TEST FACILITY

The primary features of the machine are:

Tire Positioning System

The tire, wheel, force sensing balance, and electric motor to drive or brake the tire are mounted in the movable upper head. The head provides steer, camber, and vertical loads to the tire. These motions/loads 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 1.

Table 1. TIRF CAPABILITIES

Calspan Upgraded Flat Roadway				
Description	**SI Units**		**Imperial Units**	
Minimum Loaded Radius	mm	**196**	in	**7.8**
Maximum Loaded Radius	mm	**610**	in	**24**
Maximum Loaded Displacement Rate	mm/s	**178**	in/s	**7**
Smallest Rim Diameter	mm	**254**	in	**10**
Maximum Tire Width	mm	**605**	in	**23.8**
Maximum Vertical Load	kN	**53**	lb	**12,000**
Lateral Force Capability	kN	**±40**	lb	**8992**
Longitudinal Force Capability	kN	**±40**	lb	**8992**
Slip Angle Range	deg	**±30**	deg	**±30**
Maximum Slip Angle Rate	deg/s	**12**	deg/s	**12**
Inclination Angle Range	deg	**±25**	deg	**±25**
Inclination Angle Range (Motorcycle)	deg	**50 / -10**	deg	**50 / -10**
Inclination Angle Rate	deg/s	**7**	deg/s	**7**
Spindle Speed	rpm	**±3,600**	rpm	**±3,600**
Spindle Torque at 850 rpm	kNm	**10.8**	lb-ft	**8000**
Spindle Torque at 1400 rpm	kNm	**10.8**	lb-ft	**8000**
Spindle Torque at 2200 rpm	kNm	**6.9**	lb-ft	**5110**
Spindle Torque at 3000rpm	kNm	**4.0**	lb-ft	**2900**
Spindle Torque at 3600rpm	kNm	**2**	lb-ft	**1440**
Spindle Torque Rate	kNm/s	**19**	lb-ft/s	**14,000**
Disk Brake Torque	kNm	**20**	lb-ft	**14,000**
Roadway Speed (2nd gear / 1st gear)	kph	**±360/160**	mph	**224 / 99.5**
Roadway Maximum Drag Force (2nd gear / 1st gear)	kN	**±28/64**	lb	**6295 / 14,500**
Maximum Lateral Belt Travel	mm	**±5**	in	**0.2**
Bearing Temperature Control [Surface]	deg C	**10 -38**	deg F	**50 - 100**
Tire Inflation Max	kPa	**2,400**	psi	**350**

* Can be increased to 90 deg. with special set-up.

