Report for:

DOT Pooled Funds TPF-345

CONSORTIUM FOR PAVEMENT SURFACE PROPERTIES

TWELVETH ANNUAL EQUIPMENT ROUNDUP (RODEO 2018)

Dates of Service:

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Report No. EFTC - 608

Conducted by:
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TRC Inc. Project Number: 170675p

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Federal Highway Administration Policy

This report expresses the views of the Evaluation and Field Test Center for Skid Measurement Systems which is responsible for the collection and the accuracy of the data presented. It does not necessarily reflect the official views or policies of the Federal Highway Administration, Department of Transportation; nor does the report constitute a standard, specification or regulation.

Services Performed

Various Road Surface Friction Testers were evaluated by TRC Inc. EFTC. All systems were correlated to the TRC National Standard E274 Skid System. The E274 Locked Wheel Testers were further evaluated for compliance to portions of the ASTM E274/E274M-15 Standard.

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TABLE OF CONTENTS

1.0 INTRODUCTION

Transportation Research Center has been the location of one of two centers established by contract between the Federal Highway Administration and The Ohio State University since the 1970's as part of a program to reduce interstate variation in locked-wheel skid measurements of pavement surfaces. Starting July 1, 1983, EFTC was operated by Transportation Research Center of Ohio, and since January 27th, 1988 by Transportation Research Center Inc. (TRC Inc.) when the transition from a state agency to a private not-for-profit company took place. TRC Inc. is owned by Ohio State University College of Engineering.

Virginia Tech Transportation Institute has hosted the Pooled Funds Rodeo for the past eleven years. The Rodeo moved to TRC this year and TRC Inc.'s National Standard E274 Locked Wheel Tester was used as a reference device.

2.0 SKID SYSTEMS GENERAL INFORMATION

Five E274 Locked Wheel Testers from four DOTs participated in the Rodeo

Connecticut DOT (operated by UConn)	2005 Dynatest Model Number M1270, Serial No. M1270-103, 2005 Ford F350, VIN 1FTWW32Y85ED16785, 39,547 miles

	
Illinois DOT	2001 International Cybernetics Corporation (ICC) ADC V3, 2001 GMC 2500, VIN 1GTHC23602F108780, 195,494 miles
	
Ohio DOT	2001 Dynatest 1295, Serial No. 091, 2001 Chevy 2500, VIN 1CGHC29101E295025, 109,415 miles
	
Ohio DOT	2010 Dynatest 1295, Serial No. 120, 2010 Ford F250, VIN 1FT8X3AT8BEA81652, 84,150 miles

South Carolina DOT	2008 Dynatest 1270-039, Serial No. 1D9PN13120M495124, Updated 2011, 2017, 2008 Ford F350 XL, VIN 1FDWX36Y89EA15930, 64,108 miles

Additionally, two Continuous Friction Measuring Equipment (CFME) Devices were part of the event this year.

FHWA (operated by VTTI)	2015 SCRIM, Volvo VHD64F, VIN 4V5KC9EJ8FN916085, 30,066 miles

Halliday Technologies	2016 Curve 3, 2016 Chevy 3500, VIN 1GC4KYG2GF256988, 5,105 miles

