BRAKING PERFORMANCE OF A CARHAULER LOADED TO 80,000 lb AND 88,000 lb GCW

Test Conducted for:
American Truckers Association ï Automobile Carriers Conference

Test Number: 340176 (LCVT-ATA-01)

July 2014

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Notice:
Link Commercial Vehicle Testing provides independent testing and evaluation services and does not endorse products, vehicles or equipment

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INTRODUCTION

At the request of the American Trucking Association (ATA) ï Automobile Carriers Conference, Link Commercial Vehicle Testing conducted braking performance testing on a Volvo 6x2 carhauler loaded to two different total weights. The primary purpose of these tests was to measure the dry-road stopping distance from 60-mph of the carhauler truck-trailer combination at 80,000 lb and at 88,000 lb gross combined weight (GCW).

All testing was conducted at the Transportation Research Center (TRC) facilities in East Liberty, Ohio. Stopping distance tests were performed on the Skid Pad (dry concrete).

TEST VEHICLE

Photographs of the two loading configurations are provided in Figures 1 and 2. A description of the vehicle and its components is provided in Table 1 (all figures, summary tables and data sheets follow the text).

The combination was equipped with a Bendix 6S6M ABS on the tow unit and a WABCO 4S2M ABS on the trailer. Foundation brakes were Meritor 16½x5 Q-Plus drum brakes with R301 linings on the steer axle and Meritor 15x8ę Q-Plus drum brakes with MA212 linings on the drive and tag axles and Meritor 15x8ę Q-Plus drum brakes with Abex 3030-197 linings on the trailer axles. The axle weights for both total weight configurations are found in Table 1.

TEST PROCEDURE

After receiving the carhauler, brake strokes at 85 psi were measured and recorded. The free strokes were within manufacturers allowances so no adjustments were needed. The vehicle was run on a low-speed (3 km/h) Performance Based Brake Tester (PBBT) to confirm that the brakes and ABS systems were functioning properly. The brake strokes were also measured and recorded at the end of testing.

The combination vehicle was weighed on a certified platform scale. Sand bags were added to trim the weight to the target weight of 88,000 lb (14,000 lb steer / 37,000 lb drive tandem / 37,000 lb trailer tandem). Three 60-mph stops were run at 88,000 lb GCW using a full (panic) application of the brake pedal with the vehicle on a dry concrete surface.

After running the three stops at 88,000 lb, vehicles were removed from the payload. Sand bags again were added to obtain the target weight of 80,000 lb GCW. Four stops were run at 80,000 lb GCW using the same stopping procedure as that used at 88,000 lb GCW.

After these 80,000 lb stops, the load was restored to the original level (88,000 lb GCW) and three more stops were run. In this way, the effects of any changes in brake effectiveness that occurred due to brake lining conditioning during the testing would be minimized by using the average of both sets of 88,000 lb data.

All stopping distance data was corrected to exact target speed (60 mph) using the equation in SAE J299.

TEST RESULTS

Detailed data sheets for all of the stopping distance tests are provided in Appendix A. This appendix also includes a record of brake adjustments. Figure 3 shows the summary results of the stopping distances for each configuration tested along with the average stopping distance for each configuration. Results of the PBBT are provided in Appendix B. Instrumentation used and calibration dates are provided in Appendix C. Appendix D contains individual stop history graphs of each stop.

The average stopping distance with the combination unit at 80,000 lb was 279 feet. The best of four stops was 270 feet. The stopping distances at 88,000 lb averaged 23 feet (approximately 8%) greater than what was measured with the unit at 80,000 lb. The best of six stops at 88,000 lb. was 297 feet and the average was 302 feet.

It should be noted that the ABS did not cycle on any of the tow unit axles during the testing at either loading condition, indicating that the brakes were torque limited as opposed to ñskidò or tire traction limited. There was minimal ABS activity at the beginning of seven of ten stops on the trailer. In this case the increase in stopping distance at higher weights should be approximately proportional to the weight increase (i.e. 10 percent in this case). The actual measured increase of 8 percent is relatively close to this predicted amount, given the typical level of experimental error in such a test.

For reference, FMVSS 121 requirement for loaded single-unit trucks is 310 feet. (There are no requirements in FMVSS No.121 for combinations, only single vehicles.) These requirements apply to vehicles that have had their brakes burnished (broken-in) with 500 stops according to a procedure specified in the standard. Both weight configurations of the carhauler met the FMVSS 121 distances for loaded trucks. It should be noted that although the brakes on truck and trailer combination had some ñin serviceò conditioning, they were tested without the benefit of the 500 stop FMVSS 121 burnish.

It should also be noted that the brakes used on the Volvo truck and Cottrell trailer that were tested were rated in excess of the 88,000 lb GCW. With type 24 air chamber, 5.5ò slacks,

and R301 lining the front brakes have a maximum rating of 14,600 lb. The truck drive and tag axle brakes had a maximum rating of 38,000 lb. The trailer brakes had a maximum rating of 37,500 lbs. The brakes were, therefore, rated for a total loading of 90,100 lb.

It is common practice to equip tractors and trailers with axles that have GAWRs that exceed legal highway loads. Components that permit loading to over 90,000 lb are typical on five-axle tractor semi-trailers.

SUMMARY AND CONCLUSIONS

Stopping distance of the carhauler from 60 mph on a dry road increased by about 8 percent when the weight was increased from 80,000 lb to 88,000 lb. This is very close to the 10 percent increase in weight.

Although the weight increase resulted in an 8 percent stopping distance increase, the average stopping distance of 302 feet that was measured with the 88,000 lb load was still within the distances required by FMVSS 121 for trucks (310 feet) loaded to GVWR. This is despite the fact that the brakes on vehicle tested were not conditioned by the burnish procedure specified in FMVSS 121.

Table 1 - Vehicle Information Sheet

Project Number	340176 (ATA-01)
Testing Location	LCVT / TRC
Test Dates	7/14/14 to 7/15/14

	Truck	Trailer
Vehicle Model	Volvo 6x2 Carhauler	Cottrell CX-09LS2
Vehicle VIN	4V5R99DG6EN174237	5E0AA1444EG557903
Wheelbase, in	250	364
SLR, in	16.7 / 15.9	15.7
ABS	Bendix 6S6M	WABCO 4S2M

Brake Information	Steer Axle	Drive Axle	Tag Axle	Forward Trailer Axle	Rear Trailer Axle
Manufacturer	Meritor	Meritor	Meritor	Meritor	Meritor
Type	S-Cam	S-Cam	S-Cam	S-Cam	S-Cam
Size, in	16½x5	15x8e	15x8e	15x8e	15x8e
Lining	R301	MA212	MA212	Abex 3030-197	Abex 3030-197
Brake Adjusters, in	Meritor 5½	Meritor 5½	Meritor 5½	Haldex 6	Haldex 6
Actuator Type	MGM 24L	MGM 2430L	MGM 2430L	Haldex 2424L	Haldex 2424L
Rotor / Drum	ConMet 10005332	Centrifuse 91481F	Centrifuse 91481F	Webb 61988	Webb 61988

Tire Information	Steer Axle	Drive Axle	Tag Axle	Forward Trailer Axle	Rear Trailer Axle
Manufacturer	Michelin	Michelin	Michelin	Michelin	Michelin
Make/Type	XZA2 Energy	XDE2+	XDE2+	X-Line Energy	X-Line Energy
Size, in	295/60R22.5	265/70R19.5	265/70R19.5	265/70R19.5	265/70R19.5
Pressure, psi	120	100	100	100	100

Weight Distribution, lbs	Steer Axle	Drive & Tag Axle	Trailer Axles	Total
GAWR/GCW	14,600	38,000	37,500	90,100
Laden - 88K First Run	14,370	36,100	37,630	88,100
Laden - 80K	14,710	33,300	32,000	80,010
Laden - 88K Second Run	14,160	36,310	37,570	88,040

Figure 1 – Test Vehicle Loaded to 88,000 lb

Figure 2 – Test Vehicle Loaded to 80,000 lb

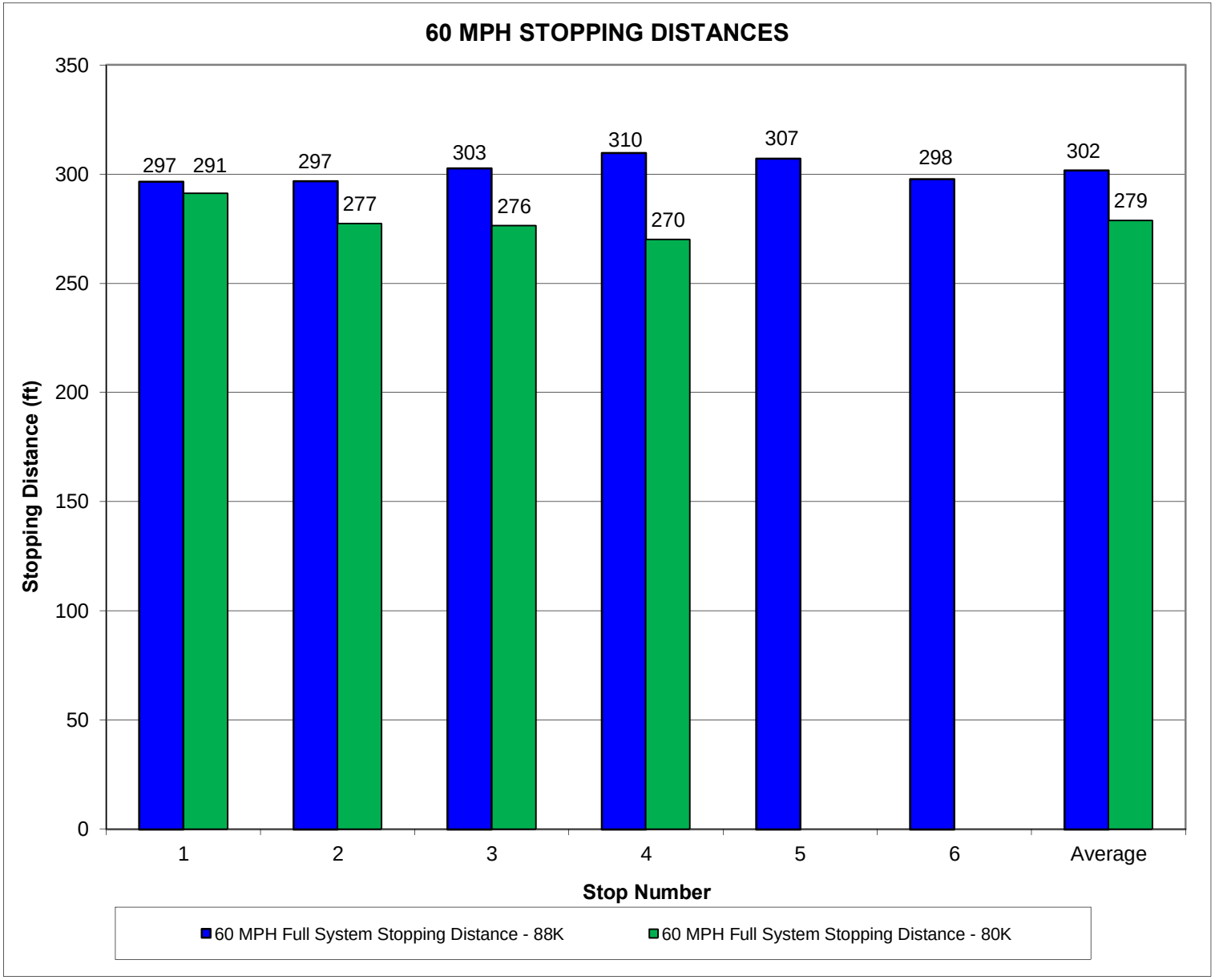


Figure 3 - Summary Results - 60 mph Stopping Distances

APPENDIX A

DATA SHEETS

STOPPING DISTANCE DATA SHEET

Chassis #: 174237 **Laden:** X **LLVW:** _____ **Project #:** 340176 (ATA-01)
Model: Volvo Carhauler w/Cottrell Trailer

A. 60 MPH Full System Stopping Distance - 88K

Stop	IBT (F)	Initial Speed (mph)	Stopping Distance Actual	Stoppping Distance Corrected	Average Control (psi)	Average Decel (ft/s/s)	In Lane ?	Comments
1		60.8	304.2	297	104	14.7	YES	
2		60.7	303.9	297	103	14.9	YES	
3		60.7	309.2	303	105	14.6	YES	
4								
5								
6								

Minimum Stopping Distance: 297 Average Stopping Distance: 299

	Time	Date	AMB F	Wind Speed	Wind Direction	Odometer
Start	09:32	07/15/2014	64°	10-12	277° W	59429
Finish	10:13	07/15/2014	65°	15	263° W	59441

Driver: M. Taylor Observer: ATA

B. 60 MPH Full System Stopping Distance - 80K

Stop	IBT (F)	Initial Speed (mph)	Stopping Distance Actual	Stoppping Distance Corrected	Average Control (psi)	Average Decel (ft/s/s)	In Lane ?	Comments
1		60.8	298.8	291	104	15.6	YES	
2		60.7	283.8	277	104	16.2	YES	
3		60.7	282.5	276	104	16.4	YES	
4		60.8	277.4	270	105	16.9	YES	
5								
6								

Minimum Stopping Distance: 270 Average Stopping Distance: 279

	Time	Date	AMB F	Wind Speed	Wind Direction	Odometer
Start	11:30	07/15/2014	67°	9	301° NW	59447
Finish	12:31	07/15/2014	68°	9	269° W	59459

Driver: M. Taylor Observer: ATA

Note: All Stopping Distances corrected using SAE J299 procedures

STOPPING DISTANCE DATA SHEET

Chassis #: **174237** **Laden:** **X** **LLVW:** _____ **Project #:** **340176 (ATA-01)**

Model: **Volvo Carhauler w/Cottrell Trailer**

C. 60 MPH Full System Stopping Distance - 88K (Re- Run)

Stop	IBT (F)	Initial Speed (mph)	Stopping Distance Actual	Stoppping Distance Corrected	Average Control (psi)	Average Decel (ft/s/s)	In Lane ?	Comments
1		60.8	318.0	310	104	14.2	YES	
2		60.7	314.3	307	105	14.6	YES	
3		60.8	306.0	298	105	14.8	YES	
4								
5								
6								

Minimum Stopping Distance: 298 Average Stopping Distance: 305

	Time	Date	AMB F	Wind Speed	Wind Direction	Odometer
Start	02:32	07/15/2014	68°	11-12	267° SW	59469
Finish	03:04	07/15/2014	68°	13	275° SW	59477

Driver: M. Taylor Observer: ATA

D.

Stop	IBT (F)	Initial Speed (mph)	Stopping Distance Actual	Stoppping Distance Corrected	Average Control (psi)	Average Decel (ft/s/s)	In Lane ?	Comments
1								
2								
3								
4								
5								
6								

Minimum Stopping Distance: _____ Average Stopping Distance: _____

	Time	Date	AMB F	Wind Speed	Wind Direction	Odometer
Start						
Finish						

Driver: _____ Observer: _____

Note: All Stopping Distances corrected using SAE J299 procedures

BRAKE STROKE SHEET

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2.25		2.25		2.69		2.63		2.69		2.88		7.00		6.88		6.88		6.88	
FREE STROKE	2.88	0.63	2.75	0.50	3.00	0.31	3.00	0.37	3.13	0.44	3.13	0.25	7.63	0.63	7.75	0.87	7.63	0.75	7.75	0.87
90 PSI	3.56	1.31	3.63	1.38	4.13	1.44	4.13	1.50	4.44	1.75	4.38	1.50	8.44	1.44	8.38	1.50	8.44	1.56	8.44	1.56
SPRING BRAKES					3.88	1.19	3.88	1.25	4.19	1.50	4.13	1.25	8.25	1.25	8.25	1.37	8.19	1.31	8.25	1.37

COMMENTS: As Received **DATE:** 07/15/14

	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2.25		2.25		2.69		2.63		2.69		2.88		7.00		6.88		6.88		6.88	
FREE STROKE	2.50	0.25	2.50	0.25	2.94	0.25	2.88	0.25	3.00	0.31	3.13	0.25	7.63	0.63	7.75	0.87	7.63	0.75	7.75	0.87
90 PSI	3.50	1.25	3.38	1.13	4.00	1.31	4.00	1.37	4.25	1.56	4.25	1.37	8.44	1.44	8.38	1.50	8.44	1.56	8.44	1.56
SPRING BRAKES					3.63	0.94	3.69	1.06	4.00	1.31	4.00	1.12	8.25	1.25	8.25	1.37	8.19	1.31	8.25	1.37

COMMENTS: Final Strokes **DATE:** 07/15/14

	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP																				
FREE STROKE																				
90 PSI																				
SPRING BRAKES																				

COMMENTS: **DATE:**

	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP																				
FREE STROKE																				
90 PSI																				
SPRING BRAKES																				

COMMENTS: **DATE:**

	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP																				
FREE STROKE																				
90 PSI																				
SPRING BRAKES																				

COMMENTS: **DATE:**

APPENDIX B

PERFORMANCE BASED BRAKE TEST RESULTS

Link Engineering BrakeTest Report

Test Number: 128 ATA-01 Test Date/Time: 7/14/2014 4:51:26 PM
Project Code: 340176
Vehicle Make: VOLVO Model: CAR HAULER Number: 237
Description: PRE STOPS DYNO

Axle	Left	Pct Diff	Right	Total	Pm / Px
Rolling Resistance Ratio					
1	0.01	12	0.02		
2	0.02	4	0.02		
3	0.02	18	0.02		
4	0.02	26	0.01		
5	0.02	29	0.01		
Service Brake Force (lb)					
1	4475	4	4295	8770	102.9 / 103.4
2	5000	18	4343 LU	9343	76.3 / 79.7
3	4215 LU	14	4017 LU	8232	70.2 / 72.4
4	4788 LU	8	3580 LU	8369	73.9 / 69.9
5	3876 LU	10	3726 LU	7601	84.0 / 80.6
Weight (lb)					
1	7584		6923	14506	
2	9348		8774	18122	
3	7231		7540	14771	
4	8333		7937	16270	
5	8289		8113	16402	
Service Brake Force / Weight Ratio					
1	0.59		0.62		
2	0.53		0.49		
3	0.58		0.53		
4	0.57		0.45		
5	0.47		0.46		
Ovality (lb)					
Threshold (psi)					
1	8.2		9.5		
2	9.4		8.7		
3	9.5		8.2		
4	10.5		10.1		
5	8.6		10.1		
Crack (psi)					
1		5.0			
2		4.5			
3		4.3			
4		5.5			
5		4.8			

Parking Brake Force (lb)

1				
2	2734	12	3122	5855
3	2562	13	2994	5556
4	2804	5	2967	5772
5	2945	3	2813	5758

Total	Weight (lb)	80072	Service Force/Weight	0.53	Park Force/Weight	0.29

Results:

Brakes Pass Test Criteria

Service Brake Results

	Axle 1				Axle 2				Axle 3			
Pm	Px	BFL	BFR	BFT	Px	BFL	BFR	BFT	Px	BFL	BFR	BFT
psi	lb	lb	lb	lb	psi	lb	lb	lb	psi	lb	lb	lb
0.0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0
2.0												
4.0	1.3				1.8				0.4			
6.0	3.4				3.7				2.5			
8.0	5.5				5.7				4.7			
10.0	7.6		35		7.6		53		6.9		61	
12.0	9.7	86	130	216	9.6	88	168	256	9.1	124	174	298
14.0	11.8	186	224	410	11.6	210	287	496	11.3	251	292	543
16.0	13.9	283	318	601	13.7	329	409	739	13.5	378	416	793
18.0	16.0	378	411	790	15.8	448	535	983	15.7	504	544	1049
20.0	18.1	471	504	975	17.9	564	664	1228	17.9	631	677	1308
25.0	23.4	696	735	1431	23.2	850	996	1846	23.4	945	1025	1970
30.0	28.6	911	964	1875	28.7	1128	1340	2467	28.8	1255	1389	2645
40.0	38.9	1322	1417	2739	39.8	1661	2039	3700	39.8	1859	2132	3991
50.0	49.3	1724	1867	3590	51.1	2173	2719	4892	50.7	2429	2838	5267
60.0	59.6	2134	2316	4450	62.3	2670	3340	6009	61.5	2953	3443	6396
70.0	69.8	2573	2767	5340	73.1	3158	3859	7017	72.3	3418	3880	7298
80.0	80.0	3059	3224	6282	83.5	3646	4235	7881	83.1	3812	4084	7896
90.0	90.2	3611	3687	7298	93.1	4141	4426	8567	93.8	4122	3989	8111
100.0	100.4	4247	4162	8409	101.7	4649	4392	9041				
Max	103.4	4475	4295	8770	79.5	3527	4343	7870	72.4	3492	4017	7509

