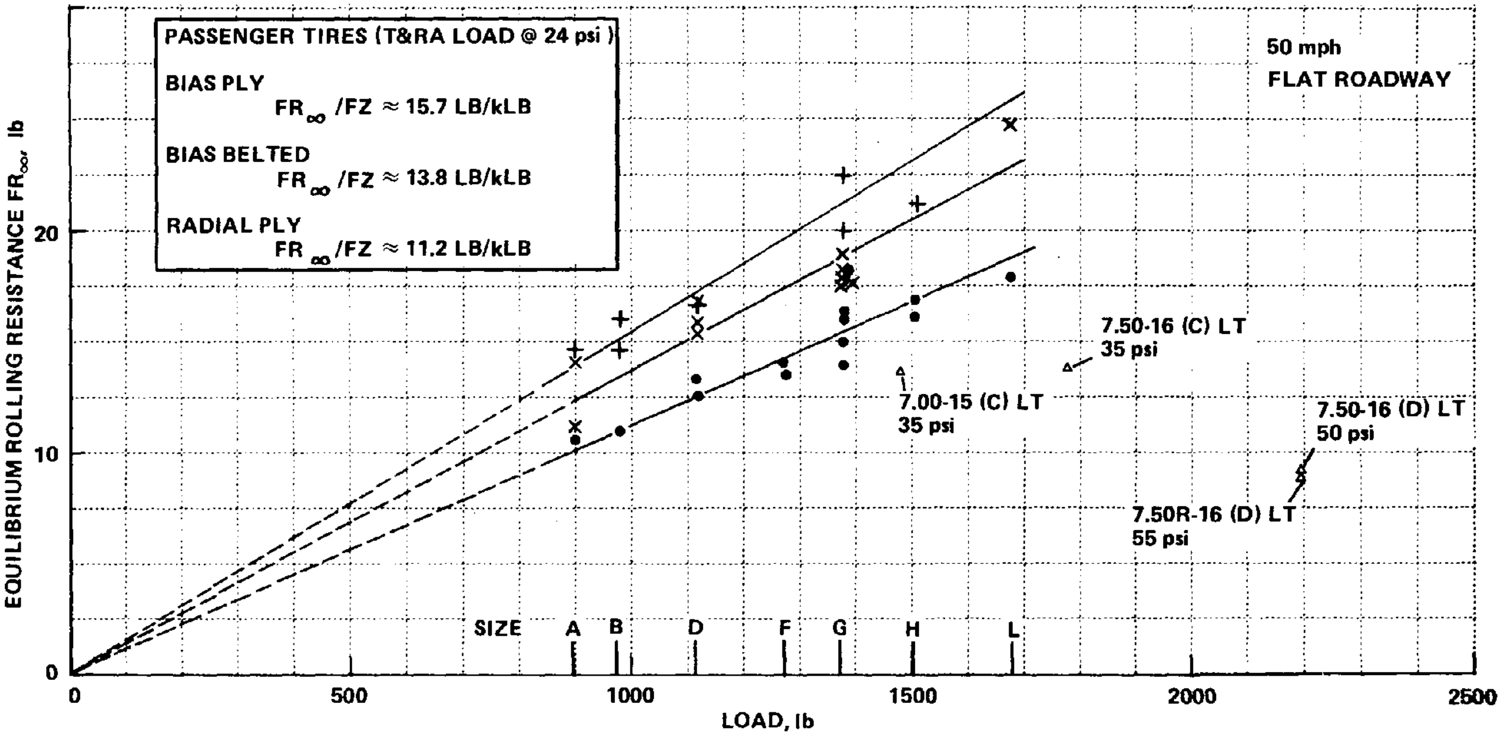

Figure 24 EFFECT OF TIRE SIZE ON EQUILIBRIUM ROLLING RESISTANCE. 31 PASSENGER TIRES (SEE TABLE 1) AND 4 LIGHT TRUCK TIRES

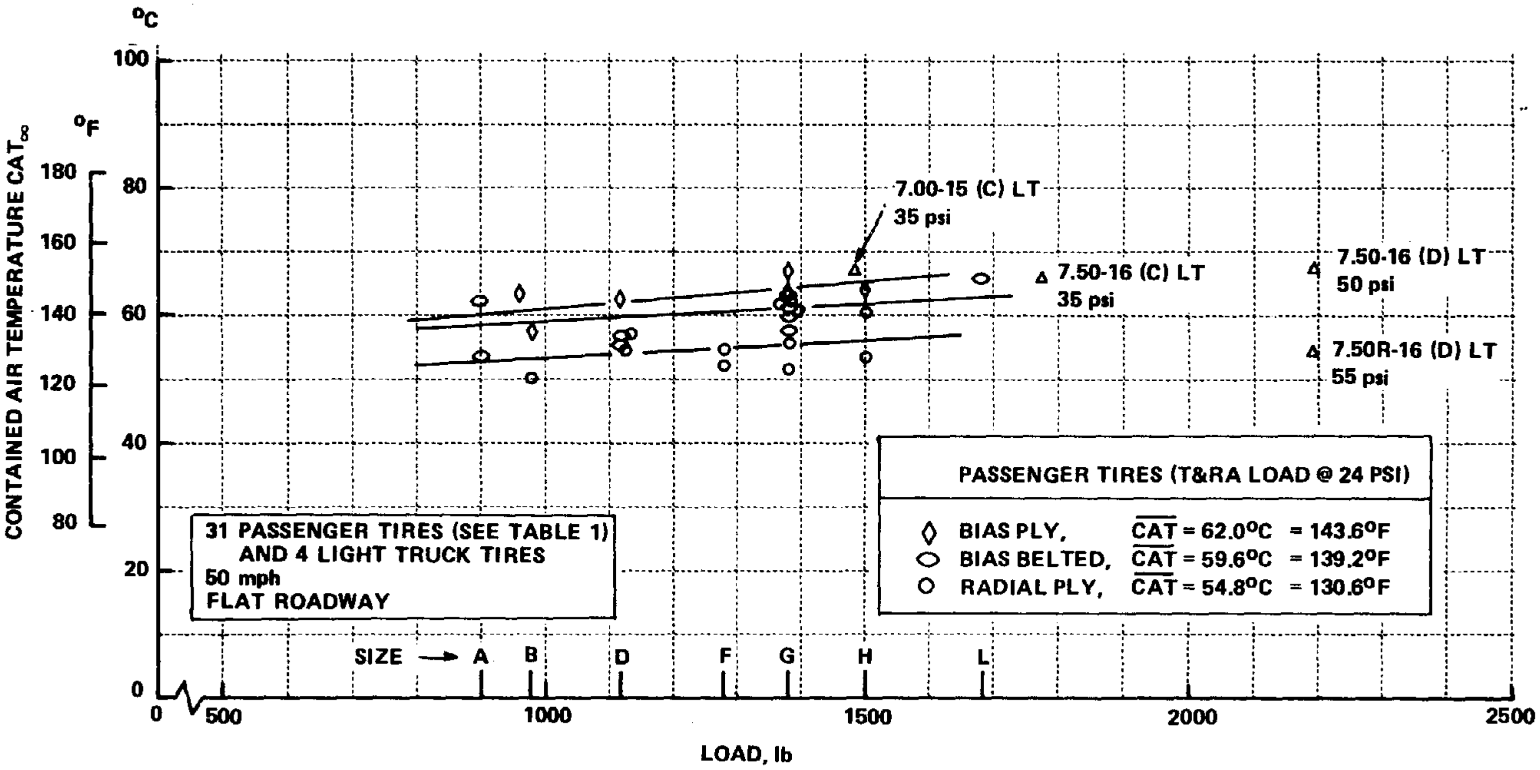

Figure 25 EFFECT OF TIRE SIZE ON EQUILIBRIUM CONTAINED AIR TEMPERATURE

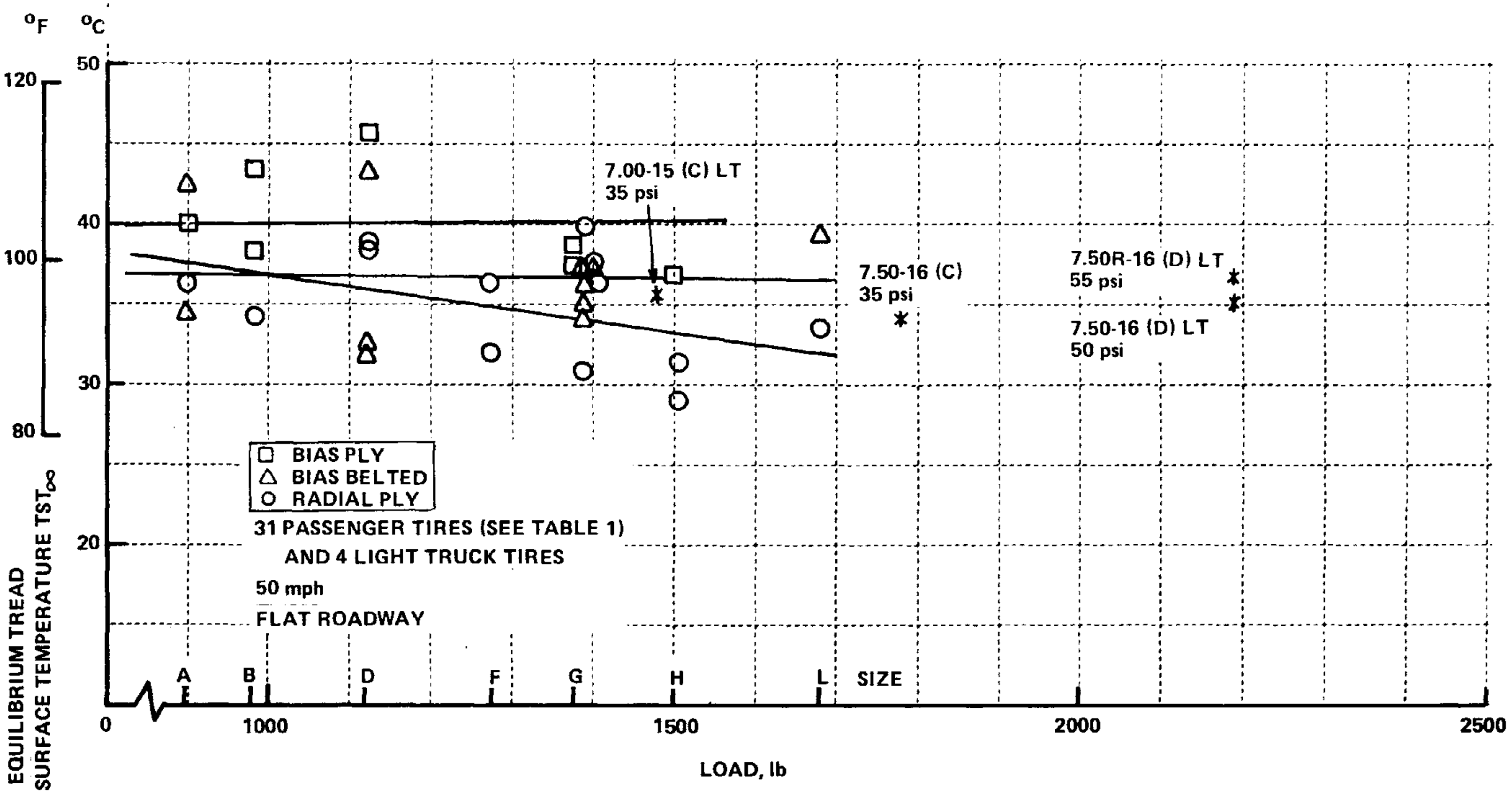

Figure 26 EFFECT OF TIRE SIZE ON EQUILIBRIUM TREAD SURFACE TEMPERATURE

0.12 lb, as noted), the question was raised if the equilibrium rolling resistance value could not be estimated from shorter runs, of the order of 10 miles. An answer was tried by analyzing the FR data of three tires, a bias ply, a bias belted, and a radial ply tire. First, FR_{∞} values were computed from experimental 25-mile run data. The experimental data were then reduced by two-mile increments. For each resulting set of data, a new FR_{∞} was computed through curve fitting and the new FR_{∞} values compared with the original FR_{∞} obtained from the 25-mile run. The relative differences

$$\frac{FR_{\infty 25} - FR_{\infty i}}{FR_{\infty 25}} ,$$

where i = 23, 21, 19, etc.,

are plotted in Figure 27. The difference or "error" is negligible beyond 20 miles; it is about 1% at 17 miles, 2% at 14 miles; and 5% at 9 miles. Below 9 miles, the error grows very rapidly. It appears then that if the equilibrium value of the rolling resistance is to be determined with good accuracy, a tire should be run for at least 15 miles.

9.3 EFFECTS OF LOAD AND SPEED ON ROLLING RESISTANCE AT CONSTANT TEMPERATURE

In actual road operations, a tire is usually subjected to changes of load and speed. If these changes are rapid (for instance, in a cornering maneuver), the tire temperature will remain constant, and the rolling resistance will assume values different from those at equilibrium conditions. To generate rolling resistance values at constant temperatures, the load and, for some tires, the speed were varied rapidly at the end of each transient run, where equilibrium status was reached, as described in Section 4. The

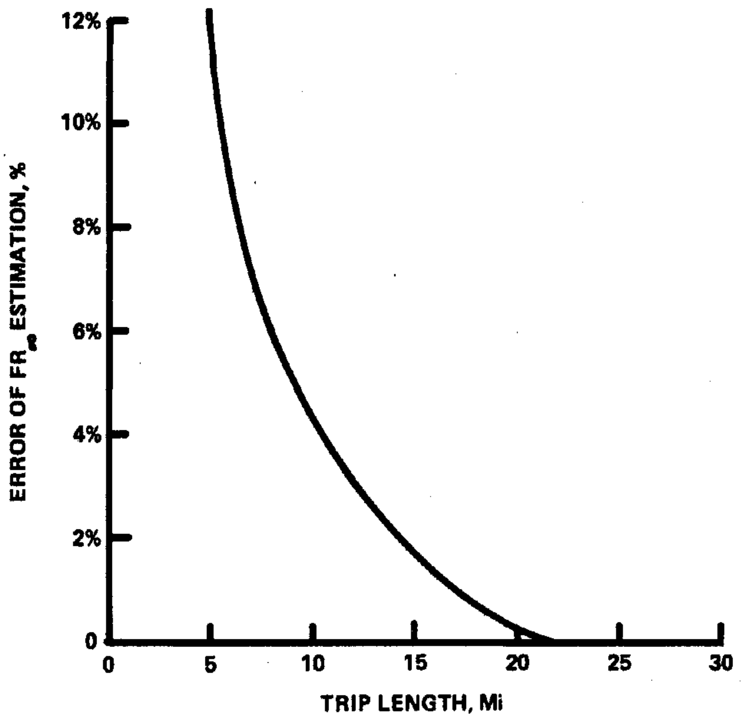

Figure 27 INFLUENCE OF TRIP LENGTH ON ERROR OF FR_{∞} ESTIMATION

resulting rolling resistance values are listed in Appendix A. A few of these values are plotted in Figures 28, 29, and 30. Figures 28 and 29 show that for rapid load variations around the equilibrium state at 100% T&RA load, the rolling resistance coefficient increases with load for bias ply and bias belted tires, but remains fairly constant for radial ply tires.

Figure 30 indicates that with the speed rapidly increased (decreased) from the state of equilibrium at 50 mph, the rolling resistance increases (decreases) slightly, too. We will see later (Section 11.0) that for very slow changes of load and speed, where the tire is allowed to assume equilibrium conditions for each load and speed, the results are somewhat different.

9.4 EFFECT OF INFLATION PRESSURE ON EQUILIBRIUM ROLLING RESISTANCE

Inflation pressure has a distinct influence on rolling resistance, as demonstrated in Figure 31. The data in this figure were obtained by running transient tests at 16 and 24 psi cold, up to equilibrium at which the pressure had risen by 4 to 6 psi (depending on tire size), and also by tests at about 32 psi equilibrium. (Figure 6 shows the schedule for 16 psi cold plus 32 psi hot, and Figure 4 for 24 psi cold).

Figure 31 shows that at equilibrium, rolling resistance decreases with pressure. If linear change is assumed between 20 and 32 psi (equilibrium) and the value of FR_{∞} at 29 psi (equilibrium), corresponding roughly to 24 psi cold, is taken as reference value, then an increase (decrease) of inflation pressure by 1 psi would decrease (increase) the equilibrium rolling resistance by roughly 3%.

