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Heavy and Overweight Vehicle Brake Testing: Combination Five-Axle Tractor-Flatbed Final Report

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HEAVY AND OVERWEIGHT VEHICLE BRAKE TESTING: COMBINATION FIVE-AXLE TRACTOR-FLATBED FINAL REPORT

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CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACRONYMNS AND ABBREVIATIONS

Term	Definition
CFR	Code of Federal Regulations
CMV	Commercial Motor Vehicle
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
ft	Feet
ft/s^2	Feet per second squared
FMVSS	Federal Motor Vehicle Safety Standards
GPS	Global Positioning System
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating
HOVBT	Heavy and Overweight Vehicle Brake Testing
Hz	Hertz
lb	Pounds
mph	Miles per hour
MTDC	Medium Truck Duty Cycle
ORNL	Oak Ridge National Laboratory
PBBT	Performance-Based Brake Tester
psi	Pounds per square inch
RSD	Reduced Stopping Distance
sec	Seconds

EXECUTIVE SUMMARY

The Federal Motor Carrier Safety Administration, in coordination with the Federal Highway Administration, sponsored the Heavy and Overweight Vehicle Brake Testing (HOVBT) program in order to provide information about the effect of gross vehicle weight (GVW) on braking performance. Because the Federal Motor Carrier Safety Regulations limit the number of braking system defects that may exist for a vehicle to be allowed to operate on the roadways, the examination of the effect of brake defects on brake performance for increased loads is also relevant. The HOVBT program seeks to provide relevant information to policy makers responsible for establishing load limits, beginning with providing test data for a combination tractor/trailer.

This testing was conducted on a five-axle combination vehicle with tractor brakes meeting the Reduced Stopping Distance requirement rulemaking. This report provides a summary of the testing activities, the results of various analyses of the data, and recommendations for future research. Following a complete brake rebuild, instrumentation, and brake burnish, stopping tests were performed from 20 and 40 mph with various brake application pressures (15 psi, 25 psi, 35 psi, 45 psi, 55 psi, and full system pressure). These tests were conducted for various brake conditions at the following GVWs: 60,000, 80,000, 91,000, 97,000, 106,000, and 116,000 lb. The 80,000-lb GVWs included both balanced and unbalanced loads. The condition of the braking system was also varied. To introduce these defects, brakes (none, forward drive axle, or rear trailer axle) were made inoperative. In addition to the stopping tests, performance-based brake tests were conducted for the various loading and brake conditions.

Analysis of the stopping test data showed the stopping distance to increase with load (as expected) and also showed that more braking force was generated by the drive axle brakes than the trailer axle brakes. The constant-pressure stopping test data revealed a linear relationship between brake application pressure and was used to develop an algorithm to normalize stopping data for weight and initial speed.

This research also revealed three lessons learned which can be used in future research of a similar nature, addressing areas of procurement, component loading, and the timing of the analysis effort in project planning. This research also shed light on areas in which future research should focus, including further data collection to develop and test an on-board brake assessment algorithm and similar tests of vehicles with other body types.

1. INTRODUCTION

1.1 BACKGROUND

Commercial trucks normally travel at or below the maximum weight allowed by the Federal Highway Administration (FHWA) Bridge Formula on the interstate highways. Many states allow commercial trucks to operate on state roads and highways at weights significantly higher than that allowed under the FHWA Bridge Formula. The Federal Motor Carrier Safety Administration (FMCSA) and FHWA are interested in gathering real-world brake performance and stopping distance test data on vehicles representative of current in-use commercial motor vehicles that are operating at Bridge Formula weights, weights that are grandfathered under state commercial truck weight provisions on non-interstate highways, and permitted weights.

1.2 OVERVIEW OF HOVBT PROGRAM

The Heavy and Overweight Vehicle Brake Testing (HOVBT) program was designed to provide information about the effect of gross vehicle weight (GVW) on braking performance. Because the Federal Motor Carrier Safety Regulations (FMCSRs) limit the number of braking system defects that may exist for a vehicle to be allowed to operate on the roadways, the examination of the effect of brake defects on brake performance for increased loads is also relevant. The HOVBT program seeks to provide relevant information to policy makers responsible for establishing load limits, beginning with providing test data for a combination tractor/trailer. It is expected that future efforts will involve straight truck testing and may be expanded to other body types.

1.3 PURPOSE OF TRACTOR-FLATBED TESTING

Oak Ridge National Laboratory (ORNL) gathered the required stopping distance data via subcontract to Link Commercial Vehicle Testing (East Liberty, Ohio) and analyzed the data to provide background information regarding the braking capability of air-braked commercial combination vehicles operating at maximum weight allowed by FHWA Bridge Formula and in heavy weight conditions under various levels of brake performance. This testing was conducted on a vehicle with larger tractor brakes meeting the Reduced Stopping Distance (RSD) requirement rulemaking reflected in Federal Motor Vehicle Safety Standards (FMVSS)-121 (49 CFR Part 571). This report provides a summary of the testing activities, the results of various analyses of the data, and recommendations for future research.

2. TEST SETUP

This section provides information regarding the test vehicle and various tests performed as part of the HOVBT effort.

2.1 DESCRIPTION OF TEST VEHICLE

The test vehicle was a 2013 model year Volvo VNL tractor with a flatbed trailer. The use of the flatbed allowed for more efficient change of test loads than would be available for a box-type trailer. Because all tests involving vehicle movement were performed along a straight-line path, the trailer type was not expected to be a significant factor in braking performance. The specifications for the tractor and trailer are shown in Table 1 and Table 2, respectively. The combination tractor/trailer is shown in the 80,000-lb GVW balanced load configuration in Figure 1.

Table 1. Tractor Specifications

General Information			
Manufacturer	Volvo		
Type	6x4 Tractor		
Model Number	2013 VNL64T 670		
Date of Manufacture	January 2012		
VIN	4V4NC9TH8DN567427		
GVWR	51,200 lb		
No. of Axles	3		
Axle Information			
	Axle 1	Axle 2	Axle 3
GAWR	13.2k	19k	19k
Suspension Type	Spring	Airbag	Airbag
Brakes			
Manufacturer	Meritor	Meritor	Meritor
Type	Q+ S-Cam	Q+ S-Cam	Q+ S-Cam
Size	16.5 x 5	16.5 x 7	16.5 x 7
Lining Code	SOR 1201	SOR 2001	SOR 2001
Chamber Make / Size	MGM 24L3	MGM 3030L3	MGM 30L3
Slack Make / Size	Meritor 5.5	Meritor 5.5	Meritor 5.5
Rotor or Drum Make / Part #	Gunite 3772	Gunite 3600A	Gunite 3600A
ABS	Bendix 6S4M		
Tires			
Manufacturer	Bridgestone	Bridgestone	Bridgestone
Tread Name	R280	M726EL	M726EL
Size	295/75R22.5	295/75R22.5	295/75R22.5
Load Range	"H"	"G"	"G"
Pressure	120 psi	110 psi	110 psi
Max Load per Tire (Config.)	7160 lb (Single)	5675 lb (Dual)	5675 lb (Dual)

Table 2. Trailer Specifications

General Information	
Make / Model	Utility Trailer 48' flatbed
GVWR	80,000 lb
Date of Mfg.	Aug-07
Wheelbase	50"
VIN	1UY FS2454 8A4536 02 FS2CHA
Suspension	Spring
Axle 1	
Make / Model	Meritor
SN	FRK00335318 PN:TN4671L4516
GAWR	20,000 lb
Axle 2	
Make / Model	Meritor
SN	PN:TN4671L4516
GAWR	20,000 lb
Brakes	
Make / Model	Meritor
Type/Size	S-cam 16.5x7
Chambers Make / Size	Haldex T3030
Slacks Make / Size	Haldex ASA 5.5"
Lining Edge Code	MA210 FF (4707)
(Drum - Rotor) Number / Size	Meritor B5123207002
ABS Manufacturer	Wabco 2S1M
Tires	
Make / Model	Bridgestone R280
Size	295/75R22.5 (Load Range H)
Static Loaded Radius	19.1"
Pressure	120 psi
Max Load per Tire	6610 lb (Dual)

Figure 1. Test vehicle in 80,000-lb GVW configuration.

The test tractor was outfitted with the larger front brakes, complying with the RSD requirements for three-axle tractors with a GVWR of 59,600 lb or less manufactured on or after August 1, 2011. While the braking capacity of this test vehicle is not representative of that of the typical vehicle on the road today, it may be representative of the typical vehicle several years in the future when the majority of similar vehicles comply with the RSD requirement.

2.2 BRAKE REBUILD AND INSTRUMENTATION

In preparation for testing, a complete foundation brake rebuild was performed. Linings, drum, anchor pins, anchor pin bushings, brake shoe rollers, and return springs were replaced. Other foundation brake components were found to be in acceptable condition and were not replaced. The tires on the test vehicle were also replaced as the originals showed excessive wear. Prior to testing, a 500-stop burnish was performed on the new brake system in accordance with the FMVSS-121 procedure.

The process of rebuilding and burnishing ensured the effects of loading, brake condition, and brake application pressure on brake performance examined in this study were not compounded by performance degradation introduced by any braking system components that were worn, faulty, or not properly broken in.

In preparation of the various tests performed as part of this research, the test vehicle was instrumented with sensors to collect speed, brake application pressure, and related data such as tire temperature. A complete list of all the signals collected appears in Section 3.1. In addition, a pressure regulator was installed near the treadle valve to allow the operator to provide a precise brake application pressure to the primary and secondary pressure circuits.

2.3 TYPES OF TESTS

The following tests were performed for various brake conditions at the following approximate GVWs: 60,000, 80,000, 91,000, 97,000, 106,000, and 116,000 lb. The 80,000-lb GVWs included both balanced and unbalanced loads. The condition of the braking system was also varied. To introduce these defects, brakes (none, forward drive axle, or rear trailer axle) were made inoperative rather than changing adjustment—not only is this the easiest to quantify (in terms of brake degradation), but it is the worst-case scenario for a brake defect. In all test scenarios, the brakes involved in ABS actuation remained enabled. All stopping tests were performed along a straight-line path.

2.3.1 Panic Stops

Panic stops were performed by bringing the test vehicle up to slightly above the target speed (20 or 60 mph) and applying the full braking capacity of the vehicle (full treadle application without the use of a pressure regulator to limit the brake application pressure) until the vehicle came to a complete stop. The procedure followed was that specified for the stopping tests in FMVSS-121, following a straight-line path. This test was performed for all combinations of loading and brake conditions. To provide comparison data, 20- and 60-mph stops were also performed using an unbraked control trailer as specified in FMVSS-121 to bring the GVW up to the required test value.

2.3.2 Constant-Pressure Stops

Constant-pressure stops were performed by bringing the test vehicle up to slightly above the target speed (20 or 60 mph) and applying the target constant pressure (15, 25, 35, 45, or 55 psi) until the vehicle came to a complete stop. An in-line pressure regulator (with driver override capability, for safety) was used to apply a constant brake system pressure during the stop. These tests were performed for all brake conditions (full, disabled drive, and disabled trailer) for 60,000-lb and 80,000-lb GVWs (75% and 100% load capacity respectively).

2.3.3 Performance-Based Brake Tests

Performance-based brake tests were performed with an FMCSA-certified Performance-Based Brake Testing (PBBT) machine. In addition to weight and brake application data, wheel-end air pressure information was also obtained for each axle using pressure transducers.

2.3.4 Other Measurements

Weigh tickets were also generated for each load configuration. Additionally, brake-stroke measurements were taken periodically throughout the test period. The temperature of the braking components was also monitored throughout testing to ensure the brakes did not overheat (primary lining temperatures remaining below 200°F).

3. OVERVIEW OF COLLECTED DATA

3.1 DESCRIPTION OF DATA

For the stopping tests, the signals shown in Table 3 were collected at 100 Hz. The temperatures listed are for the primary linings on the indicated wheel-end. For each run, data was collected beginning 1 second (sec) prior to the application of the brakes and ending 0.5 sec after the vehicle speed decreased to 0.4 mph.

Table 3. Stopping Test Streaming Data

Parameter	Units
Time	sec
Vehicle Speed	mph
Deceleration	ft/s²
Primary Control Pressure	psi
Left Front Pressure	psi
Right Front Pressure	psi
Left Intermediate (Forward Drive) Pressure	psi
Right Rear Pressure	psi
Spring Brake Pressure	psi
Primary Reservoir Pressure	psi
Secondary Reservoir Pressure	psi
Secondary Control Pressure	psi
Left Forward Trailer Axle Pressure	psi
Right Rear Trailer Axle Pressure	psi
Left Front Wheel Speed	mph
Right Front Wheel Speed	mph
Left Intermediate (Forward Drive) Wheel Speed	mph
Right Intermediate (Forward Drive) Wheel Speed	mph
Left Rear Wheel Speed	mph
Right Rear Wheel Speed	mph
Ambient Temperature	°F
Left Front Temperature	°F
Right Front Temperature	°F
Left Intermediate (Forward Drive) Temperature	°F
Right Intermediate (Forward Drive) Temperature	°F
Left Rear Temperature	°F
Right Rear Temperature	°F
Left Forward Trailer Axle Temperature	°F
Right Forward Trailer Axle Temperature	°F
Left Rear Trailer Axle Temperature	°F
Right Rear Trailer Axle Temperature	°F

A sample plot of speed and braking data are shown in Figure 2. This plot shows speed, deceleration, and brake application pressure for one of the constant-pressure stops performed at the 60,000-lb GVW loading condition with the rear trailer brakes disabled. For this stop, the original speed was approximately 20 mph before the brakes were applied at 15 psi.

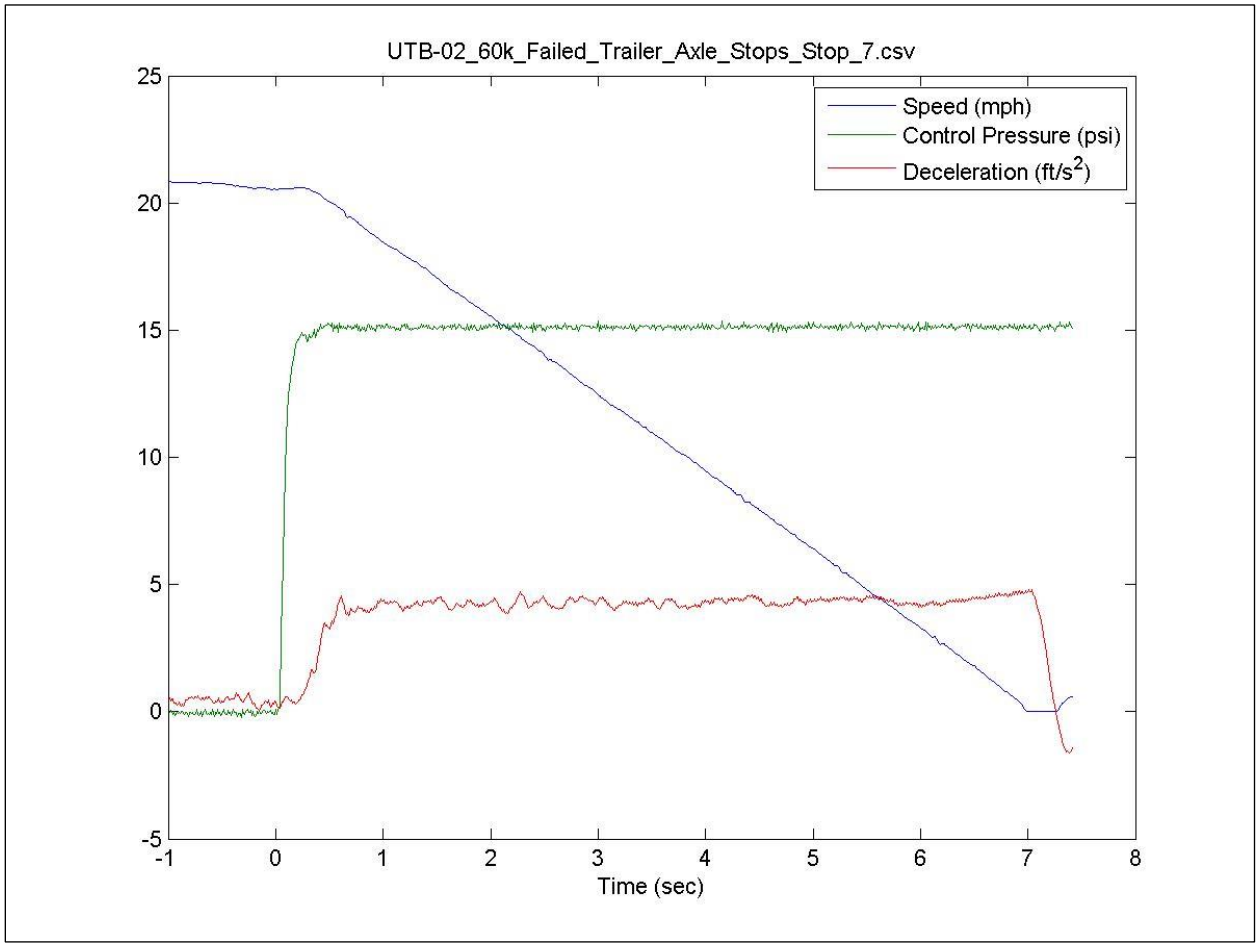

Figure 2. Time history plot of data from a constant-pressure stop.

Weigh tickets were obtained for each loading condition to determine the distribution of the load across the vehicle by axle group. A complete list of all test weights along with the nominal weight values used throughout this report is shown in Table 4.

Table 4. Test Weights (lb)

Nominal	Abbreviation	Steer	Drives	Trailer	GVW
60,000	60k	12,630	24,490	22,920	60,040
80,000 Balanced	80k Bal	12,810	32,640	34,590	80,040
80,000 Unbalanced	80k Unbal	13,200	38,710	28,100	80,010
91,000	91k	13,140	38,240	40,060	91,440
97,000	97k	12,660	33,390	51,070	97,120
106,000	106k	13,710	45,080	47,550	106,340
116,000	116k	13,780	48,770	53,550	116,100

A number of signals were collected during the PBBT tests as well. The information listed in Table 5 was collected at 10 Hz for each axle during testing of the service brakes.

Table 5. PBBT Service Brake Streaming Data

Parameter	Units
Time	sec
Brake Force Left	lb
Lock-up Left	lb
Brake Force Right	lb
Lock-up Right	lb
Weight Left	lb
Weight Right	lb
Control Pressure	psi
Chamber Pressure	psi

3.2 CALCULATION OF KEY PARAMETERS FOR EACH STOP

Link Engineering, the company which performed the tests and collected the data referenced in Section 3.1, provided several key parameters for each stopping test. These parameters are listed below in Table 6. The values for each of these parameters for every stopping test performed appear in Appendix A.

Table 6. Parameters Calculated for Each Stopping Test

Measure	Units
Stop #	- -
Target Speed	mph
Actual Speed	mph
Actual Stop Distance	ft
Corrected Stop Distance	ft
Average Primary Control Pressure	psi
Average Secondary Control Pressure	psi
Average Deceleration	ft/s^2
Stop Time (sec)	sec

Stopping distance was determined from a GPS with an internal accelerometer that is used to correct the data points between actual measurements from GPS position. The output from this accelerometer was used by the data-acquisition system to record the actual distance from the beginning of the braking event (triggered by using a pedal switch on the brake pedal) and the end of the braking event (triggered when the vehicle speed decreased to 0.4 mph). The stop time was determined by the time between these two triggers. Like the stopping-distance measurement, the deceleration was also measured with an accelerometer with the data being filtered to reduce the noise. Average pressures and decelerations were calculated from the data beginning 1.0 sec after the braking event is initiated until the end of the stop.

3.3 ADDITIONAL DATA COMMENTS

As indicated in Section 2.3.4, the brake stroke length was also monitored throughout the testing to ensure the automatic slack adjusters were functioning properly. While this data was not used in the analysis presented in this report, it is included in Appendix B for reference.

During the course of testing with the 97,000-lb GVW load, a brake component failed. Following repair, tests resumed with the next loading condition in the test sequence, 106,000-lb GVW. Consequently, data for the final brake condition—disabled pair of trailer brakes—was not collected for the 97,000-lb load.

4. ANALYSIS OF PANIC STOP DATA

Panic stops provide insight into the maximum brake force that can be developed, typical of an emergency situation where a driver would need to slam on the brakes without regard to smooth deceleration. Decelerations determined from this test data represents the maximum possible under the tested scenario (brake condition, initial speed, and road condition), and the stopping distances similarly represent the shortest distances possible. Note that driver response time is not a factor in these tests; the tests represent a driver response time of zero seconds.