	Axle 4				Axle 5			
Pm	Px	BFL	BFR	BFT	Px	BFL	BFR	BFT
psi	lb	lb	lb	lb	psi	lb	lb	lb
0.0	0.0	0	0	0	0.0	0	0	0
2.0								
4.0								
6.0	1.2				2.1			
8.0	3.4				4.3			
10.0	5.7				6.4	36		
12.0	7.9	48	53	102	8.6	155	141	296
14.0	10.0	189	186	375	10.7	275	265	539
16.0	12.2	326	320	646	12.8	394	388	782
18.0	14.3	459	454	913	14.9	514	512	1026
20.0	16.4	589	588	1177	17.0	633	635	1268
25.0	21.6	898	922	1820	22.1	930	941	1871
30.0	26.7	1188	1253	2441	27.2	1225	1242	2467
40.0	36.7	1722	1887	3609	37.1	1801	1823	3624
50.0	46.4	2209	2465	4674	46.9	2350	2362	4712
60.0	56.1	2671	2959	5630	56.7	2862	2845	5707
70.0	65.9	3126	3341	6467	66.5	3326	3255	6581
80.0	75.9	3595	3584	7180	76.5	3732	3579	7311
90.0	86.4	4098	3662	7760				
100.0								
Max	69.9	3457	3580	7037	80.0	3880	3483	7363

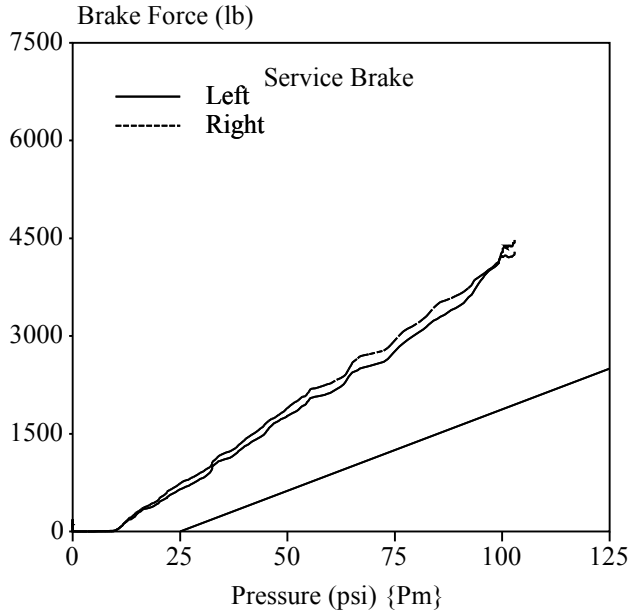
Calculated Deceleration

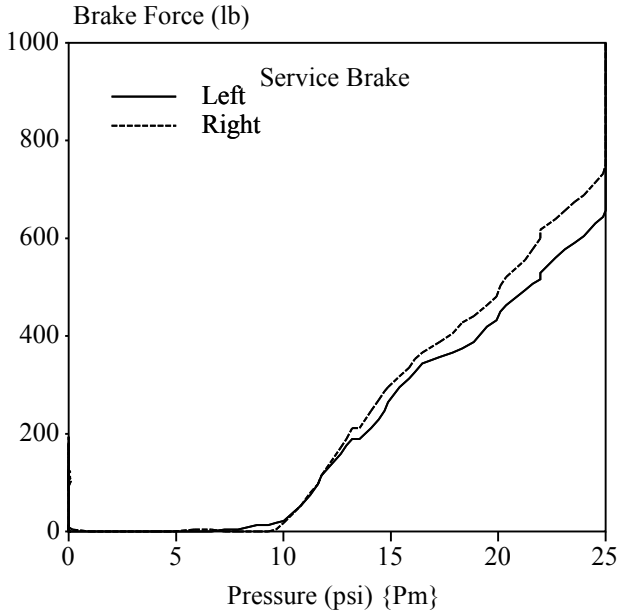
	Decel %
0	0
2	0
4	0
6	0
8	0
10	0
12	1
14	3
16	4
18	6
20	7
25	11
30	15
40	22
50	29
60	35
70	41
80	46

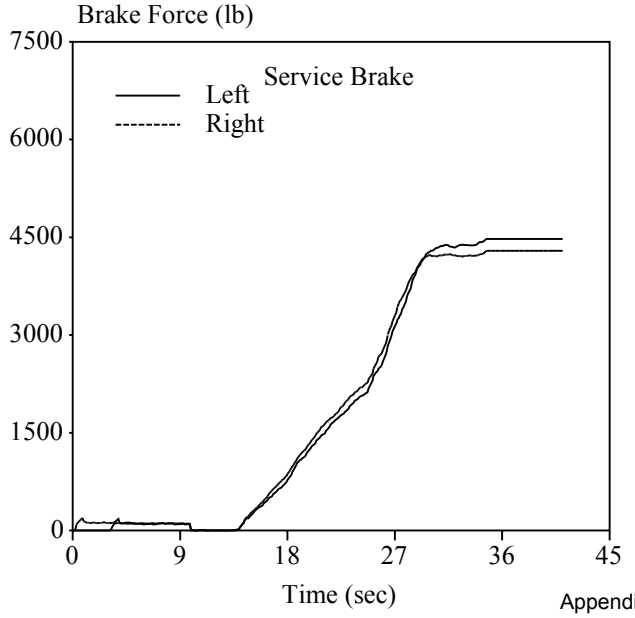
Link Engineering BrakeTest Report

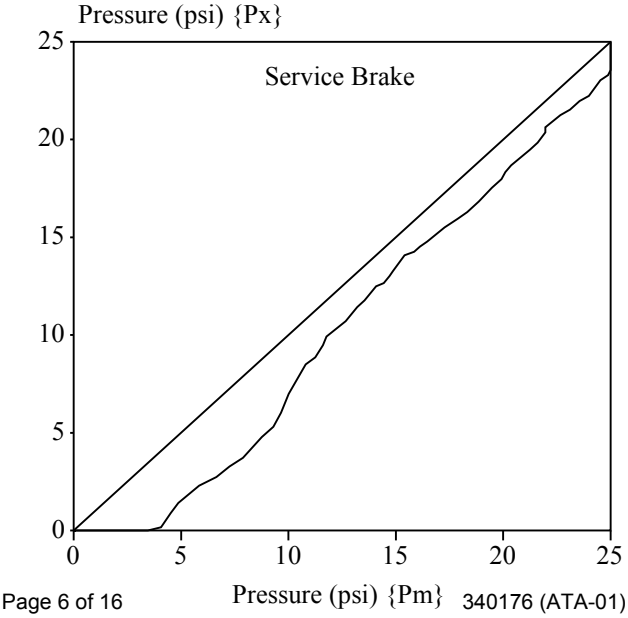
Test Number: 128 | Axle 1 | Test Date/Time: 7/14/2014 4:51:26 PM

	Left	Pct Diff	Right	Total
Roll Res Ratio	0.01	12	0.02	
Service Brk Force (lb)	4475	4	4295	8770
Static Weight (lb)	7584		6923	14506
Dynamic Weight (lb)	7628		6923	14551
Force / Weight Ratio	0.59		0.62	
Parking Brk Force (lb)				
Ovality				
Threshold	8.2		9.5	
Crack Pressure (psi)		5.0		
Pressure at Lockup	Pm 102.9 / Px 103.4			

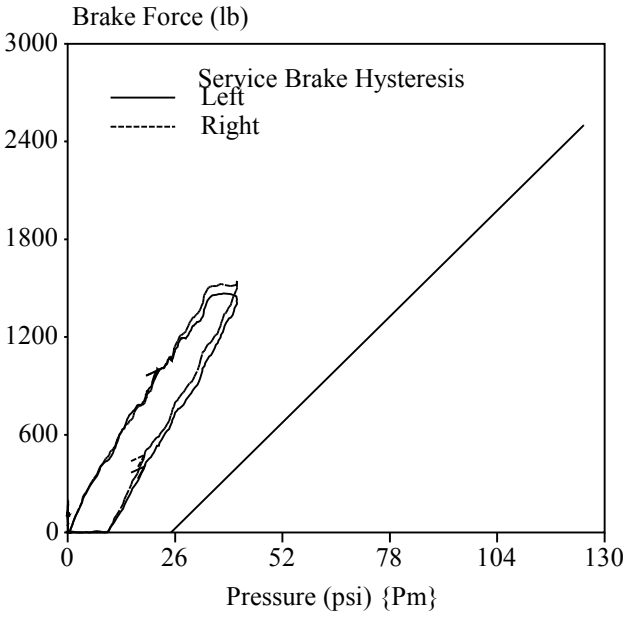


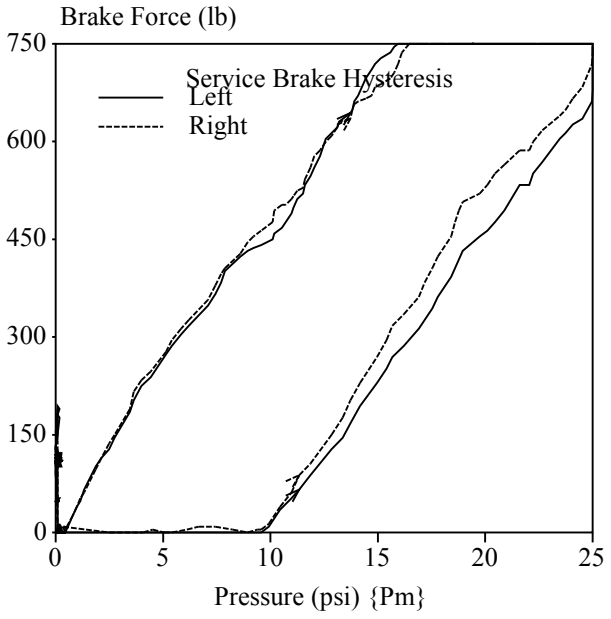


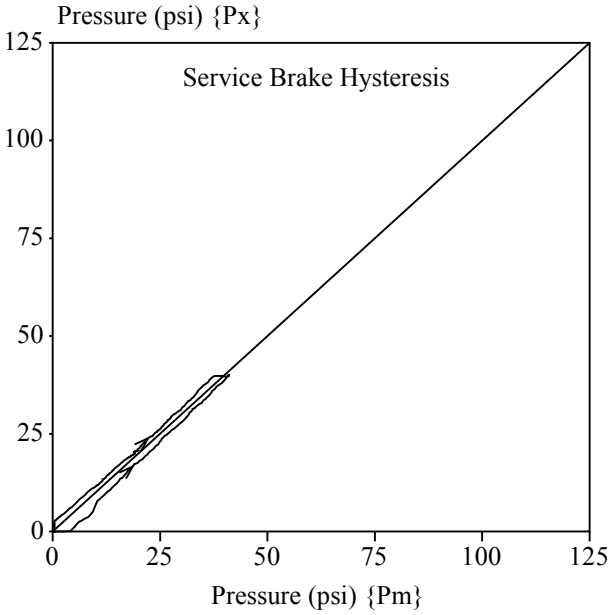


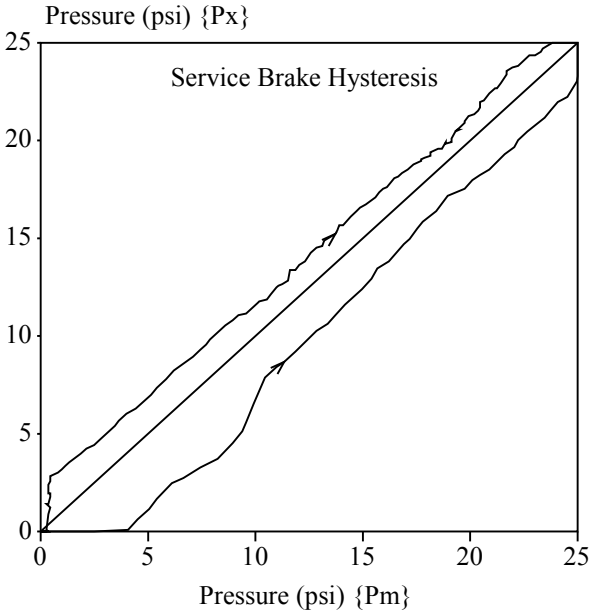


340176 (ATA-01)


Brake Force (lb)
Service Brake Hysteresis
Left
Right
3000
2400
1800
1200
600
0
0
26
52
78
104
130
Pressure (psi) {Pm}


Brake Force (lb)
Service Brake Hysteresis
Left
Right
750
600
450
300
150
0
0
5
10
15
20
25
Pressure (psi) {Pm}

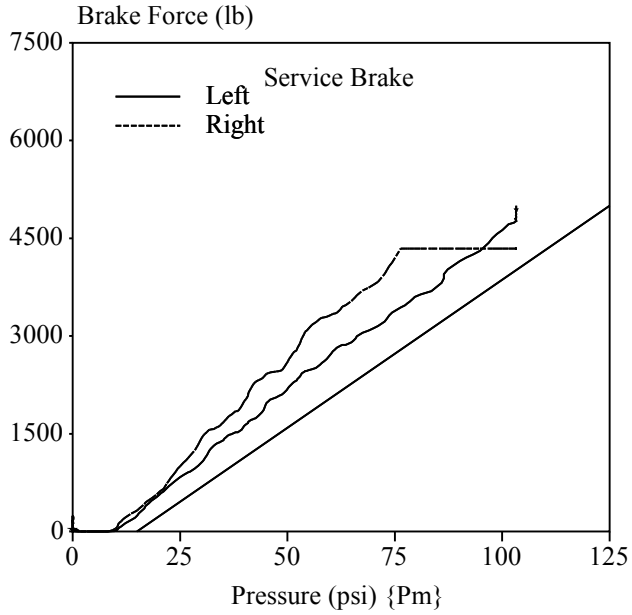

Pressure (psi) {Px}
Service Brake Hysteresis
125
100
75
50
25
0
0
25
50
75
100
125
Pressure (psi) {Pm}

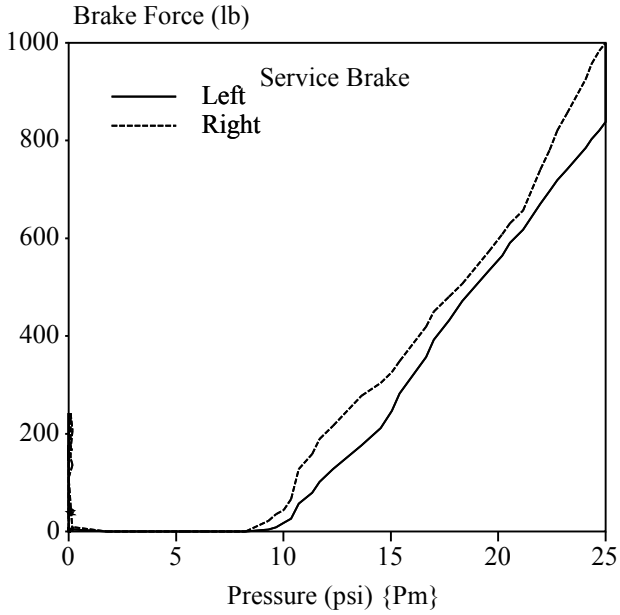

Pressure (psi) {Px}
Service Brake Hysteresis
25
20
15
10
5
0
0
5
10
15
20
25
Pressure (psi) {Pm}

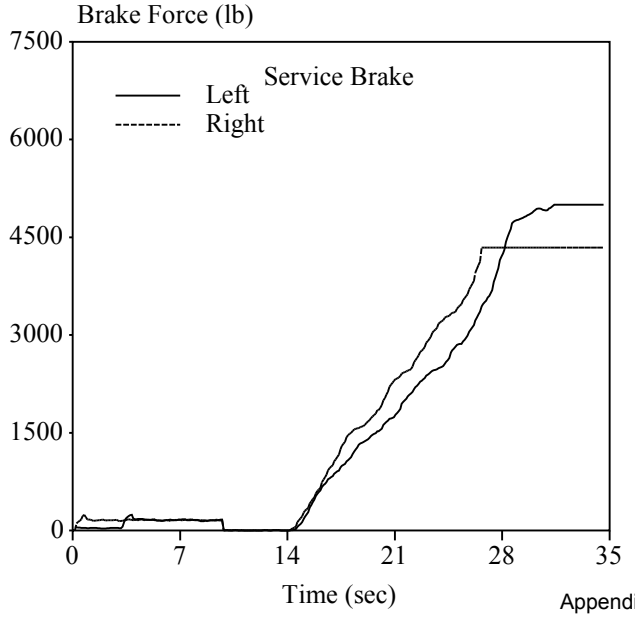
Link Engineering BrakeTest Report

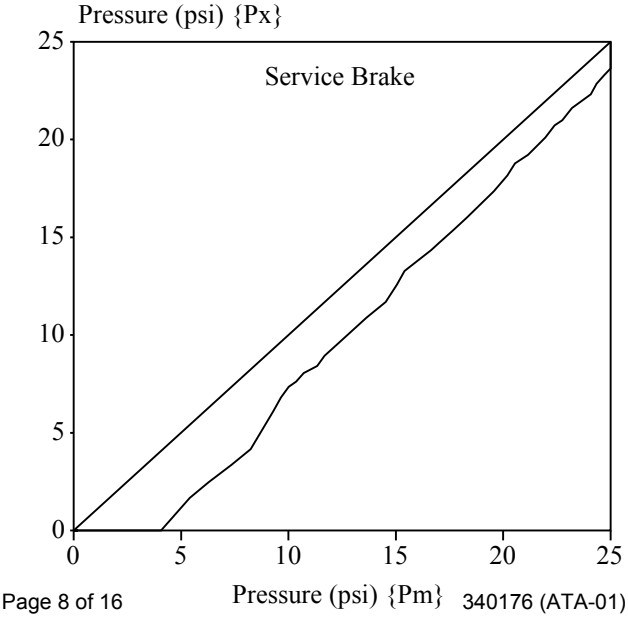
Test Number: 128 | **Axle 2** | Test Date/Time: 7/14/2014 4:51:26 PM

	Left	Pct Diff	Right	Total
Roll Res Ratio	0.02	4	0.02	
Service Brk Force (lb)	5000	18	4343 LU	9343
Static Weight (lb)	9348		8774	18122
Dynamic Weight (lb)	7848		6878	14727
Force / Weight Ratio	0.53		0.49	
Parking Brk Force (lb)	2734	12	3122	5855
Ovality				
Threshold	9.4		8.7	
Crack Pressure (psi)		4.5		
Pressure at Lockup	Pm 76.3 / Px 79.7			

