T NO. DOT-TSC-NHTSA-80-8

DOT-HS-805 451

RESULTS OF ROLLING RESISTANCE MEASUREMENTS ON TWELVE RADIAL PASSENGER CAR TIRES

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NOVEMBER 1980
FINAL REPORT

Prepared for:

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Research and Development
Washington DC 20590

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-HS-805 451		

4. Title and Subtitle	5. Report Date
RESULTS OF ROLLING RESISTANCE MEASUREMENTS ON TWELVE RADIAL PASSENGER CAR TIRES	November 1980
	6. Performing Organization Code
7. Author(s) C. Brown	8. Performing Organization Report No. DOT-TSC-NHTSA-80-8
9. Performing Organization Name and Address Calspan Advanced Technology Center* Calspan Corporation P.O. Box 400 Buffalo NY	10. Work Unit No. (TRAIS) HS154/R1416 11. Contract or Grant No. DOT-TS-14896
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Office of Research and Development Washington DC 20590	13. Type of Report and Period Covered Final Report 1978 14. Sponsoring Agency Code

15. Supplementary Notes

*Under contract to: U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Kendall Square, Cambridge MA 02142

16. Abstract

This report gives a description of the Claspan Tire Research Facility (TIRF) and the test procedure and schedule for testing low-rolling resistance radial passenger car tires. The results of force and moment measurements are contained in the form of plots and tabulations for four Goodyear elliptical P215/65 R390, four Uniroyal P185/80 R13, and four Firestone P195/75 R14 tires.

DEPARTMENT OF TRANSPORTATION
JUL 1983
LIBRARY

17. Key Words	18. Distribution Statement
Rolling Resistance Radial Tires	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	134	

PREFACE

Rolling resistance testing was performed at the CALSPAN Tire Research Facility (TIRF) on 12 government-furnished, low-rolling resistance radial passenger car tires. These were: four Goodyear elliptical P215/65R390, four Uniroyal P185/80R13, and four Firestone P195/75 R14 tires. The equilibrium rolling resistance was measured on each of the 12 tires under five conditions of pressure and load. Tires were maintained in free-rolling, straight-ahead conditions, and tire inflation pressures were regulated during the tests.

Technical coordination was maintained through Stephen N. Bobo of the Department of Transportation, Transportation Systems Center (DOT/TSC).

The results of force and moment measurements are contained in the form of plots and tabulations. Also included are a description of TIRF, a tire test schedule, a tire identification schedule, and a description of the test procedure.

METRIC CONVERSION FACTORS

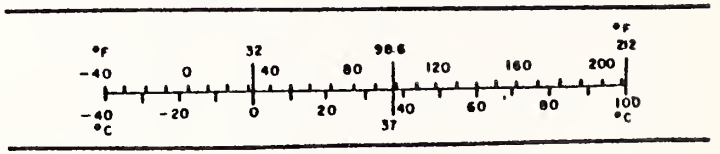
Approximate Conversions to Metric Measures

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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

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



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LIST OF ABBREVIATIONS

BFT	Bearing Friction Torque
CAT	Contained Air Temperature
CSP	Continuous Sampling Program
DAP	Data Acquisition Program
FR	Rolling Resistance
FX	Longitudinal Force
SI	Standard Internal Measurement
TIRF	Calspan Tire Research Facility
TST	Tire Tread Surface Temperature

1. TEST FACILITY

A photograph of the Calspan Tire Research Facility (TIRF) is shown in Figure 1; a dimensional view of the facility is shown in Figure 2. The primary features of the machine are as follows.*

1.1 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, chamber, 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 I.

Table I
TIRF CAPABILITIES

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

* A more complete description of this facility will be found in Ref. 1.

** Can be increased to 90° with special setup.

*** Can be increased to 60° with special setup.

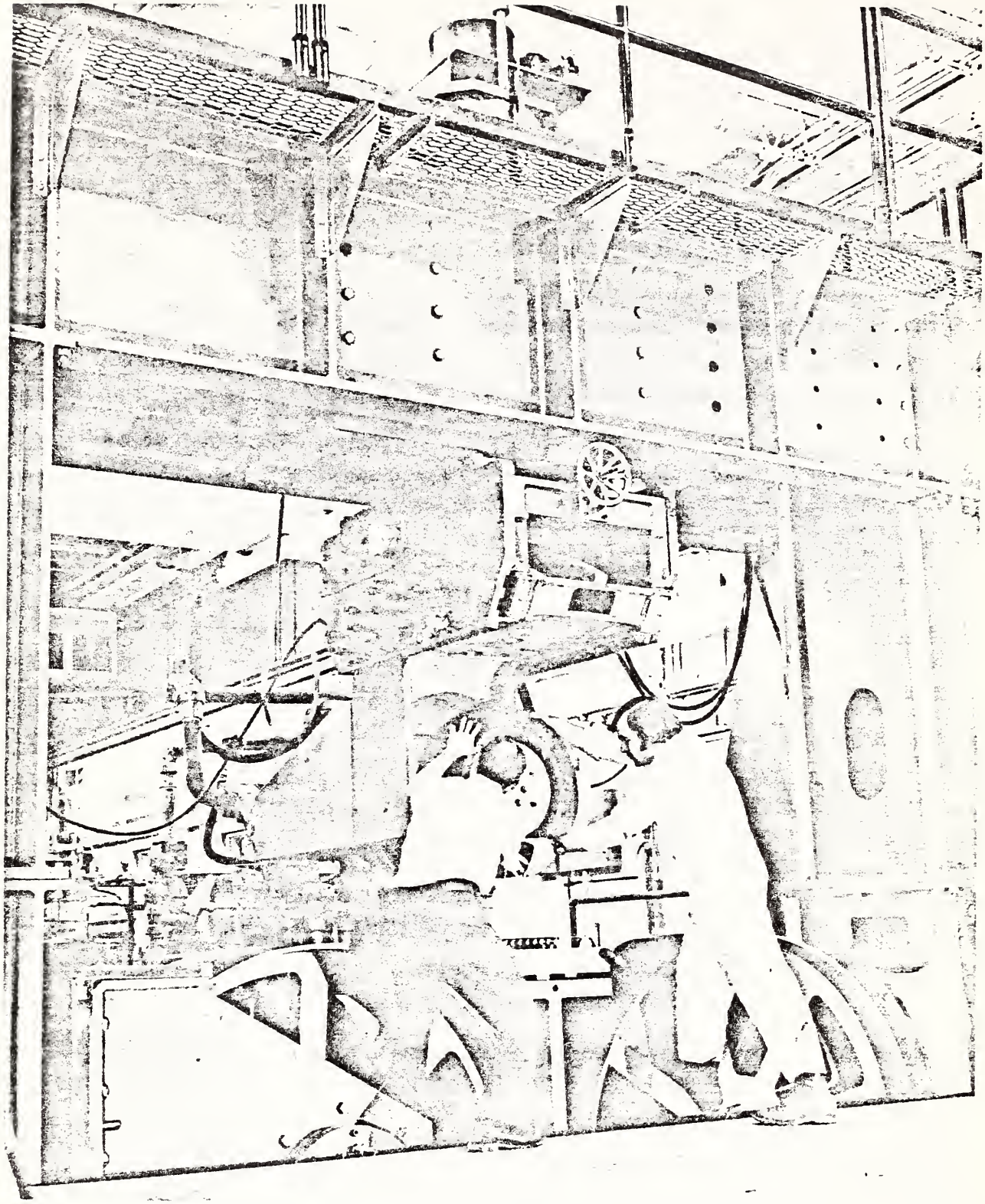

Figure 1. CALSPAN TIRE RESEARCH FACILITY (TIRF)

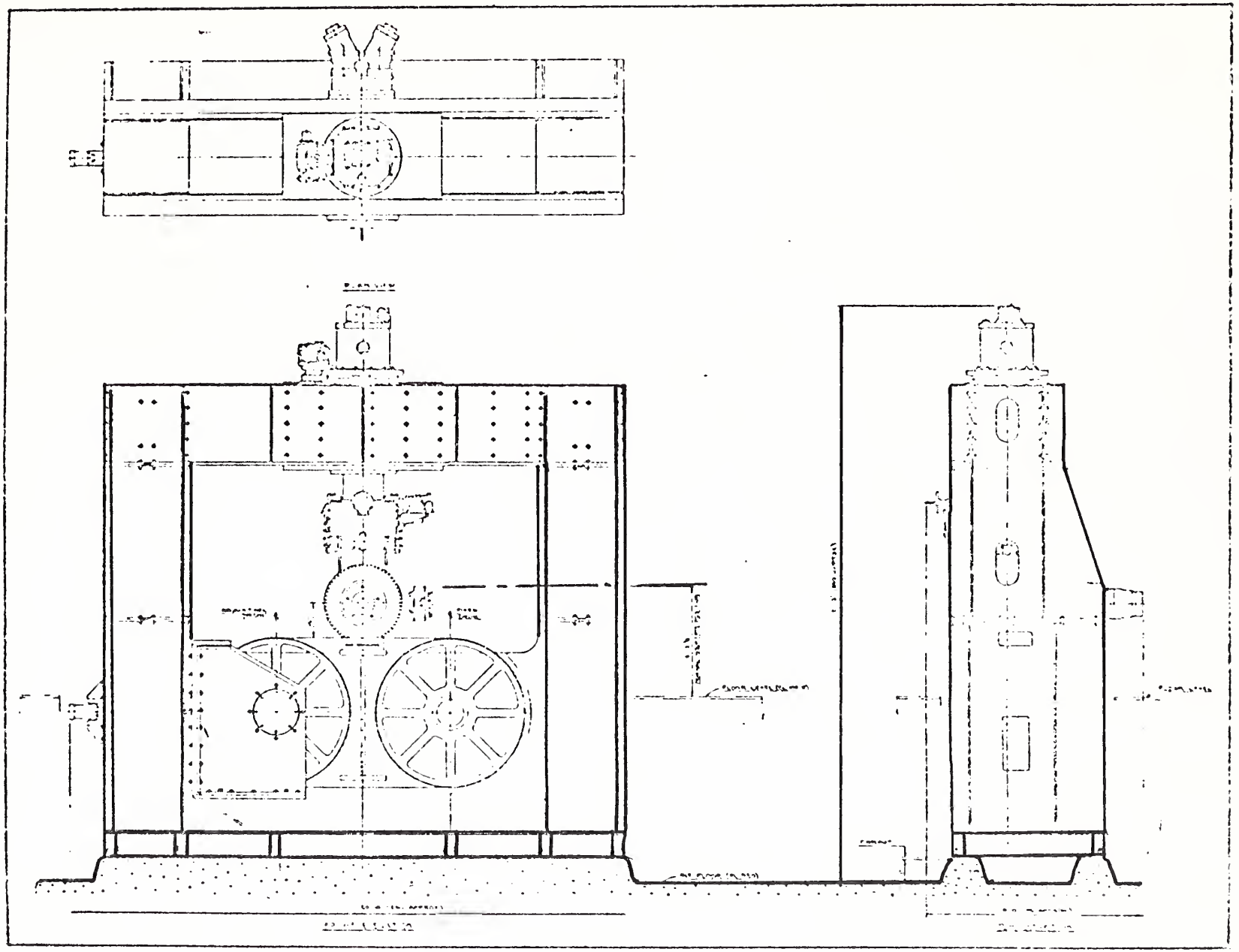

Figure 2. TIRE RESEARCH MACHINE

1.2 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 0.4 inches.

1.3 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.

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*Manufactured by the 3M Company

**At 40 mph and 0.020 in. water depth using the ASTME-501 Standard Pavement Traction Tire.

1.4 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 II. 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 II
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 on the balance systems and their calibration may be found in Refs. 1 and 2.

1.5 SYSTEM OPERATION

1.5.1 Data Acquisition Program (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 and 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 screen of a CRT console. Hard copies of this information can be made from this display.

1.5.2 Continuous Sampling Program 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.

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.

1.6 FACILITY VALIDATION

It has generally become accepted by industry and government that data taken on TIRF are valid in the sense that forces, moments, and 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 50 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 (Figure 3).*

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 1 to 3.

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*One set of drum data was found to be invalid and is not shown.

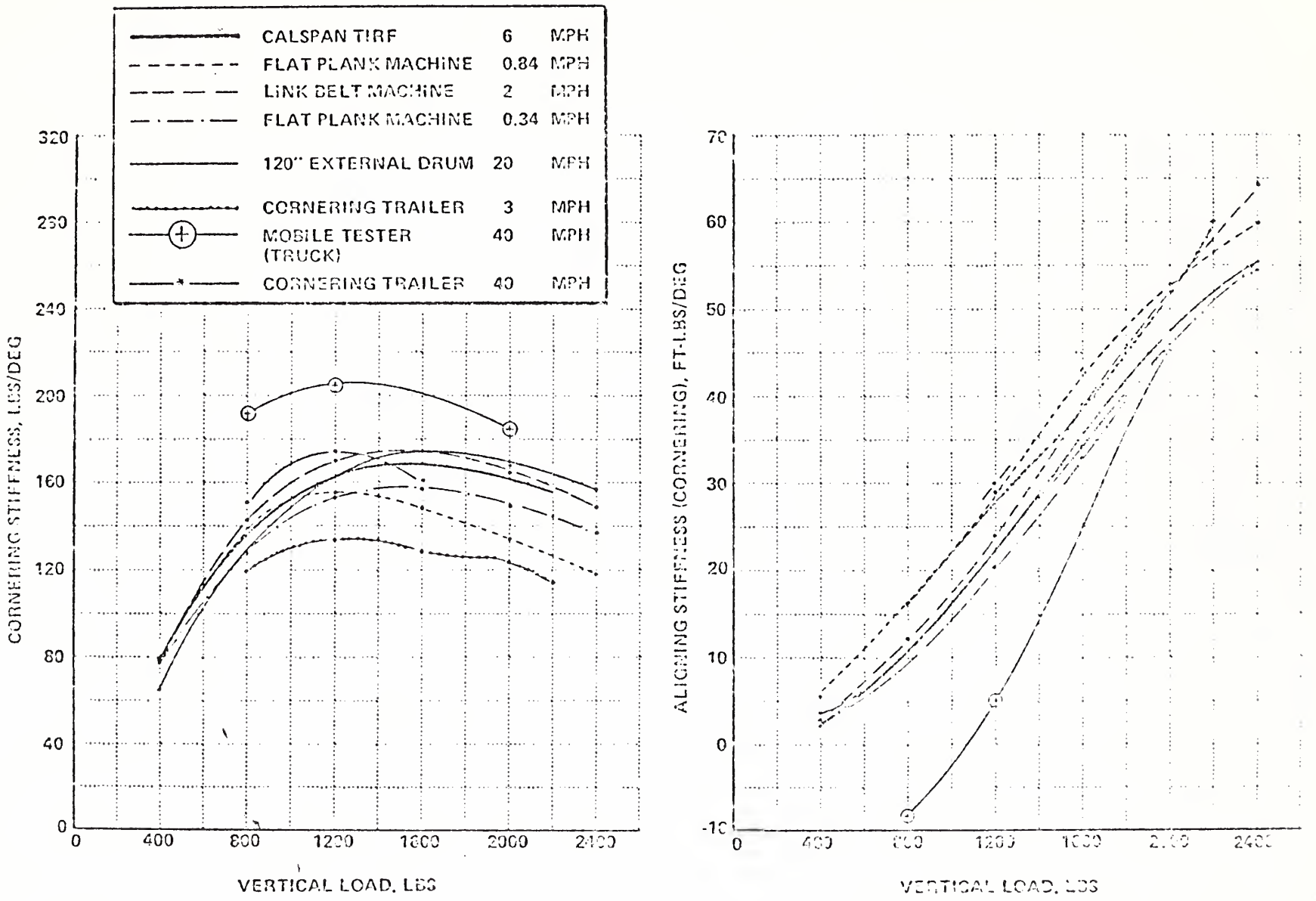


Figure 3. FACILITY VALIDATION RESULTS: CORNERING STIFFNESS AND ALIGNING TORQUE STIFFNESS VS VERTICAL LOAD FOR A G78-15 TIRE AT 28 PSI

2. NOMENCLATURE AND SYMBOLS

Figure 4 shows the SAE tire axis system* and the quantities used in reducing and presenting the tire force data. Tables III and IV list and explain all the symbols used in computer data recordings.

Data are usually given in customary English units. Sometimes, the use of SI units is required; Table V facilitates unit conversion from one system into the other.

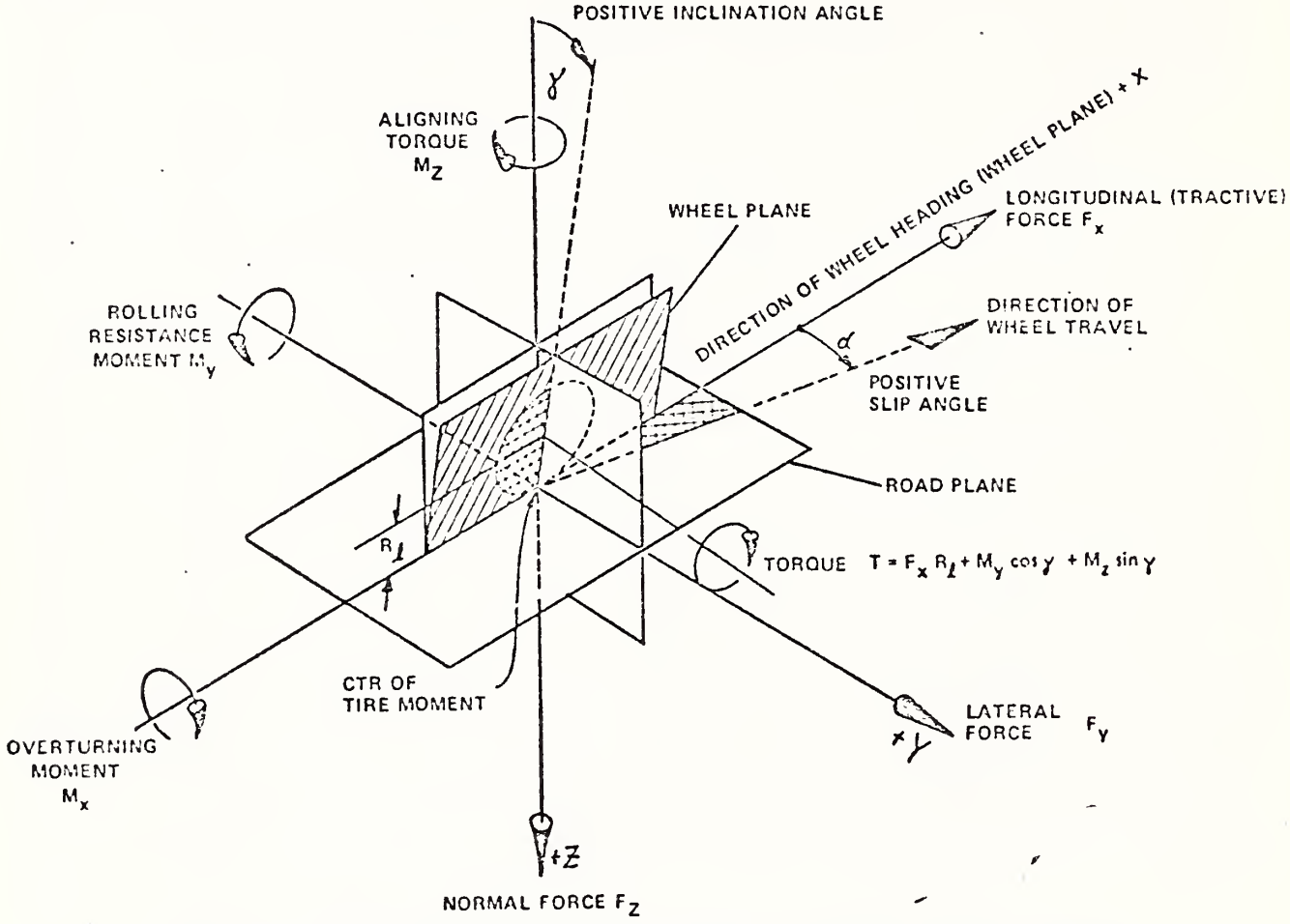


Figure 4. TIRE FORCES AND MOMENTS ACTING AT THE CENTER OF TIRE CONTACT (SAE CONVENTION)

*SAE Recommended Practice, "Vehicle Dynamics Terminology" SAE J670c.

Table III

LISTED DATA SYMBOLS

SYMBOLS	PARAMETERS	DIMENSIONS	
		ENGLISH	S.I.
	TIRE RADII		
RL	RADIUS-LOADED*	in	cm
RE	RADIUS-EFFECTIVE* (DEF. 7)	in	cm
	TIME		
TE	TIME ELAPSED	sec	sec
	TEMPERATURES		
CAT	CONTAINED AIR TEMPERATURE	F	C
TST	TREAD SURFACE TEMPERATURE	F	C
RST	ROAD SURFACE TEMPERATURE	F	C
	TIRE COEFFICIENTS		
NFX	FX/FZ	–	–
NFY	FY/FZ	–	–
NFR	FR/FZ	–	–
F	GM f-FUNCTION	–	–
G	GM g-FUNCTION	–	–
H	GM h-FUNCTION	–	–
ATC	GM ALIGNING TORQUE COEFFICIENT	ft	cm

*DEFINED ACCORDING TO SAE J670d (SEE FIGURE 4)

Table III

LISTED DATA SYMBOLS (Cont.)

SYMBOLS	PARAMETERS	DIMENSIONS	
		ENGLISH	S.I.
	TIRE RADII		
RL	RADIUS-LOADED*	in	cm
RE	RADIUS-EFFECTIVE* (DEF. 7)	in	cm
	TIME		
TE	TIME ELAPSED	sec	sec
	TEMPERATURES		
CAT	CONTAINED AIR TEMPERATURE	F	C
TST	TREAD SURFACE TEMPERATURE	F	C
RST	ROAD SURFACE TEMPERATURE	F	C
	TIRE COEFFICIENTS		
NFX	FX/FZ	–	–
NFY	FY/FZ	–	–
NFR	FR/FZ	–	–
F	GM f-FUNCTION	–	–
G	GM g-FUNCTION	–	–
H	GM h-FUNCTION	–	–
ATC	GM ALIGNING TORQUE COEFFICIENT	ft	cm

*DEFINED ACCORDING TO SAE J670d (SEE FIGURE 4)

Table IV

SYMBOL MATHEMATICAL DEFINITIONS

NO.	MATHEMATICAL DEFINITIONS
1	$FR = FX - \frac{BFT}{RL} \times 12$ (FX @ HT = 0)
2	$ER = \frac{12\,(SR + 1)\,T}{RL} - FX$
3	$HT = T - BFT^*$
4	$R = 60\,N/V$
5	$SR = \frac{N \times RL}{k^* \times V \times COS\,SA} - 1$
6	$SL = \left(\frac{V}{N}\right)_{\text{free rolling}} \times \left(\frac{N}{V}\right) - 1$
7	$RE = \frac{k^* V}{N} \cos SA$

*VALUES OF BFT ARE ALWAYS NEGATIVE

$k^* = \begin{cases} 168.07 \text{ FOR ENGLISH SYSTEM} \\ 265.26 \text{ FOR SI SYSTEM} \end{cases}$

THE DEFINITIONS OF ROLLING RESISTANCE, FR, AND ENERGY LOSS, ER, CAN BE EXTENDED TO INCLUDE THE EFFECTS OF SLIP ANGLE AND INCLINATION ANGLE.

Table V

CONVERSION OF UNITS

1 in	=	2.540 cm
1 lb	=	4.448 N (= 0.4536 kgf)
1 psi	=	0.06895 BAR (= 0.06804 atm = 6.895 kPa)
1 ft-lb	=	1.356 N-m
1 mph	=	1.609 km/h
1 cm	=	0.3937 in
1 N	=	0.2248 lb (= 0.1020 kgf)
1 bar	=	14.50 psi (= 0.9869 atm)
1 N-m	=	0.7376 ft-lb
1 km/h	=	0.6214 mph
1 daN	=	10 N
1 bar	=	10^5 N/m^2 = 100 kPa
1 kgf	=	9.8067 N = 2.2046 lb

3. TEST PROGRAM

A test outline is given in the tire test schedule of Table VI. This schedule references the tests by run numbers which are comprised of three groups. The first group is the serial run number, the second group is the test series, and the third group designates the sponsor. Tire numbers are represented similarly except for the first number which is the serial tire number.

A tire identification schedule, summarizing pertinent information about the tires, is presented in Table VII.

The twelve tests were conducted in accordance with the 70-minute General Motors test practice. The roadway speed was held constant at 50 mph throughout. The tires were operated in a straight, free-rolling condition. An initial 30-minute warmup and stabilization period at 35 psi and 100 percent load was allowed for each test. The load and pressure were then changed at 10-minute intervals to obtain five test points, as shown in Table VIII. The loads were 60, 80, and 100 percent of rated load as specified by the manufacturers and regulated tire pressures of 35, 44, and 26 psi were employed in the tests.

Data were recorded during the runs using a special option of the continuous sampling (CSP) mode of TIRF operation. The data sampling rate was set at one per second. Because of computer data storage constraints, data sampling was minimized during the 29.5-minute break-in and warmup at the start of the run to three consecutive data points every 2 minutes. Data were taken continuously in the last 30-second interval of each of the five conditions of load and speed. The detailed test procedure showing the data recording times is given in Table VIII. At the beginning and end of each run, the tire was lifted free of the roadway and brought to a full stop. Five seconds of data were taken in this condition to establish the reference zero levels of the overall measuring instrumentation.* This measurement was also made at the beginning of each test.

*Principally to determine the offsets in longitudinal force (FX) and bearing friction torque (BFT).

The signals were conditioned using .083 Hz low-pass electrical filters.

Tread and road surface temperature measurements were recorded for each run. However, in TIRF run nos. 7-5-6, 8-5-6, 9-5-6 and 10-5-6, the infrared temperature measuring device did not operate properly and generated unacceptably noisy results. Consequently, the TST data for these runs are not included in this report. Some of the extraneous data points have been removed from the plots that are included in this report. All TST data are included in the IBM tabulations and points that are not pertinent have been crossed out. Both tread and road surface temperature measurements were made with the same device. Tread surface temperature measurements were made by aiming the sensor at the center of the tire tread section and road surface temperature measurements were made by aiming the sensor at the road surface during the runs. Both sets of temperature information are contained in the TST data and are indicated correspondingly on the plots.

Contained air temperature (CAT) measurements were taken for all runs except the first four. In these runs (1-5-6, 2-5-6, 3-5-6 and 4-5-6) the aluminum rims on which the tires were mounted did not have provisions for the measurement of CAT. CAT data contain both tire-contained air temperature and ambient temperature in the vicinity of the tire information. This information is indicated on the CAT plots.

TABLE VI

TIRE TEST SCHEDULE

Run	Tire	Tire Mfg.	Road Condition	P* psi	V mph	S	Load lb.	Rim Type
1-5-6	1-5-6	Goodyear	Flat, dry	(A)	50	free-rolling	(B)	Aluminum
2-5-6	2-5-6	↓	↓	↓	↓	↓	↓	↓
3-5-6	3-5-6							
4-5-6	4-5-6	↓					↓	↓
5-5-6	5-5-6	Uniroyal					(C)	13"x5"
6-5-6	6-5-6	↓					↓	↓
7-5-6	7-5-6							
8-5-6	8-5-6	↓					↓	↓
9-5-6	9-5-6	Firestone					(D)	14"x5.5"
10-5-6	10-5-6	↓					↓	↓
11-5-6	11-5-6							
12-5-6	12-5-6	↓	↓	↓	↓	↓	↓	↓

*regulated

Pressure Schedule: (A) 35, 44 and 26 psi

Vertical Load Schedule: (B) 1331, 1065, 799 and 1065 lbs.

(C) 1301, 1041, 781 and 1041 lbs.

(D) 1400, 1120, 840 and 1120 lbs.

TABLE VII

TIRE IDENTIFICATION SCHEDULE

TIRF Tire No.	Manufacturer or Marketer	DOT Designation	Size	Kind of Tire	Serial No. and Other Identification
1-5-6	Goodyear	MA8N 982227	P215/65 R390	elliptical radial	TX8303-13
2-5-6	↓	↓	↓	↓	TX8303-18
3-5-6					TX8303-12
4-5-6					TX8303-16
5-5-6	Uniroyal	AJJR xxx 337	P185/80 R13	steel-belted radial	AJ22-3118
6-5-6	↓	↓	↓	↓	17-31181 IF
7-5-6					9-31181 IF
8-5-6					16-31181 IF
9-5-6	Firestone	W2KA 9A5307	P195/75 R14		R719
10-5-6	↓	W2KA 9A5317	↓		↓
11-5-6		↓			
12-5-6					

TABLE VIII

TEST PROCEDURE FOR
ROLLING RESISTANCE TESTS

Condition	Test Duration (min.)	Roadway Velocity (mph)	% Load	Tire Pressure (psi)	Data Samping, Comments
1	30	50	100	35	warmup - 29.5 min. stabilized data - 30 sec.
2	10	↓	80	35	stabilized data - 30 sec. at end of interval
3	10	↓	60	35	↓
4	10	↓	80	44	↓
5	10	↓	80	26	↓

Data Sampling Rate: Once per Second

4. TEST RESULTS

Test results in this report are presented in the form of IBM computer listings (under separate cover), computer-generated plots and tabular compilation of numerical data.

IBM listings of rolling resistance data are comprised of raw data and do not include any corrections that may be required. For example, rolling resistance (FR) is calculated using definition no. 1 in Table IV based on measured values of the longitudinal force (FX), the bearing friction torque (BFT) and the tire-loaded radius (RL). The FR values in these IBM listings do not account for the zero offsets in the FX and BFT data channels. The computer-generated plots of FR, BFT and FX as a function of time, utilize the same raw data. Note that both the time on the IBM listings and on the plots is a "pseudo" time. Pseudo time only includes that time during which actual data sampling took place.

Averaging was performed on the last 17 data points of each of the five conditions of load and velocity comprising a run. The standard deviations associated with each of these averages were also computed. Tabulation of both averages (AFR, AP, AFZ, ACAT, ATST, and AR) and their standard deviations (SFR, SP, SFZ, SRR, SCAT, and STST) are included in the Data Presentation. The AFR values have been corrected for zero offsets in the FX and BFT data. These are presented in Tables IX, X and XI.

5. PRESENTATION OF DATA

Test data are presented in run number order at the end of this report for TIRF run numbers 1-5-6 through 12-5-6 in the following sequence:

1. Tire/Test Description (Faceplate)
2. Plot of FR (uncorrected) versus pseudo time
3. Plot of FX versus pseudo time
4. Plot of BFT versus pseudo time
5. Plot of P versus pseudo time
6. Plot of CAT versus pseudo time
7. Plot of TST versus pseudo time
   No CAT plots for TIRF run nos. 1-5-6, 2-5-6, 3-5-6 and 4-5-6
   No TST plots for TIRF run nos. 7-5-6, 8-5-6, 9-5-6 and 10-5-6

8. Tabular Data:
   AFR, AP, AFZ, ARR, ACAT, ATST
   SFR, SP, SFZ, SRR, SCAT, STST

9. Tabular Data under separate cover:
   TE, V, FZ, RL, FX, FY, MY, MZ, P,
   BFT, N, CAT, RE, FR, TST

TABLE IX

ROLLING RESISTANCE TEST RESULTS
FOR FOUR GOODYEAR TIRES (P215/65 R390)

Run Number	TIRF Tire Number	Rolling Resistance Force (FR) in Lbs.				
		100% Load 35 psi	80% Load 35 psi	60% Load 35 psi	80% Load 44 psi	80% Load 26 psi
1-5-6	8303-13 / 1-5-6	11.42	8.83	6.62	8.12	10.64
2-5-6	8303-18 / 2-5-6	11.2	8.63	6.39	8.04	10.16
3-5-6	8303-12 / 3-5-6	11.18	8.79	6.33	7.68	10.22
4-5-6	8303-16 / 4-5-6	11.0	8.65	6.52	7.86	10.16

Note: 1331 lbs. = 100% Design Load
1065 lbs. = 80% Design Load
799 lbs. = 60% Design Load

TABLE X

ROLLING RESISTANCE TEST RESULTS
FOR FOUR UNIROYAL TIRES (P185/80 R13)

Run Number	TIRF Tire Number	Rolling Resistance Force (FR) in Lbs.				
		100% Load 35 psi	80% Load 35 psi	60% Load 35 psi	80% Load 44 psi	80% Load 26 psi
5-5-6	22-3118 / 5-5-6	10.43	8.51	6.42	7.76	10.22
6-5-6	11-31181 / 6-5-6	10.61	8.55	6.42	7.78	10.0
7-5-6	9-31181 / 7-5-6	10.75	8.59	6.3	7.7	10.25
8-5-6	16-31181 / 8-5-6	10.6	8.46	6.63	7.82	10.28

Note: 1301 lbs. = 100% Design Load
1041 lbs. = 80% Design Load
781 lbs. = 60% Design Load

TABLE XI

ROLLING RESISTANCE TEST RESULTS
FOR FOUR FIRESTONE TIRES (P195/75 R14)

Run Number	TIRF Tire Number	Rolling Resistance Force (FR) in Lbs.				
		100% Load 35 psi	80% Load 35 psi	60% Load 35 psi	80% Load 44 psi	80% Load 26 psi
9-5-6	9-5-6	14.24	11.6	8.49	10.27	13.62
10-5-6	10-5-6	15.14	11.85	8.83	10.87	14.24
11-5-6	11-5-6	14.85	11.87	8.97	10.84	14.18
12-5-6	12-5-6	14.83	11.59	9.03	10.93	14.48

Note: 1400 lbs. = 100% Design Load
1120 lbs. = 80% Design Load
840 lbs. = 60% Design Load

6. 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 MI May 14-18, 1973, SAE Paper No. 730528.

2. Martin, J. F., "Force and Moment Characteristics of Passenger Car 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 Manufacturers Association and Rubber Manufacturers Association, Inc., Calspan Report ZM-5269-K, December 21, 1973.