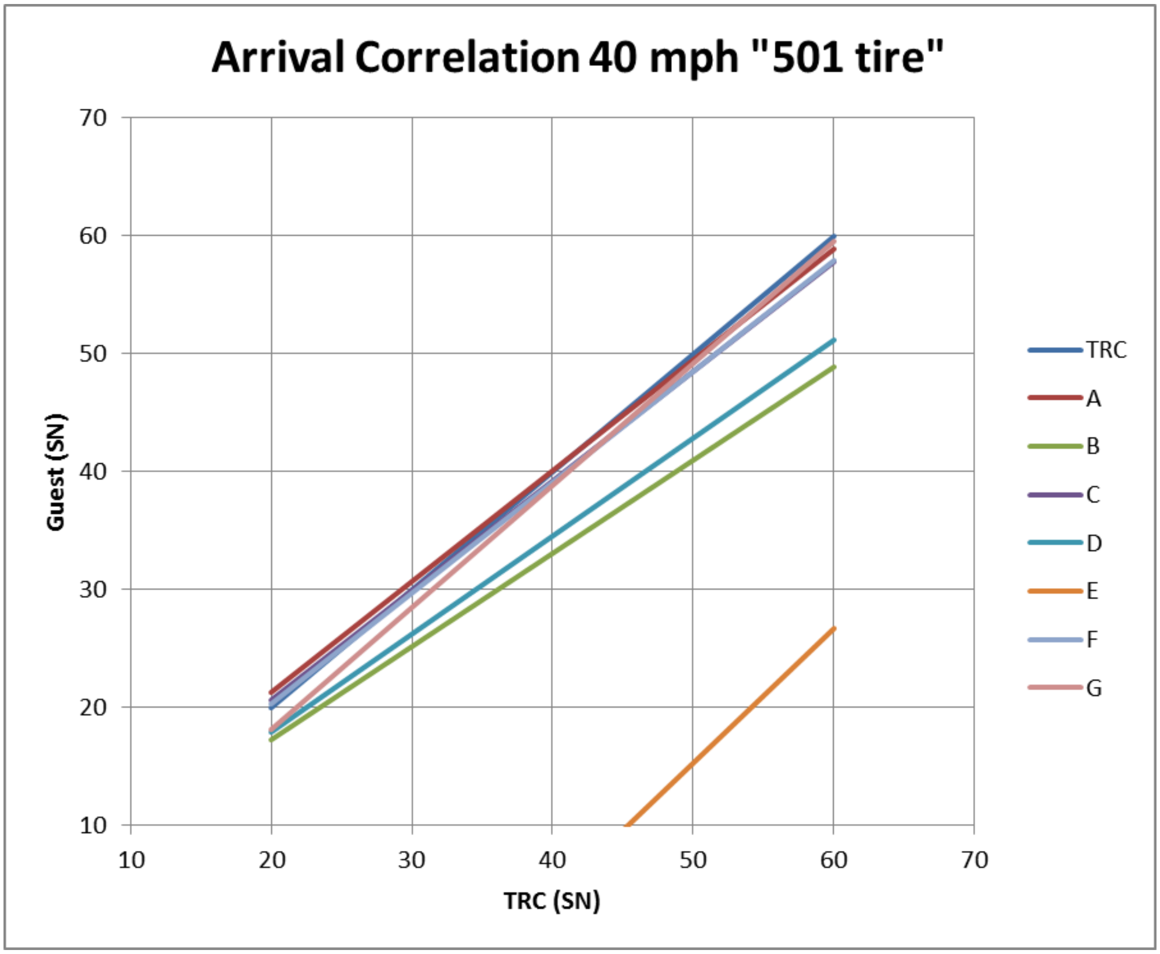
3.0 ARRIVAL CORRELATION

An arrival dynamic correlation was performed. It consisted of 12 skids on a Low Mu Pad, 12 skids on a Mid Mu Pad, and 12 skids on High Mu Pad at a speed of 40 miles per hour for a total of 36 skids, leading to 3 combinations of pad and speed. During the correlation, all systems were operated simultaneously. The Locked Wheel Tester and the Halliday all used the E501 ribbed tire. The SCRIM used its regular tire. The first order regression equations relating the measurements made by the Skid Measurement System to the TRC Skid Measurement System have been calculated and are:

E501 Ribbed (except SCRIM)

System ID	Arrival Correlation Equation
A	SN(TRC) = [SN(A) x 0.94] + 2.45
B	SN(TRC) = [SN(B) x 0.79] + 1.51
C	SN(TRC) = [SN(C) x 0.93] + 2.03
D	SN(TRC) = [SN(D) x 0.83] + 1.39
E	SN(TRC) = [SN(E) x 1.14] - 41.76
F	SN(TRC) = [SN(F) x 0.94] + 1.54
G	SN(TRC) = [SN(G) x 1.03] - 2.59

This is represented graphically as follows:



4.0 CALIBRATION CHECKS

Note: Only the E274 Locked Wheel Testers were evaluated with the following Calibration Checks

4.1 Speed Subsystem Evaluation

The system measures speed through use of speed pickups on the trailer wheels. The speed output is displayed on a digital meter for the driver's use and recorded in digital form within the computer. The driver's display and the computer have resolutions of 0.1 mile per hour. These readings were compared to the readout from a Racelogic Vbox 3. The Vbox is calibrated annually. The driver drives at each of the test speeds. An EFTC technician recorded the readings of the EFTC speed indicator, the DOT skid system digital speed display, computer readings, and vehicle speedometer readings, the latter to be used as a backup to the digital driver's display in case of a malfunction.

Findings:

System A

As Arrived (mph)				
Measured Speed	Driver's Display	Vehicle Speedometer	Trailer Wheels Left	Right
20.0	20.0	20	123*	20.7
40.0	40.6	41	247*	40.5
60.0	61.0	61	370*	60.5

*Wheel speed sensor had been replaced. Cal value corrected during cal check.

System C

As Arrived (mph)				
Measured Speed	Driver's Display	Vehicle Speedometer	Trailer Wheels Left	Right
20.0	20.0	21	20.0	20.1
40.0	40.0	41	40.0	40.1
60.0	60.0	61	60.0	60.1

System D

As Arrived (mph)				
Measured Speed	Driver's Display	Vehicle Speedometer	Trailer Wheels Left	Right
20.0	20.2	22	20.0	20.2
40.0	40.5	42	39.0	40.5
60.0	60.8	62	59.0	60.8

System F

As Arrived (mph)				
Measured Speed	Driver's Display	Vehicle Speedometer	Trailer Wheels Left	Right
20.0	20.0	21	20.0	20.0
40.0	40.0	41	40.0	40.0
60.0	60.0	61	60.0	60.0

System G

As Arrived (mph)				
Measured Speed	Driver's Display	Vehicle Speedometer	Trailer Wheels Left	Right
20.0	20.0	21	20.0	NA
40.0	40.5	41	40.0	NA
60.0	60.4	61	59.5	NA

4.2 Water Subsystem Evaluation

The water subsystem is powered from the vehicle drive shaft. A Gilmer belt and pulley system transfers the power from the drive shaft through an electric clutch on the pump. The pulley sizes allow the sub-system output to be tailored to the specific truck/trailer system. The water is delivered from the on-board tank, through the truck and trailer plumbing system, to the OSU nozzle that discharges the water directly in front of the test tire. To simulate speeds for water flow tests, the EFTC uses a digital phototachometer system, which measures exact drive shaft rotational speed. During the speed calibrations, readings are taken of the drive shaft RPM at each test speed. The driver then drives to these phototach readings when flow testing on the rollers. Flow rate testing of this unit was performed by measuring total water flow in a one-minute time interval at each test speed.

Findings:

System A

Speed (mph)	Flow (gpm)
30.0	21.1 (18.9 – 23.1)
40.0	28.0 (25.2 – 30.8)
50.0	35.0 (31.5 – 38.5)

System C

Speed (mph)	Flow (gpm)
20.0	14.1 (12.6 – 15.4)
40.0	29.0 (25.2 – 30.8)
60.0	44.0 (37.8 – 46.2)

System D

Speed (mph)	Flow (gpm)
20.0	16.9 (12.6 – 15.4)
40.0	32.1 (25.2 – 30.8)
60.0	45.1 (37.8 – 46.2)

Volume High at 20 and 40.