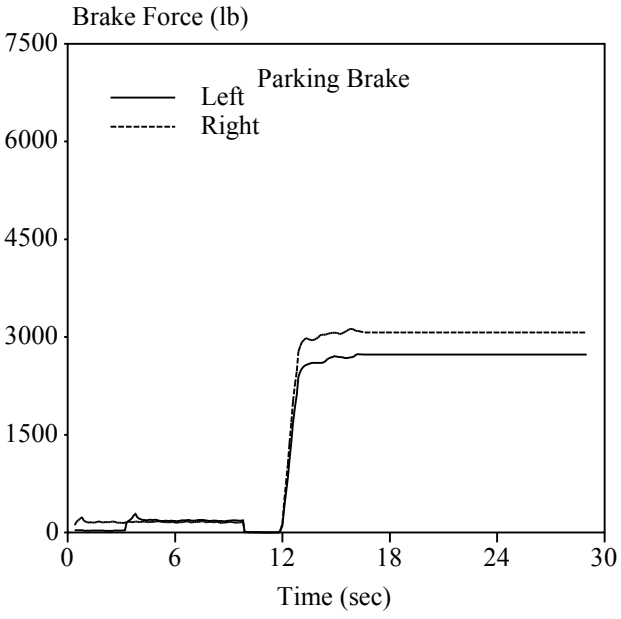


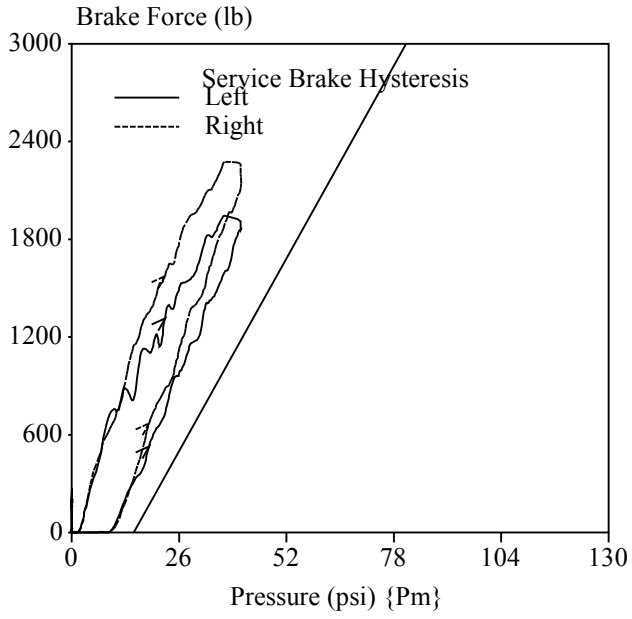


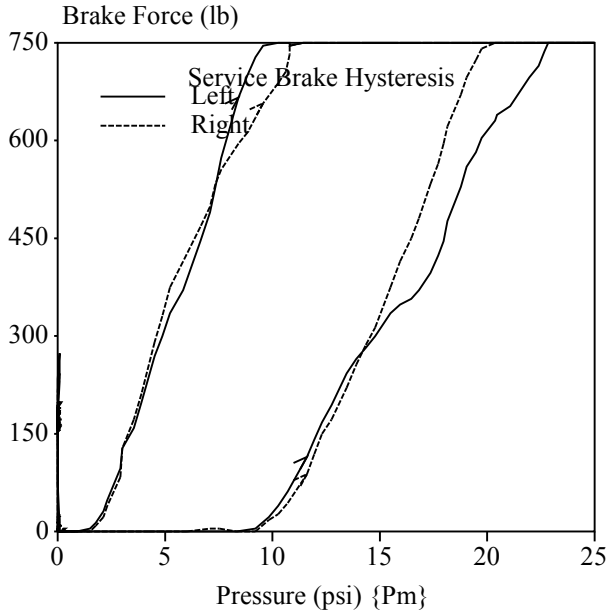


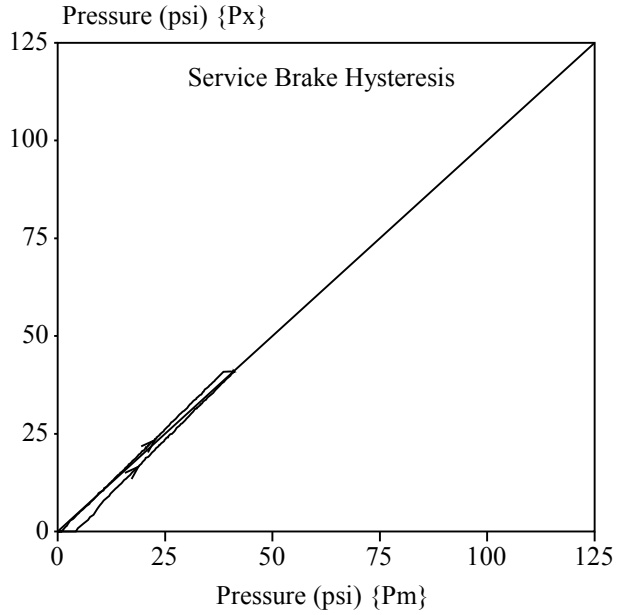


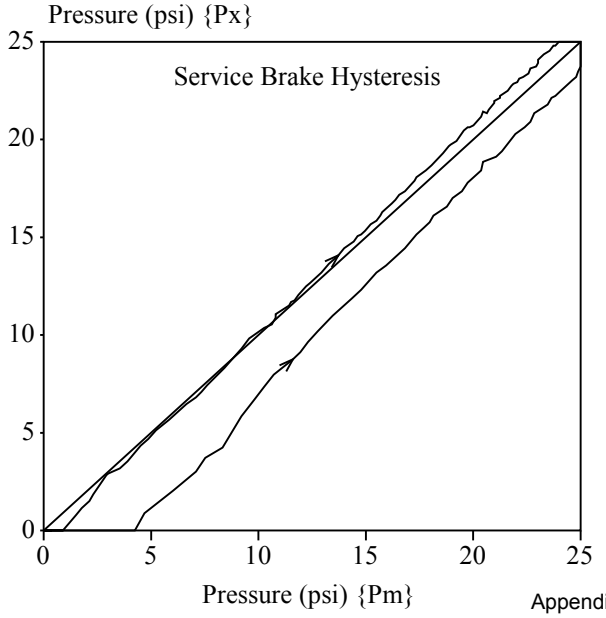
340176 (ATA-01)


Brake Force (lb)
Parking Brake
Left
Right
7500
6000
4500
3000
1500
0
0
6
12
18
24
30
Time (sec)


Brake Force (lb)
Service Brake Hysteresis
Left
Right
3000
2400
1800
1200
600
0
0
26
52
78
104
130
Pressure (psi) {Pm}


Brake Force (lb)
Service Brake Hysteresis
Left
Right
750
600
450
300
150
0
0
5
10
15
20
25
Pressure (psi) {Pm}

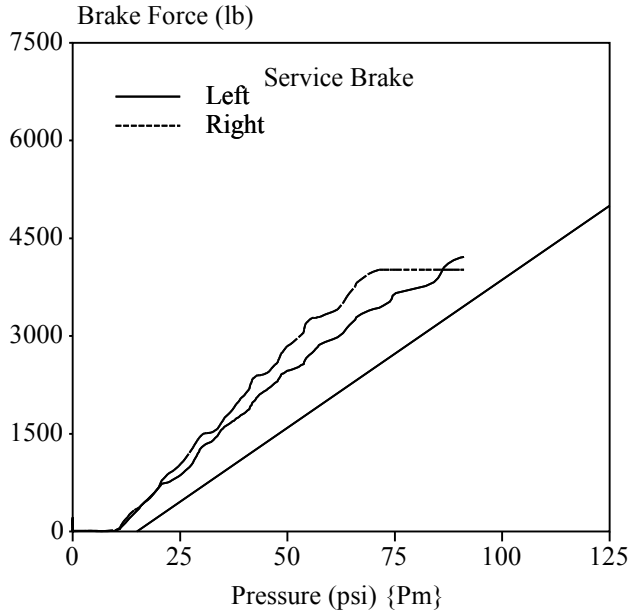

Pressure (psi) {Px}
Service Brake Hysteresis
125
100
75
50
25
0
0
25
50
75
100
125
Pressure (psi) {Pm}

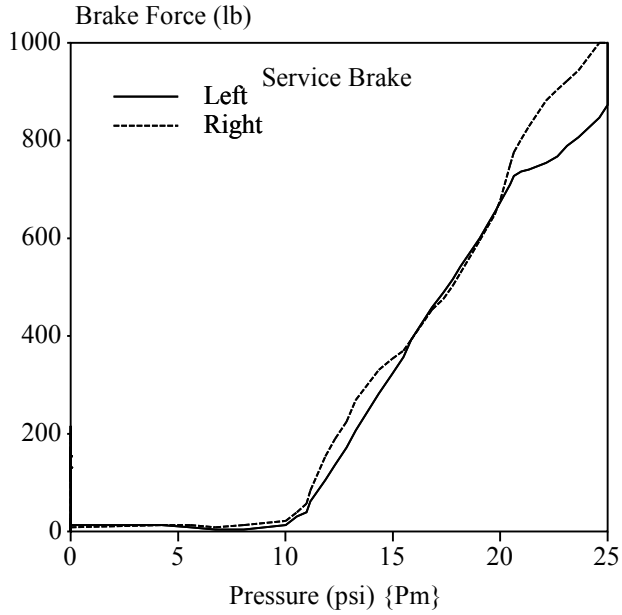

Pressure (psi) {Px}
Service Brake Hysteresis
25
20
15
10
5
0
0
5
10
15
20
25
Pressure (psi) {Pm}

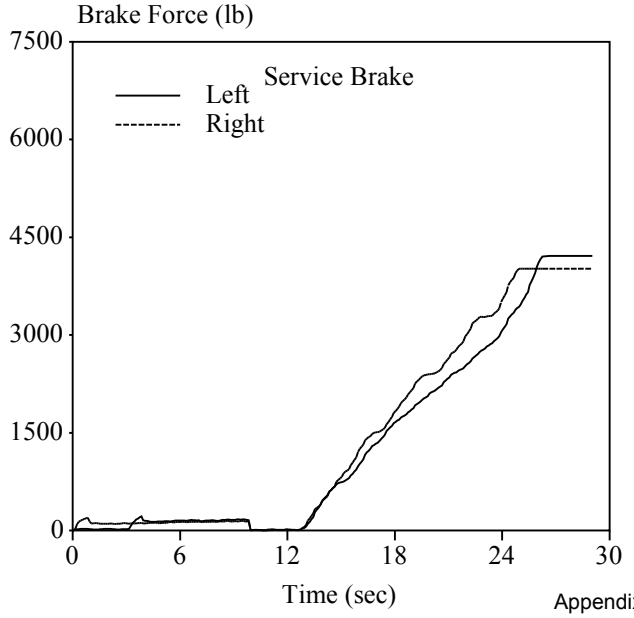
Link Engineering BrakeTest Report

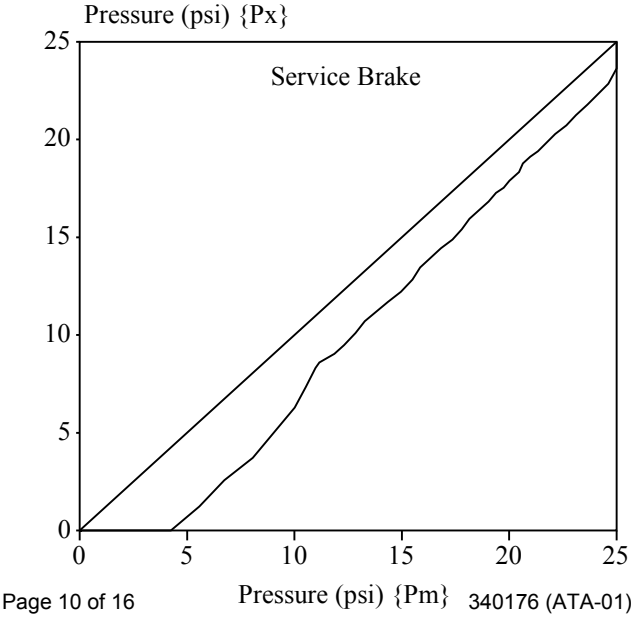
Test Number: 128 | **Axle 3** | Test Date/Time: 7/14/2014 4:51:26 PM

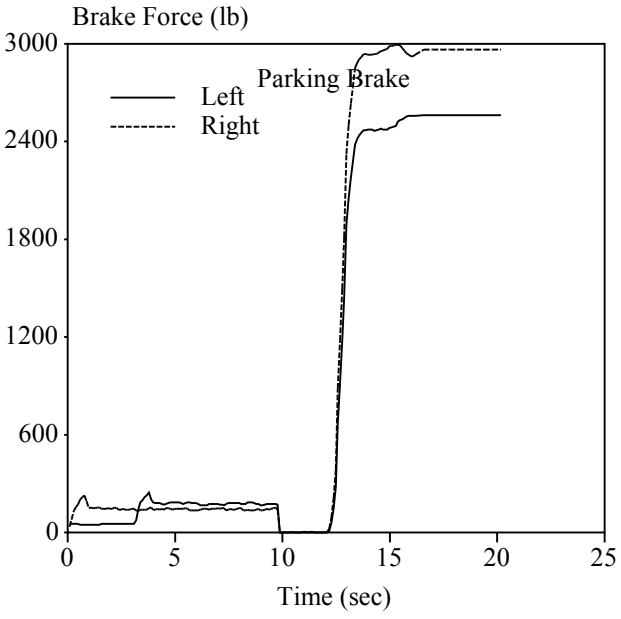
	Left		Pct Diff	Right		Total
Roll Res Ratio	0.02		18	0.02		
Service Brk Force (lb)	4215	LU	14	4017	LU	8232
Static Weight (lb)	7231			7540		14771
Dynamic Weight (lb)	5908			5467		11376
Force / Weight Ratio	0.58			0.53		
Parking Brk Force (lb)	2562		13	2994		5556
Ovality						
Threshold	9.5			8.2		
Crack Pressure (psi)			4.3			
Pressure at Lockup	Pm 70.2 / Px 72.4					

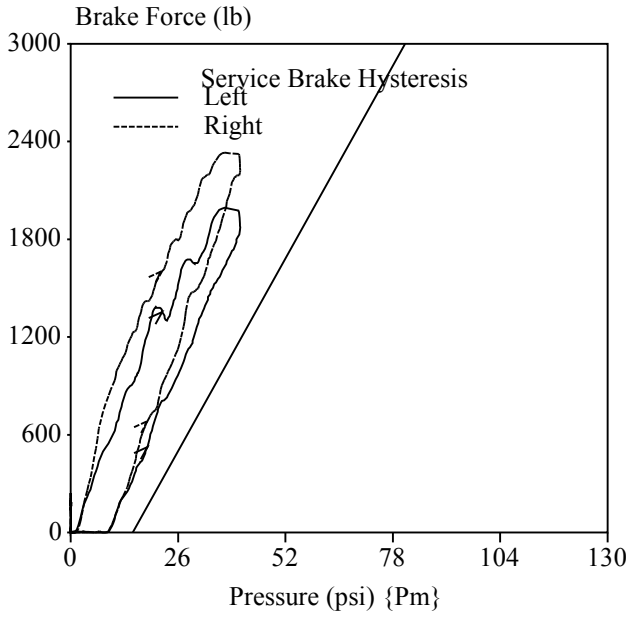


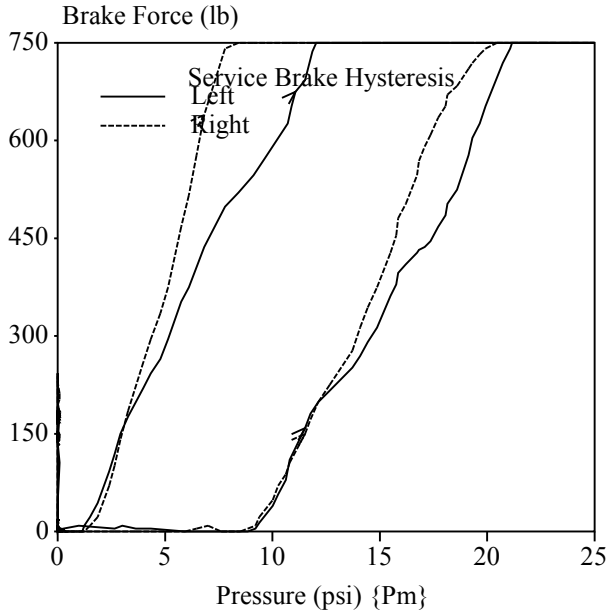


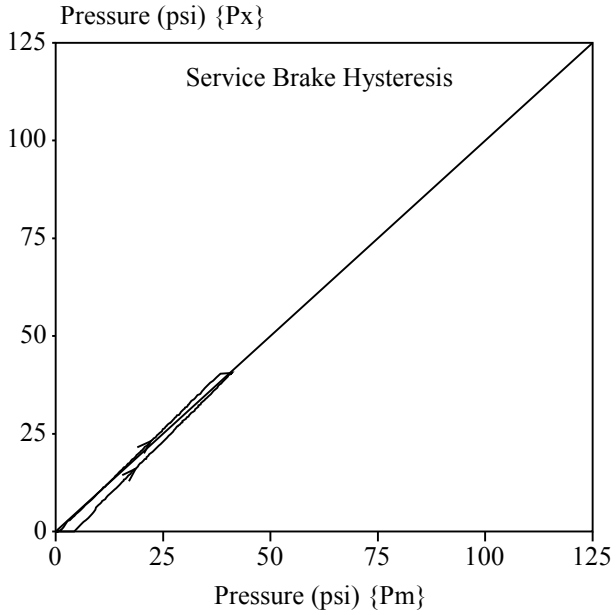


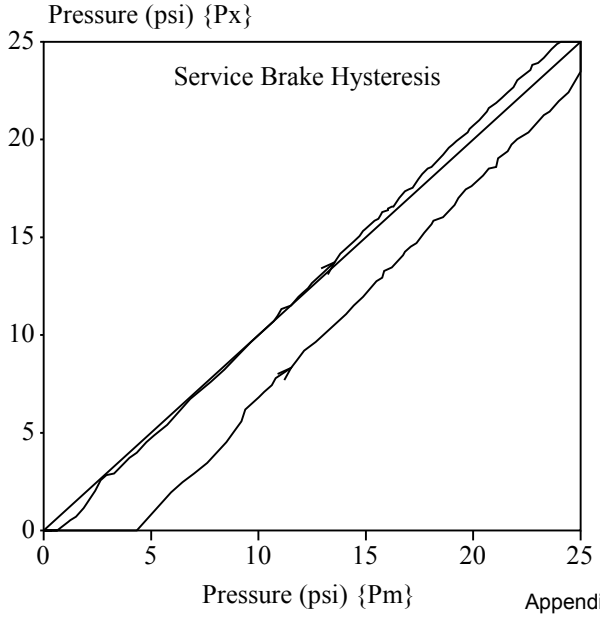



Brake Force (lb)
Parking Brake
Left
Right
3000
2400
1800
1200
600
0
0
5
10
15
20
25
Time (sec)


Brake Force (lb)
Service Brake Hysteresis
Left
Right
3000
2400
1800
1200
600
0
0
26
52
78
104
130
Pressure (psi) {Pm}


Brake Force (lb)
Service Brake Hysteresis
Left
Right
750
600
450
300
150
0
0
5
10
15
20
25
Pressure (psi) {Pm}

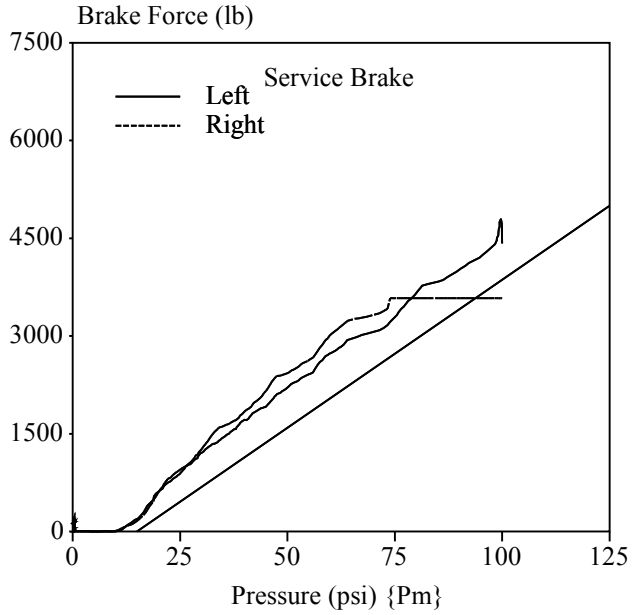

Pressure (psi) {Px}
Service Brake Hysteresis
125
100
75
50
25
0
0
25
50
75
100
125
Pressure (psi) {Pm}

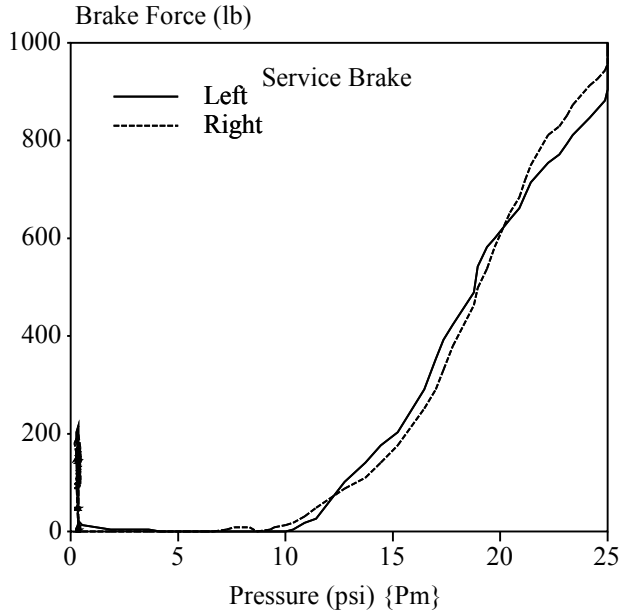

Pressure (psi) {Px}
Service Brake Hysteresis
25
20
15
10
5
0
0
5
10
15
20
25
Pressure (psi) {Pm}