APPENDIX
TABULATED DATA

RUN NUMBER..: 1- 5- 6 DATE: 2/10/73

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

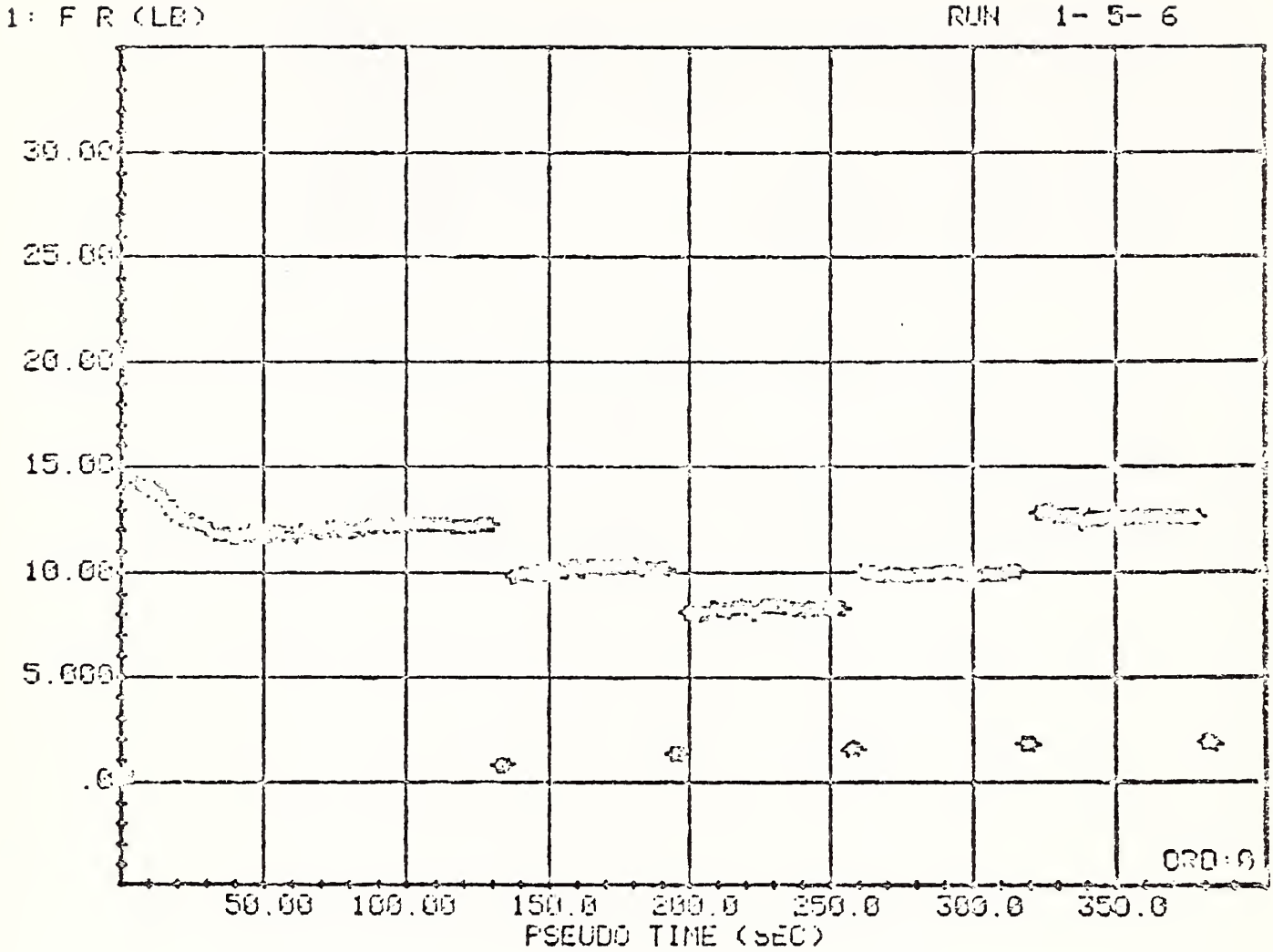
SPONSOR.....: TSC DATA FILTERS: .003 HZ

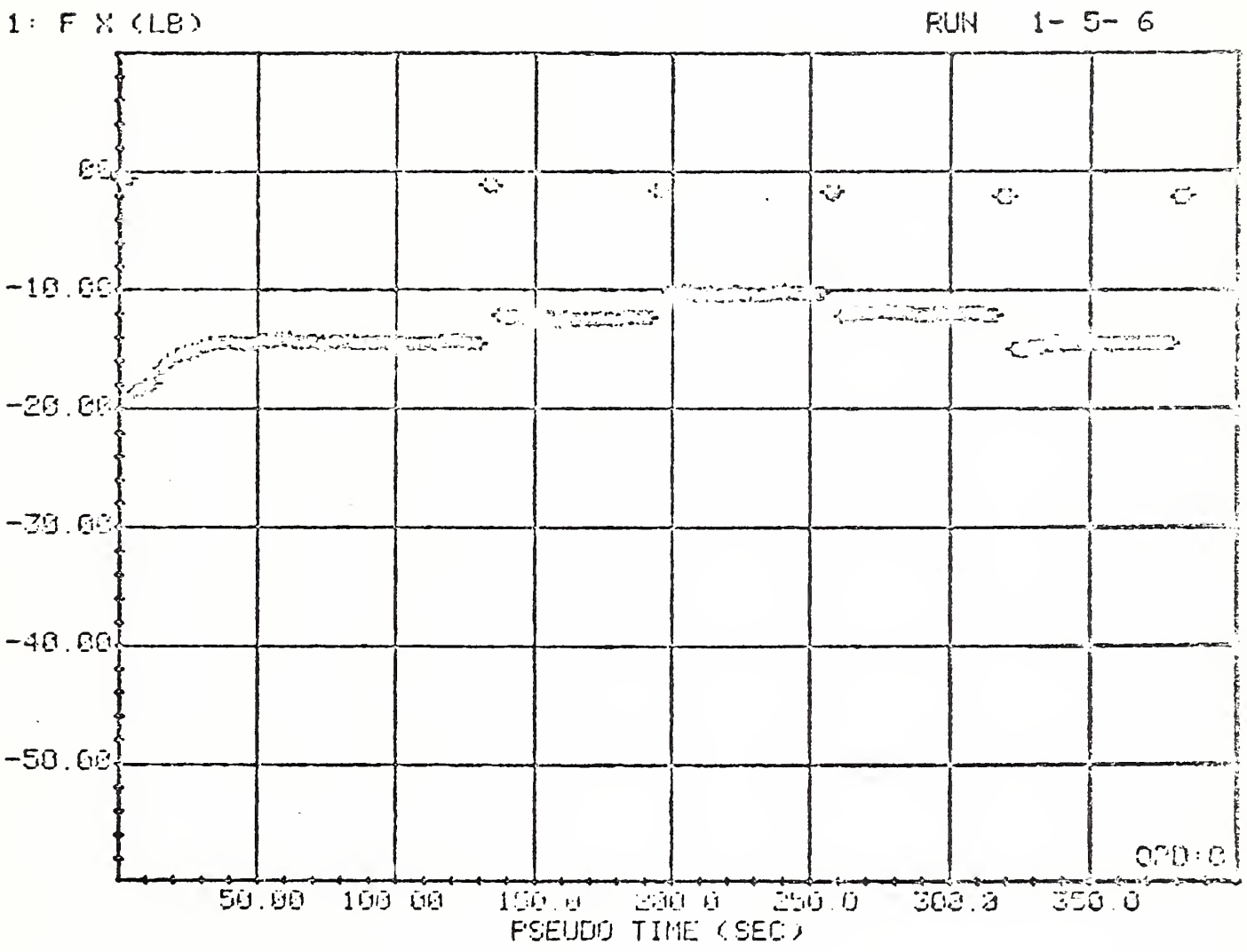
TIRE:
SPONSOR CODE: GY 8303-13
TIRE NUMBER: 1- 5- 6
SIZE.....: P215/65R390

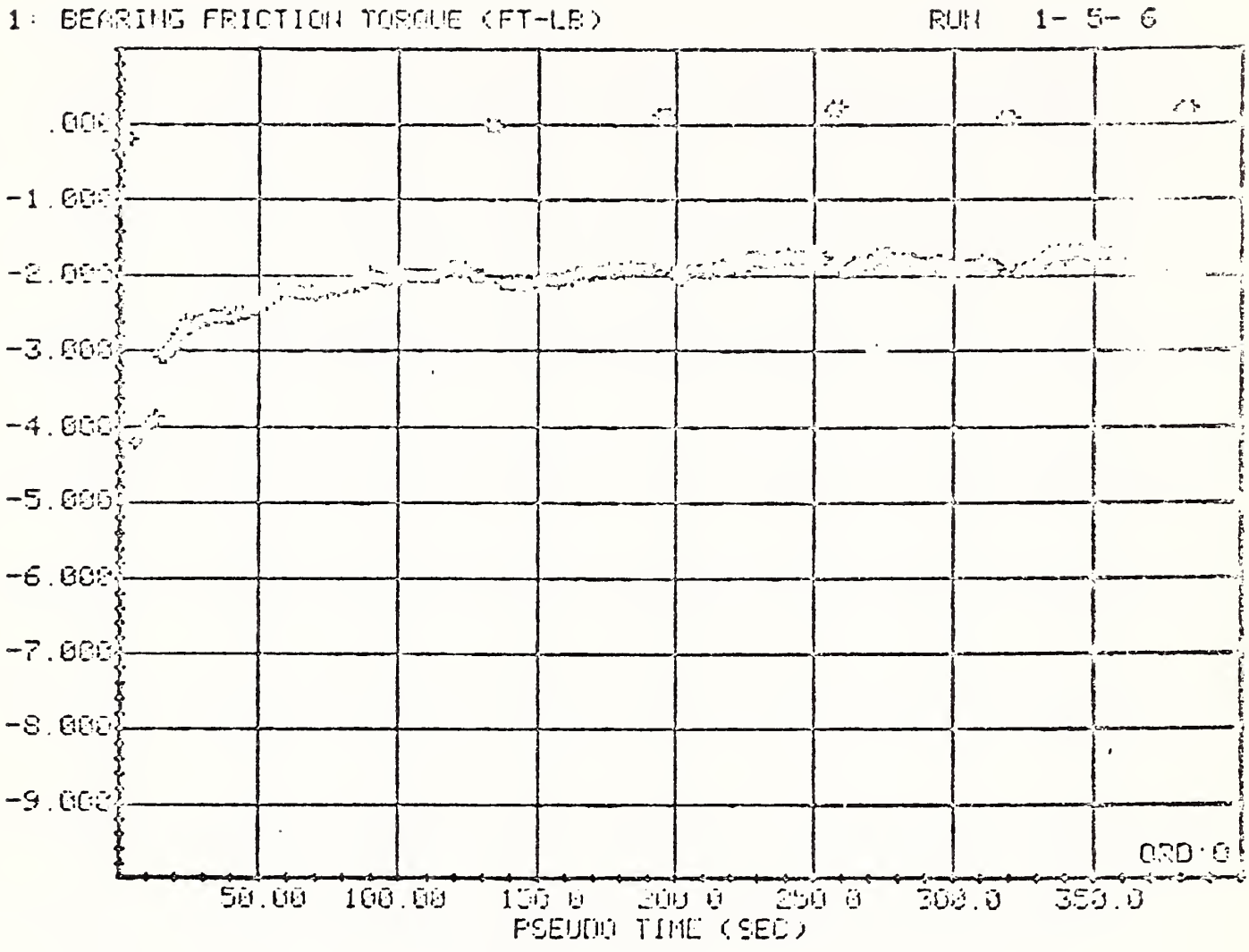
ROAD SURFACE:
WET S/N...: 39
DRY S/N...: 65
WATER DEPTH: DRY

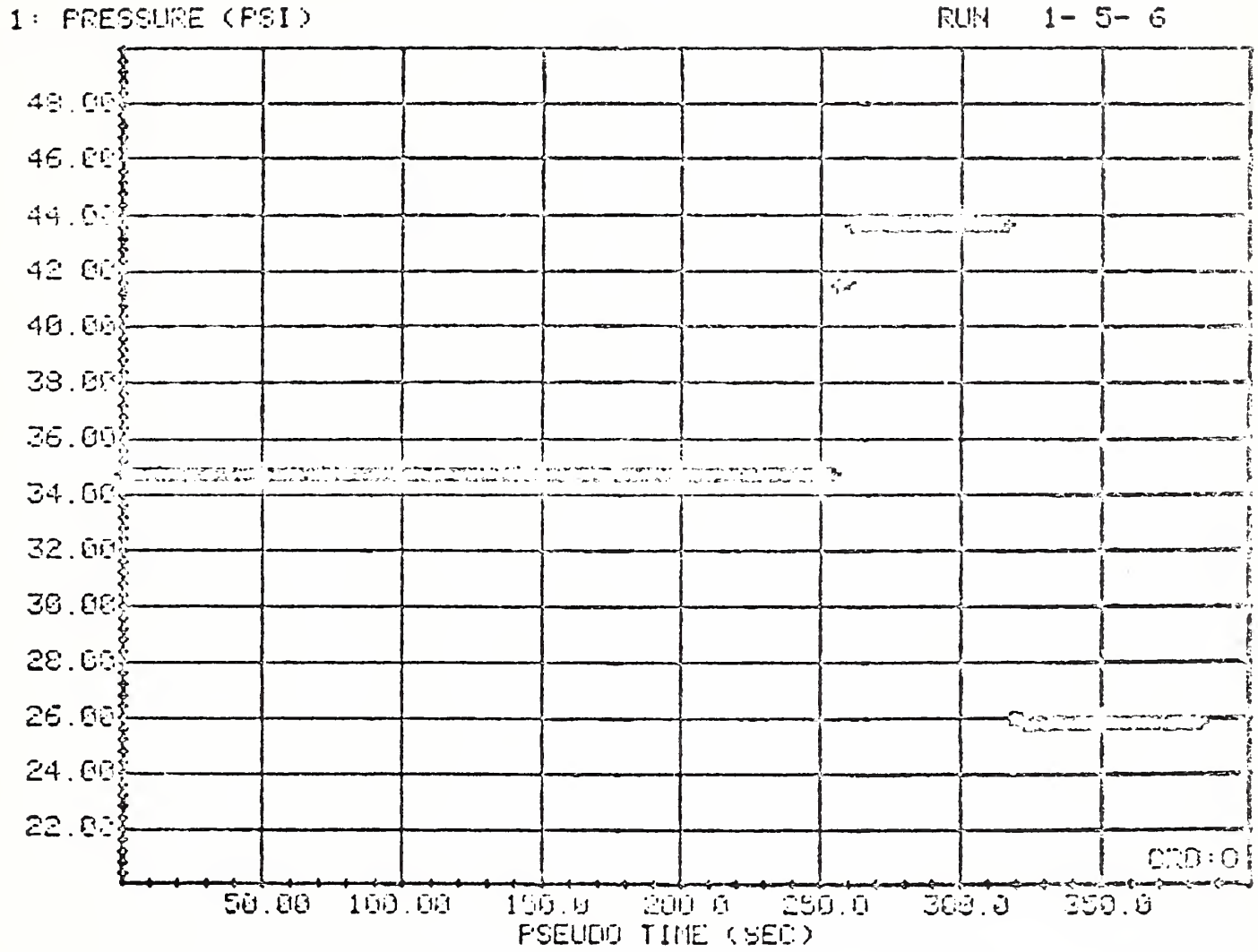
NOMINAL VALUES OF TEST PARAMETERS

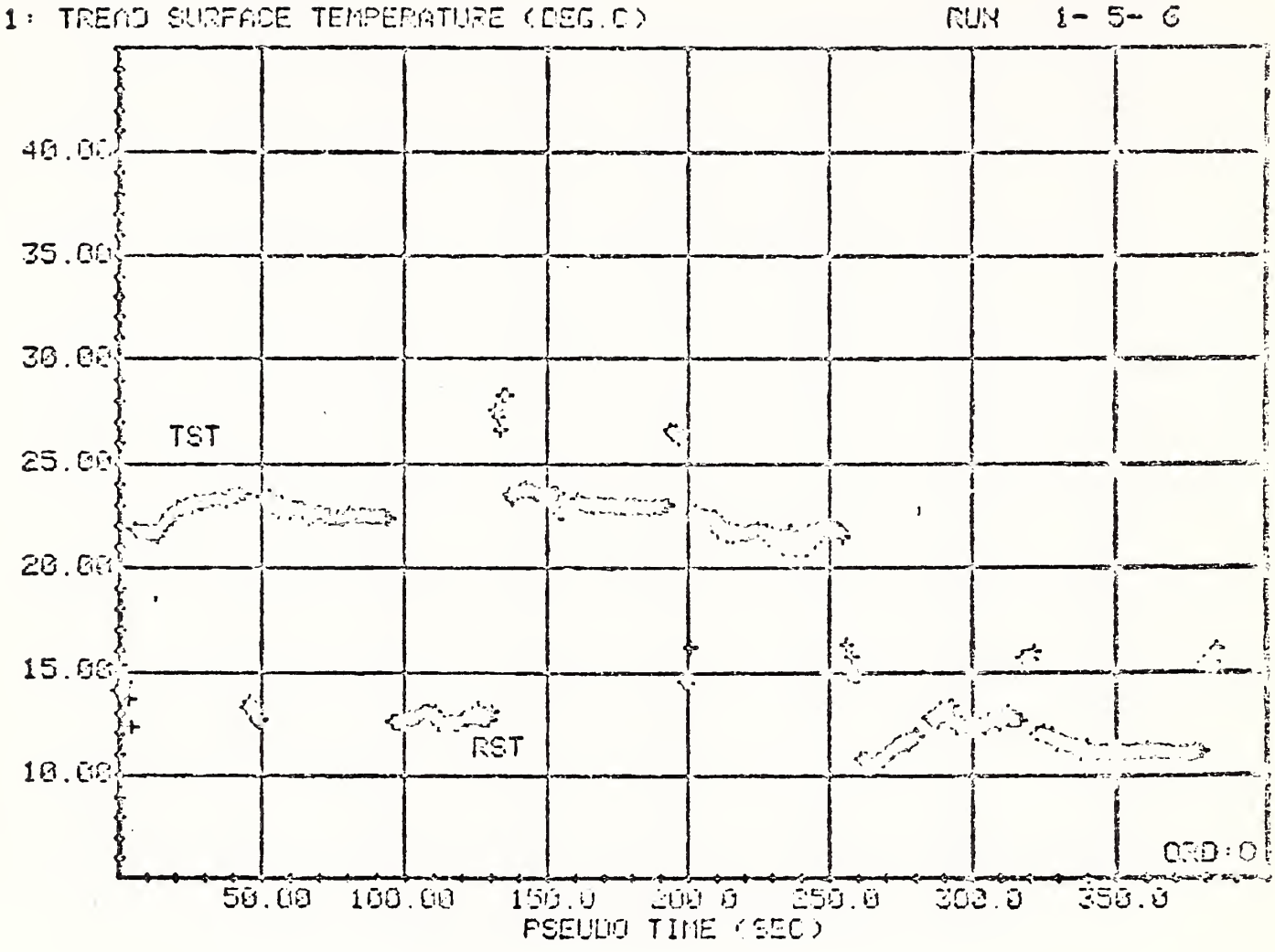
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1331,1065,799,1065
6.	INFLATION PRESSURE (PSI):	35,44,26 REG


1: F R (LB)
RUN 1- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 1- 5- 6
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 1- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 1- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREND SURFACE TEMPERATURE (DEG.C)
RUN 1- 5- 6
40.00
35.00
30.00
25.00
20.00
15.00
10.00
TST
RST
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

1-5-6 A.V.L. LB	1-5-6 F.R. LB	1-5-6 C.A.T. DEG.C	1-5-6 T.S.T DEG.C	1-5-6 P. PSI	1-5-6 R.L. IN	1-5-6 F.Z. LB
1342.	11.42	20.82	12.8	34.8	12.22	-1[illegible]7.
1074.	8.83	21.[illegible]	23.1	34.8	12.41	-1[illegible]2.
813.	6.62	20.23	21.7	34.8	12.6	-[illegible]5.
1073.	9.12	22.28	12.7	48.7	12.[illegible]3	-1[illegible]2.
1074.	10.04	23.93	11.2	25.9	12.2	-1[illegible]5.

1-5-6 A.V.L. LD	1-5-6 S.F.R.	1-5-6 S.C.A.T.	1-5-6 S.T.S.T.	1-5-6 S.P	1-5-6 S.R.R.	1-5-6 S.F.Z.
1242.	0.006	0.037	0.2	0.	0.002	1.330
1074.	0.069	0.031	0.068	0.	0.003	0.847
813.	0.041	0.009	0.338	0.011	0.003	0.033
1073.	0.064	0.027	0.214	0.011	0.004	0.771
1074.	0.024	0.025	0.075	0.016	0.004	0.765

RUN NUMBER..: 2- 5- 6 DATE: 2/10/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

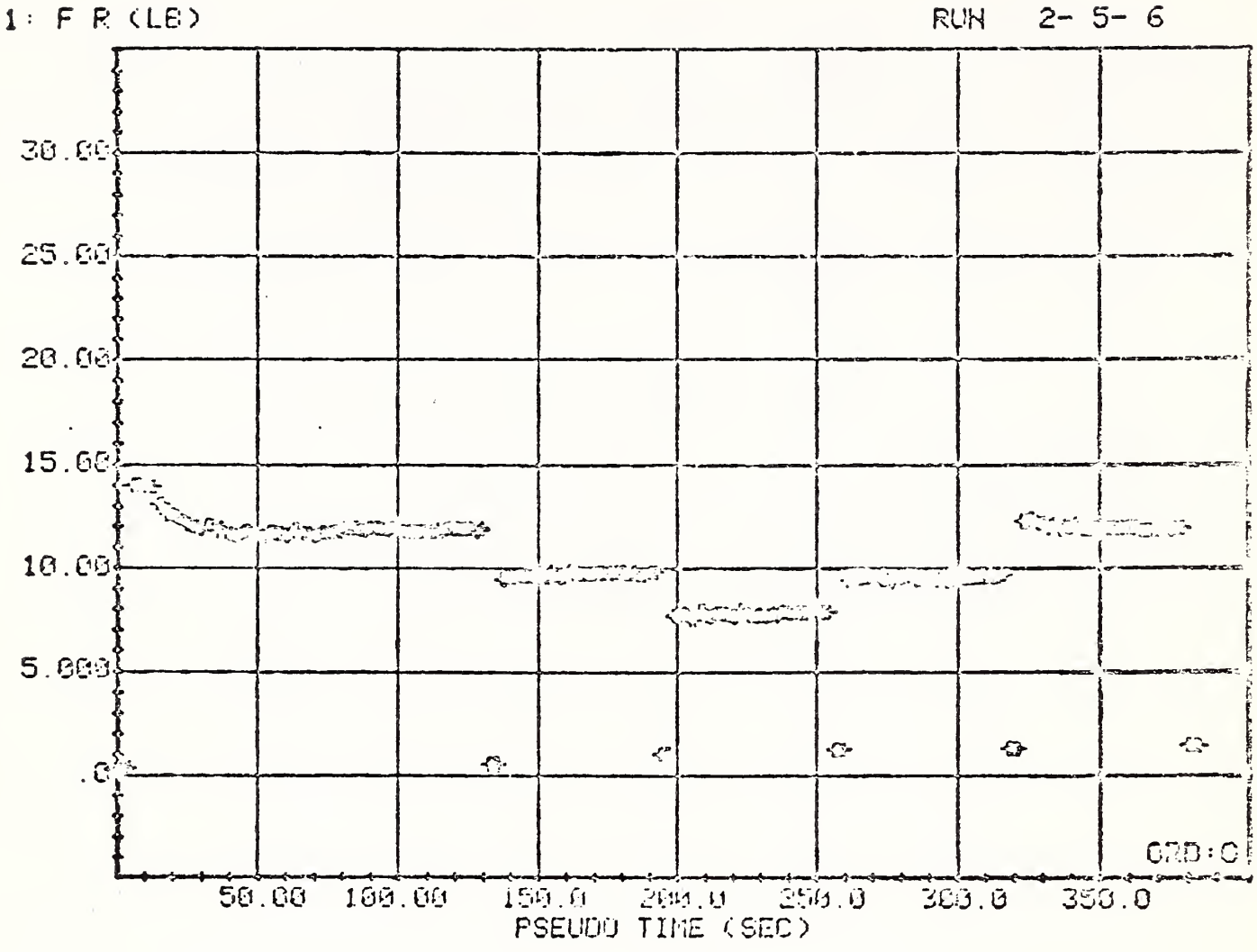
SPONSOR.....: TSC DATA FILTERS: .083 HZ

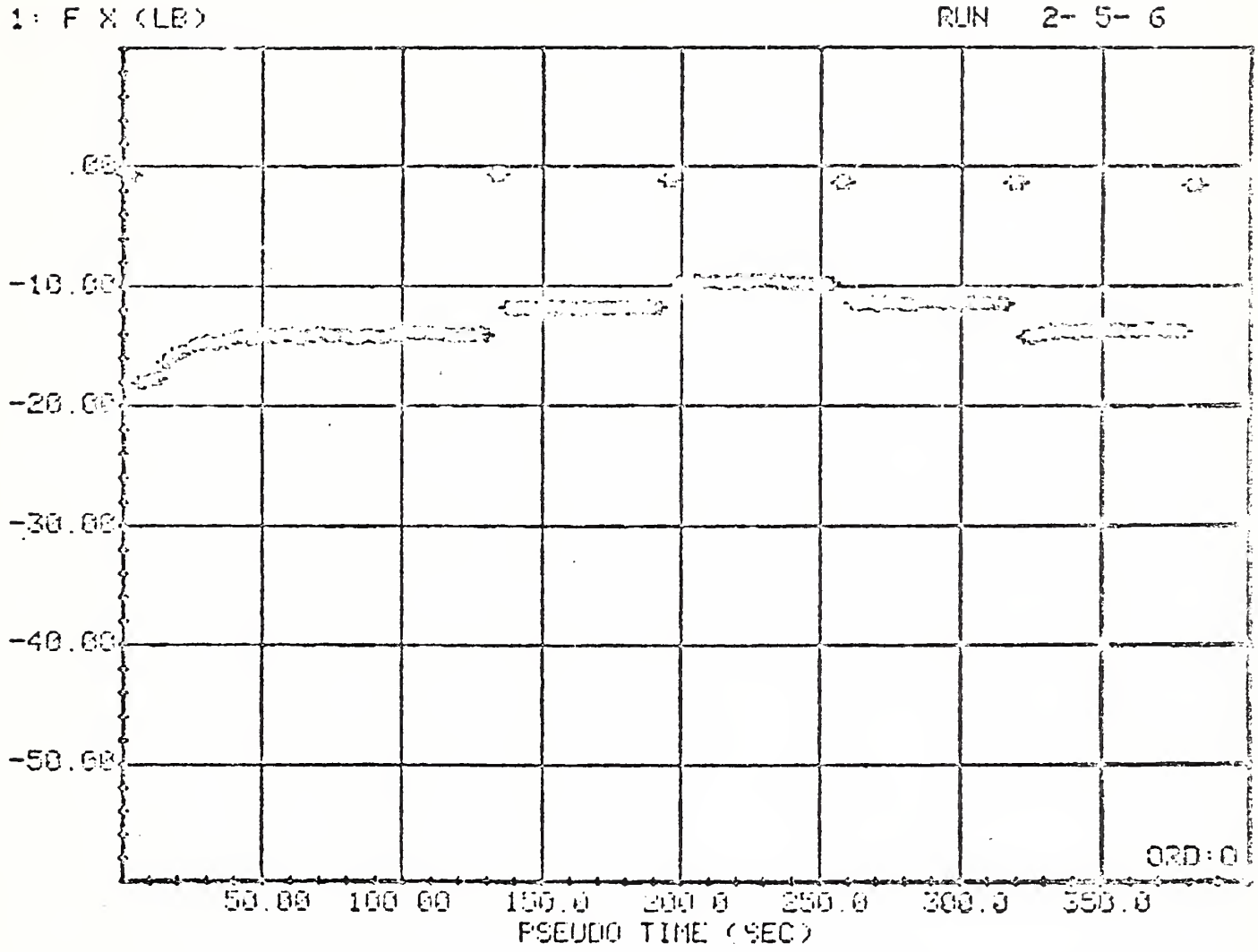
TIRE:
SPONSOR CODE: GY8303-18
TIRE NUMBER: 2- 5- 6
SIZE.....: P215/65R390

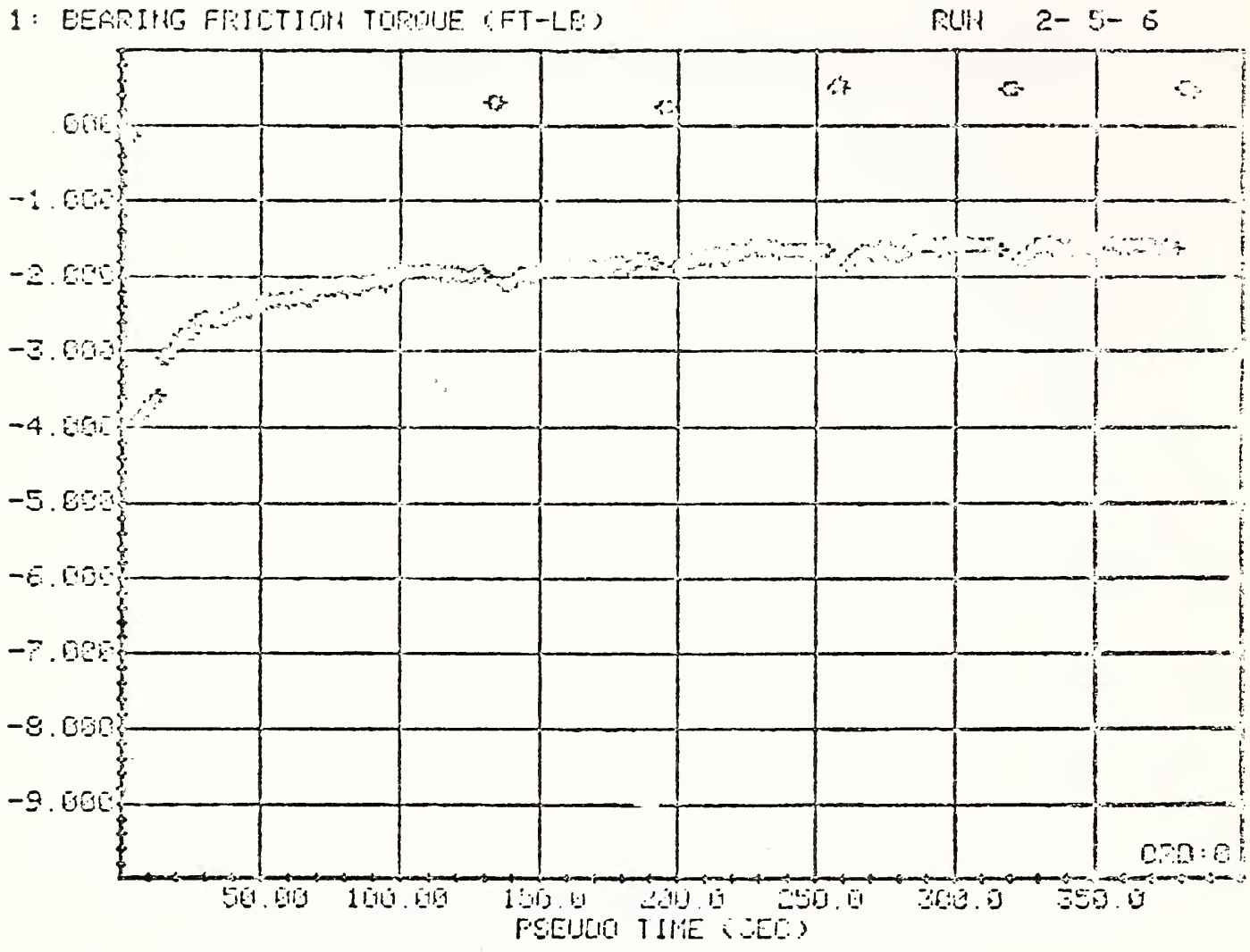
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 85
WATER DEPTH: DRY

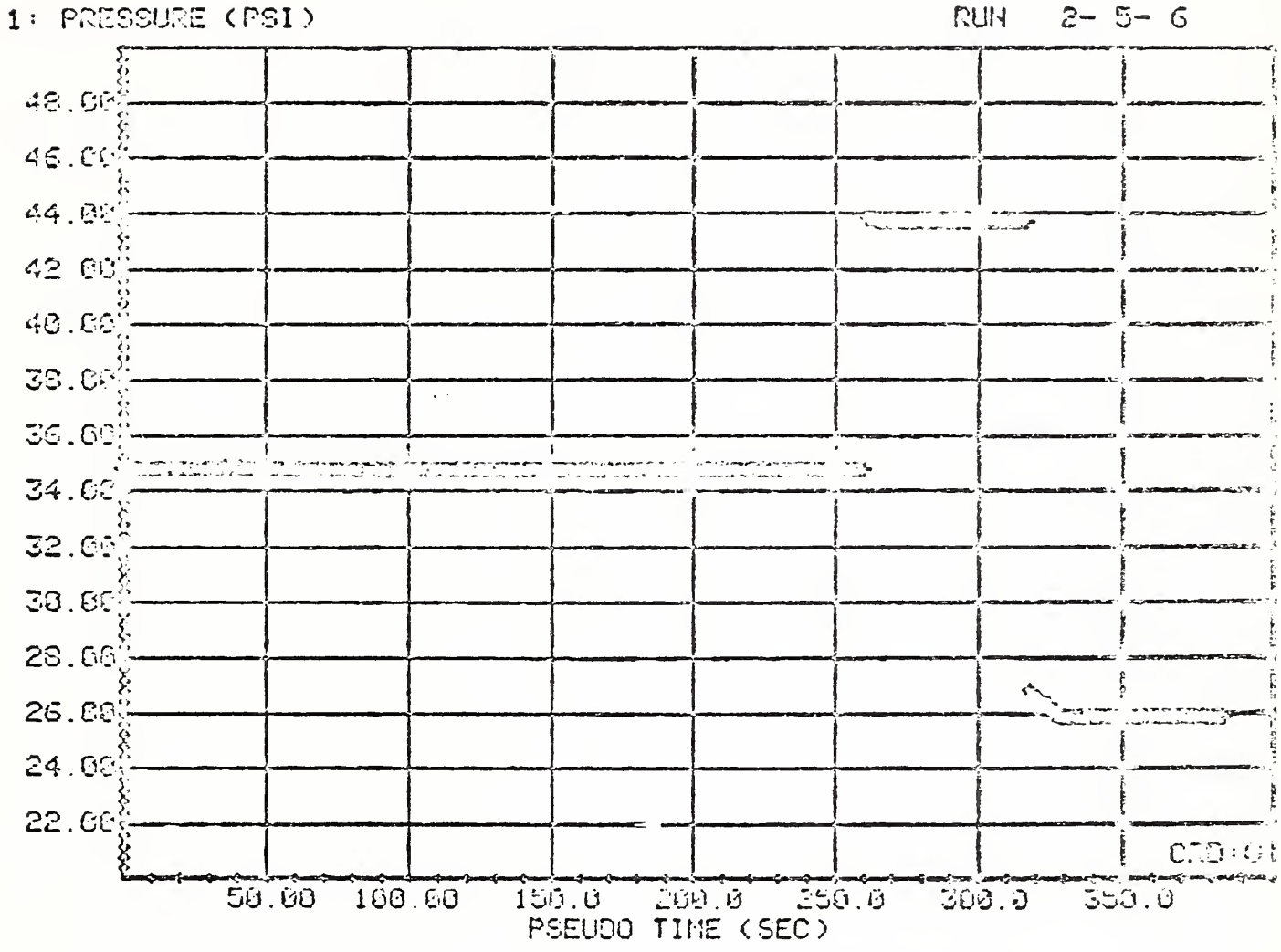
NOMINAL VALUES OF TEST PARAMETERS

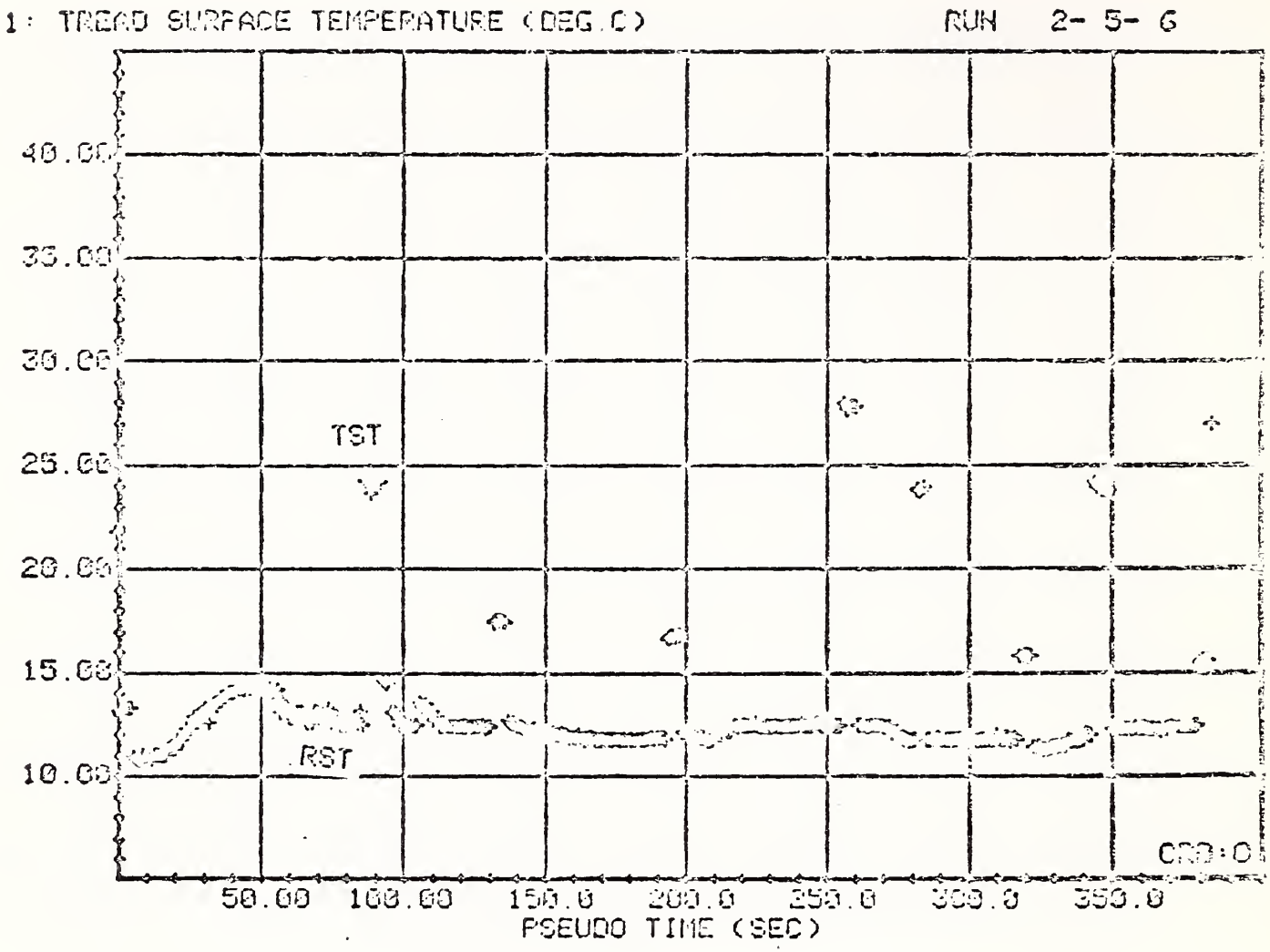
1. VELOCITY (MPH): 50
2. SLIP RATIO: FREE ROLLING
3. SLIP ANGLE (DEG): 0
4. INCLINATION ANGLE (DEG): 0
5. VERTICAL LOAD (LB): 1331,1065,799,1065
6. INFLATION PRESSURE (PSI): 35,44,26 REG


1: F R (LB)
RUN 2- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)
GRD:0


1: F X (LB)
RUN 2- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 2- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 2- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG.C)
RUN 2- 5- 6
40.00
35.00
30.00
25.00
20.00
15.00
10.00
TST
RST
CRO:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

2-5-6 A.V.L. LB	2-5-6 F.R. LB	2-5-6 C.A.T DEG.C	2-5-6 T.S.T DEG.C	2-5-6 P PSI	2-5-6 R.L. IN	2-5-6 F.Z. LB
1342.	11.2	21.71	12.5	34.9	12.21	-1[illegible]7.
1075.	8.63	21.58	11.9	34.9	12.4	-1[illegible]5.
811.	6.39	23.01	12.6	34.9	12.6	-[illegible]4.
1074.	8.04	22.36	11.9	43.8	12.50	-1[illegible]3.
1074.	10.16	22.04	12.5	26.	12.18	-1[illegible]3.