** Can be increased to 55 deg. with special set-up.

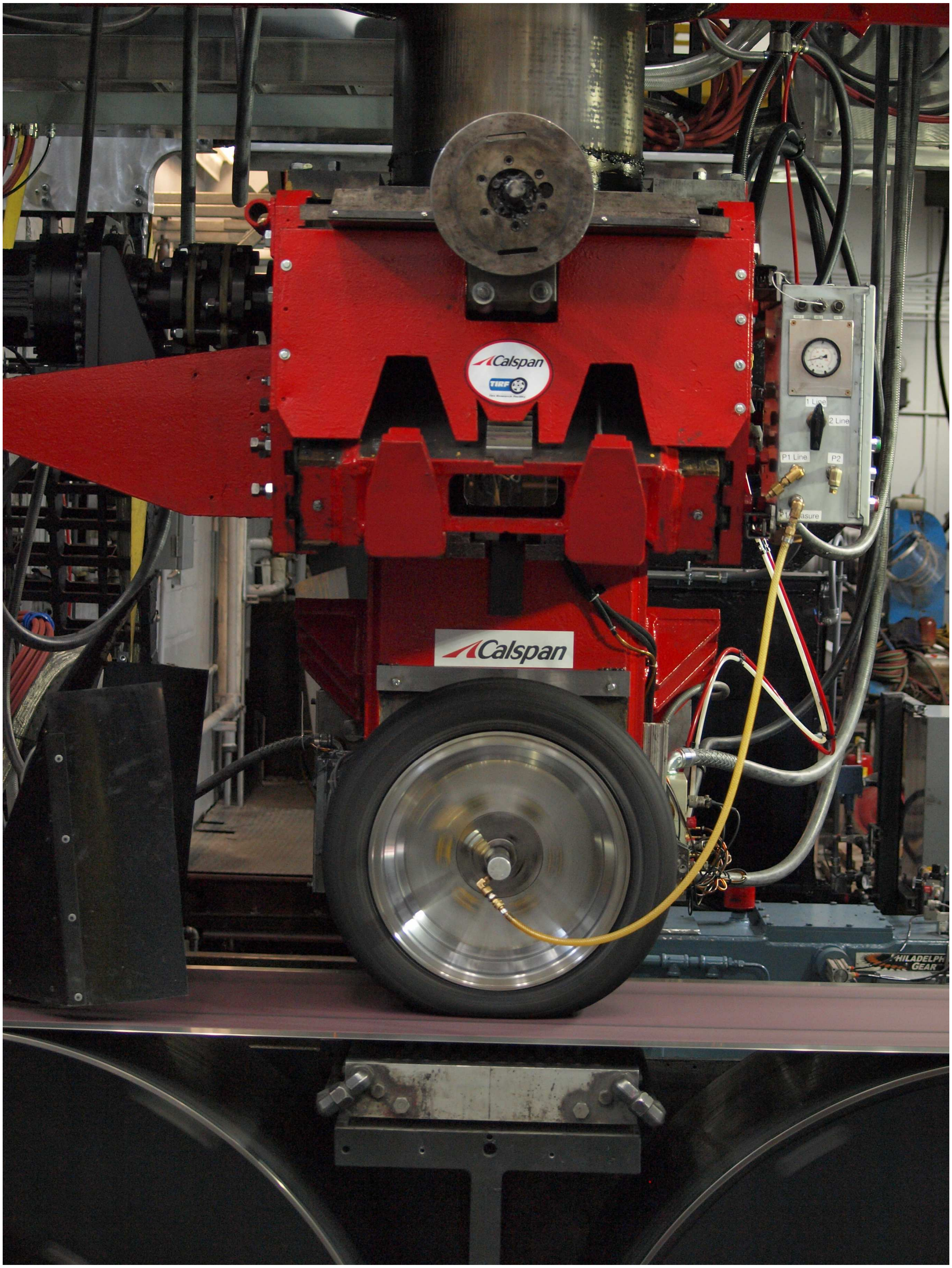


Figure 1. TIRE RESEARCH MACHINE

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.

Typical roadway surface materials used at TIRF are the "3Mite" and the "Regalite Polycut" obtained from the 3M company. The 3Mite material is used for the majority of testing even though its wear rate is considerably higher than the Polycut material. This 3Mite material can only be used for dry testing conditions. The 3Mite materials can be polished as requested. The Polycut surface material can be used for both dry and wet roadway surface testing conditions. This surface has excellent micro texture giving a wet skid number[2] of about 60 in the untreated condition.

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 velocity. The film thickness may be varied from as low as 0.005 inches up to 0.4 inches.

Tire-Wheel Drive

A drive system which is independent of the roadway 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. Additionally, there is a disk brake system capable of very high torque loads.

Balance System[3]

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 balance are shown in Table 2. 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.

---

[2] At 40 mph, 0.020-inch water depth using the ASTM-E-501 Standard Pavement Traction Tire and the E1136 test tire

[3] See Reference 1 and 2 for more detail on balances and calibrations

Table 2. BALANCE SYSTEM CAPABILITY

BALANCE SYSTEM CAPABILITY		
Component	***Passenger Car Tire Balance***	***Truck Tire Balance***
Tire Load (L)	+4,000 lb	+12,000 lb
Tire Tractive Force	± 4,000 lb	± 9,000 lb
Tire Side Force	± 4,000 lb	± 8,000 lb
Tire Self Aligning Torque	± 500 ft-lb	± 1,000 ft-lb
Tire Overturning Moment	± 1,000 lb-ft	± 2,000 ft-lb
Tire Rolling Resistance Moment	± 200 ft-lb	± 400 ft-lb

System Operation

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 2000 samples per second. Pauses are used so that data can be logged during desired intervals of the test. Pauses can be controlled through additional logic. Track simulation replays are also available.

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.