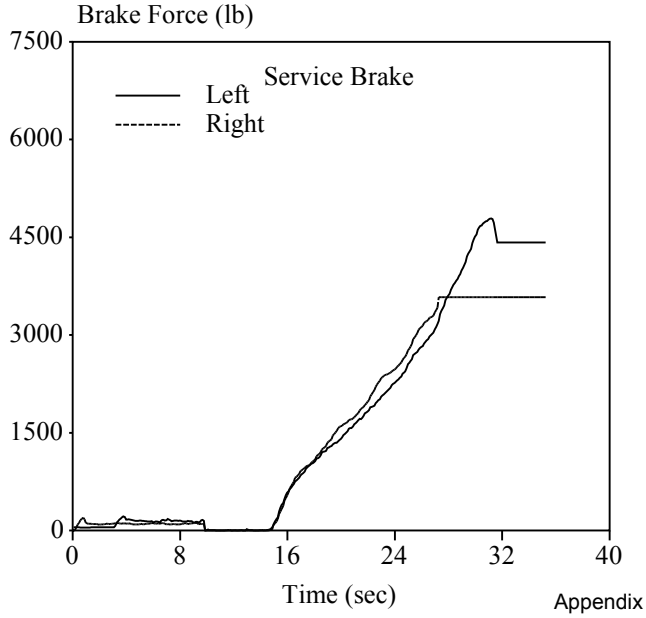
Link Engineering BrakeTest Report

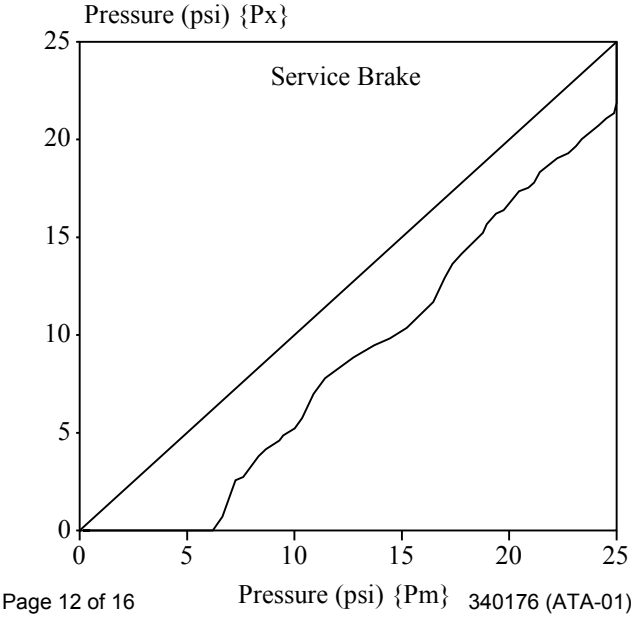
Test Number: 128 | **Axle 4** | Test Date/Time: 7/14/2014 4:51:26 PM

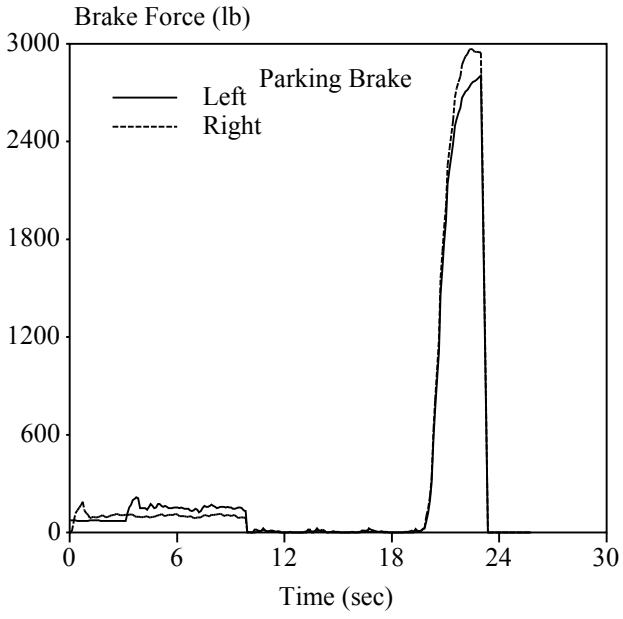
	Left		Pct Diff	Right		Total
Roll Res Ratio	0.02		26	0.01		
Service Brk Force (lb)	4788	LU	8	3580	LU	8369
Static Weight (lb)	8333			7937		16270
Dynamic Weight (lb)	6217			5159		11376
Force / Weight Ratio	0.57			0.45		
Parking Brk Force (lb)	2804		5	2967		5772
Ovality						
Threshold	10.5			10.1		
Crack Pressure (psi)			5.5			
Pressure at Lockup	Pm 73.9 / Px 69.9					

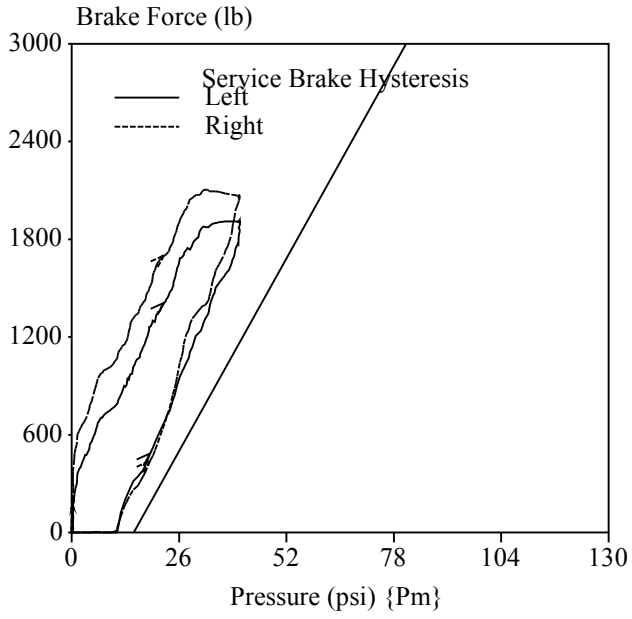


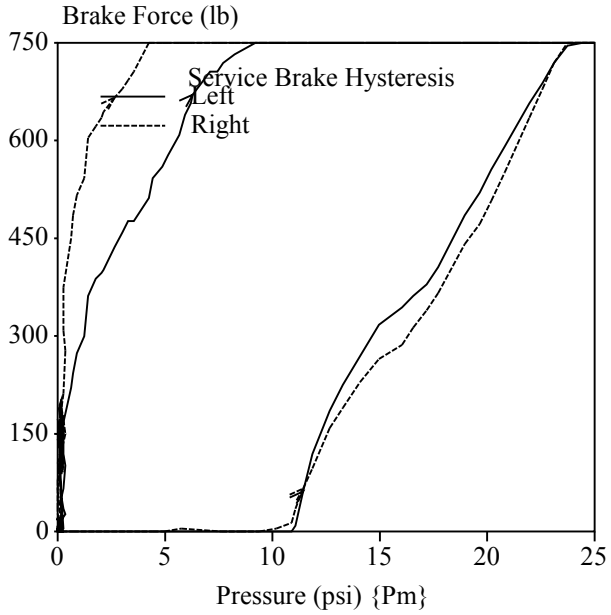


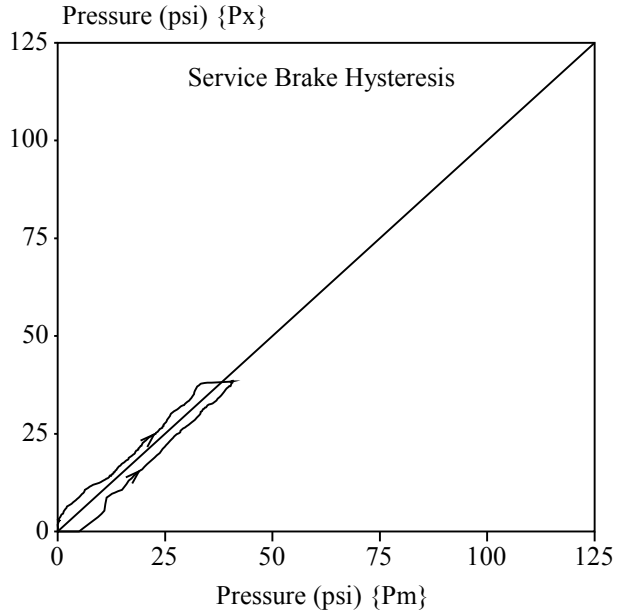


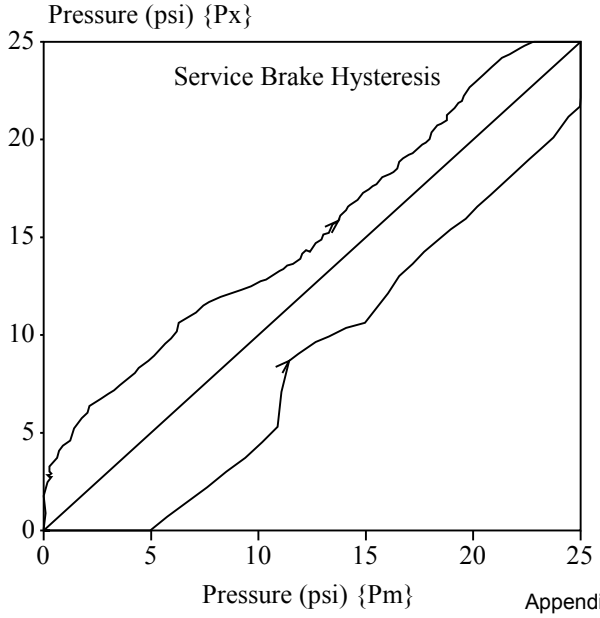



Brake Force (lb)
Parking Brake
Left
Right
3000
2400
1800
1200
600
0
0
6
12
18
24
30
Time (sec)


Brake Force (lb)
Service Brake Hysteresis
Left
Right
3000
2400
1800
1200
600
0
0
26
52
78
104
130
Pressure (psi) {Pm}


Brake Force (lb)
Service Brake Hysteresis
Left
Right
750
600
450
300
150
0
0
5
10
15
20
25
Pressure (psi) {Pm}

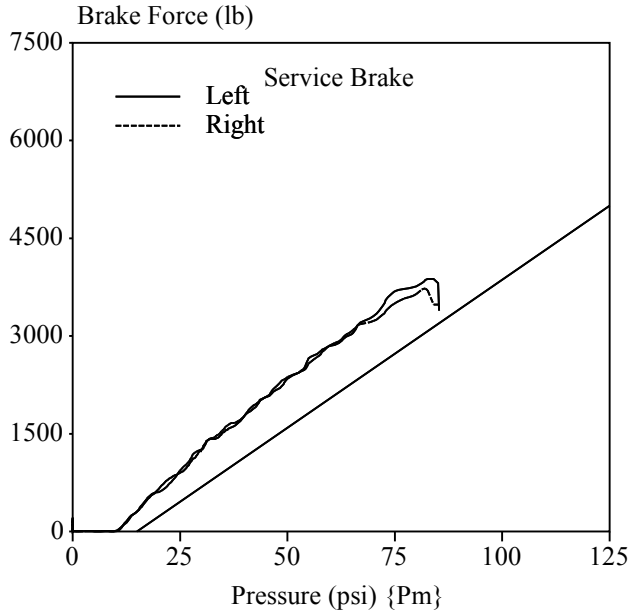

Pressure (psi) {Px}
Service Brake Hysteresis
125
100
75
50
25
0
0
25
50
75
100
125
Pressure (psi) {Pm}

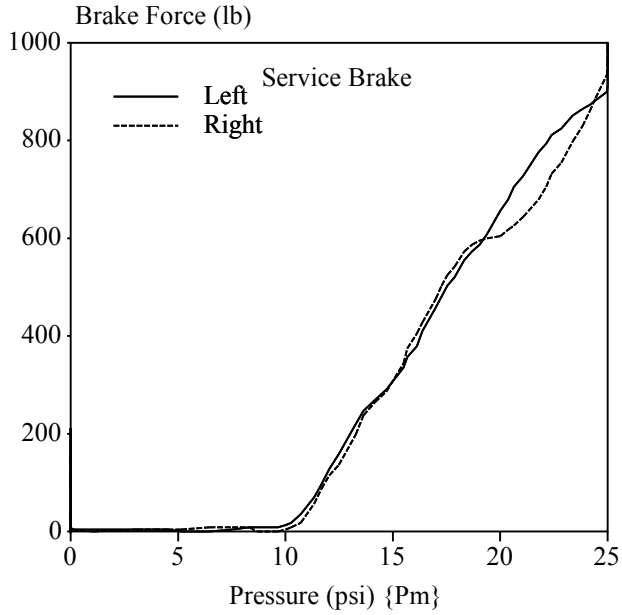

Pressure (psi) {Px}
Service Brake Hysteresis
25
20
15
10
5
0
0
5
10
15
20
25
Pressure (psi) {Pm}

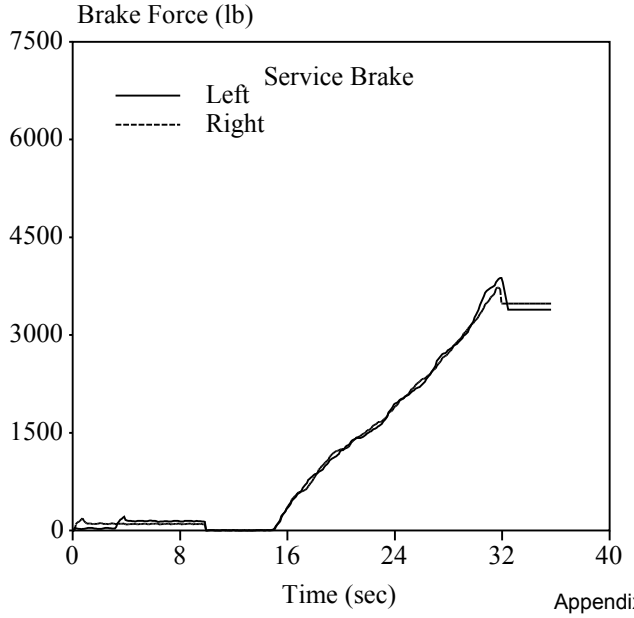
Link Engineering BrakeTest Report

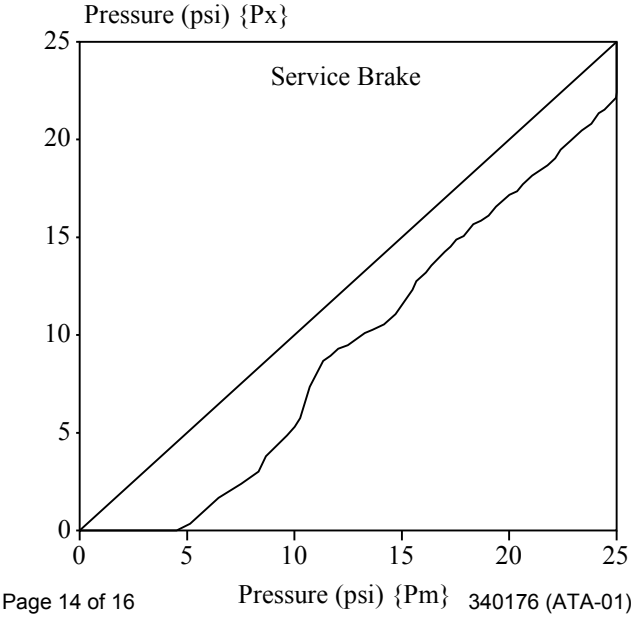
Test Number: 128 | Axle 5 | Test Date/Time: 7/14/2014 4:51:26 PM

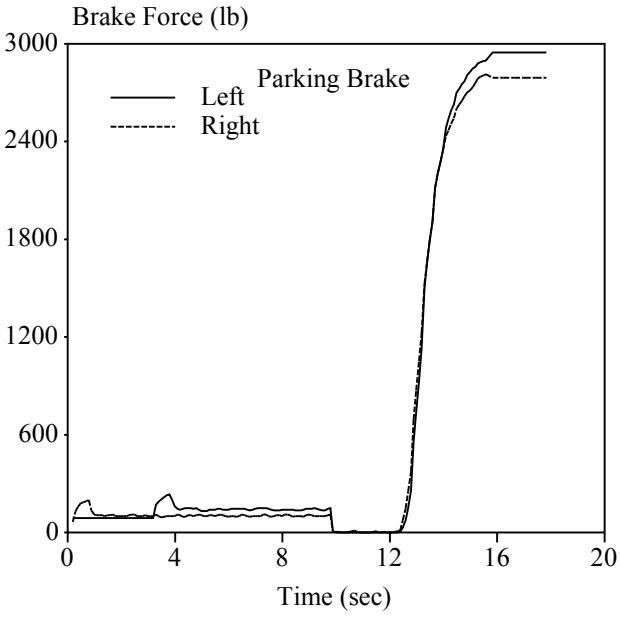
	Left		Pct Diff	Right		Total
Roll Res Ratio	0.02		29	0.01		
Service Brk Force (lb)	3876	LU	10	3726	LU	7601
Static Weight (lb)	8289			8113		16402
Dynamic Weight (lb)	5688			5556		11244
Force / Weight Ratio	0.47			0.46		
Parking Brk Force (lb)	2945		3	2813		5758
Ovality						
Threshold	8.6			10.1		
Crack Pressure (psi)			4.8			
Pressure at Lockup	Pm 84.0 / Px 80.6					