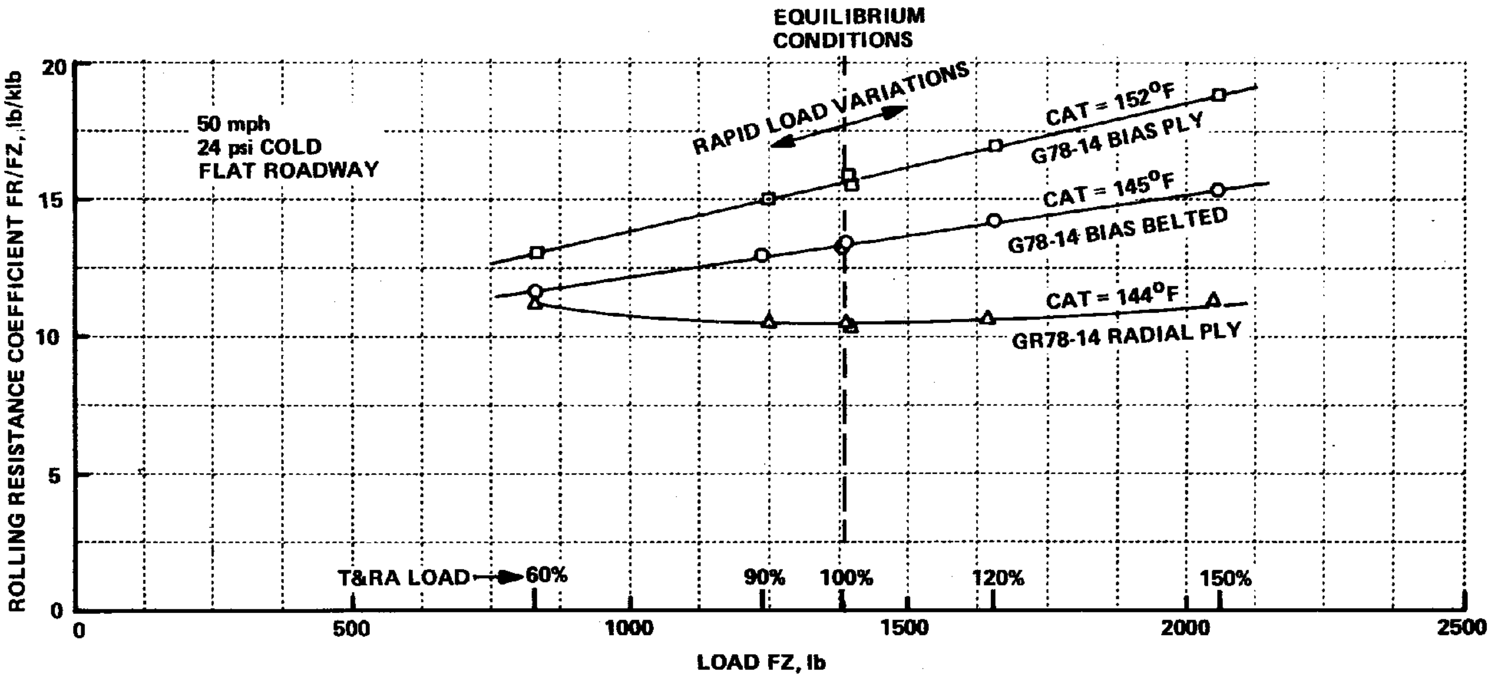

Figure 28 EFFECT OF VERTICAL LOAD ON ROLLING RESISTANCE AT CONSTANT TEMPERATURE

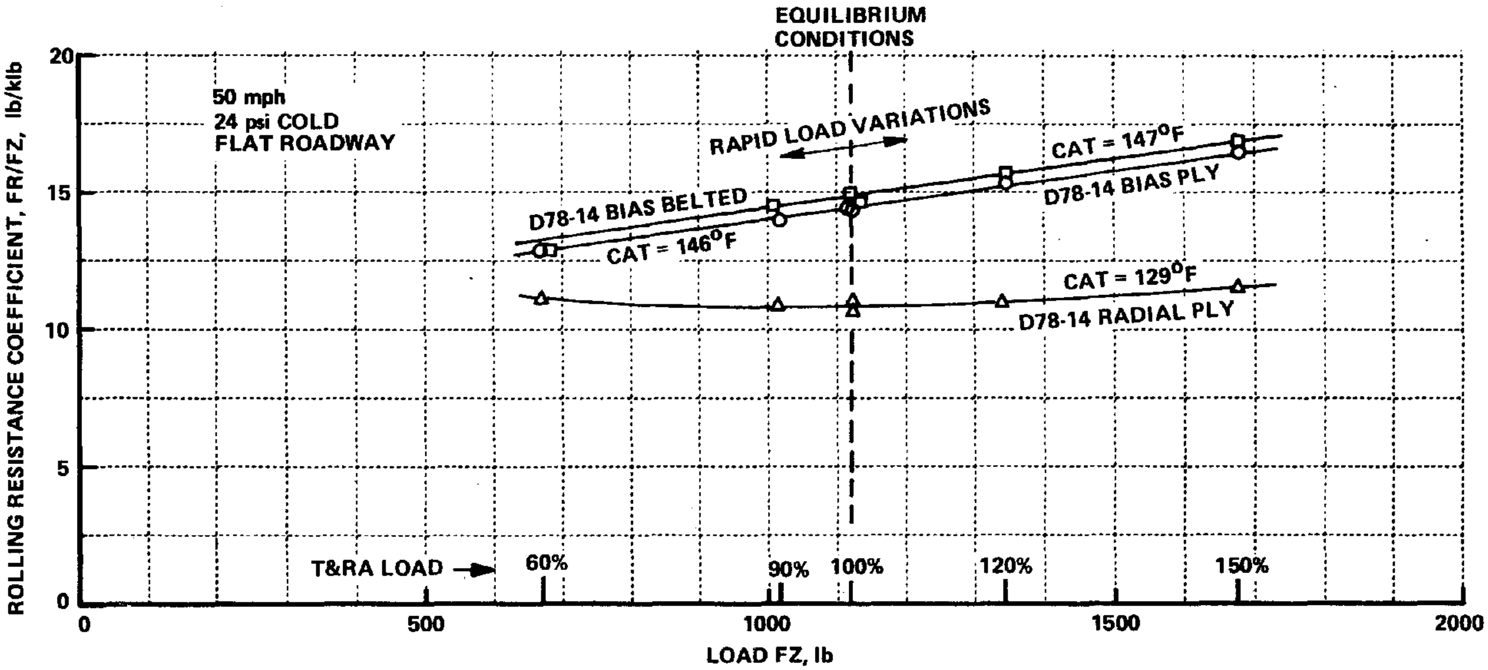

Figure 29 EFFECT OF VERTICAL LOAD ON ROLLING RESISTANCE AT CONSTANT TEMPERATURE

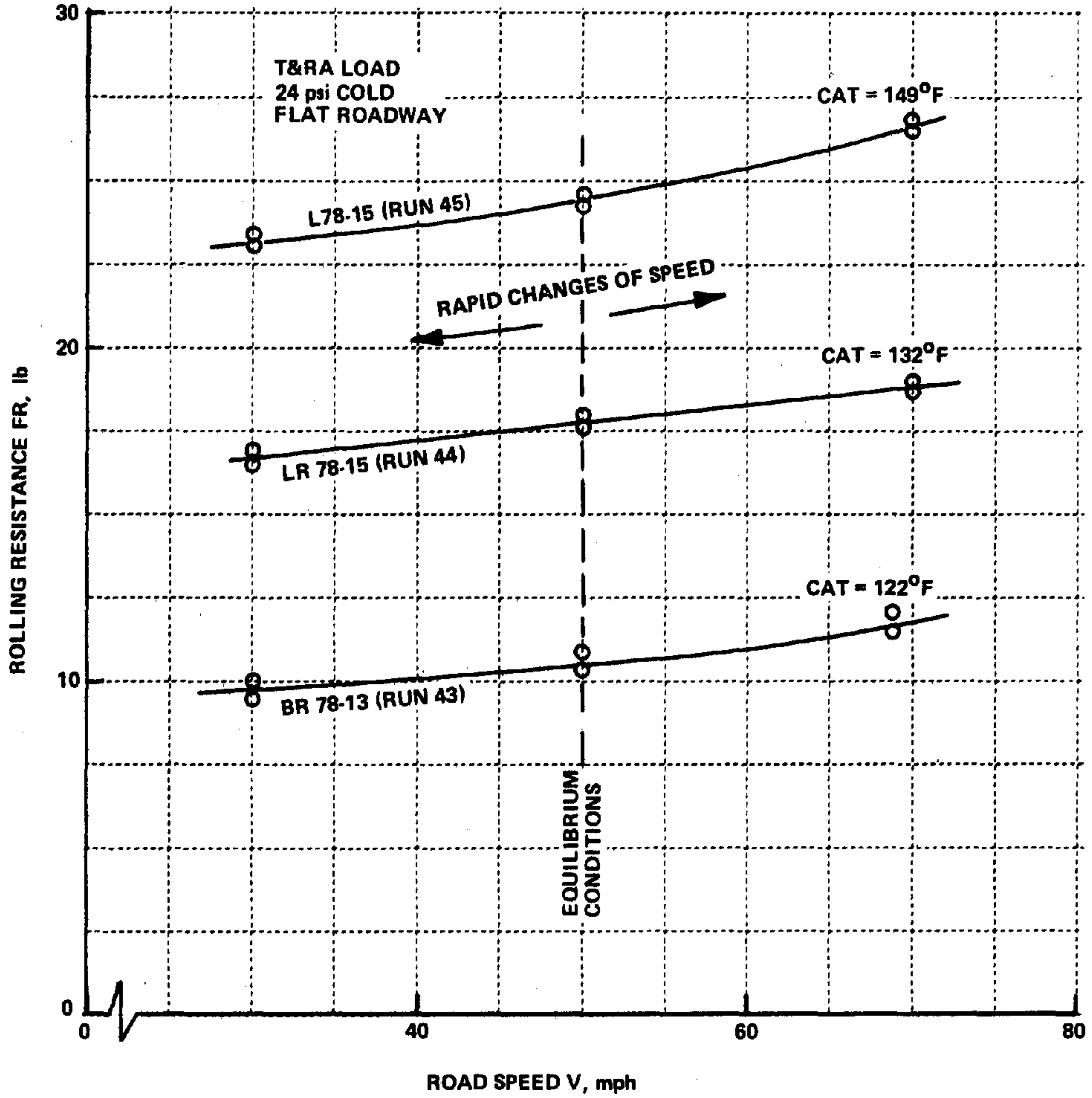

Figure 30 EFFECT OF ROAD SPEED ON ROLLING RESISTANCE AT CONSTANT TEMPERATURE

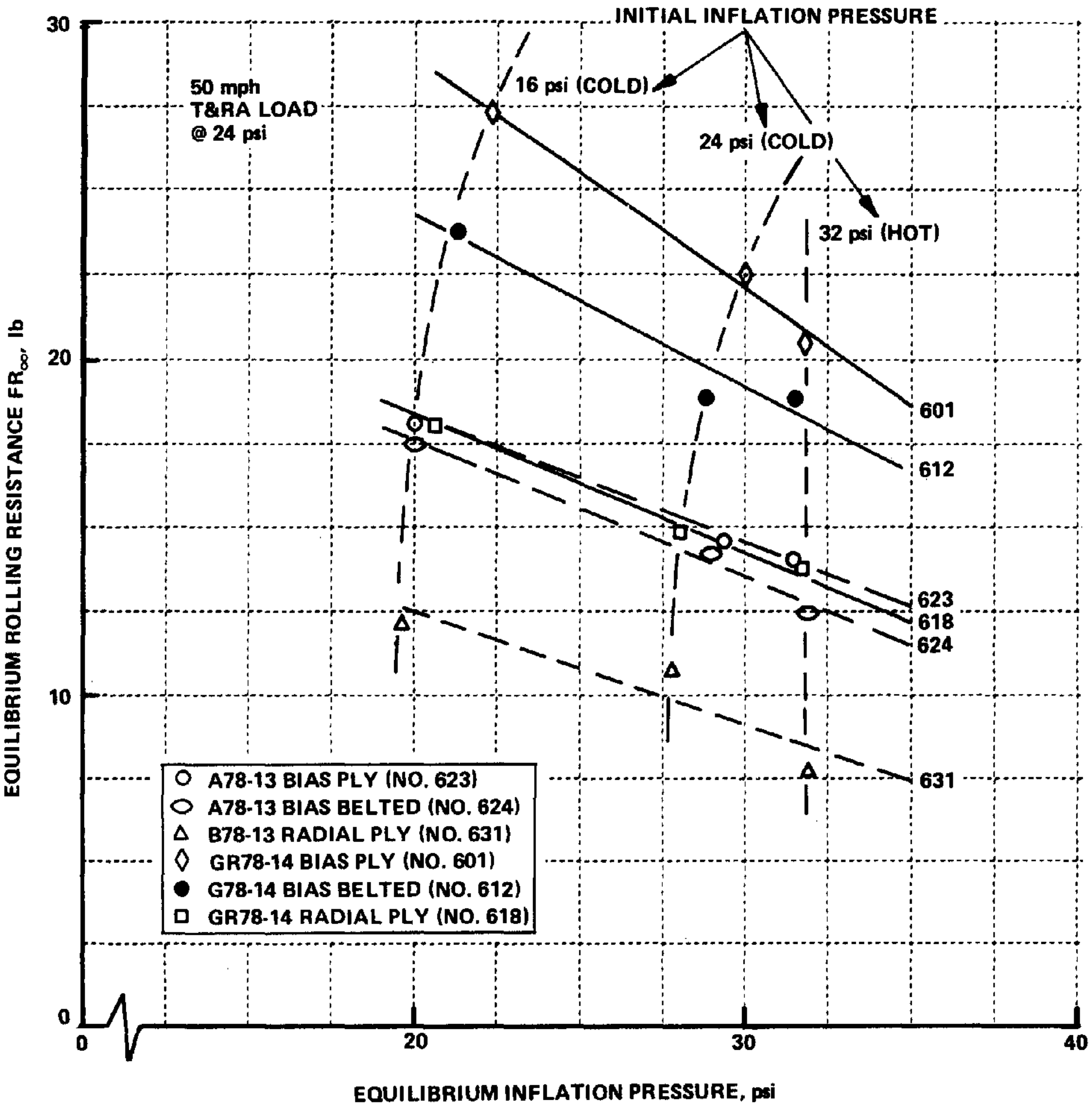

Figure 31 EFFECT OF INFLATION PRESSURE ON EQUILIBRIUM ROLLING RESISTANCE

10. FLAT ROADWAY/DRUM COMPARISONS FOR NINE TIRES

Nine of the 34 tires tested were run on both flat roadway and drum. The tire and run numbers are identified in Tables 1 and 6; they include the 5 SAE Round Robin tires and 4 more tires of suitable sizes and constructions. Only transient tests (Figure 4) were performed with the exception of the baseline tests (Tire No. 640), which will be discussed in Section 11.

Since the road temperature was known to have an important effect on rolling resistance, the drum surface was cooled down to corresponding flat roadway temperatures, as described in Section 6 and shown in Figure 17.

The influence of road curvature on rolling resistance data is illustrated in Appendix B, where the transient data of the SAE Round Robin tires are compared for flat roadway and drum tests. The comparisons include the longitudinal force FXO (which is identical with the rolling resistance FR of the flat roadway), the contained air temperature CAT, the tread surface temperature TST, and the inflation pressure P. In all instances, the FXO drum data are smaller than those of the flat roadway. Correspondingly, the drum data for CAT, TST, and P are higher than those of the flat roadway. Figure 32 shows FXO_{∞} for all tires tested on flat roadway and drum. Plotted versus tire size (Figure 33), the ratio $FXO_{\infty D}/FXO_{\infty F}$ reveals a weak dependence on tire size. Clark (Reference 11) attempted to predict the ratio $FXO_{\infty D}/FXO_{\infty F}$ on theoretical grounds. His predictions indicated in Figure 33 show fair agreement with our test results. In the average, the ratio is about 0.85;* i.e., if tested on the drum, the equilibrium longitudinal force is about 15% smaller than the corresponding flat roadway force.

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*Without tire 640, see Section 11.

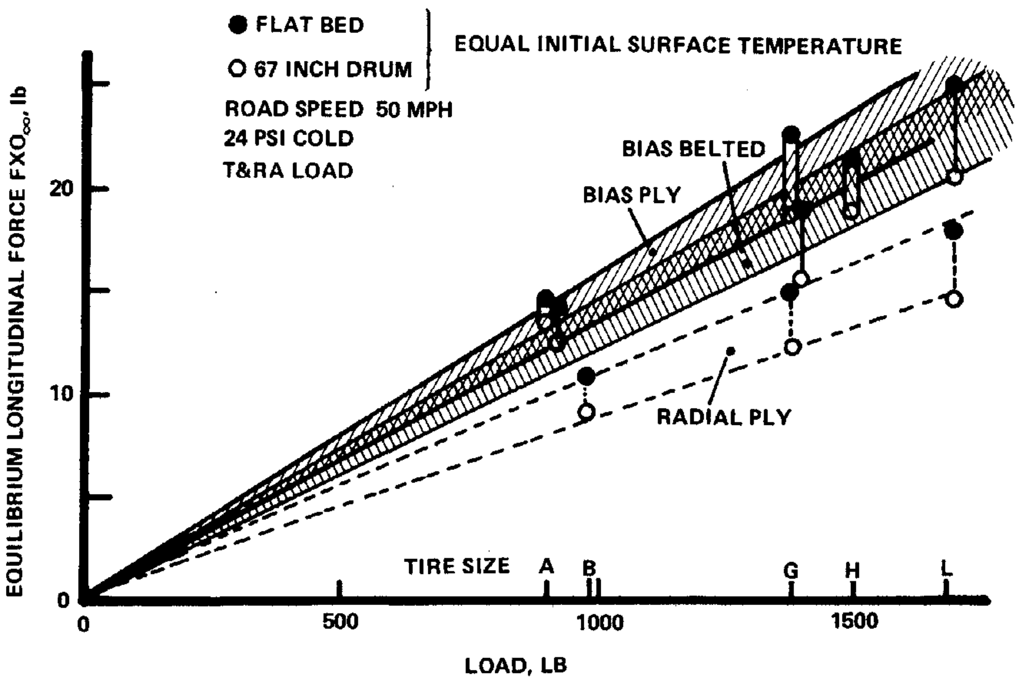


Figure 32 EFFECT OF ROAD CURVATURE ON EQUILIBRIUM LONGITUDINAL FORCE (9 TIRES, SEE TABLES 4 AND 6)

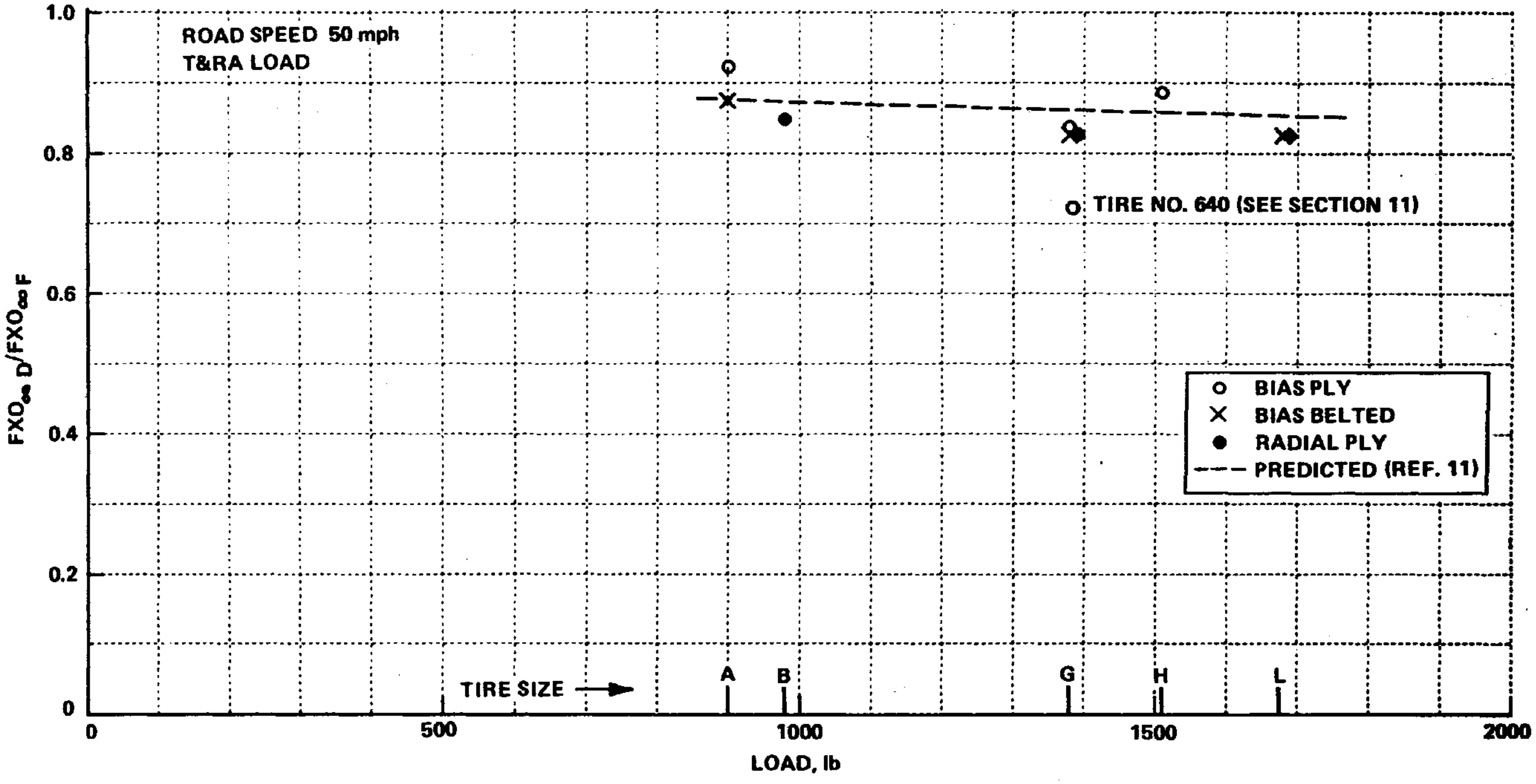


Figure 33 RATIOS OF LONGITUDINAL (EQUILIBRIUM) FORCES ON DRUM AND FLAT ROADWAY (SEE FIGURE 32)

COMPARISONS AT EQUAL CONTAINED AIR TEMPERATURES

Assuming that rolling resistance is a distinct function of tire temperature, we compared drum and flat roadway data at the same contained air temperature of 40°C or 104°F. This temperature was selected because all nine tires would pass through it shortly after the beginning of a run. The results of the comparison are presented in Table 17. It shows that the average longitudinal tire force is 13% smaller on the drum than it is on the flat roadway, a number close to the 15% stated for equilibrium values. The individual differences range from 6% (tire 623, an A18-13 bias ply tire) to 19% (tire 627, an LR78-15 tire). The reason for the differences in longitudinal forces lays probably in the different pressure distributions of the tires' footprints: on the drum, the pressure distribution is more concentrated than on a flat roadway. Consequently, on a drum, the center of the footprint pressure is closer to the tire center than on a flat surface. In other words, the moment of rolling resistance MY which is the product of distance e and tire load FZ (see sketch), is smaller for the drum operated tire than for the tire run on a flat surface. The moment of rolling resistance can be measured on TIRF very accurately. Table 17 shows that the ratio MY_D/MY_F is indeed smaller than unity for all tires tested. In fact, it is very close to, or even identical with, the product of $(FX_D/FX_F)\ (RL_D/RL_F)$, a relation that follows directly from the force diagrams in the sketch. Table 17 shows also that the loaded tire radius is on the average 1.3% smaller on the drum than it is on a flat surface (for a tire with a 12-inch radius, the difference is 0.16 inches -- a substantial amount in terms of tire deflection). The higher deflections on the drum caused the inflation pressure to increase by 1.4%.

TABLE 17 Flat Bed/Drum tire data comparisons at contained air temperature of 40 °C (104 °F); nine different tires.

Tire load = 100% T&RA @ 24 psi

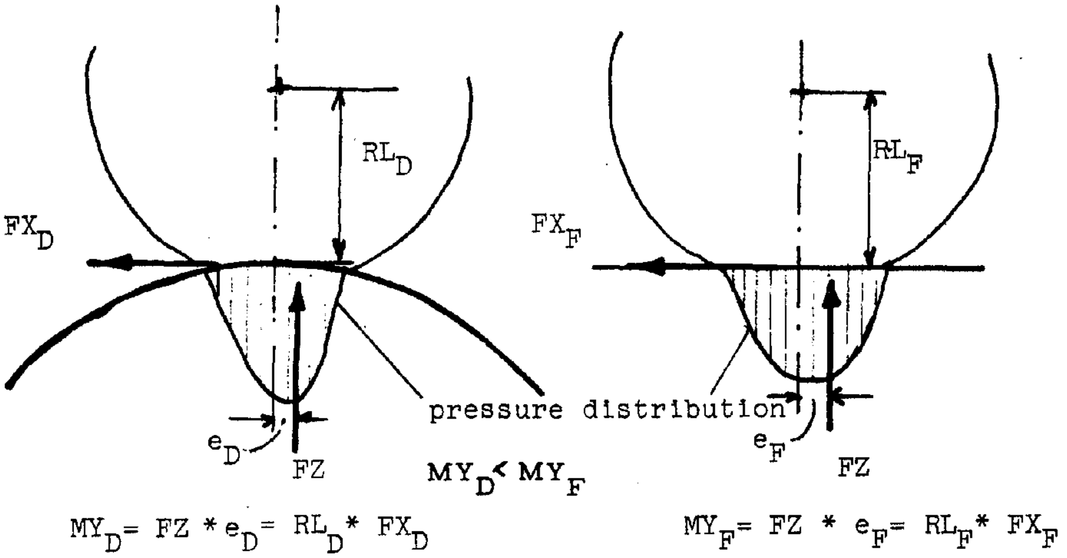
Inflation pressure cold = 24 psi

Road speed = 50 mph

* SAE Round Robin Tires

TIRE	DRUM					FLAT BED					(Long'L Force)	(Infl. pr.)	(Loaded radius)	(Power)	(Roll. Res. Moment)
No	Run No	$-FX_D$ (uncorr.) lb	P_D psi	RL_D in	MY_D ft-lb	Run No	$-FX_F$ (uncorr.) lb	P_F psi	RL_F in	MY_F ft-lb	$\frac{FX_D}{FX_F}$	$\frac{P_D}{P_F}$	$\frac{RL_D}{RL_F}$	$\frac{P_D}{P_F}$	$\frac{MY_D}{MY_F}$
623*	55	15.75	26.28	11.17	14.66	42	16.81	26.80	11.26	15.76	.937	.981	.992	1.248	.930
624*	56	15.03	26.46	11.03	13.81	41	17.06	25.96	11.14	15.83	.881	1.019	.990	1.170	.872
631*	57	10.21	25.85	10.72	9.12	43	11.66	26.27	10.91	10.60	.876	.984	.983	1.155	.860
601	48	24.88	27.04	12.67	26.27	29	28.39	26.58	12.84	30.37	.876	1.017	.987	1.206	.865
612	49	20.13	27.08	12.61	21.15	3	23.80	25.71	12.75	25.27	.846	1.053	.989	1.163	.837
618	51	13.62	27.01	11.72	13.31	28	16.53	26.01	11.89	16.42	.826	1.038	.986	1.111	.811
641	54	24.57	26.26	13.11	26.83	9	27.33	25.99	13.31	30.32	.899	1.010	.985	1.250	.885
629*	53	25.92	26.61	13.54	29.22	45	29.34	26.39	13.75	33.79	.883	1.008	.985	1.239	.865
627*	52	16.18	26.82	12.70	17.12	44	19.98	26.46	12.93	22.03	.810	1.014	.982	1.116	.777
								Average			.870	1.014	.987	1.184	.856
								Std. Deviation . . .			.039	.023	.003	.054	.044

$.870 * .987 = .859$



The power loss is higher on the drum than it is on the flat surface, between 11% (for tire 627, L78-15) and 25% (for tire 623, A78-13 bias ply, and tire 641, H78-15 bias ply), or, on the average, by 18.4%. The power loss is computed by the relations discussed in Section 2.0 and shown in Figure 3. We like to stress again that a distinction must be made between longitudinal force, which is measured directly at the tire axis, and rolling resistance, which is defined as power loss divided by road speed. On the flat surface, both longitudinal force and rolling resistance are identical (except for the sign); on the drum, they are different by a factor of $(1 + RL_D/R)$. It is also evident that a uniform ratio between the longitudinal forces (and rolling resistances) measured on drum and flat surface does not exist. The ratio depends on tire size and surely on many other parameters, too. A good discussion of these relations can be found in Reference 11.

11. EQUILIBRIUM (BASELINE) TESTS ON FLAT ROADWAY AND DRUM

Tire No. 640, a GR78-15 TPC tire, was tested on both flat roadway and drum at various speeds and loads, all under equilibrium conditions. The test schedule was shown in Figure 5. Equal road surface temperatures of correspondent drum and roadway were assured by operating a drum cooling device, as discussed.

For each load and speed condition, the tire was run as long as necessary to establish near-equilibrium conditions. The respective equilibrium values were then computed from exponential curve fits. Tables 18 and 19 show the results. From them, Figures 34 through 46 were prepared.

In Figures 34 and 35, the equilibrium rolling resistance coefficients, FR_{∞}/FZ, are plotted versus load for the flat roadway and the drum. In both plots, the influence of road speed is indicated parametrically. Comparing these plots with Figures 28 and 29 (in which the rolling resistance coefficients of the radial tires remained fairly constant at constant tire temperature), we note that under equilibrium conditions the rolling resistance tends to decrease slightly with load. We also note that with increasing speed, the equilibrium rolling resistant coefficient decreases, too, whereas under "constant temperature" conditions, the rolling resistance coefficient increased with speed, as illustrated earlier in Figure 30. This is shown more clearly in Figures 36, 37, and 38, where FXO_{∞} and FR_{∞} are plotted versus speed for flat roadway and drum, with load indicated parametrically. The rolling resistance decrease is most pronounced at lower speeds and higher loads. At higher speeds and smaller loads, very little or no influence of speed can be discerned.

TABLE 18 Equilibrium Drum data of tire no. 640 (GR78-15, GM TPC) at various road speeds and loads

( ) std. dev.

V	FZ		$FXO_{\infty D}$	$FR_{\infty D}$	$CAT_{\infty D}$	$TST_{\infty D}$	$P_{\infty D}$	RL_D	Segm.
mph	lb	% TERA	lb	lb	°C	°C	psi	in	No
15	828	60	7.61 (.04)	10.48	33,76 (.01)	25,90 (.05)	25,89 (0)	12,67	2
	1242	90	12.00 –	16,38	40.91 (0)	27,53 (.01)	27,11 (0)	12,26	4
	1656	120	15,85 (.03)	21,45	49,23 –	27,27 (.02)	28.56 –	11.88	8
	2070	150	20,15 (.05)	27,05	54,73 –	31,10 (.03)	29,79 –	11.51	10
30	828	60	7.70 –	10,61	39,70 (0)	30,40 –	26,64 (0)	12,70	3
	1242	90	11.30 –	15,44	52,01 (0)	34,12 (.01)	28,48 (0)	12.32	7
	1656	120	14.80 (.03)	20,06	60,33 (0)	35.89 (.01)	30,09 (0)	11,94	11
	2070	150	17.70 –	23,82	69,49 (0)	38,15 (.03)	31,82 (0)	11,62	14
45	828	60	7,25 –	9,99	46,14 (0)	34,22 (.01)	27,39 (0)	12,72	5
	1242	90	–	–	57,84 (0)	36,87 (.01)	29,33 (0)	12,35	9
	1656	120	13,80 –	18,73	69,04 (0)	39,81 (.04)	31,35 (0)	12,02	13
	2070	150	16,80 –	22,65	79,32 (0)	42,43 (.05)	33,21 (0)	11,70	16
60	828	60	7,20 (.07)	9,93	50,23 (0)	36,07 (.02)	27,96 (0)	12,77	6
	1242	90	10,74 (.11)	14,70	64,67 (.01)	39,61 (.02)	30,29 (0)	12,41	12
	1656	120	13,15 (.09)	17,87	75,65 (0)	41,99 (.03)	32,25 (0)	12,07	15
	2070	150	16,76 (.07)	22,62	87,78 (.01)	46,58 (.02)	34,33 (0)	11,76	17
2	2070	150	23,78 (.19)	31,74	32,22 (.01)	17,96 (.24)	26,04 (0)	11,25	1

TABLE 19 Equilibrium <u>Flat Bed</u> data of tire no. 640 (GR78-15, GM TPC) at various road speeds and loads

( ) std. dev.