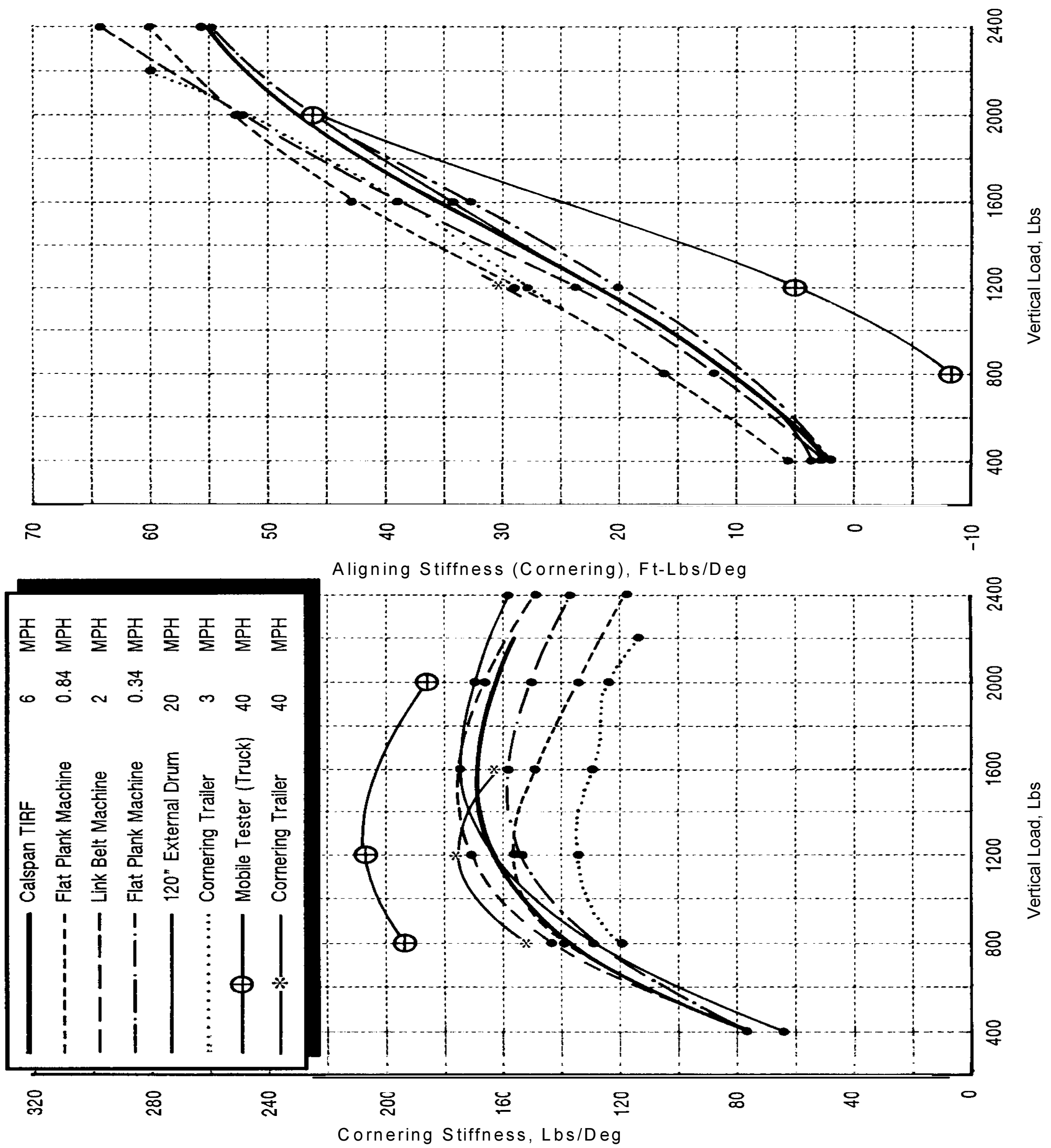
Facility Validation

It has generally become accepted by industry and government that data taken at the TIRF are valid in the sense that forces, moments, power losses measured at the facility are the same as would be experienced on the road under similar conditions. The facility has been used for over 100 different clients representing U.S. and foreign tire and vehicle manufacturers, material 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[4].

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 inch diameter) are in good agreement as are most of the flat bed data. One set of 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 was 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 1-3.



CORNERING STIFFNESS AND ALIGNING TORQUE STIFFNESS vs. VERTICAL LOAD FOR A G78-75 TIRE AT 28 PSI

Figure 2. FACILITY VALIDATION RESULTS

NOMENCLATURE AND SYMBOLS

Figure 3 shows the SAE tire axis system[5] and the quantities used in reducing and presenting the tire force data. Tables 3 and 4 list and explain all the symbols used in computer data recordings.