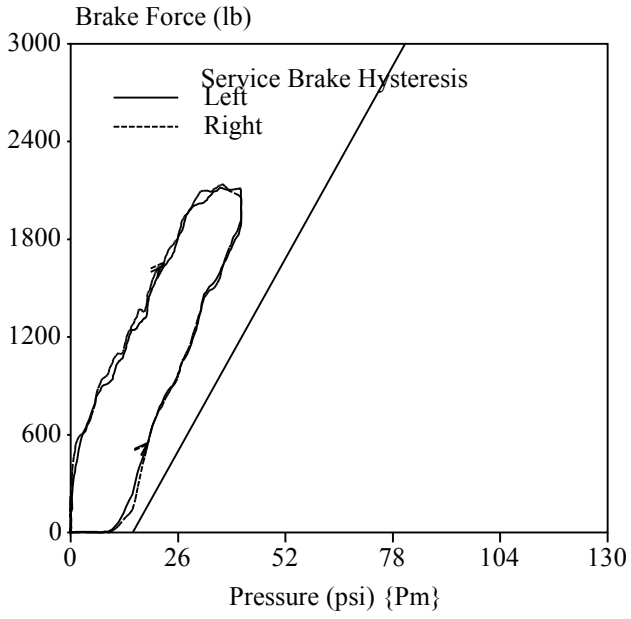


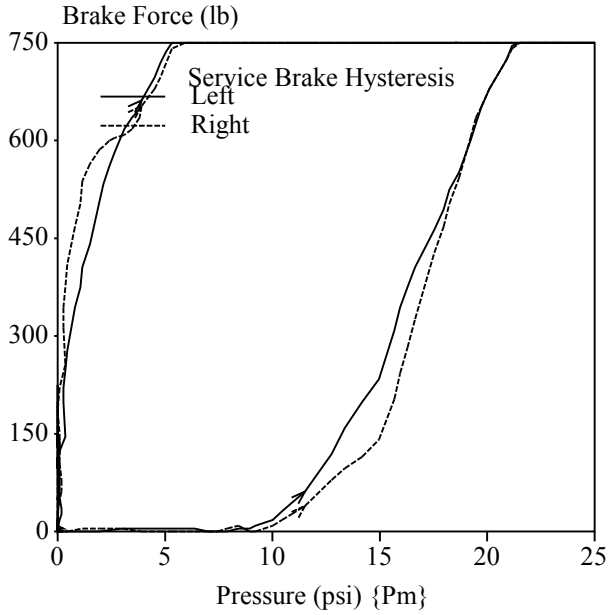


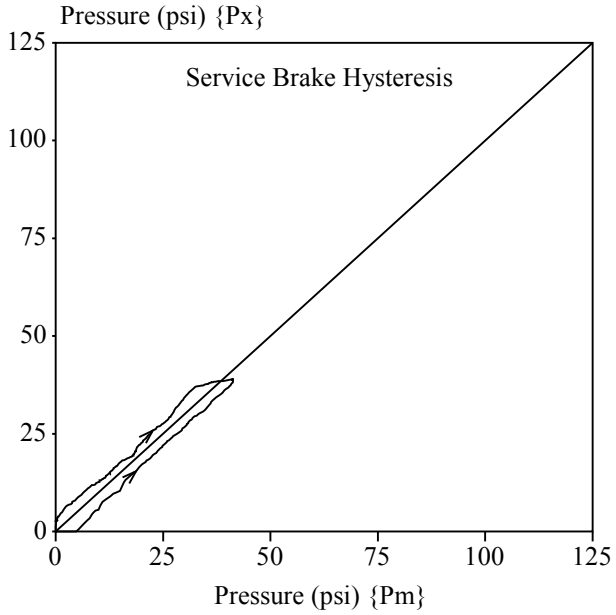


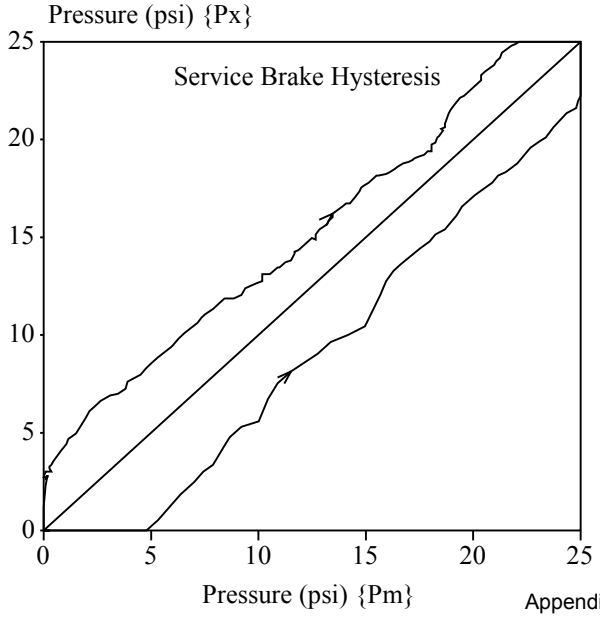



Brake Force (lb)
Parking Brake
Left
Right
3000
2400
1800
1200
600
0
0
4
8
12
16
20
Time (sec)


Brake Force (lb)
Service Brake Hysteresis
Left
Right
3000
2400
1800
1200
600
0
0
26
52
78
104
130
Pressure (psi) {Pm}


Brake Force (lb)
Service Brake Hysteresis
Left
Right
750
600
450
300
150
0
0
5
10
15
20
25
Pressure (psi) {Pm}


Pressure (psi) {Px}
Service Brake Hysteresis
125
100
75
50
25
0
0
25
50
75
100
125
Pressure (psi) {Pm}


Pressure (psi) {Px}
Service Brake Hysteresis
25
20
15
10
5
0
0
5
10
15
20
25
Pressure (psi) {Pm}

Overall - Test Passed
Total Weight: 45203

Vehicle Serial Number: 174237 | ECU Serial Number: 3D30131795

Test Date: 7/14/2014 | Tester ID: Link Ohio | Test Time: 4:41:19 PM

ABS and Brake Test

ECU & VEHICLE SPECIFICATIONS:

ECU: Bendix EC-60 6S / 6M
Part Number: EC60
Production/Release Date: 13-07-26/

Configuration: Cab 12 V Premium
Firmware: BB41102
Serial Number: 3D30131795

Configured for Retarder
Not Configured for PLC Communication

Configured for ATC

FAULT CODES

No Existing Error Codes

Tests Based On Operator Input

ABS Warning Lamp				Passed
ATC Warning Lamp		Passed		
Trailer Warning Lamp				Passed
Engine Torque Limit		Passed	Retarder Activation	Not Applicable
Drag Torque Test		Passed		
Battery (V)	13.8	13.8	Battery	Passed
ATC Off Road Switch		Passed	ABS Switch	Not Applicable
Brake Switch				Not Applicable
Stability and Control Pressure Sensors				NA
Stability and Control Trailer Modulator				NA
Steering Wheel Angle Sensor				NA
Stability and Control Yaw Rate Sensor				NA
Stability and Control Lateral Acceleration Sensor				NA

No Hill Start Assist Provided

BRAKE SYSTEM

	ROLLING RESISTANCE			BRAKING FORCE			
	Left	Right	% DIFF	Left	Right	% DIFF	
AXLE #1	108	111	3	1137	1132	0	Passed
AXLE #2	118	127	7	1635	1811	10	Passed
AXLE #3	155	156	1	1230	1538	22	Passed

ABS VALVES

AXLE #1	Passed
AXLE #2	Passed
AXLE #3	Passed

WHEEL SPEED SENSORS

	Left	Right	
AXLE #1	2.0	2.0	Passed
AXLE #2	2.0	2.0	Passed
AXLE #3	2.0	2.0	Passed

ATC

	Left	Right	
AXLE #1			NA
AXLE #2			NA
AXLE #3	0	2140	Passed

APPENDIX C

INSTRUMENTATION AND CALIBRATIONS

Active Channels

Link-Radlinski Inc.

Project Title:	340176 (ATA-01)
Data Aquisition Type:	Link 3802 MVDAS
Data Aqu LRI no. & cal due date:	3979 (7/17/14)
Engineer:	Jerry Lawruk
Data Systems Technician:	R. Jacobs
Mechanic:	E. Holt
Date sheet saved:	7/14/2015

Sample rate	100
Filter rate	none

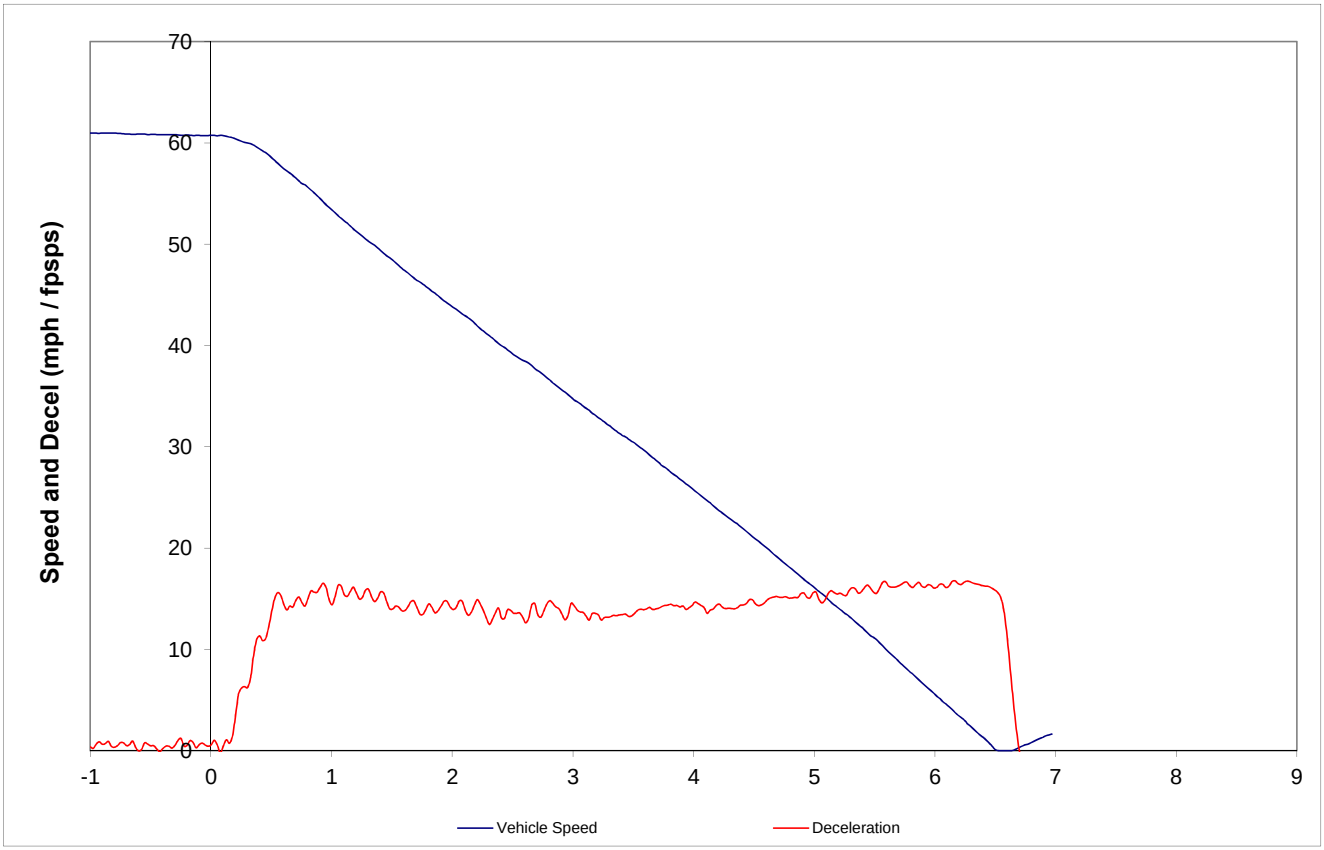
	NUMBERS	DATA AQU. CH. NO.	LOCATION/ DESCRIPTION	TRANS TYPE	MAX VALUE	MIN VALUE	SHUNT RES	CAL VALUE	Gauge / Transducer NUMBER	DATA AQU. cal due date
X	P1.1	17	Race Technolgy GPS (speed)	mph	100	0			22176	N/A
	P2.1	20		pulse	100	0				
	P2.2	21		pulse	100	0				
X	A1	1	Accelerometer	g	2	-2			13762-3	7/18/2014
	A2	2		Voltage	100	0				
	A3	3		Voltage	100	0				
	A4	4		Voltage	100	0				
	A5	5		Voltage	100	0				
	A6	6		Pressure	150	-150				
	A7	7		Pressure	150	-150				
	A8	8		Pressure	150	-150				
	A9	9		Pressure	150	-150				
X	A10	10	Control Line Pressure	Pressure	150	-150			163-04-06-0045	9/11/2014
X	A11	11	Left Steer Pressure	Pressure	150	-150			27-08-02-0054	1/22/2015
X	A12	12	Right Steer Pressure	Pressure	150	-150			264-10-06-0021	9/12/2014
X	A13	13	Left Drive Pressure	Pressure	150	-150			170-11-05-0036	9/12/2014
X	A14	14	Right Tag Pressure	Pressure	150	-150			163-04-06-0024	9/11/2014
X	A15	15	Left Forward Trailer Pressure	Pressure	150	-150			163-04-06-0031	9/11/2014
X	A16	16	Right Rear Trailer Pressure	Pressure	150	-150			163-04-06-0033	1/22/2015
	T1	23		Temperature °F	2500		K			
	T2	24		Temperature °F	2500		K			
	T3	25		Temperature °F	2500		K			
	T4	26		Temperature °F	2500		K			
	T5	27		Temperature °F	2500		K			
	T6	28		Temperature °F	2500		K			
	T7	29		Temperature °F	2500		K			
			Drawbar Load Cell	lb	15000	-15000	59k			
			Drawbar Readout	lb	15000	-15000	59k			
X			Master Gauge	Pressure	150	0			060206066	05/05/15
X			Brake Pedal Switch	Voltage	12	0				

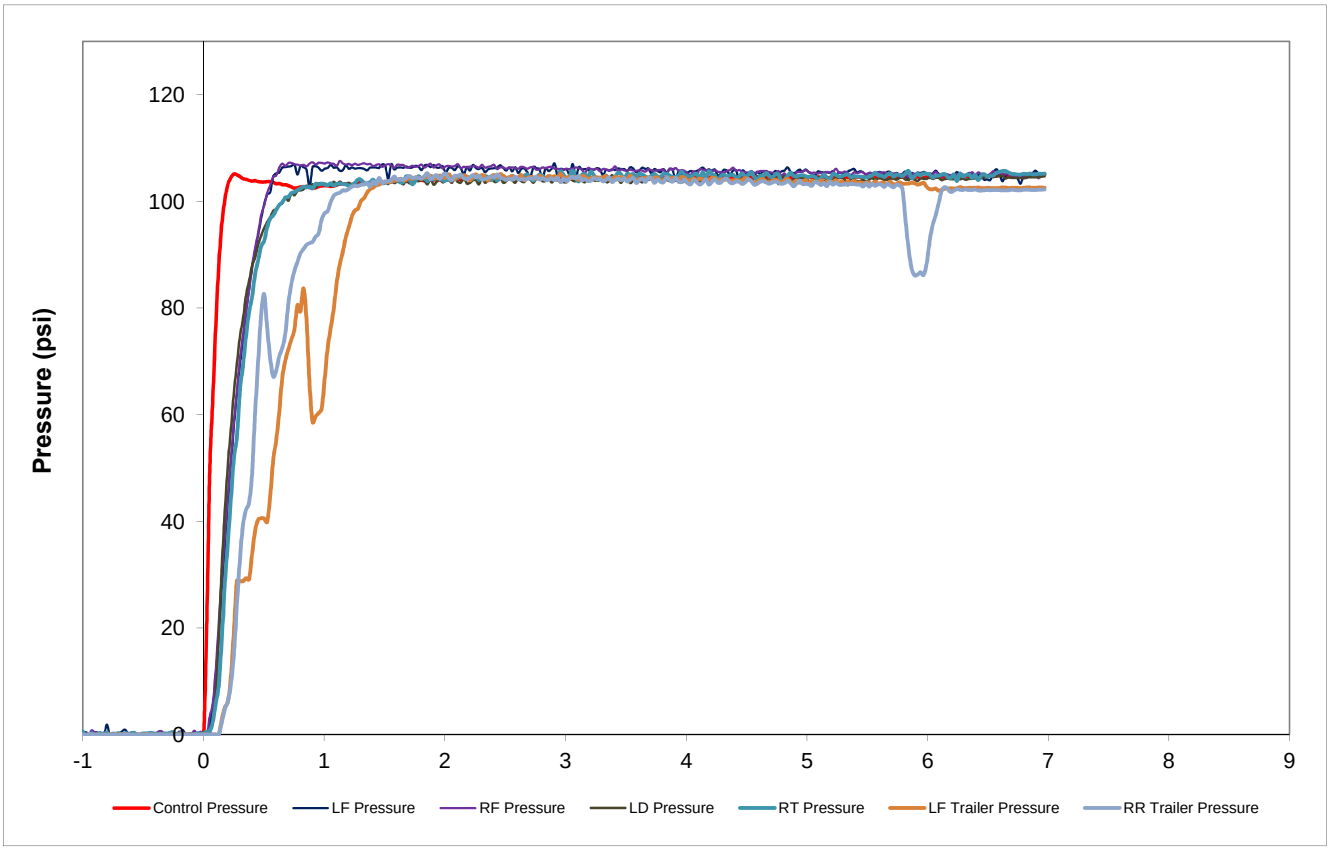
Measurement of Uncertainty available upon request

APPENDIX D

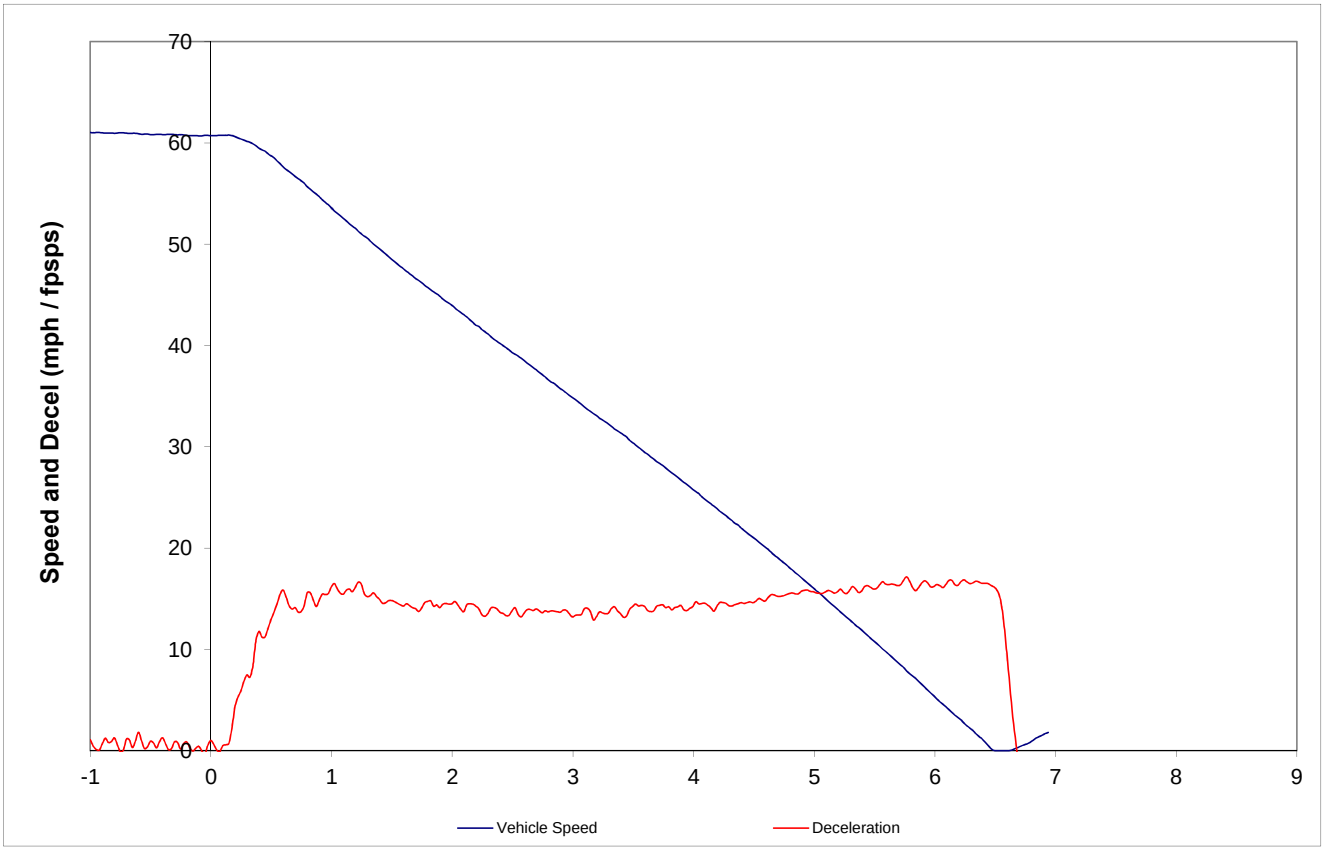
INDIVIDUAL STOP HISTORY GRAPHS

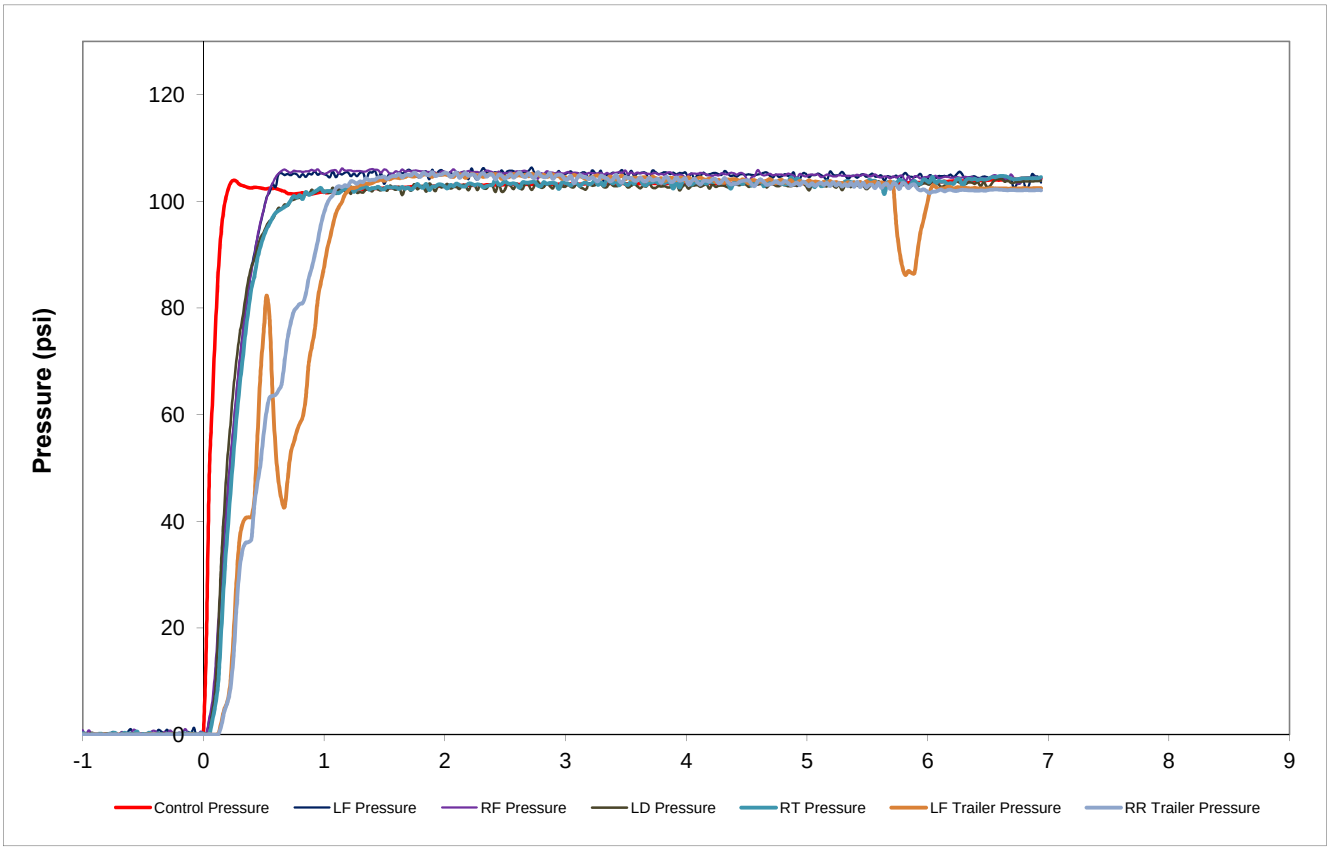
60 MPH Full System Stopping Distance - 88K - Stop 1