2-5-6 A.V.L. LB	2-5-6 S.F.R.	2-5-6 S.C.A.T.	2-5-6 S.I.S.T.	2-5-6 S.P.	2-5-6 S.R.R.	2-5-6 S.F.Z.
1342.	0.051	0.	0.035	0.012	0.004	0.475
1675.	0.037	0.027	0.043	0.012	0.003	0.531
811.	0.056	0.025	0.033	0.012	0.005	0.451
1674.	0.050	0.023	0.078	0.012	0.003	0.531
1674.	0.064	0.033	0.070	0.016	0.003	0.611

RUN NUMBER..: 3- 5- 6 DATE: 2/10/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

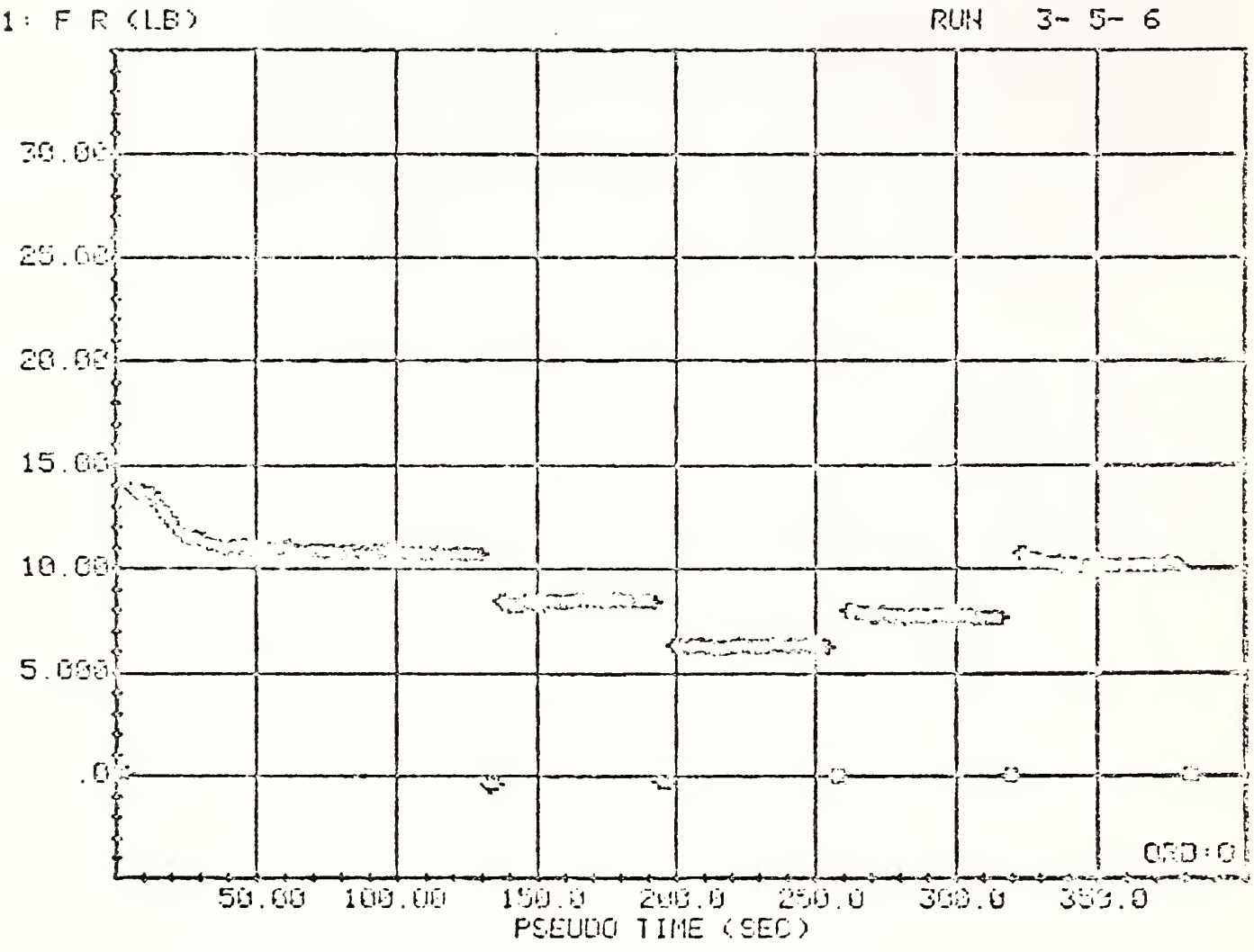
SPONSOR.....: TSC DATA FILTERS: .083 HZ

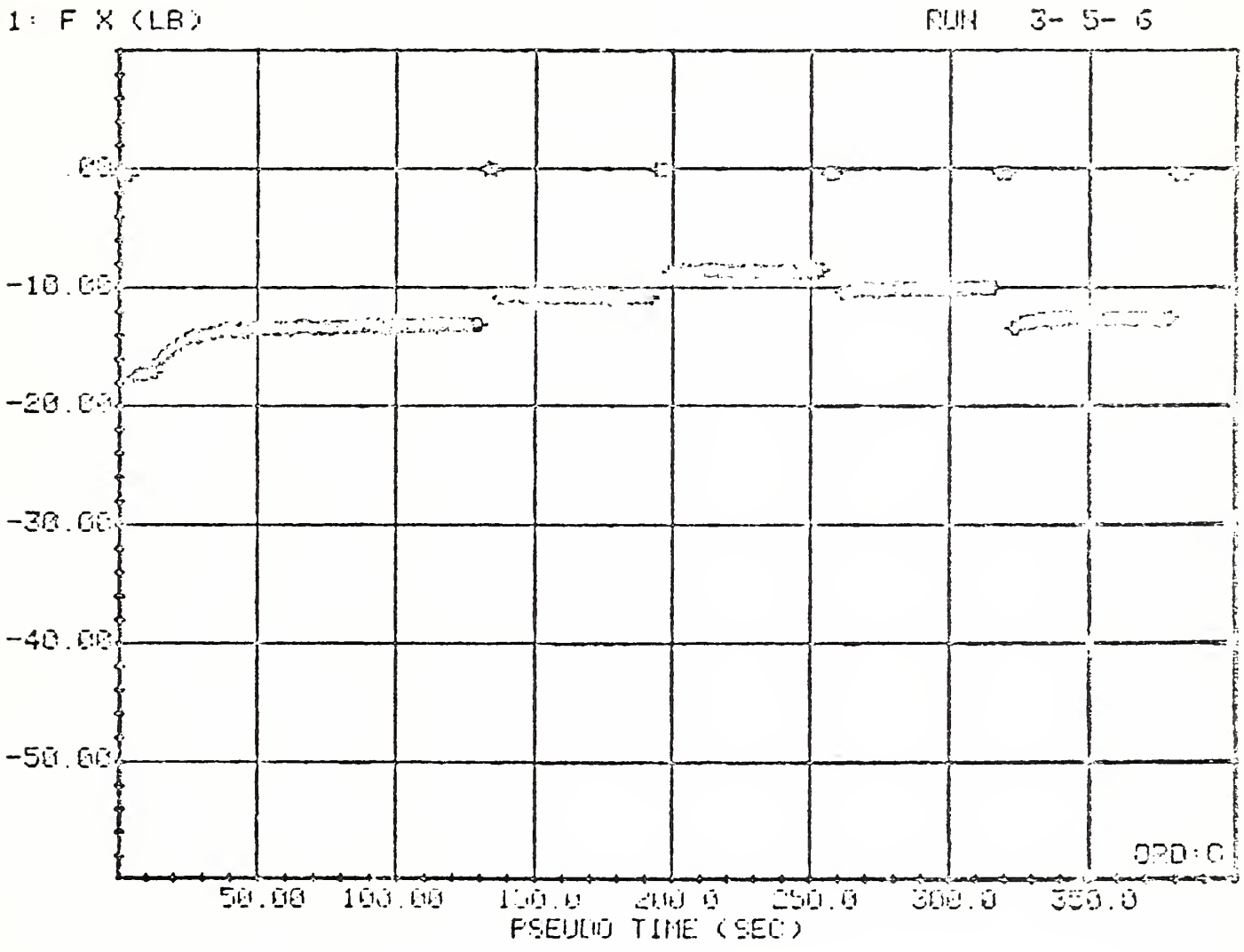
TIRE:
SPONSOR CODE: GY8303-12
TIRE NUMBER: 3- 5- 6
SIZE.....: P215/65R390

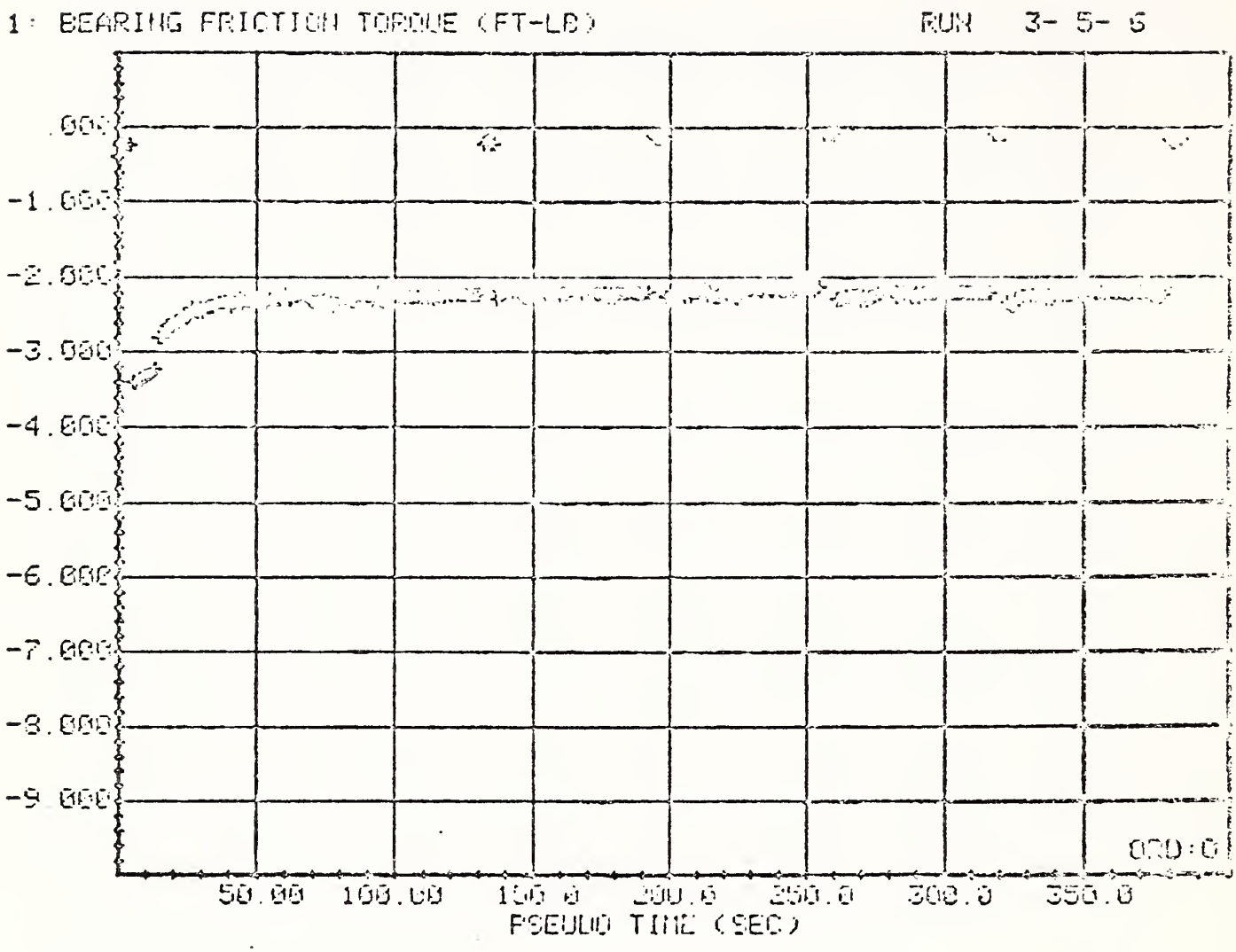
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 85
WATER DEPTH: DRY

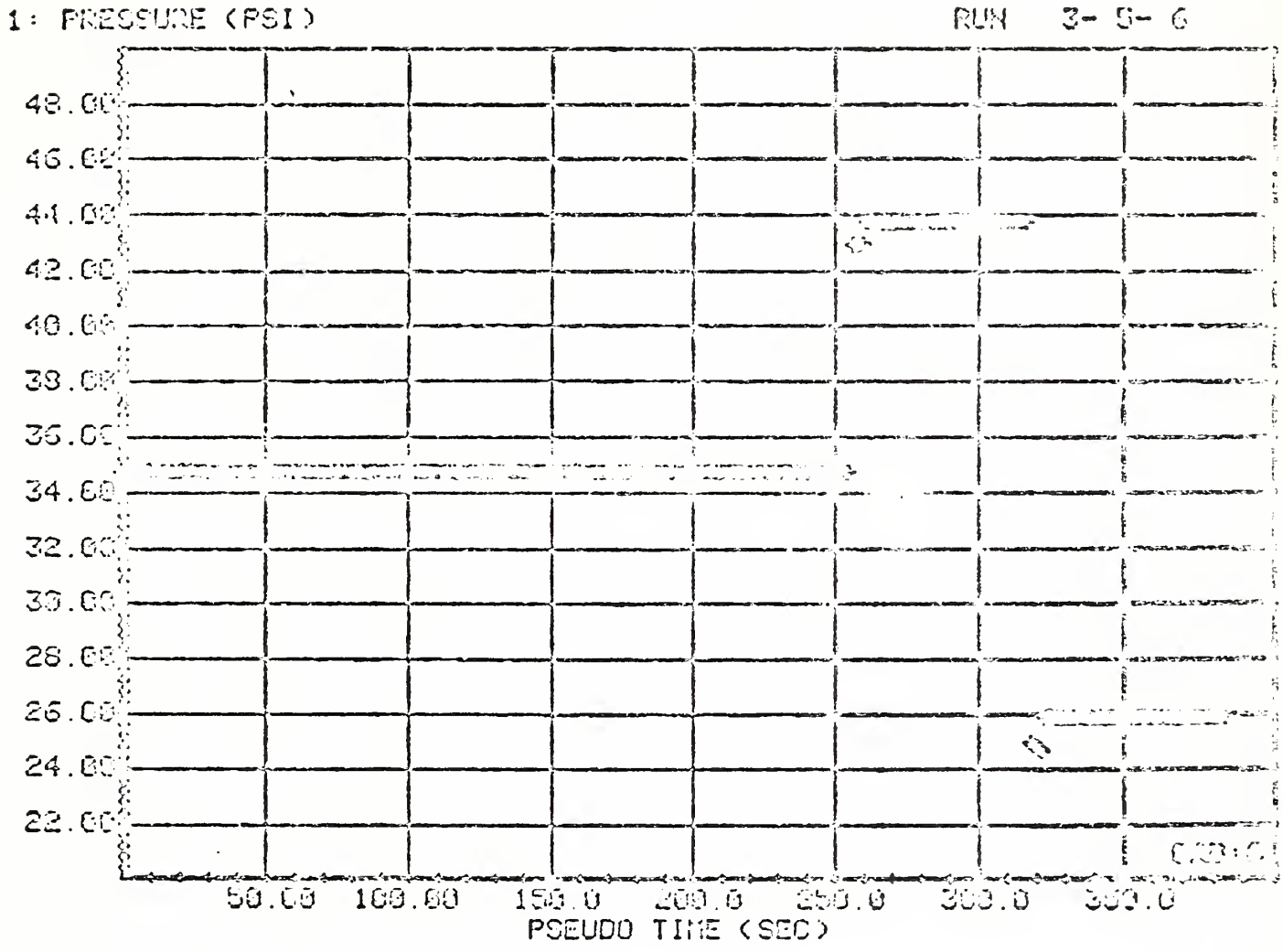
NOMINAL VALUES OF TEST PARAMETERS

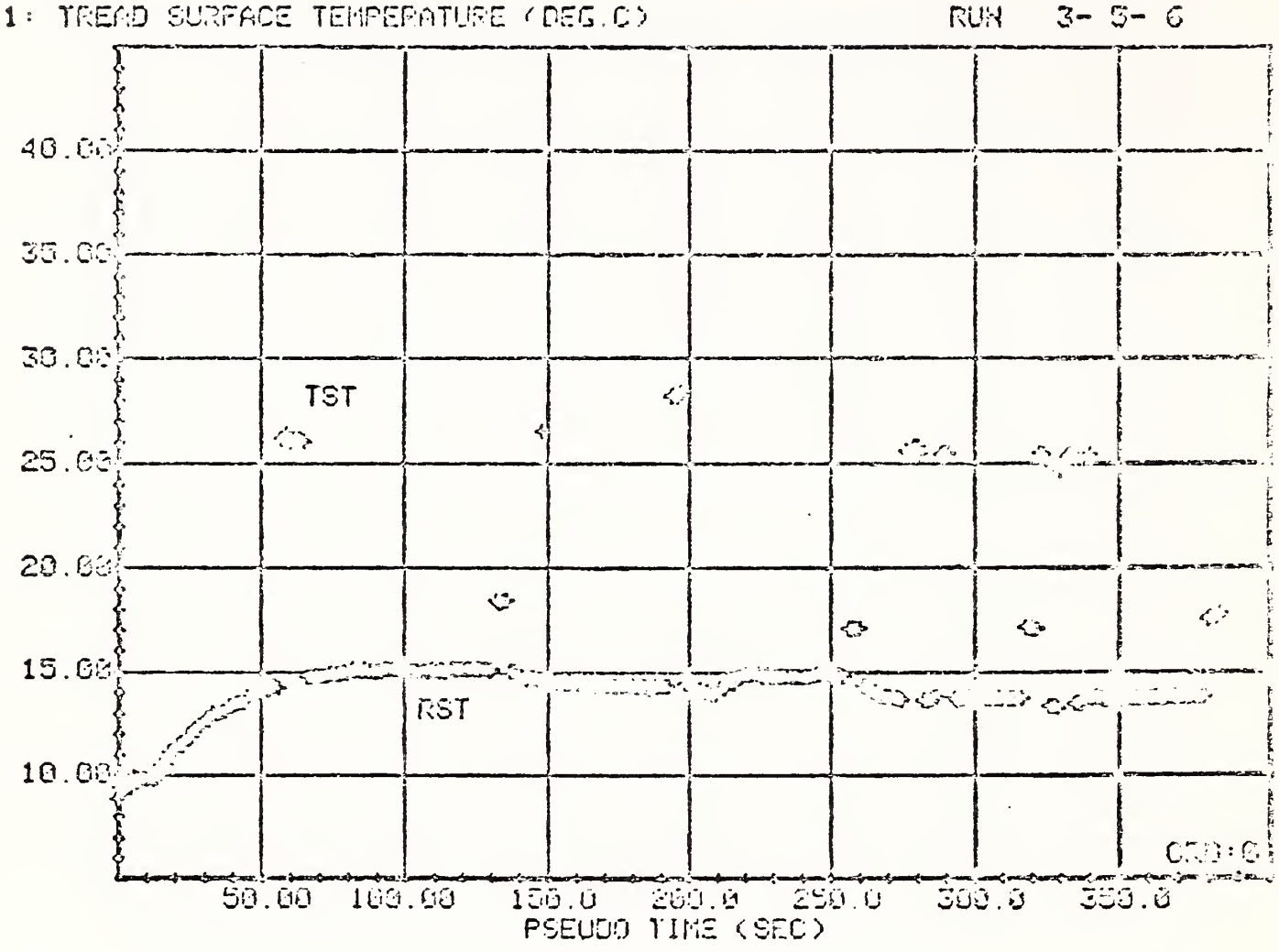
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1331,1065,799, 1065
6.	INFLATION PRESSURE (PSI):	35,44,26 REG


1: F R (LB)
RUN 3- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
050:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 3- 5- 6
-10.00
-20.00
-30.00
-40.00
-50.00
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 3- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
050.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 3- 9- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG.C)
RUN 3- 5- 6
40.00
35.00
30.00
25.00
20.00
15.00
10.00
TST
RST
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

3-5-6 A.V.L. LB	3-5-6 F.R. LB	3-5-6 C.A.T DEG.C	3-5-6 T.S.T DEG.C	3-5-6 P. PSI	3-5-6 R.L. IN	3-5-6 F.Z. LB
1343.	11.10	22.58	15.2	34.8	12.21	-1[illegible].
1074.	8.79	22.62	14.4	34.8	12.41	-1[illegible].
813.	6.33	23.63	15.	34.8	12.61	-[illegible].
1075.	7.68	22.89	13.9	43.8	12.55	-1[illegible].
1074.	10.22	22.76	14.	26.9	12.2	-10[illegible].

3-5-6 A.U.L. LD	3-5-6 S.F.R.	3-5-6 S.C.A.T.	3-5-6 D.I.S.T.	3-5-6 S.P.	3-5-6 S.R.R.	3-5-6 S.F.Z.
1243.	0.034	0.000	0.021	0.019	0.0[illegible]	0.5[illegible]
1574.	0.018	0.000	0.043	0.016	0.0[illegible]	0.0[illegible]
813.	0.023	0.000	0.031	0.	0.0[illegible]	0.0[illegible]
1625.	0.038	0.001	0.	0.	0.0[illegible]	0.[illegible]
1074.	0.044	0.000	0.043	0.012	0.005	0.719

RUN NUMBER..: 4- 5- 6 DATE: 2/10/72

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

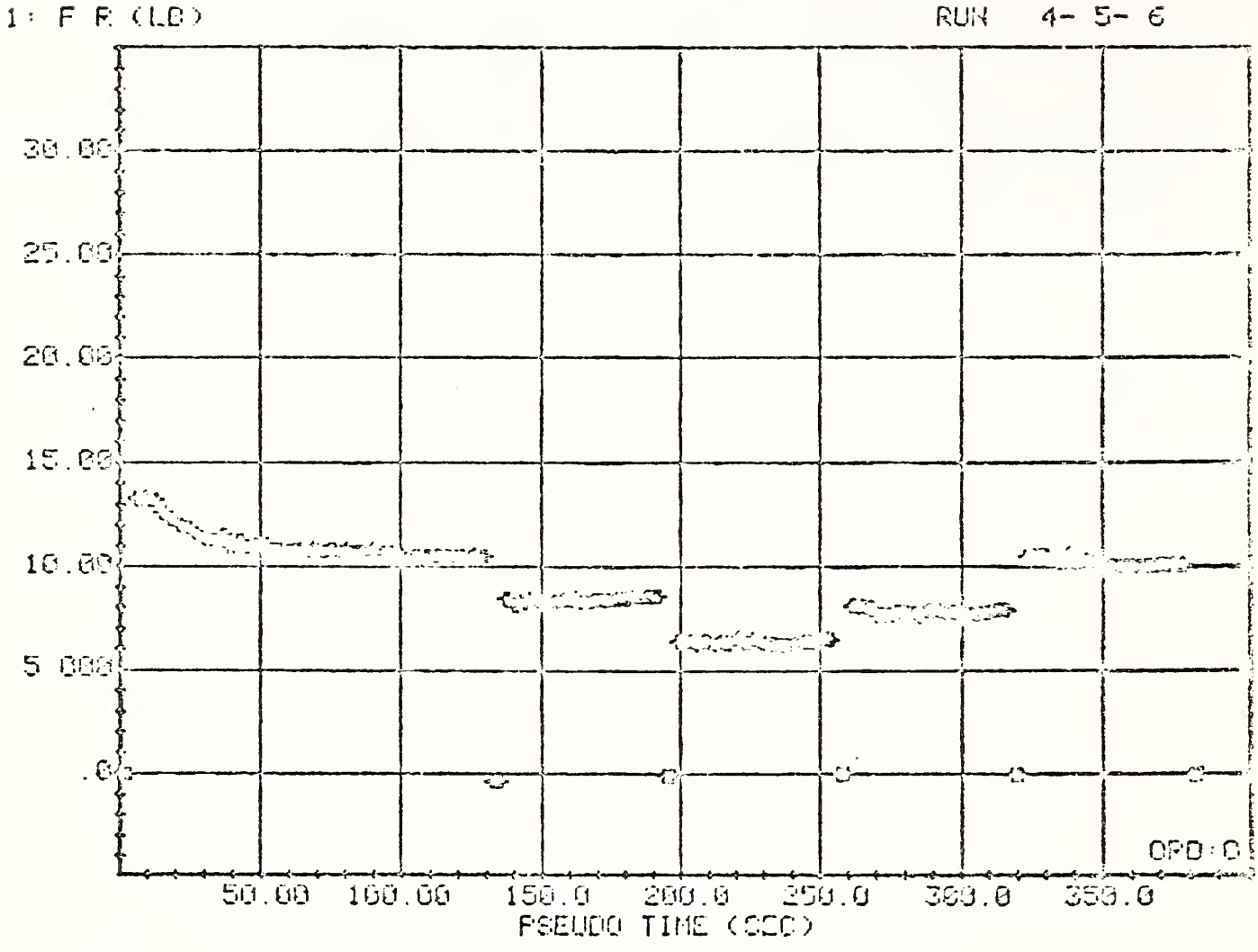
SPONSOR.....: TSC DATA FILTERS: .003 HZ

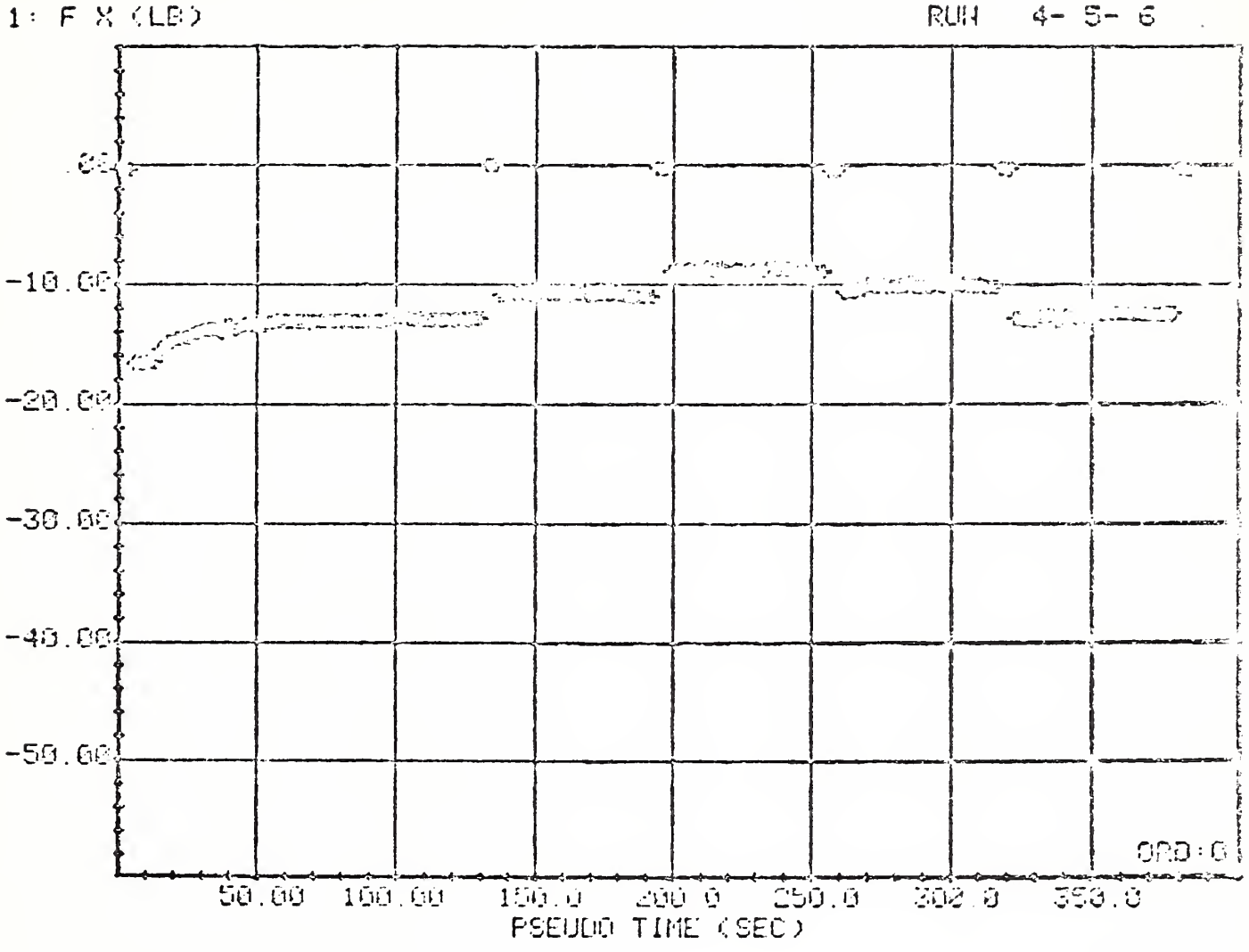
TIRE:
SPONSOR CODE: GY8303-16
TIRE NUMBER: 4- 5- 6
SIZE.....: P215/65R390

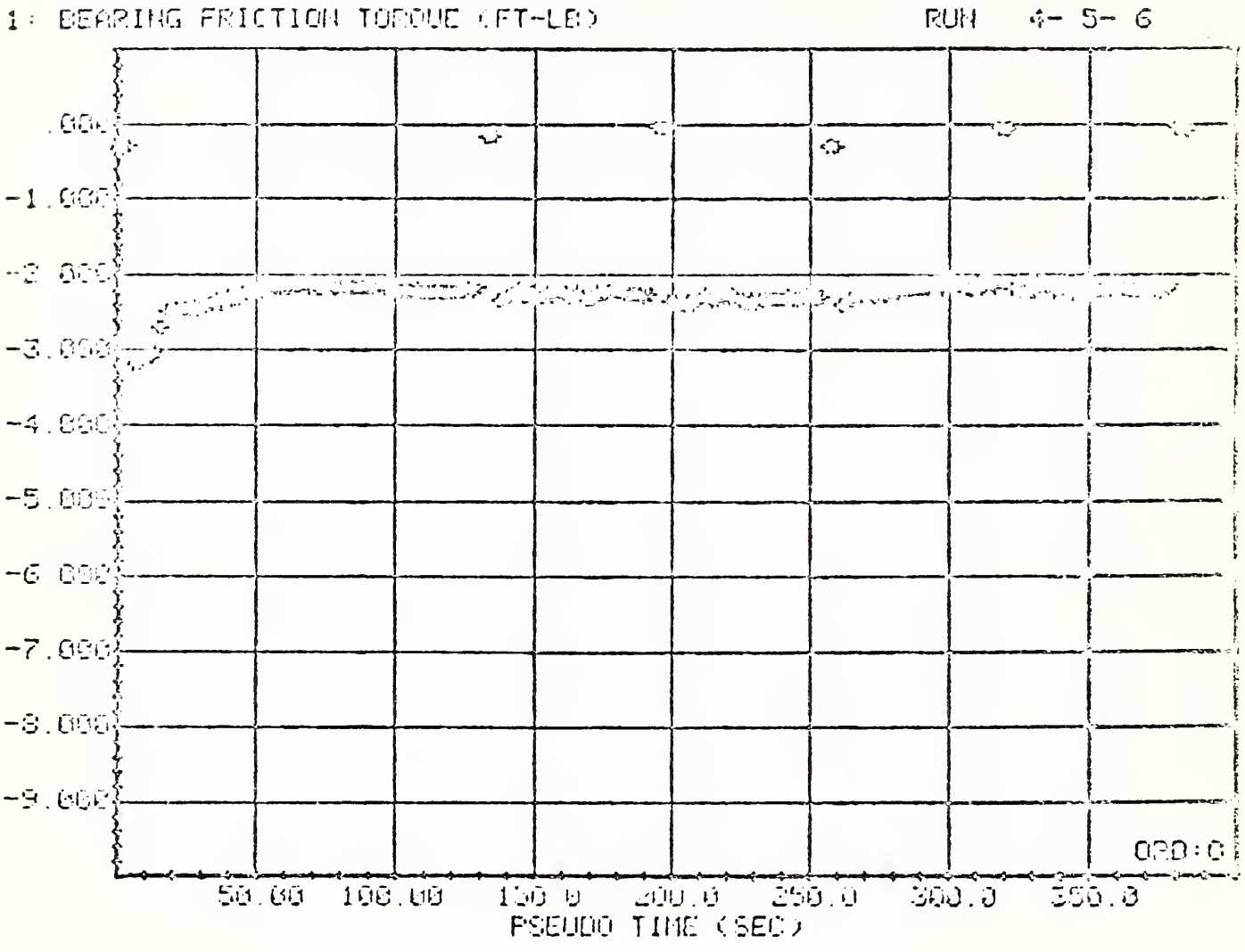
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 85
WATER DEPTH: DRY

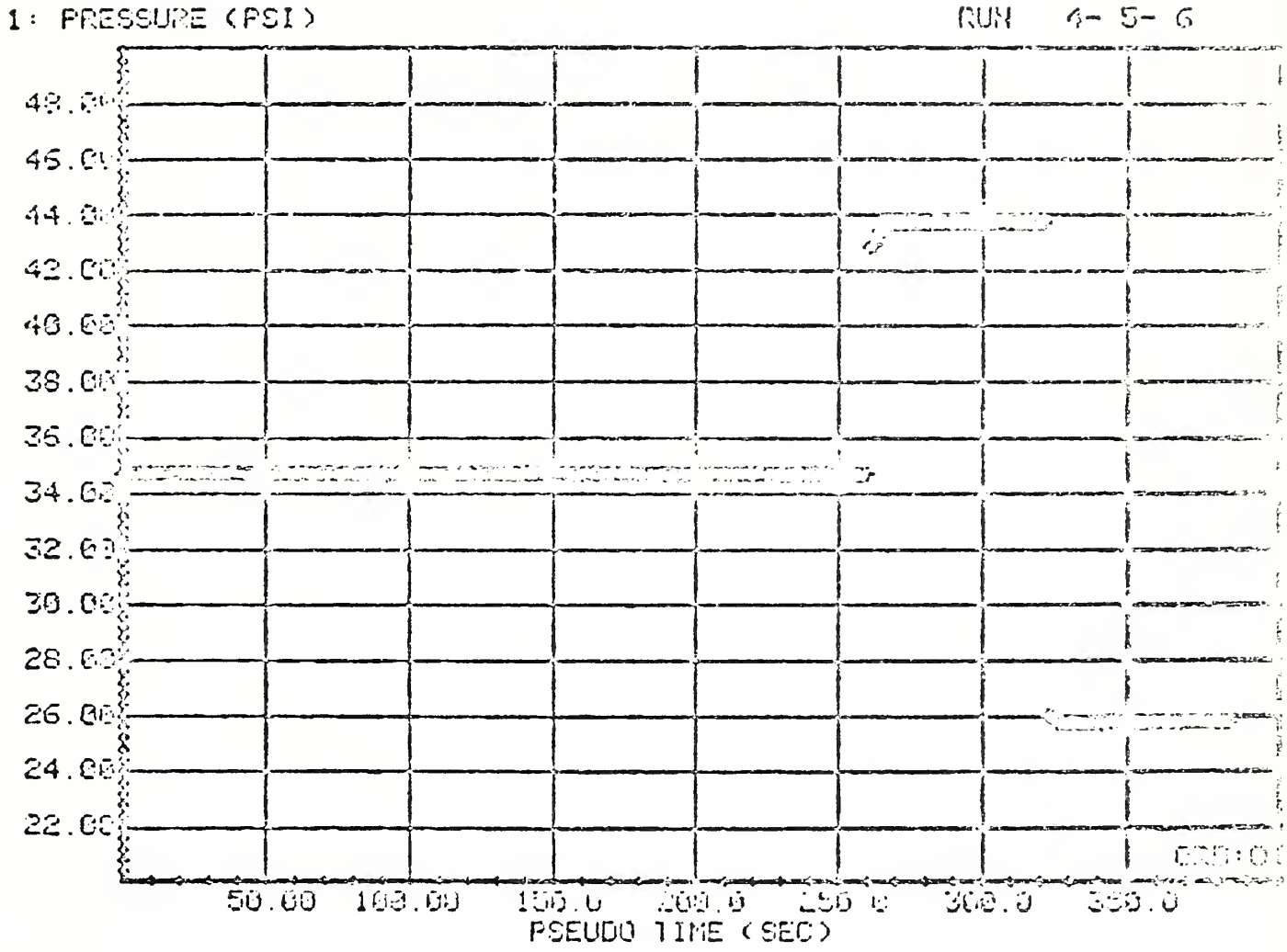
NOMINAL VALUES OF TEST PARAMETERS

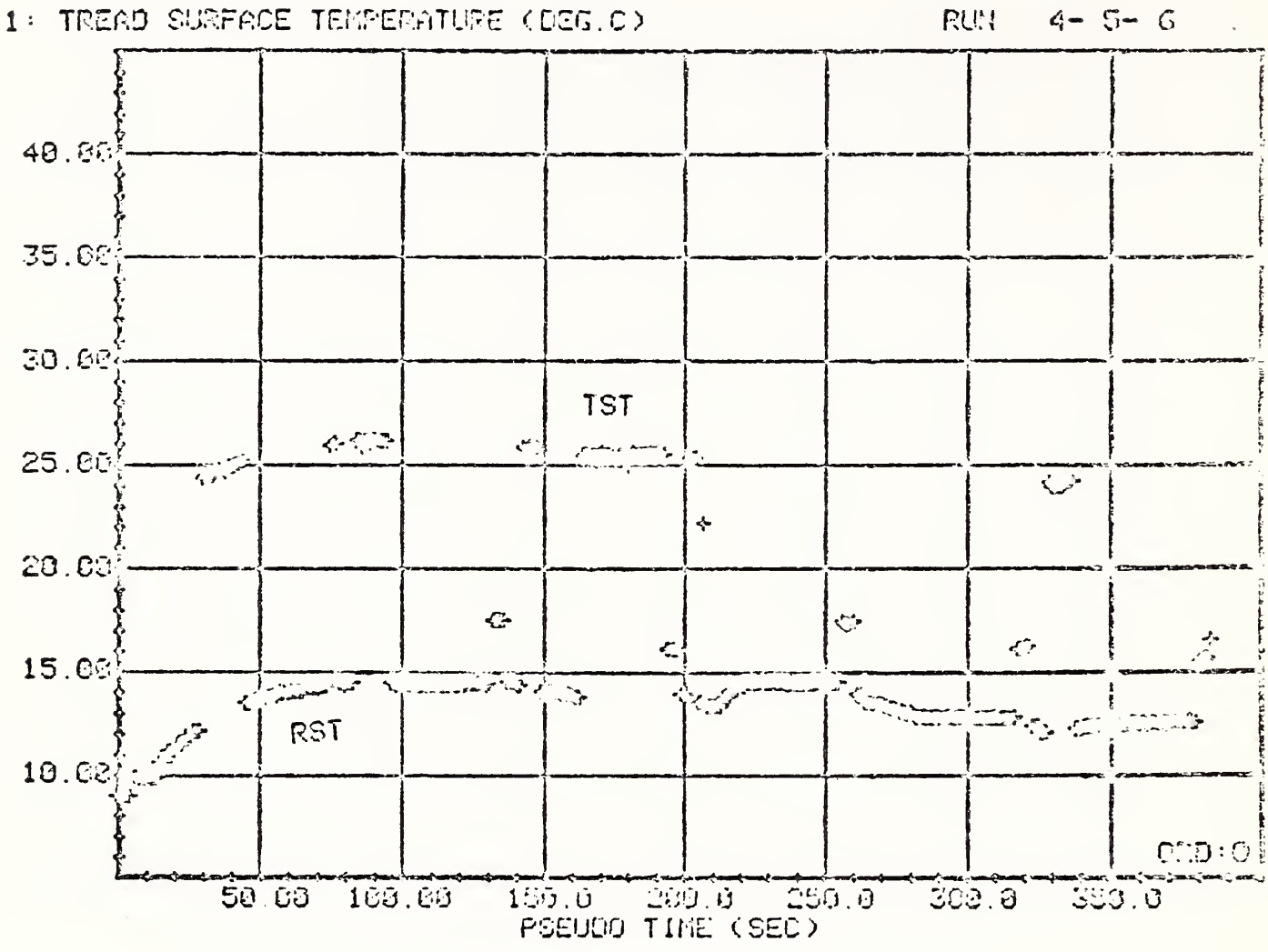
1. VELOCITY (MPH): 50
2. SLIP RATIO: FREE ROLLING
3. SLIP ANGLE (DEG): 0
4. INCLINATION ANGLE (DEG): 0
5. VERTICAL LOAD (LB): 1331,1065,799,1065
6. INFLATION PRESSURE (PSI): 35,44,26 REG


1: F R (LB)
RUN 4- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
OPD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 4- 5- 6
-10.00
-20.00
-30.00
-40.00
-50.00
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 4- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 4- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG.C)
RUN 4- 5- 6
40.00
35.00
30.00
25.00
20.00
15.00
10.00
TST
RST
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

4-5-6 A.V.L. LB	4-5-6 F.R. LB	4-5-6 C.A.T DEG.C	4-5-6 T.S.T DEG.C	4-5-6 P. PSI	4-5-6 D.L. IN	4-5-6 F.Z. LB
1343.	11.	22.68	14.5	34.8	12.82	-1[illegible].
1073.	8.65	22.68	25.6	34.8	12.41	-1[illegible].
813.	6.52	23.68	14.6	34.8	12.61	-[illegible].
1074.	7.06	23.1	13.9	23.8	12.[illegible]	-1[illegible].
1073.	10.16	22.68	12.7	25.9	12.19	-1[illegible].