Torque $T = F_x R_l + M_y \cos\gamma + M_z \sin\gamma$

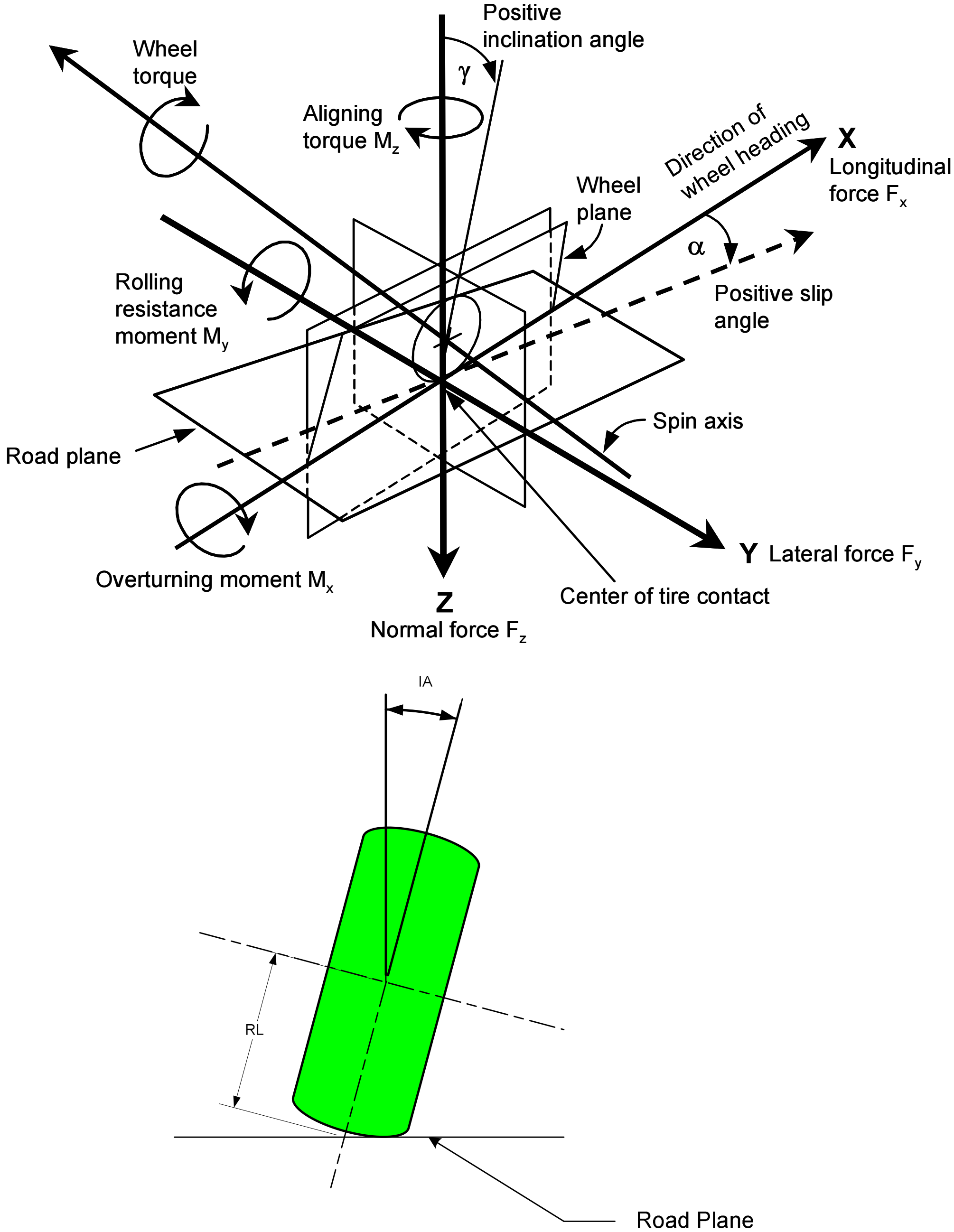


Figure 3. TIRE FORCE AND MOMENTS ACTING AT THE CENTER OF TIRE CONTACT

---

[5] SAE Recommended Practice, "Vehicle Dynamics Terminology" SAE J2047; SAE J670-2008

Table 3. LISTED DATA SYMBOLS

Symbols	*Parameters*	*Dimensions*	
		English	***S. I.***
	Forces and Moments		
AVL	ANALOG VERTICAL LOAD	Lb	N
BFT	BEARING FRICTION TORQUE	ft-lb	n-m
FR	ROLLING RESISTANCE OF STRAIGHT FREE-ROLLING TIRE (DEF. 1)	Lb	N
FX	LONGITUDINAL FORCE *	Lb	N
FY	LATERAL FORCE *	Lb	N
FZ	NORMAL FORCE *	Lb	N
HT	DRIVE OUTPUT TORQUE (DEF. 3)	ft-lb	N-m
MX	OVERTURNING MOMENT *	ft-lb	N-m
MY	ROLLING RESISTANCE MOMENT *	ft-lb	N-m
MZ	ALIGNING TORQUE *	ft-lb	N-m
T	WHEEL TORQUE *	ft-lb	N-m
	Energy Loss		
ER	ENERGY LOSS OF STRAIGHT ROLLING BRAKED OR DRIVEN TIRE (DEF. 2)	ft-lb/ft	N-m/m
	Pressure		
P	INFLATION PRESSURE	psi	kPa
	Speeds		
N	WHEEL ROTATIONS PER MINUTE	rpm	rpm
R	WHEEL ROTATIONS PER MILE (or km.) (DEF. 4)	rev/mi	rev/km
V	ROAD SPEED	mph	kph
	Longitudinal Slip		
SL	SLIP-LONGITUDINAL * (DEF. 6)	-	-
SR	SLIP RATIO (DEF. 5)	-	-