System F

Speed (mph)	Flow (gpm)
20.0	13.9 (12.6 – 15.4)
40.0	29.5 (25.2 – 30.8)
60.0	44.0 (37.8 – 46.2)

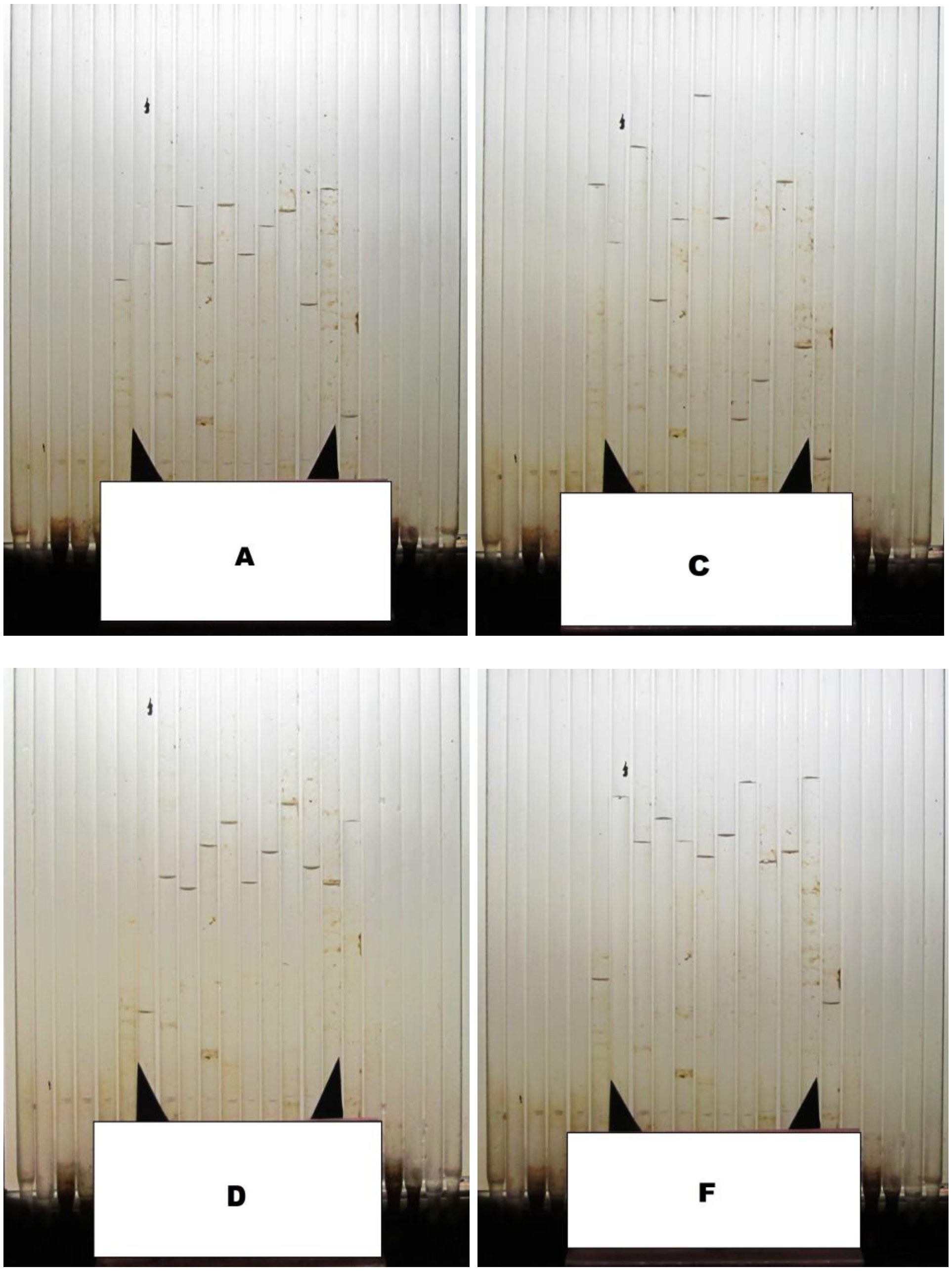
System G

Speed (mph)	Flow (gpm)
30.0	22.1 (18.9 – 23.1)
40.0	27.5 (25.2 – 30.8)
50.0	34.1 (31.5 – 38.5)

Water distribution was evaluated on the Static Distribution Gage (SDG). This consists of a collector at the level of the roadway surface which is divided into equal-width sections so that each section catches water from the nozzle and feeds it into a separate reservoir and viewing tube.

Findings:

The following photos show the typical SDG results at 40 mph. The points below the columns indicate the position of the outer edges of the test tire while the height of water in the columns represents relative volumes of water in each collector reservoir. The low level in the outside tubes is indicative of the high resolution of the SDG (5/8-inch sampling widths) rather than a non-uniform distribution. It can be seen that the water trace is sufficiently wide to cover the test tire footprint, is fairly well centered on the test tire, and the volume distribution is fairly even across the footprint.



4.3 Force Subsystem Evaluation

The tow vehicle water storage tank was adjusted to 50% capacity. The system was checked in the following conditions with the following results:

A	TRC Force Plate			DOT		
Position	Load (lbf)	Force (lbf)	SN	Load (lbf)	Force (lbf)	SN
In Air	0	0		-2.7	5.8	
Floating	1092	0		1085	496	
Pull 500	1030	500	48.5	1023	793	48.5
Pull 800	990	800	80.8	985	5.8	80.5

Estimated Crosstalk at 500 pounds = 0 pounds (5 pounds max.)

Transducer Rotation at 800 pounds pull = 0.70 degrees (1 degree max.)

C	TRC Force Plate			DOT		
Position	Load (lbf)	Force (lbf)	SN	Load (lbf)	Force (lbf)	SN
In Air	0	0		-1.7	-2.5	
Floating	1087	0		1086	0	
Pull 500	1018	500	49.1	1021.7	500	48.9
Pull 800	977	800	81.9	983.1	803.4	81.7

Estimated Crosstalk at 500 pounds = 5 pounds (5 pounds max.)

Transducer Rotation at 800 pounds pull = 0.70 degrees (1 degree max.)

D	TRC Force Plate			DOT		
Position	Load (lbf)	Force (lbf)	SN	Load (lbf)	Force (lbf)	SN
In Air	0	0		76.7	-9	
Floating	1078	0		1022	-3	
Pull 500	1004	500	49.8	953	511	53.6
Pull 800	960	800	83.3	912	818	89.7

Estimated Crosstalk at 500 pounds = 5 pounds (5 pounds max.)

Transducer Rotation at 800 pounds pull = 0.45 degrees (1 degree max.)

F	TRC Force Plate			DOT		
Position	Load (lbf)	Force (lbf)	SN	Load (lbf)	Force (lbf)	SN
In Air	0	0		0	0	
Floating	1089	0		1090	0	
Pull 500	1025	500	48.8	1025	496	48.4
Pull 800	988	800	81.0	986	784	79.5

Estimated Crosstalk at 500 pounds = 1 pounds (5 pounds max.)