4.1 TRACTOR TESTING WITH A CONTROL TRAILER

The first set of stopping tests conducted were FMVSS-121-style panic stops from 20 and 60 mph with an unbraked control trailer attached to the tractor with a GVW of approximately 56,000 lb. While these tests did not represent typical in-service loading events, they provided confirmation that the tractor still meets the brake performance standard for new equipment. FMVSS-121 specifies that for "loaded tractors with three axles and a GVWR of 70,000 lb or less…tested with an unbraked control trailer," the 20-mph stopping distance must be no more than 30 ft and the 60-mph stopping distance must be no more than 250 ft.[1] FMVSS-121-style stopping tests were performed at both 20 and 60 mph and were repeated for disabled brakes on a drive axle as well. The actual FMVSS-121 stopping distance (tested at 60 mph with fully-functioning tractor brakes) was 225 ft, below the maximum of 250 ft specified by FMVSS-121 (RSD requirement). The 20-mph stopping distance was 27.7 ft, also meeting the FMVSS-121 requirement (30 ft maximum).

4.2 OVERVIEW OF RESULTS FOR 20-MPH PANIC STOPS

The average stopping distances for the 20-mph panic stops are shown in Figure 3. Table 7 presents this same information in tabular form. For all of these tests, low variability was observed within the three repetitions of each brake/loading condition; thus, a single average value is sufficient to observe general trends in the data. The distances for all the regular panic stops for all loads and brake conditions tested were under the 40-ft limit specified in FMCSR 393.52(3).

1 http://www.nhtsa.gov/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/121_Stopping_Distance_FR.pdf (Table II p. 143)

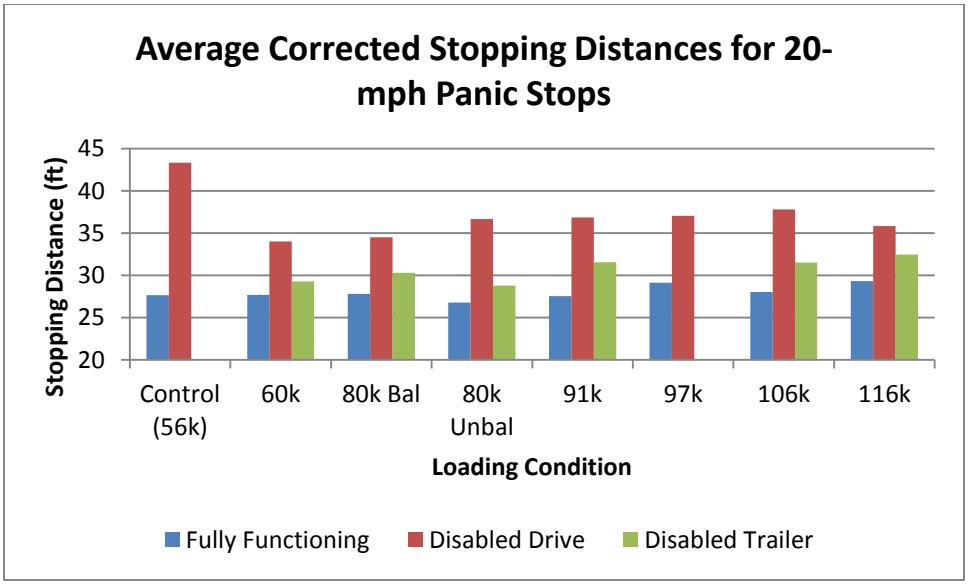

Figure 3. Comparison of stopping distances for 20-mph panic stops.

Table 7. Average Corrected Stopping Distance for 20-mph Panic Stops

Loading Condition (lb)	Stopping Distance (ft)		
	Fully Functioning	Disabled Drive	Disabled Trailer
Control Trailer (56,000)	27.7	43.3	- -
60,000 Load	27.7	34.0	29.3
80,000 Balanced Load	27.8	34.5	30.3
80,000 Unbalanced Load	26.8	36.7	28.8
91,000 Load	27.6	36.9	31.6
97,000 Load	29.1	37.1	- -
106,000 Load	28.0	37.8	31.5
116,000 Load	29.3	35.9	32.5

4.3 OVERVIEW OF RESULTS FOR 60-MPH PANIC STOPS

The average stopping distances for the 60-mph panic stops are shown Figure 4 (actual values in Table 8). For these tests as well, the variability within the three repetitions of each brake/loading condition was low.

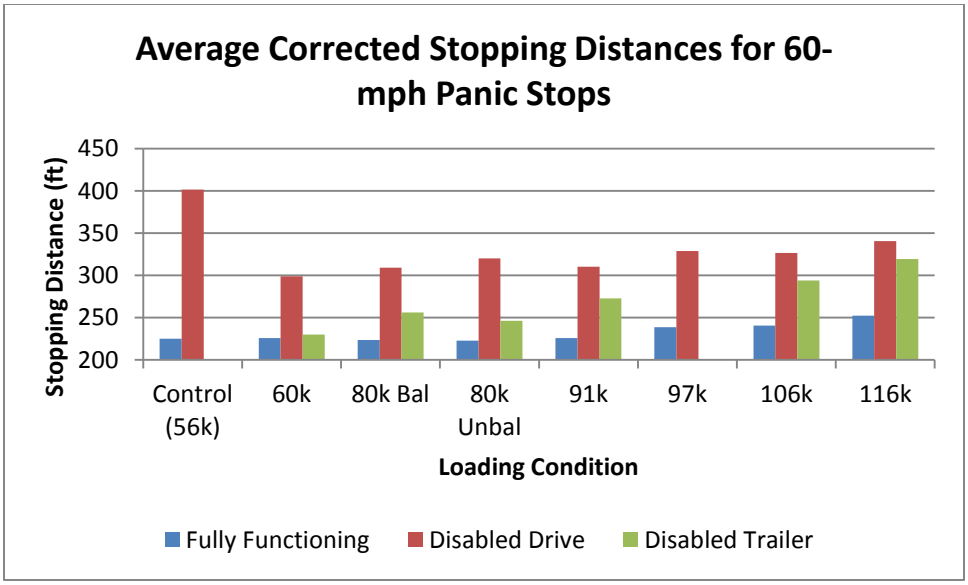

Figure 4. Comparison of stopping distances for 60-mph panic stops

Table 8. Average Corrected Stopping Distances for 60-mph Panic Stops

Loading Condition (lb)	Stopping Distance (ft)		
	Fully Functioning	Disabled Drive	Disabled Trailer
Control Trailer (56,000)	225.0	401.7	- -
60,000 Load	228.9	299.1	229.8
80,000 Balanced Load	223.6	309.3	256.1
80,000 Unbalanced Load	222.9	320.3	246.4
91,000 Load	225.8	310.3	272.7
97,000 Load	238.8	329.0	- -
106,000 Load	240.5	326.6	294.2
116,000 Load	252.4	340.7	319.5

As described previously, the control trailer testing was performed with an unbraked control trailer; thus, the panic stops performed with the control trailer with disabled drive brakes represent a stop in which the total braking force was provided by the steer axle and one drive axle only.

4.4 OBSERVED TRENDS IN PANIC STOP DATA

The test data for both 20- and 60-mph stopping tests revealed a difference in brake force supplied depending on which brakes were disabled. For the test scenarios where one set of brakes was disabled, disabling a pair of drive axle brakes resulted in a greater stopping distance (decreased braking force) than disabling a pair of trailer brakes. The relationship held true for both initial speeds and all loading conditions. Thus, for the vehicle tested, more brake force was generated by the drive axle brakes than the trailer axle brakes.

As expected, increases in load resulted in corresponding increase in stopping distance, with a few minor exceptions for unknown reasons in the 20-mph stopping data.

4.5 ANALYSIS OF TIRE LOAD CAPACITY

Another area of concern to policy-makers considering loading regulations includes tire capacity. For the purposes of this testing, all tire pressures were set at the manufacturer-specified capacity to accommodate the maximum load (details in Table 1 and Table 2). Tire capacities for each axle group are summarized and compared to the test loads in Table 9.

Table 9. Tire Load Capacity for Loading Conditions

Load Condition (lb)	GVW (lb)	Steer Axle (lb), Capacity	Drive Axle Group (lb), Capacity	Trailer Axle Group (lb), Capacity
Tire Capacity	- -	**14,320**	**45,400**	**52,880**
Control Trailer	55,860	13,340 93.2%	38,020 83.7%	- -
60,000 Load	60,040	12,630 88.2%	24,490 53.9%	22,920 43.3%
80,000 Balanced Load	80,040	12,810 89.5%	32,640 71.9%	34,590 65.4%
80,000 Unbalanced Load	80,010	13,200 92.2%	38,710 85.3%	28,100 53.1%
91,000 Load	91,440	13,140 91.8%	38,240 84.2%	40,060 75.8%
97,000 Load	97,120	12,660 88.4%	33,390 73.5%	51,070 96.6%
106,000 Load	106,340	13,710 95.7%	45,080 99.3%	47,550 89.9%
116,000 Load	116,100	13,780 96.2%	48,770 107.4%*	53,550 101.3%*

*Due to load positioning in these configurations, an overload condition was created for the rating of the tires available for testing. This was noted and will be addressed in future testing.

5. ANALYSIS OF PBBT DATA

5.1 OVERVIEW OF RESULTS

The PBBT tests were performed before and after stopping tests for each loading and brake condition. Unless otherwise specified, the numbers presented are averages of the two tests performed. Results of each individual PBBT test (including wheel-end-specific values) are included in Appendix C.
The PBBT overall vehicle scores are summarized in Table 10.

Table 10. PBBT Scores (Average)

Load Condition (lb)	Fully Functioning	Disabled Drive	Disabled Trailer
Control (Tractor Only)	54.6%		
60,000 Load	69.7%	56.5%	52.2%
80,000 Balanced Load	67.4%	55.8%	49.0%
80,000 Unbalanced Load	65.9%	53.6%	52.1%
91,000 Load	65.8%	55.4%	48.4%
97,000 Load	62.2%	51.2%	
106,000 Load	61.9%	50.0%	45.3%
116,000 Load	58.1%	47.3%	45.0%

5.2 ESTIMATES OF DISABLED-BRAKE RESULTS

The results of the PBBT tests performed when all brakes were fully functioning were used to estimate the PBBT scores for the situations where the brakes on a particular actual were disabled. This brake efficiency estimation was determined from the total braking forces of the remaining axles divided by the PBBT-reported weights for all axles. These estimated results are compared to the actual values in Table 11 below and graphed in Figure 5.

Table 11. Comparison of Actual and Estimated PBBT Scores

Load Condition (lb)	Fully Functioning	Disabled Drive		Disabled Trailer	
		Actual	Expected	Actual	Expected
Control (Tractor Only)	54.6%				
60,000 Load	69.7%	56.5%	57.0%	52.2%	54.4%
80,000 Balanced Load	67.4%	55.8%	55.1%	49.0%	50.7%
80,000 Unbalanced Load	65.9%	53.6%	51.7%	52.1%	52.0%
91,000 Load	65.8%	55.4%	53.8%	48.4%	49.0%
97,000 Load	62.2%	51.2%	53.0%		
106,000 Load	61.9%	50.0%	50.9%	45.3%	47.7%
116,000 Load	58.1%	47.3%	46.6%	45.0%	45.5%

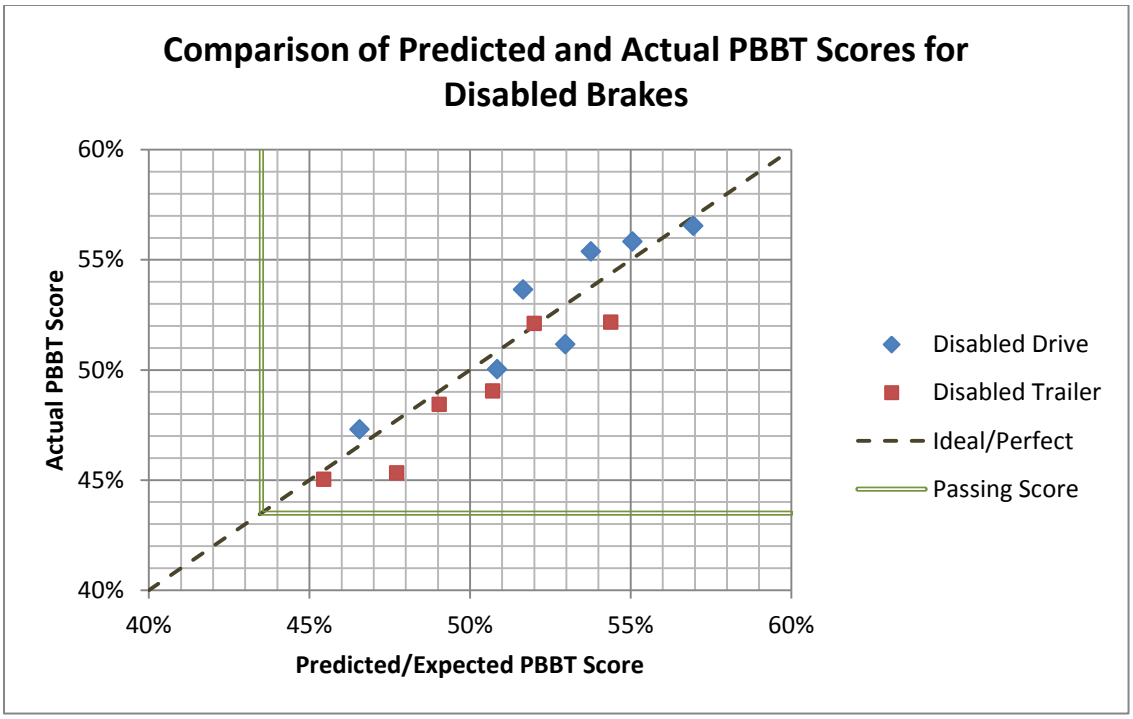

Figure 5. Comparison of predicted and actual PBBT scores for disabled brake scenarios.

As shown in Figure 5, these estimates were a fairly accurate predictor of the actual PBBT scores for these conditions, generally within 1-2%. The predictions for the disabled trailer brake scenario tended to be generally lower than the actual values, whereas the predictions for the disabled drive brake scenario were more evenly balanced with over- and under-estimates.

5.3 EFFECT OF LOAD AND DEFECT POSITION ON BRAKE EFFICIENCY

The average PBBT scores for each weight and loading condition are shown in Figure 6. As expected, the PBBT score decreases with increasing weight. However, unlike the stopping distance tests, the performance was better when a set of drive axle brakes was disabled rather that a set of trailer axle brakes.

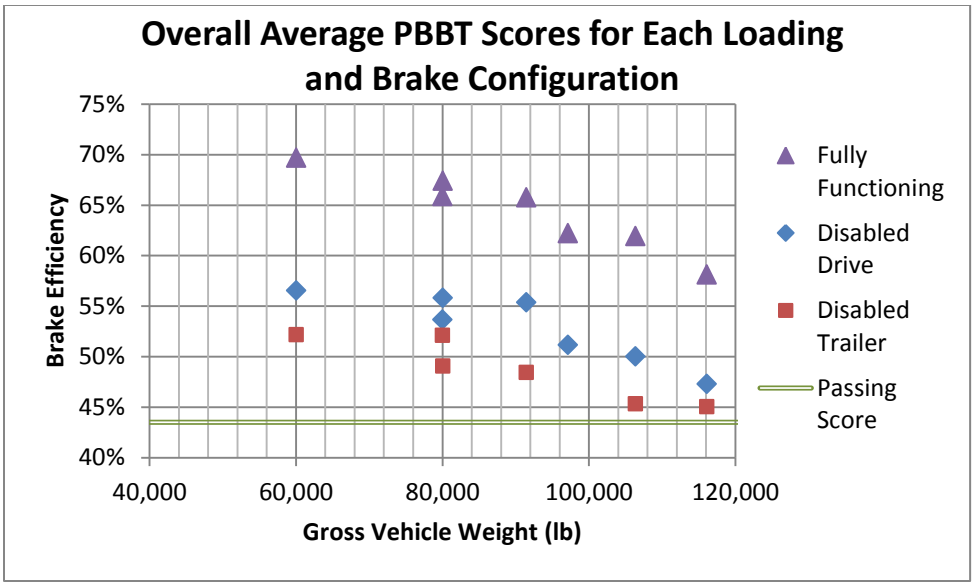

Figure 6. PBBT scores by brake condition and loading.

Actual test weights, including weight distribution by axle group, appear in Table 4.

5.4 COMPARISON OF SCALE-AND PBBT-REPORTED WEIGHTS

Brake efficiency is calculated by dividing the sum of the wheel-end brake forces by the sum of the wheel-end weights. The GVW measured and used by the PBBT machine is compared to the GVW reported in the weight ticked from the scale in Figure 7. As shown in this figure, the PBBT consistently measures a total weight value approximately 5,000 lb lower than the GVW measured on the scale. This is likely because unlike the pit scale, the axles are weighed individually and the weighing surface is not level with respect to the length of the vehicle.

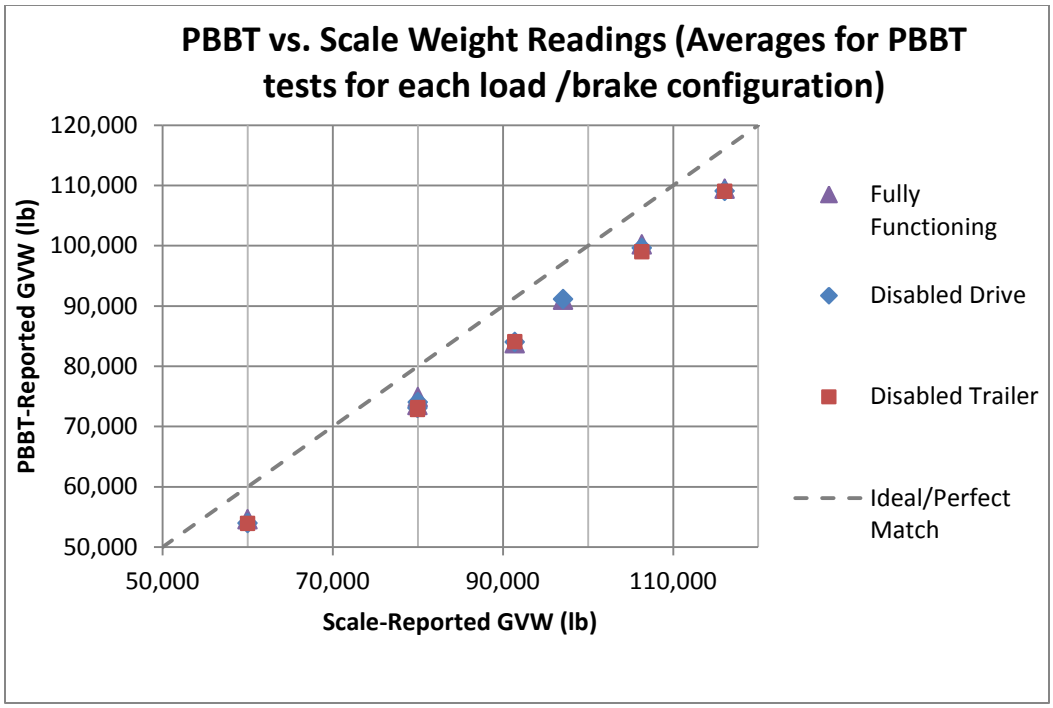

Figure 7. Comparison of PBBT and scale-reported GVW

6. ANALYSIS OF CONSTANT-PRESSURE STOP DATA

6.1 BACKGROUND

Both North American Standard Level-1 inspections and drivers' pre-trip inspections include a component to visually inspect the vehicle's braking system. Because they are visual methods, they have limited ability to determine brake performance. Although the PBBT provides a quantitative indicator of vehicle braking ability, it requires access to specialized equipment. This section describes an on-board system which will provide a real-time brake indicator based on dynamic braking data collected on board the vehicle. Such a system could be used by drivers and maintenance personnel to monitor their vehicles' braking systems, supporting preventative maintenance and providing notification of equipment problems. The system could also provide input to a number of other systems such as the Wireless Roadside Inspection system, providing advisory data to enforcement and fleet personnel regarding a commercial motor vehicle's (CMV's) brake system.