* Defined According to SAE J2047 (see Figure 3)

Table 3. LISTED DATA SYMBOLS (Cont.)

Symbols	Parameters	Dimensions	
		English	S. I.
Angles			
IA	INCLINATION ANGLE *	deg	deg
SA	SLIP ANGLE	Deg	Deg
Tire Radii			
RL	LOADED RADIUS * *	in	cm
RE	EFFECTIVE ROLLING RADIUS (DEF. 7)	in	cm
Time			
ET	TIME ELAPSED	sec	sec
Temperature			
CAT	CONTAINED AIR TEMPERATURE	F	C
TSTI	TREAD SURFACE TEMPERATURE INBOARD	F	C
TSTC	TREAD SURFACE TEMPERATURE CENTER	F	C
TSTO	TREAD SURFACE TEMPERATURE OUTBOARD	F	C
TSTS	TIRE SIDEWALL TEMPERATURE	F	C
RST	ROAD SURFACE TEMPERATURE	F	C
Tire Coefficients			
NFX	FX ÷FZ	-	-
NFY	FY ÷ FZ	-	-
NFR	FR ÷ FZ	-	-
CS	CORNERING STIFFNESS	lbs/deg	kg/deg
CSC	CORNERING STIFFNESS COEFFICIENT	-	-
F	GM f-function	-	-
G	GM g-function	-	-
H	GM h-function	-	-
ATC	GM ALIGNING TORQUE COEFFICIENT	ft	cm

* Defined According to SAE J2047 (see Figure 3)

** Defined According to SAE J670-2008;

Table 4. MATHEMATICAL DEFINITIONS

MATHEMATICAL DEFINITIONS OF TIRF SYMBOLS	
Number	***Mathematical Definitions***
1	$FR = -FX + \frac{BFT}{RL}$ (FX @ HT = 0)
2	$ER = \left\{ \frac{(SR+1)*T}{RL} - FX - [FY * \tan(SA)] \right\} * \cos(SA)$
3	HT = *T* - *BFT* [(a)]
4	$R = 60 * \left(\frac{N}{V} \right)$
5	$SR = \left[\frac{N * RL}{k^* * V * \cos(SA)} \right] - 1$
6	$SL = \left[\left(\frac{V_1}{N_1} \right) * \left(\frac{N}{V} \right) \right] - 1$ $\left(\frac{V_1}{N_1} \right)$ *@ Free Rolling*
7	$RE = \left(\frac{k^* * V}{N} \right) * \cos(SA)$

[(a)] Values of BFT are always negative

k^* = 168.07 in English units or 265.26 in S.I. units

(The definitions of rolling resistance [FR] and energy loss [ER] can be extended to include the effects of slip angle and inclination angle.)

REFERENCES

1. Bird, K.D. and Martin, J.F., " The Calspan Tire Research Facility: Design, Development and Initial Test Results" Presented at SAE Automobile Engineering Meeting, Detroit, Michigan, May 14-18, 1973, SAE Paper No. 730582

2. Martin, James F., "Force and Moment Characteristics of Passenger Tires" DOT Report No. DOT-HS-053; Calspan Report No. YD-3160-K-1, October 1973.

3. Schuring, D.J., "Experimental Validation of the Calspan Tire Research Facility" Prepared for Motor Vehicle Manufactures Association and Rubber Manufactures Association, Inc., Calspan Report ZM-5269-K, December 21, 1973.

4. Peterson, K.G., Smithson, F.D. and Hill, F.W., Jr., "General Motors Tire Performance Criteria (TPC) Specification System: SAE Paper 741103, International Automobile Tire Conference, Toronto, Canada, October 22-24, 1974.

5. Nordeen, D.L., "Application of Tire Characteristics Functions to Tire Development," SAE Preprint 680409, May 1968.