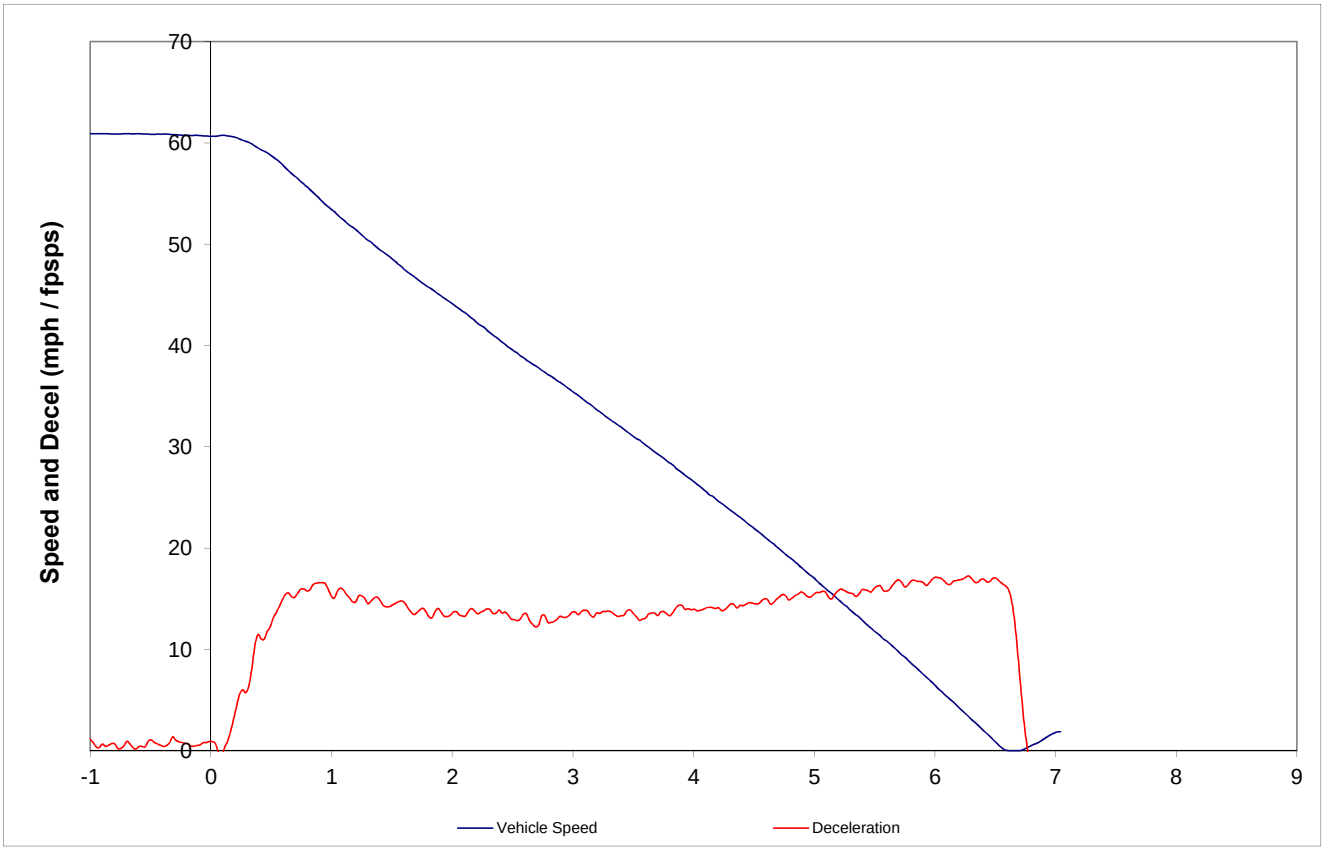


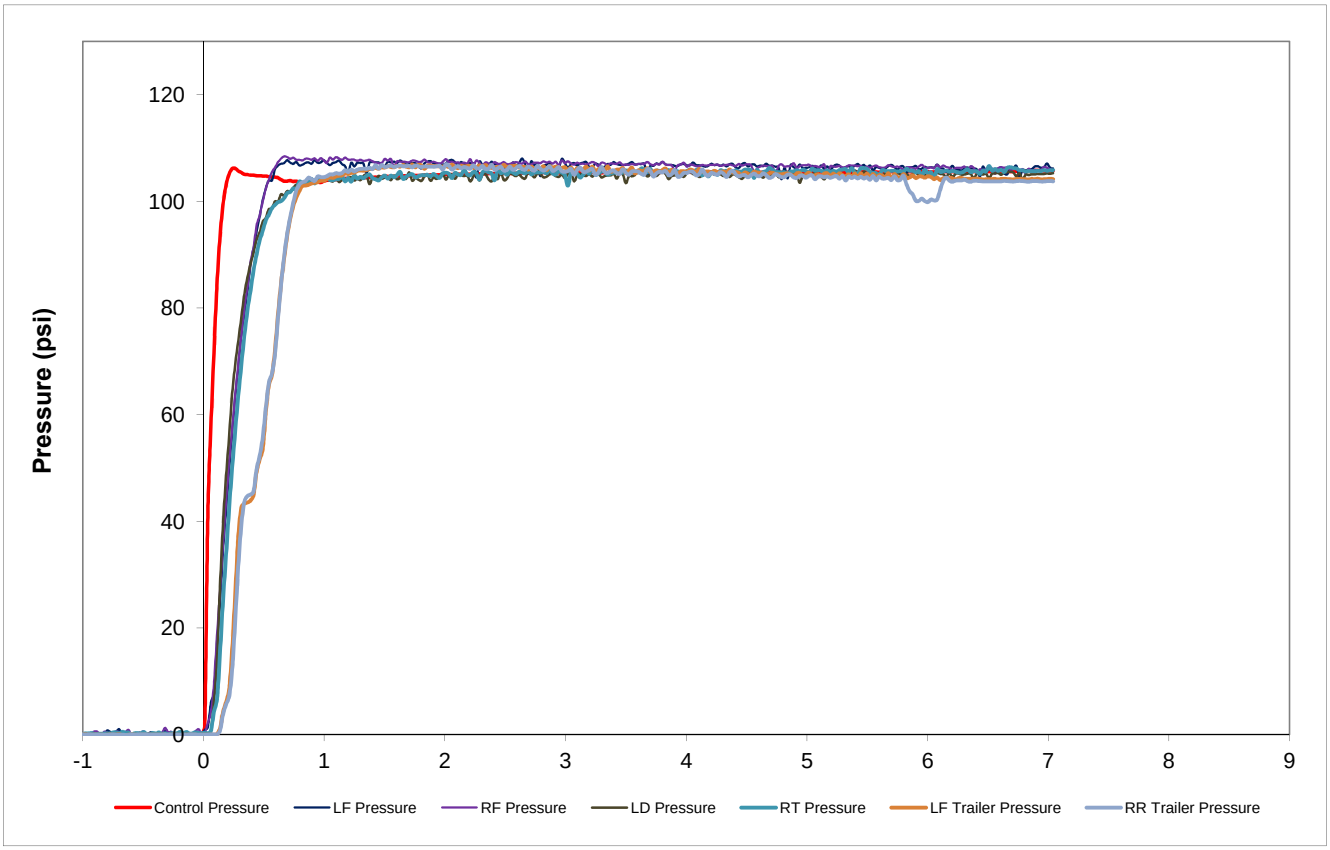
60 MPH Full System Stopping Distance - 88K - Stop 2



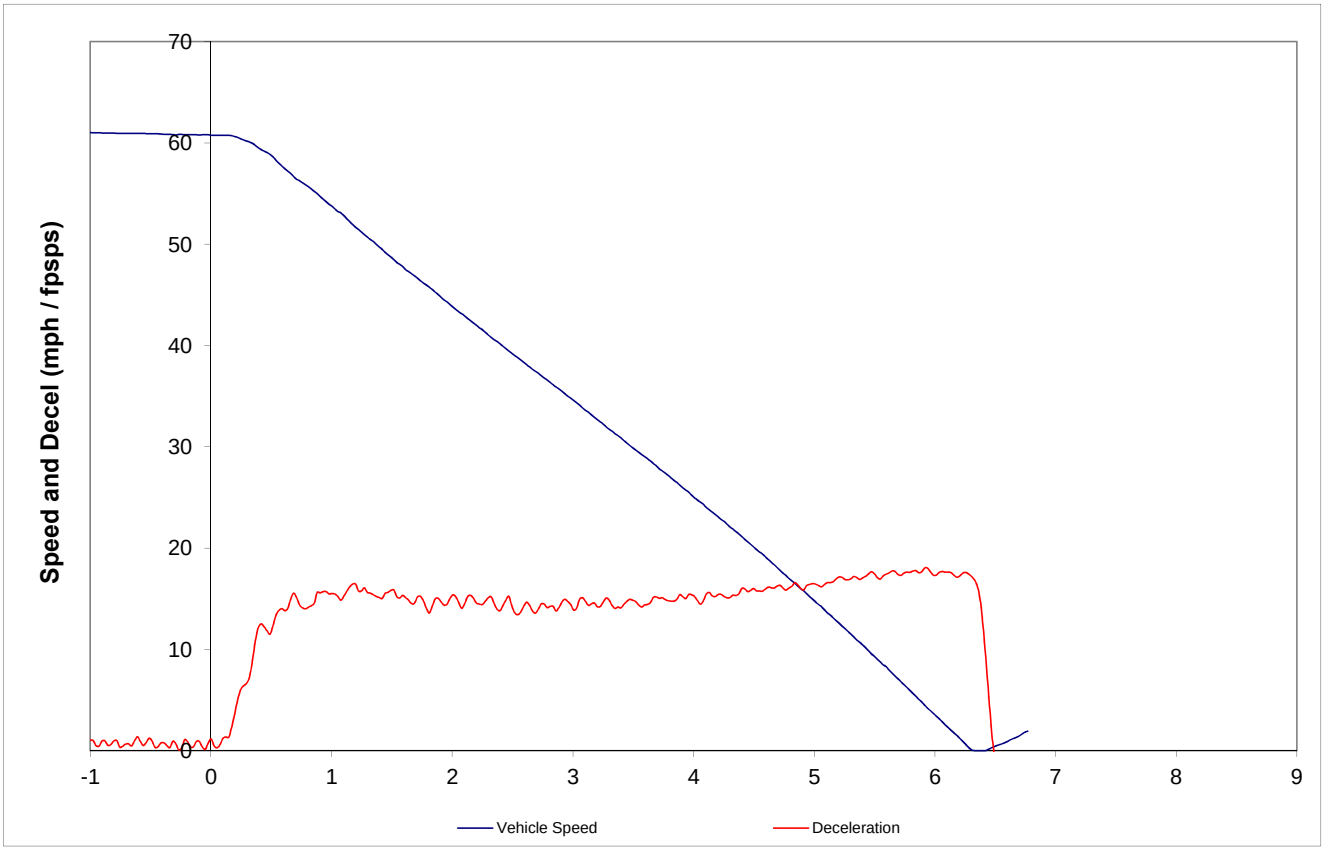


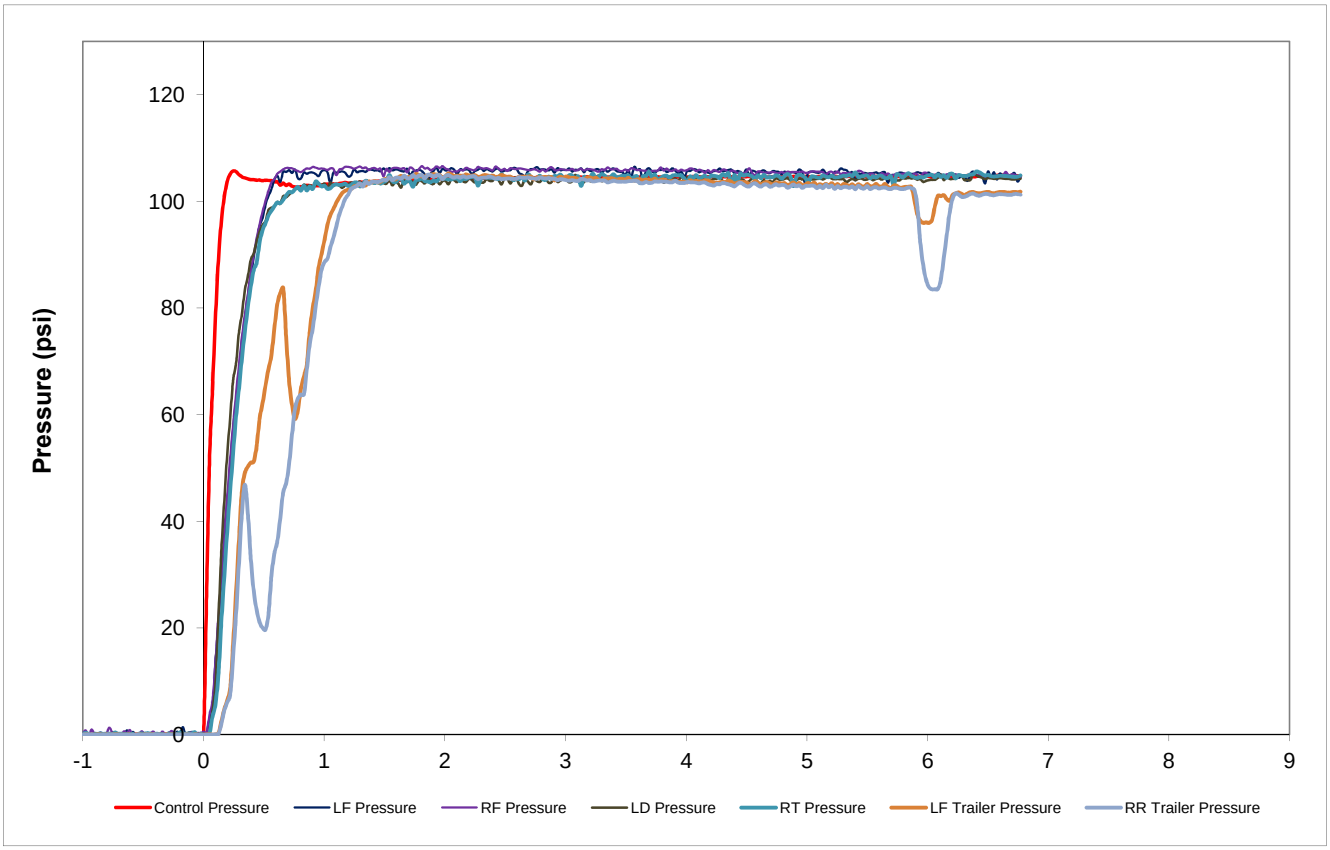
60 MPH Full System Stopping Distance - 88K - Stop 3