Transducer Rotation at 800 pounds pull = 0.40 degrees (1 degree max.)

G	TRC Force Plate			DOT		
Position	Load (lbf)	Force (lbf)	SN	Load (lbf)	Force (lbf)	SN
In Air	0	0		4	5	
Floating	1094	0		1089	0	
Pull 500	1029	500	48.6	1029	500	48.6
Pull 800	989	800	80.9	984	800	81.3

Estimated Crosstalk at 500 pounds = 5 pounds (5 pounds max.)

Transducer Rotation at 800 pounds pull = 0.35 degrees (1 degree max.)

4.4 Tire Pressure Gage Evaluation

The tire pressure gage was evaluated from each system to confirm the pressure reading at 24 psi. (pressure specified for the E501 and E524 tires).

Skid System	Pressure reading at 24 psi
A	23
C	24
D	32*
F	24
G	24

*Gage was discarded. DOT will replace with a new calibrated gage.

5.0 Departure Dynamic Correlation

Two departure dynamic correlations were performed. They consisted of 12 skids on a Low Mu Pad, 12 skids on a Mid Mu Pad, and 12 skids on High Mu Pad at speeds of 40 and 60 miles per hour for a total of 72 skids each, leading to 6 combinations of pad and speed. During the correlation, all systems were operated simultaneously. The Locked Wheel Tester and the Halliday all used the E501 ribbed tire for the first correlation, and the E524 smooth tire for the second correlation. The SCRIM used its regular tire for both. The SCRIM also ran 30 mph and 50 mph instead of 40 mph and 60 mph. A summary of the data for the locked wheel testers is as follows:

Comparison of the 501 Tire Departure Correlation Data

			TRC	A	C	D	F	G
40 mph	Pad 0	Avg	11.4	11.2	10.8	11.9	12.7	11.0
		Min	10.6	9.9	9.6	10.7	11.7	8.7
		Max	13.0	12.3	13.3	14.0	13.5	14.4
		Std Dev	0.79	0.77	1.24	1.15	0.70	1.80
	Pad 2	Avg	27.6	26.1	25.5	27.8	27.3	23.4
		Min	26.3	24.6	24.1	26.9	26.5	21.4
		Max	29.2	27.6	26.5	29.1	28.3	25.5
		Std Dev	0.78	0.79	0.77	0.67	0.50	1.34
	Pad 1	Avg	66.3	66.3	68.1	66.6	68.3	67.7
		Min	64.1	63.1	61.4	62.3	64.2	60.3
		Max	69.7	70.1	81.1	71.0	73.5	73.4
		Std Dev	2.08	2.38	5.83	2.66	3.17	3.94
60 mph	Pad 0	Avg	10.0	9.3	9.9	9.8	10.3	9.8
		Min	9.6	8.6	8.5	8.6	8.6	8.0
		Max	10.7	10.7	14.3	13.1	11.9	11.2
		Std Dev	0.32	0.70	1.73	1.54	0.79	1.27
	Pad 2	Avg	24.1	22.0	20.6	23.9	23.5	18.0
		Min	23.4	21.4	19.3	23.1	19.1	16.4
		Max	25.5	23.3	21.6	25.1	25.7	19.7
		Std Dev	0.65	0.50	0.69	0.63	1.57	0.87
	Pad 1	Avg	52.4	51.6	51.7	53.5	50.3	50.9
		Min	49.9	45.7	48.4	49.9	45.9	48.0
		Max	56.4	55.9	57.3	57.5	55.3	55.4
		Std Dev	2.08	2.65	2.56	2.25	2.86	2.27

