U.S. Department of Transportation

Federal Railroad Administration

Quasi-Static Research Testing of Workstation Tables

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Final Report
April 2019

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13. ABSTRACT (Maximum 200 words) Sharma & Associates, Inc. (SA) performed quasi-static destructive loading tests on two different designs of passenger workstation tables in accordance with the requirements of the American Public Transportation Association (APTA) safety standard APTA PR-CS-S-018-013, Revision 1. SA conducted the research tests to evaluate the performance requirements in the safety standard as well as the performance of the tables. Neither table met all the performance requirements specified in Option B.			
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

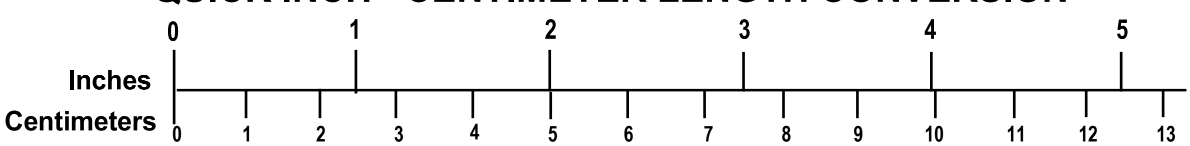
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

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Executive Summary

In order for workstation tables to be installed in passenger rail cars, they must conform to industry standards for crashworthiness. These crashworthiness requirements are outlined in the American Public Transportation Association (APTA) standard APTA PR-CS-S-018-13, "Fixed Workstation Tables in Passenger Rail Cars." As part of a research effort to evaluate the performance of existing workstation tables not designed to meet the APTA table standard, and to evaluate the performance requirements in the table standard itself, two anonymous manufacturers donated workstation tables for testing. Dynamic sled testing in accordance with Option A of the table standard had already been conducted on these tables. With funding from the Federal Railroad Administration (FRA) the Volpe National Transportation Systems Center (Volpe) contracted Sharma & Associates, Inc. (SA) to perform quasi-static loading tests on the tables in accordance with Option B in the table standard. An additional objective of the testing was to determine if the two testing options provided equivalent safety.

On October 17, 2016, at its facilities in Maywood, IL, SA executed two separate quasi-static loading tests to assess the force-crush behavior of two different passenger workstation tables. The APTA table standard prescribes that hydraulic actuators attached to rigid body blocks perform the loading on the tables. These actuators must be aligned laterally to simulate two people sitting next to one another on the same side of the table. Two manufacturers each provided SA with a table. Volpe provided the body blocks. SA developed a test fixture that accommodated the mounting of the tables as they would be installed in a passenger car. SA installed uni-axial load cells in line with the loading blocks to measure the force applied to the tables; researchers connected displacement sensors to both sides of the tables to measure table crush and table displacement at the aisle and window service positions; and they used tri-axial load cells at the table mounting locations to measure the reaction force at the points of attachment to the test fixture.

The performance requirements for the quasi-static test are specified in the APTA table standard as follows:

- The table must absorb a minimum of 6,250 in-lbf of plastic energy at each seat position without exceeding an applied load of 2,250 lbf.
- A minimum survival space of 15 inches must be preserved between the table and the seat back on the side of the table opposite the load application.

One table met the energy absorption requirement by absorbing more than 6,250 lbf at each seat position before a maximum load of 2,250 lbf was applied. However, neither table met the requirement for maintaining a minimum of 15 inches of survival space measured longitudinally from the table edge to the opposing seat back.

1. Introduction

This report describes the quasi-static testing of two workstation tables designed for use in passenger rail cars. These destructive loading tests characterize the force-crush behavior and the energy absorption capacity of the tables when impacted by passengers during an accident.

1.1 Background

Performance-based crashworthiness requirements for passenger workstation tables are defined in APTA PR-CS-S-018-13 Rev.1 (October 2015) [1]. This industry safety standard aims to provide passengers with a minimum level of protection from injury due to impact with a table during an accident.

Two manufacturers donated existing workstation tables not designed specifically to meet the requirements outlined in the aforementioned standard. The Department of Transportation's Volpe National Transportation Systems Center (Volpe) had previously conducted dynamic testing on the tables, per Option A of the APTA table standard. Volpe contracted Sharma & Associates, Inc. (SA) to conduct quasi-static loading tests on the tables, per Option B of the APTA standard. The original version of the workstation table safety standard required the use of an advanced test dummy capable of evaluating abdominal injury to demonstrate the crashworthiness of workstation tables (now Option A). Due to the limited availability of these test dummies, Revision 1 also offered an alternative set of crashworthiness requirements (Option B). An additional objective of the quasi-static testing was to determine if Options A and B provide equivalent safety, as intended.