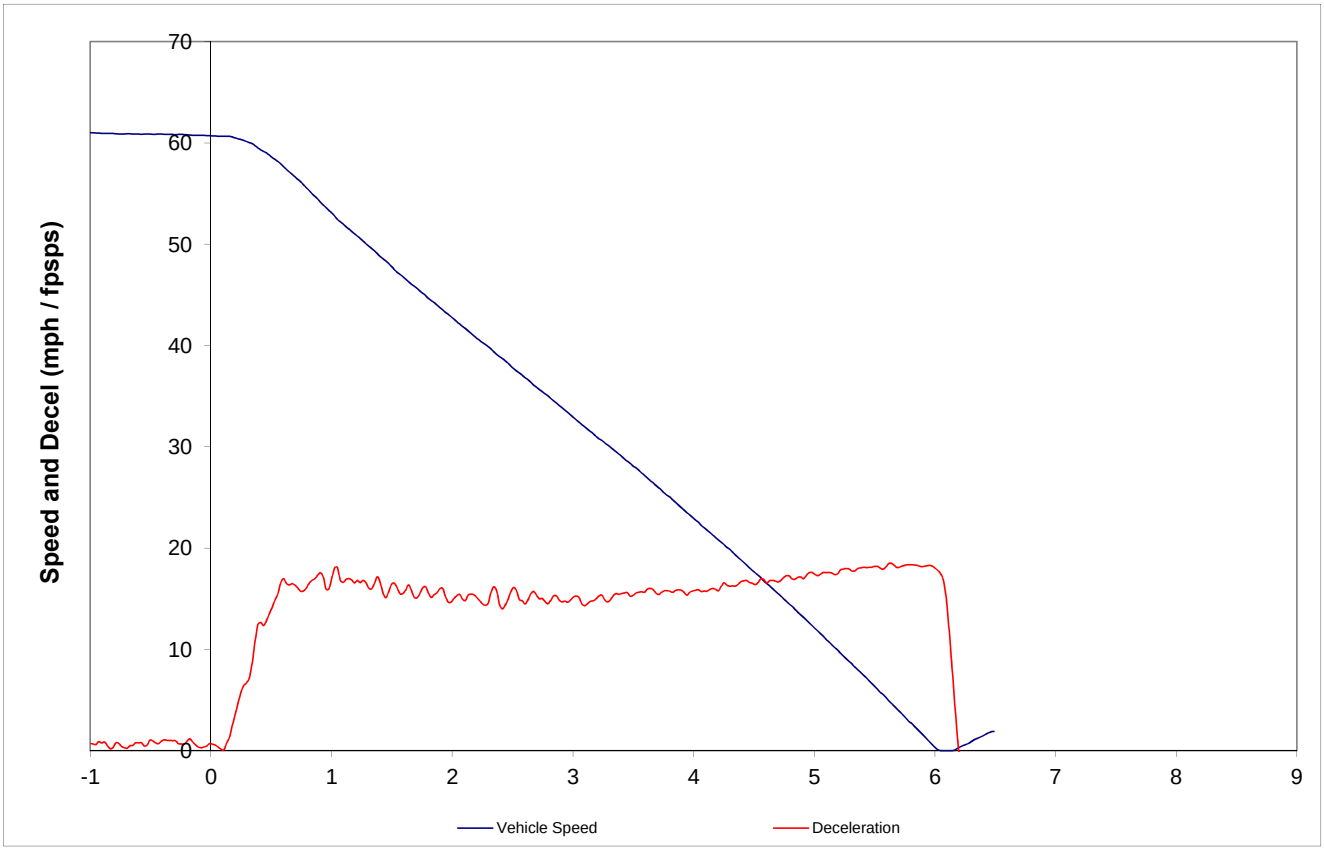


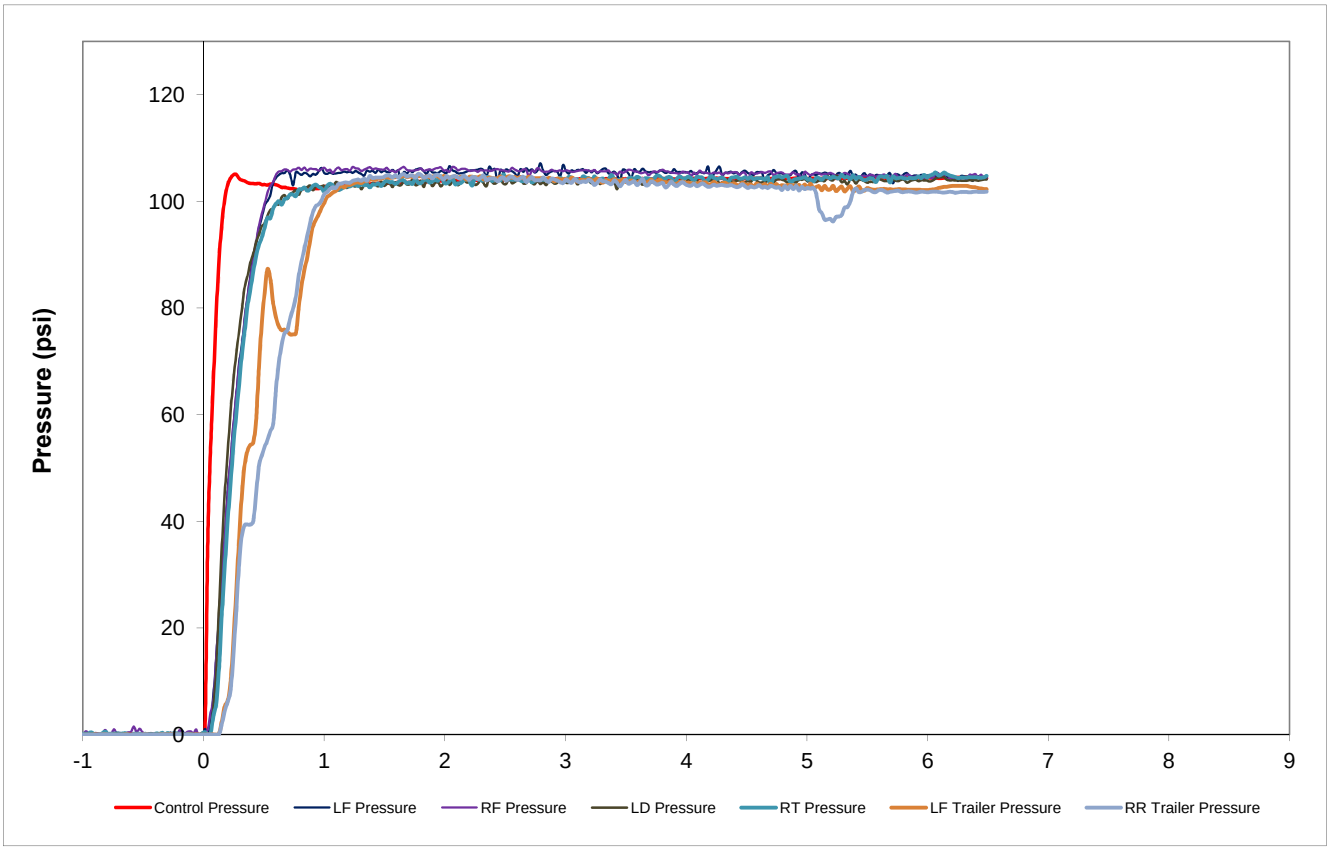
60 MPH Full System Stopping Distance - 80K - Stop 1



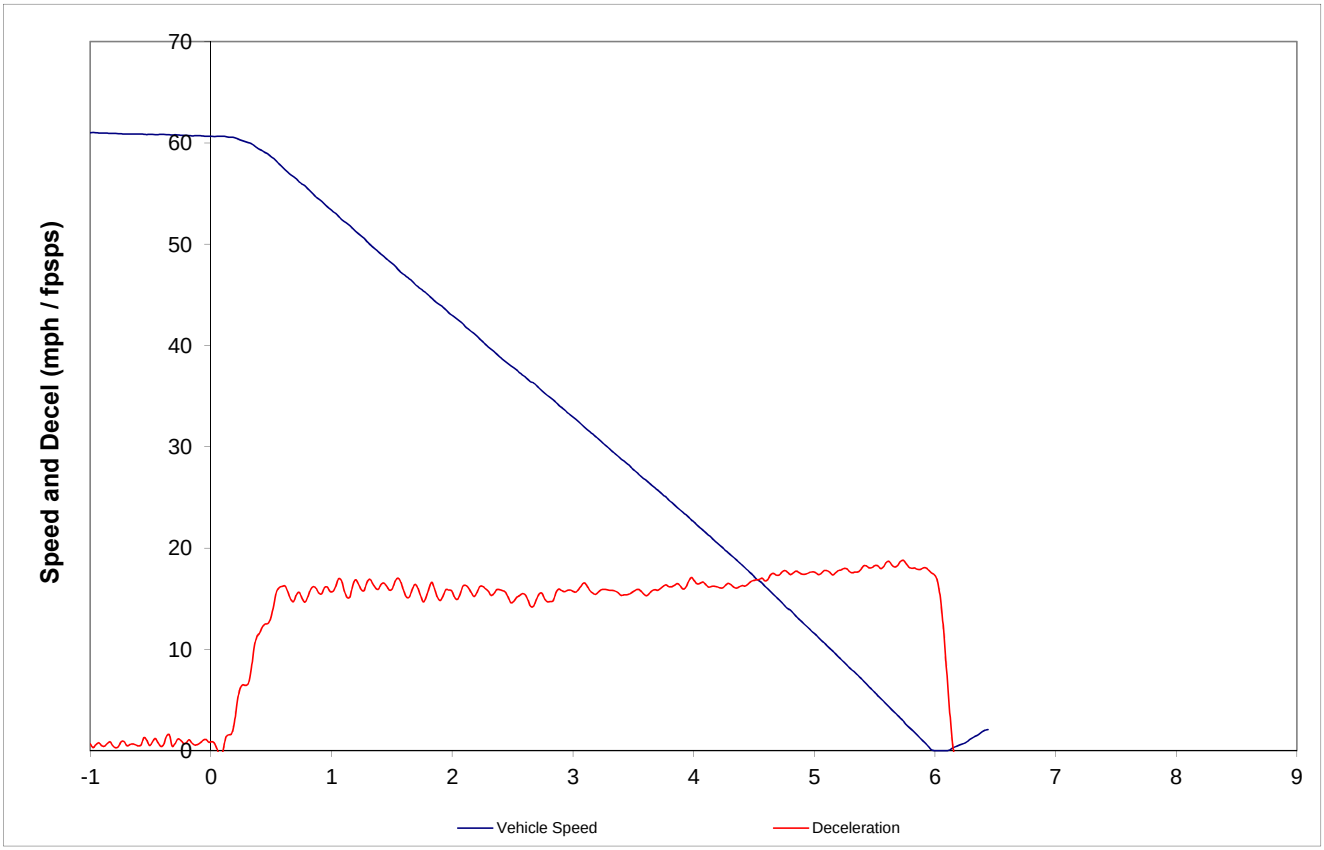


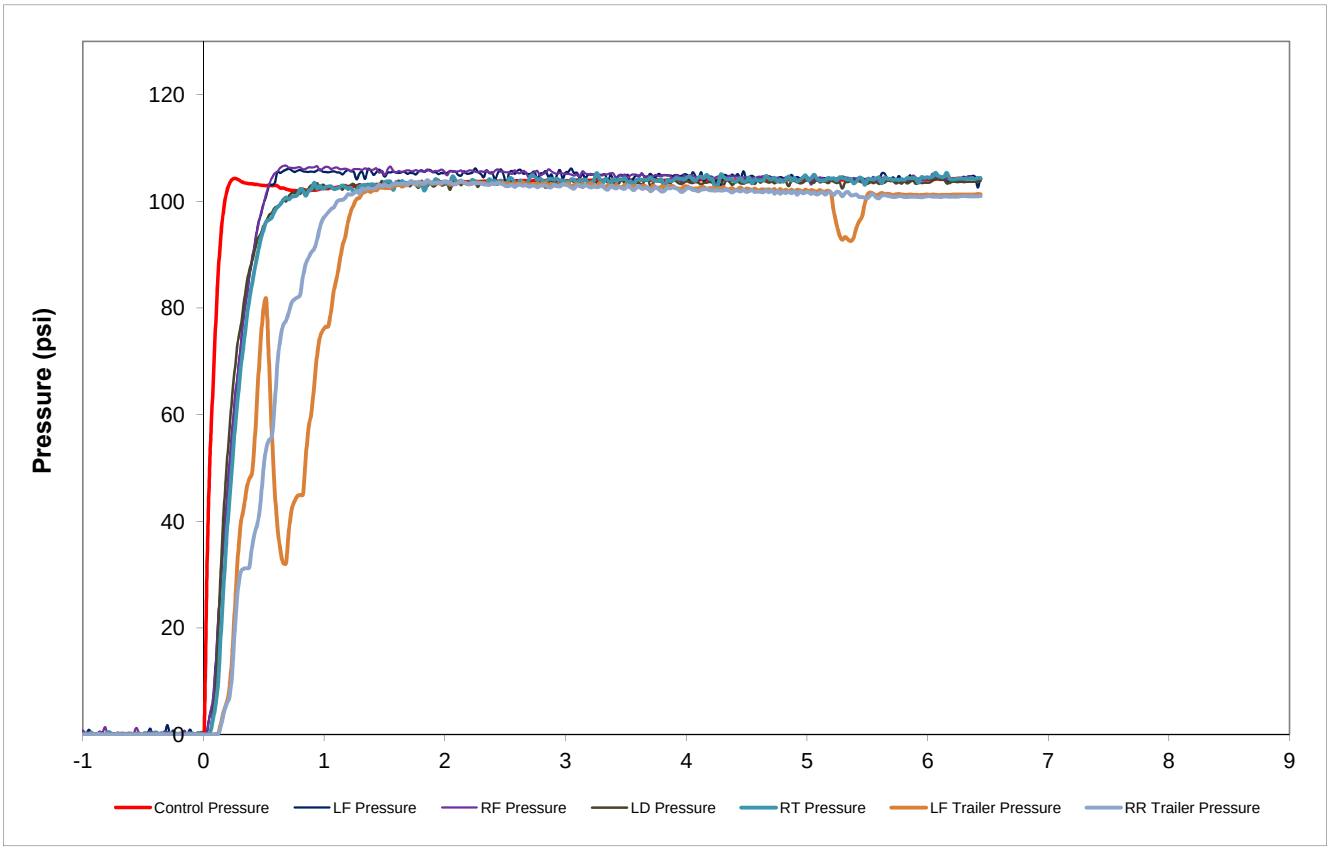
60 MPH Full System Stopping Distance - 80K - Stop 2



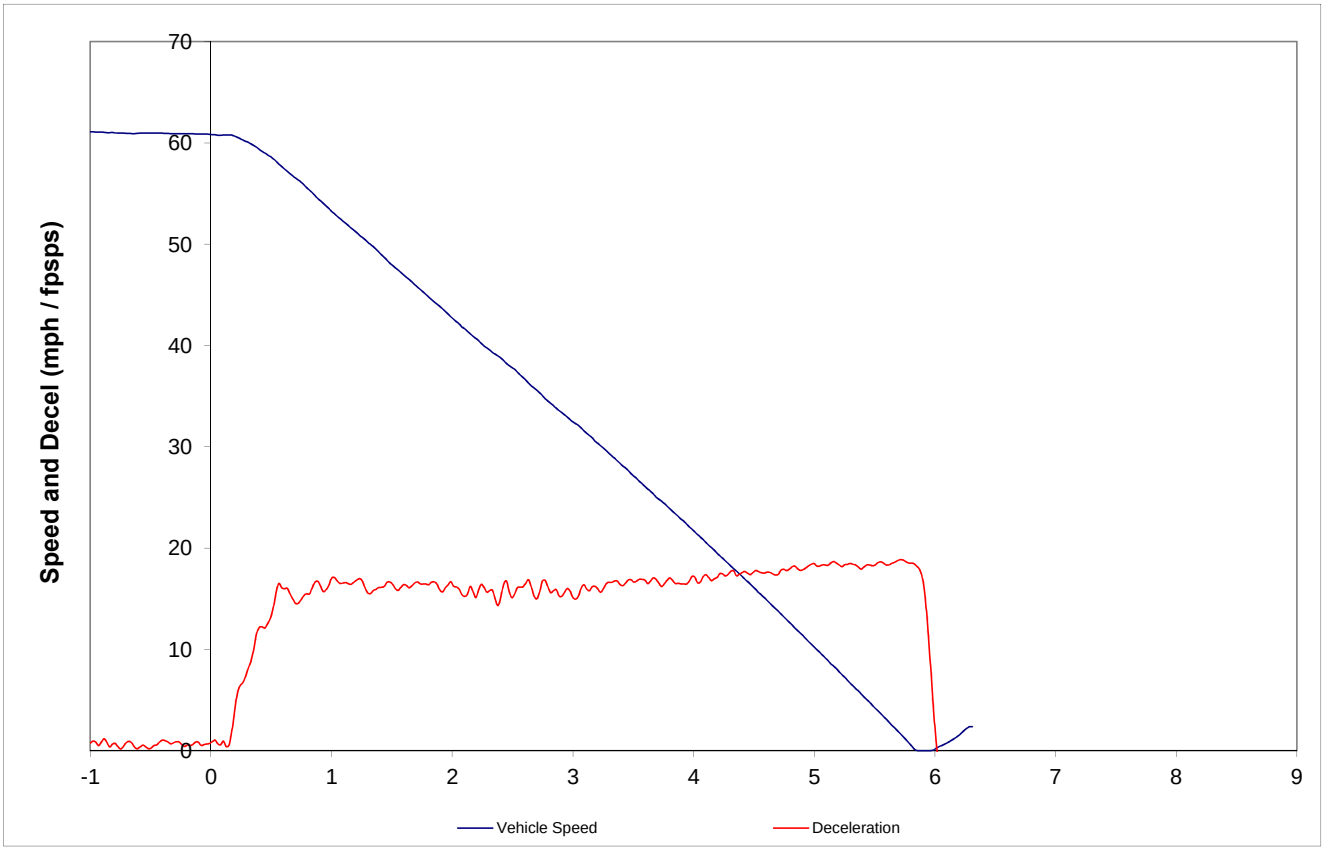


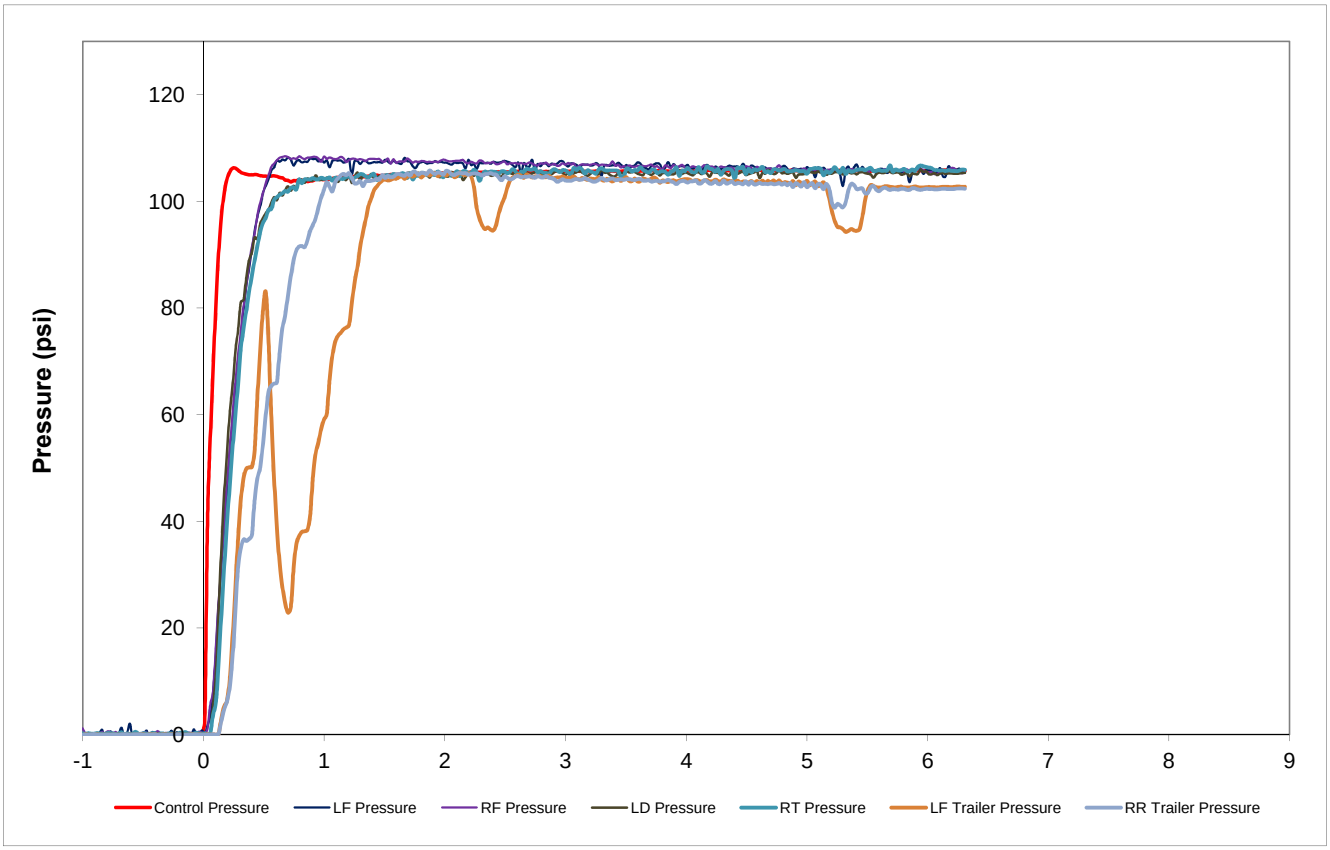
60 MPH Full System Stopping Distance - 80K - Stop 3