A cursory analysis of stopping test data for over-the-road CMVs collected 2008-2009[2] has indicated that the actual pressure-deceleration relationship is linear from the crack pressure (typically around 10 psi) up until about 60 psi. The higher-pressure region (about 60 psi up to the maximum, about 100-110 psi), is highly nonlinear. Stopping tests such as those in accordance with the FMVSS-121 guidelines or FMCSR 393.5(a)(3) provide stopping distance (typically expressed in feet, and the typical performance-based brake test provides brake efficiency (ratio of total braking force to GVW, equivalent to deceleration in g's). However, both of these metrics are based on tests conducted in the higher, nonlinear pressure region, and are thus not well correlated to typical day-to-day braking events performed at lower brake application pressures (shown in the Medium Truck Duty Cycle research[3] to generally be below 30 psi).

ORNL is seeking to develop a system which will determine, on a real-time basis from in-service activity, the condition of a CMV's braking system by monitoring deceleration as a function of brake application pressure. The algorithm will ultimately make use of pressure data from a brake application pressure sensor located at the treadle valve, speed data from either the data bus native to the vehicle (J1939 or J1708/J1587) or an installed GPS (may be present as part of a telematics device), weight data from an on-board self-weighing system (in this particular research substituted with weigh ticket data), and a telematics device where processing/analysis functions will reside. The system will use currently-available, commercial, off-the-shelf technology, and the algorithm will make use of trends in the CMVs pressure-deceleration curves to identify degradations in brake performance.

6.2 GENERAL OBSERVATIONS FROM TEST DATA

Constant-pressure stopping tests were performed by bringing the test vehicle up to a certain speed and applying a constant primary control pressure (using a pressure regulator) until the vehicle came to a complete stop. Speed and brake application pressure data were collected and used to determine average deceleration, normalized stopping distance, elapsed time, and other summary information for each test run. Constant-pressure stops were performed with 60,000-lb and 80,000-lb loads; at 15-psi, 25-psi, 35-psi, 45-psi, and 55-psi brake application pressures; and from 20-mph and 60-mph starting speeds. Two runs were performed for each test configuration.

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2 Steven J. Shaffer, Amy M. Long, *U14: Field Testing and Analysis of Braking Performance of In-Service Trucks,* National Transportation Research Center, Inc., 2009.

3 Oscar Franzese, Mary Beth Lascurain, Gary Capps, *Medium Truck Duty Cycle Data from Real-World Driving Environments: Project Interim Report*, Oak Ridge National Laboratory, 2010.

Deceleration data for each constant-pressure test is shown as a function of primary brake control pressure in Figure 8 (60,000-lb load) and Figure 9 (80,000-lb load).

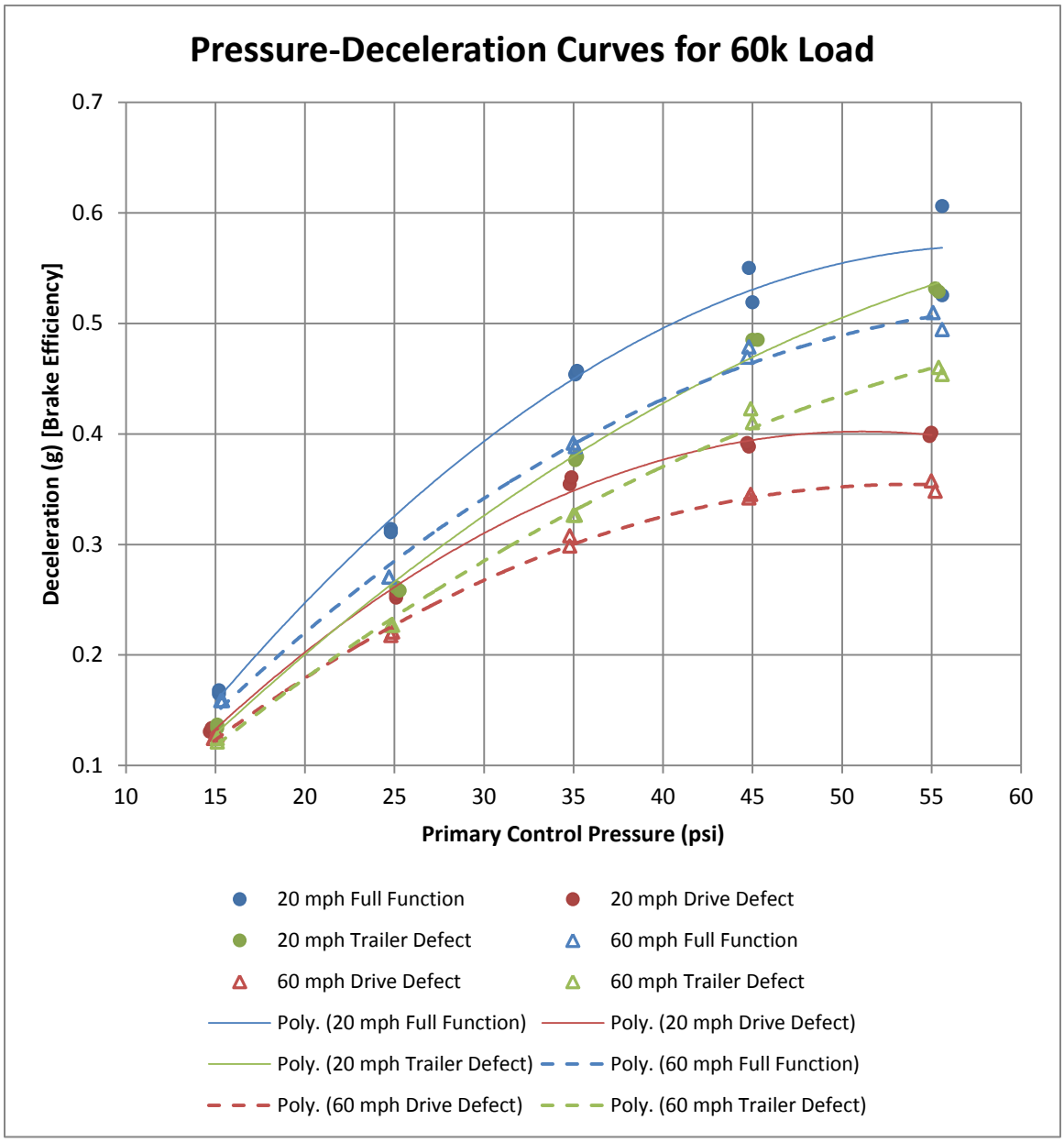

Figure 8. Pressure-deceleration curves for 60,000 lb GVW load.

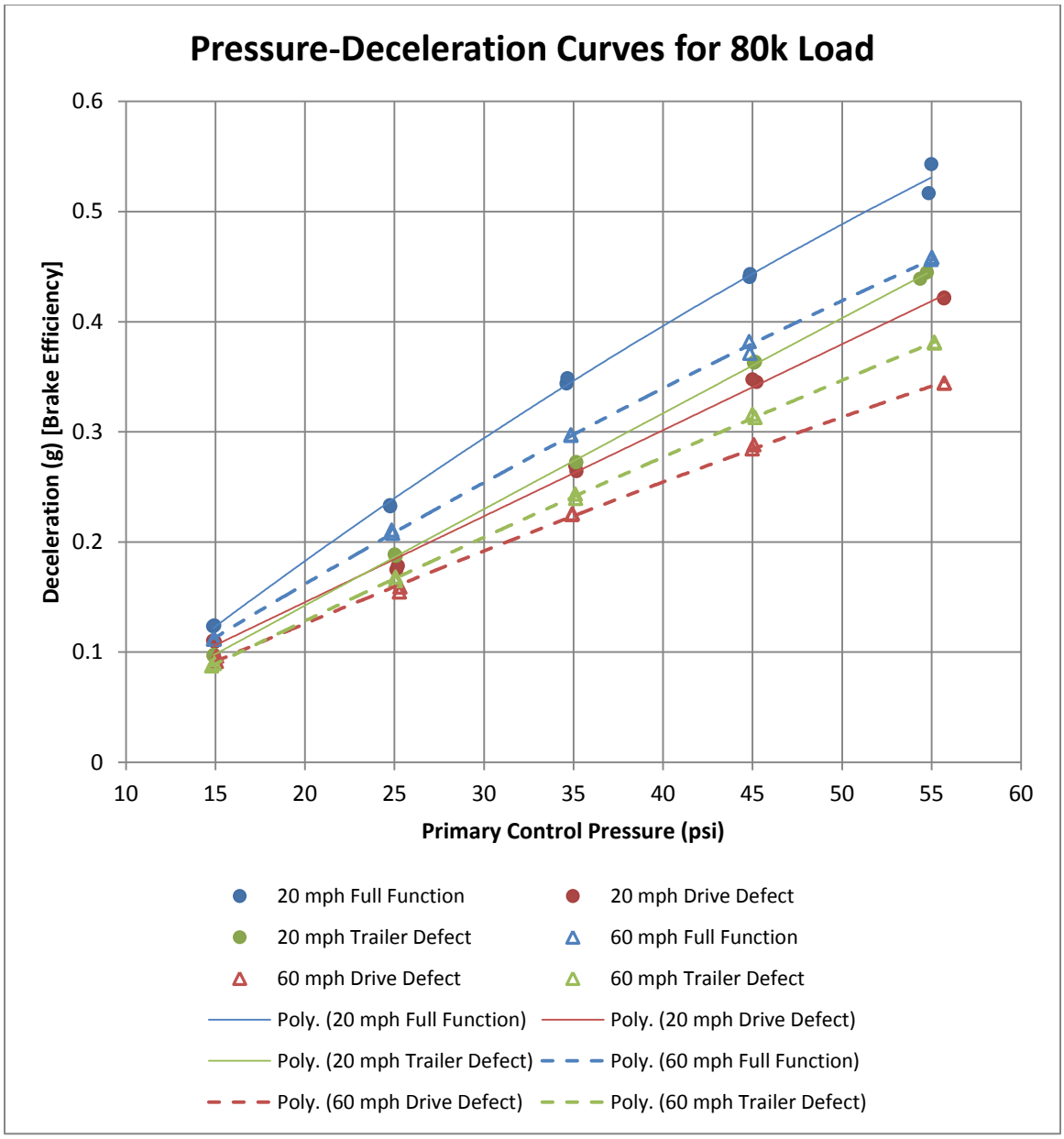

Figure 9. Pressure-deceleration curves for 80,000-lb GVW load.

6.2.1 Linearity

Previous constant pressure stopping tests only went up to about 30 mph, and data appeared very linear (first-order polynomial). However, with the addition of the higher pressures in this test (up to 55 psi), the fit is better approximated by a second-order polynomial, indicating that the linear pressure region terminates around 50 psi (for the test vehicle). With the omission of the highest test pressure (55 psi), however, the remaining data (15, 25, 35, and 45 psi) is well represented (correlation of more than 95%) by a linear fit for each of the twelve speed/load/brake configurations as shown in Figure 10 and Figure 11.

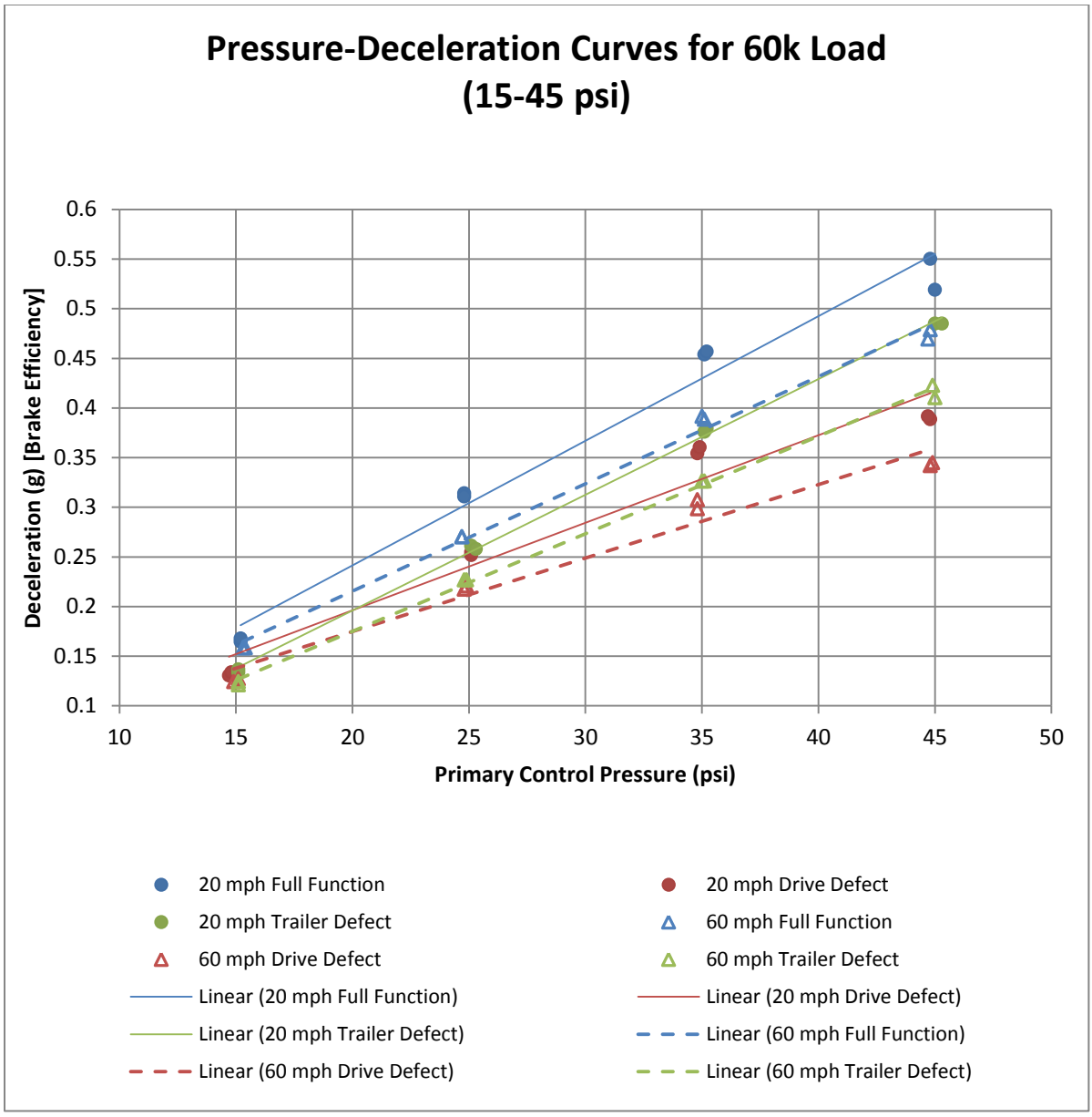

Figure 10. Pressure-decelaration curves for 60,000-lb GVW loading condition (15-45 psi).

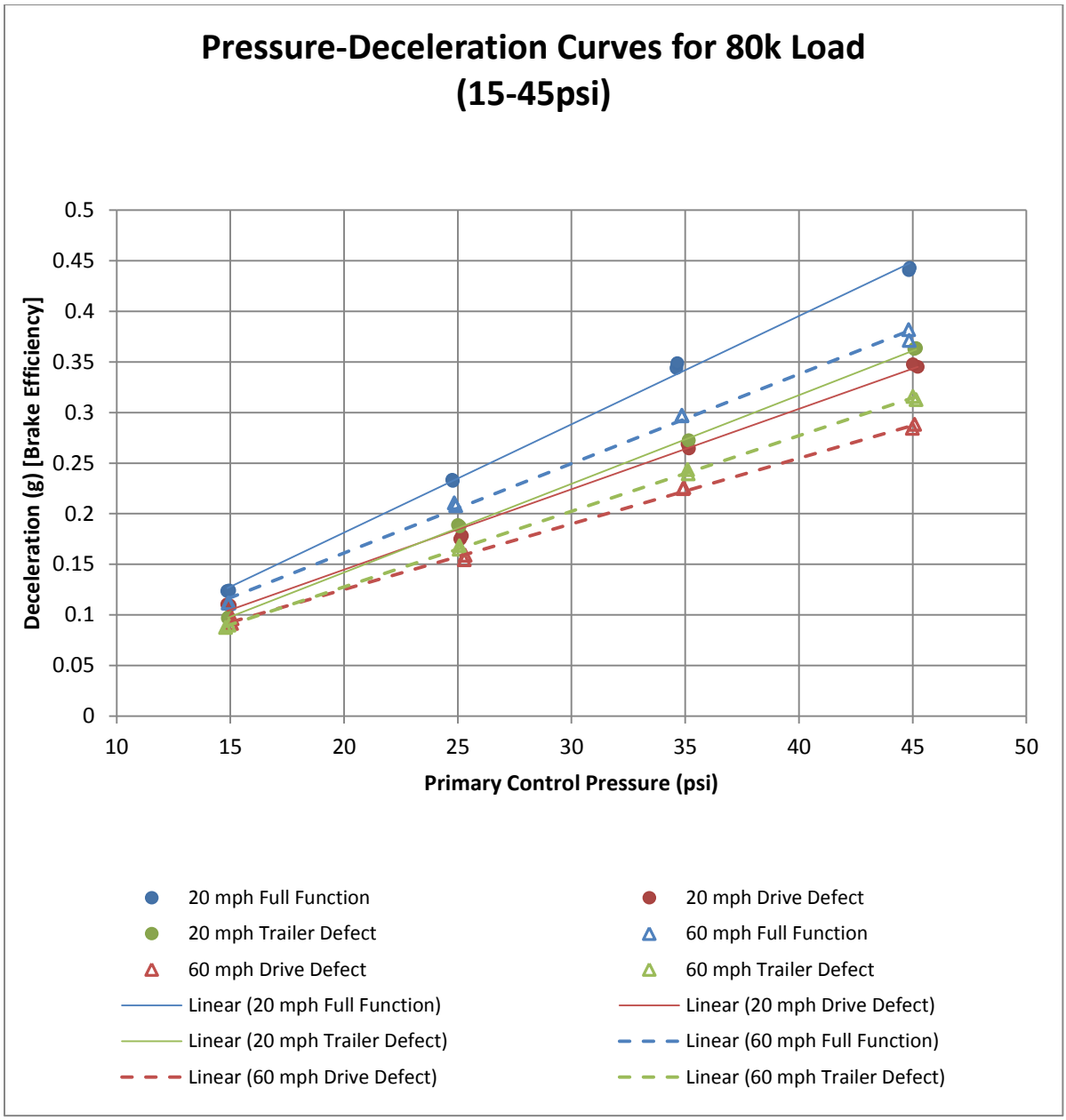

Figure 11. Pressure-deceleration curves for 80,000-lb GVW loading condition (15-45 psi).

An implication for future testing is that the linear model for the pressure-deceleration relationship should only be based on and used for brake application pressures below approximately 50 psi.

6.2.2 Effect of Speed

One item of interest from the initial exploratory analysis was the effect of initial speed (20 vs. 60 mph) on deceleration. This was not seen in previous research[4], where only 20- and 30-mph tests were conducted. For equivalent loading, braking condition, and brake application pressure, the tests conducted from higher

4 Mary Beth Lascurain, Oscar Franzese, Gary Capps, *Real-Time Dynamic Brake Assessment Proof of Concept Final Report*, Oak Ridge National Laboratory, 2011.

speeds had lower average deceleration. For the most recent analysis, speed and deceleration plots (Figure 12 and Figure 13 respectively) were generated to compare the stopping data for both starting speeds in the below-20-mph region. (Here, the data is aligned at the 19-mph point with braking events marked with x's. These graphs reveal that the difference in deceleration is also present in the lower-speed region of the data, not simply a result of unexpectedly low deceleration in the 20-to-60-mph region.