Volpe's Contracting Officer Technical Representative witnessed the tests.

1.1.1 Description of Tested Tables

Two different manufacturers designed the two tables. Although their sizes and locations within a rail car were similar, their methods of construction and mounting arrangements differed.

The tops of both tables were approximately 4 feet (laterally across the car) by 2 feet (longitudinally along the length of the car), and were mounted at a height of approximately 29 inches from the car floor. Table 1 and Figure 1 present some key dimensions in inches.

Table 1 – Relevant Table Dimensions (inches) as Depicted in Figure 1

	Table A	Table B
X	47 $^{11}/_{16}$	41 $^{1}/_{2}$
Y	25 $^{1}/_{16}$	22 $^{5}/_{8}$
A*	36	N/A
B	28 $^{1}/_{3}$	29
C	1 $^{3}/_{4}$	2 $^{1}/_{2}$

* Center of table leg mounting holes to car wall

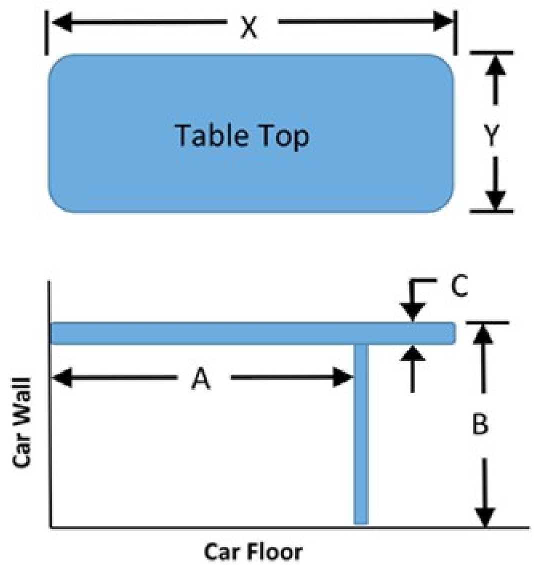


Figure 1 – Table Dimensions (inches)

The first table tested, Table A, was mounted to the wall and further supported with a table leg the aisle-side of the table (see Figure 2). The second table, Table B, was a purely cantilevered mount via the sidewall structure (see Figure 3).

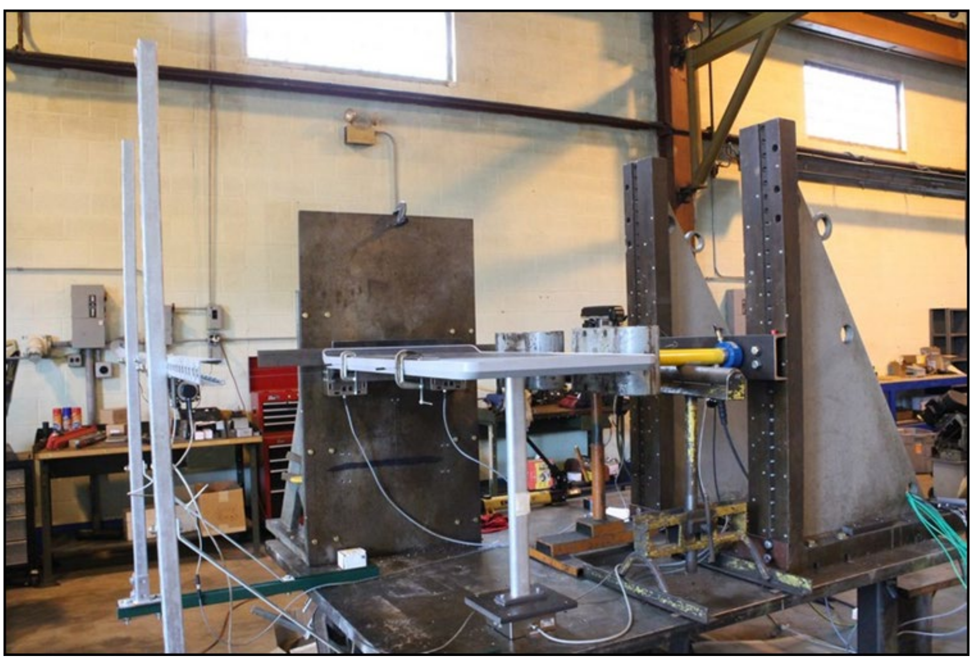


Figure 2 – Table A Test Setup

Figure 3 – Table B Test Setup

1.2 Objective

SA sought to measure the force-crush behavior of two different workstation tables under quasi-static loading. SA then evaluated the results in accordance with Option B of the APTA table standard.