Comparison of the 524 Tire Departure Correlation Data

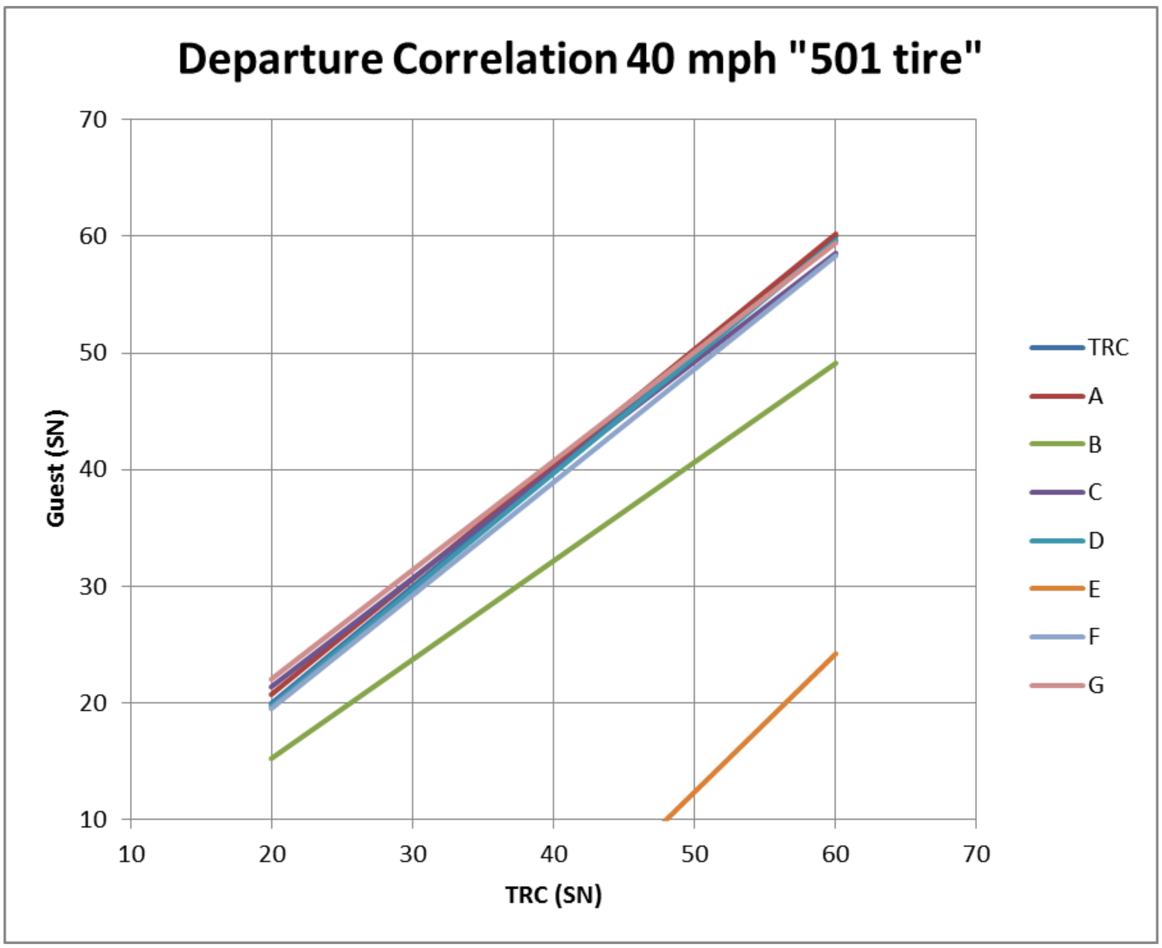
			TRC	A	C	D	F	G
40 mph	Pad 0	Avg	7.9	6.1	5.5	7.2	6.1	7.1
		Min	7.6	5.5	4.9	7.0	4.1	5.6
		Max	8.1	6.8	6.6	7.6	7.1	8.2
		Std Dev	0.18	0.41	0.56	0.19	0.72	0.75
	Pad 2	Avg	19.5	17.2	16.5	20.6	20.2	19.8
		Min	18.8	16.4	14.8	19.6	18.9	18.5
		Max	21.0	17.9	18.5	21.5	21.9	21.9
		Std Dev	0.60	0.43	1.00	0.73	1.01	1.17
	Pad 1	Avg	41.7	41.1	42.9	45.3	43.3	48.7
		Min	37.9	31.5	38.5	42.7	41.5	43.2
		Max	48.6	48.5	46.8	51.5	45.2	54.0
		Std Dev	2.70	5.06	2.71	2.50	1.38	3.93
60 mph	Pad 0	Avg	6.4	4.3	4.5	6.6	5.3	5.6
		Min	6.0	3.9	3.6	5.7	5.0	4.2
		Max	6.8	4.8	8.9	7.5	5.8	7.2
		Std Dev	0.27	0.30	1.45	0.55	0.23	0.81
	Pad 2	Avg	14.2	12.5	10.4	14.9	13.4	12.3
		Min	13.3	11.6	8.9	13.4	12.0	10.3
		Max	16.4	13.3	12.1	16.6	15.6	14.2
		Std Dev	0.91	0.62	1.14	1.03	1.10	1.18
	Pad 1	Avg	30.2	29.9	28.7	31.2	28.2	34.7
		Min	28.0	25.8	23.2	27.8	25.3	31.9
		Max	33.6	34.5	30.7	35.0	31.5	40.6
		Std Dev	1.63	3.05	2.04	1.80	1.61	2.67

The first order regression equations relating the measurements made by the Skid Measurement System to the TRC Skid Measurement System have been calculated and are:

E501 Ribbed 40 mph (except SCRIM)

System ID	Departure Correlation Equation
A	SN(TRC) = [SN(A) x 0.99] + 1.01
B	SN(TRC) = [SN(B) x 0.85] - 1.74
C	SN(TRC) = [SN(C) x 0.93] + 2.71
D	SN(TRC) = [SN(D) x 1.00] – 0.26
E	SN(TRC) = [SN(E) x 1.19] - 46.89
F	SN(TRC) = [SN(F) x 0.97] + 0.10
G	SN(TRC) = [SN(G) x 0.94] + 3.29

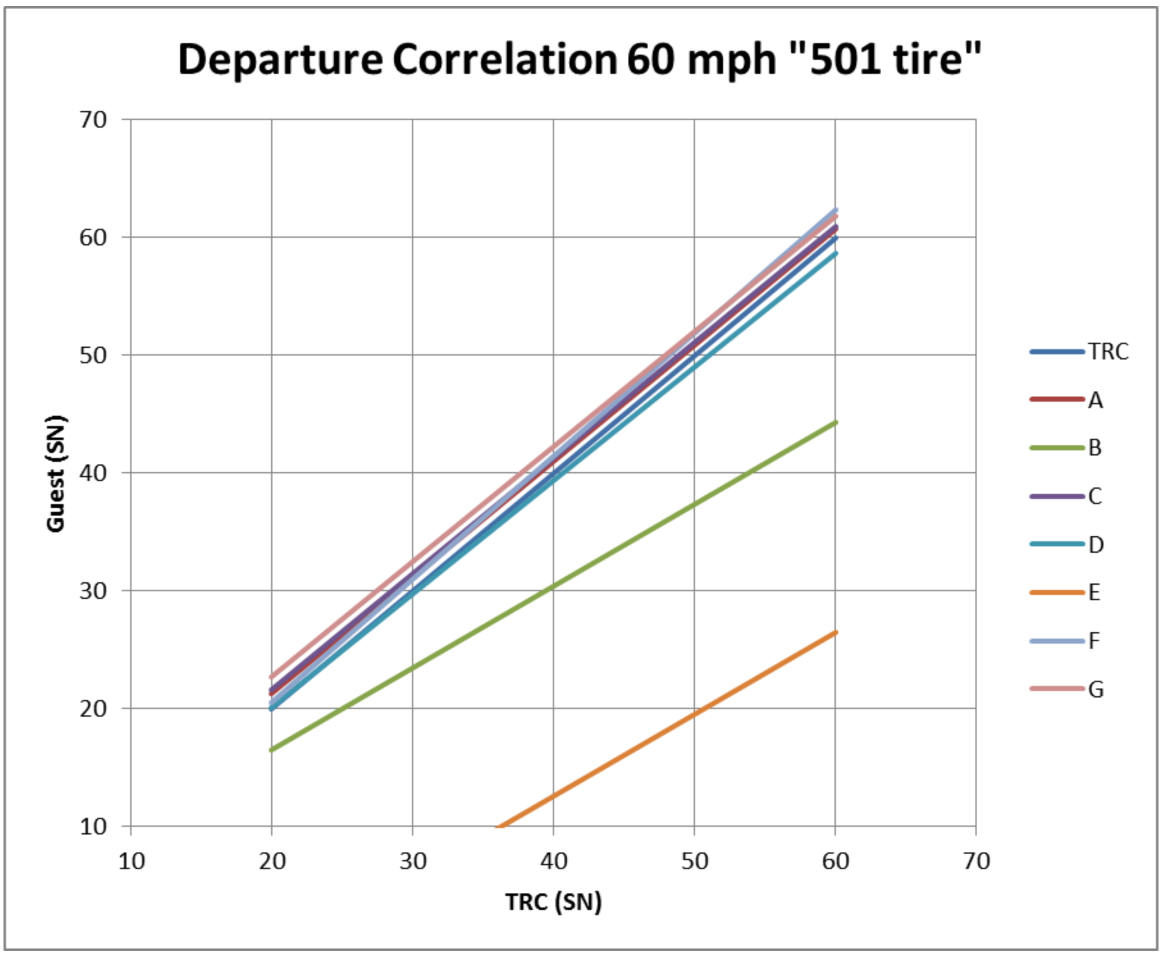
This is represented graphically as follows:



E501 Ribbed 60 mph (except SCRIM)

System ID	Departure Correlation Equation
A	SN(TRC) = [SN(A) x 0.98] + 1.65
B	SN(TRC) = [SN(B) x 0.69] + 2.67
C	SN(TRC) = [SN(C) x 0.98 + 1.92
D	SN(TRC) = [SN(D) x 0.96] + 0.82
E	SN(TRC) = [SN(E) x 0.70] - 15.23
F	SN(TRC) = [SN(F) x 1.05] - 0.56
G	SN(TRC) = [SN(G) x 0.98] + 3.21

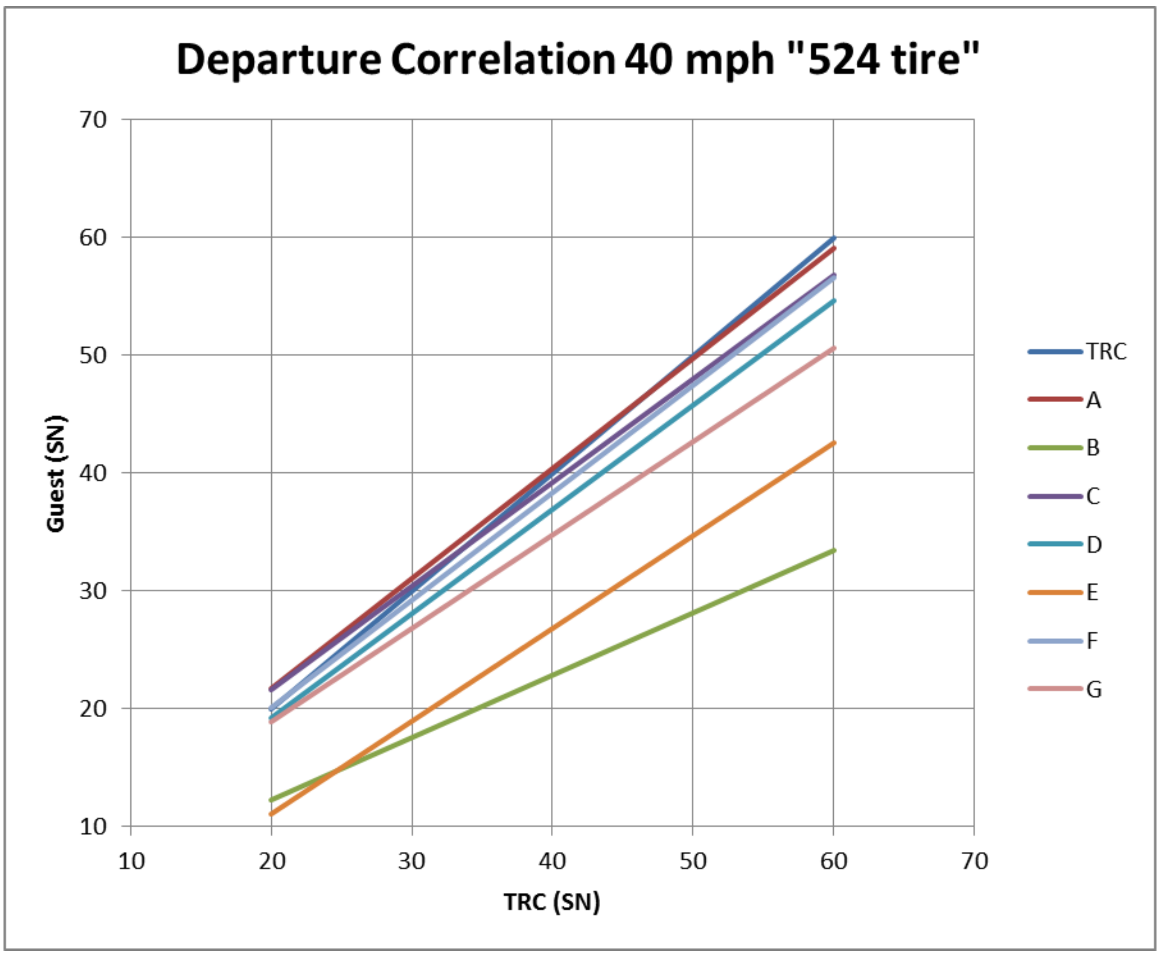
This is represented graphically as follows:



E524 Smooth 40 mph (except SCRIM)

System ID	Departure Correlation Equation
A	SN(TRC) = [SN(A) x 0.93] + 2.97
B	SN(TRC) = [SN(B) x 0.53] + 1.70
C	SN(TRC) = [SN(C) x 0.88] + 3.96
D	SN(TRC) = [SN(D) x 0.89] + 1.47
E	SN(TRC) = [SN(E) x 0.79] - 4.58
F	SN(TRC) = [SN(F) x 0.91] + 1.92
G	SN(TRC) = [SN(G) x 0.79] + 3.02