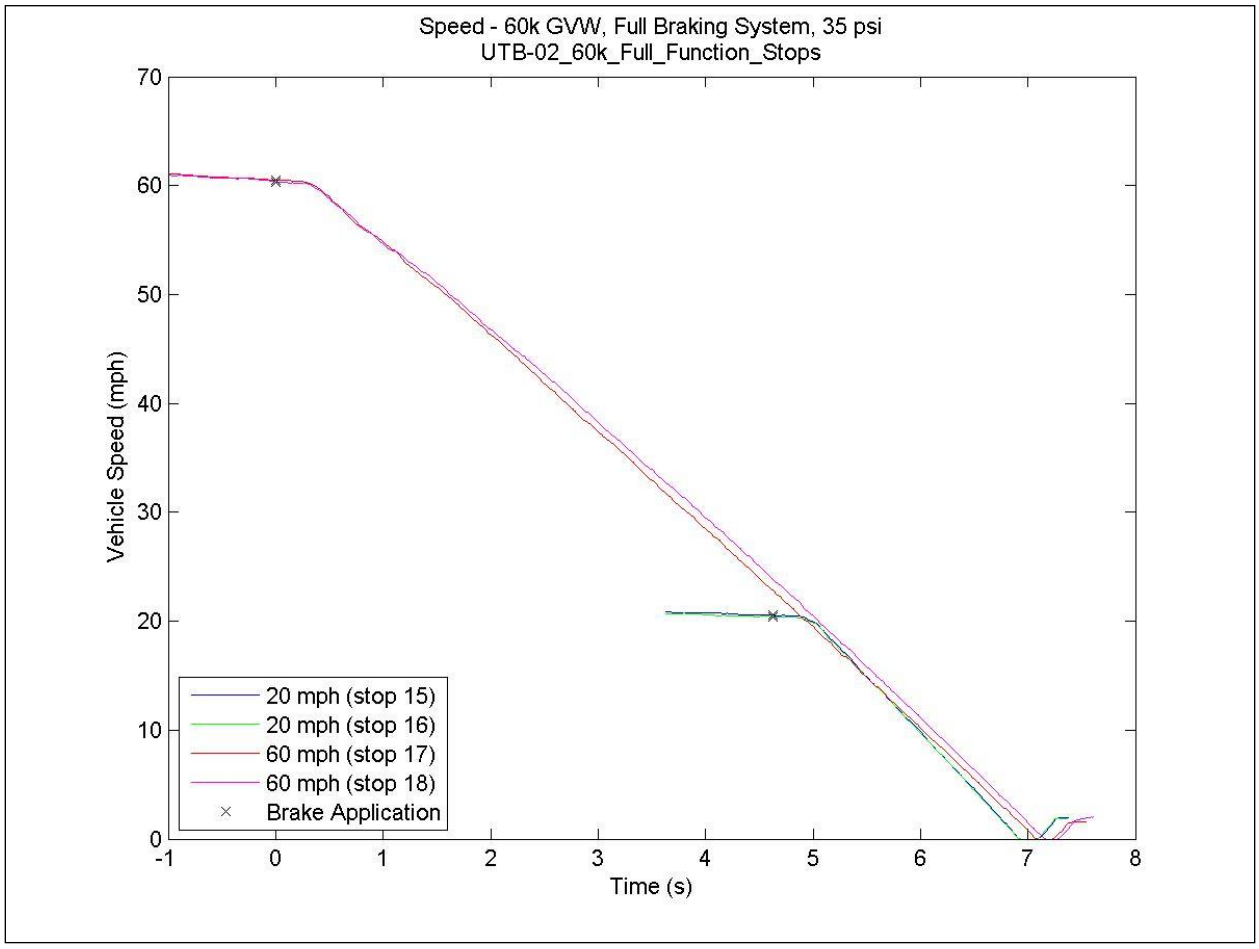

Figure 12. Comparison of sample speed profiles for 20- and 60-mph constant-pressure stops.

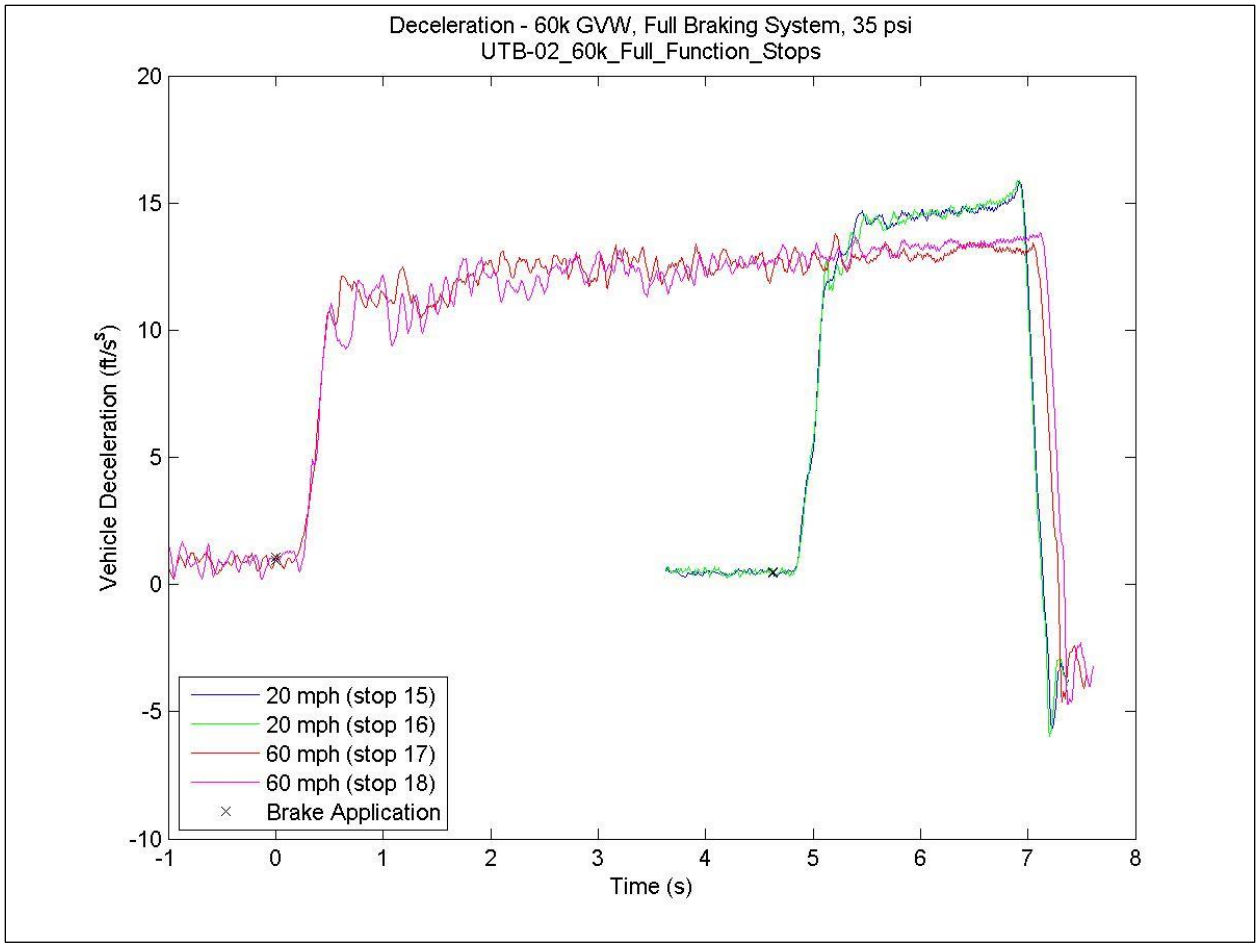

Figure 13. Comparison of sample deceleration profile for 20- and 60-mph constant-pressure stops.

6.2.3 Effect of Loading

Higher weight corresponds to lower deceleration as expected; based on Newton's second law, the deceleration of the vehicle for a given force (i.e., provided the effect of weight on braking force and drag is insignificant) is directly proportional to the mass. This was observed in both the 20- and 60-mph tests (Figure 14 and Figure 15 respectively, shown in the following section).

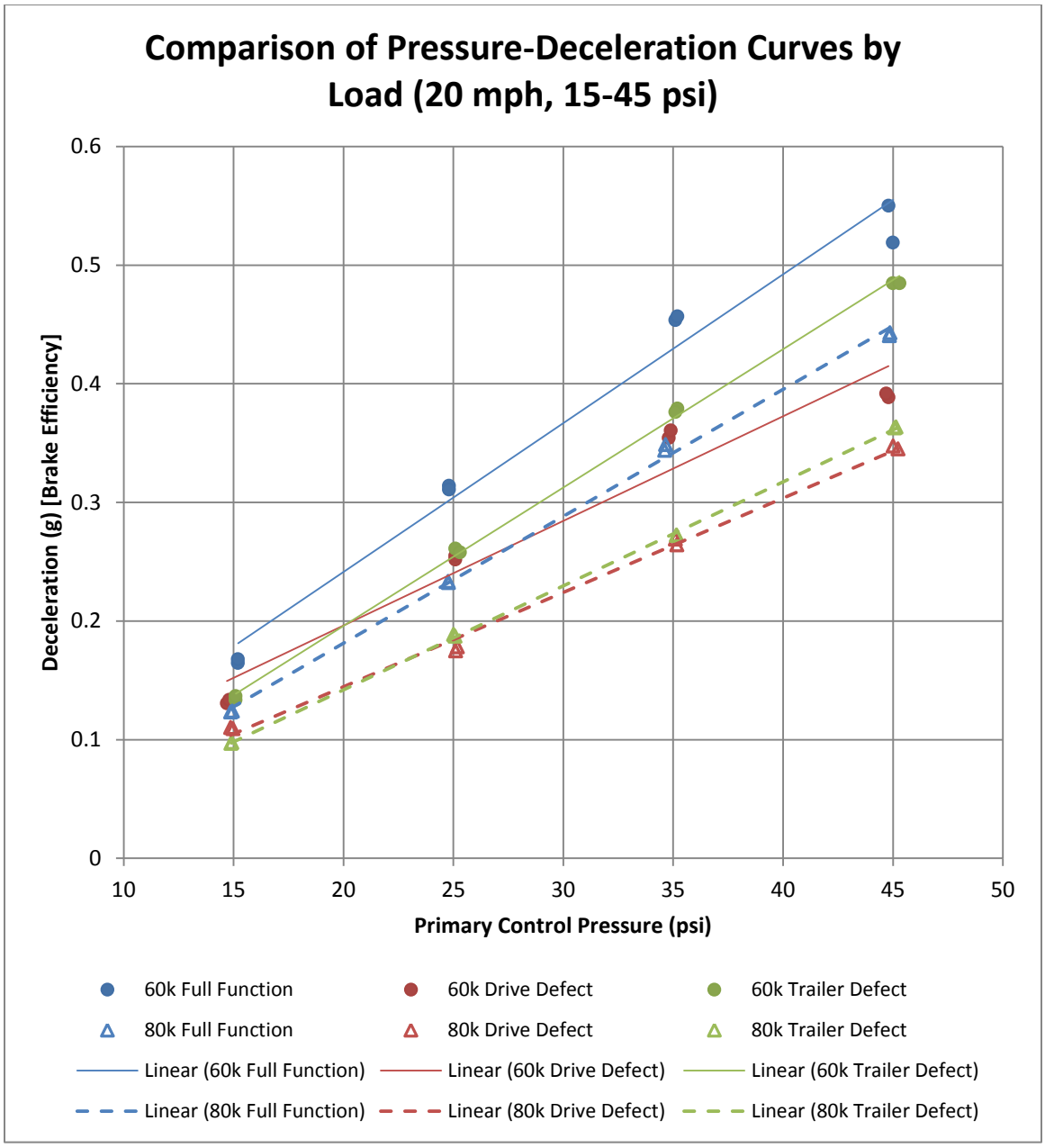

Figure 14. Pressure-deceleration curves by load and brake condition for 20 mph.

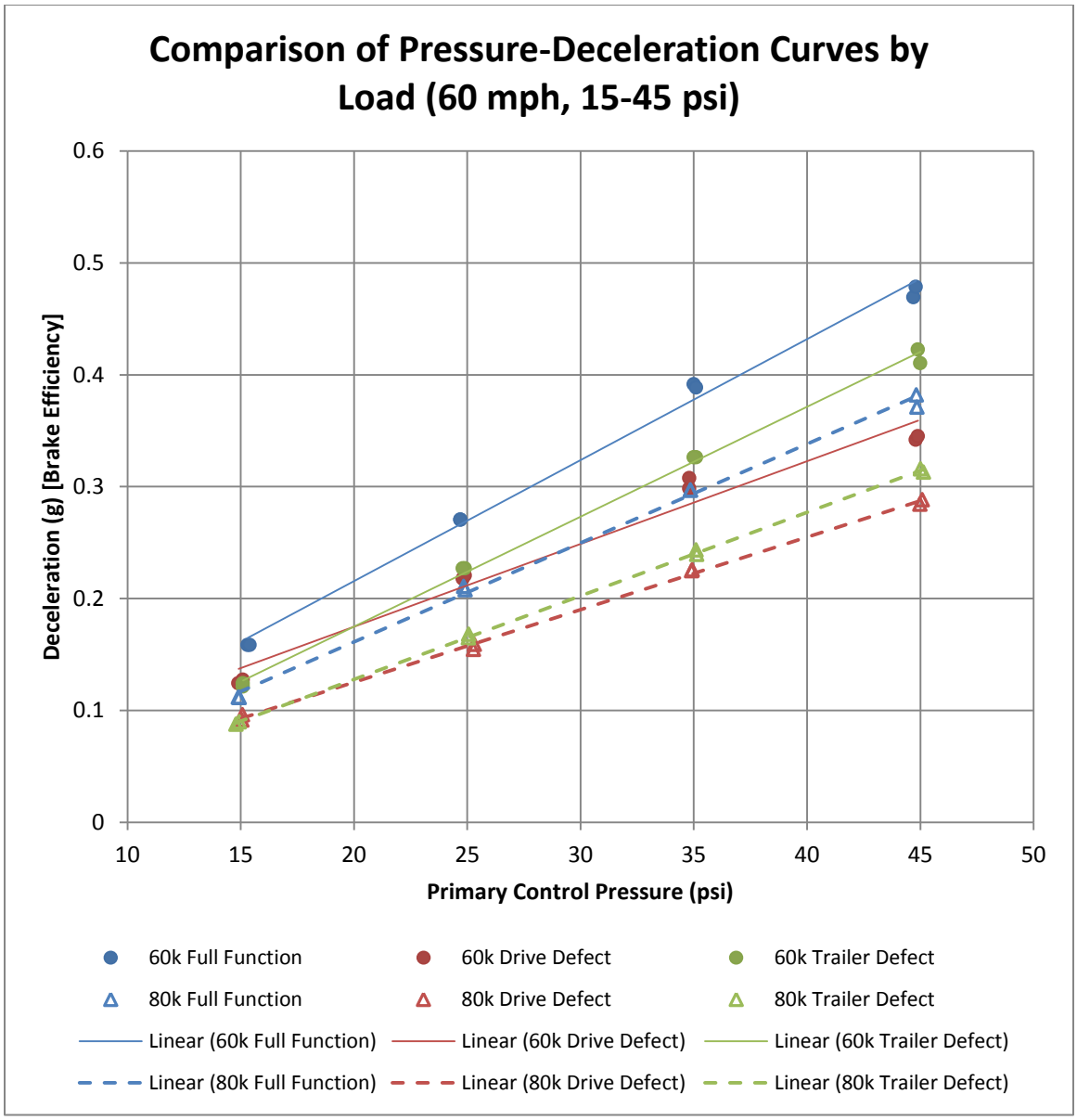

Figure 15. Pressure-deceleration curves by load and brake condition for 60 mph.

6.2.4 Effect of Defect Position

The position of the defective pair of brakes influenced the position of the pressure/deceleration line. As shown in Figure 14 and Figure 15, disabling drive axle brakes resulted in a poorer brake performance than disabling trailer brakes. This observation held for all four combinations of initial speed (20 and 60 mph) and loading condition (60,000-lb and 80,000-lb GVW).

6.3 NORMALIZATION AND OBSERVATIONS

Normalization equations were generated from full-function brake configuration only, and then applied to all data to determine how well the algorithm handles other data (the two disabled brake configurations).

The basing of such an algorithm only on data from the fully-functioning configuration is analogous to calibrating an on-board brake monitoring system with several constant-pressure stops when the brakes were in good condition (in order to detect performance degradation at a later time).

The original pressure/deceleration data is shown in Figure 16. Note that data from full-function, disabled-drive, and disabled-trailer braking conditions in the raw data set (not filtered by initial speed or GVW) overlap.

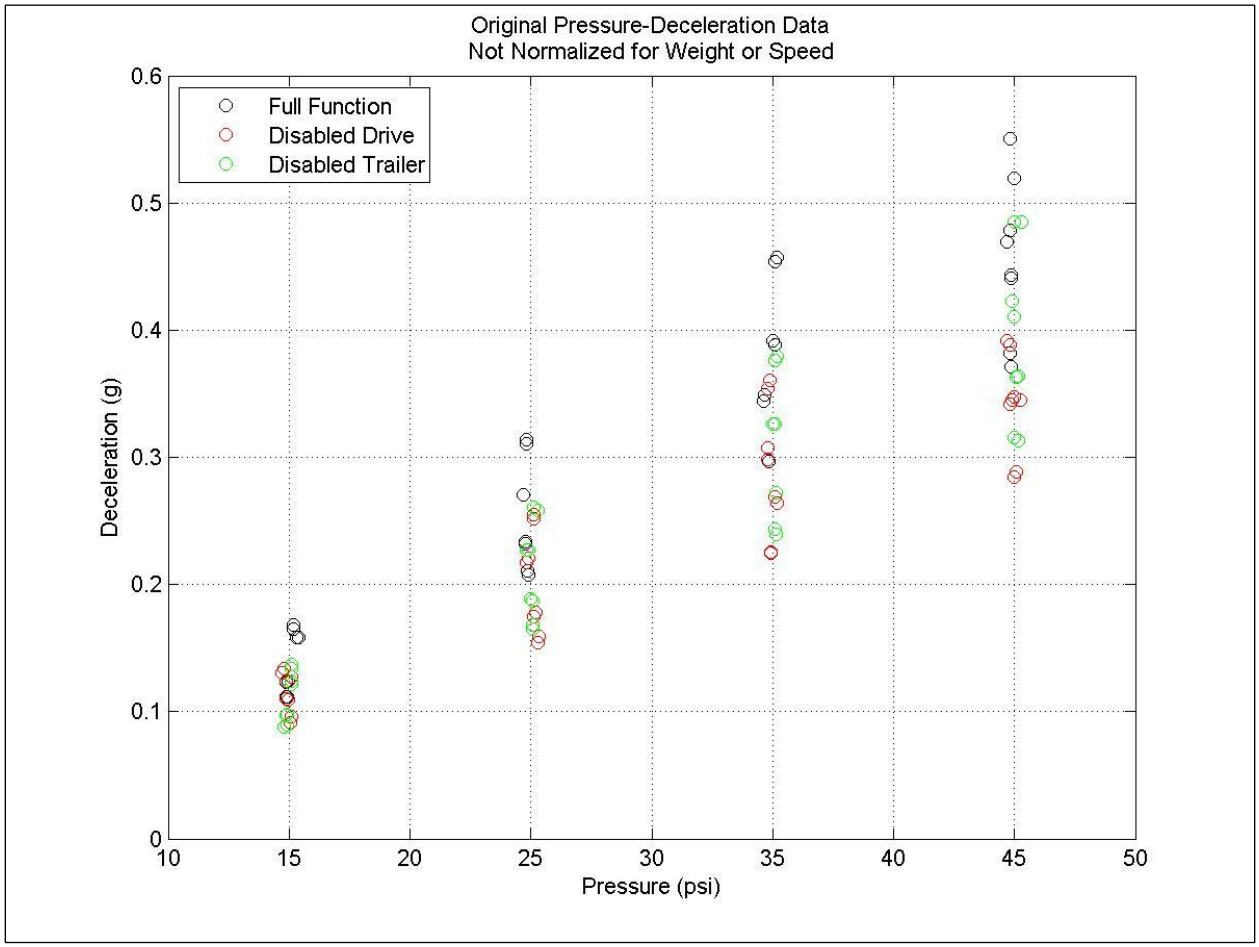

Figure 16. Original pressure-deceleration data before normalization.

6.3.1 Normalizing for speed (to 20 mph)

Since only two speeds were tested, normalizing for speed was done by finding the relationship between equivalent 20- and 60-mph tests—stops performed under the same loading conditions and at the same brake application pressure. A plot of deceleration for the 20-mph runs as a function of that of the equivalent 60-mph runs (Figure 17) revealed a strong linear relationship between the two ($r^2 = 0.99557$). The regression line generated from the full-functioning brake system data was used to "convert" all 60-mph deceleration data (including all loading conditions and brake conditions) into equivalent 20-mph decelerations: $d_{20mph} = 1.178 * d_{60mph} - 0.010154$. (While a simple linear correction was possible in this test data because only two speeds were tested, the relationship between speed and drag is more complex, with instantaneous drag proportional to instantaneous speed. The limited data collected in this testing was not conducive to the development of a more complex model able to handle a variety of speeds.)