1.3 Overall Approach

SA fabricated the test fixture for this test program. Two manufacturers provided the workstation tables that were tested quasi-statically. SA designed and fabricated interface plates for both table installations. Volpe provided the rigid body blocks.

1.4 Scope

SA performed each test on newly manufactured tables, mounted to the text fixture per the manufacturers' installation drawings.

1.5 Organization of the Report

Section 2 describes the test setup and instrumentation. The test procedures and analytical methodology are presented in Section 3, with test results and summary in Sections 4 and 5. Test data plots are presented in Appendix A.

2. Test Setup and Instrumentation

SA performed quasi-static testing at its Maywood, IL, laboratory.

2.1 Test Fixture

The test fixture consisted of rigid walls and a floor to which the table was mounted and against which the test load was reacted. In general, two parallel loads (in the transverse direction to the table, longitudinally with respect to the car) were applied to the edge of the table top, centered at the seating positions, through two independent actuators (loading jacks). The applied axial loads, as well as the reacted tri-axial loads on the wall and floor, were measured, along with the deflection (also referred to as crush) at the loading points and the deflection of the unloaded edge of the table. Figure 4 shows schematics of the test setup.

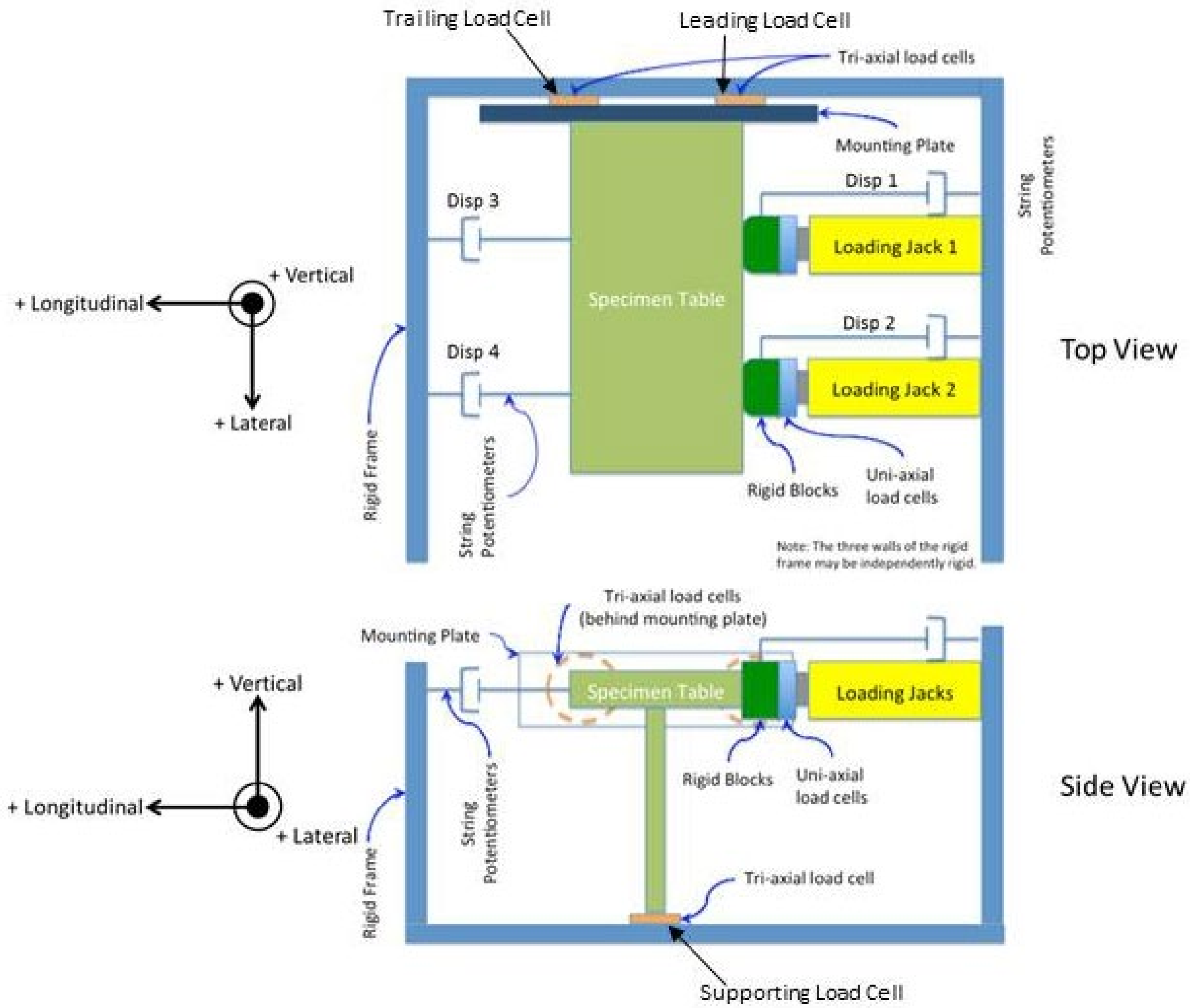


Figure 4 – Test Setup Schematics

2.2 Test Parameters

- Peak load on each jack when the motion of the jack is stopped: 2,250 lbf (unless limited by maximum table crush)
- Loading rate: 2 inches per minute (in load control)
- Lateral location of loading: centered on seating positions
- Vertical location of loading: centered on the table edge
- Loading block dimensions: 15 inches (width) x 8.5 inches (height) x 6 inches (depth)

2.3 Instrumentation and Data Acquisition

A Somat eDAQ*Lite* data collection system was used to collect all measurements:

- Data Channels:
  - Two load cells in line with the force application (0–10,000 lbf range)
  - Two string potentiometers in line with the force application (0-30-inch range)
  - Two string potentiometers on the side opposite the force application (0-30-inch range)
  - Three tri-axial load cells for Table A:
    - Two located behind the wall mounting plate, one located under the table leg
  - Three tri-axial load cells for Table B:
    - Two located at the bottom support on the wall, one located at the top support on the wall
- Triggers:
  - The data acquisition was manually started prior to loading application
- Data Acquisition:
  - Time histories of all measured parameters were recorded
  - Data were recorded at 200 samples per second, and low-pass filtered with a cutoff frequency of 30 Hz
- Videography:
  - Two regular speed video cameras were used to record the tests: one for the top view and one for the side view
  - Frame rate: 30 frames/second