V	FZ		$FXO_{\infty F}$	$FR_{\infty F}$	$CAT_{\infty F}$	$TST_{\infty F}$	$P_{\infty F}$	RL_F	Segm.
mph	lb	% T&RA	lb	lb	°C	°C	psi	in	No
15	828	60	10.38 (.03)	same as FX_{∞}	33.61 (.01)	24.10 (.03)	25.16 (0)	12.78	1
	1242	90	16.60 (.02)		41.72 (0)	25.55 (.02)	26.46 (0)	12.41	3
	1656	120	21.25 (.03)		49.62 (0)	28.88 (.02)	27.65 (0)	12.06	8
	2070	150	26.16 (.01)		55.50 -	30.81 (.02)	28.96 -	11.75	11
30	828	60	9.58 (.11)		40.05 (0)	28.85 (.02)	26.03 (0)	12.80	2
	1242	90	16.20 (.10)		51.45 (0)	31.75 (.01)	27.78 (0)	12.46	6
	1656	120	19.30 -		59.56 (0)	33.43 (.03)	29.27 (0)	12.12	10
	2070	150	23.91 (.08)		68.94 (0)	36.03 (.02)	30.65 (0)	11.85	14
45	828	60	9.90 -		45.69 (0)	32.12 (.01)	26.80 (0)	12.82	4
	1242	90	15.03 (.16)		56.48 (0)	35.43 (.01)	28.40 (0)	12.47	9
	1656	120	18.48 (.20)		67.71 (.01)	39.31 (.02)	30.21 (0)	12.18	13
	2070	150	22.50 (.17)		77.73 (0)	40.20 (.02)	31.98 (0)	11.92	16
60	828	60	10.18 (.25)		49.77 (0)	34.73 (.01)	27.18 (0)	12.85	5
	1242	90	—		63.15 (0)	38.23 (.01)	29.18 (0)	12.51	12
	1656	120	18.58 (.19)		74.08 (0)	40.67 (.01)	31.05 (0)	12.22	15
	2070	150	22.14 (.16)		85.79 (0)	43.52 (.01)	33.05 (0)	11.96	17
2	2070	150	30.10 -		37.30 (0.04)	28.85 (.02)	26.03 (0)	12.80	7

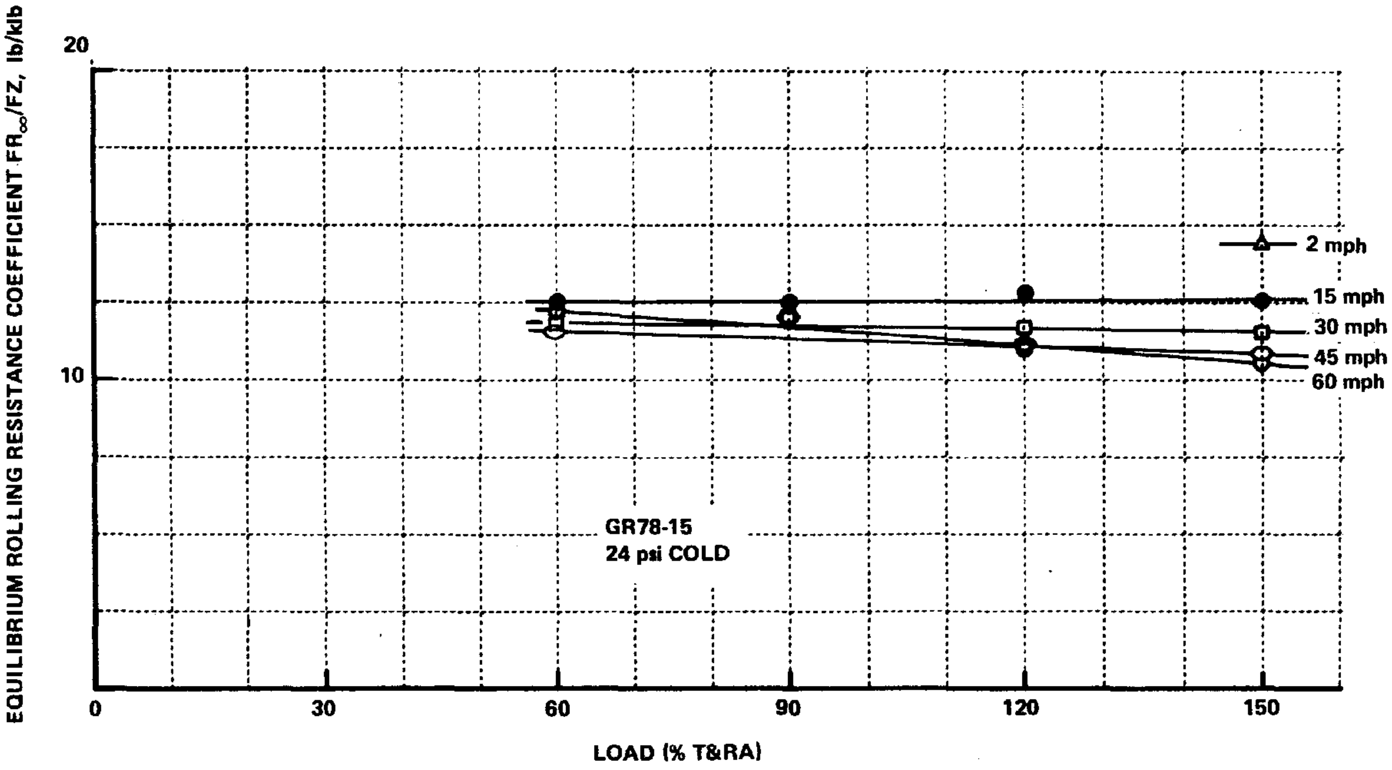


Figure 34 EQUILIBRIUM ROLLING RESISTANCE COEFFICIENT ON FLAT ROADWAY AT VARIOUS LOADS AND SPEEDS (RUN 39)

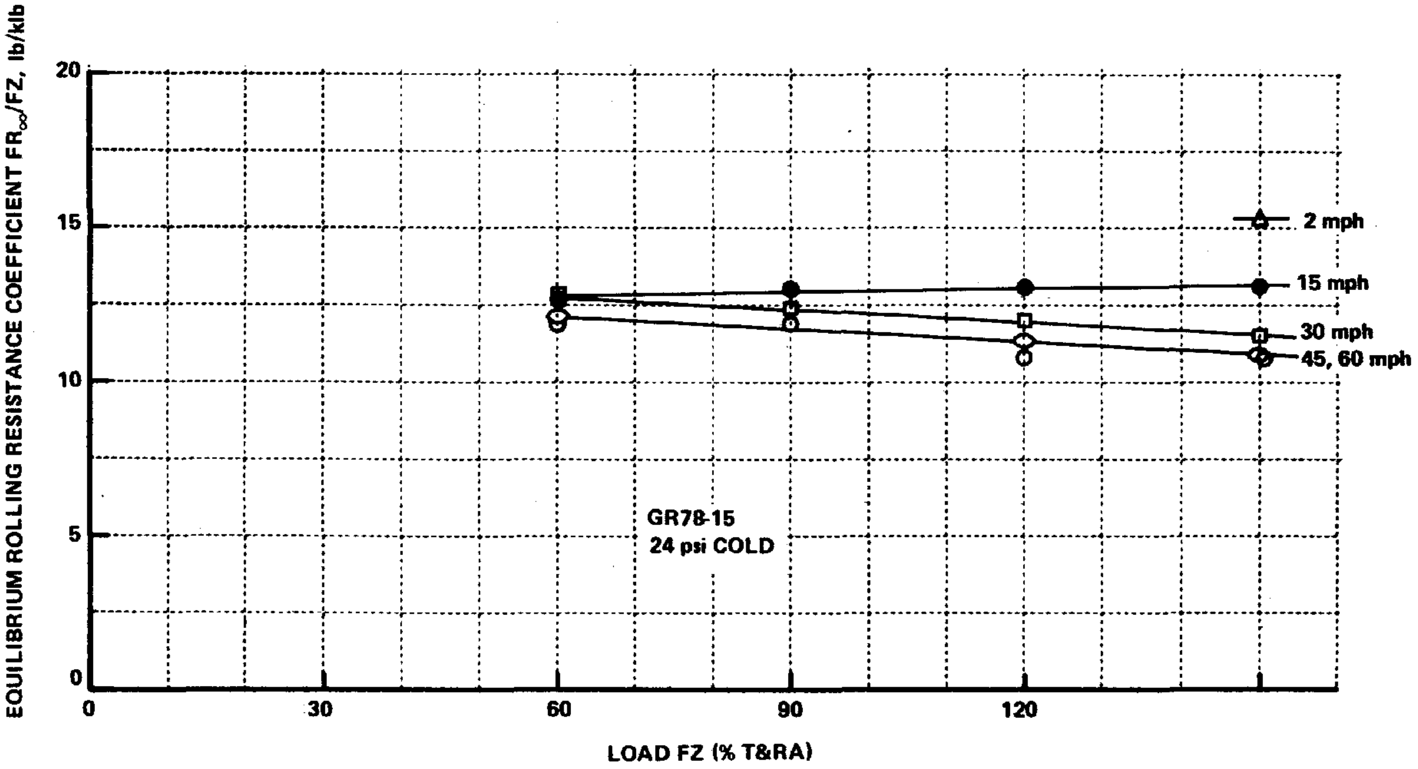


Figure 35 EQUILIBRIUM ROLLING RESISTANCE COEFFICIENT ON DRUM AT VARIOUS LOADS AND SPEEDS (RUN 50)

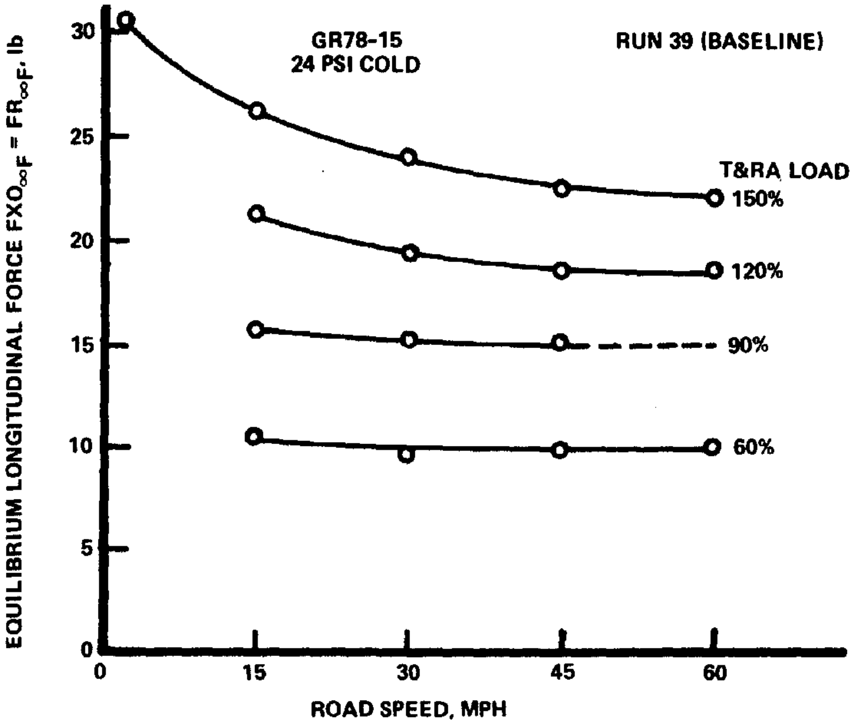


Figure 36 EQUILIBRIUM LONGITUDINAL FORCE (= ROLLING RESISTANCE) ON FLAT ROADWAY AT VARIOUS LOADS AND ROAD SPEEDS (BASLINE RUN 39)

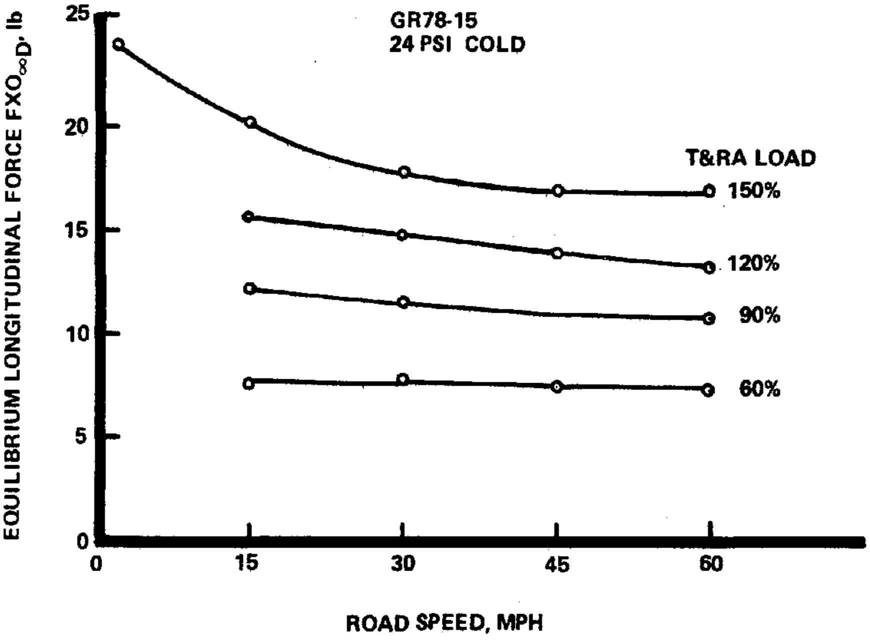


Figure 37 EQUILIBRIUM LONGITUDINAL FORCE ON DRUM AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 50)

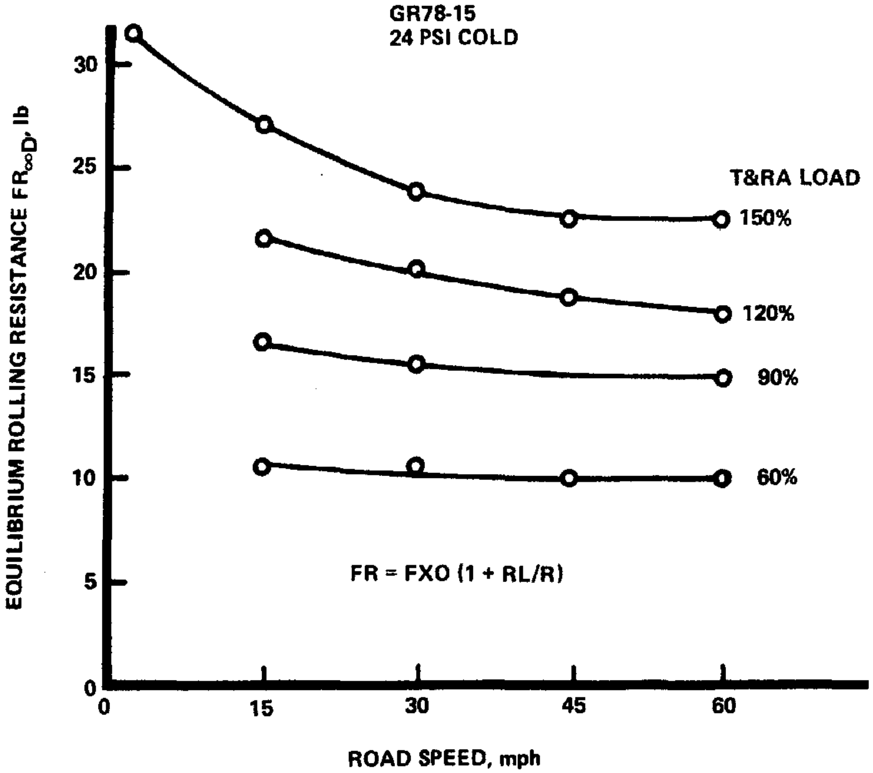


Figure 38 EQUILIBRIUM ROLLING RESISTANCE ON DRUM AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 50)

The decrease of the equilibrium rolling resistance coefficient with load and speed is an observation contradicted by other pertinent studies described in the open literature. Here, the rolling resistance is presented to be unaffected by speed in the lower range and to increase at higher values. Likewise, load is customarily shown to have no effect on rolling resistance. The causes of the differences between our findings and the usually presented relations are not clear; they could not be investigated in this program.

Figures 39 and 40 show the contained air temperature, CAT_{∞}, as function of speed and load for both flat surface and drum; the data are very consistent. We believe that between CAT_{∞} and FR_{∞} there exist intrinsic relations that could be uncovered by careful analysis. This program, however, did not provide for such an analysis.

Closely related to CAT_{∞} is the inflation pressure P_{∞}, plotted in Figures 41 and 42. The data are very well behaved. The same is true for the tread surface temperature, TST_{∞}, plotted in Figures 43 and 44, and the loaded radius, RL_{∞}, in Figures 45 and 46.

In Table 20, the drum and flat roadway data plotted in Figures 34 through 46 are compared with each other. In the average, for the particular tire tested and across all speeds and loads, the longitudinal force, $FXO_{\infty F}$, of the flat roadway is 33% larger than $FXO_{\infty D}$ of the drum. Differences of individual runs range from 24% to 41%. These differences are substantially larger than those experienced on other tires (see Section 10). This indicates again that a fixed ratio between flat and curved roadways data does not exist.* The rolling resistances on drum and flat roadway are almost equal, and so are the contained air temperatures and the inflation pressures (the flat roadway data are slightly lower than the drum data). The ratio of loaded radii is plotted in Figure 47; it increases with load and speed in very consistent fashion.

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*See again Figure 33.

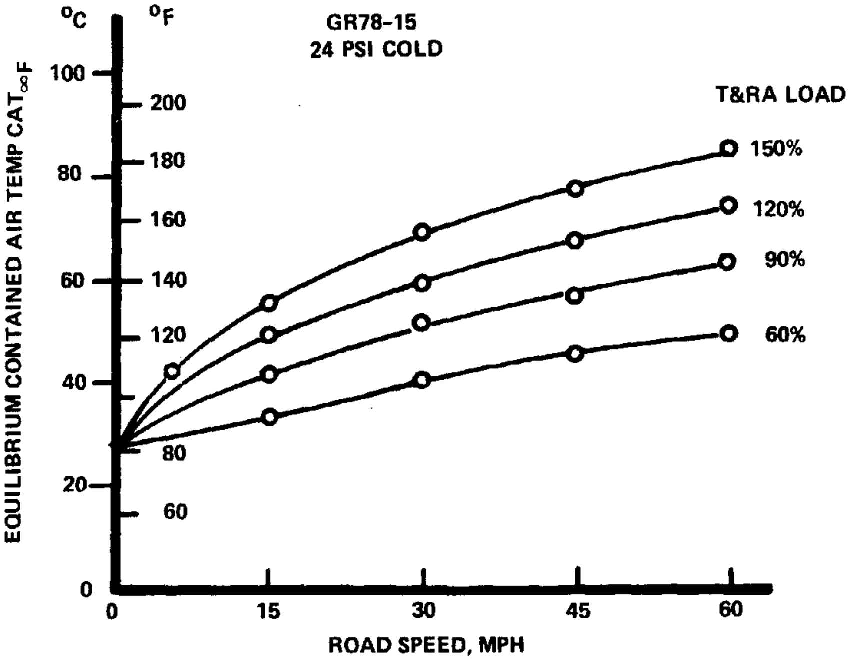

Figure 39 EQUILIBRIUM CONTAINED AIR TEMPERATURE ON FLAT ROADWAY AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 39)

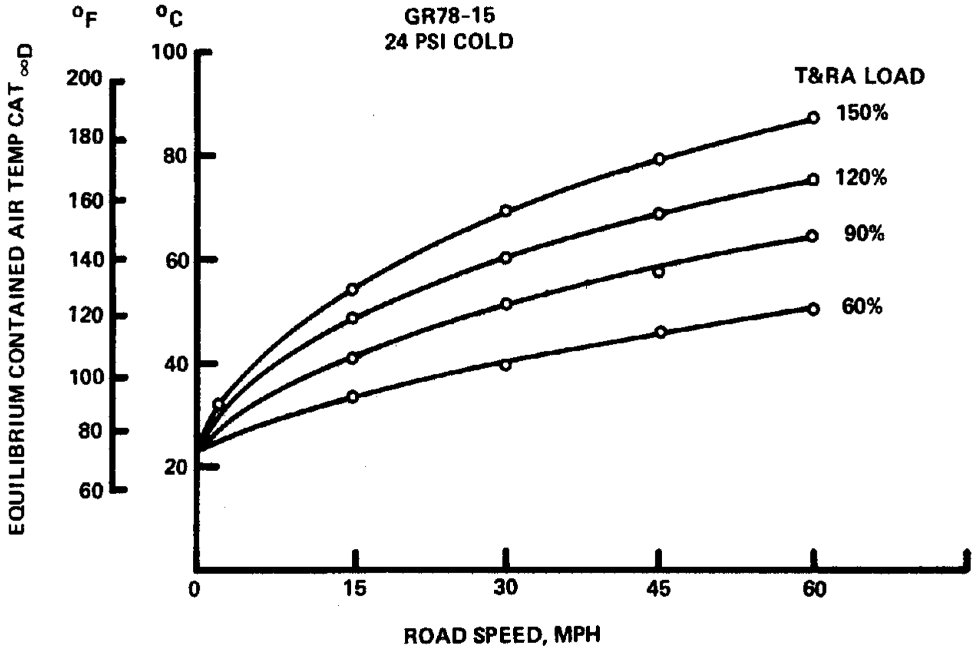

Figure 40 EQUILIBRIUM CONTAINED AIR TEMPERATURE ON DRUM AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 50)

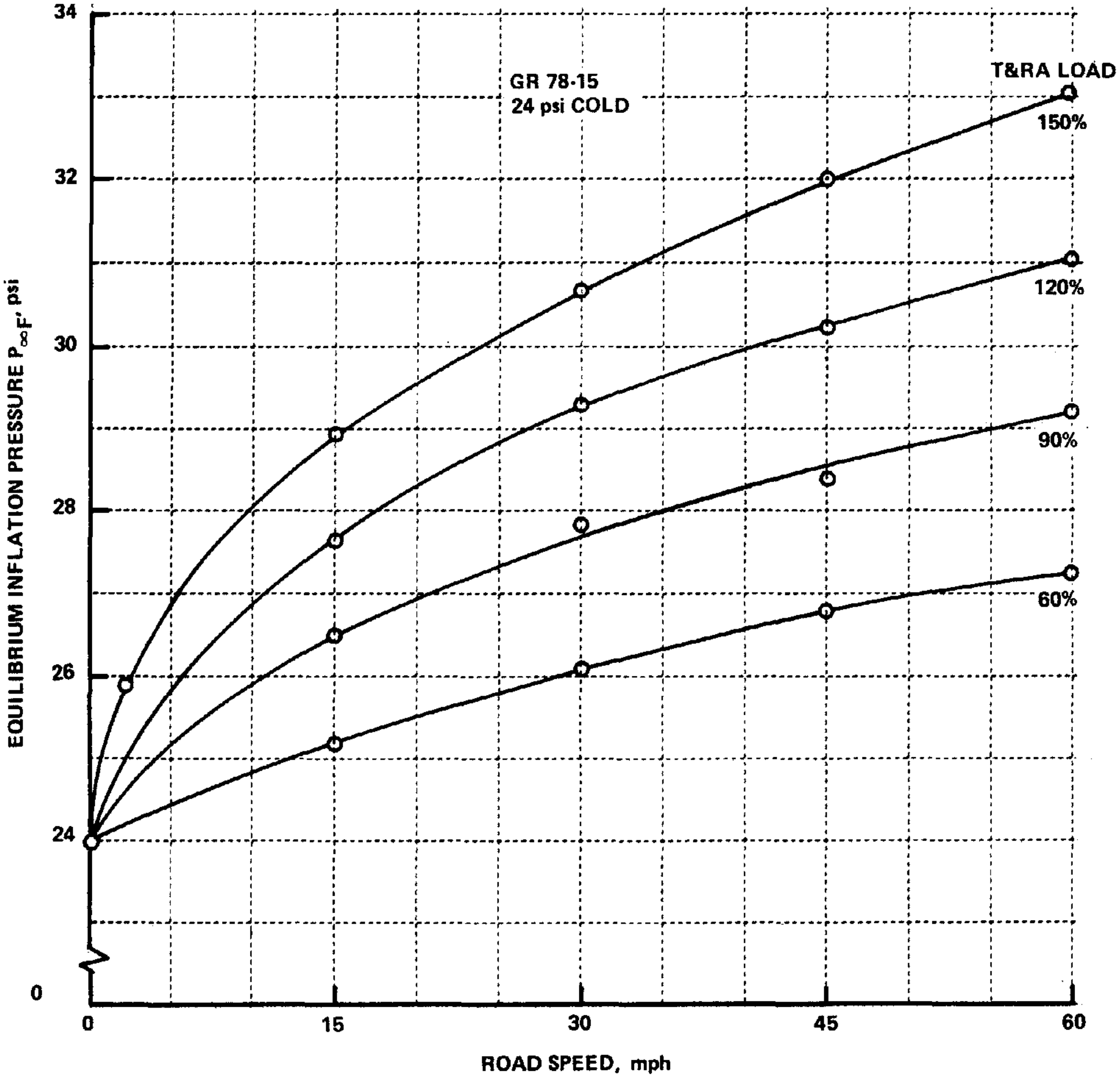

Figure 41 EQUILIBRIUM INFLATION PRESSURE ON FLAT ROADWAY AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 39)

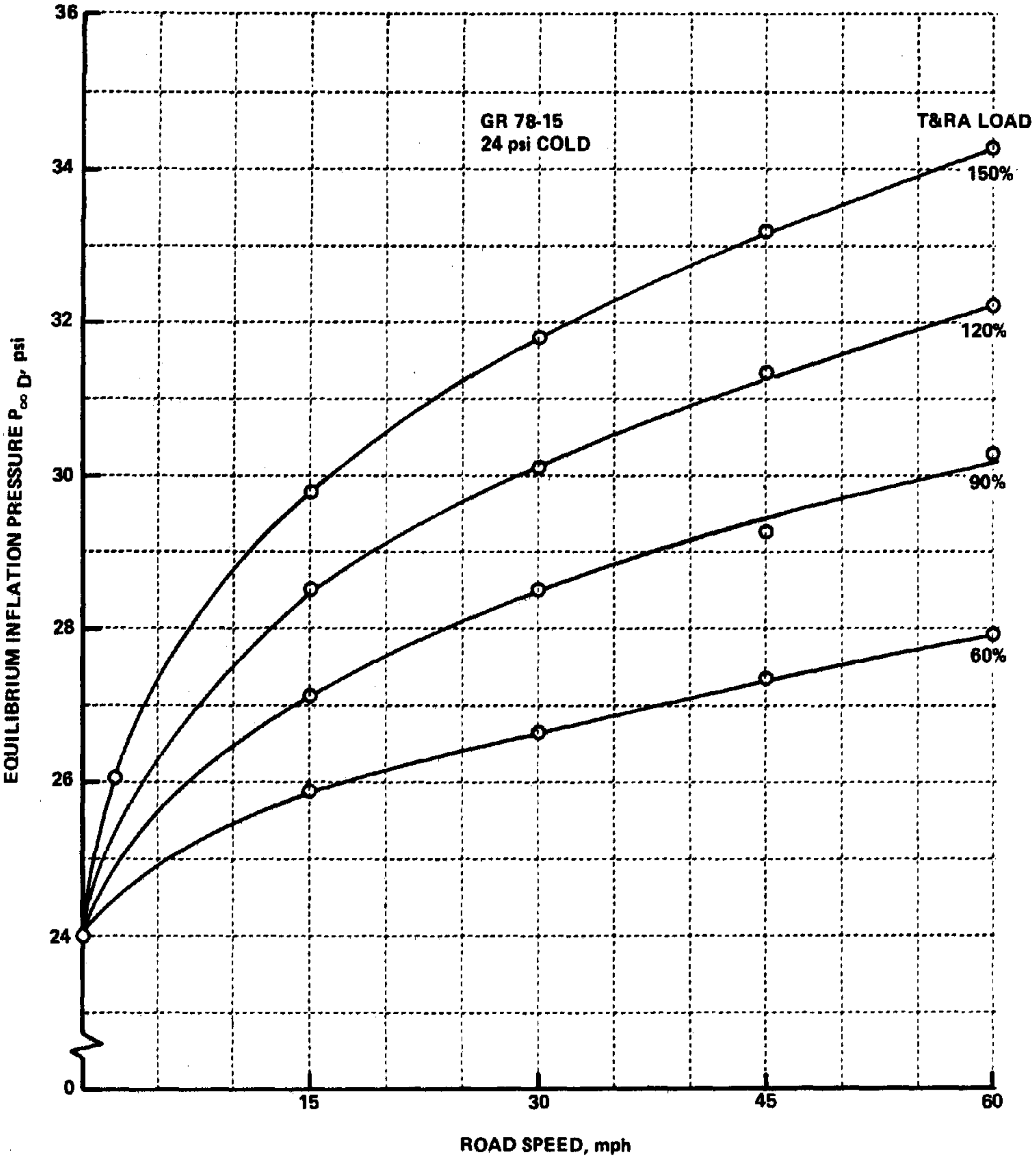

Figure 42 EQUILIBRIUM INFLATION PRESSURE ON DRUM OF VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 50)