4-5-6 R.U.L. LB	4-5-6 S.F R.	4-5-6 S.C.A T.	4-5-6 S I S T.	4-5-6 S.P	4-5-6 S.R.R.	4-5-6 S.F.Z.
1343.	0.020	0.000	0.018	0.016	0.004	0.000
1073.	0.059	0.000	0.163	0.016	0.002	0.007
813.	0.007	0.000	0.046	0.020	0.003	0.001
1074.	0.110	0.000	0.033	0.	0.004	0.003
1073.	0.041	0.000	0.042	0.016	0.000	0.004

RUN NUMBER..: 5- 5- 6 DATE: 2/10/78

TYPE OF TEST: ROLLING RESISTANCE HS PER GM PROCEDURE

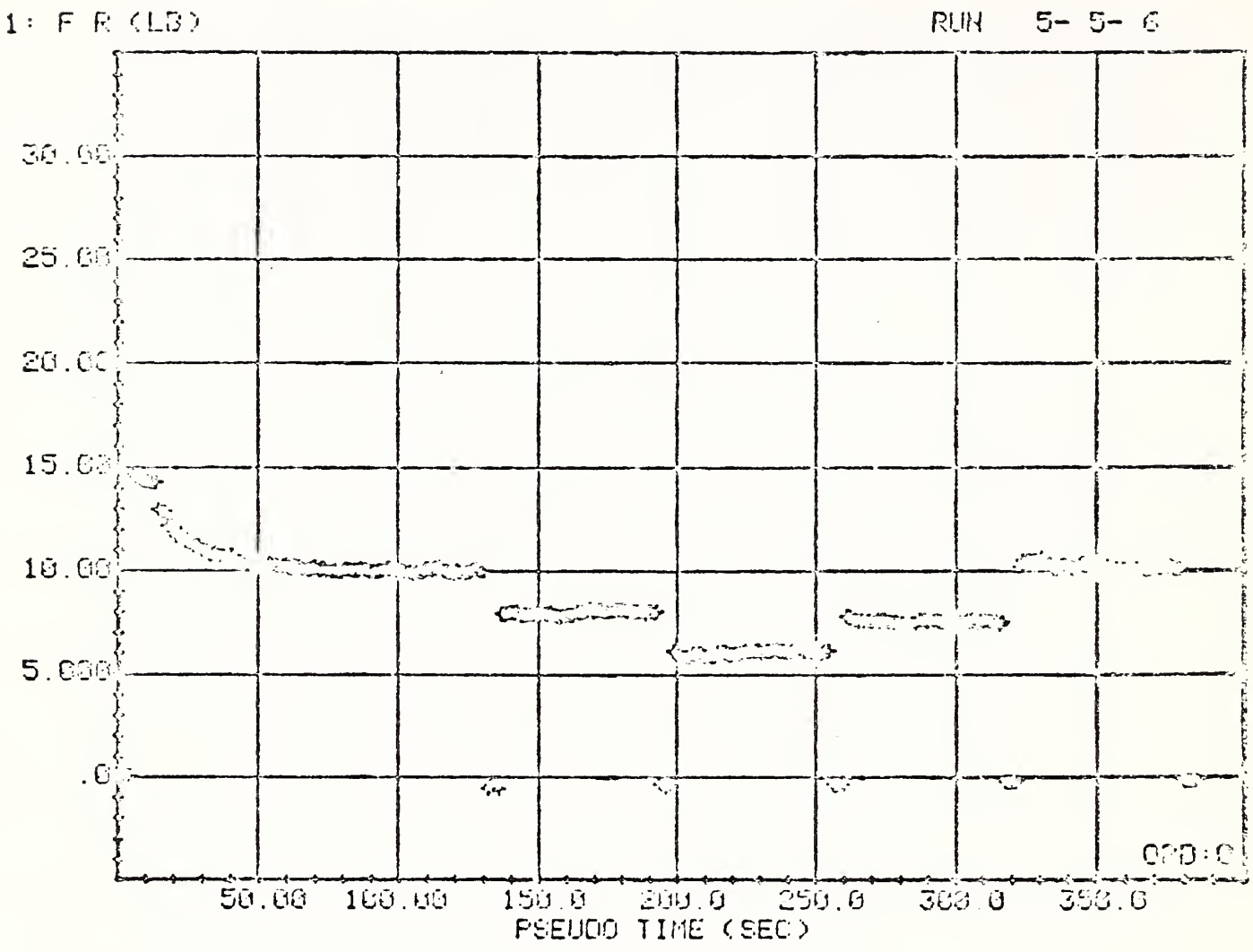
SPONSOR.....: T S C DATA FILTERS: .003 HZ

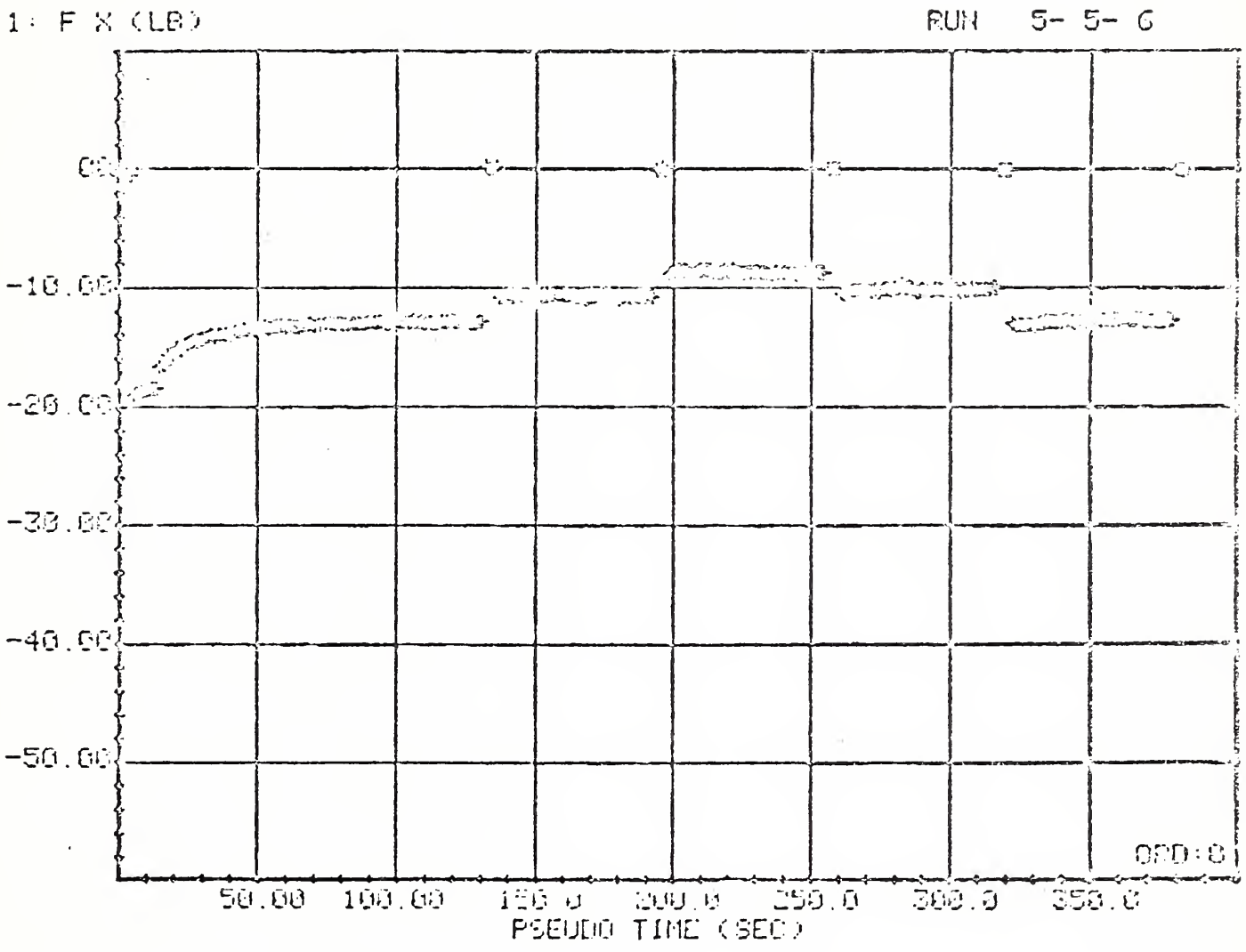
TIRE:
SPONSOR CODE: UNI 22-3118
TIRE NUMBER: 5- 5- 6
SIZE.....: P185/80 R 13

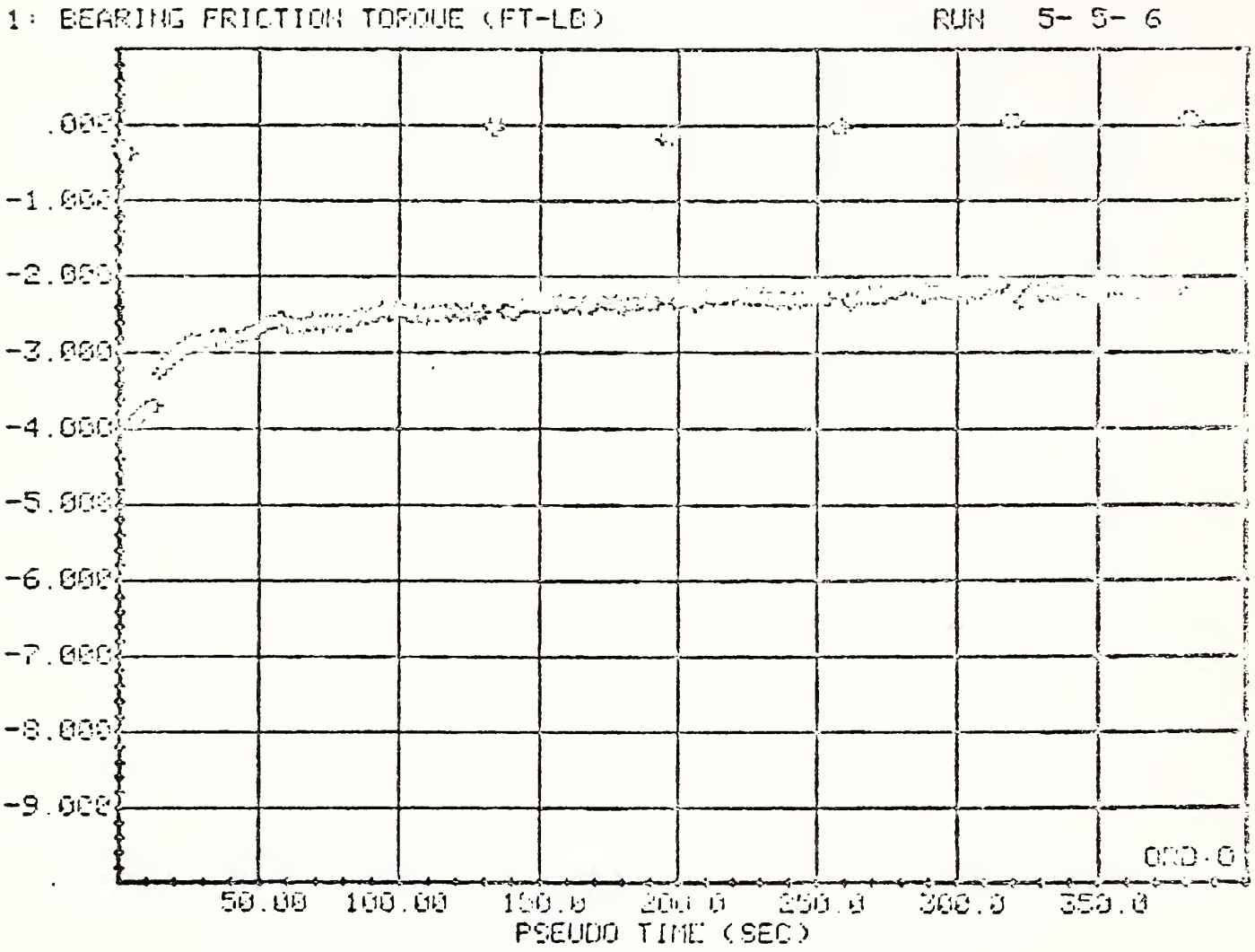
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 65
WATER DEPTH: DRY

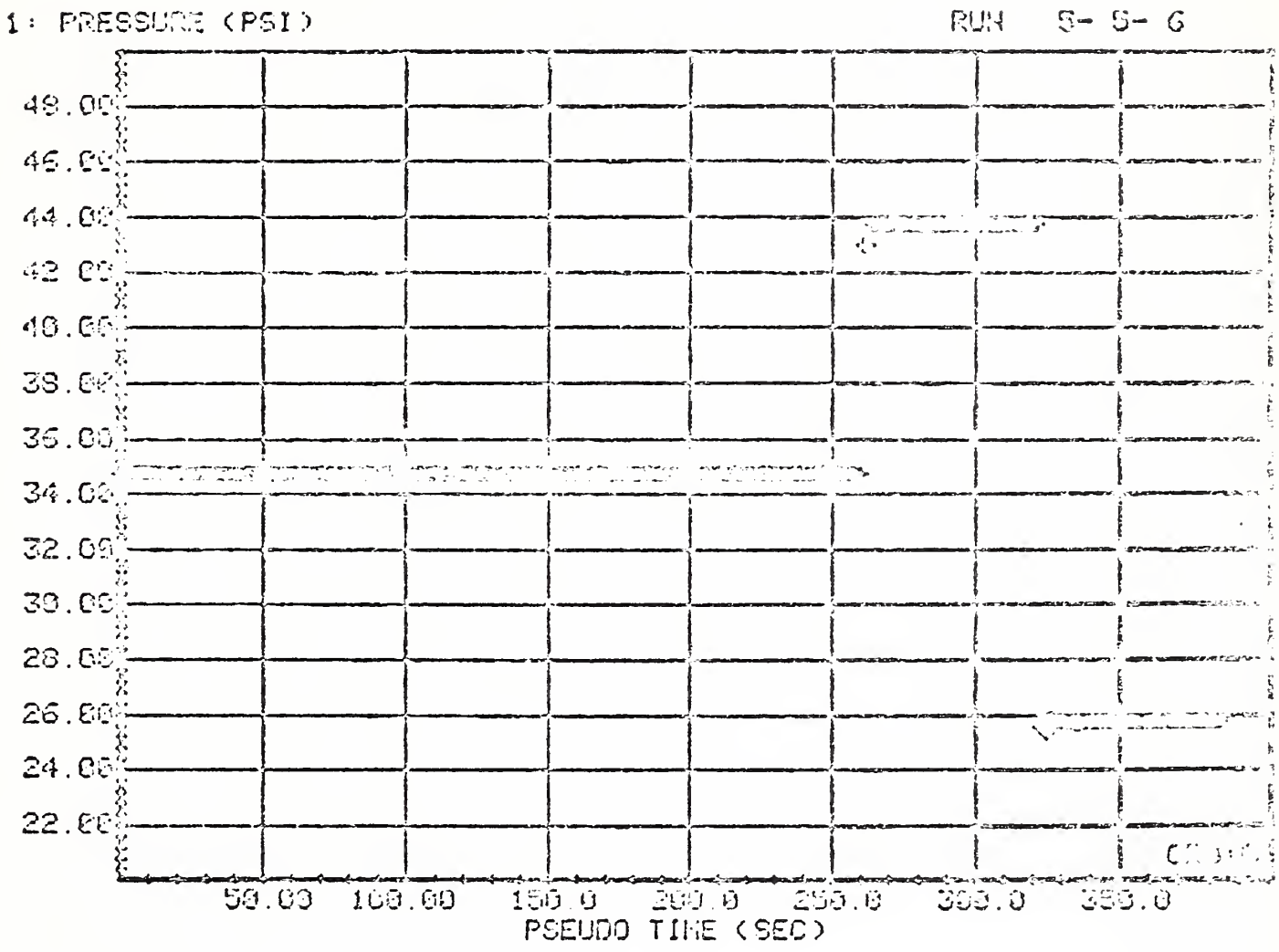
NOMINAL VALUES OF TEST PARAMETERS

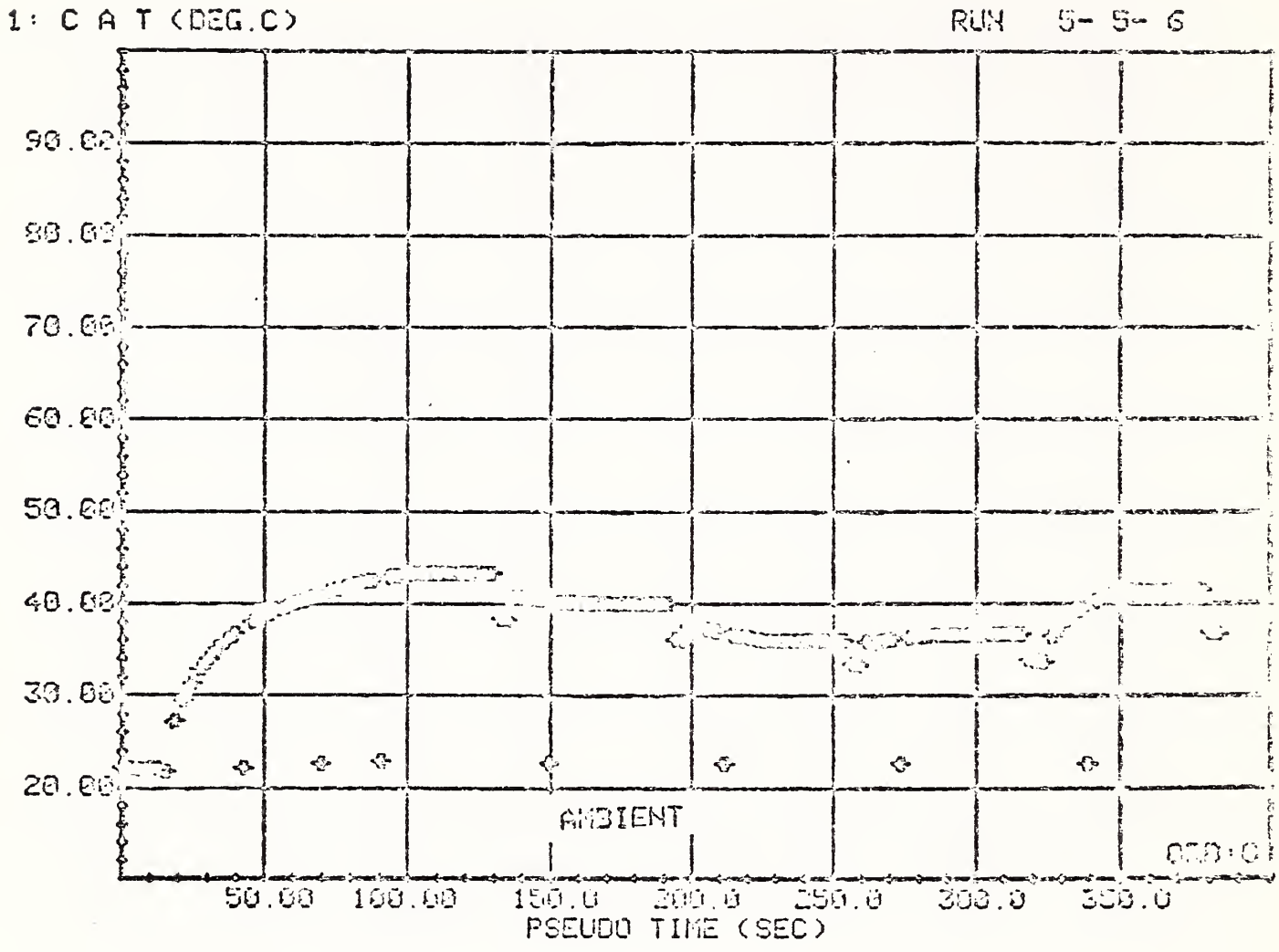
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1301,1041,781,1041
6.	INFLATION PRESSURE (PSI):	35,44,26 REG

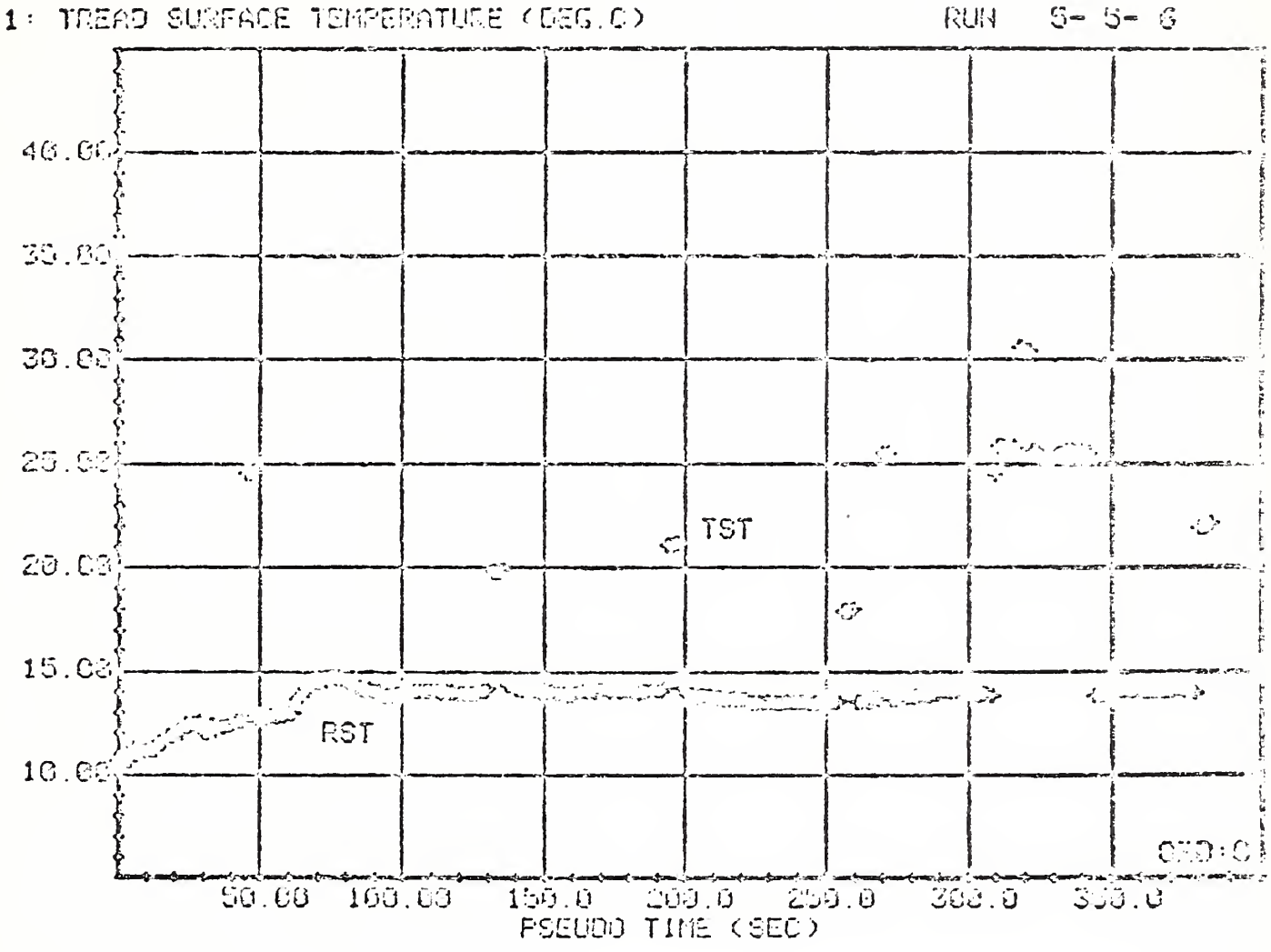

1: F R (LB)
RUN 5- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 5- 5- 6
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 5- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
000.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 5- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: C A T (DEG.C)
RUN 5- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG.C)
RUN 5- 5- 6
40.00
30.00
20.00
15.00
10.00
TST
RST
50.00
100.00
150.0
200.0
250.0
300.0
PSEUDO TIME (SEC)

5-5-6 A.V.L. LB	5-5-6 F.R. LB	5-5-6 C.A.T DEG.C	5-5-6 T.S.T DEG.C	5-5-6 P PSI	5-5-6 R.L. IN	5-5-6 F.Z. LB
1302.	10.43	43.61	14.1	34.8	11.13	[illegible]
1052.	8.51	48.38	14.2	34.8	11.31	[illegible]
791.	6.42	36.22	13.6	31.8	11.55	[illegible]
1052.	7.76	37.02	19.9	43.8	11.5	[illegible]
1052.	10.22	41.02	14.2	25.8	11.09	[illegible]

5-5-6 A.V.L. LB	5-5-6 S.F.R.	5-5-6 S.C.A T.	5-5-6 S T.S T.	5-5-6 S.P	5-5-6 S.R.R.	5-5-6 S.F.Z.
1309.	0 071	0.027	0.051	0.021	0.	0.571
1032.	0.034	0.019	0.003	0.012	0.	0.742
781.	0.079	0.022	0.050	0.021	0.	1.357
1032.	0.045	0.022	0.072	0.033	0.	0.750
1032.	0 075	0.036	0.036	0.	0.033	1.500

RUN NUMBER..: 6- 5- 6 DATE: 2/10/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

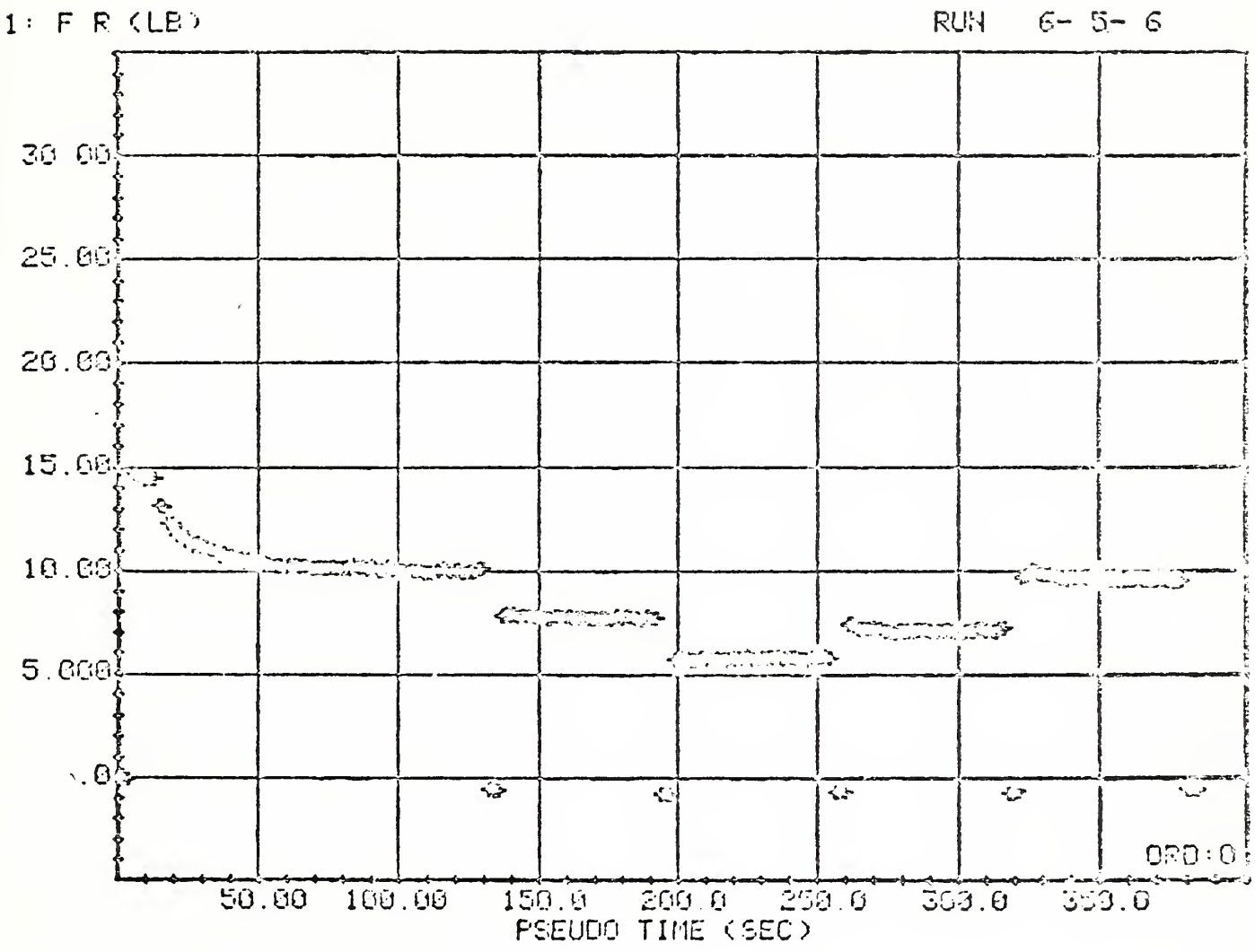
SPONSOR.....: T S C DATA FILTERS: .083 HZ

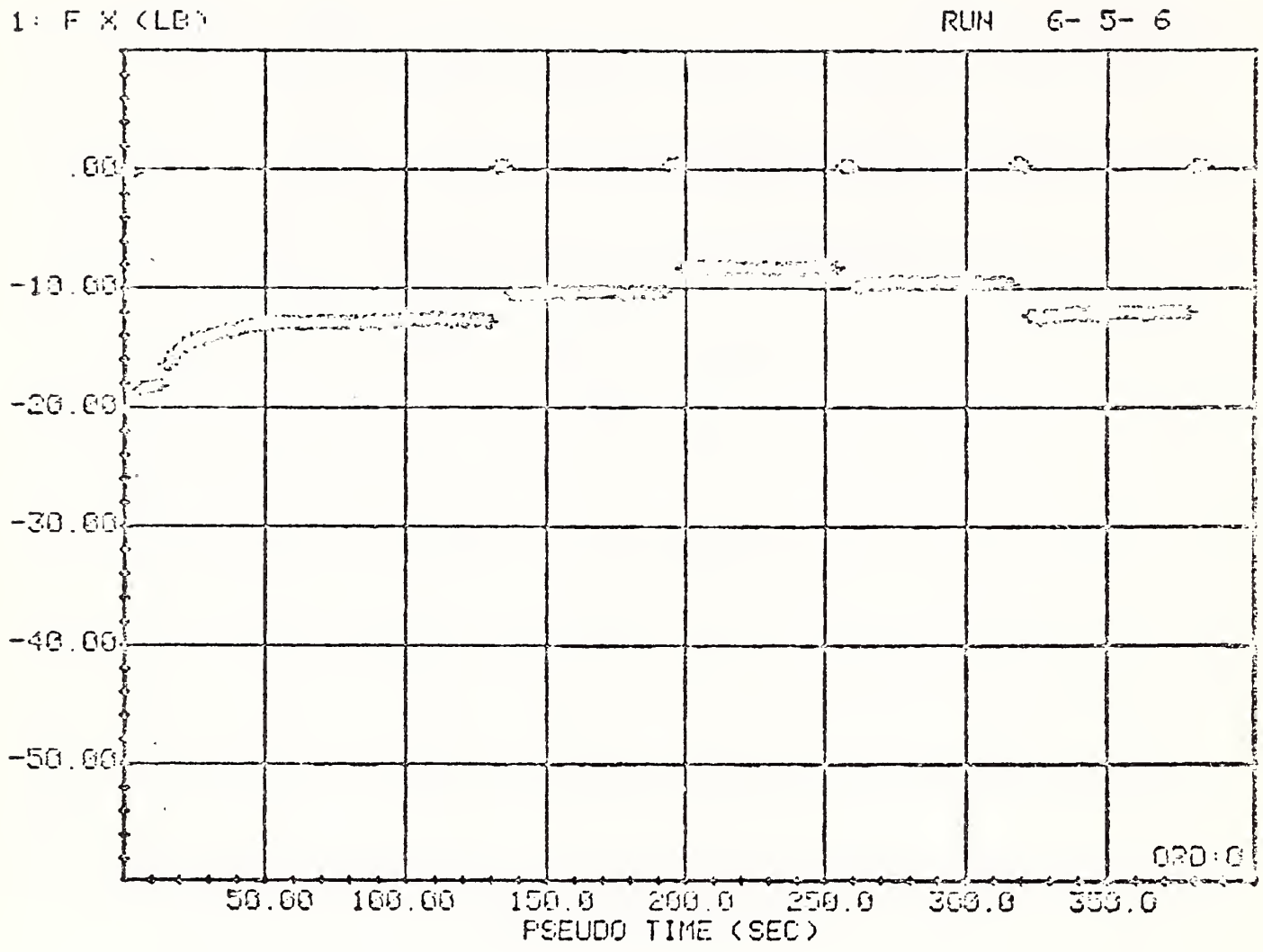
TIRE:
SPONSOR CODE: UNI 11-31181
TIRE NUMBER: 6- 5- 6
SIZE.....: P 185/80 R 13