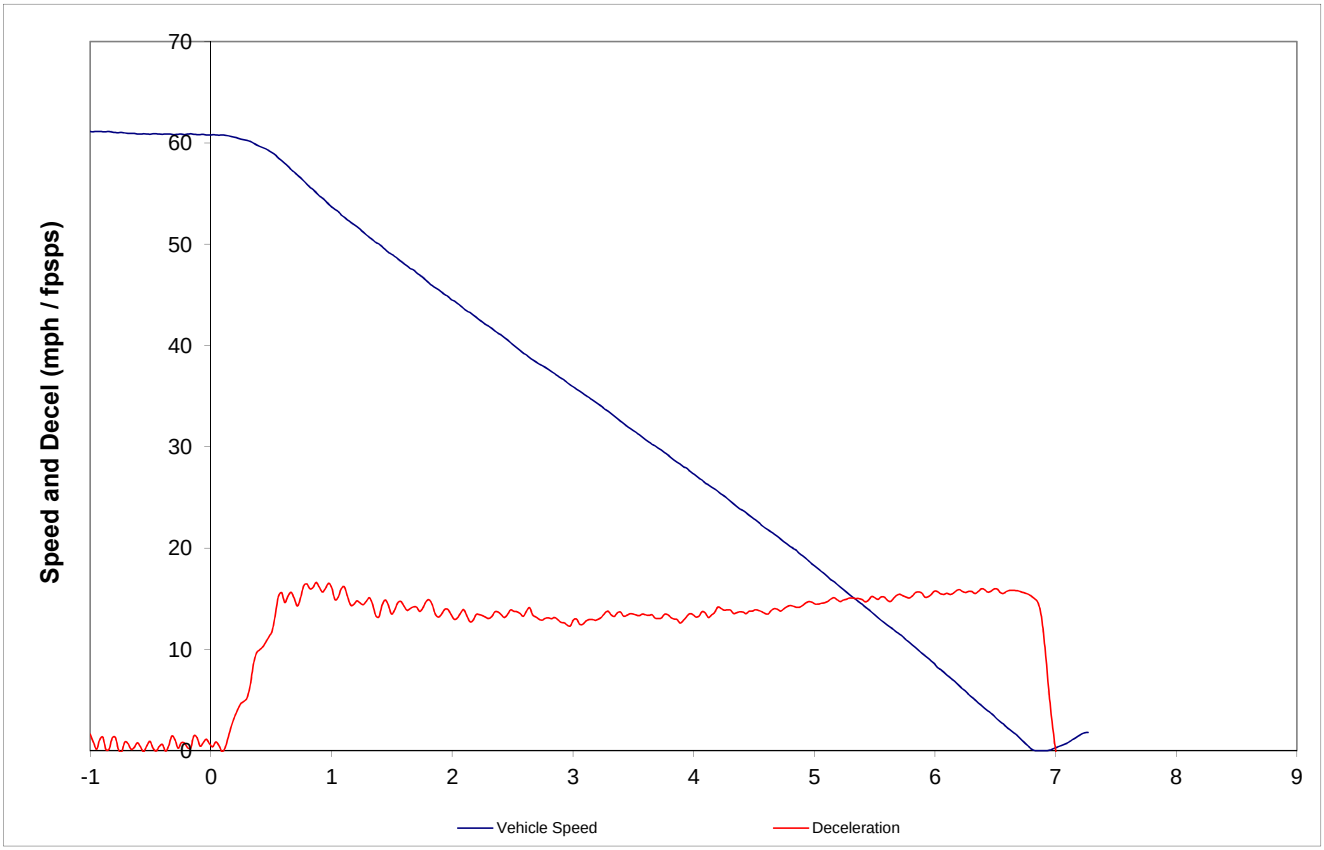


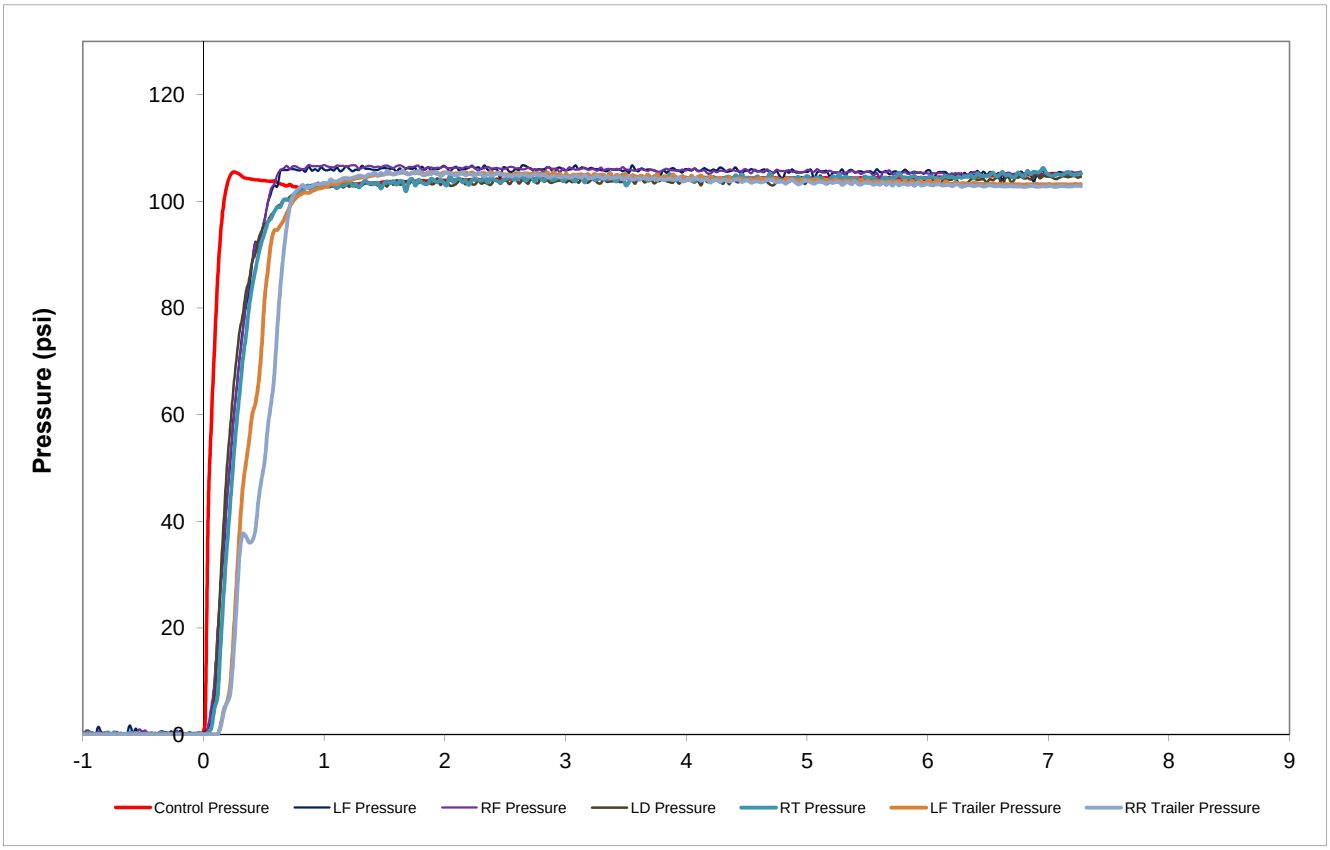
60 MPH Full System Stopping Distance - 80K - Stop 4



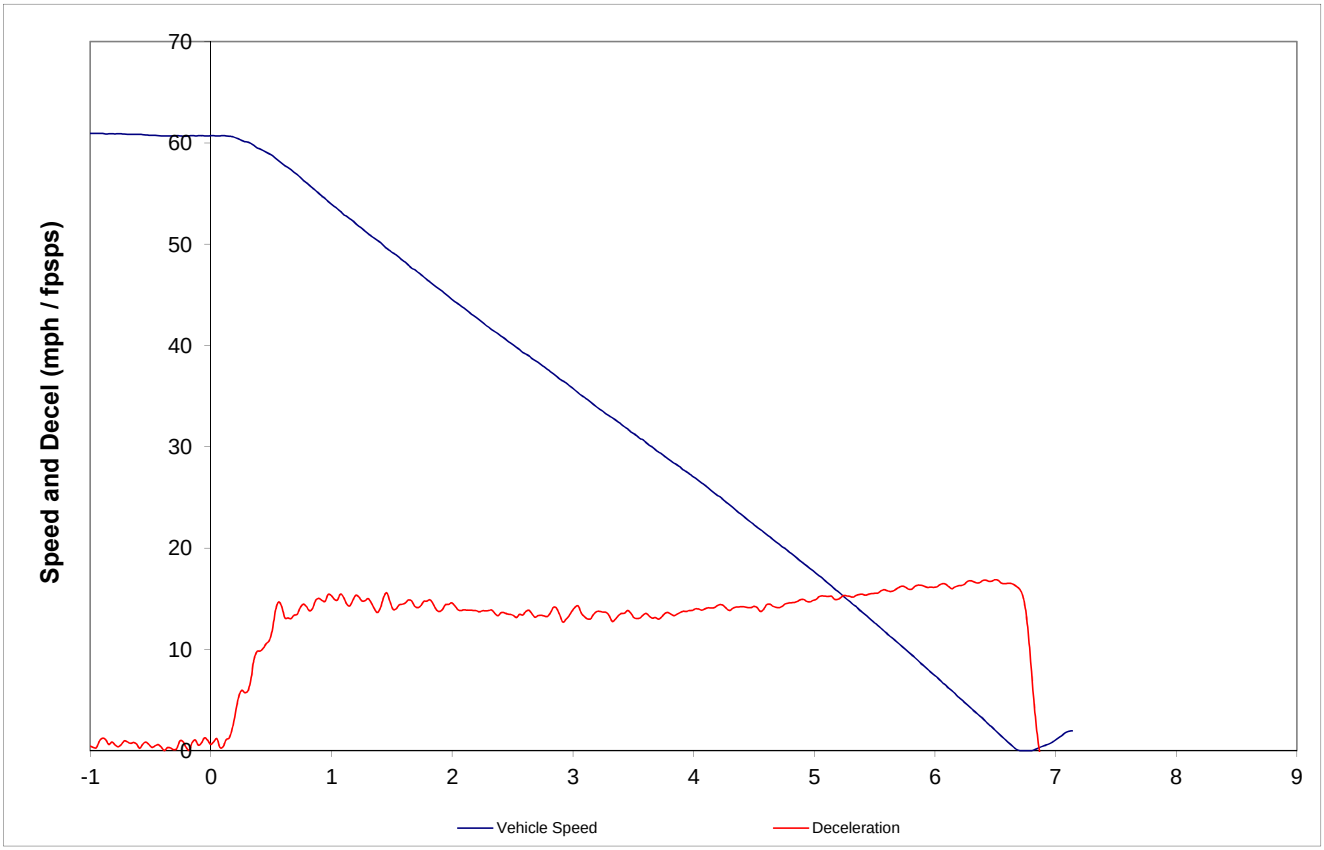


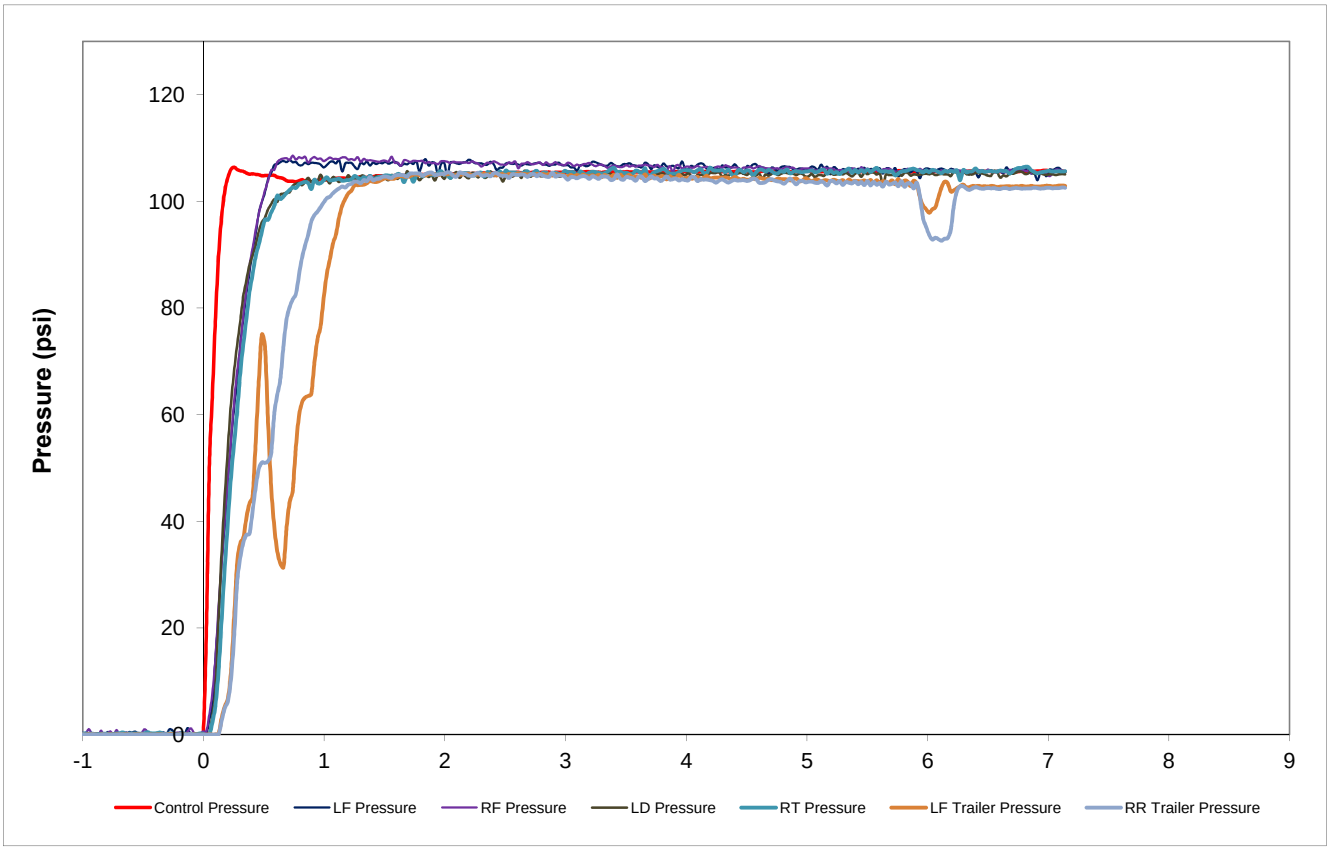
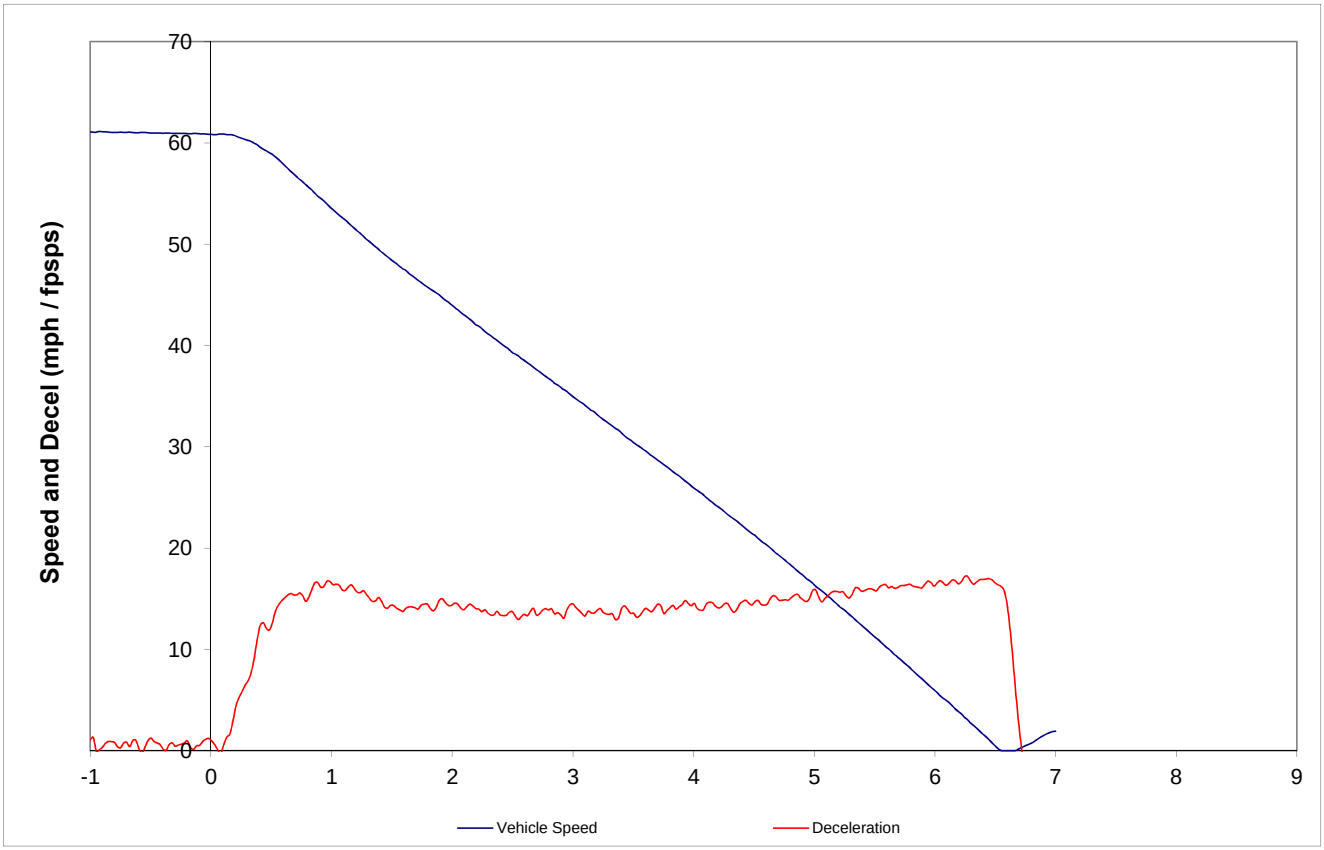
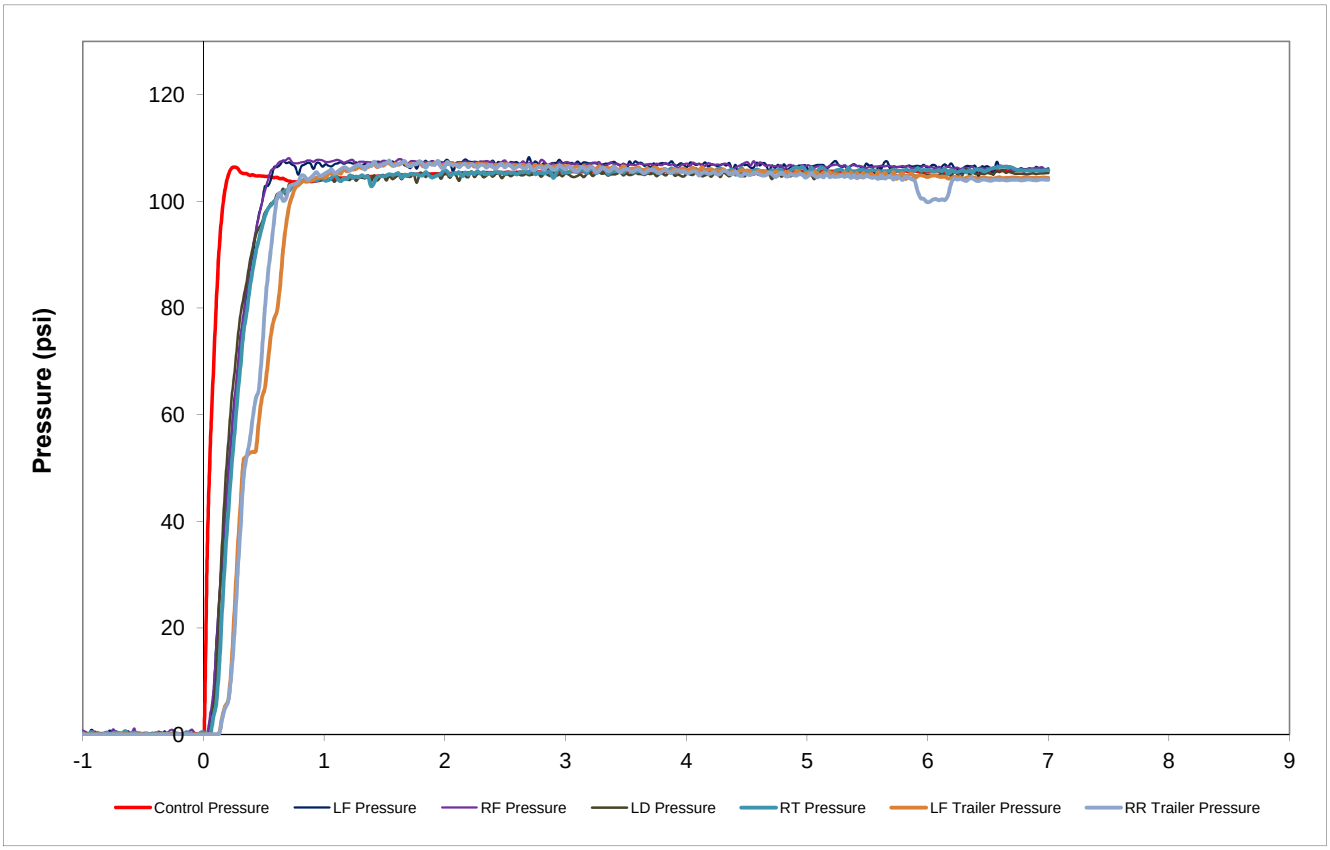
60 MPH Full System Stopping Distance - 88K (Re- Run) - Stop 1





60 MPH Full System Stopping Distance - 88K (Re- Run) - Stop 2





60 MPH Full System Stopping Distance - 88K (Re- Run) - Stop 3