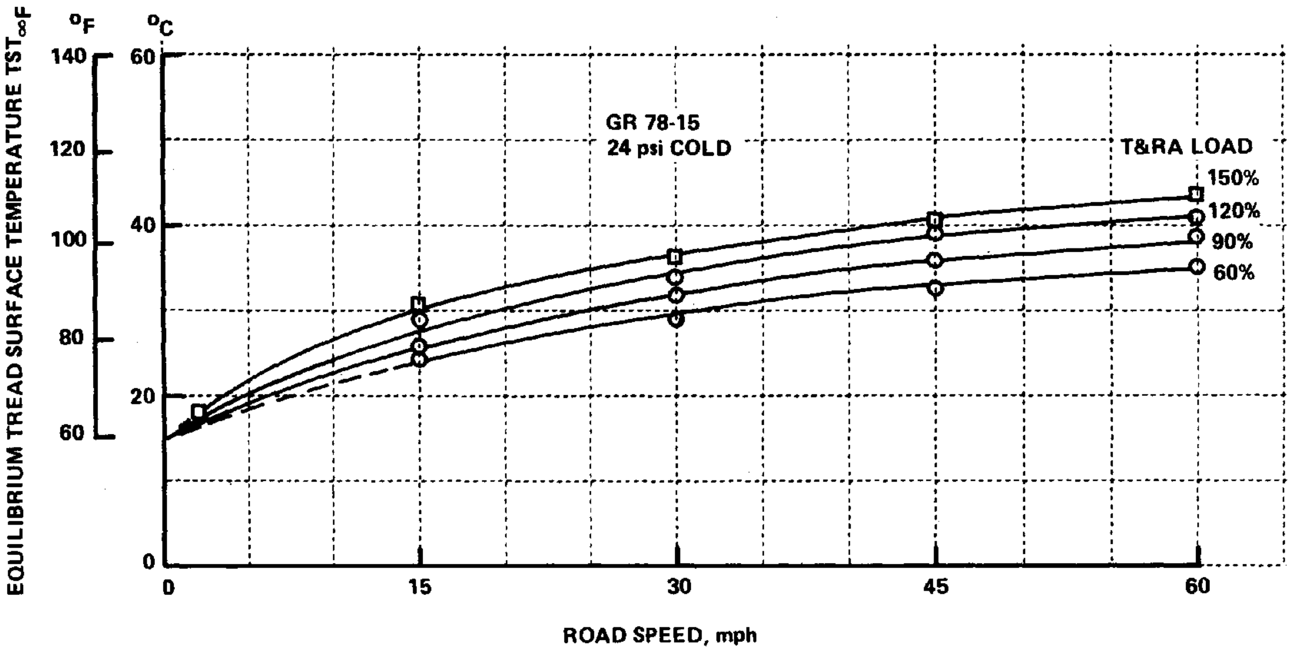

Figure 43 EQUILIBRIUM TREAD SURFACE TEMPERATURE ON FLAT ROADWAY AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 39)

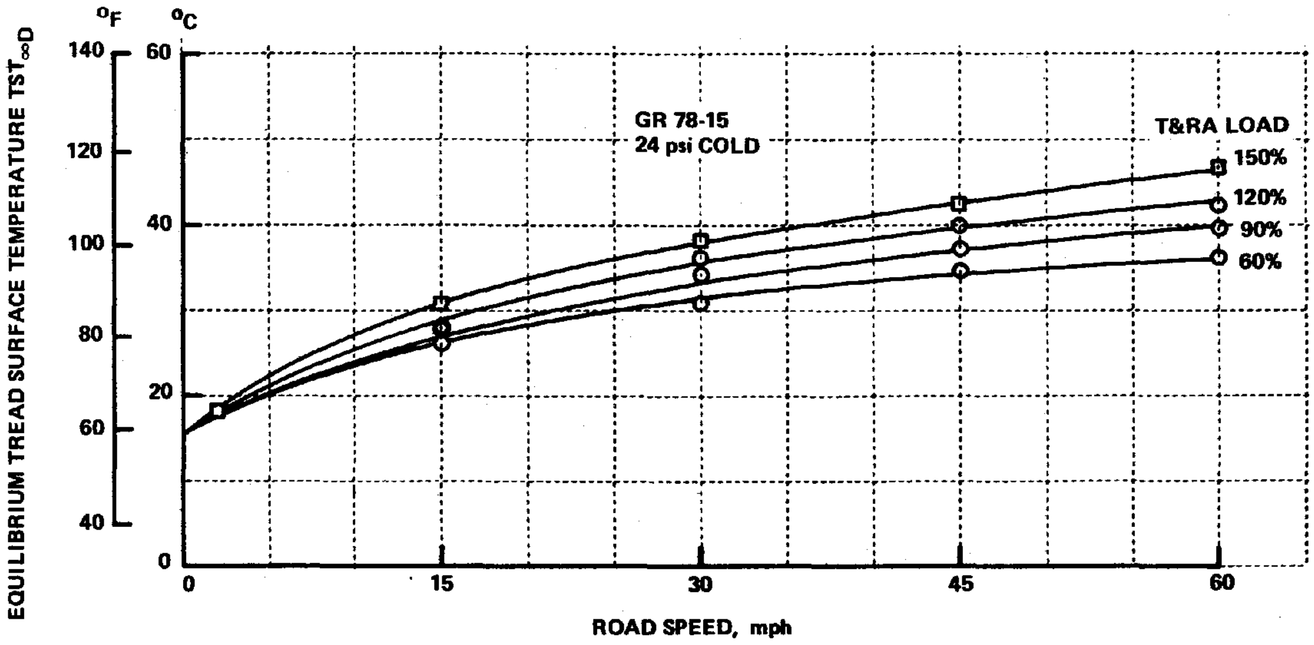

Figure 44 EQUILIBRIUM TREAD SURFACE TEMPERATURE ON DRUM AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 50)

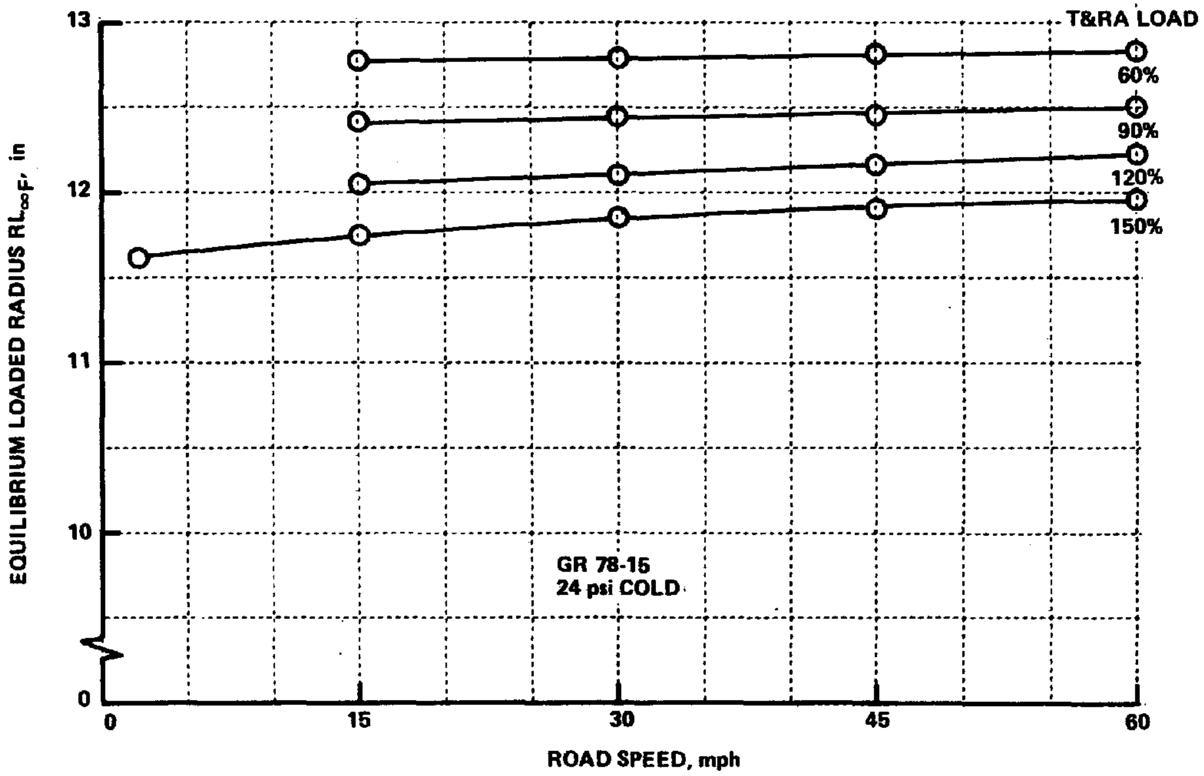

Figure 45 EQUILIBRIUM LOADED RADIUS ON FLAT ROADWAY AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 39)

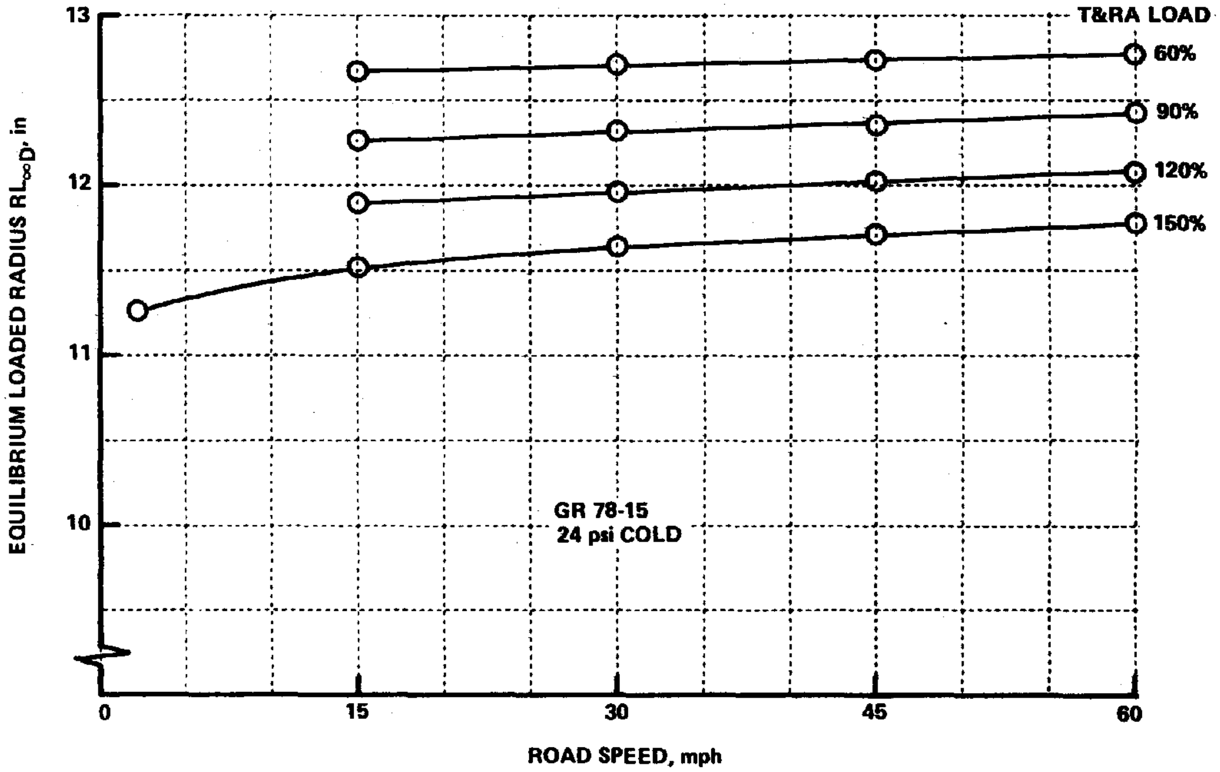

Figure 46 EQUILIBRIUM LOADED RADIUS ON DRUM AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUN 50)

TABLE 20 Flat Bed/Drum tire data comparisons at equilibrium temperatures of tire no. 640 (GR78-15, GM TPC), at various road speeds and loads (see Tables 18 and 19)

V	FZ		$\frac{FXO_{\infty F}}{FXO_{\infty D}}$	$\frac{FR_{\infty F}}{FR_{\infty D}}$	$\frac{CAT_{\infty F}}{CAT_{\infty D}}$	$\frac{TST_{\infty F}}{TST_{\infty D}}$	$\frac{P_{\infty F}}{P_{\infty D}}$	$\frac{RL_F}{RL_D}$
mph	lb	% T&RA						
15	828	60	1,364	.990	.996	.931	,972	1,009
	1242	90	1,300	.952	1.020	.928	.976	1,012
	1656	120	1.341	.991	1.008	1.059	,968	1,015
	2070	150	1,298	.967	1.014	.991	.972	1,021
30	828	60	1.244	,903	1,009	.949	.977	1,008
	1242	90	1.345	.984	.989	.931	,975	1.011
	1656	120	1.304	.962	,987	.931	.973	1,015
	2070	150	1.351	1.004	.992	.944	.963	1,020
45	828	60	1.366	.991	,990	.939	.978	1,008
	1242	90	—	—	.976	,961	,968	1,010
	1656	120	1.339	,987	,981	,987	.964	1,013
	2070	150	1.339	.993	.980	.947	.963	1,019
60	828	60	1,414	1.025	.991	.963	,972	1.006
	1242	90	—	—	.976	.965	.963	1.008
	1656	120	1.413	1.040	.979	,969	.963	1.012
	2070	150	1.321	.979	,977	.934	.963	1.017
2	2070	150	1.266	.948	(1,158)	.999	.997	1.033
	Average		1.33	0.98	0,99	0.96	0,97	
	Std. Dev		0.05	0,03	0,01	0,03	0,01	

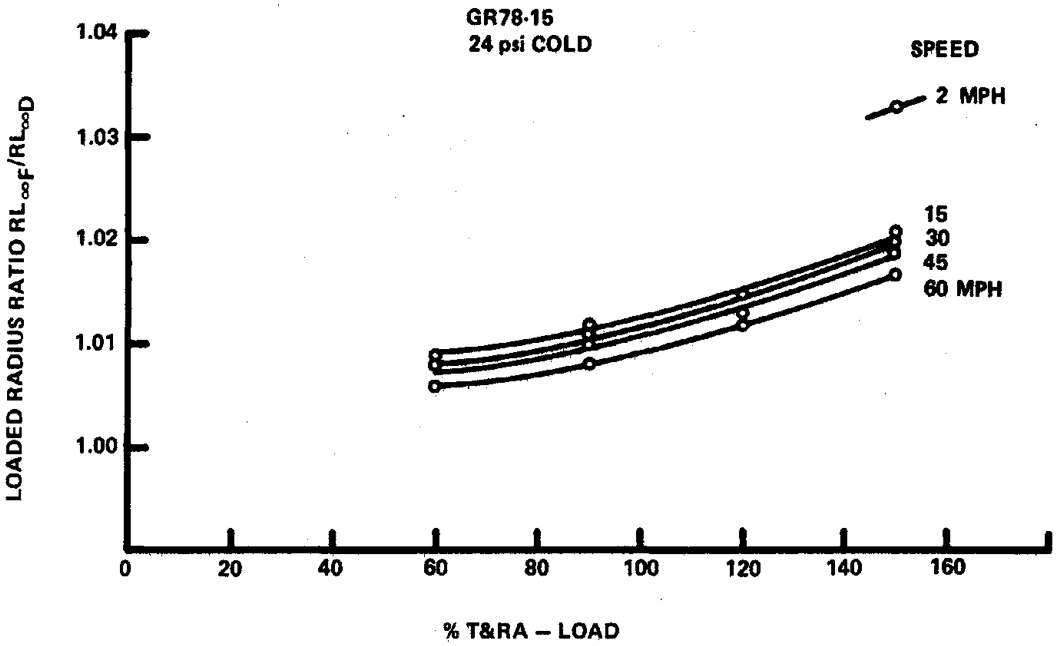

Figure 47 RATIO OF LOADED RADII ON FLAT SURFACE AND DRUM AT VARIOUS LOADS AND ROAD SPEEDS (BASELINE RUNS 39 AND 50)

12. SPECIAL TESTS

In these tests, we attempted to explore the influences of slip angle and wheel torque on rolling resistance. The effect of slip angle was determined for three G-size tires -- a bias ply, a bias belted, and a radial tire -- by measuring FR at slip angles between ±4 deg in 0.25 deg increments. During the measurements, the tire temperature remained nearly constant. Figure 48 shows the results. The bias ply and the bias belted tires exhibit a parabola-like change of FR with slip angle, with the minimums offset by about 1 deg. We suspect that these offsets are caused by lateral non-uniformities of the tires. The radial-ply tire shows two distinct minima of 19.5 lb at -1.5 deg and of 16.0 lb at +2.5 deg. The rolling resistance at zero deg is 21.5 lb. The reasons for these rather large irregularities are not known. They are not unusual and have been observed occasionally on other tires also.

The influence of braking/driving torque on rolling resistance could not be investigated without including in the definition of power loss the effects of gross slippage, SR. The extended definition (for zero slip angle) is given in Reference 12 as

$$FR = (T/RL)(1 + SR) - FX. \qquad (13)$$

The same reference shows that FR reaches a minimum under driving, not freely rolling, conditions.

The relation between FR and FX was investigated in this program by measuring the torque T, the loaded radius RL, the slip SR, and the longitudinal force FX at various braking and driving conditions for one tire (GR78-15 TPC). From the measured data, FR was computed according to Equation 13 and plotted versus FX. Figure 49 shows that the rolling loss FR reaches indeed a minimum at around 600 ft lb driving torque.

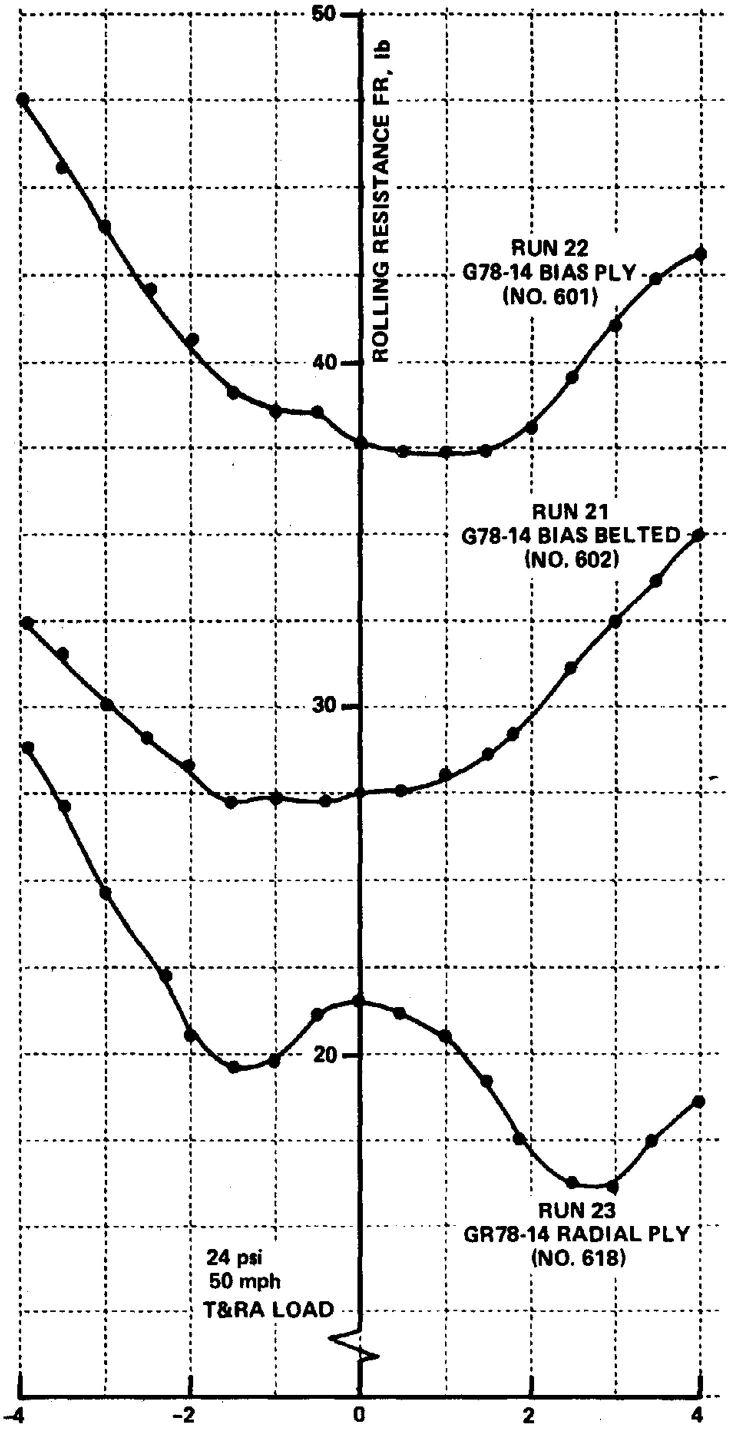

Figure 48 ROLLING RESISTANCE VS SLIP ANGLE (AT CONSTANT TEMPERATURE) ON FLAT ROADWAY

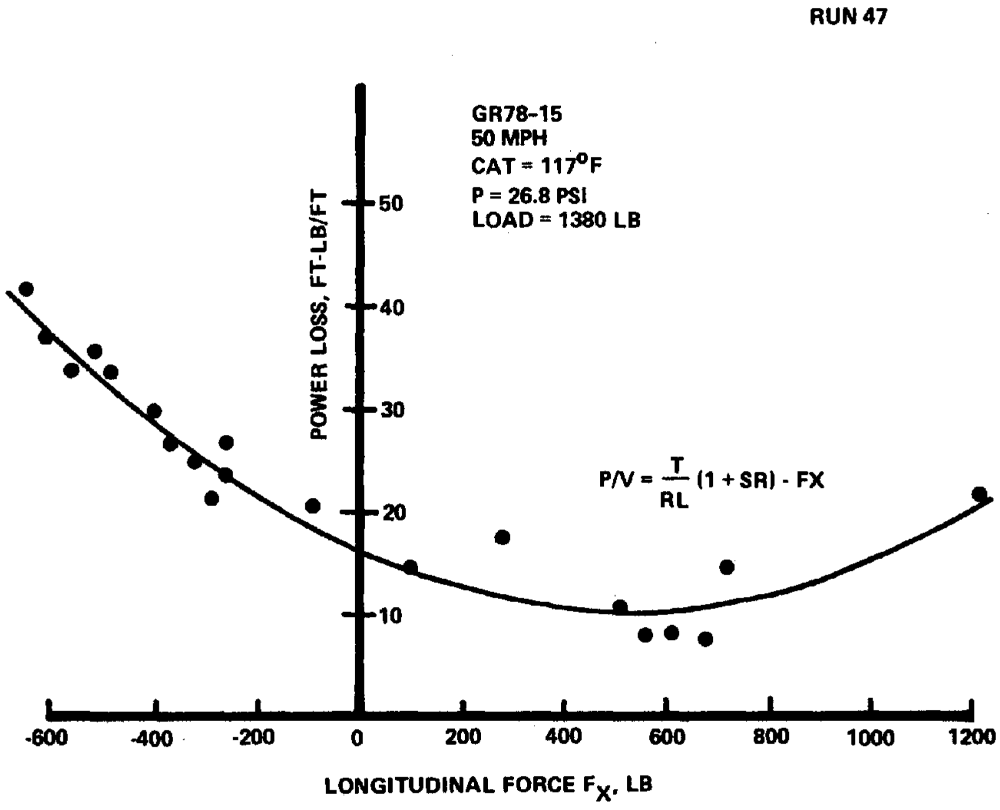

Figure 49 POWER LOSS UNDER BRAKING AND DRIVING (RUN 47)

13. CONCLUSIONS

The general objective of this program was to generate a small body of power loss data reflecting current tire usages. To this end, a sample of 35 passenger and light truck tires was tested on TIRF under various operational conditions. The tires embraced the three basic tire constructions (bias ply, bias belted, and radial ply); their sizes ranged from 13 to 15 inches diameter for passenger tires and to 16 inches for light truck tires; their design loads encompassed designations from A to L; and their widths, aspect ratios from 60 to 78. The carcass cord materials included polyester and rayon, and the belt cord materials, fiberglas and steel. The distributions of these design parameters reflected those found in the current tire population. The sample encompassed five tires from an SAE Round-Robin test and six TPC tires from GM. The rest was purchased in the open market. All tires were properly run in before testing.

The test program was designed to determine the basic relations between power loss and load, speed, inflation pressure, temperature, slip angle, and torque. In addition, the influence of road curvature (flat roadway and drum) and the effect of trip length on the rolling loss was to be investigated. To achieve these objectives, the test program was divided into transient tests, equilibrium tests and special tests. In the transient tests, loss data were sampled over a period of 30 min up to the state of equilibrium. In the equilibrium tests, stabilized data were taken under various loads, speeds, and pressures. In the special tests, the influences of slip angle and torque (braking/driving) was probed.

To compress the large amount of test data into a few empirical constants, least-square exponential fits were employed resulting in three rolling loss characteristics: initial value (cold), equilibrium value (stabilized), and distance in miles required to achieve equilibrium. These values were computed for the rolling resistance, the contained air temperature, the tread surface temperature, and the inflation pressure -- resulting in 12 tire rolling loss descriptors for the run conditions given.

The test results (in terms of the 12 descriptors) are listed in Appendix A. A cursory analysis showed that

- Rolling loss data change exponentially with time. Equilibrium of rolling resistance is achieved after about 20 miles distance traveled.
- Power loss data measured on the 67-inch drum are larger than corresponding data measured on the flat roadway. The ratio is not constant for all tires; our tests showed a range of 1.00 to 1.25.
- Radial ply tires have significantly lower rolling resistances than bias ply and bias belted tires. Our sample was too small to ascertain significant differences between bias ply and bias belted tires. Significant effects of aspect ratio and wheel diameter could not be established either.
- For passenger tires, the equilibrium rolling resistance increases linearly with size. The effects of size on equilibrium air temperature and tread surface temperature are very slight, if any.

- At *constant* tire temperature, the rolling resistance coefficient (rolling resistance/tire load) increases with load and road speed; at *equilibrium* tire temperatures, it decreases. In both cases, the changes are small.

- Equilibrium rolling resistance decreases with inflation pressure. Our tests showed a change of about 3% in rolling resistance per psi.

- The rolling resistance of a radial ply tire tested under cornering conditions displayed two minima at -1.5 deg and +2.5 deg slip angle, in contrast to a bias ply and a bias belted tire of the same size, which showed only one minimum close zero slip angle.

- The rolling loss of a braked/driven tire reached a minimum under-driving, not free-rolling, condition, as expected.