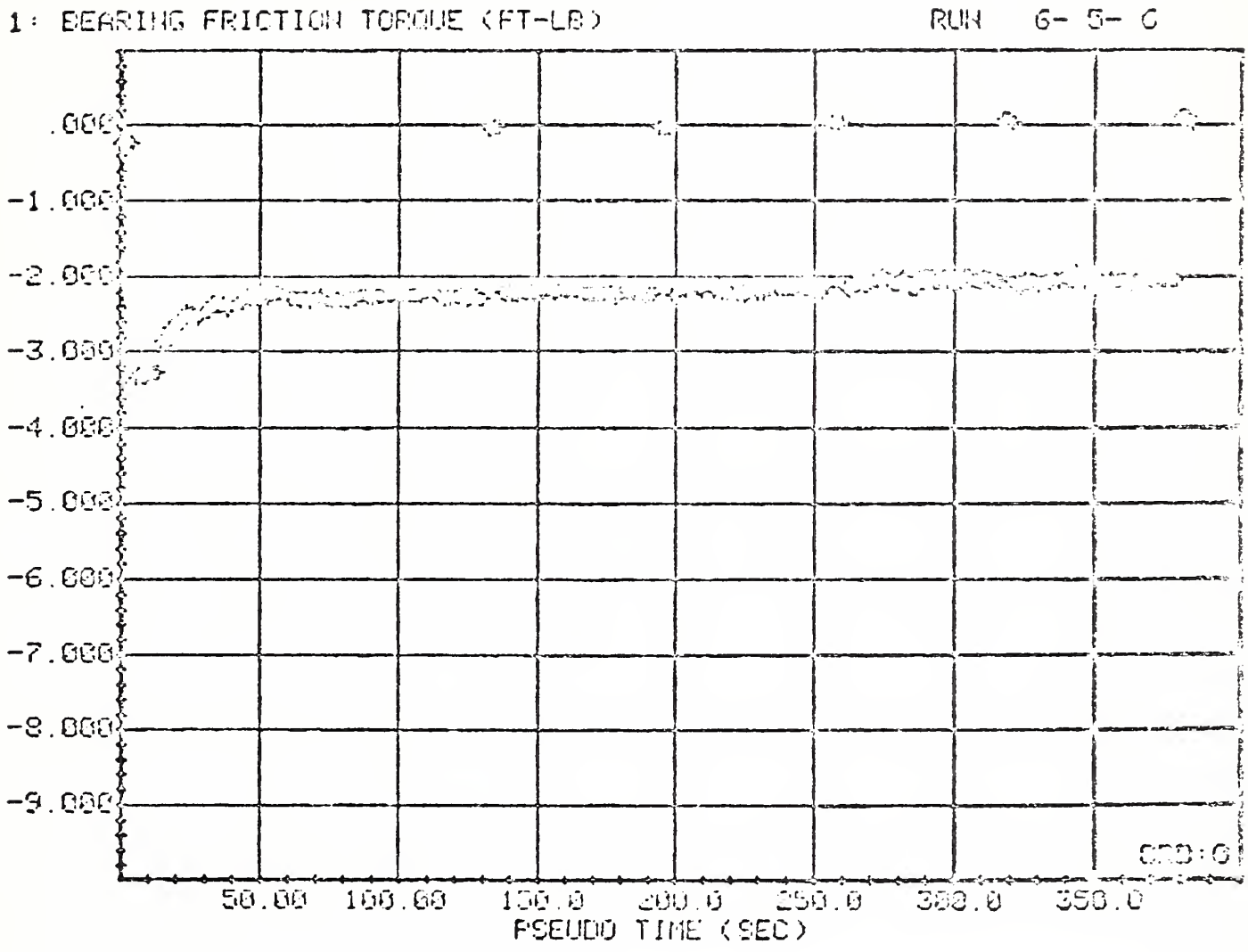
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 85
WATER DEPTH: DRY

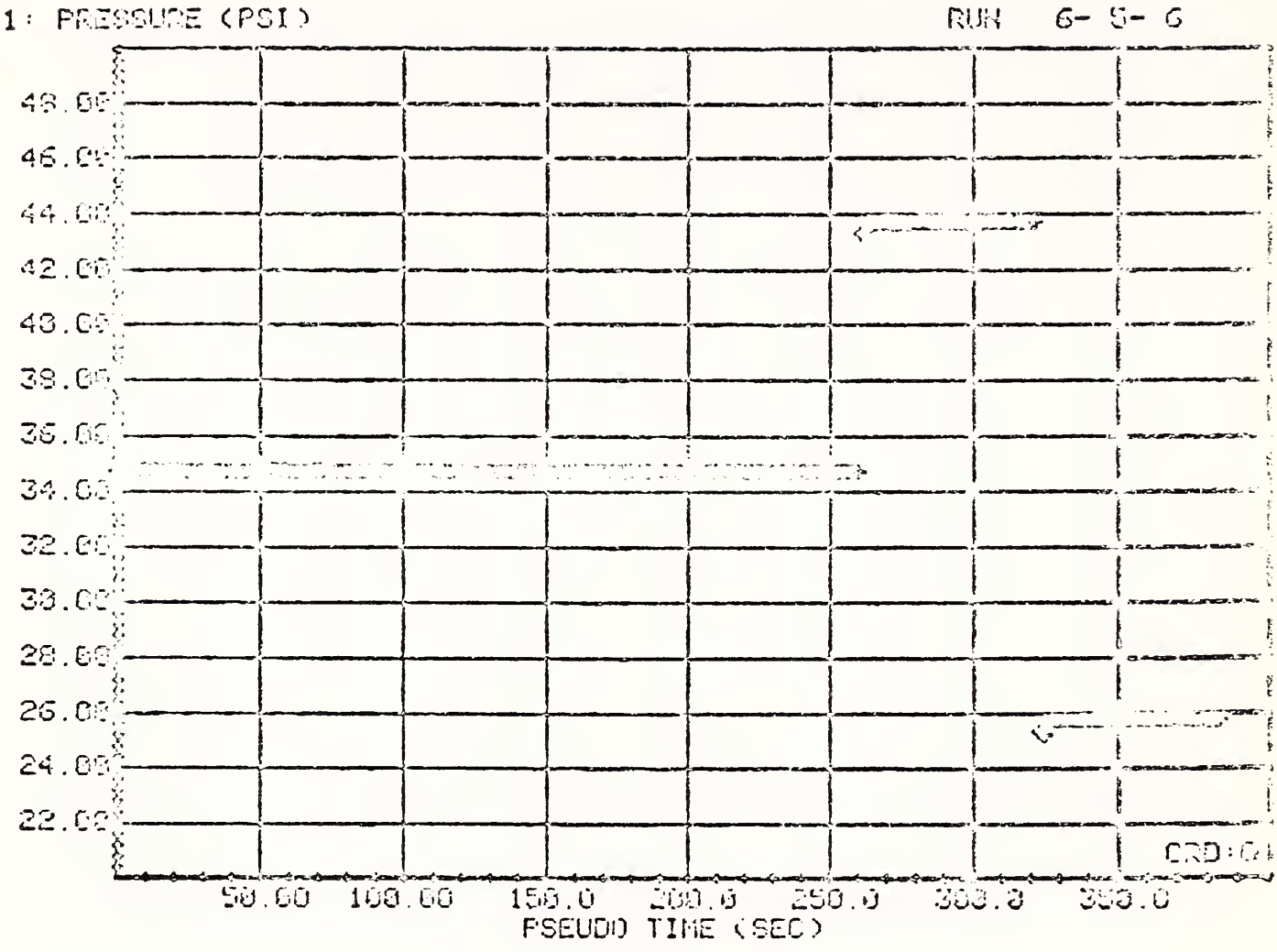
NOMINAL VALUES OF TEST PARAMETERS

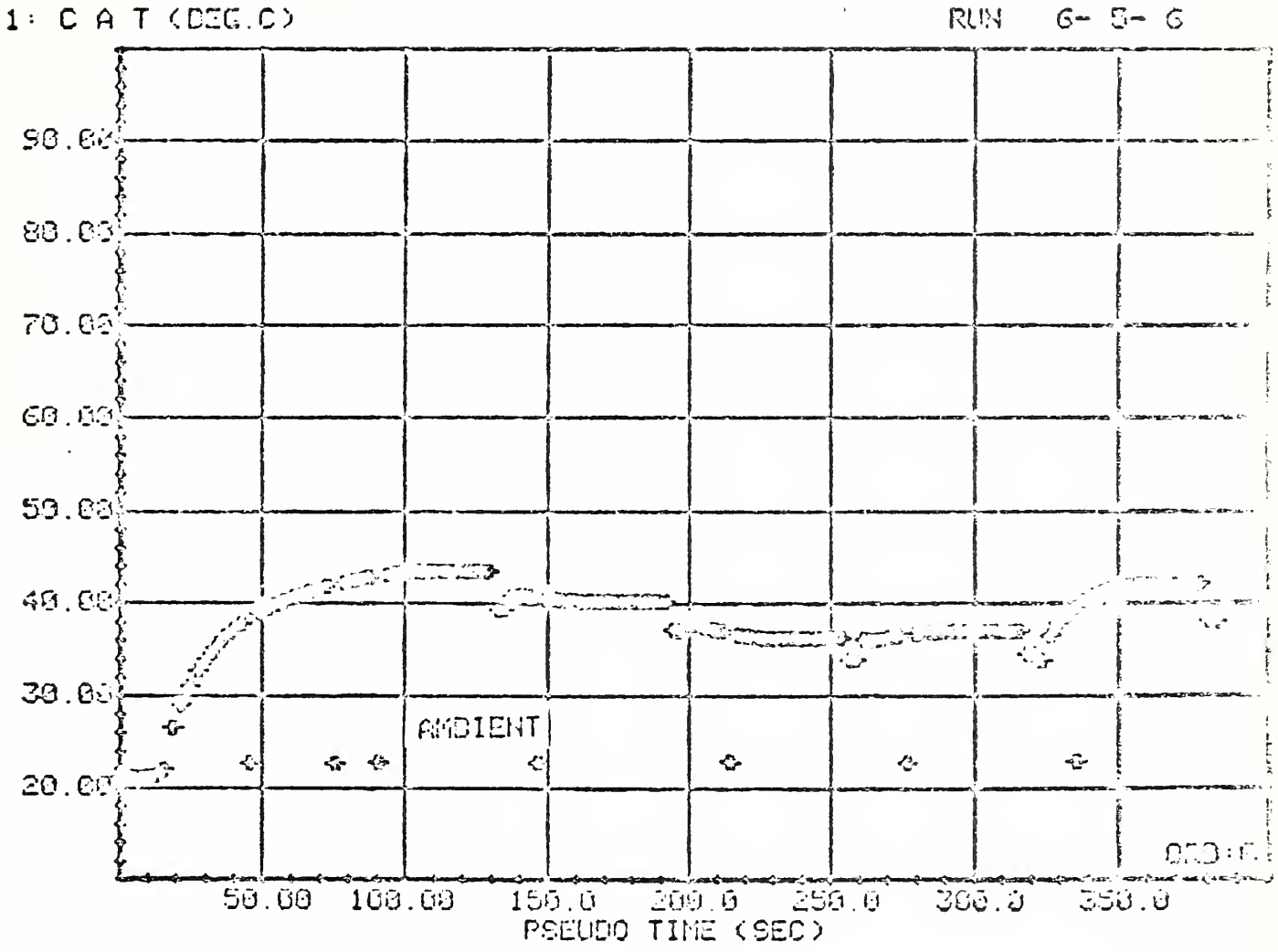
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1301,1041,781,1041
6.	INFLATION PRESSURE (PSI):	35,44,26 REG

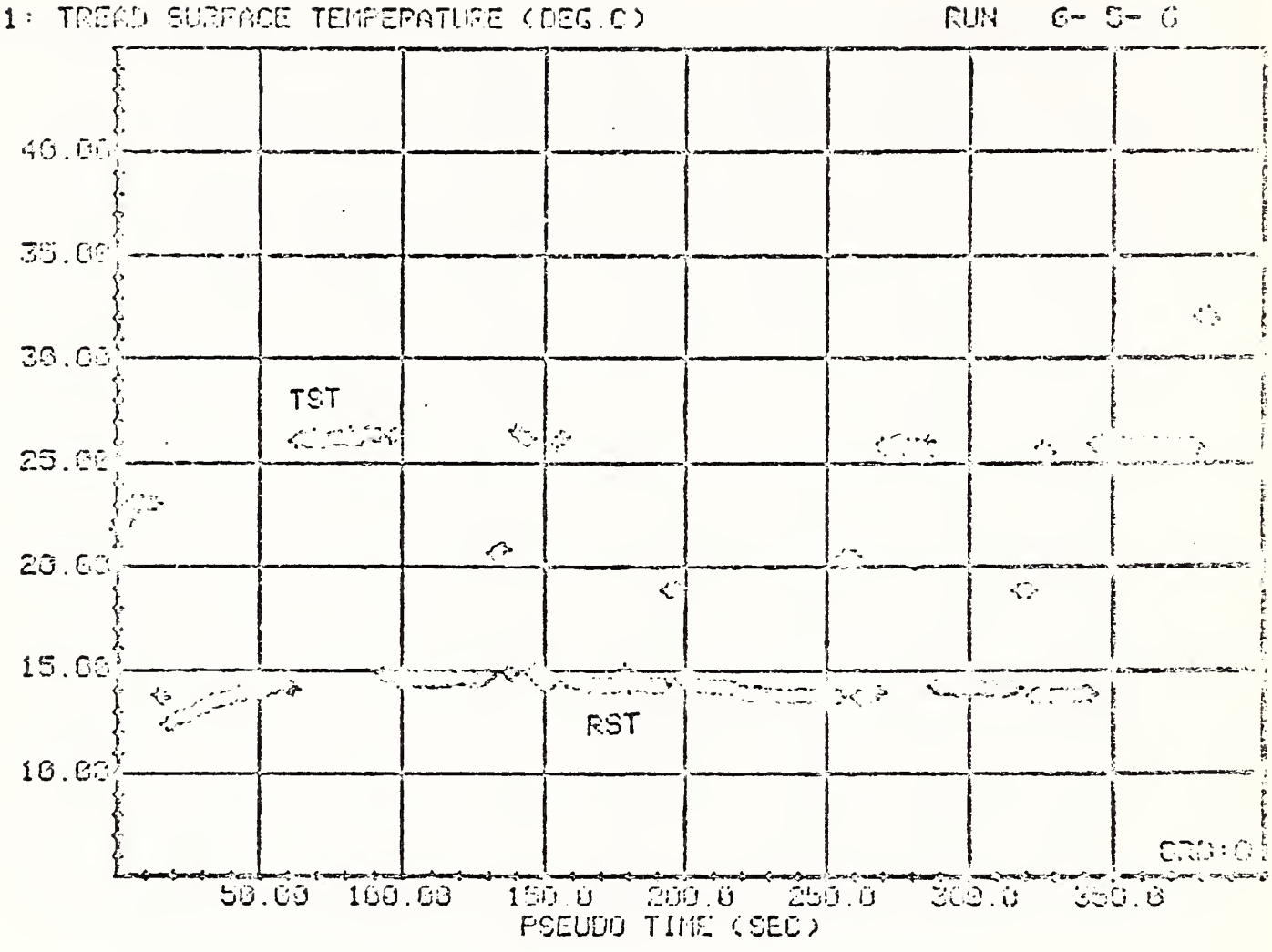

1: F R (LB)
RUN 6- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 6- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
050.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 6- 5- C
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 6- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: C A T (DEG.C)
RUN 6- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG.C)
RUN 6- 5- 6
40.00
35.00
30.00
25.00
20.00
15.00
10.00
TST
RST
CRN:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

6-5-6 A.V.L. LB	6-5-6 F.R. LB	6-5-6 C.A.T DEG.C	6-5-6 T.S.T DEG.C	6-5-6 P PSI	6-5-6 R.L. IN	6-5-6 F.Z. LB
1311.	10.61	43.75	14.7	34.8	11.12	-12[illegible]7.
1053.	8.55	40.52	14.5	34.8	11.[illegible]	-1[illegible]3.
791.	6.42	36.49	13.9	34.8	11.[illegible]	-[illegible].
1030.	7.78	37.29	14.2	43.8	11.8	-1[illegible]9.
1055.	10.	42.37	25.9	25.8	11.09	-10[illegible].

6-5-6 A.V.L. LB	6-5-6 S.F.R.	6-5-6 S C.A T.	6-5-6 S I S T.	6-5-6 S.P	6-5-6 S.R.R.	6-5-6 S.F.Z.
1311.	0.073	0.814	0.085	0.010	0.	1.[illegible]
1052.	0.004	0.822	0.251	0.	0.	0.317
791.	0.052	0.[illegible]	0.093	0.	0.	1.401
1058.	0.076	0.[illegible]	0.073	0.812	0.[illegible]	0.[illegible]
1050.	0.048	0.041	0.073	0.021	0.[illegible]2	0.[illegible]1

RUN NUMBER...: 7- 5- 6 DATE: 2/10/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

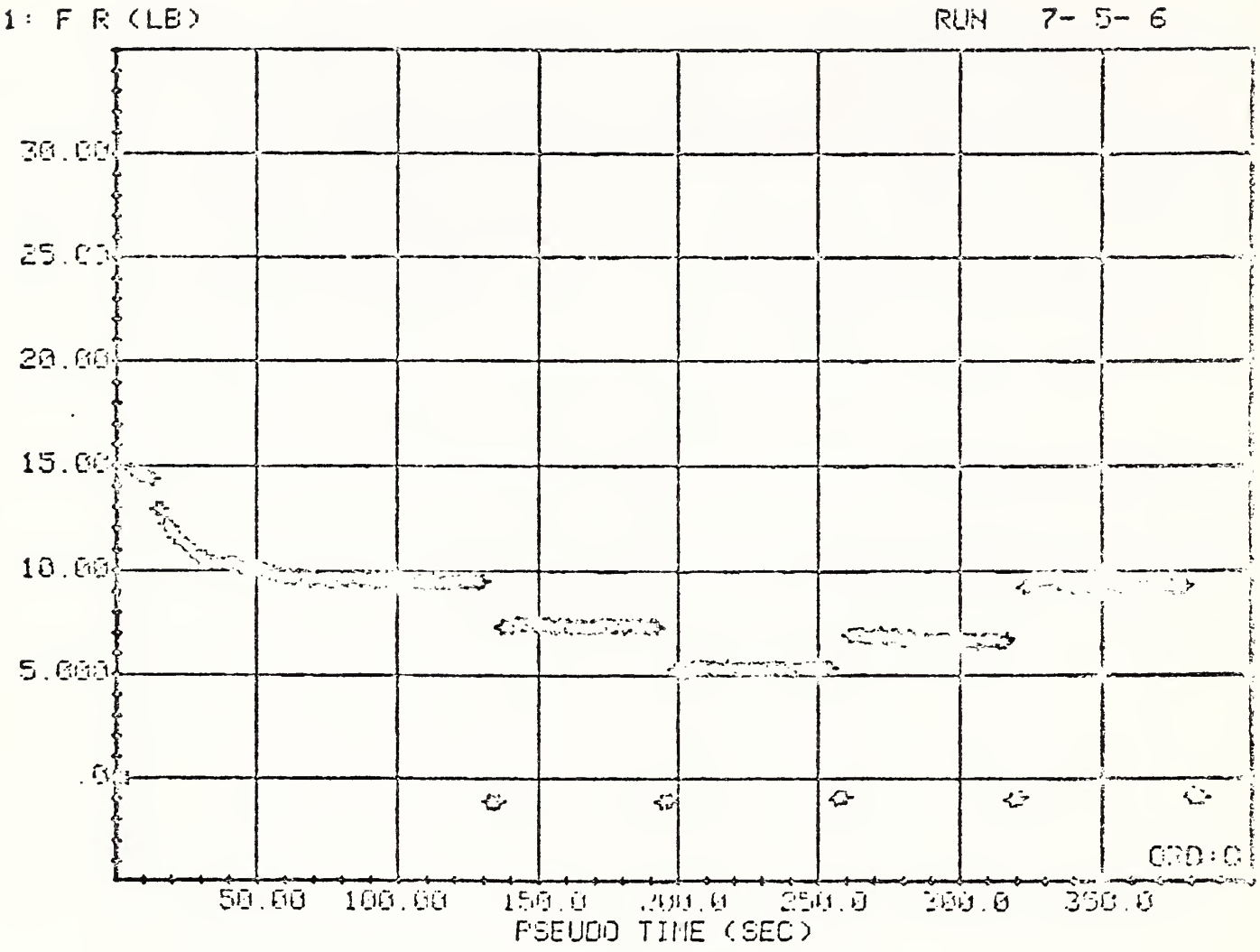
SPONSOR.....: T S C DATA FILTERS: .083 HZ

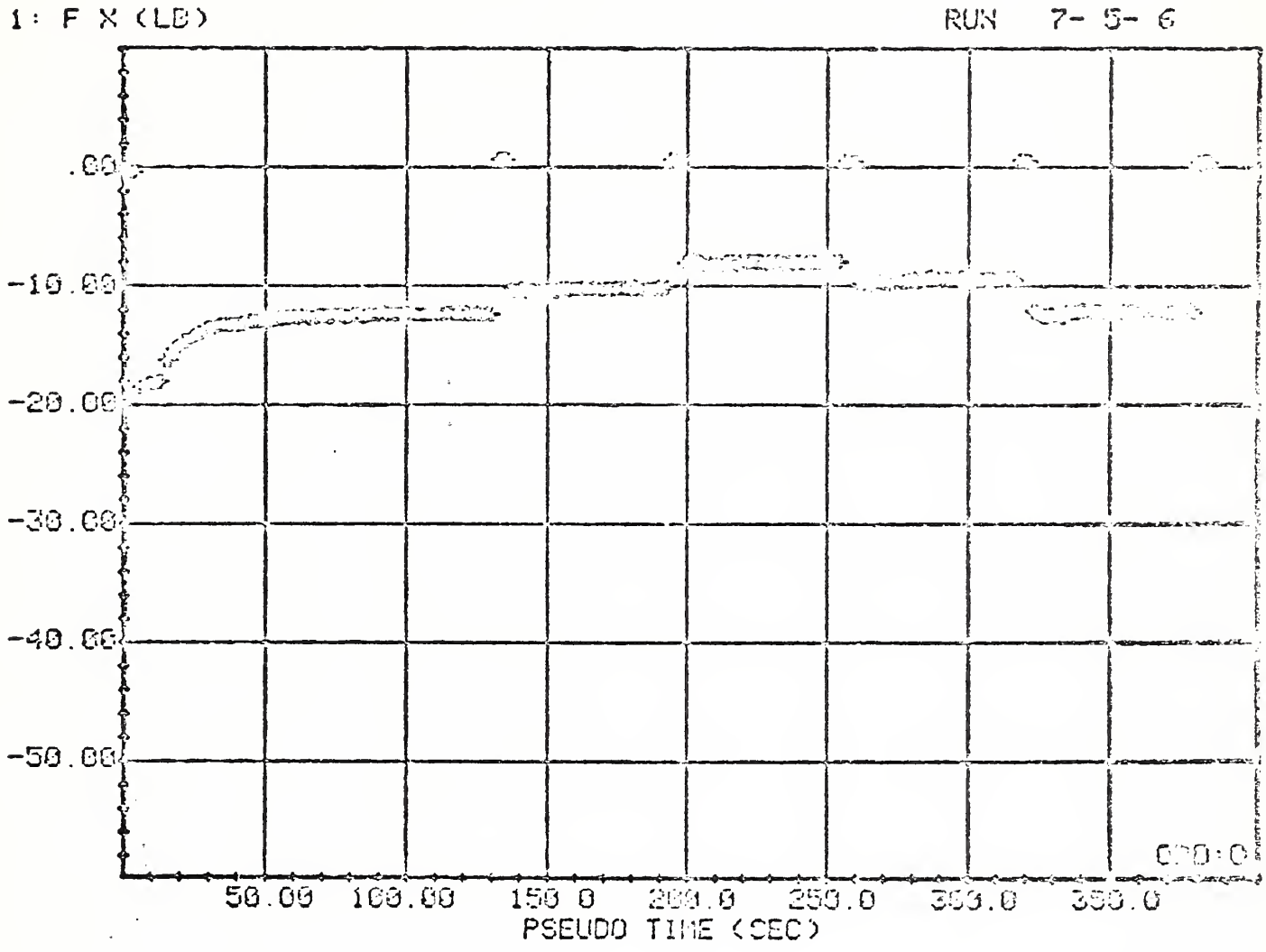
TIRE:
SPONSOR CODE: UNI 9-31181
TIRE NUMBER: 7- 5- 6
SIZE.....: P 185/80 R 13

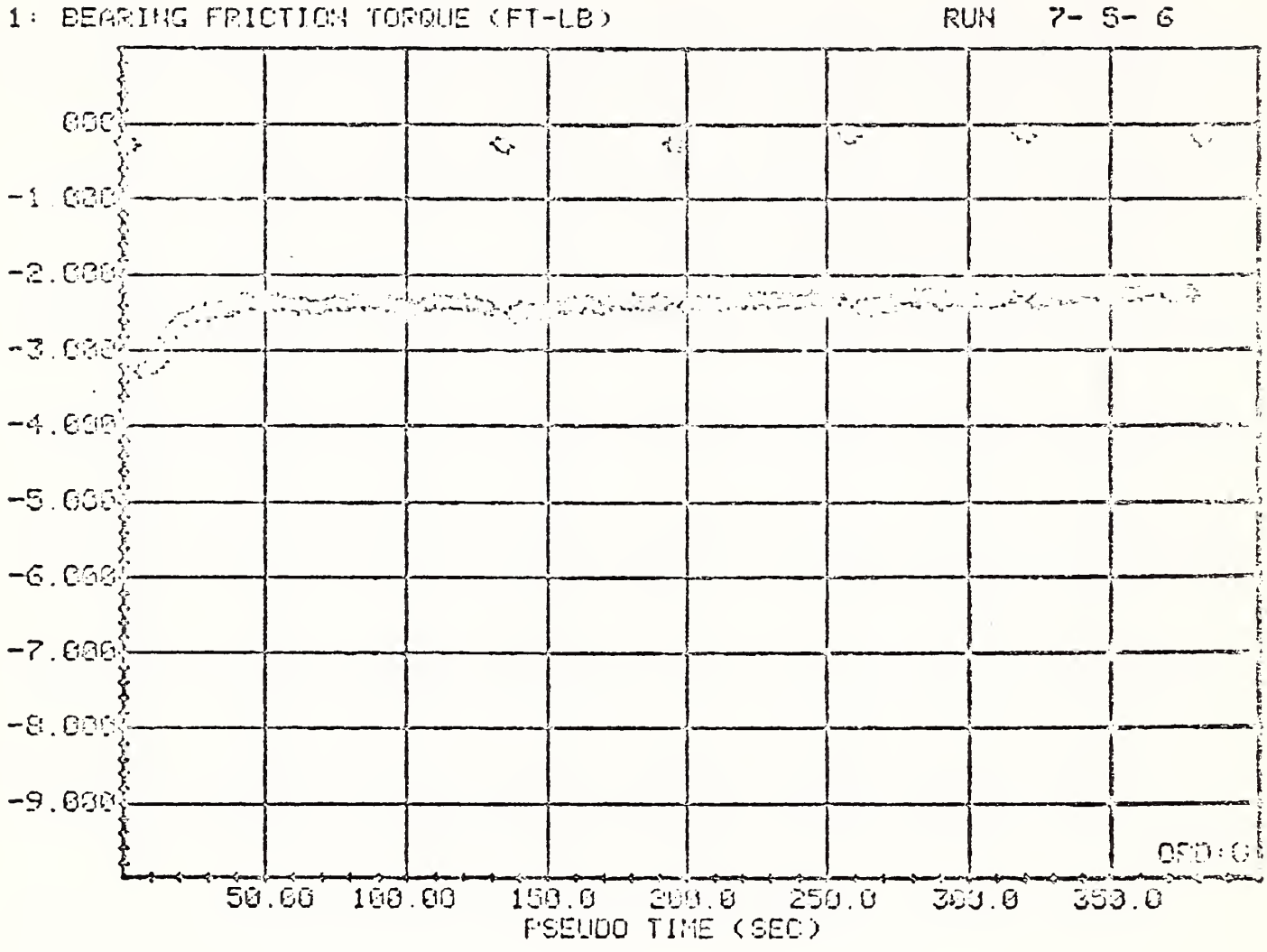
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 85
WATER DEPTH: DRY

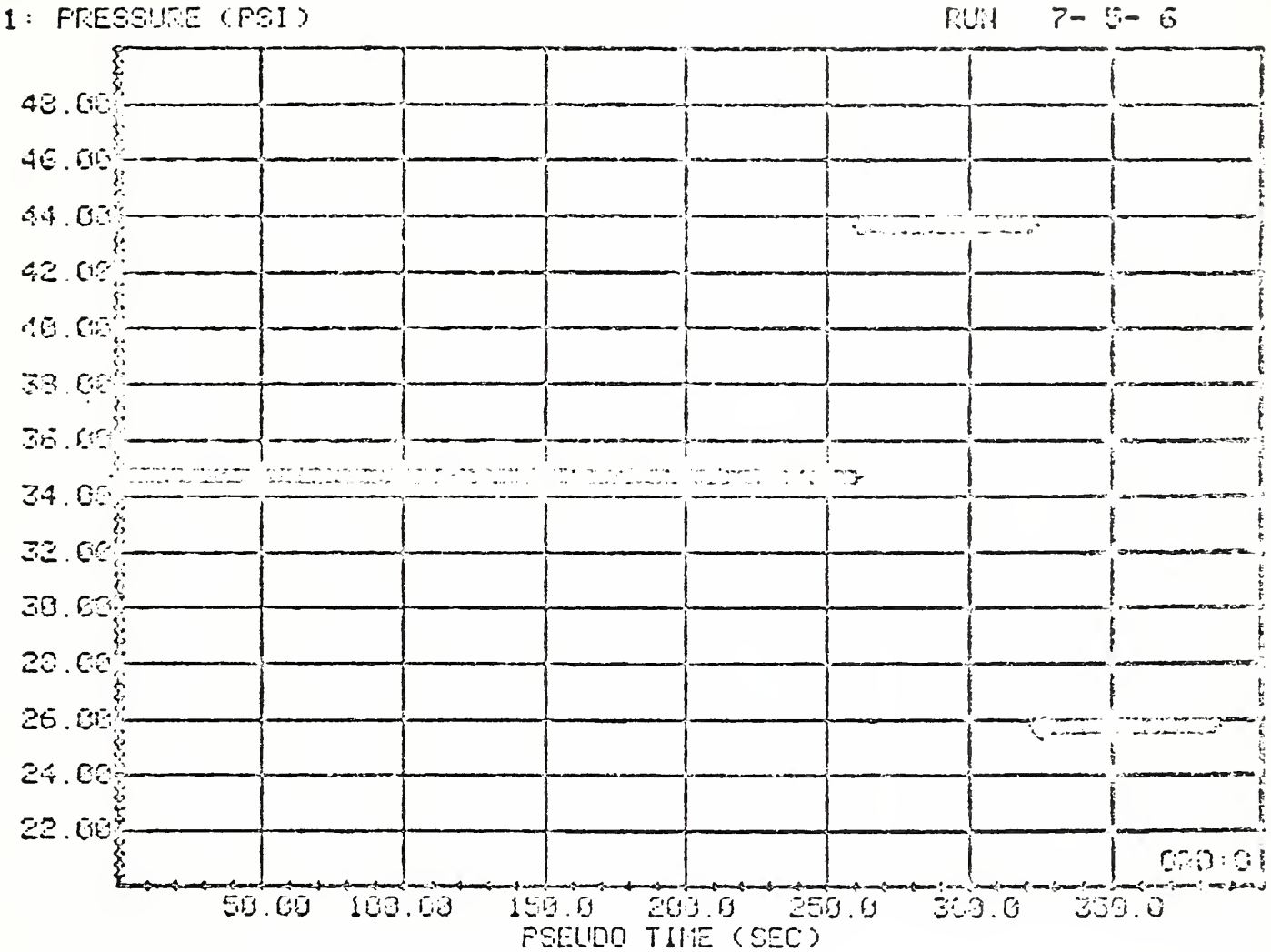
NOMINAL VALUES OF TEST PARAMETERS

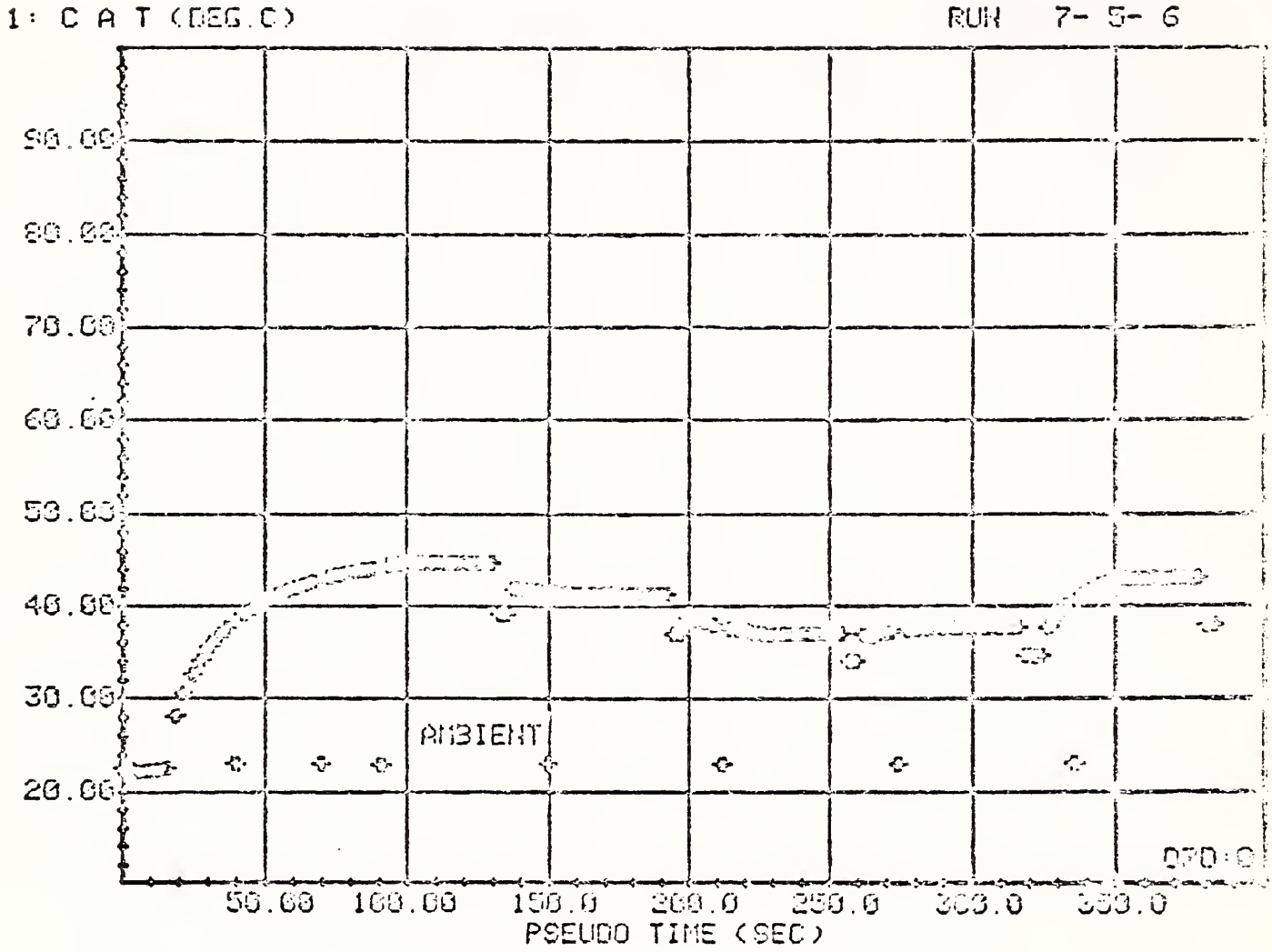
1. VELOCITY (MPH): 50
2. SLIP RATIO: FREE ROLLING
3. SLIP ANGLE (DEG): 0
4. INCLINATION ANGLE (DEG): 0
5. VERTICAL LOAD (LB): 1301,1041,781,1041
6. INFLATION PRESSURE (PSI): 35,44,26 REG


1: F R (LB)
RUN 7- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 7- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 7- 5- 6
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 7- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: C A T (DEG.C)
RUN 7- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

7-5-6 A.V.L. LB	7-5-6 F.R. LB	7-5-6 C.A.T. DEG.C	7-5-6 T.S.T DEG.C	7-5-6 P. PSI	7-5-6 R.L. IN	7-5-6 F.Z. LB
1313.	10.75	45.07	27.	34.8	11.13	-11[illegible].
1052.	8.59	41.64	15.	34.8	11.[illegible]	-10[illegible].
796.	6.3	37.32	25.1	34.8	11.07	-[illegible].
1052.	7.7	38.1	25.6	43.8	11.0	-10[illegible].
1052.	10.25	43.44	14.6	25.9	11.1	-10[illegible].