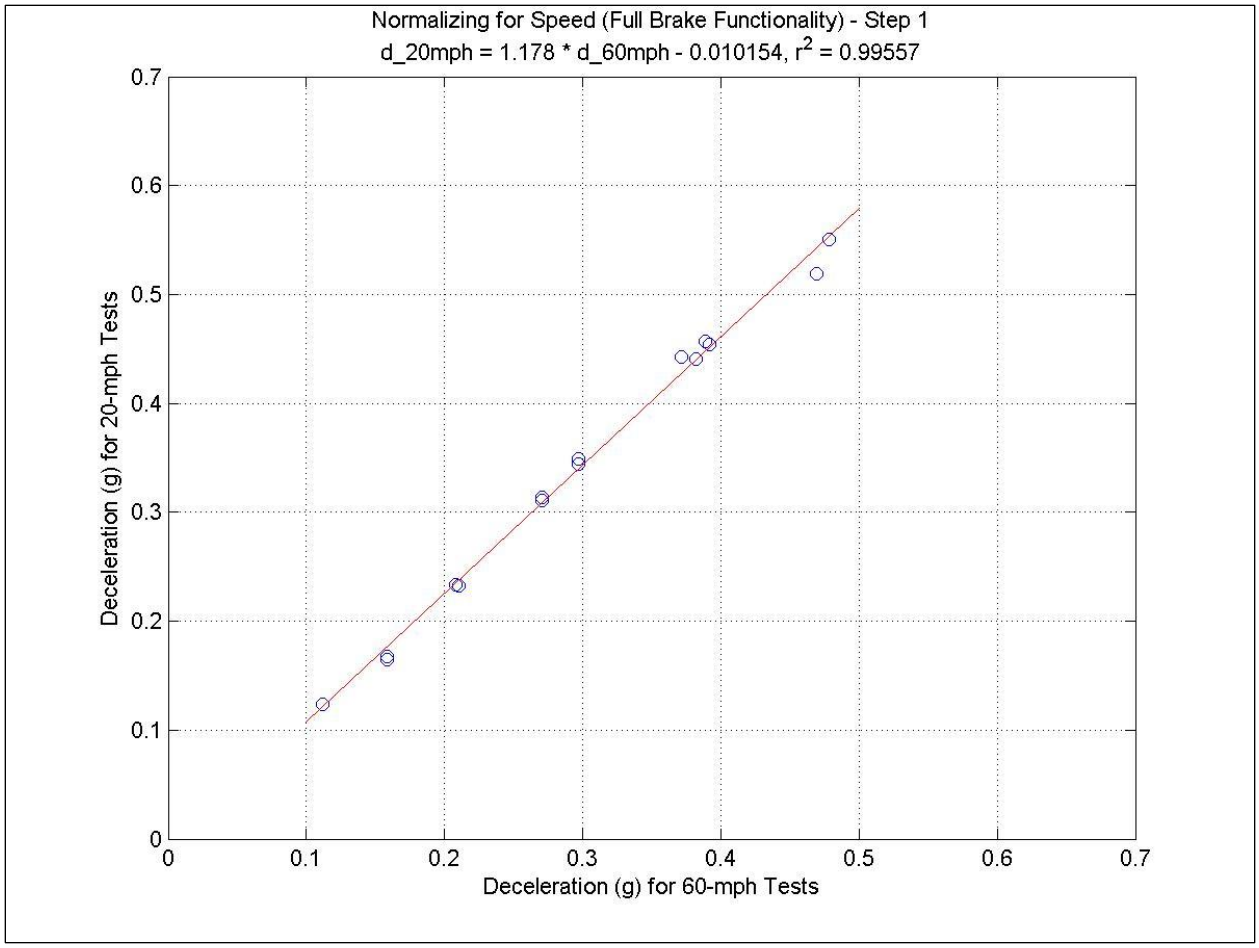

Figure 17. Full-function pressure-deceleration data normalized to 20-mph initial speed.

6.3.2 Normalizing for weight (to 60,000 lb)

Next, the vehicles were normalized for weight to 60,000 lb GVW. Deceleration for the 60,000 lb runs was plotted as a function of corresponding 80,000-lb runs (Figure 18) and found to have a strong linear relationship ($r^2 = 0.99119$). The regression line generated from the full-brake-function runs ($d_{60k} = 1.1893 * d_{80k} + 0.030578$) was used to "convert" all 80,000-lb decelerations to equivalent 60,000-lb runs.

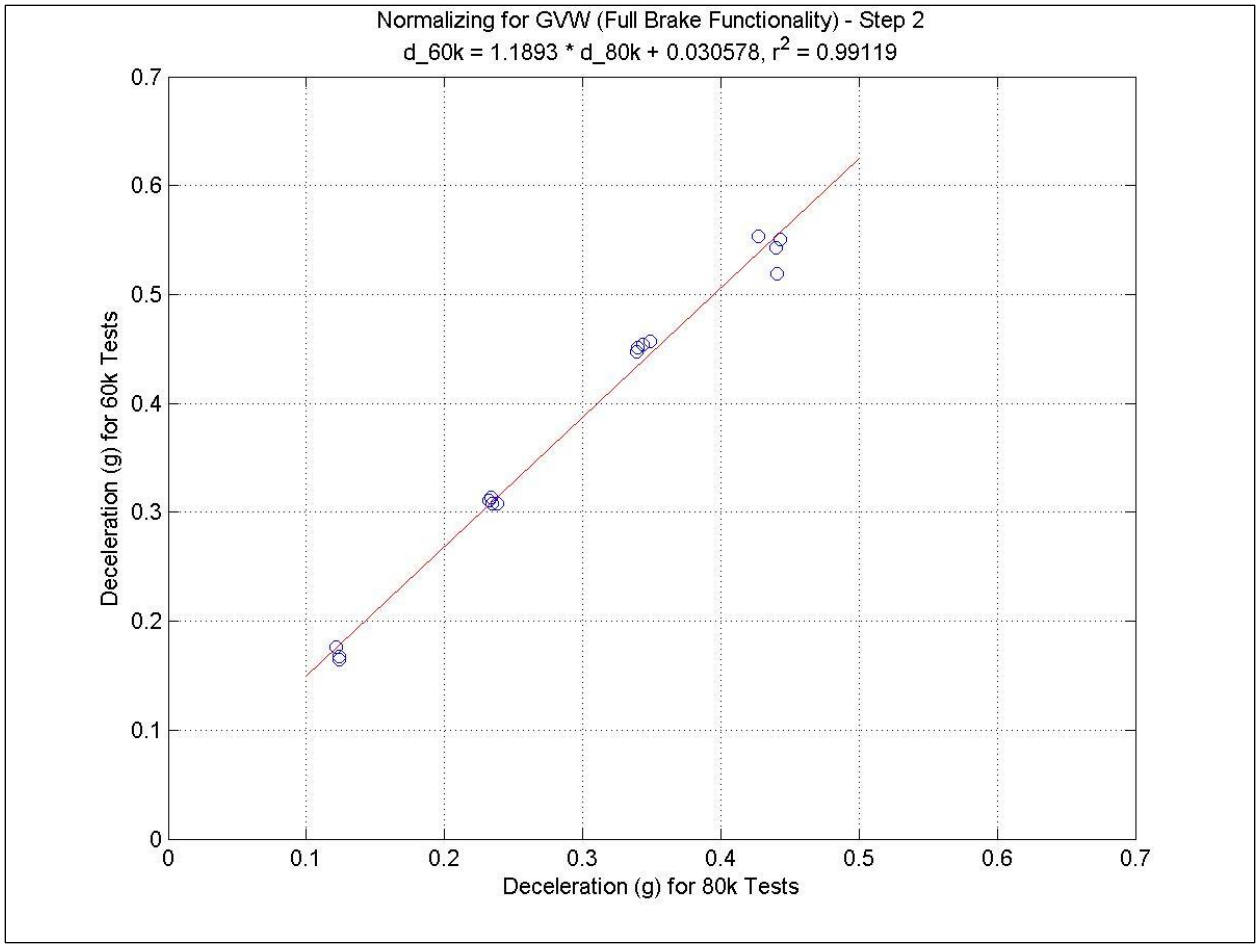

Figure 18. Full-function pressure-deceleration data normalized to 60,000-lb GVW load.

6.3.3 Results of Data Normalization

Once all the data was normalized to 20 mph and 60,000 lb, the full-function values are tightly grouped along a line with all disabled brake tests falling clearly below the trendline for the fully-functioning brake system (Figure 19).

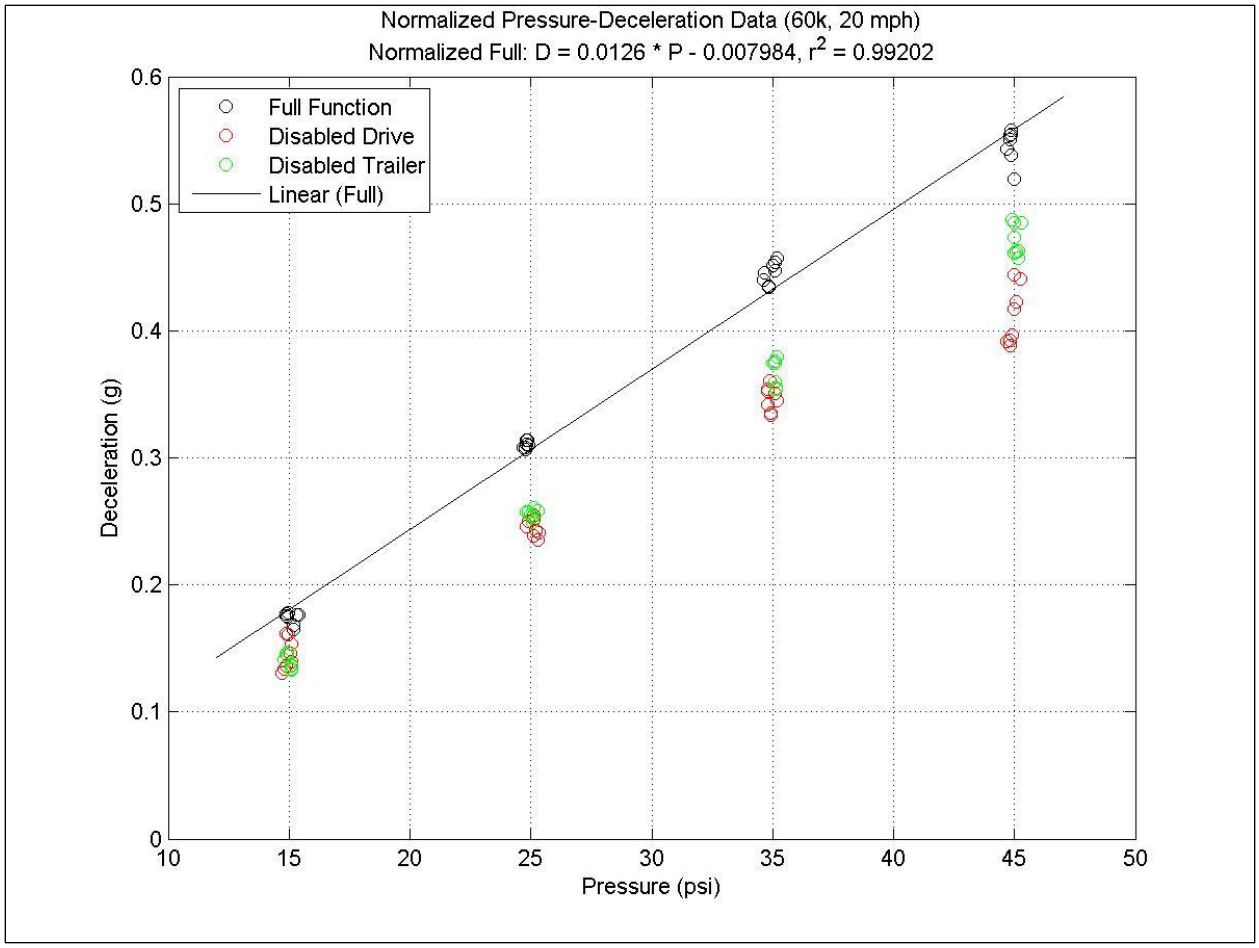

Figure 19. All pressure-deceleration data following normalization.

6.4 SUMMARY OF NOVEL RESEARCH AND PROGRESS

A simplified algorithm to normalize from 80,000-lb load to 60,000-lb load and from 60-mph to 20-mph initial speed was developed using data from the full-functioning brake system. When this algorithm was applied to the data from tests involving disabled brakes, it clearly fell below the Pressure-Deceleration trendline for fully-functioning data. In addition, the linear pressure-deceleration region was found to be consistent up through mid-range pressures (at least for this vehicle) with an upper limit of approximately 50 psi for the test vehicle.

7. LESSONS LEARNED

As with any research and testing effort, certain lessons were learned which may provide guidance for future research of a similar nature.

7.1 PROCUREMENT PROCESSES

The project team took into account procurement processes when designing the test, involving personnel from ORNL procurement during the early stages of planning. This minimized the overall delay from test planning to actual testing. The challenges encountered during this test points to need for an adaptive procurement mechanism; in this testing, a brake failure occurred during the 97,000 lb loading tests. When testing vehicles in this type of environment, there need to be plans in place to react; in this case the contract needed to be modified before proceeding with the repairs to resume testing. As such, there should be a general goal of minimizing changes, although procurement processes need to support some changes as inevitable.

7.2 CONSIDERATION OF TIRE LOAD CAPACITY

Due to load positioning in these configurations, an overload condition was created for the rating of the tires available for testing. This should be addressed in future testing to avoid exceeding load ratings of all components, including tires.

7.3 TIMING OF ANALYSIS COMPONENT

In this testing effort, an initial data analysis was budgeted for, thus allowing for the validation of test signals and values early in the data collect. Additionally, the data was subject to low-level analysis as it came in during the entire testing period. This provided an opportunity to catch any missing or clearly erroneous data while testing could still be repeated. . This approach is recommended for future data collections to decrease the risk of invalid or lost data. Further, an ideal project plan would allow the entire analysis task to be conducted concurrently with data collection.

8. FUTURE DIRECTIONS

This research revealed areas in which future research should focus in order to further develop and test an on-board brake assessment algorithm. Additional information needed to build a model includes intermediate speed(s). The correction factors for other speeds may be estimated from the relationship between drag and speed but should be confirmed using test data. It is suggested testing be performed at speeds such as 10 mph, 20 mph, 40 mph, and 60 mph. (Ideally, testing would be performed for two vehicles with different aerodynamic profiles. Data from the first vehicle would be used to fine-tune a simplified speed normalization algorithm. Then, looking at data from the second vehicle for only two speeds (e.g., 20 and 60 mph), a speed normalization algorithm unique to the second vehicle's aerodynamics would be generated. The actual test data from the remaining test speeds for that vehicle would be used to corroborate the model.)

While this research focused on the typical five-axle tractor-trailer vehicle with only two disabled-brake configurations (in addition to the fully-functioning system) to obtain a more complete picture of the vehicles on the roadway, testing should be expanded to other vehicle configurations such as straight trucks and six-axle combination trucks. Testing of vehicles meeting the older stopping distance requirements (currently more typical of vehicles currently on the roadways) may also provide a more complete picture of heavy vehicle braking capacities.