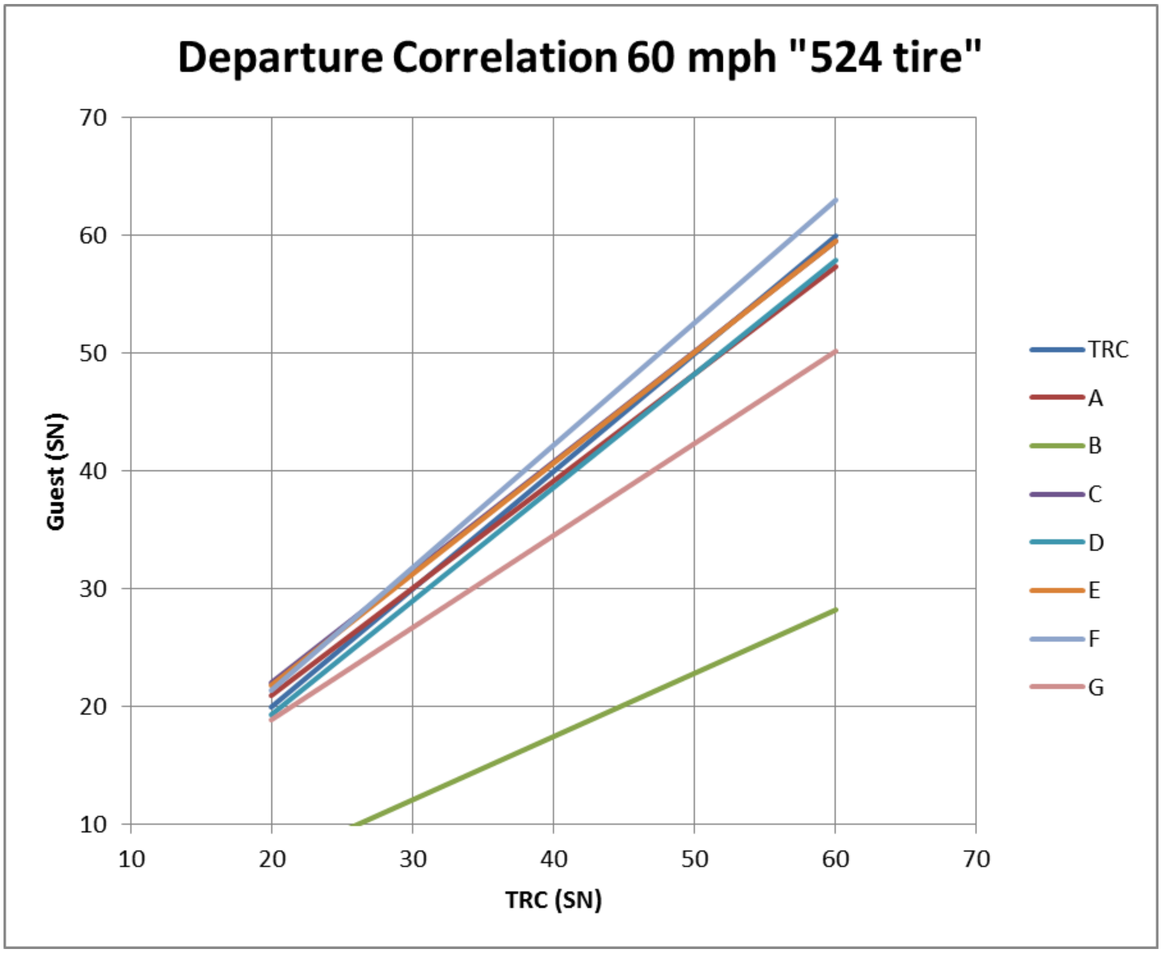
This is represented graphically as follows:



E524 Smooth 60 mph (except SCRIM)

System ID	Departure Correlation Equation
A	SN(TRC) = [SN(A) x 0.91] + 2.75
B	SN(TRC) = [SN(B) x 0.54] - 3.99
C	SN(TRC) = [SN(C) x 0.94 + 3.28
D	SN(TRC) = [SN(D) x 0.96] + 0.02
E	SN(TRC) = [SN(E) x 0.94] - 3.04
F	SN(TRC) = [SN(F) x 1.04] + 0.66
G	SN(TRC) = [SN(G) x 0.78] + 3.21

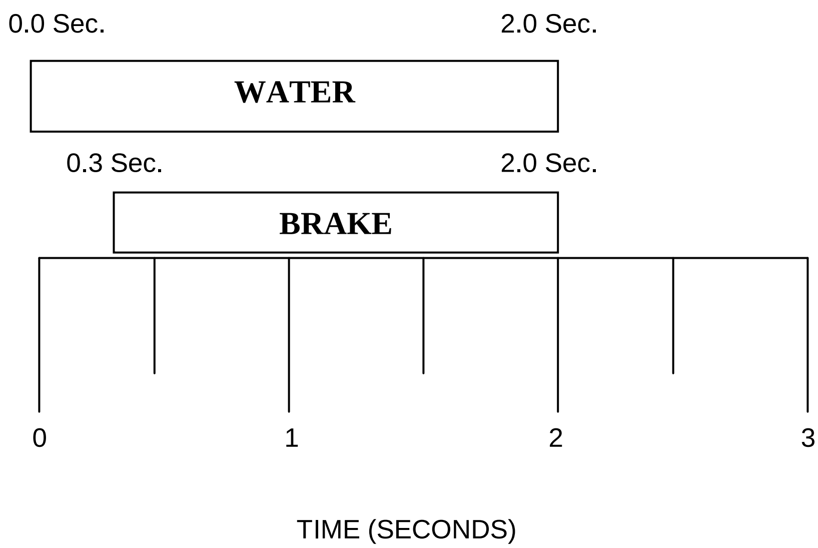
This is represented graphically follows:



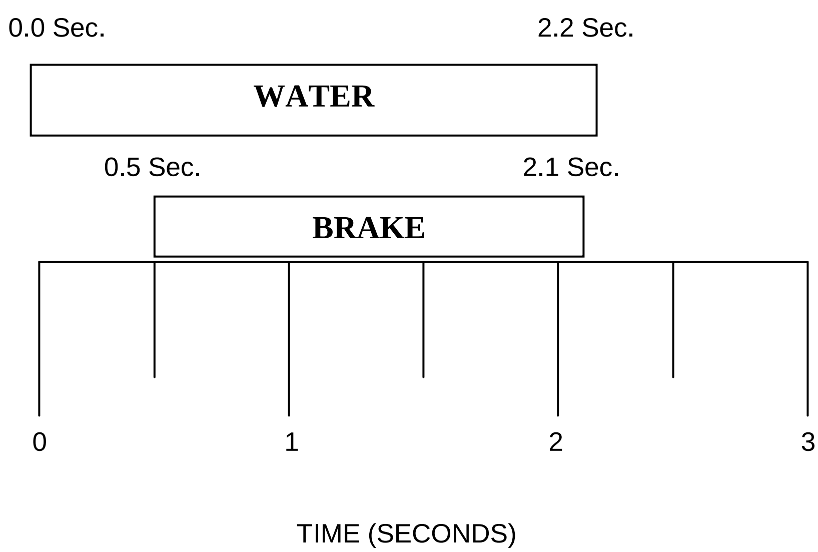
6.0 <u>System Timings</u>

Skid System timings were verified during the Departure Correlation

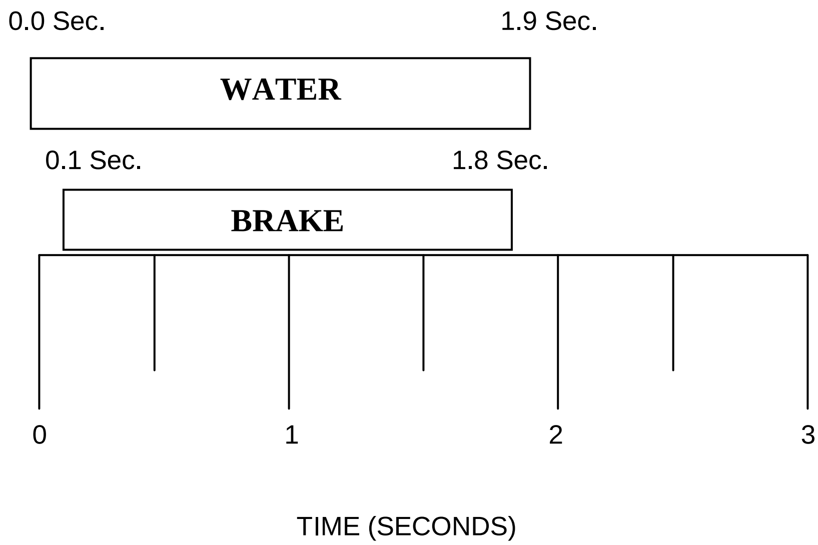
System A



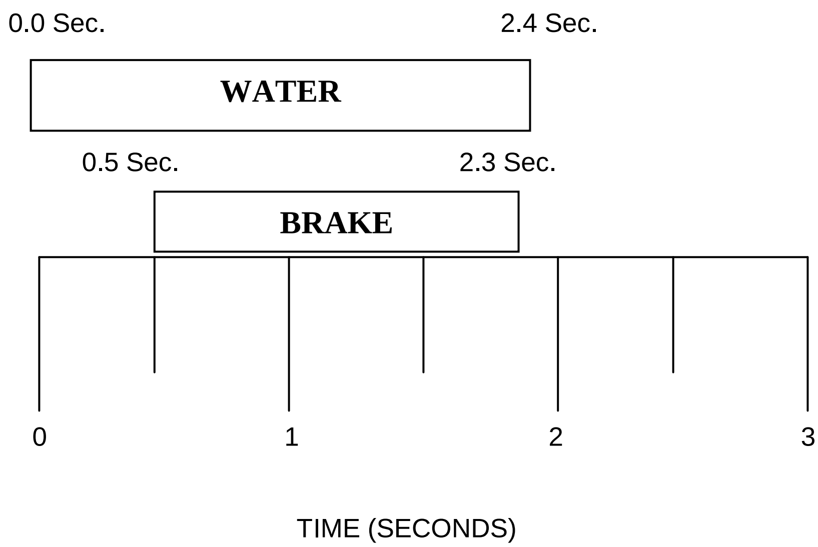
System C



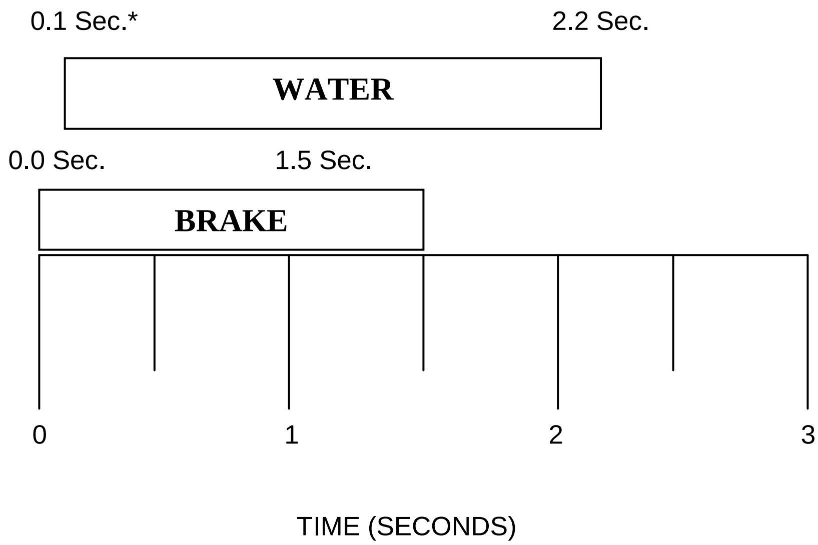
System D



System F



System G



Note that the brake was locking before the water was delivered to the pavement. This did not affect the correlation since there was plenty of water on the pads from the large number of systems running at the same time. After the testing was completed, the settings were adjusted to correct the issue to assure the tire did not lock on dry pavement during actual use on the highways.