14. REFERENCES

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APPENDIX A

ROLLING LOSS DATA FOR ALL TIRES TESTED

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		600
TIRF RUN NO (0604-Series)		02
SIZE		B78-14
MANUFACTURER		GY
BRAND NAME		POWER CUSHION VITACORD
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1150
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	4P
	SIDEWALL	4P
DOT NO		MJ LY XJA 123
CONSTRUCTION TYPE		B
RIM WIDTH, in		4.50
SHORE HARDNESS		52.2
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 600	
RUN NO 0604002	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 980 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	14.59	8.36	.225	20.5	.11
CAT, °C	62.43	-33.06	.179	25.8	.29
TST, °C	43.03	-12.23	.282	16.3	.07
P, psi	29.10	-4.49	.175	26.3	.01
$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$					

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	599	7.03	62.68	43.48	29.00
↓	1461	24.75	↓	↓	↓
	903	12.99			
	1170	18.26			
	987	14.14			
	986	14.07			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		601
TIRF RUN NO (0604-Series)		22*,29,36,48
SIZE		G78-14
MANUFACTURER		GY
BRAND NAME		POWER CUSHION VITACORD
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	4P
	SIDEWALL	4P
DOT NO		CK L9 E2A 443
CONSTRUCTION TYPE		B
RIM WIDTH, in		6.00
SHORE HARDNESS		56.8
REMARKS		* See Fig. 48

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 601	
RUN NO 0604029	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	22.56	12.45	.281	16.4	.16
CAT, °C	66.26	-40.41	.175	26.3	.63
TST, °C	38.81	-11.92	.193	23.9	.07
P, psi	29.95	-5.31	.179	25.8	.02

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1396	22.19	66.70	38.91	30.03
↓	827	10.82	↓	↓	↓
↓	2064	38.74	↓	↓	↓
↓	1252	18.98	↓	↓	↓
↓	1651	28.39	↓	↓	↓
↓	1373	21.57	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	601
RUN NO	0604036
INFL PRESS COLD	16 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	27.36	18.41	.349	13.2	.47
CAT, °C	79.73	-46.12	.202	22.8	1.24
TST, °C	46.50	-15.73	.210	22.0	.06
P, psi	22.22	-5.02	.188	24.5	.03

$$Y = Y_\infty + (Y_o - Y_\infty)\ e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1387	26.65	81.05	46.90	22.36
↓	838	13.61	↓	↓	↓
↓	2061	47.09	↓	↓	↓
↓	1251	23.74	↓	↓	↓
↓	1649	34.34	↓	↓	↓
↓	1385	26.78	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	601
RUN NO	06040 36
INFL PRESS COLD	— psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	$\approx Y_\infty$	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	20.55				
CAT, °C	72.03				
TST, °C	45.20				
P, psi	31.74				

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1377	20.55	72.03	45.20	31.74
↓	833	10.48	↓	↓	↓
	2061	37.39			
	1247	18.36			
	1648	27.15			
	1389	20.84			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	601
RUN NO	0604048
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	18.77	13.65	.313	14.7	.22
CAT, °C	71.12	-47.36	.194	23.8	.69
TST, °C	42.02	-15.38	.223	20.7	.18
P, psi	30.94	-6.04	.187	24.7	.03

$$Y = Y_\infty + (Y_o - Y_\infty)\ e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1394	18.27	72.14	42.62	31.10
↓	826	8.23	↓	↓	↓
↓	2060	33.11	↓	↓	↓
↓	1251	15.54	↓	↓	↓
↓	1649	23.75	↓	↓	↓
↓	1381	17.64	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		602
TIRF RUN NO (0604-Series)		13
SIZE		G78-15
MANUFACTURER		GY
BRAND NAME		POWER CUSHION VITACORD
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	4P
	SIDEWALL	4P
DOT NO		MD VV E2A 084
CONSTRUCTION TYPE		B
RIM WIDTH, in		5.50
SHORE HARDNESS		62.6
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 602

RUN NO 0604013

INFL PRESS COLD 24 psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	19.87	9.68	.264	17.5	.08
CAT, °C	63.49	-30.99	.157	29.4	.27
TST, °C	37.62	-9.89	.211	21.8	.03
P, psi	28.75	-4.23	.160	28.8	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	830	9.67	63.48	37.81	28.81
↓	2062	32.53	↓	↓	↓
↓	1240	16.68	↓	↓	↓
↓	1649	23.91	↓	↓	↓
↓	1400	19.76	↓	↓	↓
↓	1376	19.01	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		603
TIRF RUN NO (0604-Series)		16
SIZE		B78-13
MANUFACTURER		GY
BRAND NAME		POWER CUSHION POLYESTER
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1150
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P
	SIDEWALL	2P
DOT NO		MD FV ECA 424
CONSTRUCTION TYPE		B
RIM WIDTH, in		5.00
SHORE HARDNESS		58.8
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	603
RUN NO	0604016
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 980 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	15.91	8.04	.322	14.3	.10
CAT, °C	56.72	-24.49	.207	22.3	.12
TST, °C	38.26	-11.21	.315	14.6	.02
P, psi	28.27	-3.96	.226	20.4	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	604	8.37	57.13	38.47	28.47
↓	1465	26.65	↓	↓	↓
↓	898	14.48	↓	↓	↓
↓	1174	19.84	↓	↓	↓
↓	990	16.45	↓	↓	↓
↓	989	15.46	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		604
TIRF RUN NO (0604-Series)		40
SIZE		D78-14
MANUFACTURER		GY
BRAND NAME		POWER CUSHION POLYESTER
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1320
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P
	SIDEWALL	2P
DOT NO		MEL3 EAA 393
CONSTRUCTION TYPE		B
RIM WIDTH, in		5.00
SHORE HARDNESS		58.8
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 604	
RUN NO 0604040	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1120 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	16.74	7.11	.297	15.5	.12
CAT, °C	62.66	-29.52	.200	23.1	.36
TST, °C	45.80	-11.78	.307	15.0	.05
P, psi	28.56	-3.98	.211	21.8	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1135	16.30	63.35	45.84	28.71
↓	682	8.70	↓	↓	↓
	1681	27.76			
	1012	14.07			
	1343	20.72			
	1126	16.17			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		605
TIRF RUN NO (0604-Series)		15
SIZE		A70-13
MANUFACTURER		GY
BRAND NAME		CUSTOM WIDETREAD POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1060
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MJ F4 44A 354
CONSTRUCTION TYPE		BB
RIM WIDTH, in		5.00
SHORE HARDNESS		54.4
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 605	
RUN NO 0604015	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 900 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	11.11	5.38	.207	22.3	.06
CAT, °C	53.35	-20.11	.140	32.9	.04
TST, °C	34.52	-7.47	.218	21.1	.03
P, psi	27.78	-3.44	.171	27.0	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value
Y_∞ = equilibrium value
X = distance traveled
$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	549	5.43	52.77	34.47	27.78
↓	1348	19.88	↓	↓	↓
	811	9.54			
	1085	14.34			
	909	10.98			
	902	10.84			

CAT = Contained Air Temperature
TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		606
TIRF RUN NO (0604-Series)		17
SIZE		D70-13
MANUFACTURER		GY
BRAND NAME		CUSTOM WIDETREAD POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1320
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MD FU Y4A 054
CONSTRUCTION TYPE		BB
RIM WIDTH, in		5.50
SHORE HARDNESS		58.0
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	606
RUN NO	0604017
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1120 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	15.09	6.62	.233	19.8	.10
CAT, °C	54.71	-21.79	.149	30.9	.08
TST, °C	31.94	-6.80	.172	26.8	.02
P, psi	28.07	-3.62	.180	25.6	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	676	7.96	54.37	31.76	28.13
↓	1673	25.85	↓	↓	↓
	1007	13.50			
	1339	19.18			
	1133	14.98			
	1124	15.25			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		607
TIRF RUN NO (0604-Series)		01
SIZE		D70-14
MANUFACTURER		GY
BRAND NAME		CUSTOM WIDE TREAD POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1320
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MB K9 Y4N 314
CONSTRUCTION TYPE		BB
RIM WIDTH, in		5.50
SHORE HARDNESS		58.0
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 607	
RUN NO 0604091	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1120 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	15.76	6.70	.221	20.9	.05
CAT, °C	55.99	-30.67	.131	35.2	.21
TST, °C	32.54	-5.88	.158	29.2	.04
P, psi	28.71	-4.27	.134	34.4	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	676	8.09	55.27	32.67	28.66
↓	1678	26.59	↓	↓	↓
↓	1008	13.58	↓	↓	↓
↓	1341	19.67	↓	↓	↓
↓	1130	15.52	↓	↓	↓
↓	1122	15.36	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		608
TIRF RUN NO (0604-Series)		30
SIZE		G70-14
MANUFACTURER		GY
BRAND NAME		CUSTOM WIDE TREAD POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MF LF DM5 104
CONSTRUCTION TYPE		BB
RIM WIDTH, in		6.00
SHORE HARDNESS		60.8
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 608	
RUN NO 0604030	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	17.63	7.80	.226	20.4	.14
CAT, °C	56.92	-32.07	.137	33.6	.19
TST, °C	34.11	-8.58	.136	33.9	.06
P, psi	28.79	-4.40	.141	32.7	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1380	16.89	56.03	34.02	28.71
↓	825	8.95	↓	↓	↓
	2065	24.44			
	1241	15.14			
	1653	21.83			
	1376	17.19			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		609
TIRF RUN NO (0604-Series)		04
SIZE		G70-15
MANUFACTURER		GY
BRAND NAME		CUSTOM WIDE TREAD POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		no DOT No
CONSTRUCTION TYPE		BB
RIM WIDTH, in		6.00
SHORE HARDNESS		63.6
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL

B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL

TT	TUBETYPE
TL	TUBELESS

TIRE NO	609 .
RUN NO	0604094
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V =50 mph AND FZ =1380 lb					
Y Variable measured	Y_{∞}	$Y_o - Y_{\infty}$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	17.78	8.30	.237	19.5	.10
CAT, °C	59.40	-29.43	.135	34.1	.12
TST, °C	3631	-8.24	.124	37.2	.08
P, psi	28.57	-4.05	.137	33.6	.00

$$Y = Y_{\infty} + (Y_o - Y_{\infty})\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_{∞} = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_{\infty}$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	833	9.49	58.52	35.81	28.52
↓	2066	30.61	↓	↓	↓
↓	1240	15.45	↓	↓	↓
↓	1652	22.25	↓	↓	↓
↓	1395	17.45	↓	↓	↓
↓	1376	17.28	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		610
TIRF RUN NO (0604-Series)		32
SIZE		G60-14
MANUFACTURER		GY
BRAND NAME		POLYGLAS GT
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MB KX DLA 264
CONSTRUCTION TYPE		BB
RIM WIDTH, in		7.00
SHORE HARDNESS		61.0
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	610
RUN NO	0604032
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	17.66	7.52	.166	27.8	.18
CAT, °C	60.61	-30.06	.126	36.6	.15
TST, °C	37.20	-10.16	.116	39.7	.03
P, psi	28.70	- 4.27	.128	36.0	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1380	17.76	59.42	36.70	28.56
↓	829	9.57	↓	↓	↓
↓	2063	30.41	↓	↓	↓
↓	1242	15.63	↓	↓	↓
↓	1653	22.84	↓	↓	↓
↓	1380	17.63	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		611			
TIRF RUN NO (0604-Series)		38			
SIZE		D 78-14			
MANUFACTURER		GY			
BRAND NAME		CUSTOM POWER CUSHION POLYGLAS			
LOAD RANGE (PLY RATING)		B			
MAX T&RA LOAD, lb		1320			
MAX INFL PRESS, psi		32			
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F			
	SIDEWALL	2P			
DOT NO		MP	L3	DDA	244
CONSTRUCTION TYPE		BB			
RIM WIDTH, in		5.00			
SHORE HARDNESS		59.6			
REMARKS					

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	611
RUN NO	0604038
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1120 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	16.62	7.90	.288	16.0	.05
CAT, °C	63.54	-30.32	.165	27.9	.27
TST, °C	43.10	-9.90	.221	20.9	.06
P, psi	28.79	-4.26	.172	26.8	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1134	16.77	63.65	43.27	28.86
↓	673	8.67	↓	↓	↓
	1671	28.08			
	1005	14.72			
	1338	20.93			
	1119	16.32			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		612
TIRF RUN NO (0604-Series)		03, 21*, 27, 49
SIZE		G78-14
MANUFACTURER		GY
BRAND NAME		CUSTOM POWER CUSHION POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MD | L9 | DDA | 304
CONSTRUCTION TYPE		BB
RIM WIDTH, in		6.00
SHORE HARDNESS		61.8
REMARKS		*See Fig. 48

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	612
RUN NO	0604093
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	18.97	9.71	.218	21.1	.16
CAT, °C	62.75	-30.92	.160	28.8	.30
TST, °C	37.42	-8.48	.182	25.3	.04
P, psi	28.72	-4.22	.168	27.4	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value
Y_∞ = equilibrium value
X = distance traveled
X_{99} = $4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	826	9.70	62.82	37.59	28.76
↓	2060	31.80	↓	↓	↓
↓	1253	16.56	↓	↓	↓
↓	1649	23.65	↓	↓	↓
↓	1387	18.68	↓	↓	↓
↓	1383	18.53	↓	↓	↓

CAT = Contained Air Temperature
TST = Tread Surface Temperature

TIRE NO 612	
RUN NO 0604027	
INFL PRESS COLD 16 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	23.84	12.33	.290	15.9	.16
CAT, °C	72.81	-38.80	.179	25.8	.68
TST, °C	42.18	-9.46	.164	28.1	.05
P, psi	21.26	-4.28	.153	30.1	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1389	23.72	73.55	42.19	21.29
↓	837	12.91	↓	↓	↓
↓	2060	41.09	↓	↓	↓
↓	1247	20.71	↓	↓	↓
↓	1653	29.85	↓	↓	↓
↓	1388	23.72	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO 612

RUN NO 0604027

INFL PRESS COLD – psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	≈ Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	18.90				
CAT, °C	65.42				
TST, °C	41.54				
P, psi	31.49				

$$Y = Y_\infty + (Y_o - Y_\infty)\ e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1381	18.90	65.42	41.54	31.49
↓	827	10.55	↓	↓	↓
	2062	31.06			
	1241	16.63			
	1650	23.33			
	1377	18.93			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO 612	
RUN NO 0604049	
INFL PRESS COLD 24 psi	
REMARKS [redacted] DRUM	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	15.65	11.54	.283	16.3	.13
CAT, °C	63.74	-40.04	.157	29.4	.50
TST, °C	37.79	-11.20	.187	24.7	.21
P, psi	30.26	-5.44	.160	28.8	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1385	15.25	63.76	38.03	30.27
↓	833	7.64	↓	↓	↓
↓	2059	27.46	↓	↓	↓
↓	1238	13.22	↓	↓	↓
↓	1648	19.62	↓	↓	↓
↓	1384	15.76	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		G13
TIRF RUN NO (0604-Series)		05
SIZE		G78-15
MANUFACTURER		GY
BRAND NAME		CUSTOM POWER CUSHION POLYGLAS
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		MD VV DDA 454
CONSTRUCTION TYPE		BB
RIM WIDTH, in		5.50
SHORE HARDNESS		56.2
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 613
RUN NO 0604095
INFL PRESS COLD 24 psi
REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	18.35	9.10	.236	19.5	.09
CAT, °C	60.86	-29.27	.172	26.8	.21
TST, °C	34.87	-7.57	.181	25.5	.02
P, psi	28.37	-3.91	.171	27.0	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	832	9.67	61.13	34.69	28.42
↓	2059	31.92	↓	↓	↓
↓	1242	15.75	↓	↓	↓
↓	1651	23.44	↓	↓	↓
↓	1375	18.70	↓	↓	↓
↓	1372	18.27	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		614
TIRF RUN NO (0604-Series)		14
SIZE		AR70-13
MANUFACTURER		GY
BRAND NAME		POWERSTEEL RADIAL WT
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1060
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+4R+1S
	SIDEWALL	2P
DOT NO		MJ DJ JKT 104
CONSTRUCTION TYPE		R
RIM WIDTH, in		5.00
SHORE HARDNESS		59.8
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL.
TT	TUBETYPE
TL	TUBELESS

TIRE NO	614
RUN NO	0604014
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 900 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	10.32	5.72	.194	23.8	.07
CAT, °C	53.86	-23.85	.125	36.9	.05
TST, °C	36.49	-8.70	.188	24.5	.04
P, psi	27.93	-3.61	.154	29.9	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	543	5.43	52.72	36.48	27.93
↓	1347	16.46	↓	↓	↓
↓	809	8.56	↓	↓	↓
↓	1082	12.51	↓	↓	↓
↓	916	10.09	↓	↓	↓
↓	902	9.81	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		615
TIRF RUN NO (0604-Series)		35
SIZE		DR70-14
MANUFACTURER		GY
BRAND NAME		POWERSTEEL RADIAL WT
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1320
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+4R+1S
	SIDEWALL	2P
DOT NO		MJ LA JKT 304
CONSTRUCTION TYPE		R
RIM WIDTH, in		5.50
SHORE HARDNESS		62.4
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 615	
RUN NO 0604035	
INFL PRESS COLD 24 psi	
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1120 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	13.26	5.54	.184	25.1	.07
CAT, °C	51.44	-24.94	.135	34.1	.05
TST, °C	38.12	-8.63	.152	30.3	.03
P, psi	27.80	-3.42	.146	31.6	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1127	13.48	55.54	38.03	27.78
↓	679	8.02	↓	↓	↓
↓	1680	21.57	↓	↓	↓
↓	1013	11.70	↓	↓	↓
↓	1345	16.28	↓	↓	↓
↓	1174	13.72	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		616
TIRF RUN NO (0604-Series)		.31
SIZE		GR70-14
MANUFACTURER		GY
BRAND NAME		POWERSTEEL RADIAL WT
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+4R+1S
	SIDEWALL	2P
DOT NO		MK LH JKT 034
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.00
SHORE HARDNESS		64.4
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 616	
RUN NO 0604031	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	18.01	8.76	.259	17.8	.08
CAT, °C	61.51	-32.29	.124	37.2	.07
TST, °C	36.89	-9.68	.153	30.1	.05
P, psi	28.97	-4.51	.131	35.2	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1387	17.99	60.00	36.92	28.81
↓	831	10.82	↓	↓	↓
↓	2065	28.26	↓	↓	↓
↓	1244	15.96	↓	↓	↓
↓	1655	21.61	↓	↓	↓
↓	1379	17.53	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		617
TIRF RUN NO (0604-Series)		34
SIZE		DR78-14
MANUFACTURER		GY
BRAND NAME		CUSTOM POLYSTEEL RADIAL
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1320
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		MK | L4 | HCT | 444
CONSTRUCTION TYPE		R
RIM WIDTH, in		5.00
SHORE HARDNESS		56.4
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 617	
RUN NO 0604034	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1120 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	12.40	4.44	.314	14.7	.03
CAT, °C	54.23	-23.10	.142	32.5	.06
TST, °C	38.65	-8.38	.171	27.0	.04
P, psi	27.80	-3.30	.151	30.5	.00
$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$					

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1136	12.66	53.66	38.47	27.78
↓	684	7.68	↓	↓	↓
↓	1675	19.68	↓	↓	↓
↓	1021	11.21	↓	↓	↓
↓	1341	14.94	↓	↓	↓
↓	1127	12.05	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		618
TIRF RUN NO (0604-Series)		23*, 28, 37, 51
SIZE		GR78-14
MANUFACTURER		GY
BRAND NAME		CUSTOM POWERSTEEL RADIAL
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		MK MA HCE 354
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.00
SHORE HARDNESS		56.6
REMARKS		*See Fig. 48

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 618

RUN NO 060428

INFL PRESS COLD 24 psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	14.82	5.95	.219	21.1	.09
CAT, °C	55.56	-25.37	.138	33.4	.06
TST, °C	40.02	-7.27	.190	24.3	.06
P, psi	28.04	-3.49	.147	31.4	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1383	14.53	54.77	40.23	27.98
↓	834	9.43	↓	↓	↓
↓	2063	23.21	↓	↓	↓
↓	1248	13.20	↓	↓	↓
↓	1648	17.41	↓	↓	↓
↓	1380	14.36	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	618
RUN NO	0604037
INFL PRESS COLD	16 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	18.20	9.83	.311	14.8	.08
CAT, °C	63.15	-32.32	.144	32.0	.16
TST, °C	42.13	-10.17	.189	24.4	.07
P, psi	20.61	-3.71	.149	30.9	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1412	17.83	62.68	42.19	20.56
↓	831	10.68	↓	↓	↓
	2068	30.44			
	1240	15.59			
	1652	21.78			
	1377	17.37			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO 618

RUN NO 0604037

INFL PRESS COLD — psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	$\approx Y_\infty$	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	13.68				
CAT, °C	56.49				
TST, °C	41.32				
P, psi	31.74				

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1382	13.68	56.49	41.32	31.74
↓	828	8.81	↓	↓	↓
↓	2068	21.78	↓	↓	↓
↓	1245	12.67	↓	↓	↓
↓	1652	16.72	↓	↓	↓
↓	1379	13.55	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	618
RUN NO	0604051
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	12.26	6.05	.275	16.8	.08
CAT, °C	54.48	-31.28	.142	32.5	.12
TST, °C	39.84	-11.85	.169	27.3	.22
P, psi	28.99	-4.37	.143	32.2	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1397	12.07	53.57	40.01	28.96
↓	830	7.31	↓	↓	↓
↓	2062	19.88	↓	↓	↓
↓	1238	10.65	↓	↓	↓
↓	1652	14.76	↓	↓	↓
↓	1383	12.06	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		619			
TIRF RUN NO (0604-Series)		24			
SIZE		7.50-16 LT			
MANUFACTURER		GY			
BRAND NAME		CUSTOM HI-MILER			
LOAD RANGE (PLY RATING)		C			
MAX T&RA LOAD, lb		2060			
MAX INFL PRESS, psi		45			
NO OF PLIES AND CORD MATERIAL	TREAD	N			
	SIDEWALL	N			
DOT NO		MD	WY	BWA	414
CONSTRUCTION TYPE		B			
RIM WIDTH, in		5.50			
SHORE HARDNESS		53.4			
REMARKS					

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	619
RUN NO	060424
INFL PRESS COLD	35 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1770 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	24.60	12.05	.181	25.5	.04
CAT, °C	65.28	-38.97	.143	32.2	.37
TST, °C	34.15	-7.88	.155	29.7	.03
P, psi	40.82	-5.68	.132	34.9	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1775	24.77	64.67	33.80	40.63
↓	1063	13.67	↓	↓	↓
↓	2645	42.04	↓	↓	↓
↓	1591	21.77	↓	↓	↓
↓	2117	31.18	↓	↓	↓
↓	1766	24.52	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		620
TIRF RUN NO (0604-Series)		25
SIZE		7.50-16 LT
MANUFACTURER		GY
BRAND NAME		CUSTOM HI-MILER
LOAD RANGE (PLY RATING)		D
MAX T&RA LOAD, lb		2440
MAX INFL PRESS, psi		60
NO OF PLIES AND CORD MATERIAL	TREAD	N
	SIDEWALL	N
DOT NO		MD WY BYA 374
CONSTRUCTION TYPE		B
RIM WIDTH, in		5.50
SHORE HARDNESS		55.0
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	620
RUN NO	0604025
INFL PRESS COLD	50 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 2190 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	19.94	15.28	.0742	62.1	.26
CAT, °C	67.66	-36.54	.145	31.8	.29
TST, °C	35.26	-8.24	.108	42.7	.04
P, psi	57.49	-7.25	.139	33.2	.02

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50					
↓					

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		621			
TIRF RUN NO (0604-Series)		26			
SIZE		7.50R16LT			
MANUFACTURER		GY			
BRAND NAME		CUSTOM FLEXSTEEL LT			
LOAD RANGE (PLY RATING)		D			
MAX T&RA LOAD, lb		2440			
MAX INFL PRESS, psi		65			
NO OF PLIES AND CORD MATERIAL	TREAD	P+S			
	SIDEWALL	P			
DOT NO		MM	WY	PTA	284
CONSTRUCTION TYPE		R			
RIM WIDTH, in		5.50			
SHORE HARDNESS		57.4			
REMARKS					

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	621
RUN NO	0604026
INFL PRESS COLD	55 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 2190 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	19.49	4.29	.199	23.2	.17
CAT, °C	54.71	-21.97	.091	50.7	.01
TST, °C	36.92	-7.76	.0863	53.4	.04
P, psi	60.27	-5.01	.112	41.2	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	2185	19.33	51.88	36.03	59.91
↓	1309	11.91	↓	↓	↓
↓	3266	30.25	↓	↓	↓
↓	1967	17.80	↓	↓	↓
↓	2616	23.48	↓	↓	↓
↓	2183	19.58	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		622
TIRF RUN NO (0604-Series)		12
SIZE		7.00-15 LT
MANUFACTURER		GY
BRAND NAME		CUSTOM HI-MILER
LOAD RANGE (PLY RATING)		C
MAX T&RA LOAD, lb		1720
MAX INFL PRESS, psi		45
NO OF PLIES AND CORD MATERIAL	TREAD	N
	SIDEWALL	N
DOT NO		MD NV BWA 084
CONSTRUCTION TYPE		B
RIM WIDTH, in		5.50
SHORE HARDNESS		59.0
REMARKS		

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 622

RUN NO 0604012

INFL PRESS COLD 35 psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1480 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	20.34	9.45	.150	30.7	.06
CAT, °C	66.28	-36.99	.140	32.9	.15
TST, °C	35.45	-7.85	.141	32.7	.04
P, psi	40.21	-5.35	.128	36.0	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	890	10.87	65.16	35.81	39.84
↓	2205	35.02	↓	↓	↓
↓	1328	17.75	↓	↓	↓
↓	1770	25.64	↓	↓	↓
↓	1484	20.92	↓	↓	↓
↓	1474	20.57	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		623
TIRF RUN NO (0604-Series)		19,42,55
SIZE		A78-13
MANUFACTURER		FI
BRAND NAME		DELUXE CHAMPION
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1060
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2R
	SIDEWALL	2R
DOT NO		VB F5 ECV 404
CONSTRUCTION TYPE		B
RIM WIDTH, in		4.50
SHORE HARDNESS		57.6
REMARKS		SAE ROUND ROBIN