APPENDIX A: SUMMARY OF STOPPING TEST RESULTS

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02 Control Trailer Stops	None	1	20	20.7	29.9	28	104.1	111.2	21.6	1.69	13340	38020	4500	55860
UTB-02 Control Trailer Stops	None	2	20	20.8	29.1	27	106.4	112.9	20.4	1.68	13340	38020	4500	55860
UTB-02 Control Trailer Stops	None	3	20	20.5	29.3	28	107.2	113	19.6	1.73	13340	38020	4500	55860
UTB-02 Control Trailer Stops	None	4	60	60.7	232.6	227	101.1	112	18.8	4.99	13340	38020	4500	55860
UTB-02 Control Trailer Stops	None	5	60	60.6	225.5	221	100.6	111.8	19.6	4.77	13340	38020	4500	55860
UTB-02 Control Trailer Stops	None	6	60	60.3	229	227	100.6	111.7	19.5	4.81	13340	38020	4500	55860
UTB-02 Control Trailer Stops	Front Drive	7	20	20.8	47.6	44	106.4	107.8	11.1	2.94	13340	38020	4500	55860
UTB-02 Control Trailer Stops	Front Drive	8	20	20.9	46.9	43	106.5	107.7	11.3	2.91	13340	38020	4500	55860
UTB-02 Control Trailer Stops	Front Drive	9	20	20.6	45.6	43	105.5	107.1	11.6	2.83	13340	38020	4500	55860
UTB-02 Control Trailer Stops	Front Drive	10	60	60.7	414.2	405	95.1	107.6	10.2	8.97	13340	38020	4500	55860
UTB-02 Control Trailer Stops	Front Drive	11	60	60.5	410.4	404	93.9	106.9	10.1	8.97	13340	38020	4500	55860
UTB-02 Control Trailer Stops	Front Drive	12	60	60.2	399.2	396	94.5	106	10.6	8.67	13340	38020	4500	55860
UTB-02_60k_Full_Function_Stops	None	1	20	20.6	29.8	28.08936	107.7	107.7	19.4	1.7	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	2	20	20.5	29	27.60262	106.9	107.5	18.8	1.7	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	3	20	20.4	28.5	27.39331	106.4	106.6	19.2	1.7	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	4	60	60.3	221.4	219.2025	98.2	103.6	19.5	4.7	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	5	60	60.5	225.5	221.7881	101.2	105.7	19.7	4.7	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	6	60	60.4	239.9	236.733	103.3	107	18.7	4.9	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	7	20	20.4	90.5	86.98577	15.2	13.9	5.3	5.6	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	8	20	20.4	89.9	86.40907	15.2	13.8	5.4	5.6	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	9	60	60.2	777.7	772.5411	15.3	14	5.1	17.1	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	10	60	60.3	779.7	771.9611	15.4	14	5.1	17	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	11	20	20.4	51.8	49.78854	24.8	23.7	10.1	3.1	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	12	20	20.4	52.3	50.26913	24.8	23.7	10	3.1	12630	24490	22920	60040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_60k_Full_Function_Stops	None	13	60	60.4	466.6	460.4403	24.7	23.8	8.7	10	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	14	60	60.2	457.1	454.0678	24.7	23.8	8.7	9.9	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	15	20	20.6	38.6	36.3842	35.1	33.8	14.6	2.3	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	16	20	20.4	331.6	318.7236	35.2	33.8	14.7	2.2	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	17	60	60.5	338.8	333.2231	35	33.9	12.6	7	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	18	60	60.3	33.9	33.56353	35.1	34.1	12.5	7.1	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	19	20	20.5	32.9	31.31469	45	44.6	16.7	2	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	20	20	20.5	32.9	31.31469	44.8	44.5	17.7	1.9	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	21	60	60.3	284.9	282.0722	44.7	44.5	15.1	5.9	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	22	60	60.2	286.3	284.4008	44.8	44.5	15.4	5.9	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	23	20	20.5	32	30.45806	55.6	55	16.9	1.9	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	24	20	20.4	31.6	30.37293	55.6	55.1	19.5	1.8	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	25	60	60.1	270.5	269.6006	55.6	55.1	15.9	5.6	12630	24490	22920	60040
UTB-02_60k_Full_Function_Stops	None	26	60	60.1	264.7	263.8199	55.1	55.2	16.4	5.5	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	1	20	20.6	36.5	34.40475	110	108.3	14.6	2.2	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	2	20	20.7	36.4	33.97979	109.3	108.1	14.6	2.2	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	3	20	20.6	35.7	33.65067	111.1	109	14.3	2.2	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	4	60	60.3	295.2	292.27	105.1	106.9	14	6.3	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	5	60	60.4	313	308.868	103.8	106.1	13.4	6.7	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	6	60	60.3	299	296.0323	104.1	105.7	13.9	6.4	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	7	20	20.6	112	105.5707	14.7	13.3	4.2	7	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	8	20	20.5	109.2	103.9381	14.8	13.5	4.3	6.8	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	9	60	60.4	968.3	955.5173	14.9	13.6	4	21.2	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	10	60	60.4	925.5	913.2823	15.1	13.6	4.1	20.5	12630	24490	22920	60040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	11	20	20.4	61.7	59.30411	25.1	23.8	8.1	3.8	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	12	20	20.6	62.1	58.53521	25.1	24	8.2	3.8	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	13	60	60.4	559.3	551.9166	24.8	24	7	12.3	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	14	60	60.2	549.4	545.7556	24.9	24.1	7.1	12.1	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	15	20	20.2	45.4	44.50544	34.8	33.7	11.4	2.8	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	16	20	20.2	45.6	44.7015	34.9	33.8	11.6	2.7	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	17	60	60.3	435.2	430.8804	34.8	33.9	9.6	9.2	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	18	60	60.2	411.3	408.5716	34.8	33.9	9.9	8.9	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	19	20	20.3	40.9	39.70007	44.8	44.2	12.5	2.5	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	20	20	20.2	41.9	41.0744	44.7	44.3	12.6	2.5	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	21	60	60.1	380.6	379.3345	44.8	44.2	11	7.9	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	22	60	60.4	386.4	381.2991	44.9	44.3	11.1	8	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	23	20	20.2	41.4	40.58426	54.9	54.5	12.8	2.5	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	24	20	20.3	40.2	39.0206	55	54.5	12.9	2.4	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	25	60	60.3	370.2	366.5256	55.2	54.9	11.2	7.8	12630	24490	22920	60040
UTB-02_60k_Failed_Drive_Axle_Stops	Front Drive	26	60	60.1	364.8	363.587	55	54.8	11.5	7.7	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	1	20	20.3	29.3	28.44039	110.6	110.6	17.9	1.8	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	2	20	20.2	30.2	29.60494	110	110.7	16.6	1.9	12630	24490	22920	60040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	3	20	20.2	30.4	29.801	110.2	110.2	16.6	1.9	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	4	60	60.2	246.1	244.4675	104	105.1	17.4	5.2	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	5	60	60.5	254	249.819	103.3	108.8	17.1	5.3	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	6	60	60.4	257	253.6073	101.7	109	17	5.4	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	7	20	20.5	111	105.6514	15.1	13.5	4.3	6.9	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	8	20	20.7	111	103.6197	15.1	13.5	4.4	6.9	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	9	60	59.7	991.6	1001.591	15.1	13.9	3.9	22.1	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	10	60	60.4	977.5	964.5959	15.1	13.9	4	21.8	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	11	20	20.4	60.8	58.43906	25.1	24	8.4	3.7	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	12	20	20.6	61.4	57.87539	25.3	24.1	8.3	3.7	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	13	60	60.7	547.5	534.9451	24.9	24	7.3	11.9	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	14	60	59.8	525.5	529.0209	24.8	23.9	7.3	11.6	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	15	20	20.2	42.9	42.0547	35.2	34.1	12.2	2.6	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	16	20	20.6	44.7	42.13404	35.1	34.1	12.1	2.6	12630	24490	22920	60040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	17	60	60.5	395.1	388.5964	35.1	34.1	10.5	8.4	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	18	60	60.3	383.8	379.9906	35	34.1	10.5	8.3	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	19	20	20.7	37	34.5399	45	44	15.6	2.1	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	20	20	20.6	37.5	35.34735	45.3	44.3	15.6	2.2	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	21	60	60.5	318.8	313.5524	45	44.5	13.2	6.7	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	22	60	60.2	311.2	309.1357	44.9	44.4	13.6	6.6	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	23	20	19.9	32.9	33.23148	55.2	54.8	17.1	2	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	24	20	20.7	35.5	33.13963	55.4	54.9	17	2	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	25	60	60.5	300.2	295.2585	55.4	55	14.8	6.1	12630	24490	22920	60040
UTB-02_60k_Failed_Trailer_Axle_Stops	Rear Trailer	26	60	60.5	300.1	295.1602	55.6	55.1	14.6	6.1	12630	24490	22920	60040
UTB-02_80k_Full_Function_Stops	None	1	20	20.28	28.05	27.28079	109.29	111.73	20.659	1.63	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	2	20	20.17	28.38	27.90362	108.87	110.88	19.574	1.66	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	3	20	20.28	29	28.20474	109.68	110.87	18.81	1.71	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	4	60	60.32	217.95	215.6437	100.79	111.38	19.342	4.66	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	5	60	60.58	228.18	223.8317	99.3	110.68	19.073	4.81	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	7	60	60.32	233.83	231.3556	95.11	107.48	18.283	4.92	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	8	20	20.17	115.52	113.5809	14.87	13.43	3.972	7.38	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	9	20	20.36	115.78	111.7218	14.95	13.42	3.993	7.32	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	10	60	60.21	1057.71	1050.345	14.94	13.55	3.592	23.57	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	11	60	60.51	1045.51	1027.96	14.9	13.56	3.598	23.15	12810	32640	34590	80040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_80k_Full_Function_Stops	None	12	20	20.32	63.75	61.75794	24.76	23.79	7.511	3.97	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	13	20	20.32	63.91	61.91294	24.78	23.83	7.475	3.97	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	14	60	60.06	574.15	573.0034	24.91	24.2	6.684	12.66	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	15	60	60.25	567.75	563.0482	24.85	24.22	6.779	12.49	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	16	20	20.24	46.59	45.49165	34.62	33.63	11.067	2.82	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	17	20	20.32	46.39	44.9404	34.66	33.68	11.22	2.79	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	18	60	60.17	410.14	407.8257	34.86	33.94	9.56	8.99	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	19	60	60.21	414.5	411.6137	34.86	33.95	9.545	9.05	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	20	20	20.13	38.39	37.89575	44.84	44.36	14.175	2.28	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	21	20	20.24	38.75	37.83648	44.87	44.4	14.254	2.29	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	22	60	60.51	335.3	329.6718	44.83	44.47	12.289	7.19	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	23	60	60.66	350.03	342.4546	44.85	44.53	11.941	7.41	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	24	20	20.43	33.96	32.5455	54.99	54.49	17.472	1.95	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	25	20	20.43	34.68	33.23551	54.84	54.47	16.624	2	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	26	60	60.14	286.71	285.3767	54.98	54.63	14.686	6.04	12810	32640	34590	80040
UTB-02_80k_Full_Function_Stops	None	27	60	60.4	295.08	291.1846	55.03	54.75	14.744	6.14	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	7	20	20.54	36.15	34.27421	106.9	106.21	14.38	2.18	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	8	20	20.69	37.14	34.70411	106.6	105.62	13.906	2.24	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	9	20	21.18	38.75	34.55252	105.07	104.98	13.906	2.29	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	10	60	60.43	319.52	314.989	100.71	104.17	12.763	6.86	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	11	60	60.43	312.37	307.9404	100.2	103.05	13.169	6.73	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	12	60	60.14	306.33	304.9054	98.25	102.51	13.121	6.67	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	1	20	20.54	131.36	124.5438	14.87	13.84	3.55	8.34	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	2	20	20.36	131.59	126.9777	14.98	13.9	3.513	8.36	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	4	60	60.55	1291.96	1268.596	15.05	14.26	2.939	28.88	12810	32640	34590	80040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	5	60	60.58	1273.29	1249.025	15.08	14.29	3.097	28.19	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	13	20	20.51	85.79	81.57655	25.11	23.81	5.626	5.36	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	14	20	20.65	85.04	79.77065	25.19	23.92	5.731	5.3	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	15	60	60.58	780.28	765.4105	25.28	24.14	4.972	17.34	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	16	60	59.76	694.85	700.4423	25.32	24.14	5.115	16.06	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	17	20	20.8	60.66	56.08358	35.17	33.98	8.502	3.68	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	18	20	20.62	59.06	55.56178	35.11	33.96	8.654	3.59	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	19	60	60.4	545.96	538.7527	34.91	34.11	7.232	12	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	20	60	60.47	546.82	538.3528	34.94	34.04	7.264	12.01	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	21	20	20.8	47.93	44.31398	45.23	44.53	11.104	2.86	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	22	20	20.47	46.88	44.75194	45.01	44.47	11.183	2.82	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	23	60	60.43	423.82	417.8099	45.09	44.72	9.276	9.26	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	24	60	60.32	426.08	421.5712	44.99	44.7	9.15	9.35	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	25	20	20.65	41.31	38.7503	55.72	55.04	13.569	2.42	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	26	20	20.62	41.6	39.13596	55.7	55.11	13.548	2.42	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	27	60	60.32	363.98	360.1284	55.72	55.39	11.083	7.86	12810	32640	34590	80040
UTB-02_80k_Failed_Drive_Axle_Stops	Front Drive	28	60	60.4	367.65	362.7966	55.71	55.45	11.072	7.89	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	1	20	20.58	33.1	31.2606	106.71	109.83	16.482	1.96	12810	32640	34590	80040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	2	20	20.73	31.4	29.22746	105.82	110.43	18.304	1.83	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	3	20	20.88	33.2	30.4605	104.51	108.54	17.952	1.89	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	4	60	60.43	264.24	260.4929	98.63	108.79	15.871	5.64	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	5	60	60.51	260.24	255.8717	97.9	106.94	16.076	5.57	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	6	60	60.62	257.05	251.8189	97.27	106.48	16.113	5.54	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	7	20	20.54	148.33	140.6333	14.89	13.64	3.113	9.36	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	8	20	20.62	148.13	139.356	14.93	13.63	3.139	9.35	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	9	60	60.47	1360.53	1339.463	14.79	13.79	2.818	30.4	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	10	60	60.17	1337.27	1329.724	14.94	13.9	2.887	29.61	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	11	20	20.54	79.17	75.06194	25.01	23.92	6.073	4.91	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	12	20	20.58	79.99	75.54486	25.08	23.99	6.026	4.95	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	13	60	60.32	724.34	716.6751	25.06	24.11	5.304	15.99	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	14	60	60.4	703.18	693.8972	25.07	24.14	5.41	15.44	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	15	20	20.54	57.87	54.86717	35.16	33.9	8.765	3.52	12810	32640	34590	80040

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	16	20	20.58	58.27	55.03187	35.16	33.88	8.755	3.54	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	17	60	60.58	511.06	501.3209	35.13	34	7.701	11.18	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	18	60	60.43	501.74	494.625	35.11	33.96	7.833	10.99	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	19	20	20.51	45.14	42.92302	45.15	44.69	11.699	2.71	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	20	20	20.54	45.05	42.71239	45.08	44.59	11.673	2.7	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	21	60	60.36	391.9	387.2392	45.15	44.84	10.066	8.55	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	22	60	60.62	399.25	391.125	45.01	44.8	10.161	8.63	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	23	20	20.1	37.43	37.05849	54.75	54.27	14.306	2.24	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	25	20	20.17	38.19	37.54895	54.37	53.75	14.117	2.28	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	26	60	60.43	332.94	328.2187	55.15	54.75	12.268	7.16	12810	32640	34590	80040
UTB-02_80k_Failed_Trailer_Axle_Stops	Rear Trailer	27	60	60.21	338.32	335.9641	55.17	54.69	12.242	7.2	12810	32640	34590	80040
UTB-02_80k_Unbalanced_Stops	None	1	20	20.69	29.95	27.98568	107.01	110.68	18.742	1.77	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	None	2	20	20.65	28.18	26.43388	105.64	110.53	21.765	1.62	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	None	3	20	20.8	28.12	25.99852	106.47	110.28	21.465	1.61	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	None	4	60	60.66	226.84	221.9307	99.21	109.92	19.347	4.78	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	None	5	60	60.32	223.49	221.125	99.93	108.29	19.363	4.71	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	None	6	60	60.55	229.72	225.5657	99.55	109.6	18.721	4.83	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Front Drive	7	20	20.77	39.24	36.38447	107.12	107.76	13.232	2.35	13200	38710	28100	80010

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_80k_Unbalanced_Stops	Front Drive	8	20	20.54	39.04	37.01425	108.88	109.36	13.306	2.34	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Front Drive	9	20	20.65	39.07	36.6491	104.93	105.51	13.395	2.37	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Front Drive	10	60	60.55	325.23	319.3484	99.93	105.18	12.458	7.04	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Front Drive	11	60	60.55	329.17	323.2172	99.25	103.96	12.421	7.11	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Front Drive	12	60	60.58	324.38	318.1984	97.41	102.67	12.51	7.06	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Rear Trailer	14	20	20.62	29.95	28.17601	104.3	109.37	18.931	1.75	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Rear Trailer	15	20	20.73	31.14	28.98545	106.89	110.53	17.92	1.82	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Rear Trailer	16	20	20.8	31.56	29.17899	103.5	108.1	16.993	1.87	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Rear Trailer	17	60	60.47	247.05	243.2246	98.71	109.92	17.093	5.26	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Rear Trailer	18	60	60.47	254.23	250.2934	98.7	109.79	16.661	5.41	13200	38710	28100	80010
UTB-02_80k_Unbalanced_Stops	Rear Trailer	19	60	60.73	251.8	245.7829	98.8	110.43	17.035	5.33	13200	38710	28100	80010
UTB-02_91.2k_Stops	None	1	20	20.51	28.77	27.357	108.21	110.71	18.815	1.7	13140	38240	40060	91440
UTB-02_91.2k_Stops	None	2	20	20.73	30.05	27.97086	106.47	108.86	19.021	1.73	13140	38240	40060	91440
UTB-02_91.2k_Stops	None	3	20	20.77	29.49	27.34398	106.29	110.52	19.758	1.7	13140	38240	40060	91440
UTB-02_91.2k_Stops	None	4	60	60.66	234.88	229.7967	99.22	108.79	18.526	4.94	13140	38240	40060	91440
UTB-02_91.2k_Stops	None	5	60	60.55	224.31	220.2535	100.26	110.36	19.258	4.73	13140	38240	40060	91440
UTB-02_91.2k_Stops	None	6	60	60.14	228.38	227.3179	99.53	109.74	19.247	4.75	13140	38240	40060	91440
UTB-02_91.2k_Stops	Front Drive	7	20	20.69	38.94	36.38605	108.86	108.77	13.216	2.34	13140	38240	40060	91440
UTB-02_91.2k_Stops	Front Drive	8	20	20.62	39.5	37.16035	105.92	106.53	13.385	2.33	13140	38240	40060	91440
UTB-02_91.2k_Stops	Front Drive	9	20	20.65	39.47	37.02431	107.97	108.15	12.789	2.39	13140	38240	40060	91440
UTB-02_91.2k_Stops	Front Drive	10	60	60.66	318.57	311.6754	100.66	105.71	13.311	6.73	13140	38240	40060	91440
UTB-02_91.2k_Stops	Front Drive	11	60	60.58	316.31	310.2822	99.59	103.49	13.174	6.74	13140	38240	40060	91440

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02_91.2k_Stops	Front Drive	12	60	60.81	317.42	309.0201	100.34	105.29	13.421	6.65	13140	38240	40060	91440
UTB-02_91.2k_Stops	Rear Trailer	13	20	20.43	32.61	31.25173	108.95	111.74	16.377	1.93	13140	38240	40060	91440
UTB-02_91.2k_Stops	Rear Trailer	14	20	20.73	33.96	31.61033	105.77	109.54	15.908	2.01	13140	38240	40060	91440
UTB-02_91.2k_Stops	Rear Trailer	15	20	20.73	34.19	31.82442	105.27	108.75	16.919	1.98	13140	38240	40060	91440
UTB-02_91.2k_Stops	Rear Trailer	16	60	60.51	274.61	270.0005	98.49	109.67	15.581	5.77	13140	38240	40060	91440
UTB-02_91.2k_Stops	Rear Trailer	17	60	60.88	279.3	271.284	98.14	108.74	15.634	5.77	13140	38240	40060	91440
UTB-02_91.2k_Stops	Rear Trailer	19	60	60.62	282.71	276.9567	94.46	108.59	15.56	5.85	13140	38240	40060	91440
UTB-02_97k_Stops	None	1	20	20.62	31.66	29.78472	107.02	110.03	16.403	1.87	12660	33390	51070	97120
UTB-02_97k_Stops	None	2	20	20.54	29.95	28.39592	104.86	108.5	20.891	1.69	12660	33390	51070	97120
UTB-02_97k_Stops	None	3	20	20.8	31.56	29.17899	105.81	108.02	19.305	1.77	12660	33390	51070	97120
UTB-02_97k_Stops	None	4	60	60.73	246.42	240.5315	98.99	106.7	17.646	5.12	12660	33390	51070	97120
UTB-02_97k_Stops	None	5	60	60.51	236.19	232.2254	98.21	106.97	18.236	4.98	12660	33390	51070	97120
UTB-02_97k_Stops	None	6	60	60.7	249.34	243.6223	98.7	106.89	17.514	5.19	12660	33390	51070	97120
UTB-02_97k_Stops	Front Drive	7	20	20.65	39.27	36.83671	108.27	100.2	13.964	2.32	12660	33390	51070	97120
UTB-02_97k_Stops	Front Drive	8	20	20.69	39.96	37.33916	107.4	106.47	13.759	2.32	12660	33390	51070	97120
UTB-02_97k_Stops	Front Drive	9	20	20.77	39.93	37.02425	106.9	101.36	13.353	2.38	12660	33390	51070	97120
UTB-02_97k_Stops	Front Drive	10	60	60.66	336.45	329.1685	99.02	103.45	12.489	7.17	12660	33390	51070	97120
UTB-02_97k_Stops	Front Drive	11	60	60.62	340.42	333.4922	98.39	103.05	11.852	7.36	12660	33390	51070	97120
UTB-02_97k_Stops	Front Drive	12	60	60.7	331.89	324.2793	99.23	101.18	12.579	7.17	12660	33390	51070	97120
UTB-02 106k Stops	None	1	20	20.54	29.59	28.0546	107.33	113.1	18.541	1.74	13710	45080	47550	106340
UTB-02 106k Stops	None	2	20	20.77	30.02	27.83541	105.93	111.65	18.757	1.74	13710	45080	47550	106340
UTB-02 106k Stops	None	3	20	20.69	30.22	28.23797	107.01	112.24	18.631	1.76	13710	45080	47550	106340
UTB-02 106k Stops	None	4	60	60.47	248.1	244.2583	104.98	110.09	17.161	5.26	13710	45080	47550	106340
UTB-02 106k Stops	None	5	60	60.17	241.01	239.6501	98.72	109.18	17.488	5.1	13710	45080	47550	106340
UTB-02 106k Stops	None	6	60	60.14	238.71	237.5999	104.69	110.88	18.231	5.02	13710	45080	47550	106340

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02 106k Stops	Front Drive	7	20	20.51	40.85	38.84371	106.84	108.55	12.71	2.45	13710	45080	47550	106340
UTB-02 106k Stops	Front Drive	8	20	20.69	39.14	36.57294	104.5	107.84	13.095	2.37	13710	45080	47550	106340
UTB-02 106k Stops	Front Drive	9	20	20.54	40.09	38.00976	106.41	108.54	12.953	2.42	13710	45080	47550	106340
UTB-02 106k Stops	Front Drive	10	60	60.14	325.33	323.8171	100.48	105.71	12.268	7.1	13710	45080	47550	106340
UTB-02 106k Stops	Front Drive	11	60	59.99	334.25	334.3614	100.04	104.6	12.178	7.25	13710	45080	47550	106340
UTB-02 106k Stops	Front Drive	12	60	60.25	324.41	321.7234	101.23	106.34	12.384	7.08	13710	45080	47550	106340
UTB-02 106k Stops	Rear Trailer	13	20	20.06	32.19	31.99773	104.51	115.21	17.193	1.9	13710	45080	47550	106340
UTB-02 106k Stops	Rear Trailer	14	20	20.39	32.81	31.56689	103.61	113.73	17.778	1.89	13710	45080	47550	106340
UTB-02 106k Stops	Rear Trailer	15	20	20.54	32.74	31.04115	103.51	114.25	17.878	1.88	13710	45080	47550	106340
UTB-02 106k Stops	Rear Trailer	20	60	60.51	299.18	294.1581	103.69	113.27	13.58	6.48	13710	45080	47550	106340
UTB-02 106k Stops	Rear Trailer	21	60	60.21	291.54	289.5099	103.11	112.04	14.138	6.29	13710	45080	47550	106340
UTB-02 106k Stops	Rear Trailer	22	60	60.1	299.87	298.8729	102.01	112.44	13.716	6.44	13710	45080	47550	106340
UTB-02 116k Stops	None	1	20	20.77	31.96	29.63424	105.24	113.57	17.757	1.85	13780	48770	53550	116100
UTB-02 116k Stops	None	2	20	20.73	31.23	29.06922	104.62	111.81	18.668	1.79	13780	48770	53550	116100
UTB-02 116k Stops	None	3	20	20.73	31.5	29.32054	105.35	111.36	18.863	1.78	13780	48770	53550	116100
UTB-02 116k Stops	None	4	60	58.65	234.48	245.3987	103.63	109.22	16.529	5.22	13780	48770	53550	116100
UTB-02 116k Stops	None	5	60	59.13	243.57	250.7902	99.83	108.48	16.219	5.35	13780	48770	53550	116100
UTB-02 116k Stops	None	6	60	59.2	254.07	260.9832	102.28	108.7	15.776	5.5	13780	48770	53550	116100
UTB-02 116k Stops	Front Drive	7	20	20.65	37.7	35.36399	107.34	110.58	14.248	2.25	13780	48770	53550	116100
UTB-02 116k Stops	Front Drive	8	20	20.77	40.75	37.78458	105.24	108.1	14.038	2.34	13780	48770	53550	116100
UTB-02 116k Stops	Front Drive	9	20	20.84	37.37	34.41816	104.45	108.88	16.419	2.12	13780	48770	53550	116100
UTB-02 116k Stops	Front Drive	10	60	59.09	333.69	344.047	103.83	106.57	11.552	7.45	13780	48770	53550	116100
UTB-02 116k Stops	Front Drive	11	60	59.24	330.25	338.778	104.87	106.94	11.752	7.37	13780	48770	53550	116100
UTB-02 116k Stops	Front Drive	12	60	58.94	327.49	339.3753	103.71	107.2	11.904	7.25	13780	48770	53550	116100