7-5-6 A.V.L. LB	7-5-6 S.F.R	7-5-6 S.C.A T.	7-5-6 S T.S T.	7-5-6 S.P	7-5-6 S.R.R.	7-5-6 S.F.Z.
1313.	0.054	0.855	0.000	0.612	0.	0.[illegible]
1052.	0.057	0.622	0.066	0.619	0.	1.13[illegible]
790.	0.030	0.019	0.121	0.	0.	1.21[illegible]
1052.	0.057	0.023	0.076	0.	0.010	1.1[illegible]
1052.	0 030	0.649	0.093	0.612	0.	0.025

RUN NUMBER..: 8- 5- 6 DATE: 2/11/73

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

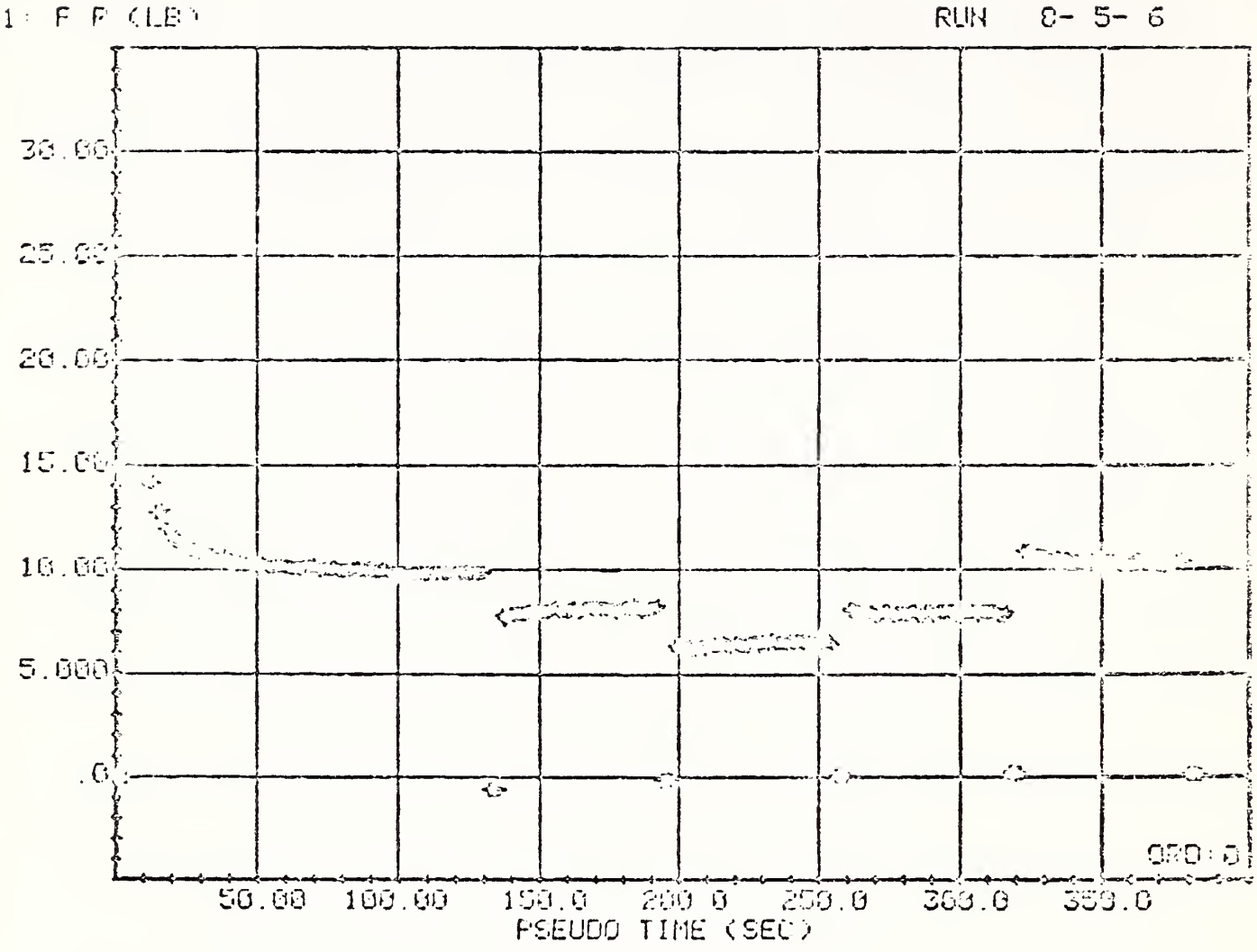
SPONSOR.....: TSC DATA FILTERS: .003 HZ

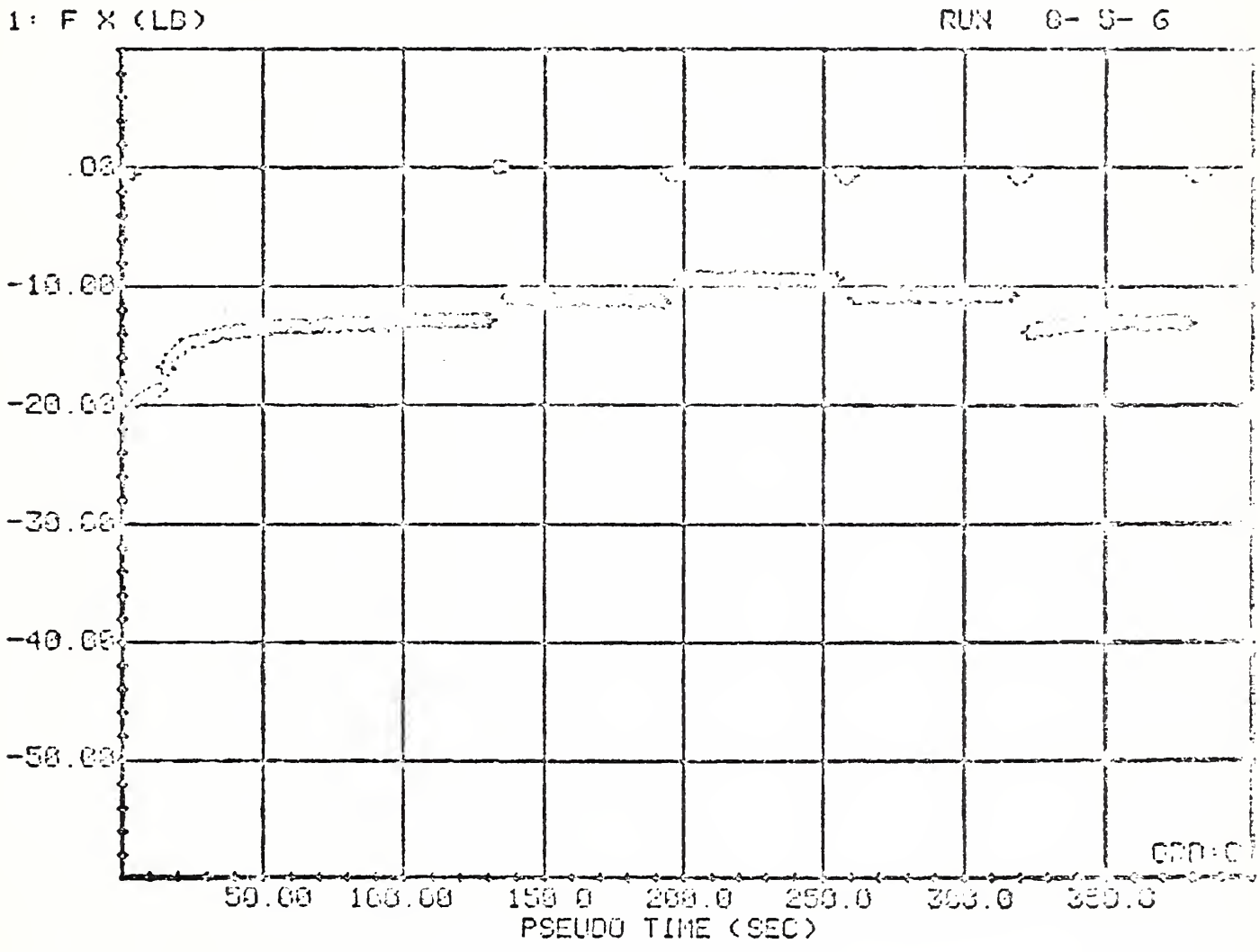
TIRE:
  SPONSOR CODE: UNI 16-31191
  TIRE NUMBER: 8- 5- 6
  SIZE.....: P185/80R13

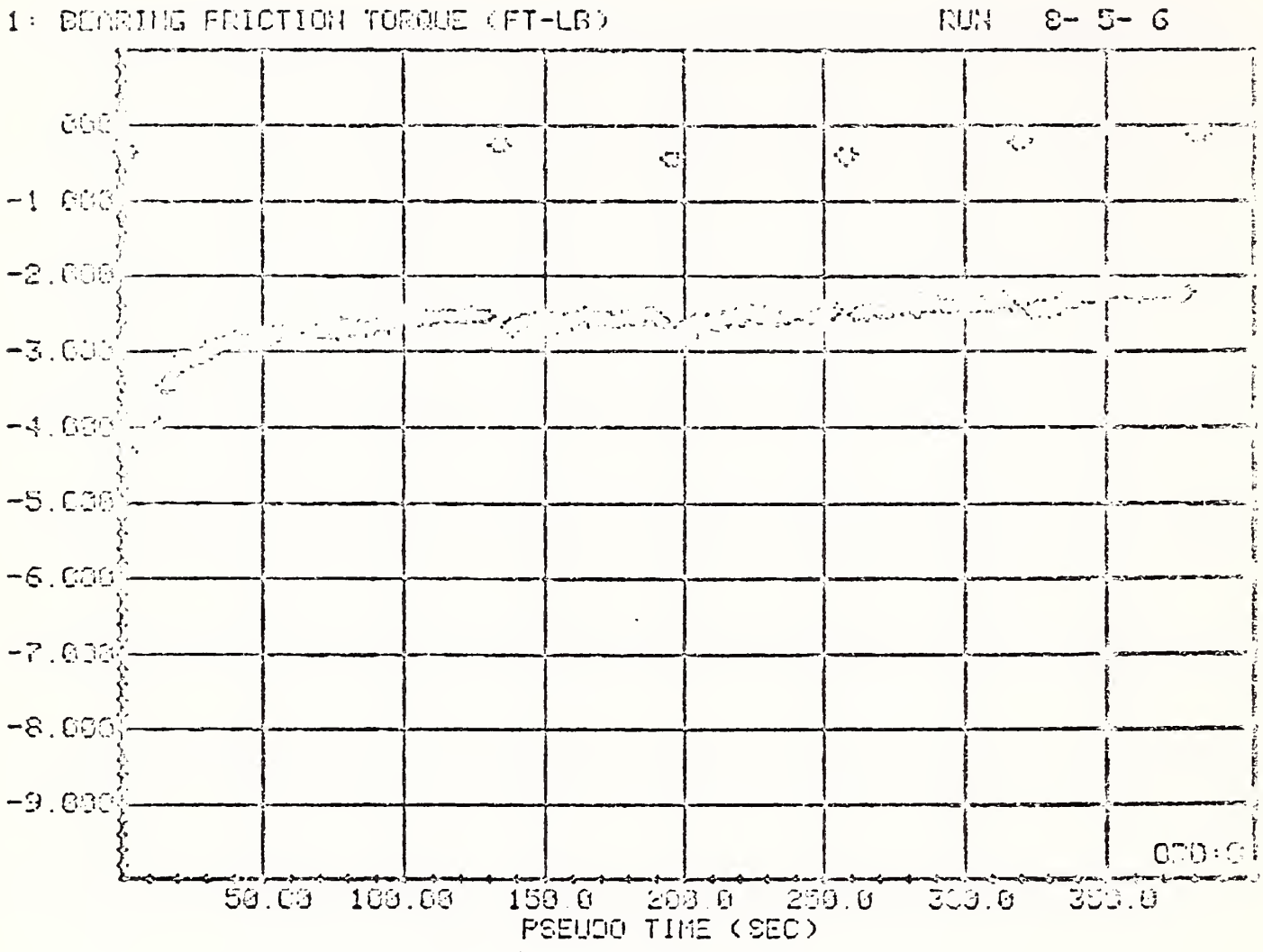
ROAD SURFACE:
  WET S/R...: 30
  DRY S/R...: 80
  WATER DEPTH: DRY

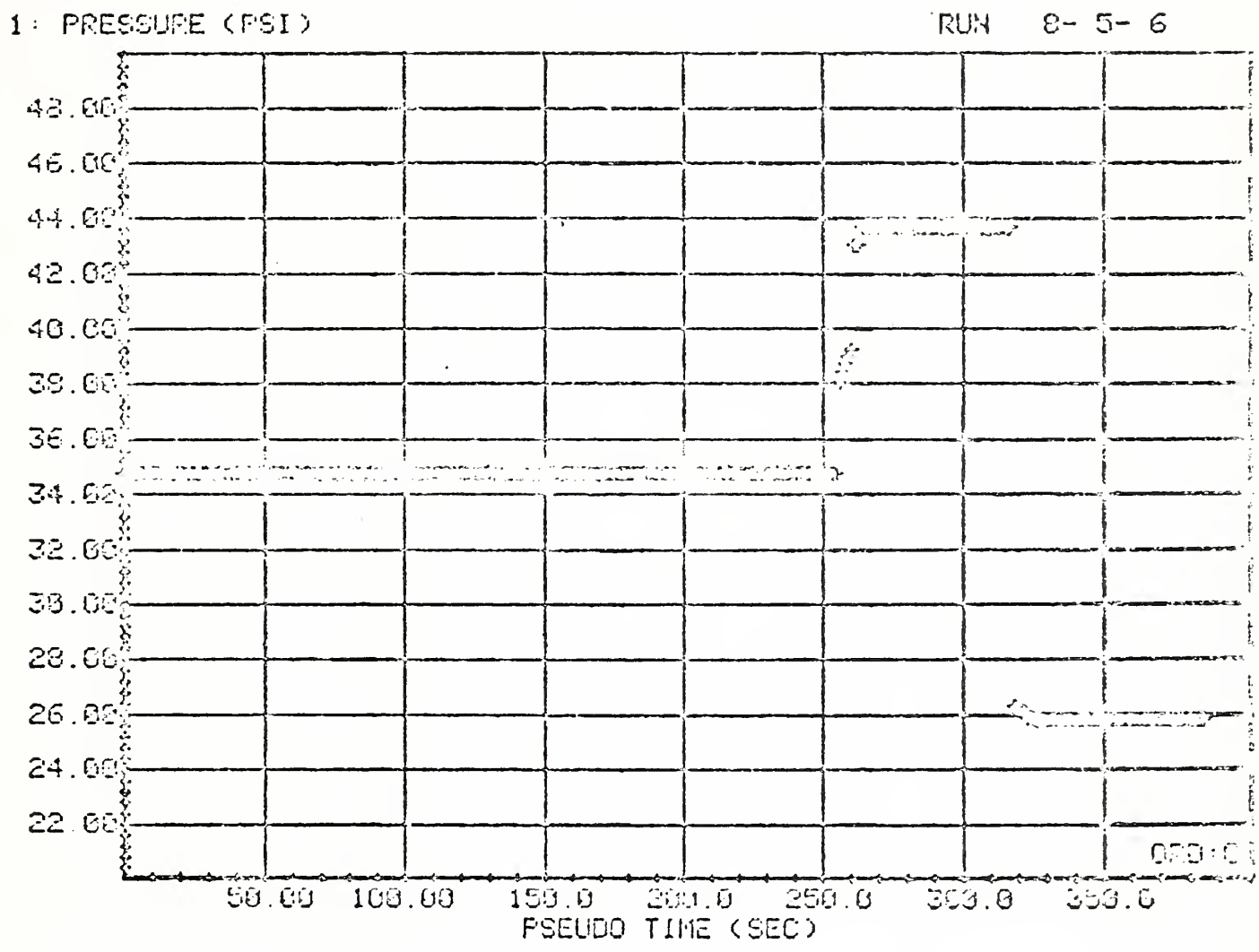
NOMINAL VALUES OF TEST PARAMETERS

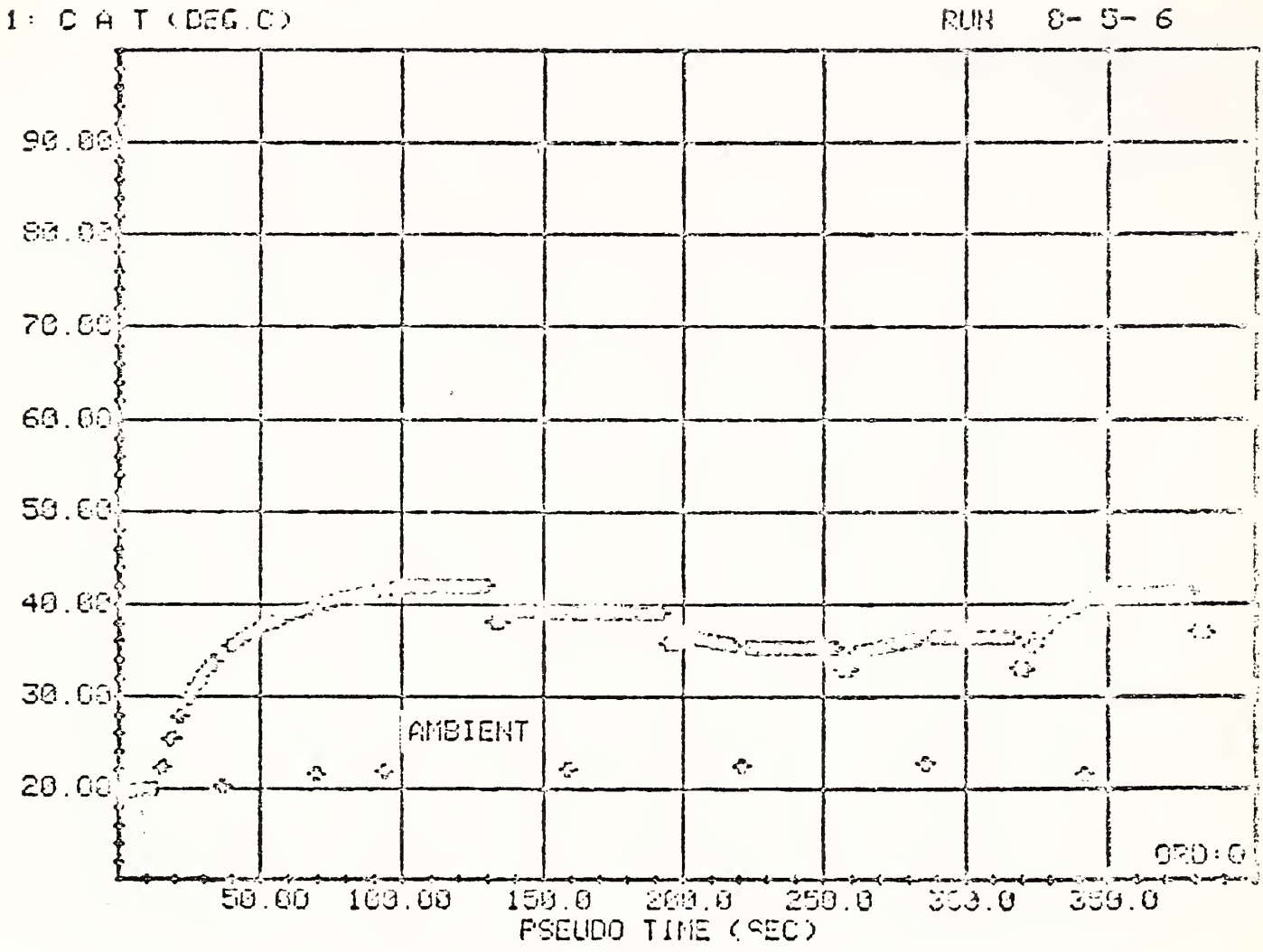
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1201,1041,781, 1041
6.	INFLATION PRESSURE (PSI):	30,44,26 REG


1: F P (LB)
RUN 8- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 8- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 8- 5- 6
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 8- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: C A T (DEG.C)
RUN 8- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
050:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

8-5-6 A.V.L. LB	8-5-6 F.R. LB	8-5-6 C.A.T DEG.C	8-5-6 T.S.T DEG.C	8-5-6 P. PSI	8-5-6 R.L. IN	8-5-6 F.Z. LB
1313.	10.6	42.37	24.1	34.9	11.12	-1[illegible]7.
1684.	8.46	39.45	24.3	34.9	11.03	-1[illegible]4.
791.	6.63	38.66	24.3	34.9	11.55	-1[illegible]5.
1084.	7.82	38.8	24.6	33.8	11.09	-1[illegible]6.
1082.	10.20	41.62	12.4	23.9	11.03	-1[illegible]3.

8-5-6 R.V.L. LB	8-5-6 S.F.R.	8-5-6 S.C.A.T.	8-5-6 S.T.S.T.	8-5-6 S.P	8-5-6 S.R.R.	8-5-6 S.F.Z.
1313.	0.012	0.033	0.017	0.020	0.032	0.777
1004.	0.091	0.053	0.032	0.	0.103	0.1[illegible]
791.	0.041	0.022	0.037	0.016	0.034	0.[illegible]
1054.	0.[illegible]	0.010	0.069	0.021	0.	0.[illegible]
1052.	0.699	0.022	0.168	0.	0.035	0.[illegible]2

RUN NUMBER..: 9- 5- 6 DATE: 2/11/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

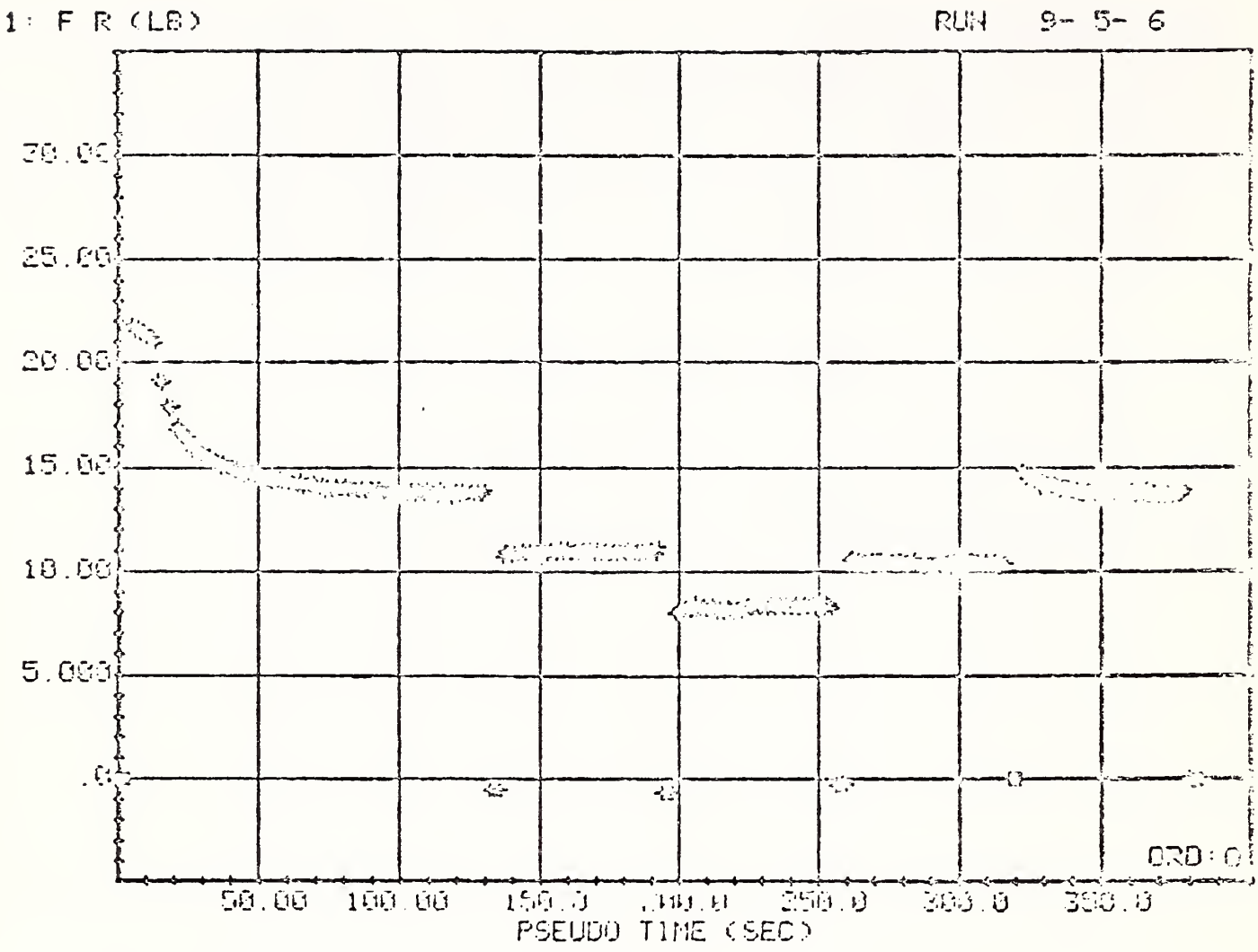
SPONSOR.....: TSC DATA FILTERS: .003 HZ

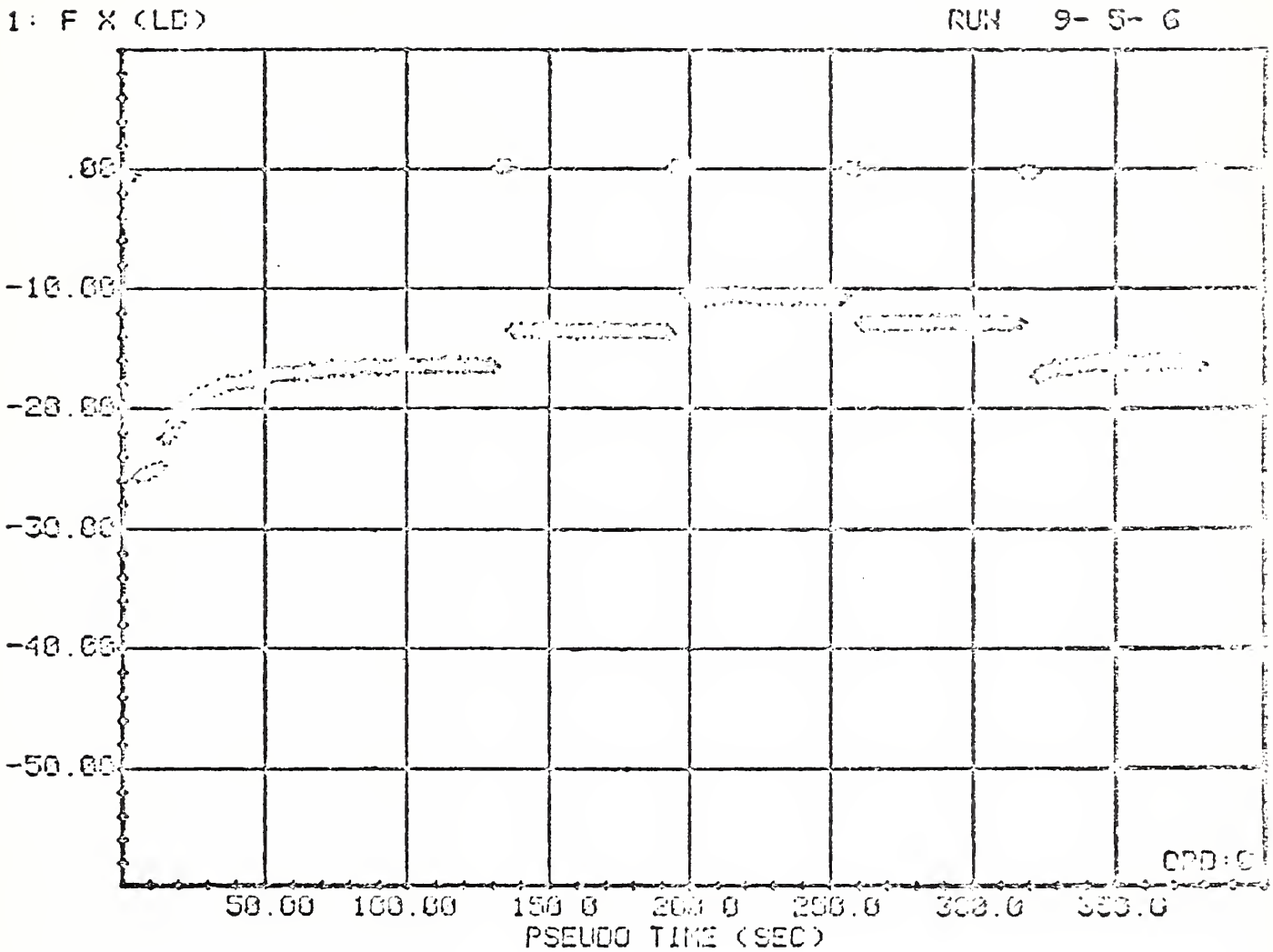
TIRE:
SPONSOR CODE: F1-R719
TIRE NUMBER: 9- 5- 6
SIZE... ....: P195/75R14

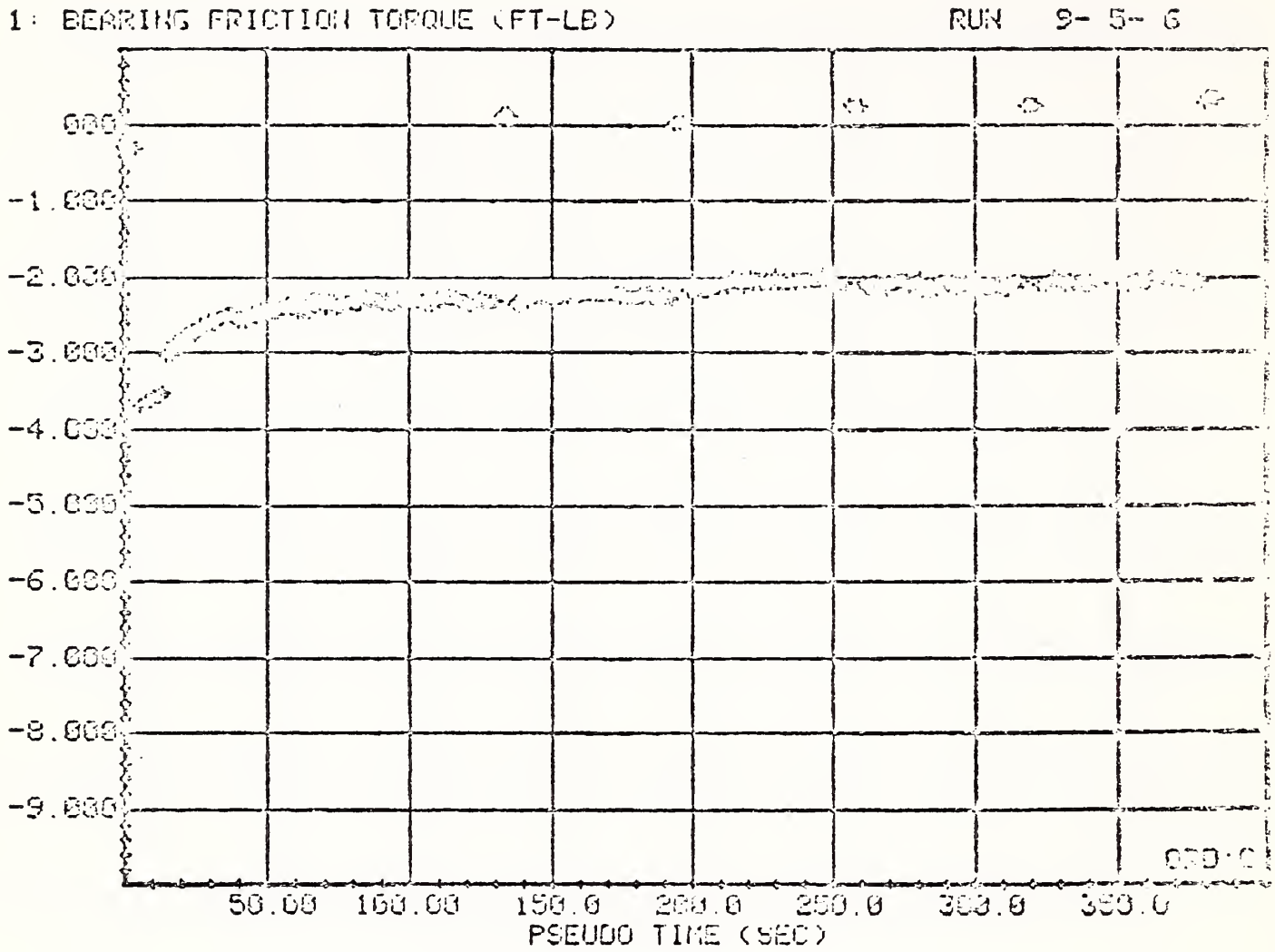
ROAD SURFACE:
WET S/N...: 33
DRY S/N...: 65
WATER DEPTH: DRY

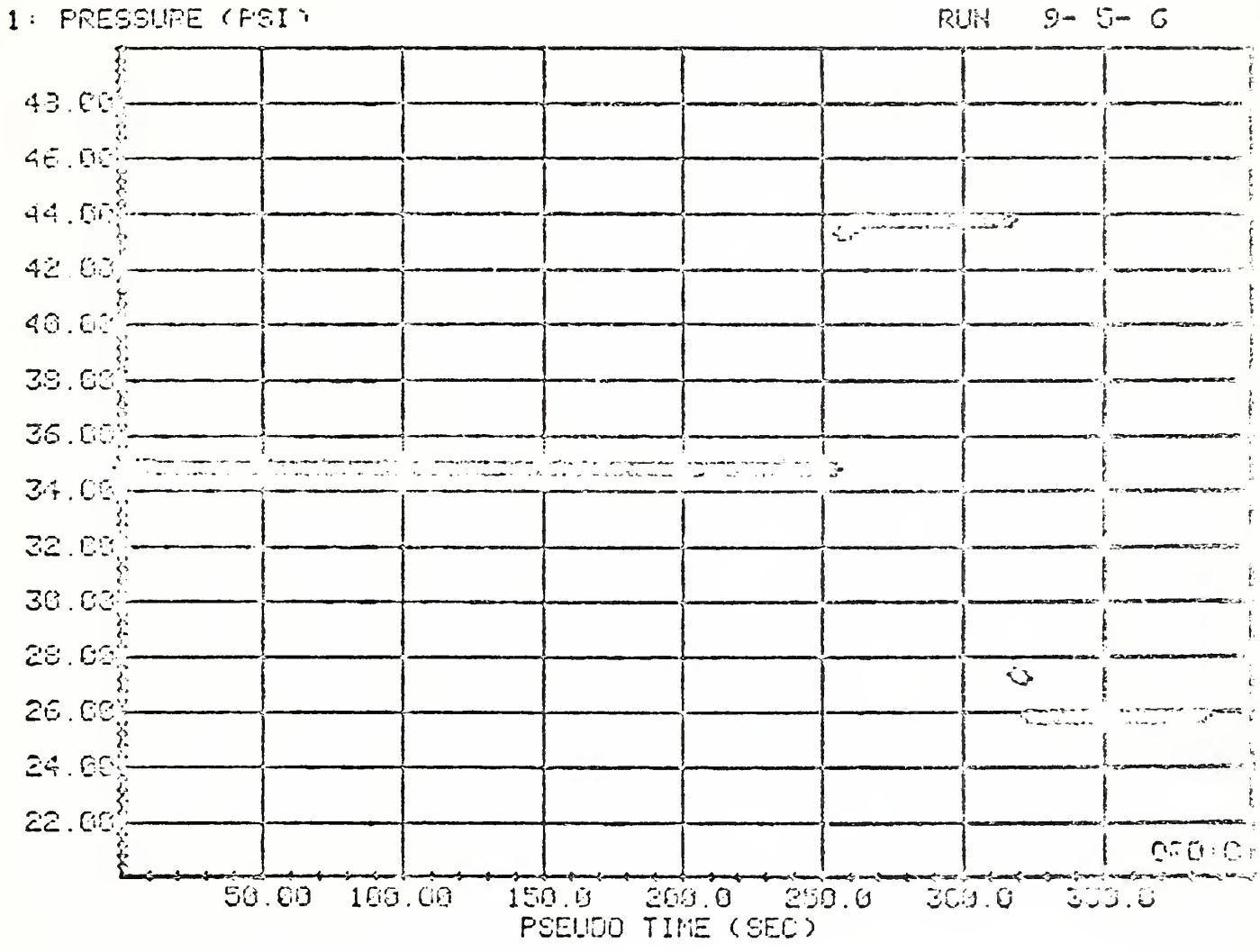
NOMINAL VALUES OF TEST PARAMETERS

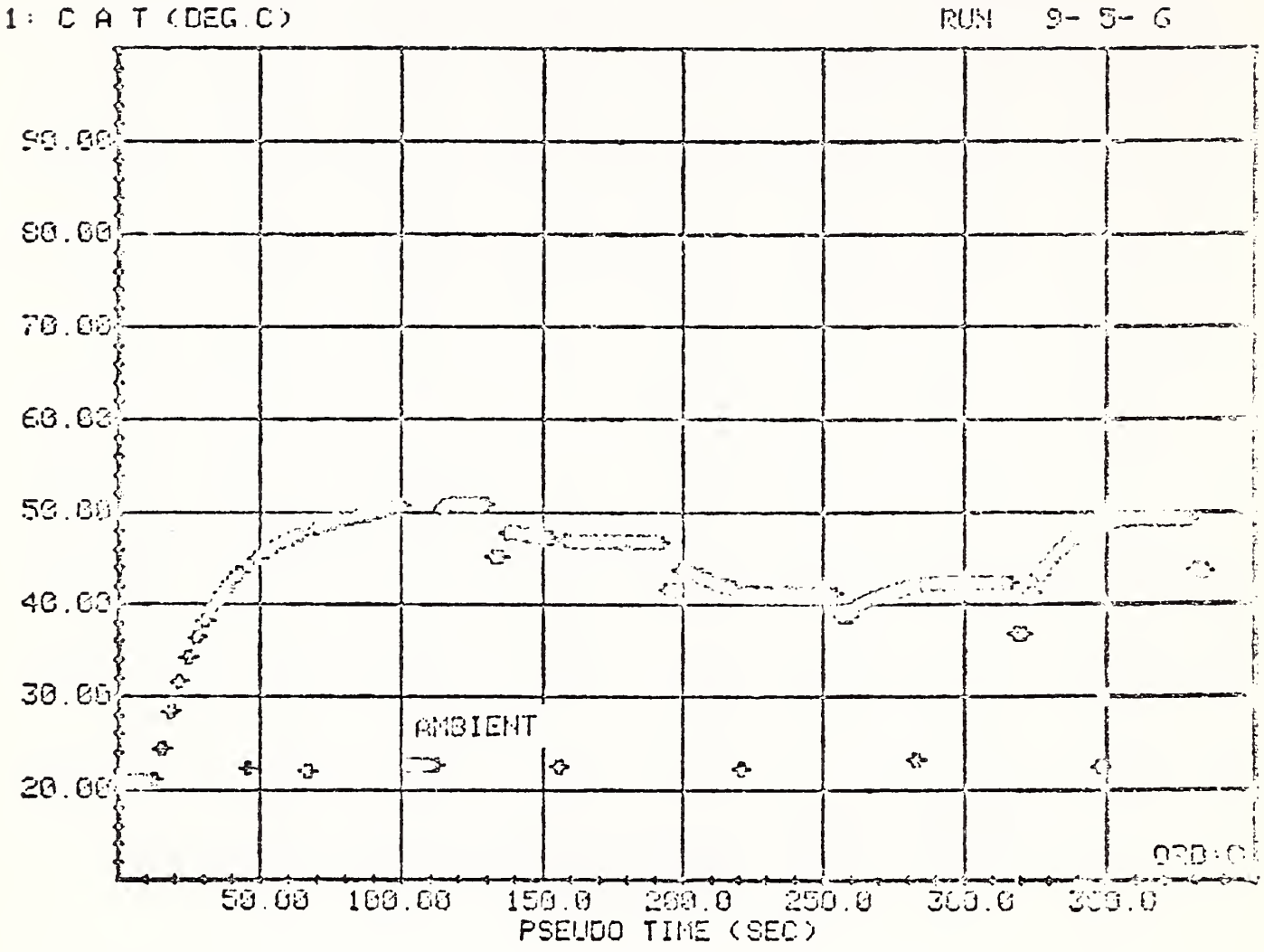
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1400,1123,840,1123
6.	INFLATION PRESSURE (PSI):	36,44,26 REG


1: F R (LB)
RUN 9- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)
ORD:0


1: F X (LB)
RUN 9- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 9- 5- 6
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 9- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
PSEUDO TIME (SEC)


1: C A T (DEG.C)
RUN 9- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
PSEUDO TIME (SEC)

9-5-6 A.V.L. LB	9-5-6 F.R. LB	9-5-6 C.A.T DEG.C	9-5-6 T.S.T DEG.C	9-5-6 P PSI	9-5-6 R.L. IN	9-5-6 F.Z. LB
1414.	14.24	51.19	27.6	34.9	11.69	-14[illegible]1.
1132.	11.6	47.15	25.8	34.9	11.91	-1121.
850.	8.49	41.55	14.1	34.9	12.13	-[illegible]2.
1130.	10.27	42.73	13.7	43.9	12.07	-119.1.
1132.	13.62	49.62	18.7	25.9	11.67	-1122.