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 623

RUN NO 0604019

INFL PRESS COLD 16 psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 30 mph AND FZ = 900 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	18.32	8.12	.232	19.9	.07
CAT, °C	56.06	-24.58	.143	32.2	.07
TST, °C	33.95	-9.05	.177	26.0	.04
P, psi	20.04	-3.39	.169	27.3	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
30	915	18.38	55.54	34.02	20.07
↓	552	9.43	↓	↓	↓
↓	1343	32.16	↓	↓	↓
↓	820	16.36	↓	↓	↓
↓	1078	23.11	↓	↓	↓
↓	914	18.63	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO 623	
RUN NO 0604019	
INFL PRESS COLD — psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 30 mph AND FZ = 900 lb					
Y Variable measured	$\approx Y_\infty$	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	14.02				
CAT, °C	49.54				
TST, °C	31.54				
P, psi	31.45				

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
30	902	14.02	49.54	31.54	31.45
↓	541	7.45	↓	↓	↓
↓	1347	24.67	↓	↓	↓
↓	812	12.55	↓	↓	↓
↓	1080	18.18	↓	↓	↓
↓	901	14.17	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	623
RUN NO	060442
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 900 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	14.62	7.56	.256	18.0	.08
CAT, °C	59.81	-32.99	.135	34.1	.15
TST, °C	39.93	-11.27	.234	19.7	.07
P, psi	29.42	-4.93	.166	27.8	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	917	14.51	58.75	40.01	29.44
↓	540	6.90	↓	↓	↓
	1345	25.46			
	813	12.49			
	1079	18.12			
	897	13.92			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	623
RUN NO	0604055
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 900 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	13.48	6.30	.369	12.5	.07
CAT, °C	68.56	-39.36	.150	30.7	.16
TST, °C	41.90	-13.53	.263	17.5	.10
P, psi	29.71	-5.27	.181	25.5	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\ e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	910	13.23	67.87	42.40	29.74
↓	548	7.00	↓	↓	↓
↓	1341	23.31	↓	↓	↓
↓	813	11.73	↓	↓	↓
↓	1078	16.63	↓	↓	↓
↓	907	12.79	↓	↓	↓
30	900	12.01	66.08	43.91	29.88
30	↓	11.72	↓	↓	↓
70	↓	14.98	↓	↓	↓
70	↓	15.01	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		624			
TIRF RUN NO (0604-Series)		18,41,56			
SIZE		A78-13			
MANUFACTURER		FI			
BRAND NAME		SUP-R-BELT DELUXE CHAMPION			
LOAD RANGE (PLY RATING)		B			
MAX T&RA LOAD, lb		1060			
MAX INFL PRESS, psi		32			
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F			
	SIDEWALL	2P			
DOT NO		VB	F5	E81	424
CONSTRUCTION TYPE		BB			
RIM WIDTH, in		4.50			
SHORE HARDNESS		64.8			
REMARKS		SAE ROUND ROBIN			

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	624
RUN NO	0604018
INFL PRESS COLD	16 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 30 mph AND FZ = 900 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	17.48	8.10	.274	16.8	.08
CAT, °C	54.47	-21.81	.146	31.6	.09
TST, °C	31.88	-7.64	.151	30.5	.04
P, psi	19.97	-3.31	.171	27.0	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
30	911	17.47	54.10	31.76	20.02
↓	541	9.00	↓	↓	↓
↓	1344	31.41	↓	↓	↓
↓	813	15.21	↓	↓	↓
↓	1080	22.59	↓	↓	↓
↓	903	16.94	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	624
RUN NO	0604018
INFL PRESS COLD	– psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 30 mph AND FZ = 900 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	12.37				
CAT, °C	47.43				
TST, °C	30.17				
P, psi	31.93				

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
30	900	12.37	47.43	30.17	31.93
↓	547	6.37	↓	↓	↓
	1348	22.53			
	808	10.84			
	1082	16.33			
	900	12.50			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	624
RUN NO	0604041
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 900 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	14.26	5.53	.202	22.8	.12
CAT, °C	61.95	-29.82	.140	32.9	.13
TST, °C	42.52	-11.95	.175	26.3	.06
P, psi	29.03	-4.60	.171	27.0	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	913	13.90	61.37	42.40	29.05
↓	543	7.18	↓	↓	↓
↓	1348	24.19	↓	↓	↓
↓	811	12.33	↓	↓	↓
↓	1079	17.31	↓	↓	↓
↓	907	13.39	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	624
RUN NO	060405G
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V =50 mph AND FZ = 900 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	12.51	5.86	.253	18.2	.11
CAT, °C	64.82	-35.07	.144	32.0	.24
TST, °C	42.57	-14.65	.209	22.1	.10
P, psi	29.73	-5.17	.179	25.8	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	906	12.74	64.13	43.05	29.79
↓	545	6.90	↓	↓	↓
↓	1346	21.77	↓	↓	↓
↓	823	11.18	↓	↓	↓
↓	1076	16.03	↓	↓	↓
↓	904	12.03	↓	↓	↓
30	900	11.67	62.12	44.77	30.00
30	↓	11.40	↓	↓	↓
70	↓	14.72	↓	↓	↓
70	↓	14.20	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		627
TIRF RUN NO (0604-Series)		44,52
SIZE		LR78-15
MANUFACTURER		FI
BRAND NAME		STEEL RADIAL 500
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1970
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		VD V4 DWJ 404
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.50
SHORE HARDNESS		57.2
REMARKS		SAE ROUND ROBIN

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	627
RUN NO	060404
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1680 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	17.89	7.17	.242	19.0	.11
CAT, °C	55.83	-28.82	.150	30.7	.14
TST, °C	33.53	-6.76	.153	30.1	.02
P, psi	28.63	-3.94	.149	30.9	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1690	17.78	55.54	33.57	28.61
↓	1011	10.13	↓	↓	↓
↓	2510	29.13	↓	↓	↓
↓	1513	15.92	↓	↓	↓
↓	2010	21.44	↓	↓	↓
↓	1676	17.72	↓	↓	↓
30	1680	16.79	54.95	34.02	28.71
30	↓	16.32	↓	↓	↓
70	↓	18.84	↓	↓	↓
70	↓	18.71	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	627
RUN NO	0604052
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 1680 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	14.61	7.05	.277	16.6	.10
CAT, °C	57.35	-32.19	.153	30.1	.17
TST, °C	35.94	-9.81	.157	29.4	.07
P, psi	29.14	-4.35	.151	30.5	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1682	14.59	57.08	35.81	29.01
↓	1010	8.24	↓	↓	↓
↓	2506	24.06	↓	↓	↓
↓	1507	12.89	↓	↓	↓
↓	2008	18.21	↓	↓	↓
↓	1676	14.13	↓	↓	↓
30	1680	13.52	56.44	36.48	29.20
30	↓	12.88	↓	↓	↓
70	↓	16.33	↓	↓	↓
70	↓	16.41	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		629
TIRF RUN NO (0604-Series)		45,53
SIZE		L78-15
MANUFACTURER		FI
BRAND NAME		SUP-R-BELT DELUXE CHAMPION
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1970
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2F
	SIDEWALL	2P
DOT NO		VB V3 C71 034
CONSTRUCTION TYPE		BB
RIM WIDTH, in		6.00
SHORE HARDNESS		62.2
REMARKS		SAE ROUND ROBIN

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	629
RUN NO	0604045
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1680 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	24.78	11.02	.316	14.6	.16
CAT, °C	65.32	-36.70	.158	29.2	.35
TST, °C	39.50	-11.89	.190	24.3	.04
P, psi	29.55	-4.87	.167	27.6	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1684	24.24	65.09	39.57	29.59
↓	1011	13.15	↓	↓	↓
↓	2509	41.78	↓	↓	↓
↓	1509	21.79	↓	↓	↓
↓	2010	31.08	↓	↓	↓
↓	1680	24.38	↓	↓	↓
30	1680	23.05	64.34	40.66	29.69
30	↓	23.18	↓	↓	↓
70	↓	26.85	↓	↓	↓
70	↓	26.77	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	629
RUN NO	0604053
INFL PRESS COLD	— psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 1680 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	20.48	12.41	.322	14.3	.33
CAT, °C	71.08	-43.83	.176	26.2	.49
TST, °C	41.94	-14.52	.208	22.2	.13
P, psi	30.67	-5.79	.172	26.8	.02

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1677	19.79	71.57	42.40	30.76
↓	1007	9.16	↓	↓	↓
↓	2508	38.13	↓	↓	↓
↓	1509	18.29	↓	↓	↓
↓	2013	26.86	↓	↓	↓
↓	1677	20.99	↓	↓	↓
30	1680	18.49	70.80	43.48	30.91
30	↓	18.43	↓	↓	↓
70	↓	23.22	↓	↓	↓
70	↓	22.22	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		631
TIRF RUN NO (0604-Series)		20,43,57
SIZE		BR78-13
MANUFACTURER		FI
BRAND NAME		STEEL RADIAL 500
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1150
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		VD FW BYJ 374
CONSTRUCTION TYPE		R
RIM WIDTH, in		4.50
SHORE HARDNESS		61.2
REMARKS		SAE ROUND ROBIN

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	631
RUN NO	0604020
INFL PRESS COLD	16 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 30 mph AND FZ = 980 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	12.10	681	.178	25.9	.06
CAT, °C	44.94	-19.77	.130	35.5	.03
TST, °C	29.39	-3.74	.194	23.8	.03
P, psi	19.69	-2.79	.158	29.2	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value
Y_∞ = equilibrium value
X = distance traveled
$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
30	985	11.87	44.18	29.49	19.68
↓	595	6.11	↓	↓	↓
↓	1465	22.10	↓	↓	↓
↓	893	10.39	↓	↓	↓
↓	1172	15.62	↓	↓	↓
↓	979	11.79	↓	↓	↓

CAT = Contained Air Temperature
TST = Tread Surface Temperature

TIRE NO	631
RUN NO	0604020
INFL PRESS COLD	– psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 30 mph AND FZ = 980 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	7.66				
CAT, °C	40.64				
TST, °C	27.43				
P, psi	31.84				

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
30	982	7.66	40.64	27.43	31.84
↓	596	3.45	↓	↓	↓
	1464	13.65			
	885	6.19			
	1173	9.76			
	980	7.61			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	631
RUN NO	0604043
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 980 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	10.81	4.11	.210	22.0	.08
CAT, °C	49.76	-16.82	.142	32.5	.04
TST, °C	34.16	-7.18	.173	26.6	.02
P, psi	27.77	-3.21	.186	24.8	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	986	10.27	49.32	34.24	27.83
↓	601	6.33	↓	↓	↓
↓	1461	17.42	↓	↓	↓
↓	893	9.16	↓	↓	↓
↓	1171	13.25	↓	↓	↓
↓	986	10.63	↓	↓	↓
30	980	9.91	48.26	34.69	27.98
30	↓	9.47	↓	↓	↓
68	↓	11.95	↓	↓	↓
68	↓	11.44	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	631
RUN NO	0604057
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 980 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	9.14	3.82	.296	15.6	.07
CAT, °C	53.88	-20.60	.154	29.9	.05
TST, °C	36.77	-8.25	.107	43.1	.14
P, psi	27.95	-3.39	.172	26.8	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	$\overline{FXO}$ lb	CAT °C	TST °C	P psi
50	993	9.23	53.57	36.48	27.98
↓	605	5.37	↓	↓	↓
↓	1467	15.41	↓	↓	↓
↓	898	7.56	↓	↓	↓
↓	1176	10.89	↓	↓	↓
↓	991	8.96	↓	↓	↓
30	980	7.88	52.50	36.92	28.13
30	↓	8.20	↓	↓	↓
70	↓	10.51	↓	↓	↓
70	↓	10.42	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		633
TIRF RUN NO (0604-Series)		11
SIZE		FR78-15
MANUFACTURER		GY
BRAND NAME		CUSTOM TREAD STEEL BELTED RADIAL
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1500
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		MK VU BWE 494
CONSTRUCTION TYPE		R
RIM WIDTH, in		5.50
SHORE HARDNESS		54.2
REMARKS		GM TPC

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	633
RUN NO	0604011
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1280 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	13.47	5.34	.256	18.0	.06
CAT, °C	51.73	-20.45	.160	28.8	.05
TST, °C	31.95	-5.83	.145	31.8	.02
P, psi	27.30	-2.91	.182	25.3	.00

$$Y = Y_\infty + (Y_o - Y_\infty) e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	770	7.63	51.48	31.76	27.30
↓	1918	22.64	↓	↓	↓
↓	1155	12.23	↓	↓	↓
↓	1531	16.71	↓	↓	↓
↓	1282	13.64	↓	↓	↓
↓	1280	13.68	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		634
TIRF RUN NO (0604-Series)		.06
SIZE		GR70-15
MANUFACTURER		GY
BRAND NAME		CUSTOM TREAD STEEL BELTED RADIAL
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		MJ U5 CXE 454
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.00
SHORE HARDNESS		54.8
REMARKS		GM TPC

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 634

RUN NO 0604006

INFL PRESS COLD 24 psi

REMARKS FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1380 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	13.95	4.86	.237	19.5	.13
CAT, °C	51.09	-19.82	.166	27.8	.05
TST, °C	30.68	-4.55	.183	25.2	.02
P, psi	27.19	-2.82	.176	26.2	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	830	7.53	51.00	30.63	27.20
	2063	23.35			
	1238	12.84			
	1648	17.53			
	1389	13.71			
	1375	13.49			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		G37
TIRF RUN NO (0604-Series)		07
SIZE		HR78-15
MANUFACTURER		UN
BRAND NAME		STEEL BELTED RADIAL PR6
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1770
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S+2N
	SIDEWALL	2P
DOT NO		AP VY EL 025
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.00
SHORE HARDNESS		53.0
REMARKS		GM TPC

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	637
RUN NO	0604097
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1510 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	1681	7.79	.240	19.2	.24
CAT, °C	59.98	-28.17	.155	29.7	.14
TST, °C	31.13	-6.00	.177	26.0	.04
P, psi	28.37	-3.93	.159	29.0	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	906	8.67	59.76	31.08	28.37
↓	2263	27.86	↓	↓	↓
↓	1360	14.46	↓	↓	↓
↓	1808	20.69	↓	↓	↓
↓	1512	16.12	↓	↓	↓
↓	1511	16.33	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		638
TIRF RUN NO (0604-Series)		33
SIZE		FR78-14
MANUFACTURER		GY
BRAND NAME		STEEL BELTED RADIAL
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1500
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S+1N
	SIDEWALL	2P
DOT NO		MK L8 DWH 433
CONSTRUCTION TYPE		R
RIM WIDTH, in		5.50
SHORE HARDNESS		59.0
REMARKS		GM TPC

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	638
RUN NO	060433
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1280 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	13.92	4.94	.270	17.1	.12
CAT, °C	54.39	-22.18	.148	31.1	.07
TST, °C	36.34	-6.72	.155	29.7	.04
P, psi	27.64	-3.20	.158	29.2	.00

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1302	13.59	54.01	36.26	27.64
↓	774	8.23	↓	↓	↓
	1914	21.71			
	1153	12.32			
	1534	1506			
	1455	1388			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		639
TIRF RUN NO (0604-Series)		08
SIZE		HR70-15
MANUFACTURER		UN
BRAND NAME		STEEL BELTED RADIAL PR6
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1770
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S
	SIDEWALL	2P
DOT NO		AP UZ CN1 364
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.50
SHORE HARDNESS		57.2
REMARKS		GM TPC

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO 639	
RUN NO 0604008	
INFL PRESS COLD 24 psi	
REMARKS FLAT BED [redacted]	

TRANSIENT TESTS @ V = 50 mph AND FZ = 1510 lb					
Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	16.02	6.34	.222	20.8	.10
CAT, °C	53.25	-26.93	.163	28.3	.27
TST, °C	28.78	-3.83	.0765	60.3	.01
P, psi	28.37	-3.68	.161	28.6	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES					
V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	914	8.95	53.43	28.12	28.42
↓	2257	26.03	↓	↓	↓
↓	1355	13.89	↓	↓	↓
↓	1803	19.10	↓	↓	↓
↓	1516	15.76	↓	↓	↓
↓	1516	15.50	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		640
TIRF RUN NO (0604-Series)		39*, 47†, 50*
SIZE		GR78-15
MANUFACTURER		UN
BRAND NAME		STEEL BELTED RADIAL PR6
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1620
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	2P+2S+2N
	SIDEWALL	2P
DOT NO		AP VW DR 015
CONSTRUCTION TYPE		R
RIM WIDTH, in		6.00
SHORE HARDNESS		54.75
REMARKS		GM TPC

* See Section 11.0

† See Fig. 49

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE AND RUN IDENTIFICATION

TIRF TIRE NO		641
TIRF RUN NO (0604-Series)		09,54
SIZE		H78-15
MANUFACTURER		FI
BRAND NAME		DELUXE CHAMPION
LOAD RANGE (PLY RATING)		B
MAX T&RA LOAD, lb		1770
MAX INFL PRESS, psi		32
NO OF PLIES AND CORD MATERIAL	TREAD	4 P
	SIDEWALL	4P
DOT NO		WK VX VEE 145
CONSTRUCTION TYPE		B
RIM WIDTH, in		6.00
SHORE HARDNESS		57.2
REMARKS		Tire added at Request of S. Bobo, TSC

NOTATIONS

FI	FIRESTONE
GY	GOODYEAR
UN	UNIROYAL
B	BIAS PLY
BB	BIAS BELTED
R	RADIAL PLY

F	FIBERGLAS
H	HIGH PERFORMANCE ORGANIC FIBER
N	NYLON
P	POLYESTER
R	RAYON
S	STEEL
TT	TUBETYPE
TL	TUBELESS

TIRE NO	641
RUN NO	0604099
INFL PRESS COLD	24 psi
REMARKS	FLAT BED [redacted]

TRANSIENT TESTS @ V = 50 mph AND FZ = 1510 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std.Error of estimate
FXO, lb	21.26	12.41	.298	15.5	.26
CAT, °C	62.80	-32.66	.190	24.3	.32
TST, °C	36.69	-11.01	.264	17.5	.04
P, psi	28.94	-4.58	.191	24.1	.01

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	911	9.44	63.31	36.92	29.05
│	2257	36.07	│	│	│
│	1361	18.44	│	│	│
│	1806	26.28	│	│	│
│	1514	20.61	│	│	│
↓	1509	20.92	↓	↓	↓

CAT = Contained Air Temperature

TST = Tread Surface Temperature

TIRE NO	641
RUN NO	0604054
INFL PRESS COLD	24 psi
REMARKS	[redacted] DRUM

TRANSIENT TESTS @ V = 50 mph AND FZ = 1510 lb

Y Variable measured	Y_∞	$Y_o - Y_\infty$	λ	X_{99} mi	Std. Error of estimate
FXO, lb	18.82	12.31	.381	12.1	.23
CAT, °C	69.57	-39.53	.201	22.9	.34
TST, °C	40.40	-12.35	.302	15.3	.09
P, psi	30.00	-5.15	.193	23.9	.02

$$Y = Y_\infty + (Y_o - Y_\infty)\, e^{-\lambda X}$$

Y_o = initial (cold) value

Y_∞ = equilibrium value

X = distance traveled

$X_{99} = 4.61/\lambda$, distance at which $Y \approx Y_\infty$

LOAD AND SPEED VARIATION TESTS @ CONSTANT TEMPERATURES

V mph	FZ lb	FXO lb	CAT °C	TST °C	P psi
50	1512	18.41	70.15	40.66	30.13
↓	909	8.91	↓	↓	↓
	2259	33.33			
	1359	15.78			
	1808	23.80			
	1510	18.38			

CAT = Contained Air Temperature

TST = Tread Surface Temperature

APPENDIX B

FLAT ROADWAY/DRUM TRANSIENT TEST RESULTS OF FIVE TIRES

FLAT ROADWAY – DRUM COMPARISONS

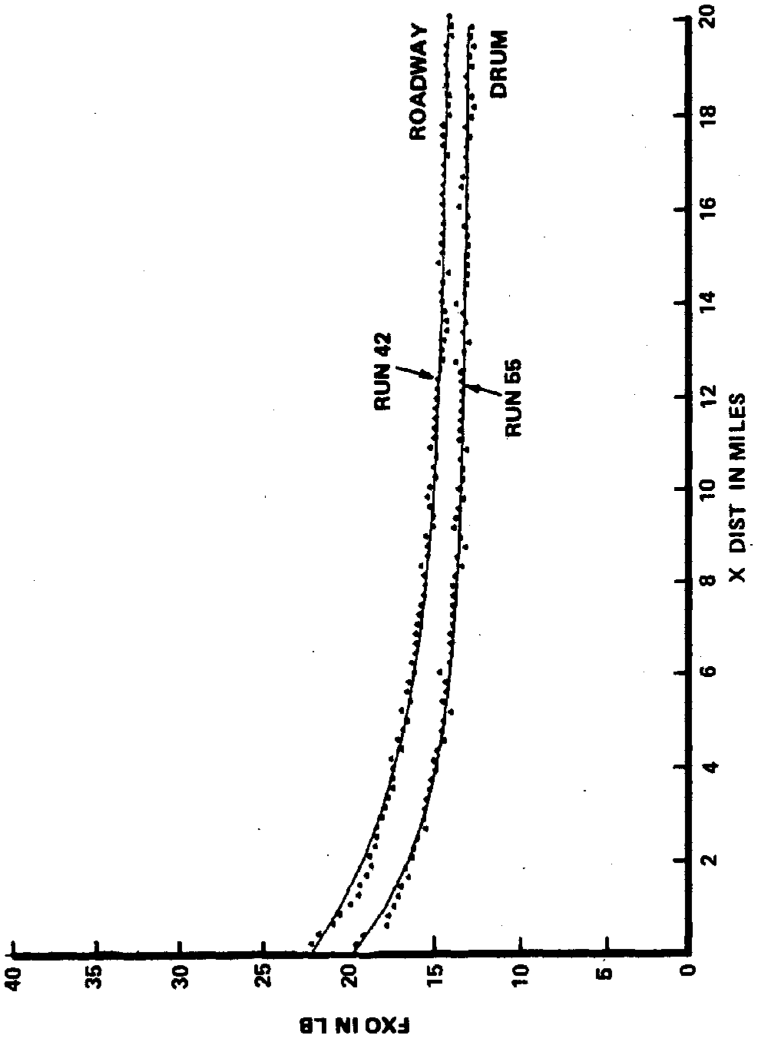
TRANSIENT TESTS

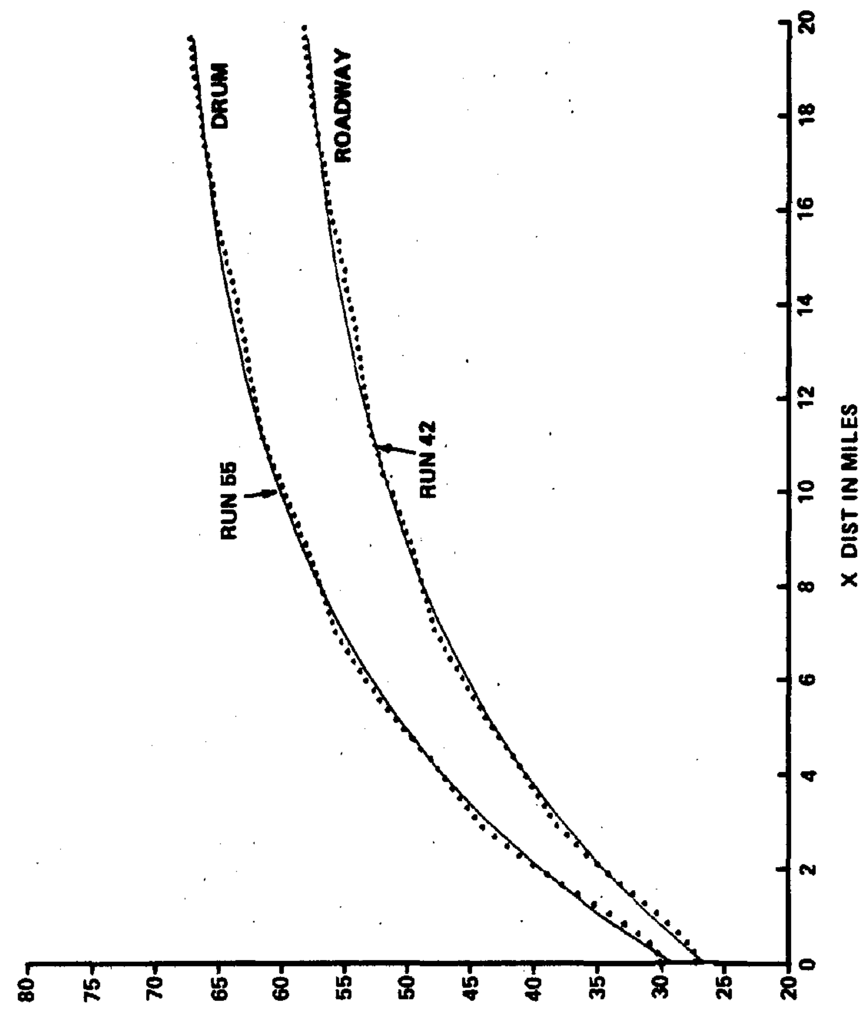
TIRE NO. 623 (SAE ROUND ROBIN)
A78-13 BIAS PLY