Filename	Brakes Disabled	Stop # (in File)	Target Speed (mph)	Actual Speed (mph)	Actual Stop Distance (ft)	Corrected Stop Distance (ft)	Avg. Primary Control Pressure (psi)	Avg. Secondary Control Pressure (psi)	Avg. Decel (ft/s/s)	Stop Time (sec)	Steer Axle Weight (lb)	Drive Tandem Axles Weight (lb)	Trailer Tandem Axles Weight (lb)	Gross Vehicle Weight (lb)
UTB-02 116k Stops	Rear Trailer	13	20	20.51	34.22	32.53934	106.55	116.27	16.635	1.98	13780	48770	53550	116100
UTB-02 116k Stops	Rear Trailer	14	20	20.73	34.68	32.28052	104.36	113.02	17.014	1.99	13780	48770	53550	116100
UTB-02 116k Stops	Rear Trailer	15	20	20.47	34.19	32.63799	104.58	114.37	16.255	2.01	13780	48770	53550	116100
UTB-02 116k Stops	Rear Trailer	16	60	59.24	313.25	321.339	102.14	110.8	12.389	6.95	13780	48770	53550	116100
UTB-02 116k Stops	Rear Trailer	17	60	58.94	308.83	320.0381	101.8	109.14	12.468	6.92	13780	48770	53550	116100
UTB-02 116k Stops	Rear Trailer	18	60	59.17	308.4	317.1128	102.95	109.94	12.684	6.86	13780	48770	53550	116100

APPENDIX B: BRAKE STROKE MEASUREMENT LOG

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4									
FREE STROKE	2 7/8	5/8	2 7/8	5/8	2 7/8	5/8	2 7/8	5/8	2 7/8	5/8	2 7/8	5/8		0		0		0		0
90 PSI	3 7/8	1 5/8	3 7/8	1 5/8	4	1 3/4	4	1 3/4	4	1 3/4	4	1 3/4		0		0		0		0
SPRING BRAKES					3 5/8	3/4	3 5/8	3/4						0		0		0		0

COMMENTS: Pre Burnish Trailer not measured (free stokes set to 5/8") **DATE:** 4/21/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 13/16	9/16	2 13/16	9/16	2 3/4	1/2	2 3/4	1/2	2 5/8	3/8	2 9/16	5/16	7 7/16	11/16	7 7/8	1 1/8	7 1/2	3/4	7 3/8	5/8
90 PSI	3 3/4	1 1/2	3 5/8	1 3/8	3 7/8	1 5/8	3 7/8	1 5/8	3 13/16	1 9/16	3 5/8	1 3/8	8 5/8	1 7/8	8 1/2	1 3/4	8 3/4	2	8 11/16	1 15/16
SPRING BRAKES					3 1/2	3/4	3 1/2	3/4					8 3/16	1 7/16	8 1/8	1 3/8	8 3/8	1 5/8	8 1/4	1 1/2

COMMENTS: Post Burnish **DATE:** 5/1/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4									
FREE STROKE	2 13/16	9/16	2 13/16	9/16	2 3/4	1/2	2 3/4	1/2	2 5/8	3/8	2 9/16	5/16		0		0		0		0
90 PSI	3 3/4	1 1/2	3 5/8	1 3/8	3 7/8	1 5/8	3 7/8	1 5/8	3 13/16	1 9/16	3 5/8	1 3/8		0		0		0		0
SPRING BRAKES					3 1/2	3/4	3 1/2	3/4						0		0		0		0

COMMENTS: Pre Control Trailer **DATE:** 5/2/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 5/8	3/8	2 5/8	3/8	2 1/2	1/4	2 9/16	5/16	2 4/9	3/16	2 3/8	1/8	7 7/16	11/16	7 3/8	5/8	7 5/8	7/8	7 1/2	3/4
90 PSI	3 3/8	1 1/8	3 1/4	1	3 5/8	1 3/8	3 1/2	1 1/4	3 7/16	1 3/16	3 3/8	1 1/8	8 9/16	1 13/16	8 1/2	1 3/4	8 7/8	2 1/8	8 5/8	1 7/8
SPRING BRAKES					3 1/4	3/4	3 1/4	11/16					8 3/16	1 7/16	8 1/8	1 3/8	8 3/8	1 5/8	8 3/16	1 7/16

COMMENTS: Pre 60k Full Function **DATE:** 5/7/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 3/8	1/8	7 3/8	5/8	7 3/8	5/8	7 9/16	13/16	7 1/2	3/4
90 PSI	2 3/8	1/8	3 1/4	1	3 1/2	1 1/4	3 1/2	1 1/4	3 3/8	1 1/8	3 3/8	1 1/8	8 1/2	1 3/4	8 7/16	1 11/16	8 5/8	1 7/8	8 9/16	1 13/16
SPRING BRAKES					3 1/4	3/4	3 1/4	3/4					8 1/8	1 3/8	8 1/8	1 3/8	8 1/4	1 1/2	8 3/16	1 7/16

COMMENTS: Pre 60k Failed Drive Axle **DATE:** 5/10/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/4	0	7 3/8	5/8	7 3/8	5/8	7 1/2	3/4	7 1/4	1/2
90 PSI	3 3/8	1 1/8	3 1/4	1	3 1/2	1 1/4	3 1/2	1 1/4	3 1/2	1 1/4	3 1/4	1	8 1/2	1 3/4	8 3/8	1 5/8	8 1/2	1 3/4	8 1/2	1 3/4
SPRING BRAKES					3 1/4	3/4	3 1/4	3/4					8 1/8	1 3/8	8 1/8	1 3/8	8 1/8	1 3/8	8 1/8	1 3/8

COMMENTS: Pre 60k Failed Trailer Axle Brakes **DATE:** 5/11/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 5/8	3/8	7 1/2	3/4	7 3/8	5/8	7 5/8	7/8	7 1/2	3/4
90 PSI	3 3/8	1 1/8	3 3/8	1 1/8	3 1/2	1 1/4	3 9/16	1 5/16	3 5/8	1 3/8	8 5/8	6 3/8	8 5/8	1 7/8	8 1/2	1 3/4	8 3/4	2	8 3/4	2
SPRING BRAKES					3 1/4	3/4	3 1/4	3/4					8 1/4	1 1/2	8 3/16	1 7/16	8 3/8	1 5/8	8 1/4	1 1/2

COMMENTS: Pre 80k Full Functioning Brakes **DATE:** 5/14/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 5/8	3/8	2 1/2	1/4	7 1/2	3/4	7 7/16	11/16	7 1/2	3/4	7 1/2	3/4
90 PSI	3 5/16	1 1/16	3 5/16	1 1/16	3 1/2	1 1/4	3 9/16	1 5/16	3 9/16	1 5/16	3 1/2	1 1/4	8 3/4	2	8 5/8	1 7/8	8 13/16	2 1/16	8 11/16	1 15/16
SPRING BRAKES					3 1/4	3/4	3 1/4	3/4					8 1/4	1 1/2	8 1/4	1 1/2	8 3/8	1 5/8	8 1/4	1 1/2

COMMENTS: Pre 80k Failed Drive Axle **DATE:** 5/15/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 9/16	5/16	2 3/4	1/2	2 1/2	1/4	7 5/8	7/8	7 1/2	3/4	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 5/16	1 1/16	3 1/2	1 1/4	3 1/2	1 1/4	3 7/8	1 5/8	3 1/2	1 1/4	8 3/4	2	8 5/8	1 7/8	8 3/4	2	8 5/8	1 7/8
SPRING BRAKES					3 1/4	3/4	3 1/4	11/16					8 1/4	1 1/2	8 1/4	1 1/2	8 3/8	1 5/8	8 1/4	1 1/2

COMMENTS: Pre 80k Failed Trailer Axle **DATE:** 5/16/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 3/8	1/8	2 5/8	3/8	2 7/16	3/16	7 3/4	1	7 1/2	3/4	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/2	1 1/4	3 3/8	1 1/8	3 5/8	1 3/8	3 3/4	1 1/2	3 7/16	1 3/16	8 5/8	1 7/8	8 5/8	1 7/8	8 3/4	2	8 5/8	1 7/8
SPRING BRAKES					3 1/8	3/4	3 1/8	3/4					8 1/4	1 1/2	8 1/4	1 1/2	8 3/8	1 5/8	8 1/4	1 1/2

COMMENTS: Pre 80k Unbalanced Full Function **DATE:** 5/16/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 3/8	1/8	2 1/2	1/4	2 3/8	1/8	7 7/8	1 1/8	7 1/2	3/4	7 1/2	3/4	7 3/8	5/8
90 PSI	3 3/4	1 1/2	3 1/2	1 1/4	3 3/8	1 1/8	3 5/8	1 3/8	3 1/2	1 1/4	3 3/8	1 1/8	8 1/2	1 3/4	8 1/2	1 3/4	8 5/8	1 7/8	8 9/16	1 13/16
SPRING BRAKES					3 1/8	3/4	3 1/8	3/4					8 3/16	1 7/16	8 3/16	1 7/16	8 1/4	1 1/2	8 1/4	1 1/2

COMMENTS: Pre 80k Unbalanced Failed Drive Axle **DATE:** 5/17/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	7 1/2	3/4	7 7/16	11/16	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 5/8	1 3/8	3 1/2	1 1/4	3 5/8	1 3/8	3 5/8	1 3/8	8 1/2	1 3/4	8 1/2	1 3/4	8 5/8	1 7/8	8 7/16	1 11/16
SPRING BRAKES					3 1/8	5/8	3 1/8	5/8					8 3/16	1 7/16	8 3/16	1 7/16	8 1/4	1 1/2	8 1/4	1 1/2

COMMENTS: Pre 80k Unbalanced Failed Trailer Axle **DATE:** 5/17/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	7 1/2	3/4	7 7/16	11/16	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 5/8	1 3/8	3 1/2	1 1/4	3 5/8	1 3/8	3 5/8	1 3/8	8 1/2	1 3/4	8 1/2	1 3/4	8 5/8	1 7/8	8 7/16	1 11/16
SPRING BRAKES					3 1/8	5/8	3 1/8	5/8					8 3/16	1 7/16	8 3/16	1 7/16	8 1/4	1 1/2	8 1/4	1 1/2

COMMENTS: Pre 91.2k Full Function **DATE:** 5/18/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 7/16	3/16	7 1/2	3/4	7 1/2	3/4	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 1/2	1 1/4	3 1/2	1 1/4	3 1/2	1 1/4	3 1/2	1 1/4	8 5/8	1 7/8	8 1/2	1 3/4	8 3/4	2	8 5/8	1 7/8
SPRING BRAKES					3 1/4	3/4	3 3/16	11/16					8 3/16	1 7/16	8 3/16	1 7/16	8 3/8	1 5/8	8 1/4	1 1/2

COMMENTS: Pre 91.2k Failed Drive Axle **DATE:** 5/18/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	7 3/8	5/8	7 3/8	5/8	7 3/8	5/8	7 5/16	9/16
90 PSI	3 1/4	1	3 1/4	1	3 1/4	1	3 1/4	1	3 5/16	1 1/16	3 3/8	1 1/8	8 5/8	1 7/8	8 7/16	1 11/16	8 5/8	1 7/8	8 5/8	1 7/8
SPRING BRAKES					3 1/4	3/4	3 1/8	5/8					8 3/16	1 7/16	8 3/16	1 7/16	8 1/4	1 1/2	8 1/8	1 3/8

COMMENTS: Pre 91.2k Failed Trailer Axle **DATE:** 5/19/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 5/8	3/8	2 3/8	1/8	7 3/8	5/8	7 3/8	5/8	7 3/8	5/8	7 5/16	9/16
90 PSI	3 1/4	1	3 1/4	1	3 3/4	1 1/2	3 9/16	1 5/16	3 3/4	1 1/2	3 1/2	1 1/4	8 5/8	1 7/8	8 9/16	1 13/16	8 1/8	1 3/8	8 1/8	1 3/8
SPRING BRAKES					3 1/4	3/4	3 1/8	3/4					8 3/16	1 7/16	8 3/16	1 7/16	8 1/4	1 1/2	8 3/16	1 7/16

COMMENTS: Pre 97k Full Function **DATE:** 5/19/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 5/8	3/8	2 5/8	3/8	7 3/8	5/8	7 3/8	5/8	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 9/16	1 5/16	3 1/2	1 1/4	3 13/16	1 9/16	3 3/4	1 1/2	8 1/2	1 3/4	8 5/8	1 7/8	8 3/4	2	8 9/16	1 13/16
SPRING BRAKES					3 1/4	3/4	3 1/8	3/4					8 7/16	1 11/16	8 3/16	1 7/16	8 1/4	1 1/2	8 3/16	1 7/16

COMMENTS: Pre 97k Failed Drive Axle **DATE:** 5/20/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	7 3/8	5/8	7 3/8	5/8	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 1/2	1 1/4	3 1/2	1 1/4	3 1/2	1 1/4	3 1/2	1 1/4	8 1/2	1 3/4	8 5/8	1 7/8	8 3/4	2	8 9/16	1 13/16
SPRING BRAKES					3 1/4	3/4	3 1/8	5/8					8 3/16	1 7/16	8 3/16	1 7/16	8 1/4	1 1/2	8 3/16	1 7/16

COMMENTS: Pre 106k Full System **DATE:** 5/21/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 3/8	1/8	2 4/7	5/16	2 5/8	3/8	7 1/2	3/4	7 1/2	3/4	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 3/8	1 1/8	3 5/16	1 1/16	3 3/4	1 1/2	3 3/4	1 1/2	8 1/2	1 3/4	8 1/2	1 3/4	8 3/4	2	8 1/2	1 3/4
SPRING BRAKES					3 1/8	3/4	3 1/8	3/4					8 3/16	1 7/16	8 3/16	1 7/16	8 3/8	1 5/8	8 3/16	1 7/16

COMMENTS: Pre 106k Failed Drive **DATE:** 5/22/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 3/8	1/8	2 3/8	1/8	2 1/2	1/4	2 1/2	1/4	7 1/2	3/4	7 3/8	5/8	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 7/8	1 5/8	3 5/16	1 1/16	3 3/4	1 1/2	3 3/16	15/16	8 1/2	1 3/4	8 1/2	1 3/4	8 3/4	2	8 1/2	1 3/4
SPRING BRAKES					3 1/8	3/4	3 1/8	3/4					8 3/16	1 7/16	8 3/16	1 7/16	8 3/8	1 5/8	8 3/16	1 7/16

COMMENTS: Pre 106k Failed Trailer Axle #1 **DATE:** 5/22/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 5/8	3/8	2 5/8	3/8	2 1/2	1/4	2 5/8	3/8	7 1/4	1/2	7 5/16	9/16	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 5/8	1 3/8	3 11/16	1 7/16	5 3/8	3 1/8	3 5/8	1 3/8	8 7/16	1 11/16	8 5/8	1 7/8	8 3/4	2	8 1/2	1 3/4
SPRING BRAKES					3 1/4	5/8	3 1/4	5/8					8	1 1/4	8 3/16	1 7/16	8 3/8	1 5/8	8 1/8	1 3/8

COMMENTS: Post 106k Failed Trailer Axle #1 **DATE:** 5/23/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 5/8	3/8	2 5/8	3/8	2 1/2	1/4	2 5/8	3/8	7 1/4	1/2	7 5/16	9/16	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 5/8	1 3/8	3 11/16	1 7/16	4 1/8	1 7/8	4	1 3/4	8 9/16	1 13/16	8 5/8	1 7/8	8 3/4	2	8 1/2	1 3/4
SPRING BRAKES					3 1/8	1/2	3 1/4	5/8					8	1 1/4	8 3/16	1 7/16	8 3/8	1 5/8	8 1/8	1 3/8

COMMENTS: Pre 106k Failed Trailer #2 **DATE:** 5/31/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 4/7	5/16	2 1/2	1/4	7 1/4	1/2	7 5/16	9/16	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	3 5/8	1 3/8	3 5/8	1 3/8	3 3/4	1 1/2	3 11/16	1 7/16	8 7/16	1 11/16	8 5/8	1 7/8	8 3/4	2	8 1/2	1 3/4
SPRING BRAKES					3 1/8	5/8	3 1/4	3/4					8	1 1/4	8 3/16	1 7/16	8 3/8	1 5/8	8 5/8	1 7/8

COMMENTS: Pre 116k Full Function **DATE:** 5/31/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 5/8	3/8	2 3/4	1/2	2 3/4	1/2	2 3/4	1/2	7 1/4	1/2	2 3/8	-4 3/8	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	1	3 1/4	1	4 1/8	1 7/8	4 1/8	1 7/8	4 1/6	1 11/12	4 1/16	1 13/16	8 1/2	1 3/4	8 5/8	1 7/8	8 3/4	2	8 5/8	1 7/8
SPRING BRAKES					3 9/16	15/16	3 9/16	13/16					8	1 1/4	8 1/4	1 1/2	8 1/4	1 1/2	8 1/8	1 3/8

DATE: 6/2/2012

COMMENTS: Pre 116k Failed Drive

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 1/2	1/4	2 1/2	1/4	2 1/2	1/4	2 5/8	3/8	2 5/8	3/8	2 5/8	3/8	7 1/4	1/2	7 3/8	5/8	7 1/2	3/4	7 3/8	5/8
90 PSI	3 1/4	0	3 1/4	1	4	1 3/4	4	1 3/4	4	1 3/4	4	1 3/4	8 9/16	1 13/16	8 5/8	1 7/8	8 3/4	2	8 1/2	1 3/4
SPRING BRAKES					3 1/2	1	3 1/2	7/8					8	1 1/4	8 3/16	1 7/16	8 3/8	1 5/8	8 1/8	1 3/8

COMMENTS: Pre 116k Failed Trailer **DATE:** 6/2/2012

AXLE POSITION	1L		1R		2L		2R		3L		3R		4L		4R		5L		5R	
BSAP	2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		2 1/4		6 3/4		6 3/4		6 3/4		6 3/4	
FREE STROKE	2 3/8	1/8	2 3/8	1/8	2 1/2	1/4	2 1/2	1/4	2 4/7	5/16	2 9/16	5/16	7 1/4	1/2	7 3/8	5/8	7 9/16	13/16	7 3/8	5/8
90 PSI	3 1/4	0	3 1/4	1	3 1/2	1 1/4	3 1/2	1 1/4	3 3/4	1 1/2	3 3/4	1 1/2	8 7/16	1 11/16	8 5/8	1 7/8	8 7/8	2 1/8	8 9/16	1 13/16
SPRING BRAKES					3 1/4	3/4	3 1/4	3/4					8 1/16	1 5/16	8 1/4	1 1/2	8 3/8	1 5/8	8 1/8	1 3/8