9-5-6 A.V.L. LB	9-5-6 S.F.R.	9-5-6 S.C.H T.	9-5-6 S T S T.	9-5-6 S.P	9-5-6 S.R.R.	9-5-6 S.F.Z.
1414.	0.105	0.025	0.043	0.	0.002	0.057
1132.	0.104	0.026	0.035	0.012	0.004	0.074
859.	0.093	0.031	0.015	0.	0.	1.103
1139.	0.104	0.019	0.030	0.	0.005	0.509
1132.	0.123	0.033	5.019	0.016	0.002	1.401

RUN NUMBER..: 10- 5- 6 DATE: 2/11/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

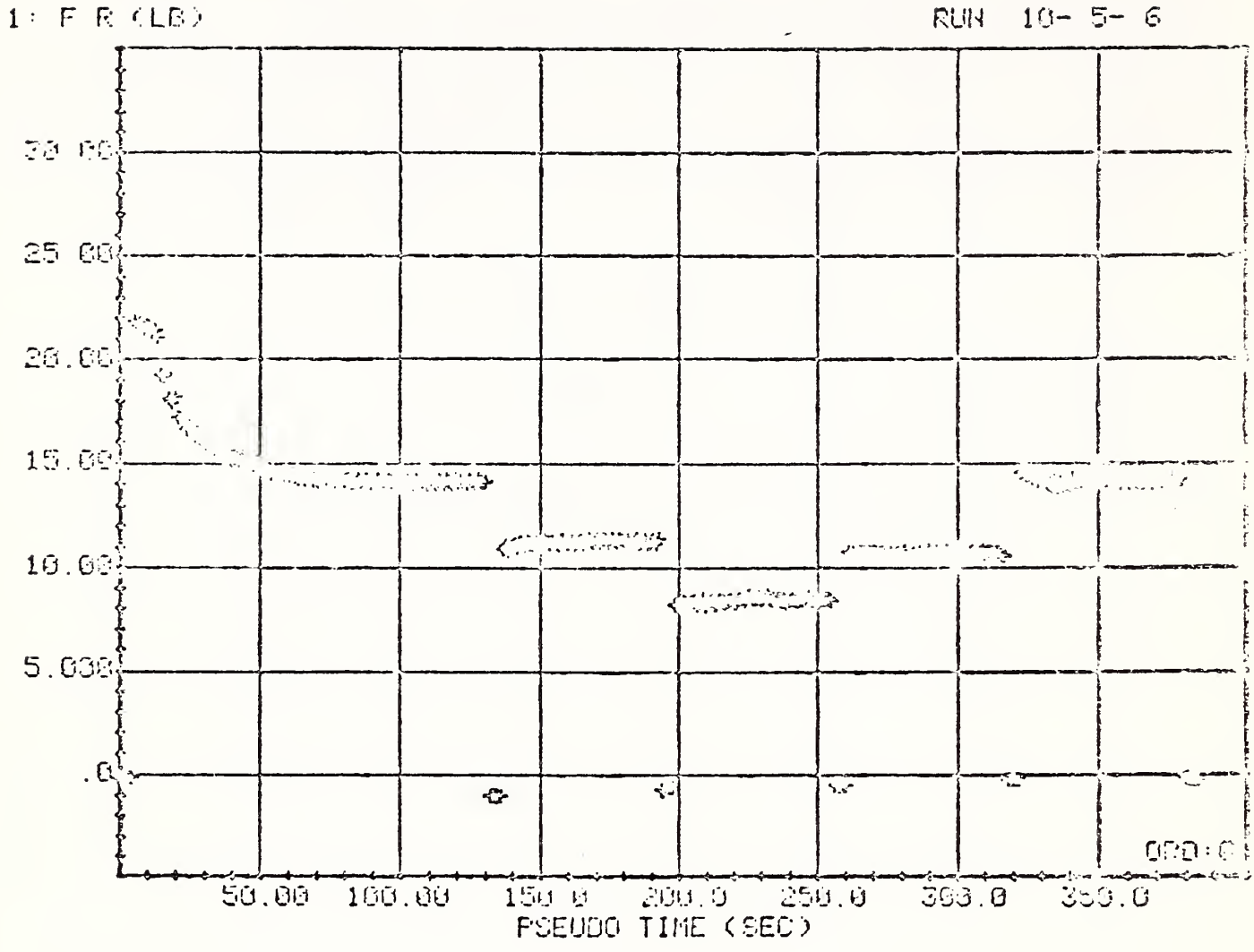
SPONSOR.....: TSC DATA FILTERS: .003 HZ

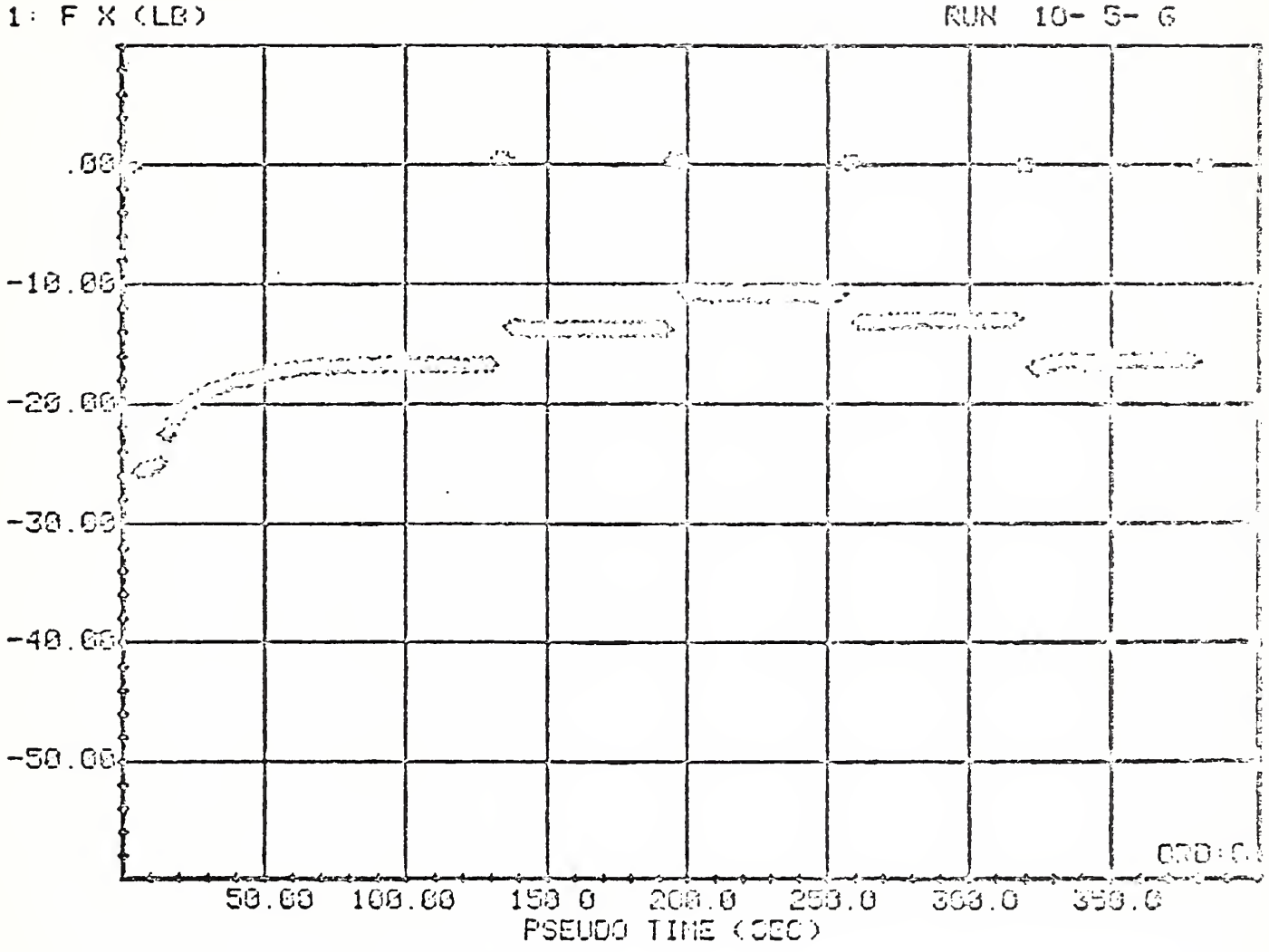
TIRE:
SPONSOR CODE: F1 R719
TIRE NUMBER: 10- 5- 6
SIZE.....: P195/75R14

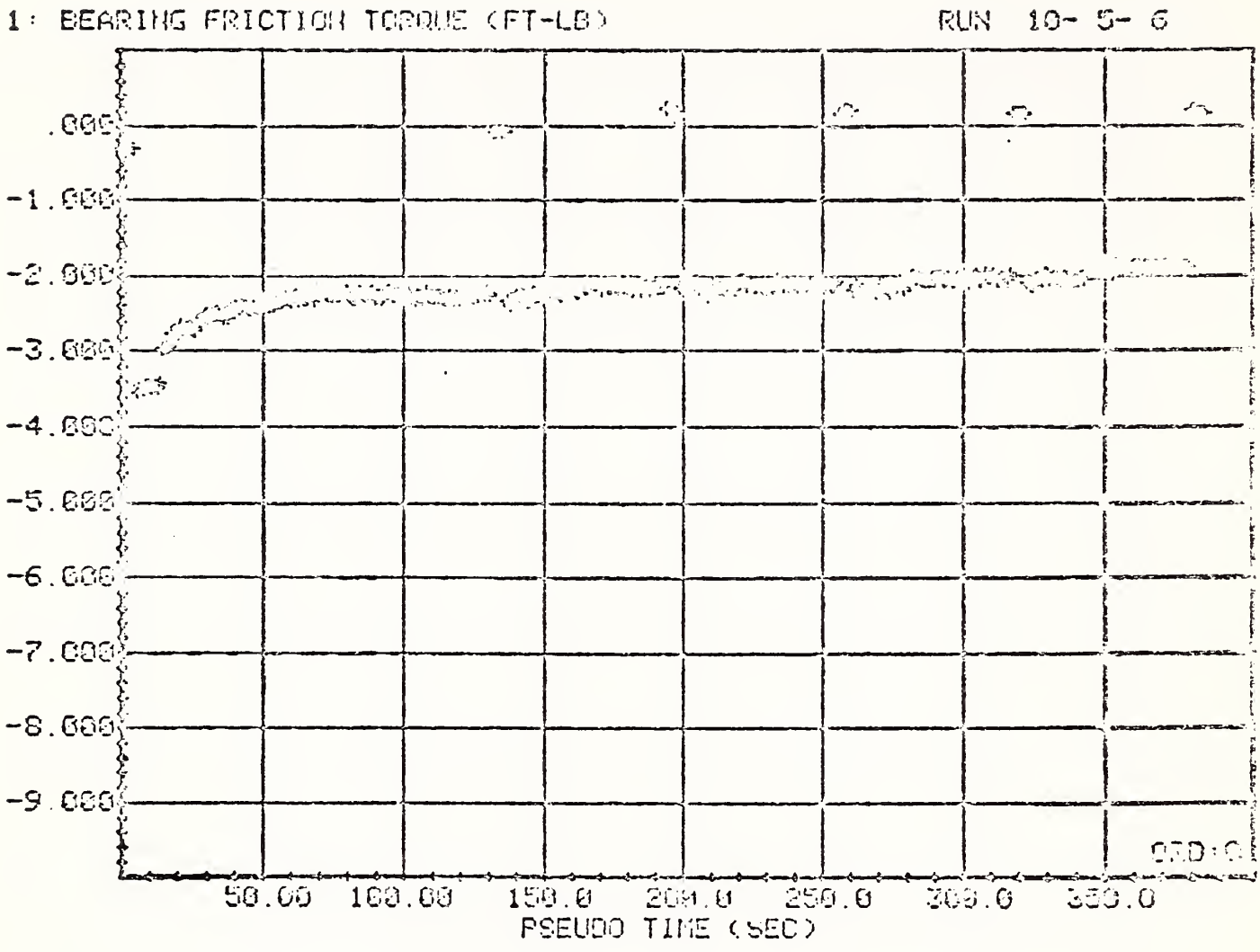
ROAD SURFACE:
WET S/N...: 39
DRY S/N...: 65
WATER DEPTH: DRY

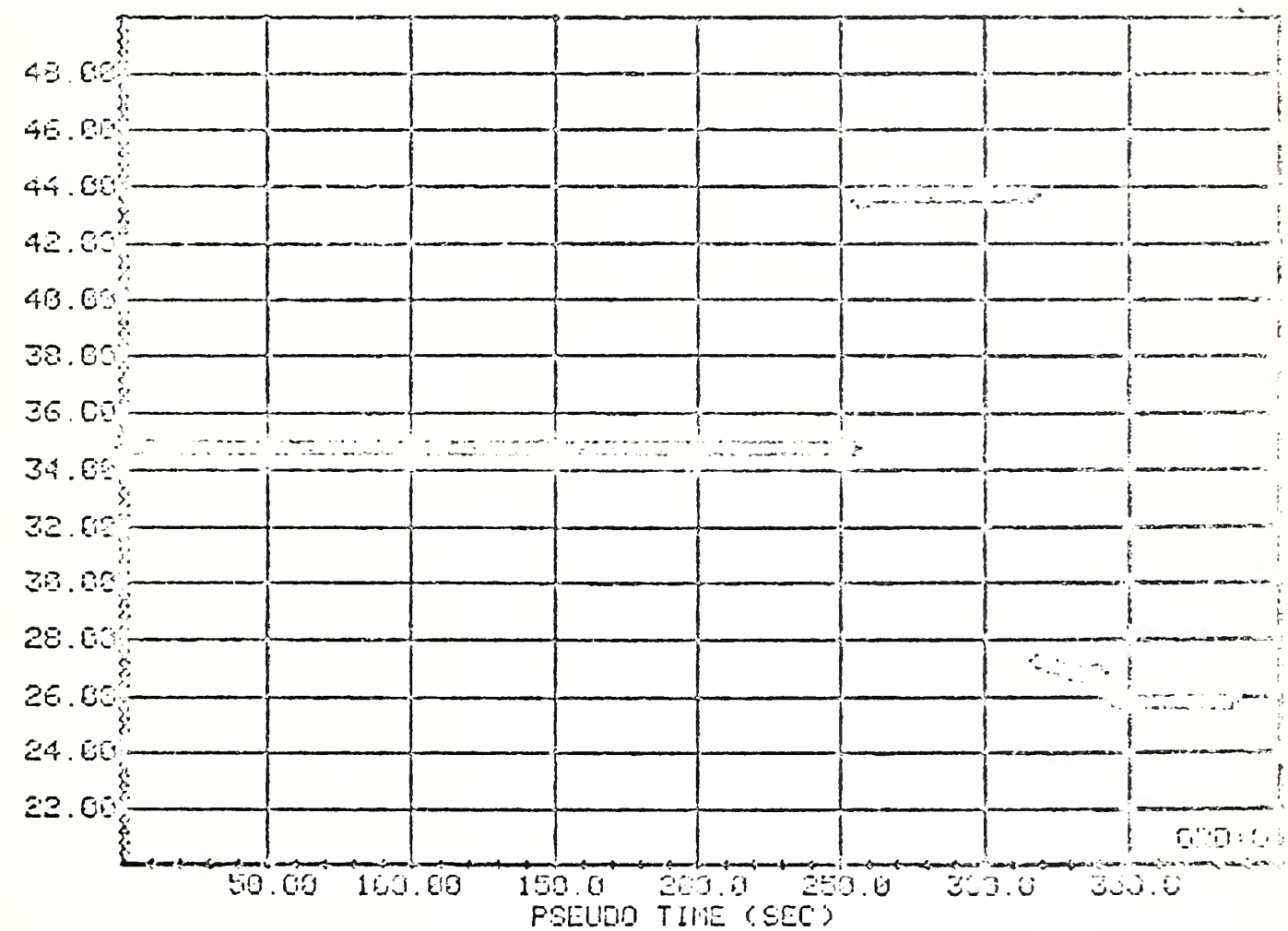
NOMINAL VALUES OF TEST PARAMETERS

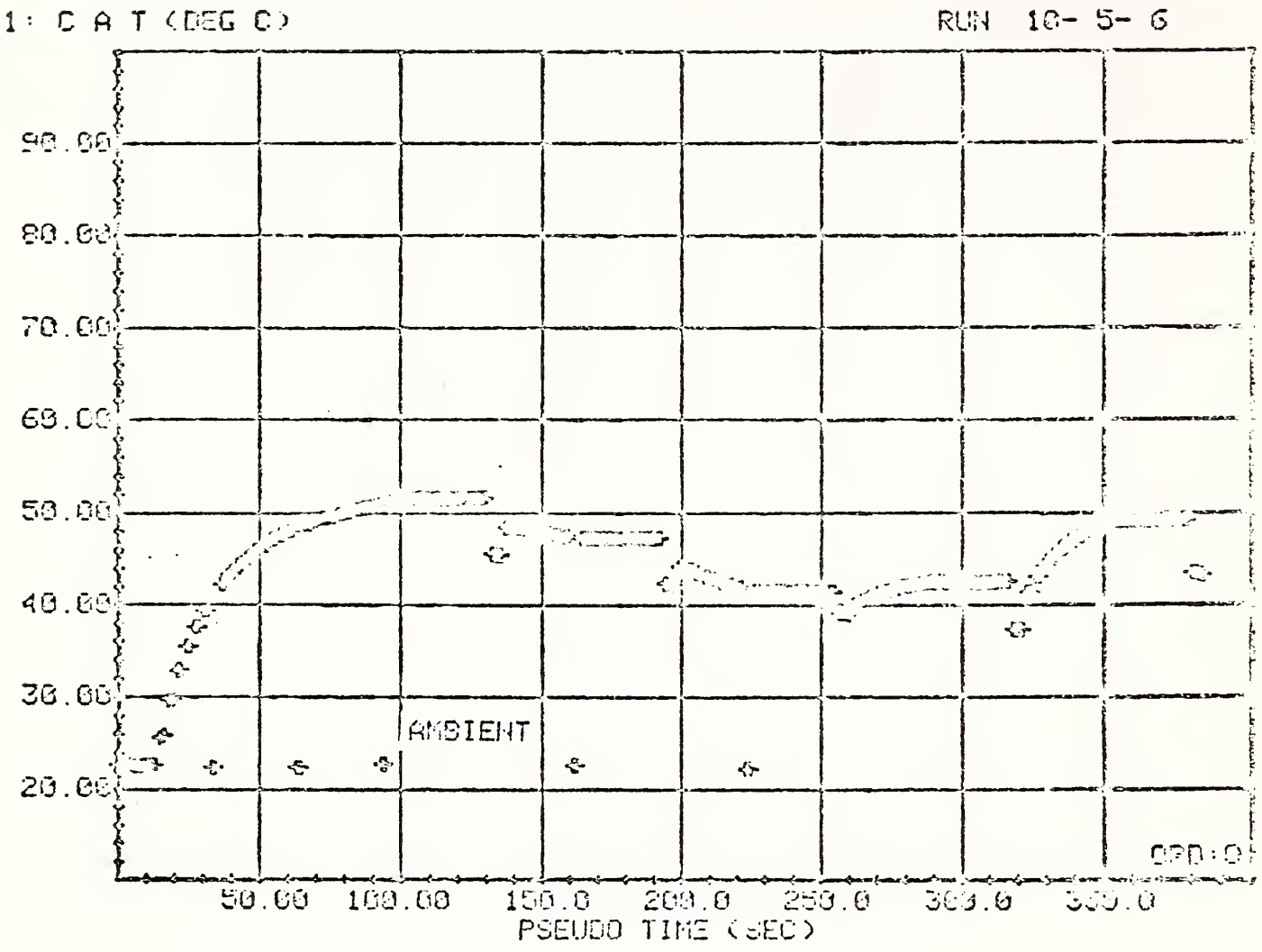
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1400,1120,840, 1120
6.	INFLATION PRESSURE (PSI):	38,44,26 REG


1: F R (LB)
RUN 10- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 10- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 10- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 10- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: C A T (DEG C)
RUN 10- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

10-5-6 A.V.L. LB	10-5-6 F.R. LB	10-5-6 C.A.T DEG.C	10-5-6 T.O.T. DEG.C	10-5-6 P. PSI	10-5-6 R.L. IN	10-5-6 F.Z. LB
1414.	15.14	51.93	288.	34.9	11.7	-1[illegible].
1131.	11.85	47.61	288.	34.9	11.92	-1[illegible].
856.	8.03	41.87	283.	31.9	12.10	-[illegible].
1130.	10.87	42.92	288.	43.8	12.03	-1[illegible].
1130.	14.24	49.6	283.	25.9	11.88	-1[illegible].

10-5-6 A.V.L. LD	10-5-6 S.F.R.	10-5-6 S.C.A T.	10-5-6 S.T.B T.	10-5-6 S.P	10-5-6 S.R.R.	10-5-6 S.F.Z.
1414.	0.000	0.633	0.	0.611	0.	0.[illegible]2
1131.	0.092	0.019	0.	0.	0.004	0.565
850.	0.076	0.019	0.	0.	0.	1.
1130.	0.000	0.020	0.	0.	0.003	0.675
1130.	0.032	0.032	0.	0.	0.	0.712

RUN NUMBER..: 11- 5- 6 DATE: 2/11/78

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

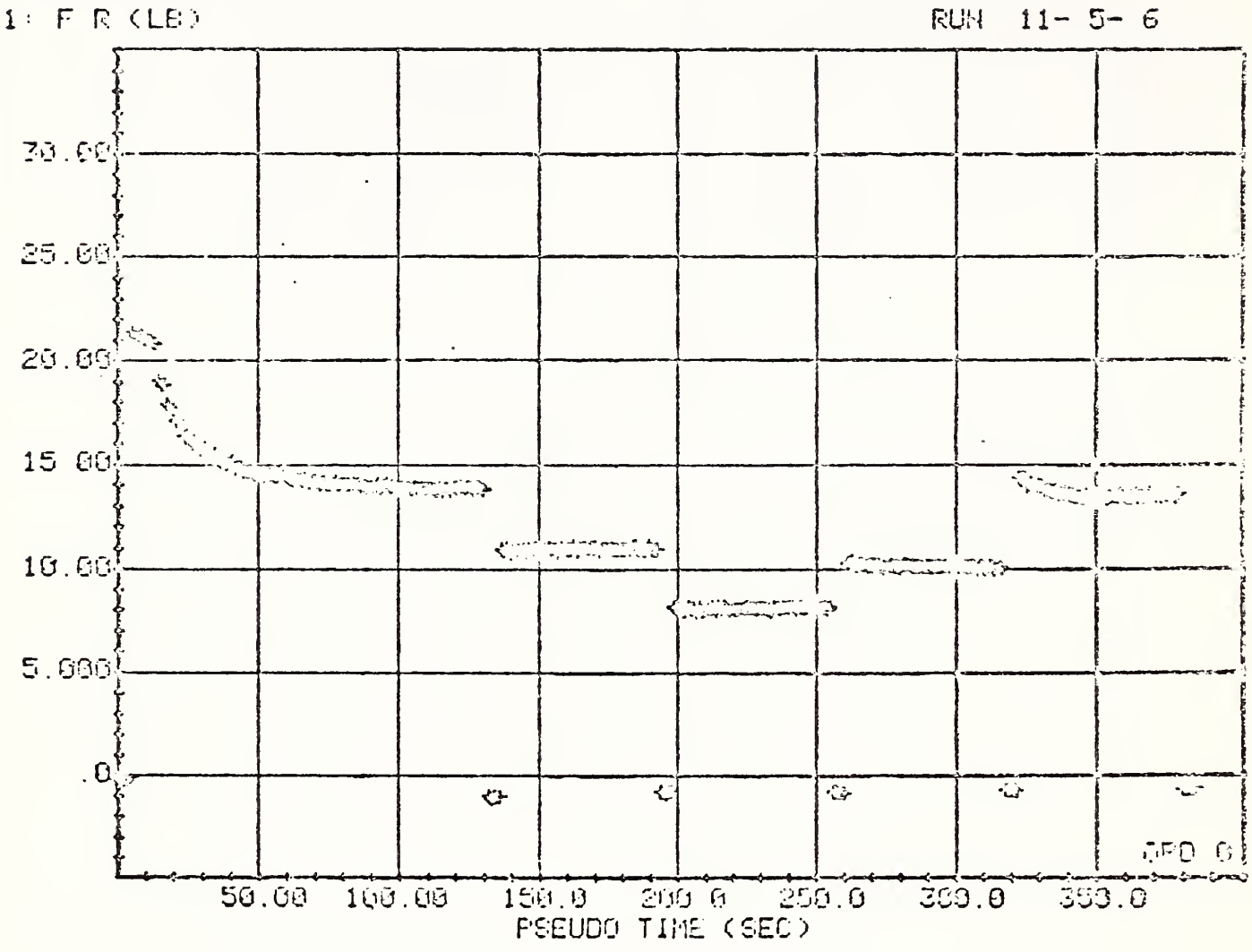
SPONSOR.....: TSC DATA FILTERS: .003 HZ

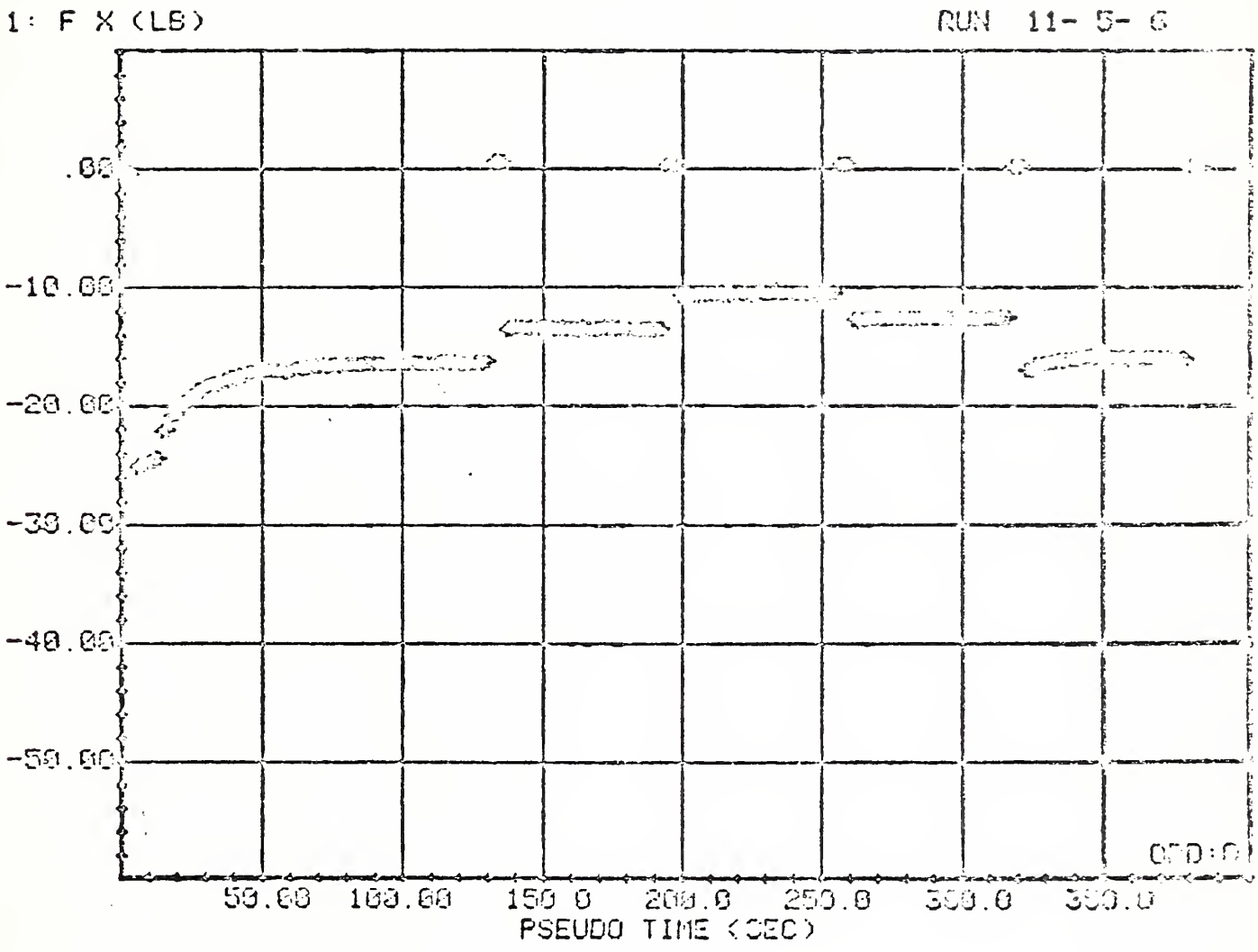
TIRE:
SPONSOR CODE: F1 R719
TIRE NUMBER: 11- 5- 6
SIZE.....: P195/75R14

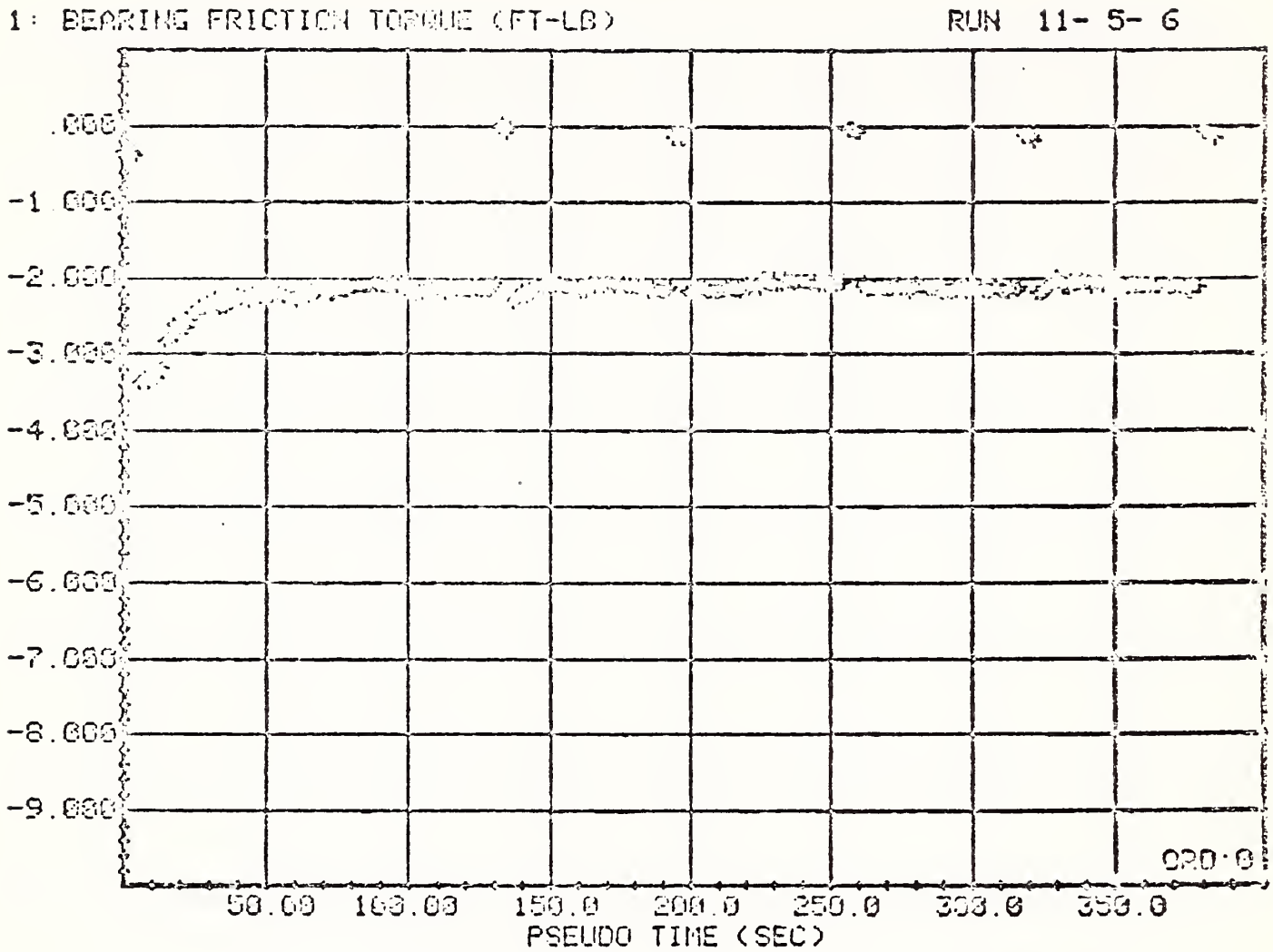
ROAD SURFACE:
WET S/N...: 38
DRY S/N...: 64
WATER DEPTH: DRY