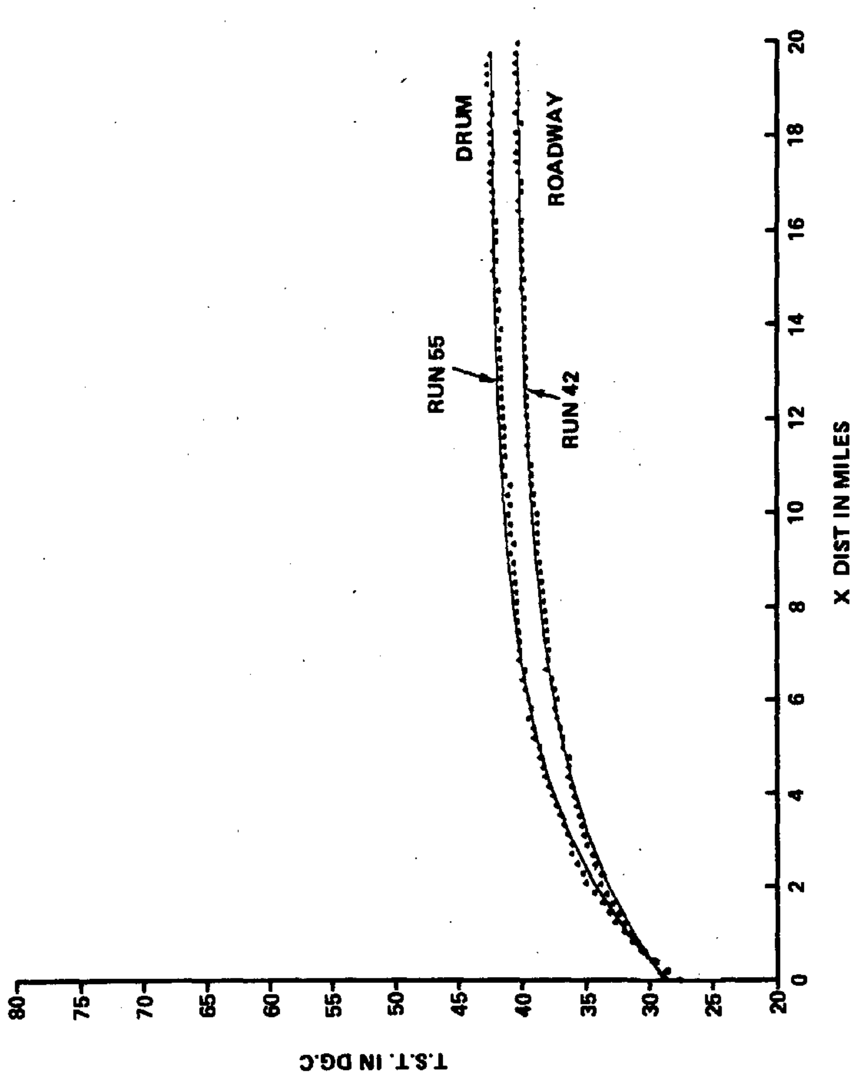
LOAD = T&RA @ 24 PSI

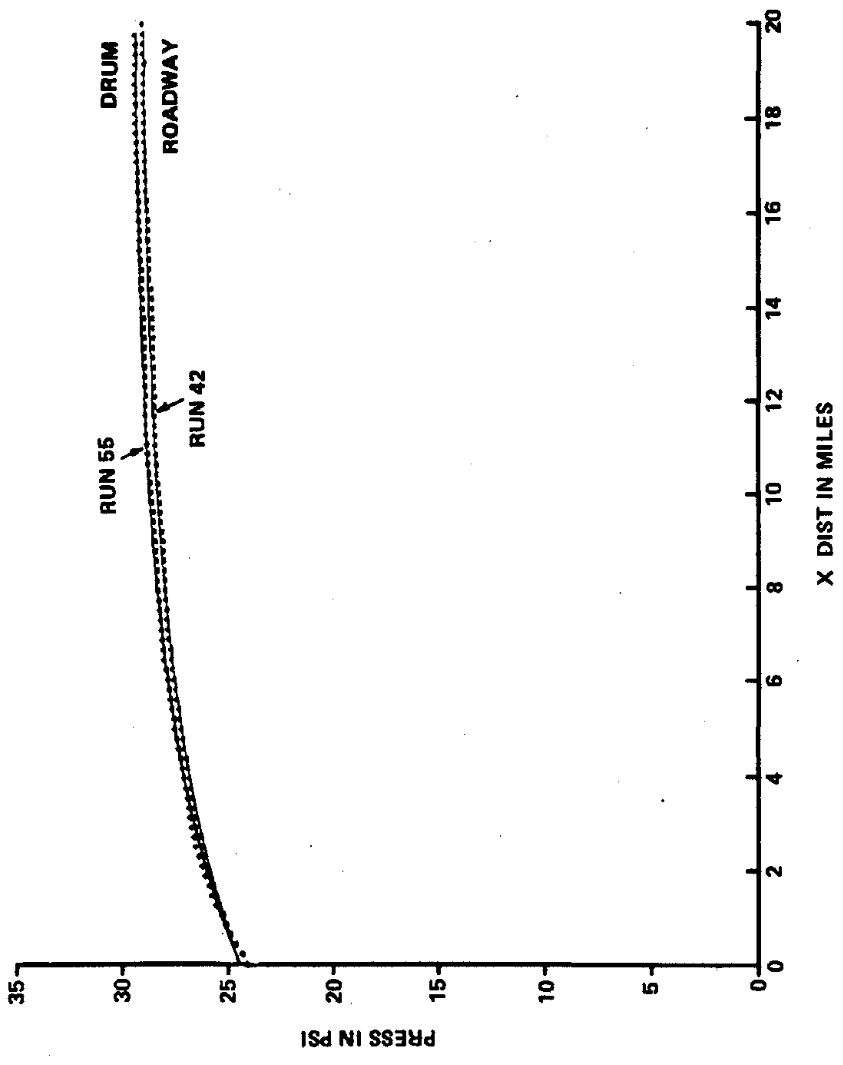
INFLATION PRESSURE = 24 PSI COLD

ROAD SPEED = 50 MPH


FXO IN LB
40
35
30
25
20
15
10
5
0
X DIST IN MILES
2
4
6
8
10
12
14
16
18
20
ROADWAY
DRUM
RUN 42
RUN 55


C.A.T. IN DG.C
20
25
30
35
40
45
50
55
60
65
70
75
80
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20
DRUM
ROADWAY
RUN 55
RUN 42


T.S.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20
DRUM
ROADWAY
RUN 55
RUN 42


PRESS IN PSI
35
30
25
20
15
10
5
0
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20
DRUM
ROADWAY
RUN 55
RUN 42

FLAT ROADWAY – DRUM COMPARISONS

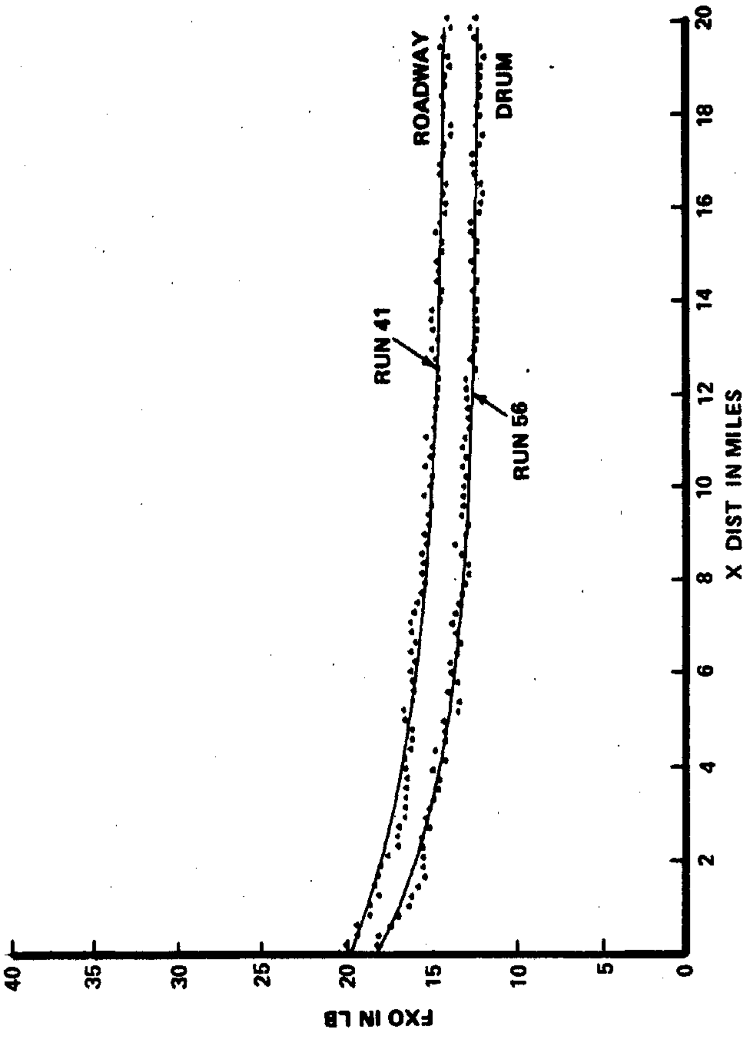
TRANSIENT TESTS

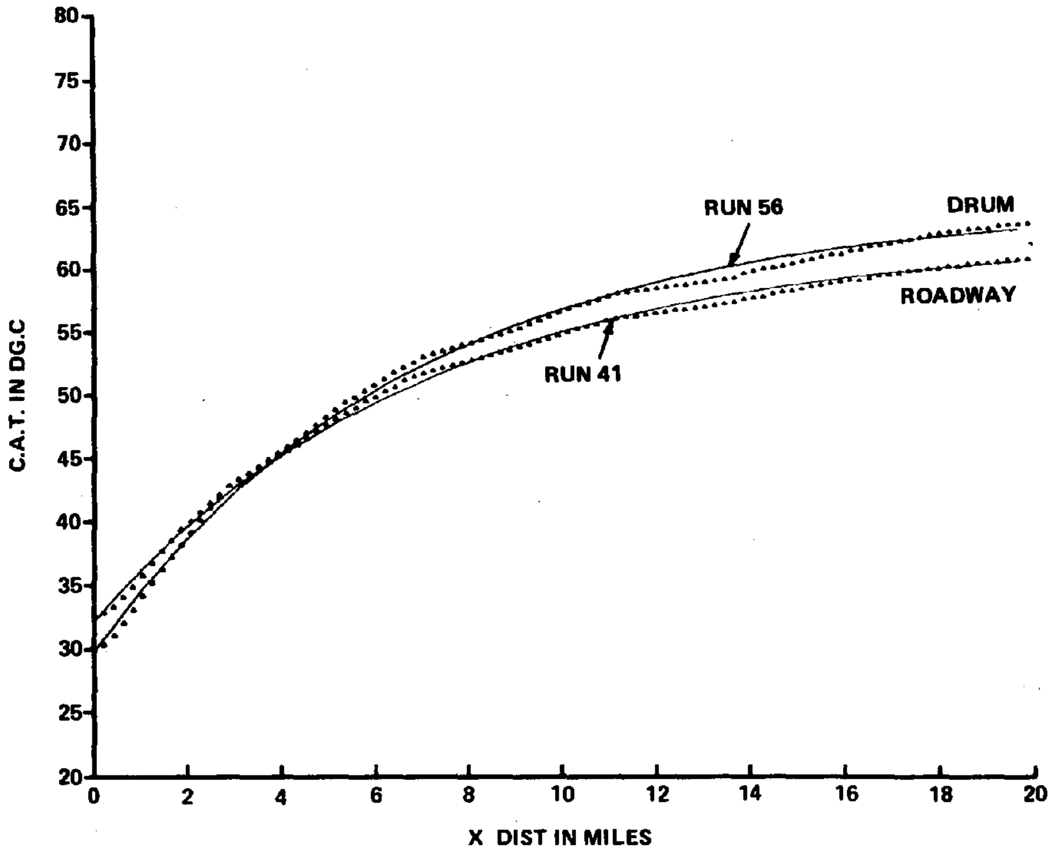
TIRE NO. 624 (SAE ROUND ROBIN)
A78-13 BIAS BELTED

LOAD = T&RA @ 24 PSI

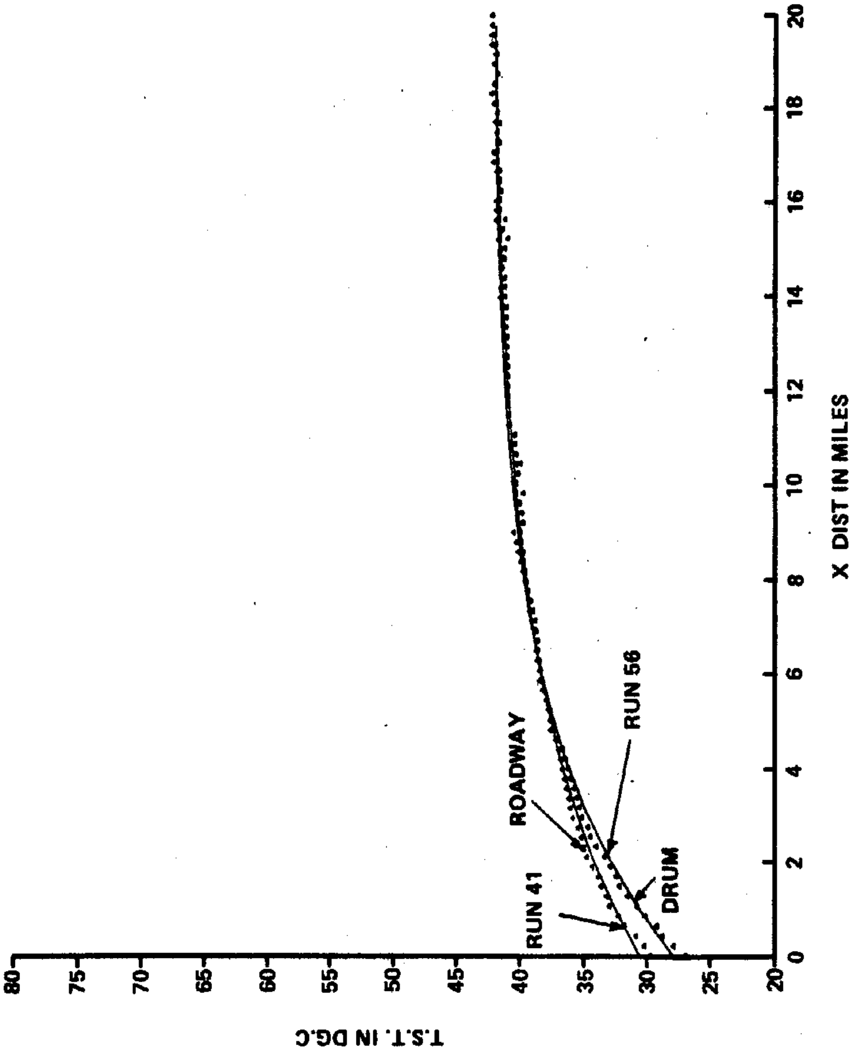
INFLATION PRESSURE = 24 PSI COLD

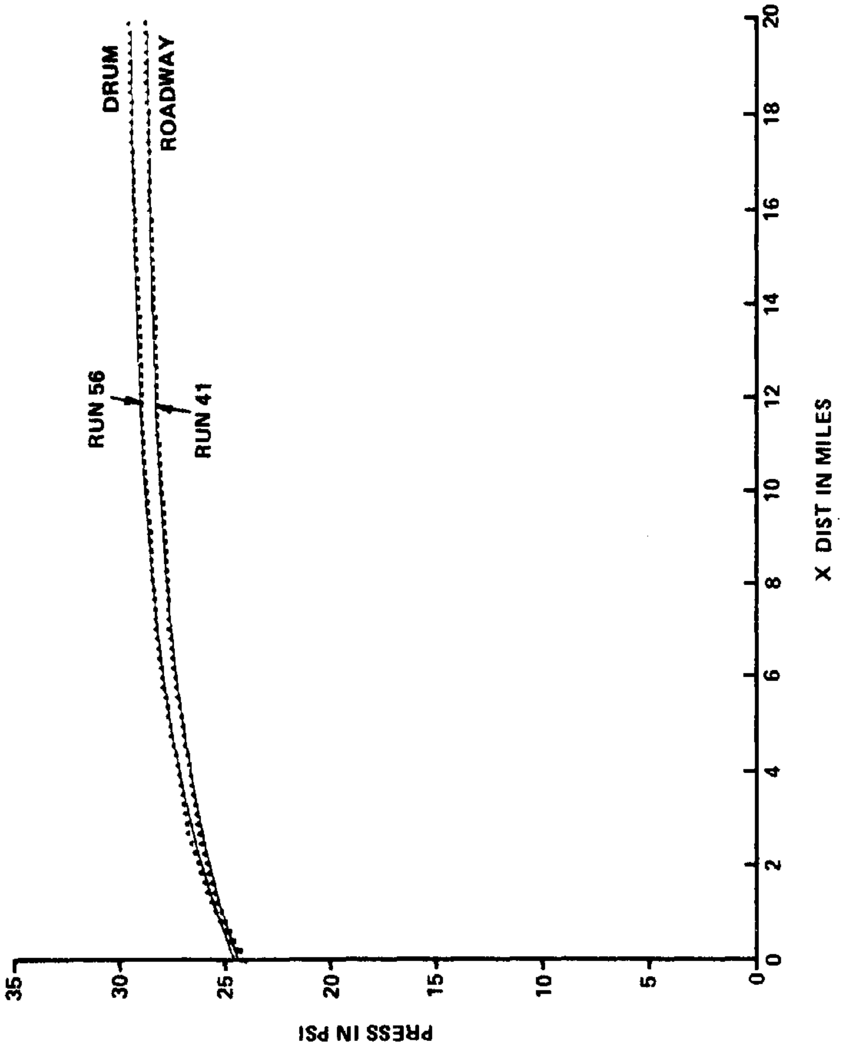
ROAD SPEED = 50 MPH


FXO IN LB
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 41
RUN 56
ROADWAY
DRUM



C.A.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 56
DRUM
ROADWAY
RUN 41


T.S.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 41
ROADWAY
RUN 56
DRUM


PRESS IN PSI
35
30
25
20
15
10
5
0
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20
DRUM
ROADWAY
RUN 56
RUN 41

FLAT ROADWAY – DRUM COMPARISONS

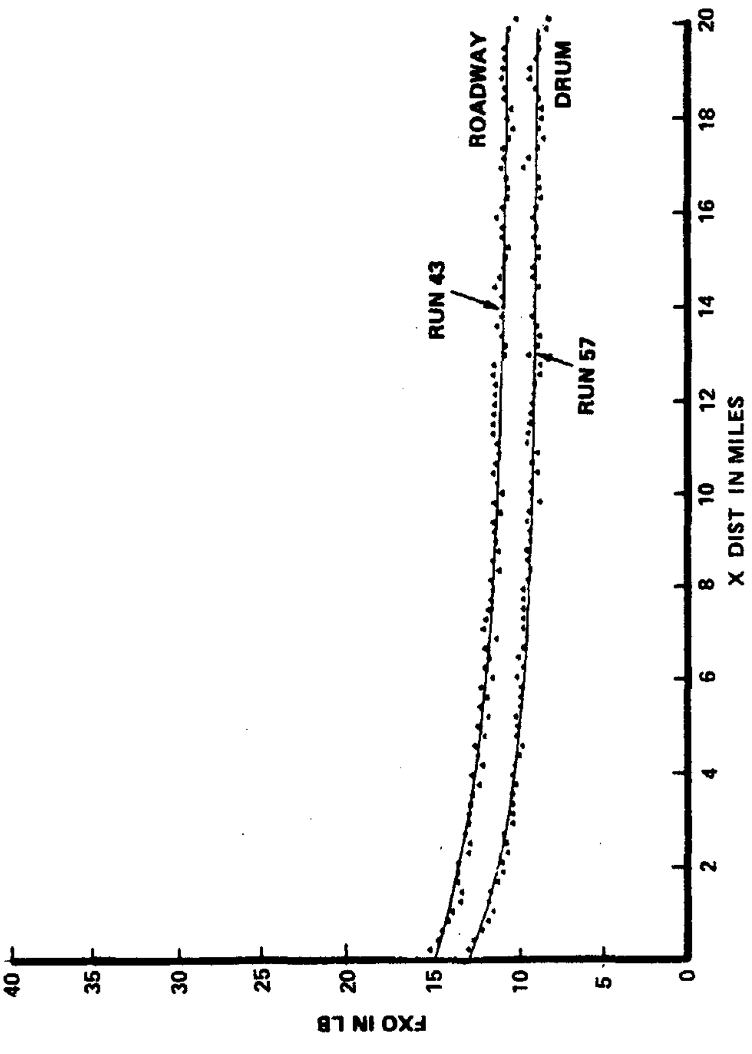
TRANSIENT TESTS

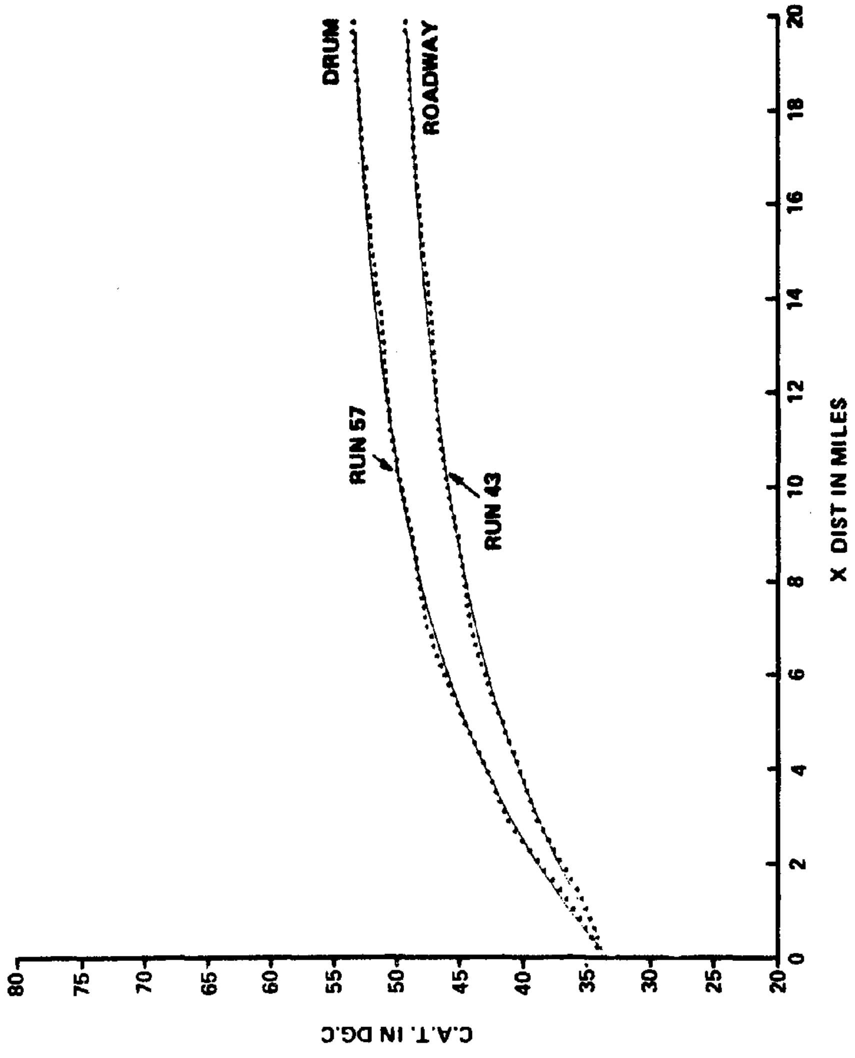
TIRE NO. 631 (SAE ROUND ROBIN)
BR78-13 RADIAL PLY

LOAD = T&RA @ 24 PSI

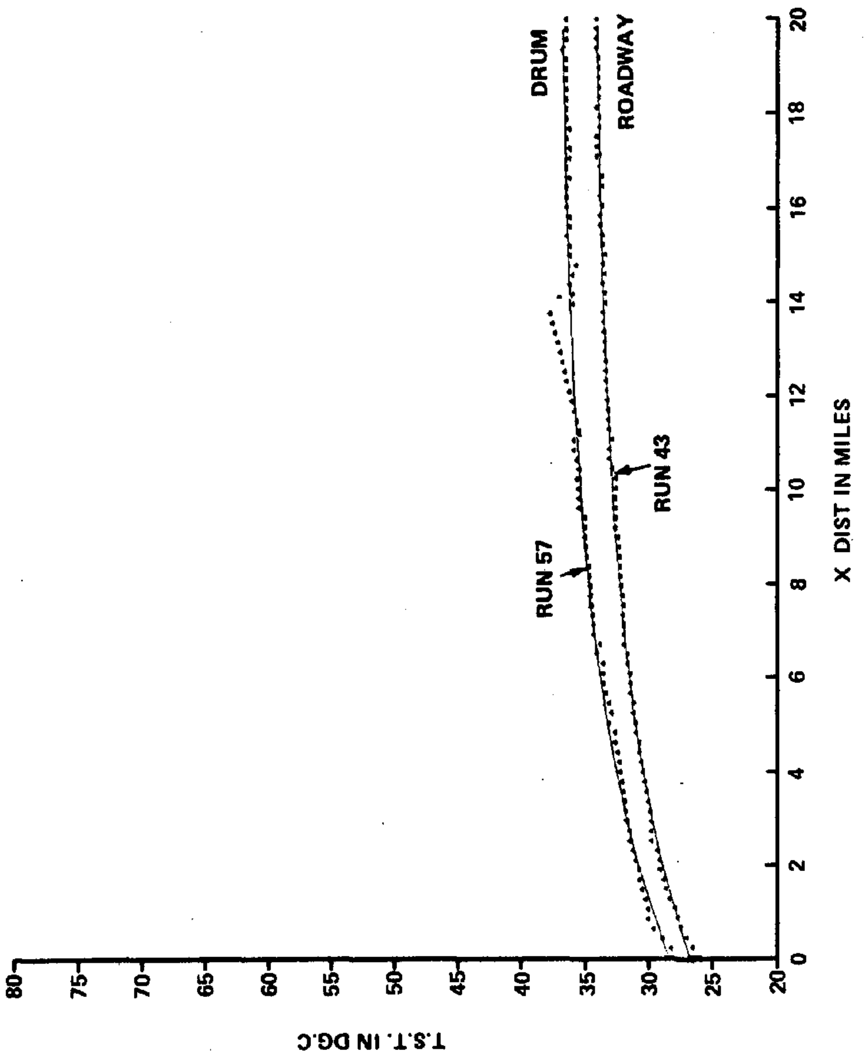
INFLATION PRESSURE = 24 PSI COLD

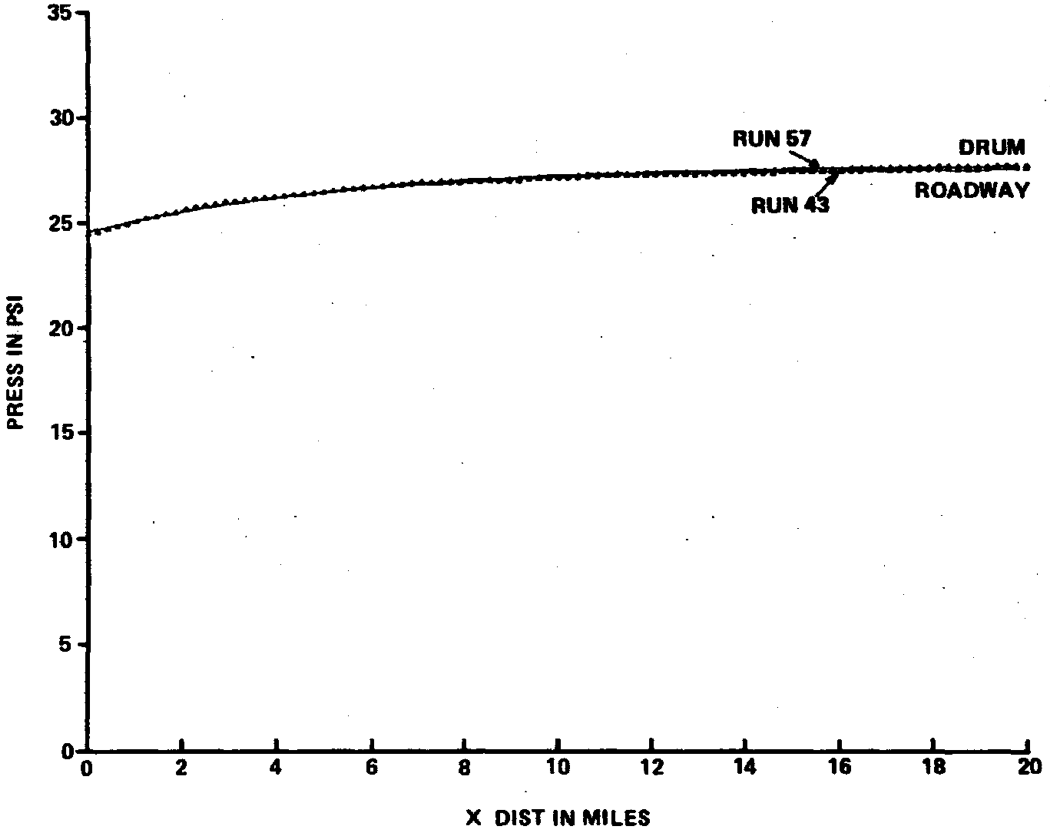
ROAD SPEED = 50 MPH


FXO IN LB
40
35
30
25
20
15
10
5
0
X DIST IN MILES
2
4
6
8
10
12
14
16
18
20
RUN 43
RUN 57
ROADWAY
DRUM



C.A.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
DRUM
ROADWAY
RUN 57
RUN 43