COMMENTS: Post 116k Failed Trailer **DATE:** 6/4/2012

APPENDIX C: PBBT RESULTS

Table C1. PBBT Scores – Fully Functioning Brakes, Before Test Set

Load Condition	Measure	Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Total
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Control Trailer	Brake Force (lb)	4,658	4,114	4,078	5,733	4,141	5,305					**28,029**
	Weight (lb)	7,011	6,305	9,700	9,039	9,171	8,554					**49,780**
	Efficiency	66.4%	65.2%	42.0%	63.4%	45.2%	62.0%					**56.3%**
60,000 lb Load	Brake Force (lb)	4,995	4,541	2,734	3,898	2,783	3,628	3,008	3,314	3,952	4,474	**37,327**
	Weight (lb)	6,437	6,349	6,349	6,217	5,864	5,644	4,586	4,321	4,982	5,203	**55,952**
	Efficiency	77.6%	71.5%	43.1%	62.7%	47.5%	64.3%	65.6%	76.7%	79.3%	86.0%	**66.7%**
80,000 lb Balanced Load	Brake Force (lb)	5,580	3,831	6,245	3,408	5,261	3,476	5,859	4,761	6,196	6,434	**51,051**
	Weight (lb)	6,614	5,997	8,686	7,584	8,466	7,231	8,069	6,923	7,628	7,496	**74,694**
	Efficiency	84.4%	63.9%	71.9%	44.9%	62.1%	48.1%	72.6%	68.8%	81.2%	85.8%	**68.3%**
80,000 lb Unbalanced Load	Brake Force (lb)	5,373	5,261	4,150	6,686	4,352	5,966	4,150	4,217	4,829	5,234	**50,218**
	Weight (lb)	6,967	6,349	9,656	9,392	9,524	7,981	5,908	5,423	6,129	5,997	**73,326**
	Efficiency	77.1%	82.9%	43.0%	71.2%	45.7%	74.8%	70.2%	77.8%	78.8%	87.3%	**68.5%**
91,000 lb Load	Brake Force (lb)	5,292	4,914	4,231	6,047	4,465	4,343	6,227	5,647	7,306	7,023	**55,495**
	Weight (lb)	6,658	5,908	9,744	9,039	9,171	8,289	9,039	8,510	8,995	8,686	**84,039**
	Efficiency	79.5%	83.2%	43.4%	66.9%	48.7%	52.4%	68.9%	66.4%	81.2%	80.9%	**66.0%**
97,000 lb Load	Brake Force (lb)	4,955	5,634	3,759	4,011	3,781	5,270	7,428	8,044	7,104	7,365	**57,351**
	Weight (lb)	6,437	5,820	8,642	7,981	8,201	7,099	12,125	10,759	12,302	11,464	**90,830**
	Efficiency	77.0%	96.8%	43.5%	50.3%	46.1%	74.2%	61.3%	74.8%	57.7%	64.2%	**63.1%**
106,000 lb Load	Brake Force (lb)	5,499	5,148	6,564	5,211	5,126	6,573	6,965	7,572	7,019	7,401	**63,078**
	Weight (lb)	7,011	6,526	11,288	10,803	11,023	9,833	11,111	10,670	11,067	10,891	**100,223**
	Efficiency	78.4%	78.9%	58.2%	48.2%	46.5%	66.8%	62.7%	71.0%	63.4%	68.0%	**62.9%**
116,000 lb Load	Brake Force (lb)	5,625	5,553	5,521	7,167	5,993	6,191	6,875	7,117	6,735	6,875	**63,652**
	Weight (lb)	7,319	6,217	12,522	11,640	11,817	10,538	12,787	11,552	13,095	12,037	**109,524**
	Efficiency	76.9%	89.3%	44.1%	61.6%	50.7%	58.7%	53.8%	61.6%	51.4%	57.1%	**58.1%**

Table C2. PBBT Scores – Fully Functioning Brakes, After Test Set

Load Condition	Measure	Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Total
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Control Trailer	Brake Force (lb)	4,334	4,321	3,844	4,285	4,096	5,283					**26,163**
	Weight (lb)	6,878	6,217	9,656	9,039	9,304	8,422					**49,516**
	Efficiency	63.0%	69.5%	39.8%	47.4%	44.0%	62.7%					**52.8%**
60,000 lb Load	Brake Force (lb)	5,072	4,896	2,608	4,645	2,747	4,384	2,945	3,183	3,984	4,276	**38,740**
	Weight (lb)	6,614	5,732	5,908	5,820	5,908	5,115	4,409	4,012	4,894	4,806	**53,218**
	Efficiency	76.7%	85.4%	44.1%	79.8%	46.5%	85.7%	66.8%	79.3%	81.4%	89.0%	**72.8%**
80,000 lb Balanced Load	Brake Force (lb)	5,431	5,036	3,601	5,229	4,096	3,673	5,400	5,045	6,142	6,232	**49,885**
	Weight (lb)	6,878	6,129	8,289	7,760	8,245	6,967	7,937	7,319	7,937	7,584	**75,045**
	Efficiency	79.0%	82.2%	43.4%	67.4%	49.7%	52.7%	68.0%	68.9%	77.4%	82.2%	**66.5%**
80,000 lb Unbalanced Load	Brake Force (lb)	5,045	4,348	4,321	5,764	4,253	4,303	4,110	4,172	5,135	5,220	**46,671**
	Weight (lb)	6,967	6,041	9,744	9,348	9,568	8,245	6,173	5,556	6,129	5,952	**73,723**
	Efficiency	72.4%	72.0%	44.3%	61.7%	44.5%	52.2%	66.6%	75.1%	83.8%	87.7%	**63.3%**
91,000 lb Load	Brake Force (lb)	5,004	5,022	5,697	4,123	4,505	5,085	5,517	6,079	6,704	6,987	**54,723**
	Weight (lb)	6,614	6,041	9,965	8,863	9,259	8,069	8,951	8,157	8,995	8,641	**83,555**
	Efficiency	75.7%	83.1%	57.2%	46.5%	48.7%	63.0%	61.6%	74.5%	74.5%	80.9%	**65.5%**
97,000 lb Load	Brake Force (lb)	4,761	5,171	3,651	5,422	3,799	4,950	6,731	7,401	6,965	7,055	**55,906**
	Weight (lb)	6,526	5,908	8,466	7,893	8,378	7,099	11,905	10,979	12,478	11,552	**91,184**
	Efficiency	73.0%	87.5%	43.1%	68.7%	45.3%	69.7%	56.5%	67.4%	55.8%	61.1%	**61.3%**
106,000 lb Load	Brake Force (lb)	5,688	5,427	5,301	5,135	5,234	5,971	6,938	7,284	7,104	6,965	**61,047**
	Weight (lb)	6,967	6,526	11,817	10,714	11,023	9,700	11,067	10,582	10,979	10,803	**100,178**
	Efficiency	81.6%	83.2%	44.9%	47.9%	47.5%	61.6%	62.7%	68.8%	64.7%	64.5%	**60.9%**
116,000 lb Load	Brake Force (lb)	5,841	5,256	7,117	5,521	6,101	5,908	6,758	6,920	6,920	7,230	**63,572**
	Weight (lb)	7,055	6,129	12,610	11,773	12,037	10,538	12,655	11,685	12,787	12,037	**109,306**
	Efficiency	82.8%	85.8%	56.4%	46.9%	50.7%	56.1%	53.4%	59.2%	54.1%	60.1%	**58.2%**

Table C3. PBBT Scores – Disabled Front Drive Axle Brakes, Before Test Set

Load Condition	Measure	Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Total
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Control Trailer	Brake Force (lb)											
	Weight (lb)											
	Efficiency											
60,000 lb Load	Brake Force (lb)	5,103	4,743	0	4	2,878	3,862	3,075	3,084	4,002	4,060	**30,811**
	Weight (lb)	6,570	5,952	6,047	5,864	5,997	5,335	4,630	3,836	5,027	4,806	**54,064**
	Efficiency	77.7%	79.7%	0.0%	0.1%	48.0%	72.4%	66.4%	80.4%	79.6%	84.5%	**57.0%**
80,000 lb Balanced Load	Brake Force (lb)	5,297	4,276	9	18	3,849	4,699	5,472	5,081	6,007	6,137	**40,845**
	Weight (lb)	6,702	5,732	8,378	7,672	8,025	7,055	7,716	7,143	7,981	7,496	**73,900**
	Efficiency	79.0%	74.6%	0.1%	0.2%	48.0%	66.6%	70.9%	71.1%	75.3%	81.9%	**55.3%**
80,000 lb Unbalanced Load	Brake Force (lb)	5,328	5,198	36	18	4,321	5,948	3,772	4,550	4,806	5,400	**39,377**
	Weight (lb)	6,834	6,129	9,789	9,127	9,348	8,289	6,129	5,556	6,261	5,864	**73,326**
	Efficiency	78.0%	84.8%	0.4%	0.2%	46.2%	71.8%	61.5%	81.9%	76.8%	92.1%	**53.7%**
91,000 lb Load	Brake Force (lb)	5,112	5,081	9	18	4,379	5,899	5,517	6,434	6,771	7,135	**46,355**
	Weight (lb)	6,570	5,997	9,436	8,995	9,436	8,025	9,039	8,333	9,215	8,863	**83,909**
	Efficiency	77.8%	84.7%	0.1%	0.2%	46.4%	73.5%	61.0%	77.2%	73.5%	80.5%	**55.2%**
97,000 lb Load	Brake Force (lb)	4,973	4,910	9	22	3,997	4,797	7,014	7,522	6,362	6,623	**46,229**
	Weight (lb)	6,702	5,776	8,466	7,937	8,554	7,187	11,817	10,803	12,478	11,508	**91,228**
	Efficiency	74.2%	85.0%	0.1%	0.3%	46.7%	66.7%	59.4%	69.6%	51.0%	57.6%	**50.7%**
106,000 lb Load	Brake Force (lb)	5,283	5,153	22	22	5,436	5,998	6,618	6,915	6,893	7,158	**49,498**
	Weight (lb)	6,967	6,570	11,729	10,626	11,420	9,700	10,979	10,318	11,111	10,538	**99,958**
	Efficiency	75.8%	78.4%	0.2%	0.2%	47.6%	61.8%	60.3%	67.0%	62.0%	67.9%	**49.5%**
116,000 lb Load	Brake Force (lb)	5,661	5,530	4	22	7,284	5,076	7,365	7,405	6,884	7,347	**52,578**
	Weight (lb)	6,746	6,437	12,478	11,552	12,037	10,582	12,699	11,685	12,919	11,993	**109,128**
	Efficiency	83.9%	85.9%	0.0%	0.2%	60.5%	48.0%	58.0%	63.4%	53.3%	61.3%	**48.2%**

Table C4. PBBT Scores – Disabled Front Drive Axle Brakes, After Test Set

Load Condition	Measure	Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Total
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Control Trailer	Brake Force (lb)											
	Weight (lb)											
	Efficiency											
60,000 lb Load	Brake Force (lb)	4,699	4,096	0	9	3,039	3,471	2,958	3,404	3,939	4,555	**30,170**
	Weight (lb)	6,570	5,688	6,614	5,688	6,085	5,291	4,321	3,748	4,938	4,850	**53,793**
	Efficiency	71.5%	72.0%	0.0%	0.2%	49.9%	65.6%	68.5%	90.8%	79.8%	93.9%	**56.1%**
80,000 lb Balanced Load	Brake Force (lb)	5,332	5,099	4	13	4,932	3,565	5,647	5,099	6,124	5,975	**41,790**
	Weight (lb)	6,349	6,217	8,510	7,628	8,025	7,011	7,760	7,231	7,937	7,452	**74,120**
	Efficiency	84.0%	82.0%	0.0%	0.2%	61.5%	50.8%	72.8%	70.5%	77.2%	80.2%	**56.4%**
80,000 lb Unbalanced Load	Brake Force (lb)	5,584	5,036	31	22	4,492	5,733	4,132	4,101	4,887	5,018	**39,036**
	Weight (lb)	7,055	6,129	9,700	8,951	9,436	7,893	6,173	5,688	6,041	5,776	**72,842**
	Efficiency	79.1%	82.2%	0.3%	0.2%	47.6%	72.6%	66.9%	72.1%	80.9%	86.9%	**53.6%**
91,000 lb Load	Brake Force (lb)	4,905	4,613	9	13	4,406	5,625	5,728	7,180	6,668	7,518	**46,665**
	Weight (lb)	6,570	6,129	9,965	8,951	9,171	8,201	8,863	8,598	8,907	8,730	**84,085**
	Efficiency	74.7%	75.3%	0.1%	0.1%	48.0%	68.6%	64.6%	83.5%	74.9%	86.1%	**55.5%**
97,000 lb Load	Brake Force (lb)	5,238	4,685	4	13	5,054	3,624	7,230	7,140	6,911	7,131	**47,030**
	Weight (lb)	6,658	5,908	8,818	7,716	8,642	7,143	11,905	10,714	12,390	11,155	**91,049**
	Efficiency	78.7%	79.3%	0.0%	0.2%	58.5%	50.7%	60.7%	66.6%	55.8%	63.9%	**51.7%**
106,000 lb Load	Brake Force (lb)	5,463	5,827	9	13	5,207	6,488	6,753	7,032	6,794	6,596	**50,182**
	Weight (lb)	6,923	6,526	11,155	10,847	10,847	9,744	10,979	10,229	11,376	10,670	**99,296**
	Efficiency	78.9%	89.3%	0.1%	0.1%	48.0%	66.6%	61.5%	68.7%	59.7%	61.8%	**50.5%**
116,000 lb Load	Brake Force (lb)	5,769	4,937	13	13	6,151	6,007	6,659	7,063	6,843	7,149	**50,604**
	Weight (lb)	7,011	6,261	12,522	11,640	12,316	10,494	12,699	11,332	12,787	11,993	**109,055**
	Efficiency	82.3%	78.9%	0.1%	0.1%	49.9%	57.2%	52.4%	62.3%	53.5%	59.6%	**46.4%**

Table C5. PBBT Scores – Disabled Rear Trailer Axle Brakes, Before Test Set

Load Condition	Measure	Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Total
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Control Trailer	Brake Force (lb)											
	Weight (lb)											
	Efficiency											
60,000 lb Load	Brake Force (lb)	4,734	3,898	4,253	2,432	3,035	3,516	2,707	3,228	4	9	**27,816**
	Weight (lb)	6,570	5,688	6,526	5,776	6,129	5,423	4,233	3,836	5,159	5,029	**54,369**
	Efficiency	72.1%	68.5%	65.2%	42.1%	49.5%	64.8%	63.9%	84.2%	0.1%	0.2%	**51.2%**
80,000 lb Balanced Load	Brake Force (lb)	4,793	4,815	3,570	5,377	3,993	4,406	4,577	4,402	9	13	**35,955**
	Weight (lb)	6,129	5,864	8,289	7,628	8,069	7,011	7,716	7,011	7,716	7,231	**72,664**
	Efficiency	78.2%	82.1%	43.1%	70.5%	49.5%	62.8%	59.3%	62.8%	0.1%	0.2%	**49.5%**
80,000 lb Unbalanced Load	Brake Force (lb)	5,157	4,833	4,074	6,695	4,357	5,935	3,727	4,020	4	9	**38,811**
	Weight (lb)	6,702	6,305	9,700	9,039	9,392	8,245	6,129	5,423	6,173	5,776	**72,884**
	Efficiency	76.9%	76.7%	42.0%	74.1%	46.4%	72.0%	60.8%	74.1%	0.1%	0.2%	**53.3%**
91,000 lb Load	Brake Force (lb)	4,896	4,213	4,213	6,524	4,303	5,827	5,373	6,843	13	13	**42,218**
	Weight (lb)	6,702	6,041	9,833	8,774	9,524	7,937	8,995	8,245	8,992	8,510	**83,553**
	Efficiency	73.1%	69.7%	42.8%	74.4%	45.2%	73.4%	59.7%	83.0%	0.1%	0.2%	**50.5%**
97,000 lb Load	Brake Force (lb)	5,247	5,323	4,690	7,248	5,710	5,072	5,998	7,068	40	18	**46,414**
	Weight (lb)	6,967	6,261	11,244	10,803	11,111	9,744	10,935	10,229	11,067	10,406	**98,767**
	Efficiency	75.3%	85.0%	41.7%	67.1%	51.4%	52.1%	54.9%	69.1%	0.4%	0.2%	**47.0%**
106,000 lb Load	Brake Force (lb)	5,238	5,512	5,022	6,731	6,313	5,099	6,771	6,074	9	18	**46,787**
	Weight (lb)	6,658	6,393	11,464	10,670	10,935	9,392	11,155	10,009	11,023	10,274	**97,973**
	Efficiency	78.7%	86.2%	43.8%	63.1%	57.7%	54.3%	60.7%	60.7%	0.1%	0.2%	**47.8%**
116,000 lb Load	Brake Force (lb)	5,647	4,919	7,365	5,350	6,295	5,926	6,510	6,794	18	18	**48,842**
	Weight (lb)	7,011	6,217	12,787	11,376	11,993	10,626	12,655	11,508	12,699	11,905	**108,777**
	Efficiency	80.5%	79.1%	57.6%	47.0%	52.5%	55.8%	51.4%	59.0%	0.1%	0.2%	**44.9%**
No 97,000 lb testing was performed for this brake configuration; two sets of PBBTs were performed for the 106k loading condition.												

Table C6. PBBT Scores – Disabled Rear Trailer Axle Brakes, After Test Set

Load Condition	Measure	Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Total
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	
Control Trailer	Brake Force (lb)											
	Weight (lb)											
	Efficiency											
60,000 lb Load	Brake Force (lb)	4,910	4,145	2,693	3,979	2,828	3,637	2,887	3,300	4	9	**28,392**
	Weight (lb)	6,393	5,688	6,041	5,776	5,908	5,247	4,674	3,968	4,762	4,938	**53,395**
	Efficiency	76.8%	72.9%	44.6%	68.9%	47.9%	69.3%	61.8%	83.2%	0.1%	0.2%	**53.2%**
80,000 lb Balanced Load	Brake Force (lb)	4,609	4,519	5,458	3,489	5,004	3,476	4,842	4,357	0	13	**35,767**
	Weight (lb)	6,437	6,217	8,289	7,672	7,981	7,231	7,540	7,231	7,496	7,469	**73,563**
	Efficiency	71.6%	72.7%	65.8%	45.5%	62.7%	48.1%	64.2%	60.3%	0.0%	0.2%	**48.6%**
80,000 lb Unbalanced Load	Brake Force (lb)	4,874	5,085	4,213	5,868	4,582	5,256	3,574	3,588	4	9	**37,053**
	Weight (lb)	6,923	5,997	9,700	9,171	9,567	8,289	5,820	5,247	6,173	5,820	**72,707**
	Efficiency	70.4%	84.8%	43.4%	64.0%	47.9%	63.4%	61.4%	68.4%	0.1%	0.2%	**51.0%**
91,000 lb Load	Brake Force (lb)	4,784	4,690	5,485	4,253	4,465	4,937	5,117	5,454	4	13	**39,202**
	Weight (lb)	7,011	5,864	9,789	9,039	9,567	8,157	8,995	8,378	9,127	8,642	**84,569**
	Efficiency	68.2%	80.0%	56.0%	47.1%	46.7%	60.5%	56.9%	65.1%	0.0%	0.2%	**46.4%**
97,000 lb Load	Brake Force (lb)	5,679	4,523	5,081	6,061	2,887	5,193	6,618	5,984	0	18	**42,044**
	Weight (lb)	6,834	6,526	11,508	10,759	11,376	9,700	11,288	10,318	11,420	10,582	**100,311**
	Efficiency	83.1%	69.3%	44.2%	56.3%	25.4%	53.5%	58.6%	58.0%	0.0%	0.2%	**41.9%**
106,000 lb Load	Brake Force (lb)	5,117	5,031	6,807	4,869	5,476	4,685	6,119	6,038	9	18	**44,169**
	Weight (lb)	7,011	6,305	11,685	10,582	11,067	9,568	10,979	10,009	11,111	10,494	**98,811**
	Efficiency	73.0%	79.8%	58.3%	46.0%	49.5%	49.0%	55.7%	60.3%	0.1%	0.2%	**44.7%**
116,000 lb Load	Brake Force (lb)	5,508	4,856	7,149	5,544	5,899	6,569	6,843	6,915	13	31	**49,327**
	Weight (lb)	7,187	6,393	12,610	11,729	11,685	10,406	12,919	11,508	12,787	12,037	**109,261**
	Efficiency	76.6%	76.0%	56.7%	47.3%	50.5%	63.1%	53.0%	60.1%	0.1%	0.3%	**45.1%**
No 97,000 lb testing was performed for this brake configuration; two sets of PBBTs were performed for the 106k loading condition.												

HOVBT Combination Vehicle Final Report Revision Log			
Revision Number	Description of Change	Editor(s)	Change Effective Date
0	Initial draft	MBL	26 Aug 2013
1	Incorporated changes from GC, OF	MBL	20 Sep 2013
2	Marked edits	SAM	23 Sep 2013