- Other documentation:
  - Photographs of the test setup and test tables before, during and after testing were taken
  - Post-test measurements were made of the final deformed geometry of the tables

3. Testing Procedure and Analytical Methodology

This section describes the test procedure and methodology adopted for analyzing the results.

3.1 Test Procedure

- Mounted the test table to the test frame by following the relevant table manufacturer's instructions.
- Extended the hydraulic jacks so that the rigid blocks barely touched the edge of the table without applying any significant load.
- Initialized the load cells, string potentiometers, data acquisition system and video cameras.
- Applied load through the hydraulic jacks, using independent load control of the two jacks.
- Monitored the loads measured by the load cells and stopped the test if either the peak load (2,250 lbf) or peak crush values were reached.
- Once either load cell reached 2,250 lbf, the load in the corresponding jack was held constant while the load in the other jack was increased until it also reached 2,250 lbf.
- Retracted the cylinders.
- Stopped the data collection system and saved the data.
- Documented the deformed shape through photographs and measurements.

3.2 Measurement and Analytical Methodology

Per the APTA table standard, force and displacement time histories were measured in accordance with SAE International (originally the Society of Automotive Engineers) SAE J211-1 [2]. The energy absorbed by the table crush at each table position was calculated as follows:

1. Plotted the applied force vs. time and table crush vs. time, where crush is equal to the displacement of the loading block, from t_0 to t_f, where:
   - t_0 = time that block contacts the table
   - t_f = time that force returns to zero
2. Cross-plotted the force and table crush time histories from t_0 to t_f.
3. Integrated the force vs. table crush time history from t_0 to t_f to calculate the energy absorbed by plastic (permanent) table crush deformation.

The longitudinal displacement of the table top on the side opposite the applied load was measured in line with the applied load using string potentiometers. Because there was significant out-of-plane motion of the table top, the potentiometers did not accurately measure longitudinal displacement into the space opposite the applied load. To calculate the table penetration into the theoretical passenger space on the opposing side of the table, pre- and post-test longitudinal positions of the table top were marked on the sidewall using a carpenter's square. The maximum longitudinal displacement was calculated as the difference between the pre- and post-test measurements.

The table penetration into the theoretically occupied space opposite the applied load was calculated by subtracting the maximum longitudinal displacement of the table top from the recommended longitudinal distance between the table top and the seat back shown on the manufacturer's installation drawing.