T.S.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 57
RUN 43
DRUM
ROADWAY



35
30
25
20
15
10
5
0
PRESS IN PSI
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 57
DRUM
RUN 43
ROADWAY

FLAT ROADWAY – DRUM COMPARISONS

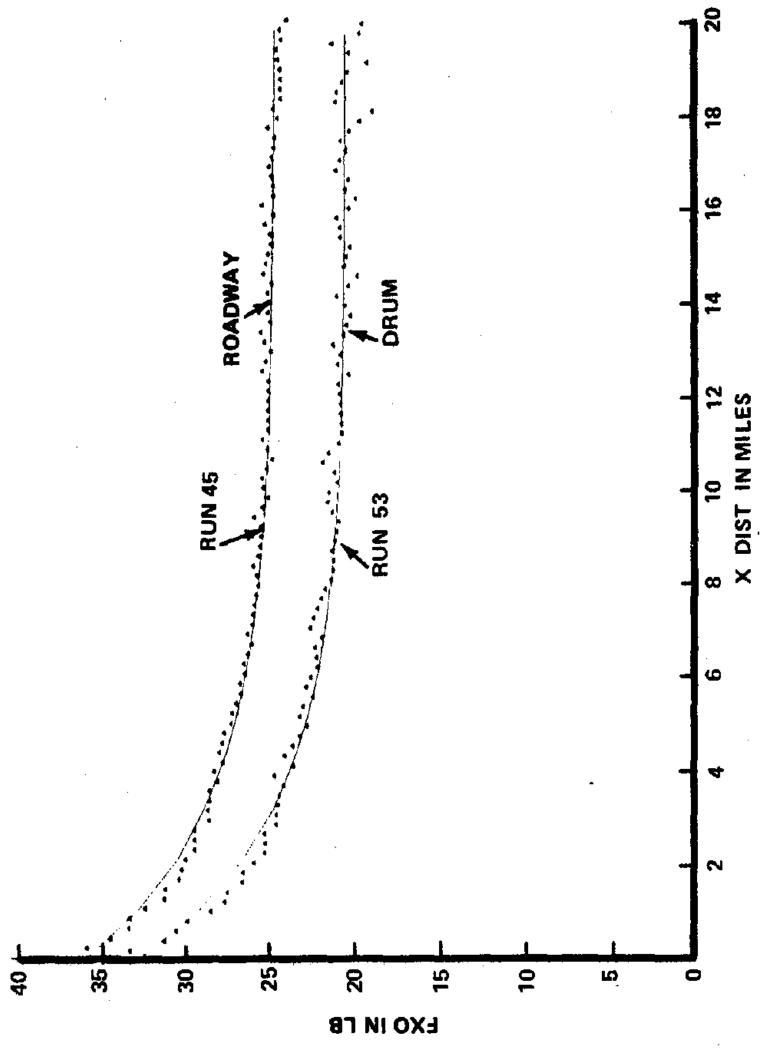
TRANSIENT TESTS

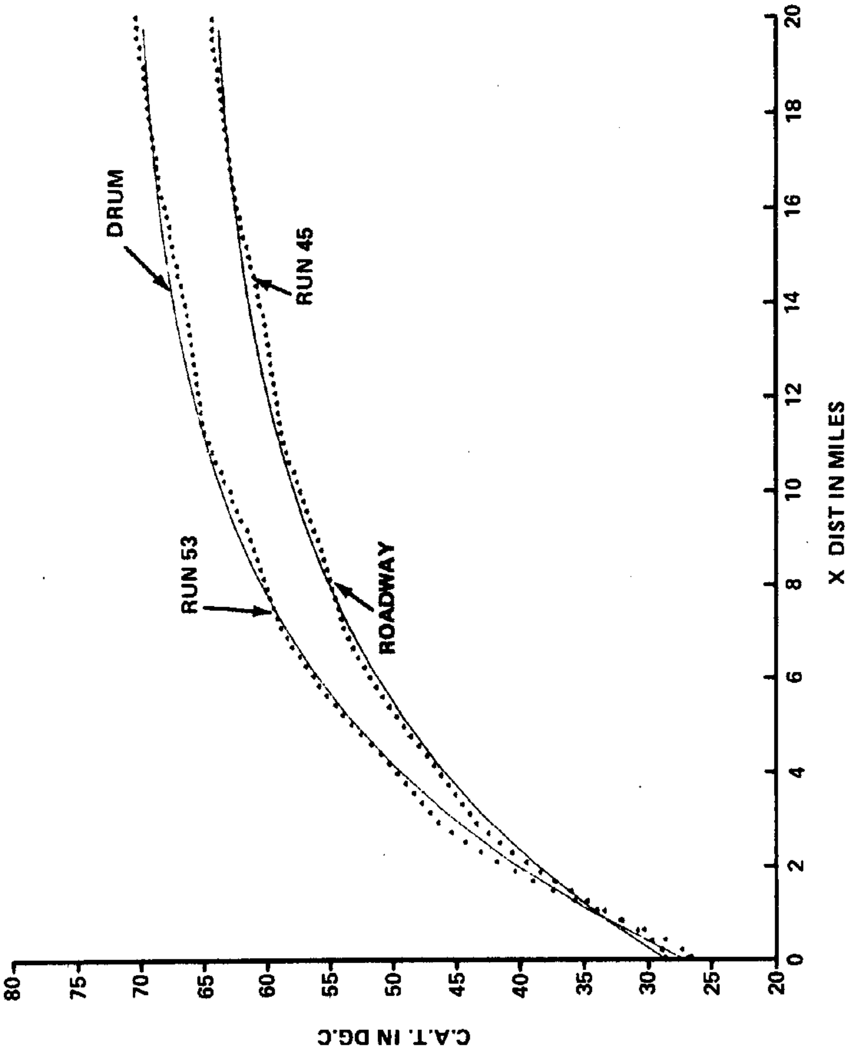
TIRE NO. 629 (SAE ROUND ROBIN)
L78-15 BIAS BELTED

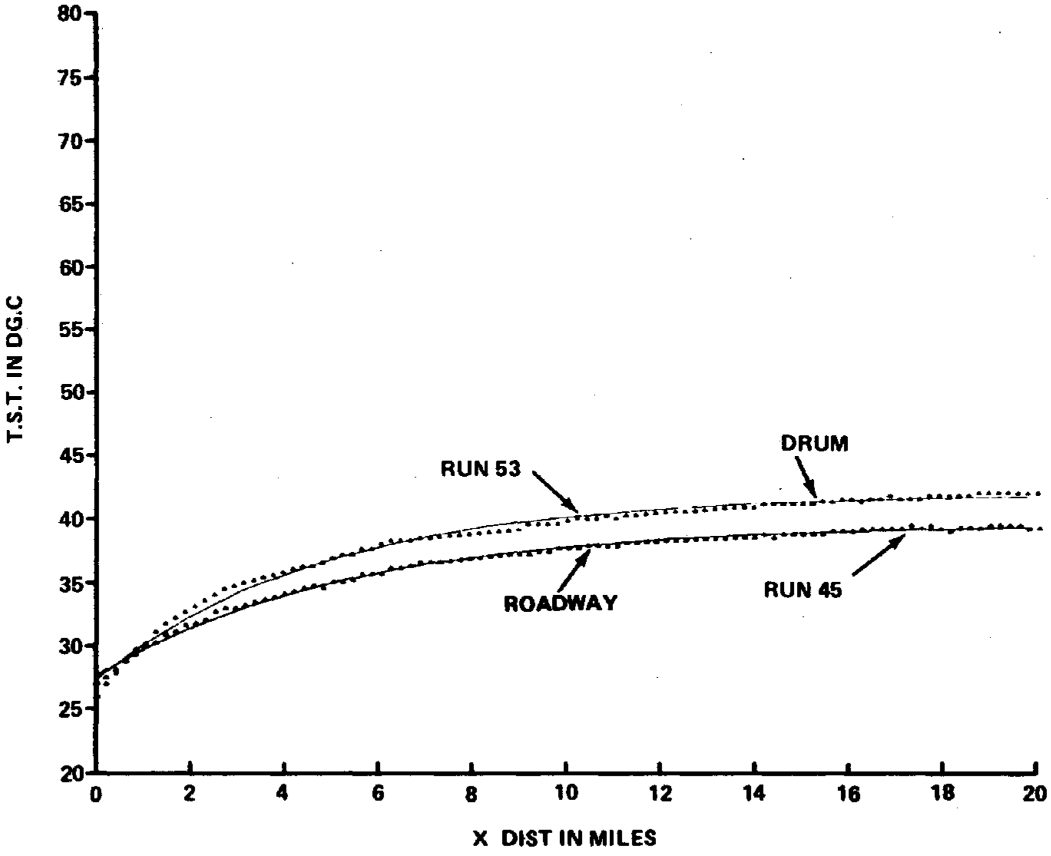
LOAD = T&RA @ 24 PSI

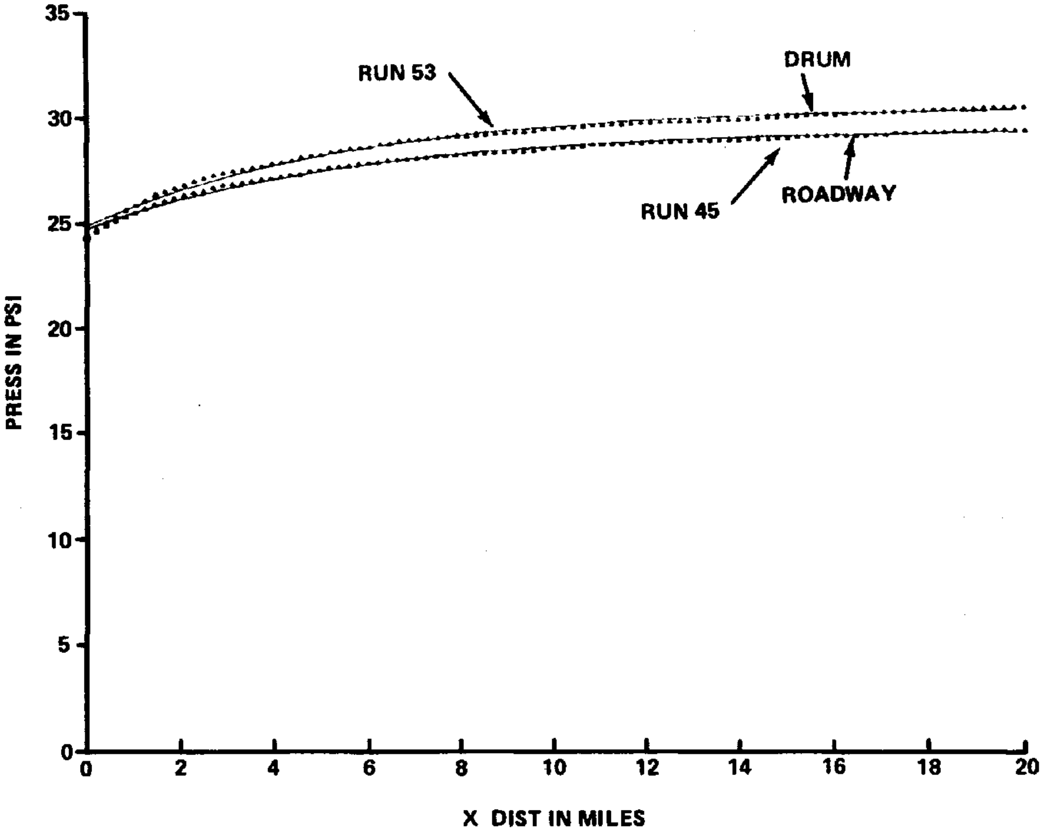
INFLATION PRESSURE = 24 PSI COLD

ROAD SPEED = 50 MPH


FXO IN LB
X DIST IN MILES
RUN 45
RUN 53
ROADWAY
DRUM
0
5
10
15
20
25
30
35
40
2
4
6
8
10
12
14
16
18
20


C.A.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20
DRUM
RUN 53
RUN 45
ROADWAY


80
75
70
65
60
55
50
45
40
35
30
25
20
T.S.T. IN DG.C
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 53
DRUM
ROADWAY
RUN 45


RUN 53
DRUM
RUN 45
ROADWAY
PRESS IN PSI
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES

FLAT ROADWAY – DRUM COMPARISONS

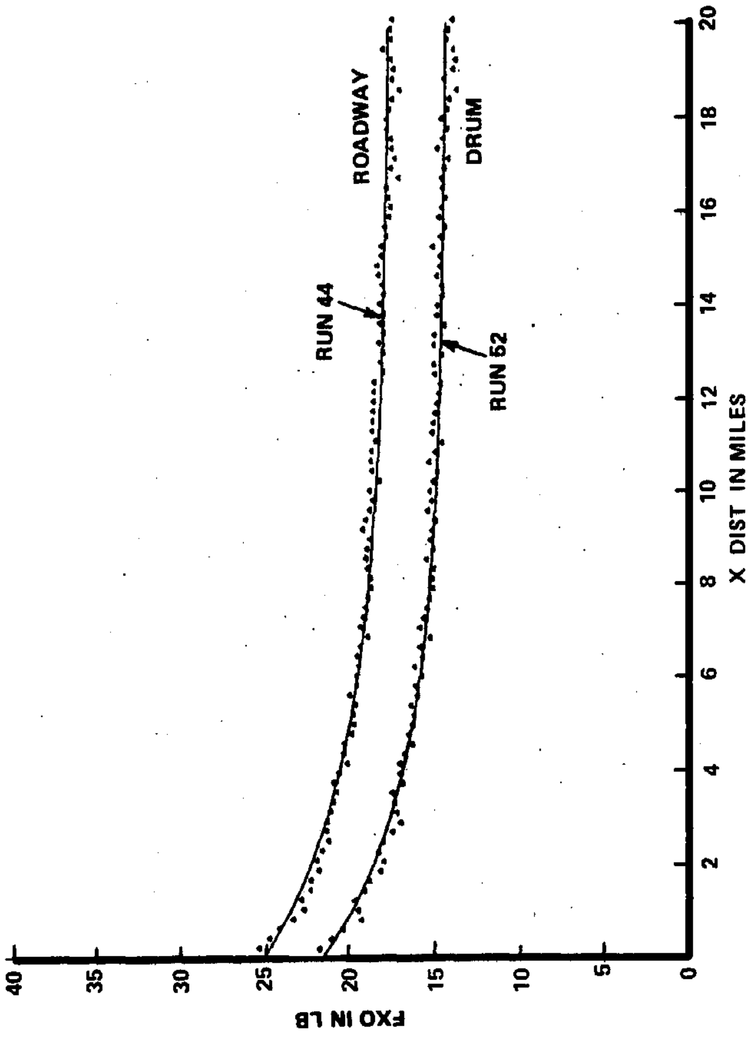
TRANSIENT TESTS

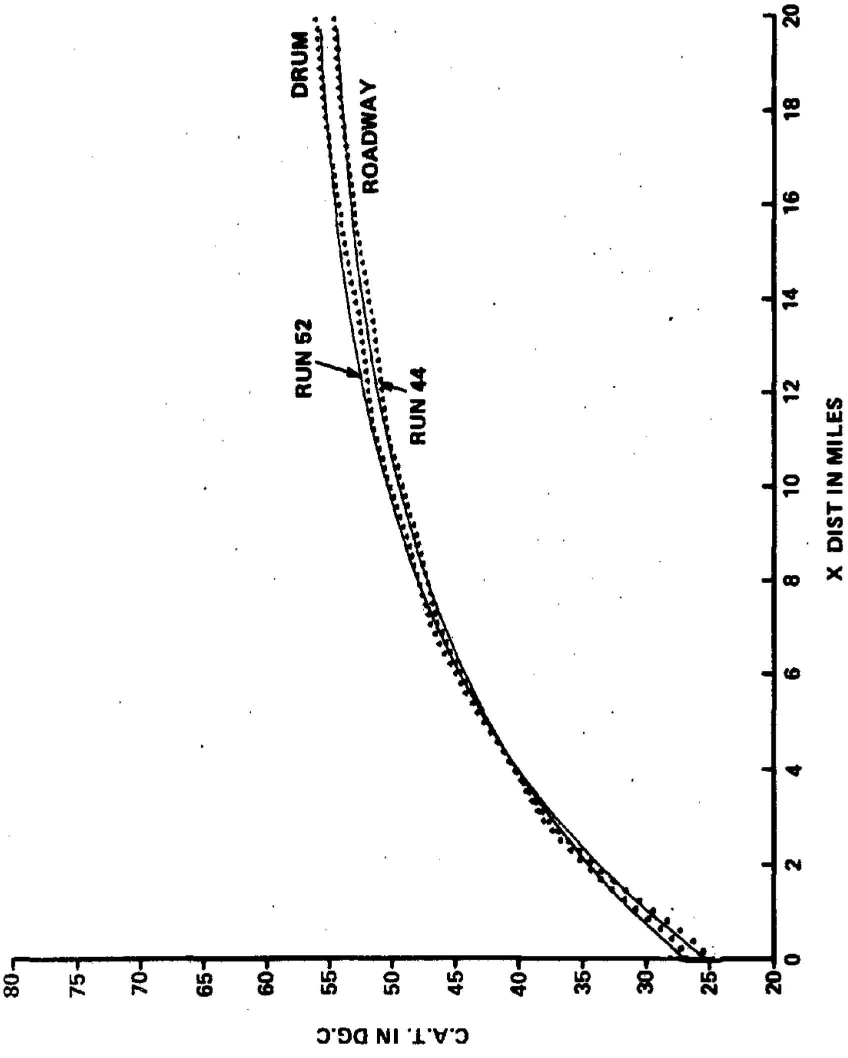
TIRE NO. 627 (SAE ROUND ROBIN)
LR78-15 RADIAL PLY

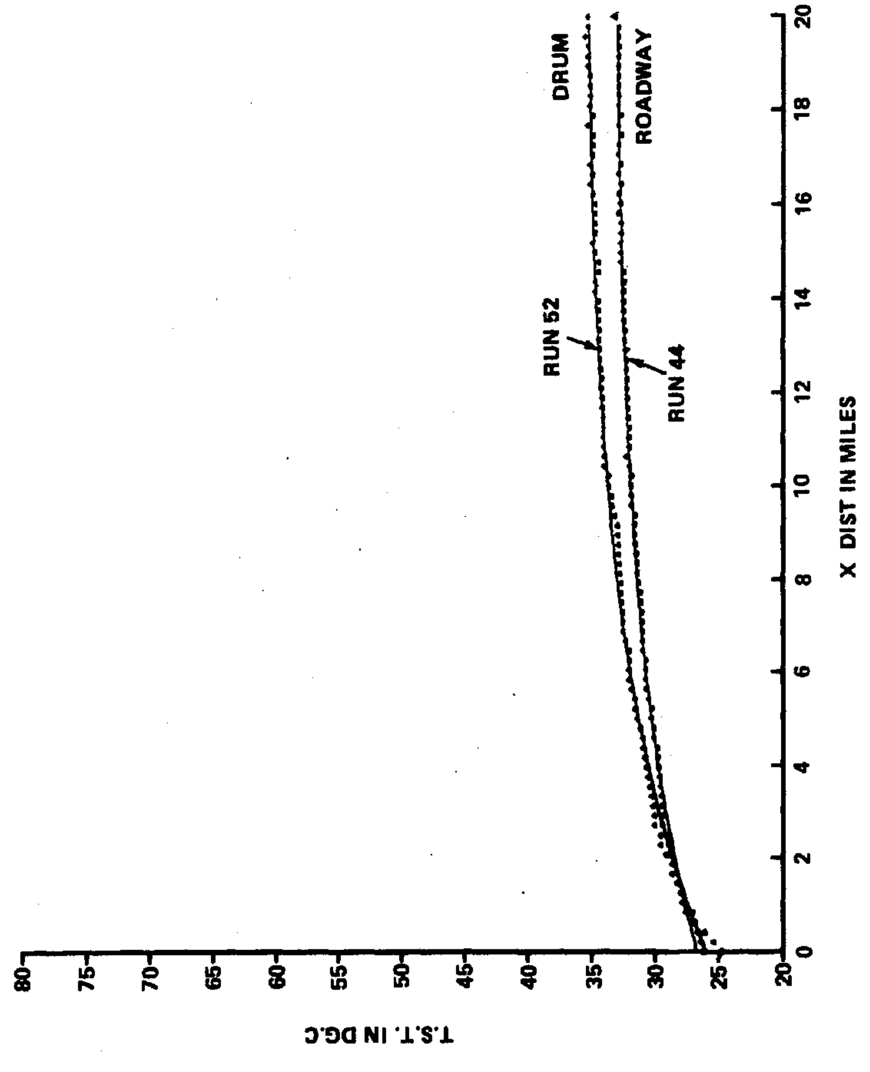
LOAD = T&RA @ 24 PSI

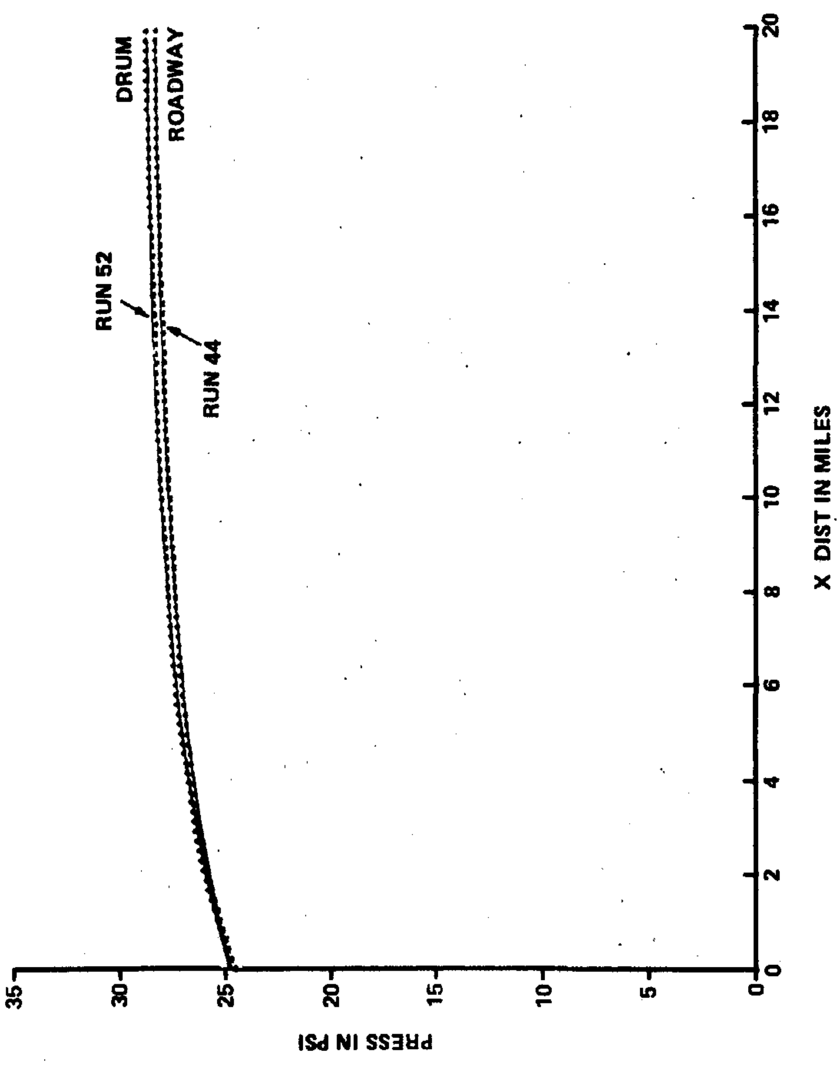
INFLATION PRESSURE = 24 PSI COLD

ROAD SPEED = 50 MPH


FXO IN LB
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 44
RUN 52
ROADWAY
DRUM


C.A.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20
DRUM
ROADWAY
RUN 52
RUN 44


T.S.T. IN DG.C
80
75
70
65
60
55
50
45
40
35
30
25
20
0
2
4
6
8
10
12
14
16
18
20
X DIST IN MILES
RUN 52
RUN 44
DRUM
ROADWAY


DRUM
ROADWAY
RUN 52
RUN 44
PRESS IN PSI
35
30
25
20
15
10
5
0
X DIST IN MILES
0
2
4
6
8
10
12
14
16
18
20

APPENDIX C

REPORT OF INVENTIONS

APPENDIX C

REPORT OF INVENTIONS

After a diligent review of the work performed under this contract, it was determined that no innovation, discovery, improvement, or invention was made.