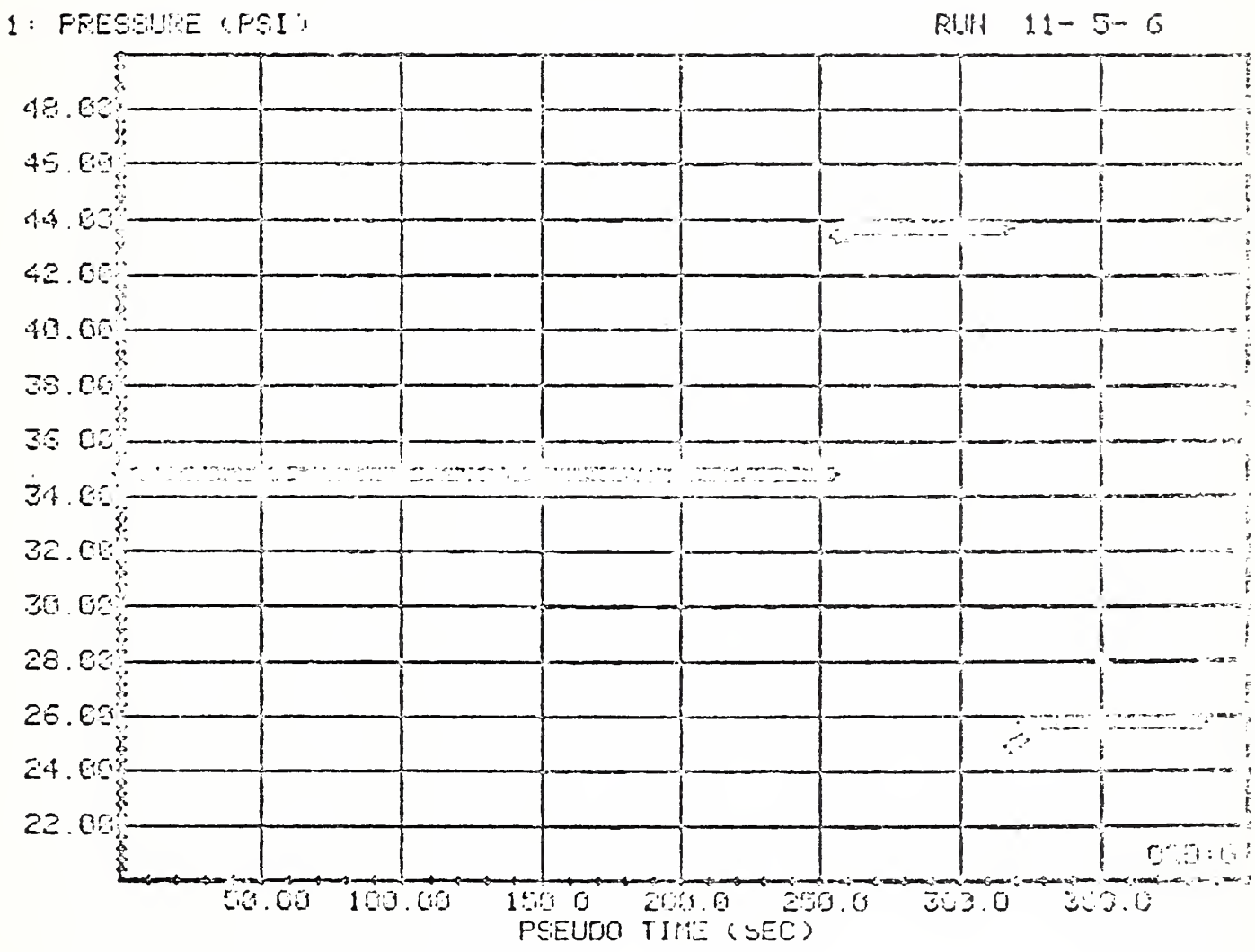
NOMINAL VALUES OF TEST PARAMETERS

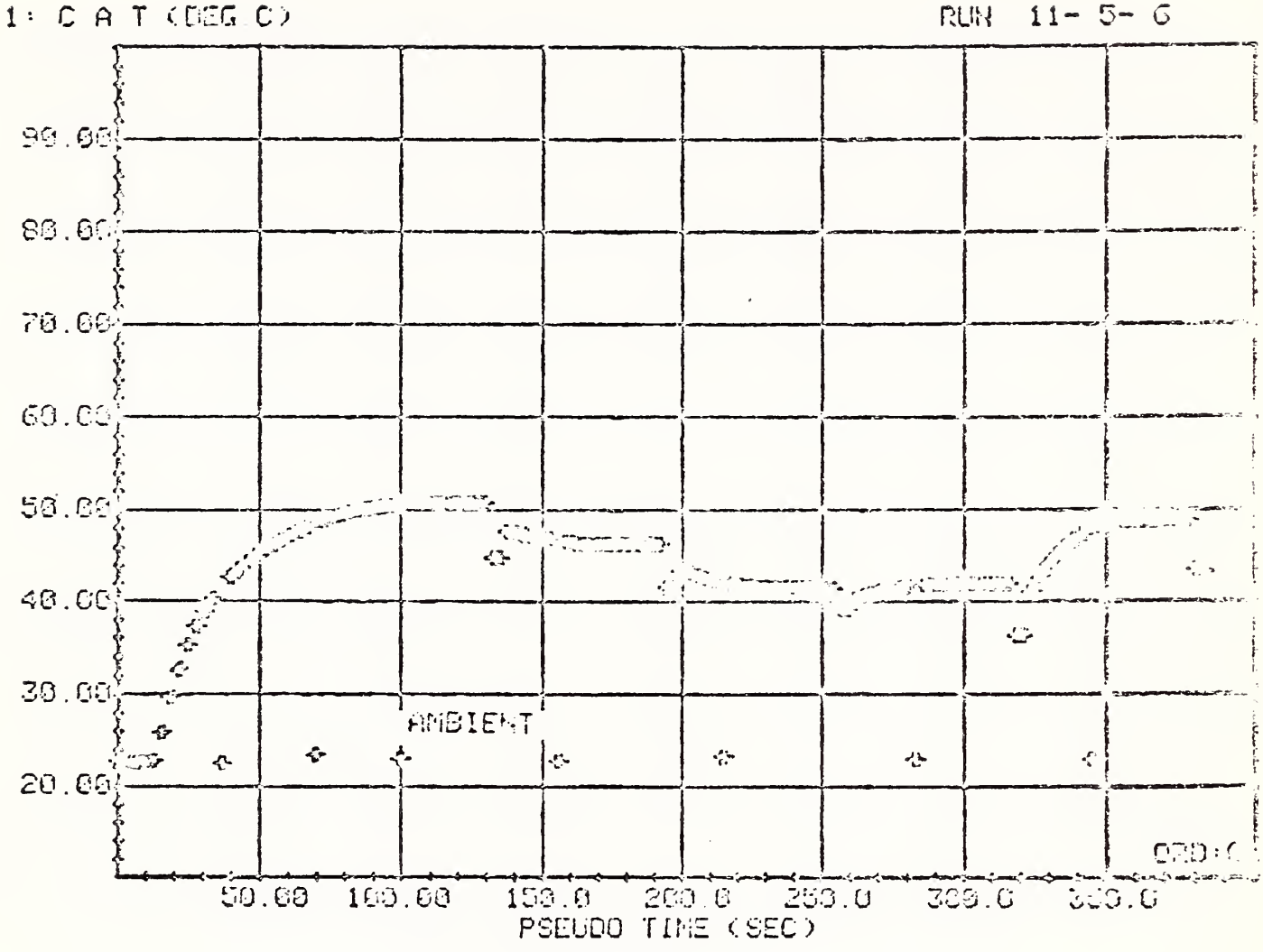
1.	VELOCITY (MPH):	50
2.	SLIP RATIO:	FREE ROLLING
3.	SLIP ANGLE (DEG):	0
4.	INCLINATION ANGLE (DEG):	0
5.	VERTICAL LOAD (LB):	1400,1120,840, 1120
6.	INFLATION PRESSURE (PSI):	35,44,26 REG

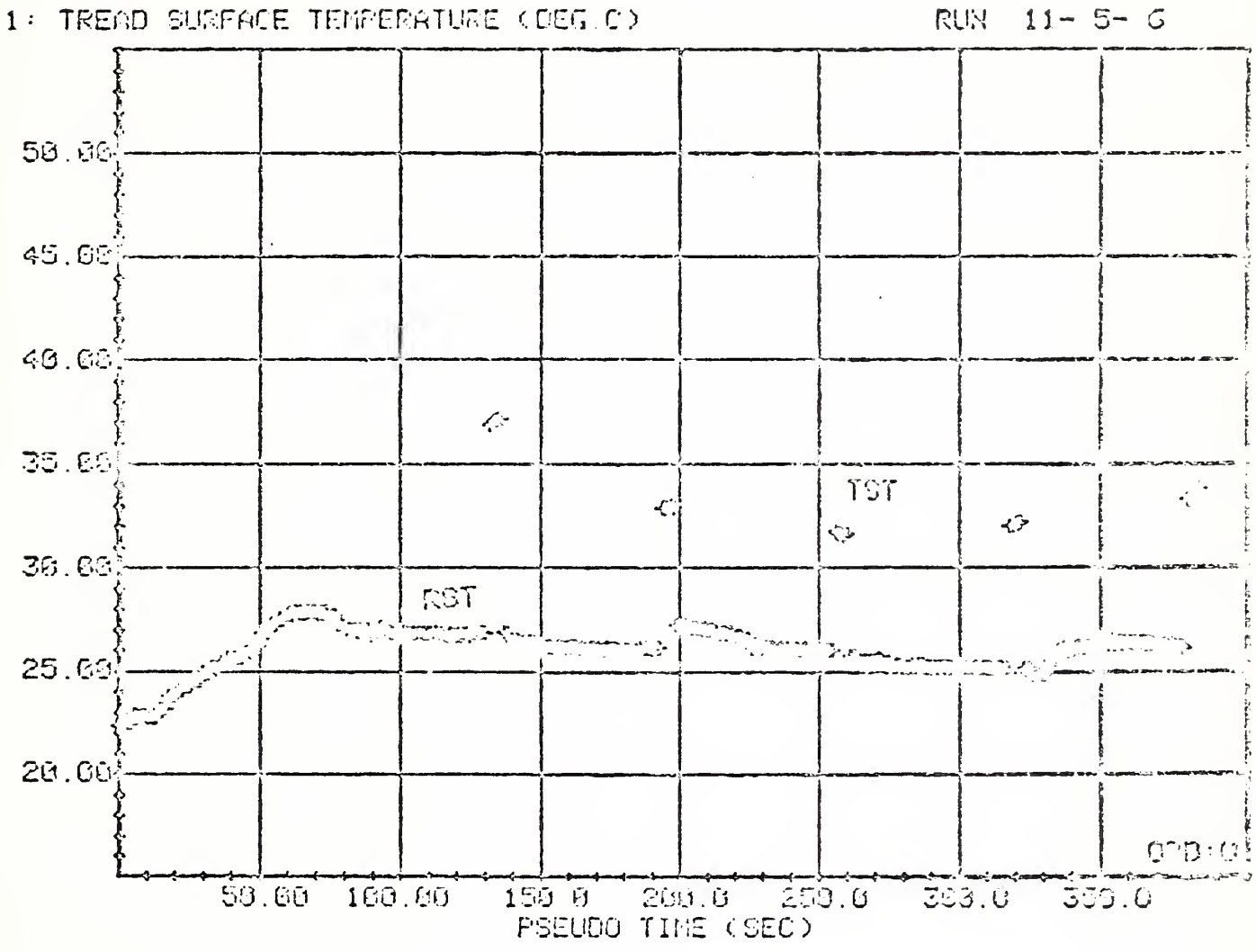

1: F R (LB)
RUN 11- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 11- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 11- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
ORD:0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 11- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
PSEUDO TIME (SEC)


1: C A T (DEG C)
RUN 11- 5- 6
99.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG.C)
RUN 11- 5- 6
50.00
45.00
40.00
35.00
30.00
25.00
20.00
TST
RST
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

11-5-6 A.V.L. LB	11-5-6 F.R. LB	11-5-6 C.A.T. DEG C	11-5-6 T.S.T DEG.C	11-5-6 C. PSI	11-5-6 R.L. IN	11-5-6 F.Z. LB
1414.	14.05	51.1	26.9	34.9	11.69	-1[illegible]1.
1133.	11.07	46.72	26.2	34.9	11.91	-1[illegible].
850.	8.97	41.89	26.2	34.9	12.13	-[illegible].
1132.	10.84	42.32	25.4	33.8	12.07	-1[illegible].
1131.	14.18	49.23	26.4	25.8	11.67	-1[illegible]1.

11-5-6 A.V.L. LB	11-5-6 S.F.R.	11-5-6 S.C.A.T.	11-5-6 S.I.S.T.	11-5-6 S.P	11-5-6 S.R.R.	11-5-6 S.F.Z.
1414.	0.070	0.020	0.079	0.006	0.	1.11
1133.	0.036	0.014	0.043	0.020	0.003	0.01
882.	0.049	0.031	0.039	0.010	0.	0.0
1132.	0.057	0.022	0.053	0.	0.	0.0
1131.	0.070	0.035	0.056	0.012	0.003	0.00

RUN NUMBER..: 12- 5- 6 DATE: 2/11/70

TYPE OF TEST: ROLLING RESISTANCE AS PER GM PROCEDURE

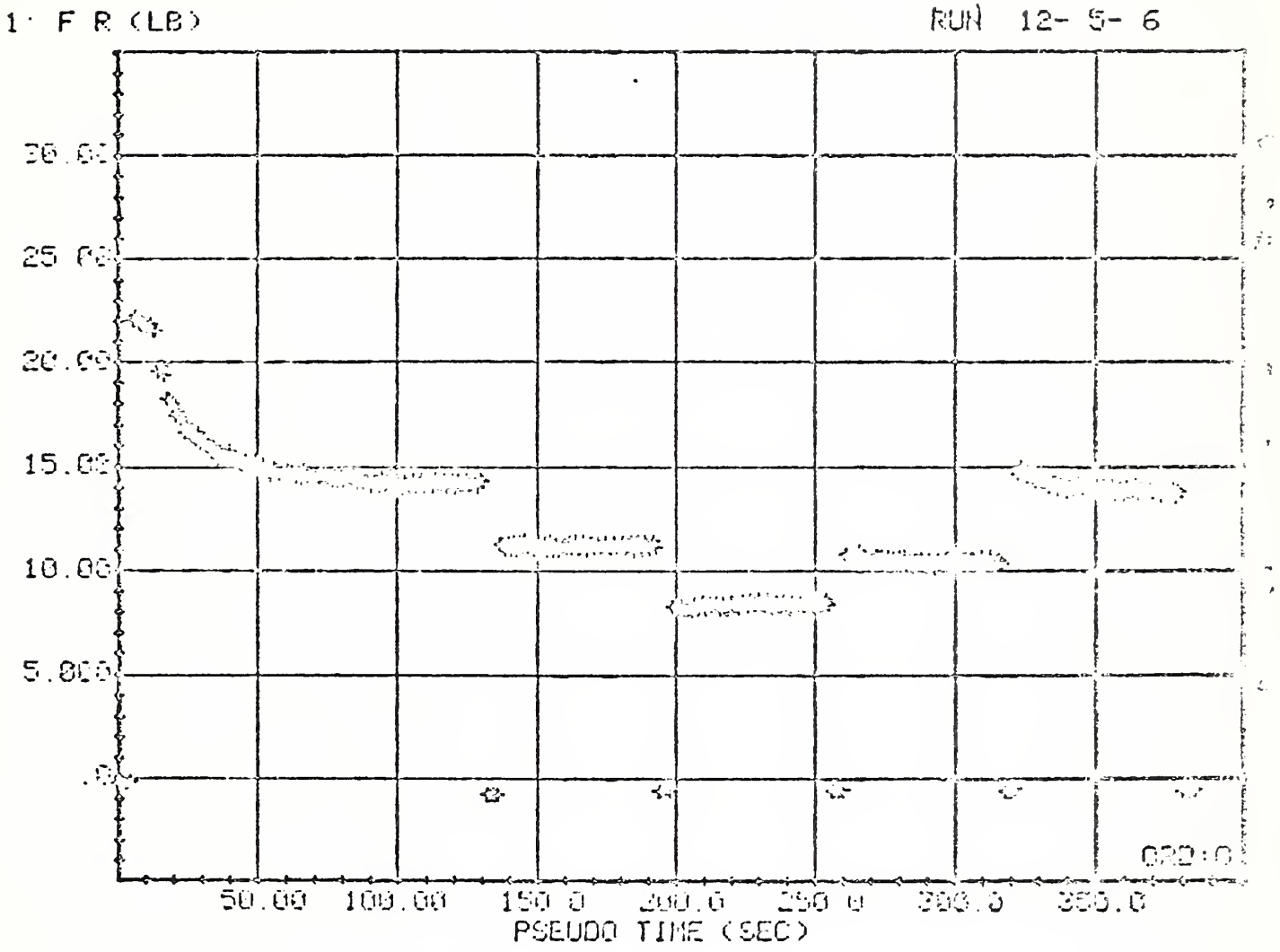
SPONSOR.....: T S C DATA FILTERS: .033 HZ

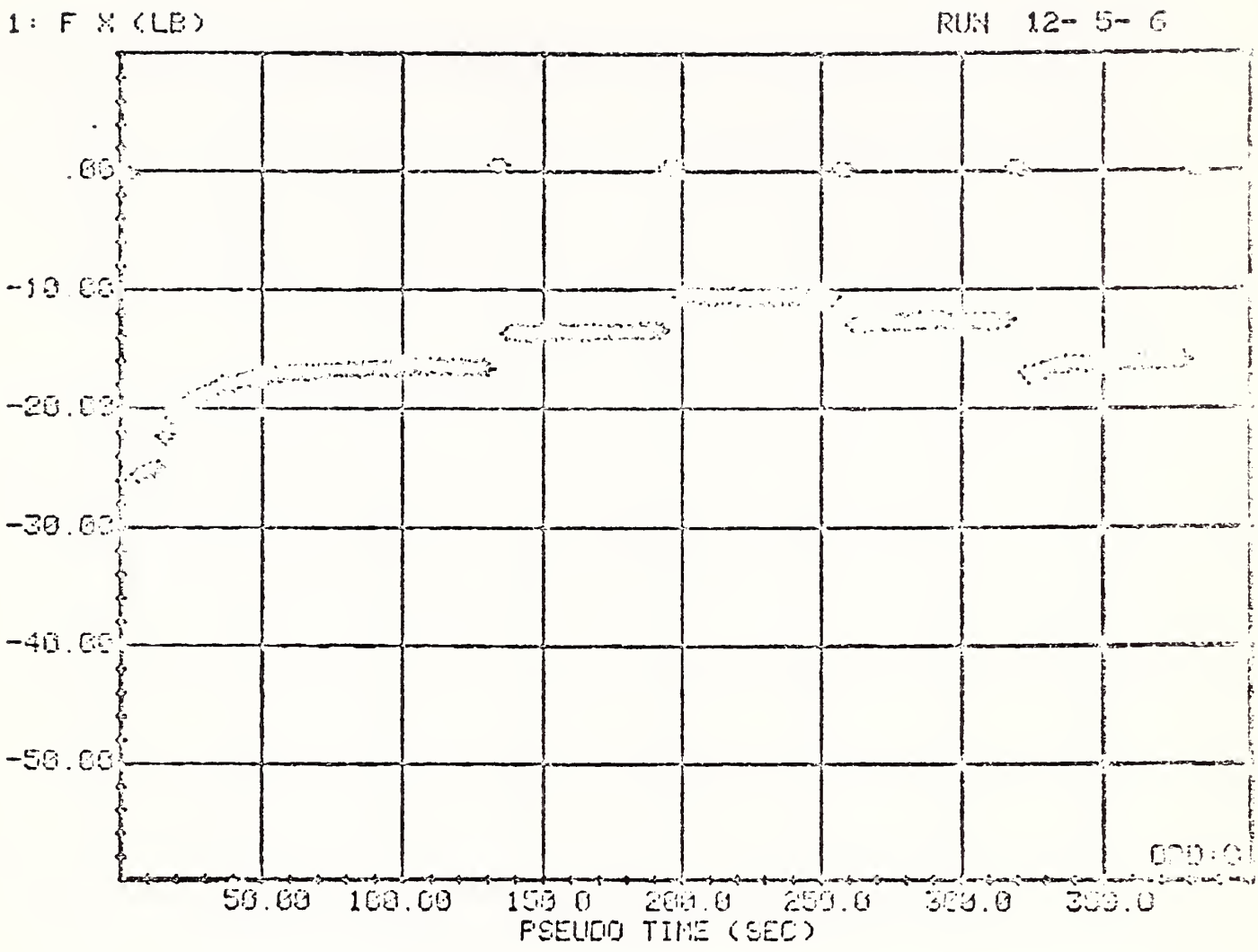
TIRE:
SPONSOR CODE: FI-R 719
TIRE NUMBER: 12- 5- 6
SIZE.....: P 195/75 R 14

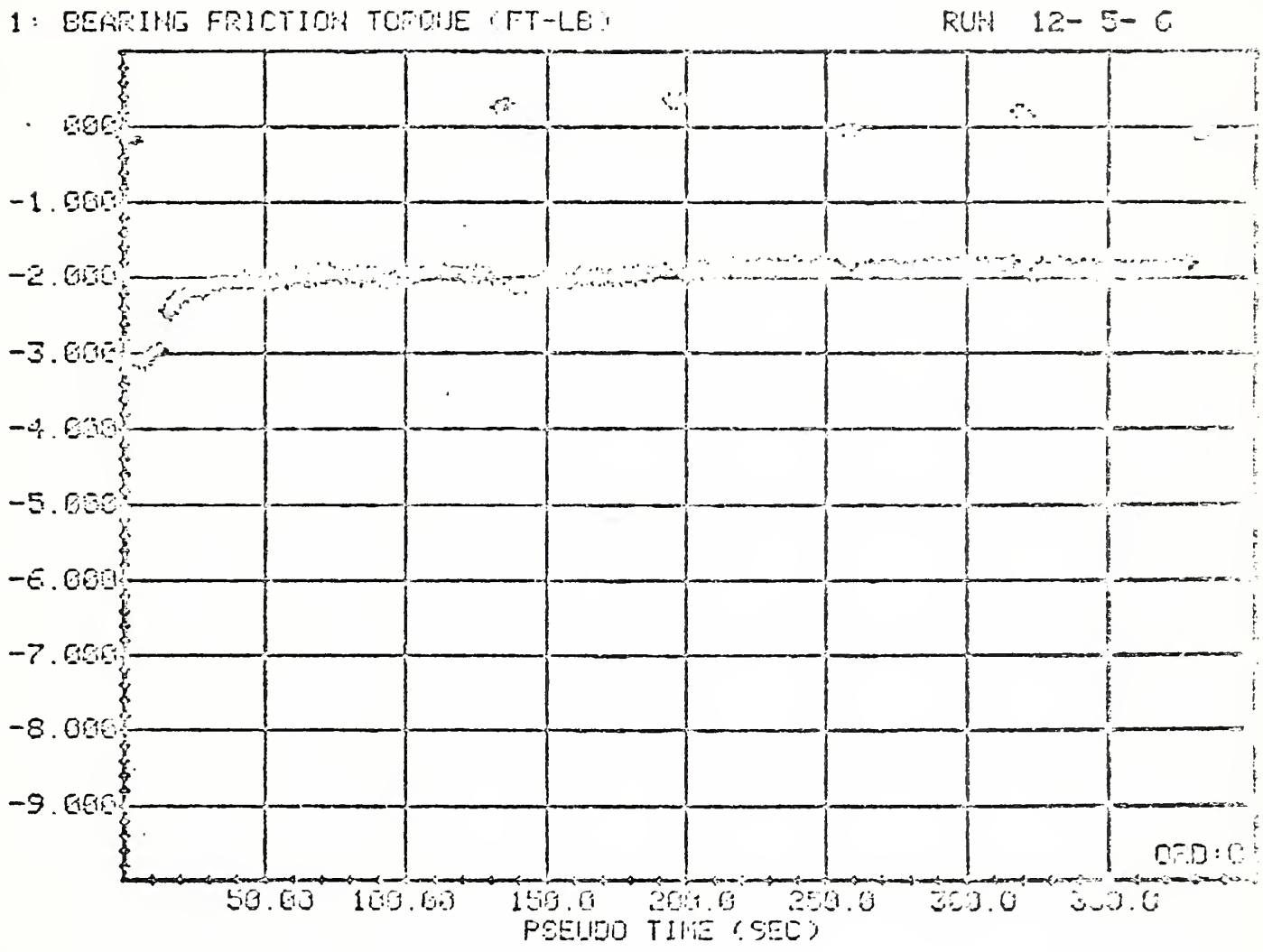
ROAD SURFACE:
WET S/N...: 30
DRY S/N...: 85
WATER DEPTH: DRY

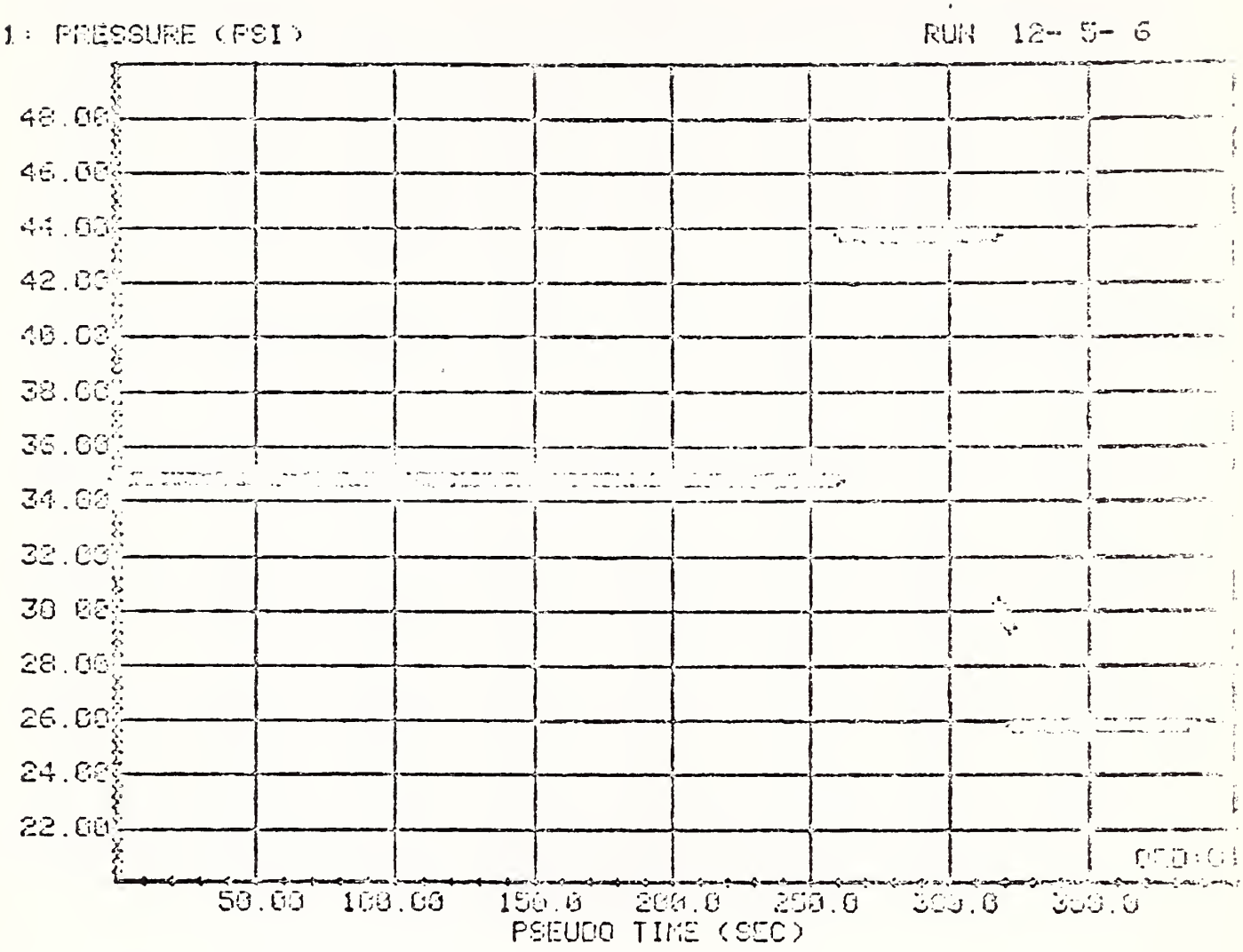
NOMINAL VALUES OF TEST PARAMETERS

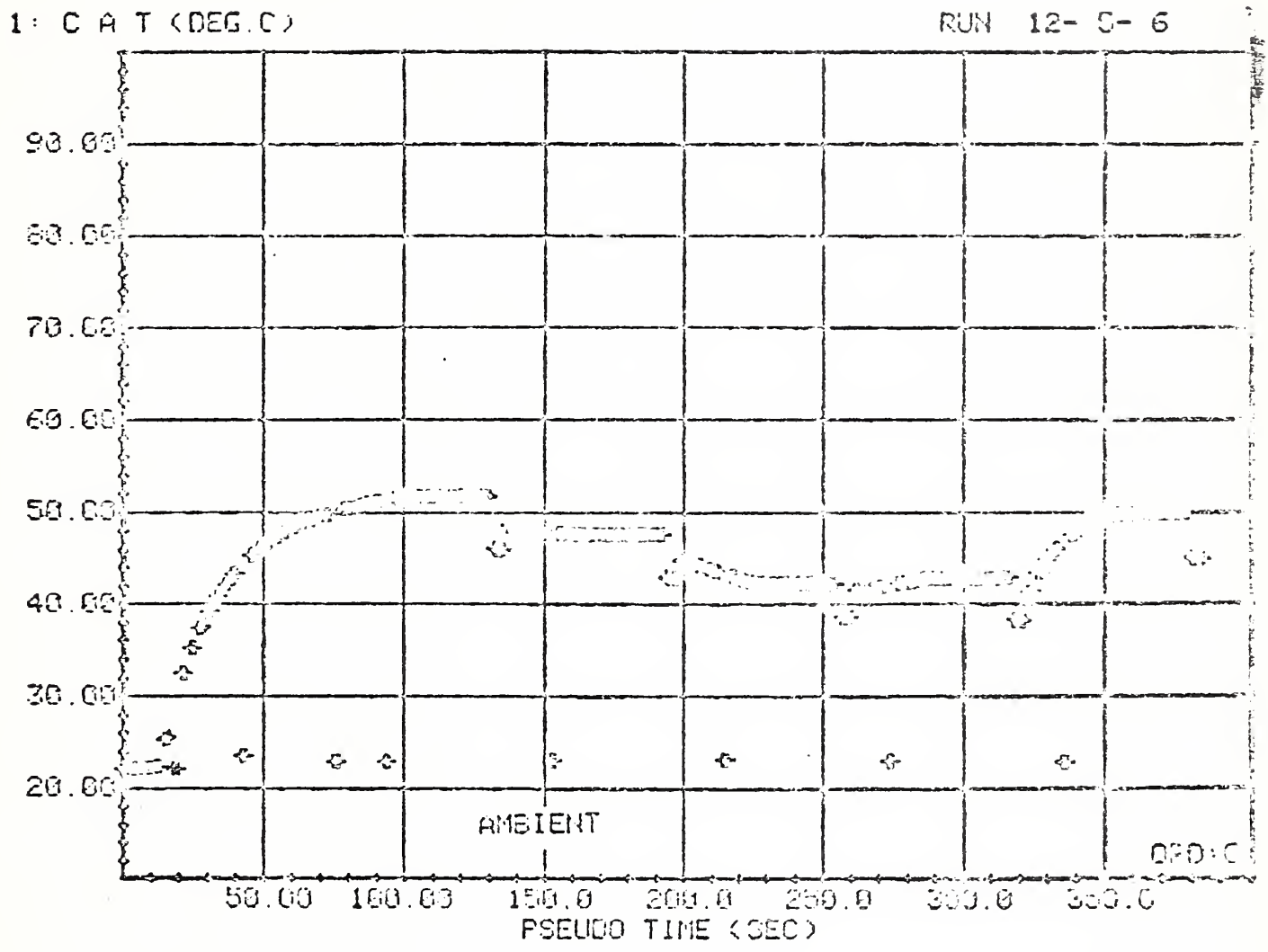
1. VELOCITY (MPH): 50
2. SLIP RATIO: FREE ROLLING
3. SLIP ANGLE (DEG): 0
4. INCLINATION ANGLE (DEG): 0
5. VERTICAL LOAD (LB): 1400,1120,840,1120
6. INFLATION PRESSURE (PSI): 35,44,26 REG

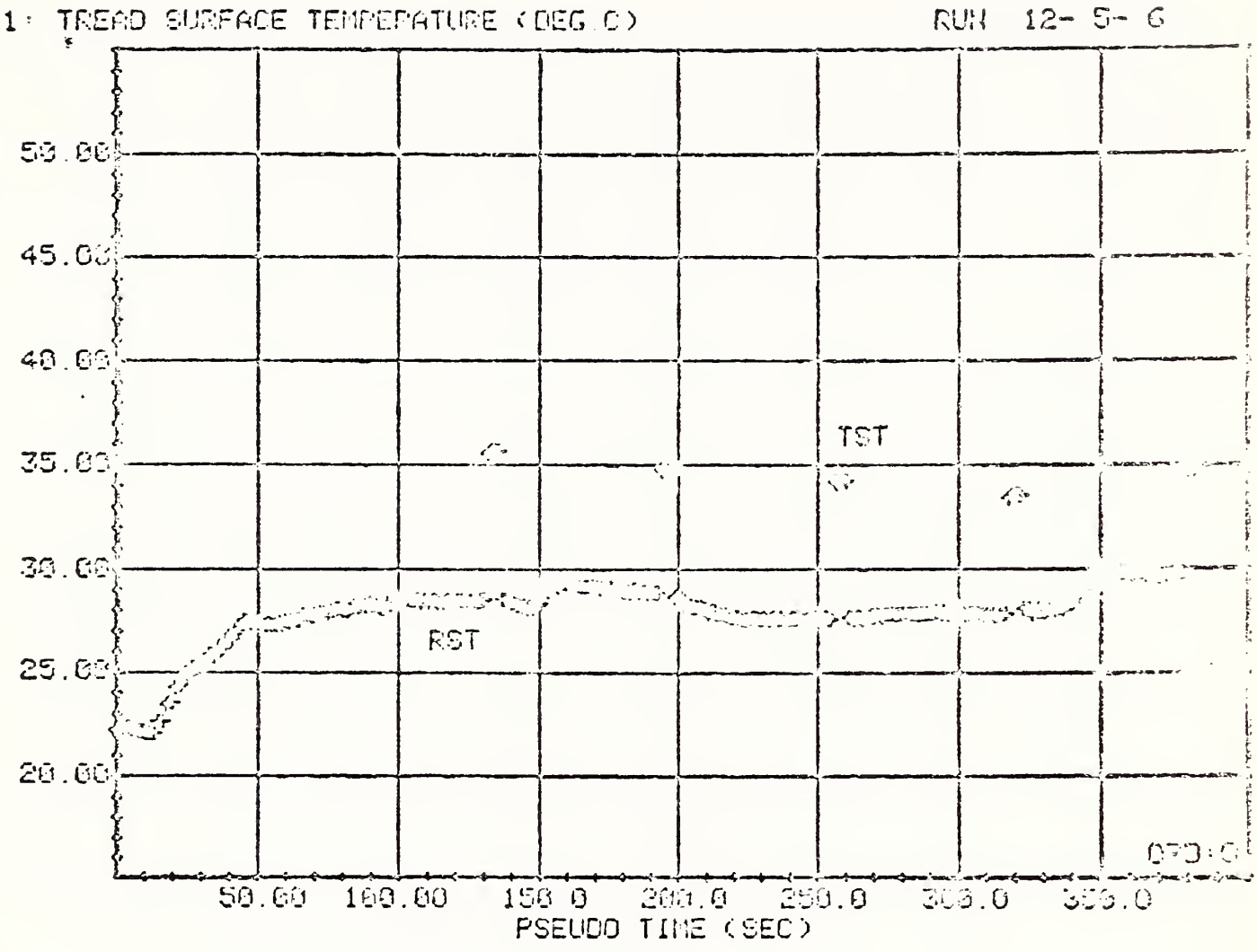

1: F R (LB)
RUN 12- 5- 6
30.00
25.00
20.00
15.00
10.00
5.000
.0
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: F X (LB)
RUN 12- 5- 6
.00
-10.00
-20.00
-30.00
-40.00
-50.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: BEARING FRICTION TORQUE (FT-LB)
RUN 12- 5- 6
.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
-9.000
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: PRESSURE (PSI)
RUN 12- 5- 6
48.00
46.00
44.00
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
24.00
22.00
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: C A T (DEG.C)
RUN 12- 5- 6
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
AMBIENT
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)


1: TREAD SURFACE TEMPERATURE (DEG C)
RUN 12- 5- 6
50.00
45.00
40.00
35.00
30.00
25.00
20.00
TST
RST
50.00
100.00
150.0
200.0
250.0
300.0
350.0
PSEUDO TIME (SEC)

12-5-6 A.V.L. LB	12-5-6 F.R. LB	12-5-6 C.A.T. DEG.C	12-5-6 T.S.T. DEG.C	12-5-6 P. PSI	12-5-6 R.L. IN	12-5-6 F.Z. LB
1416.	14.83	52.64	28.6	31.9	11.7	-1[illegible].
1120.	11.59	40.64	33.1	34.9	11.92	-1[illegible].
846.	9.63	42.67	27.8	34.8	12.15	-[illegible].
1128.	10.93	43.27	28.	33.8	12.03	-1117.
1127.	14.48	58.3	30.	25.9	11.03	-1116.

12-5-6 A.V.L. LB	12-5-6 S.F.R.	12-5-6 S.C.A T.	12-5-6 S T S T.	12-5-6 S.P	12-5-6 S.R.R.	12-5-6 S.F.Z.
.1410.	0.146	0.021	0.031	0.012	0.	1.
1128.	0.152	0.010	0.078	0.	0.	0.
846.	0.131	0.022	0.036	0.025	0.	1.
1126.	0.137	0.017	0.029	0.012	0.	0.
1127.	0.169	0.032	0.030	0.	0.032	0.

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