Still photographs of the tables were taken pre- and post-test. The progress of the test was recorded using video cameras at two locations providing top and side views.

3.3 Performance Requirements

As defined in the APTA table standard [1] Section 5.2.2.3, an acceptable table must meet the following requirements:

1. The table and any table components must remain attached to the test fixture.
2. The table shall not penetrate the survival space reserved for occupants in the facing seat, so as not to entrap the facing passengers or prevent egress. The survival space, measured longitudinally between the table top and the seat back, shall not be less than 15 inches, as measured post-test (theoretical location if facing seat is not used in actual test) based on the predominant longitudinal distance between the table top and seat back.
3. The energy absorbed by the plastic (permanent) table crush, as calculated above, must be at least 6,250 in-lbf before the force reaches 2,250 lbf.

4. Test Results

The table testing was performed on October 17, 2016.

4.1 Data Processing

Data were processed before being analyzed. All channels were zeroed and displacement measurements were converted to inches. Additionally, all force measurements were directionally corrected to conform to the defined global coordinate system shown in Figure 4.

4.2 Table A Results

Figure 5 shows the Table A setup prior to testing. Two tri-axial load cells were located at the attachment of the table top to the wall (indicated by the yellow arrows). A third tri-axial load cell was located at the attachment of the table leg to the floor (indicated by the green arrow).

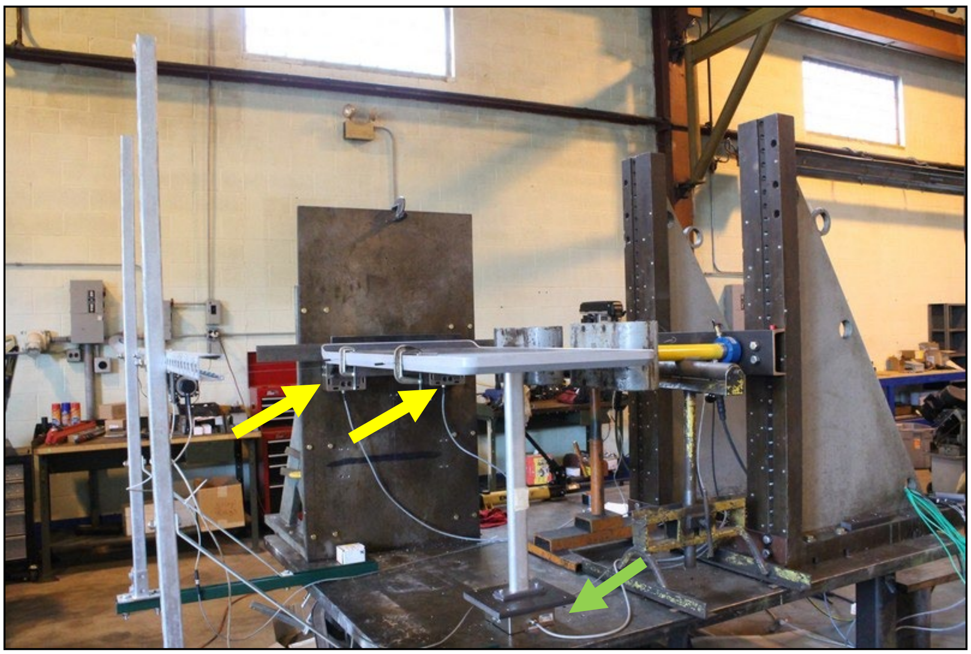


Figure 5 – Photo of Table A Setup

Figure 6 shows Table A during testing. The table's edge only deformed slightly, but the bolts attached to the thin sheet metal that formed the lower table surface ripped through the sheet metal. The table top detached completely from the two wall mounting points. This behavior allowed the table to intrude into the facing passengers' space (on the left in the picture). Based on table drawings from the manufacturer, the nominal clearance is 19.7 inches between the table top and the seat back. Therefore, table top displacement greater than 4.7 inches would encroach on the minimum clearance space of 15 inches. The survival space was breached as the resting position of the table encroached over 2 inches into the passengers' survival space. The test was stopped after the loading ram had displaced approximately 10 inches, with minimal resistance from the table top after the first 2 to 3 inches of displacement. The failure of the sheet metal underneath the table top and the table leg connection at the floor occurred after approximately 1 inch of travel of the loading rams. Subsequently, the reaction loads measured at the load cells rapidly decreased. It was evident that even with continued loading, the table would not comply with the minimum energy absorption requirement or the minimum space requirement.

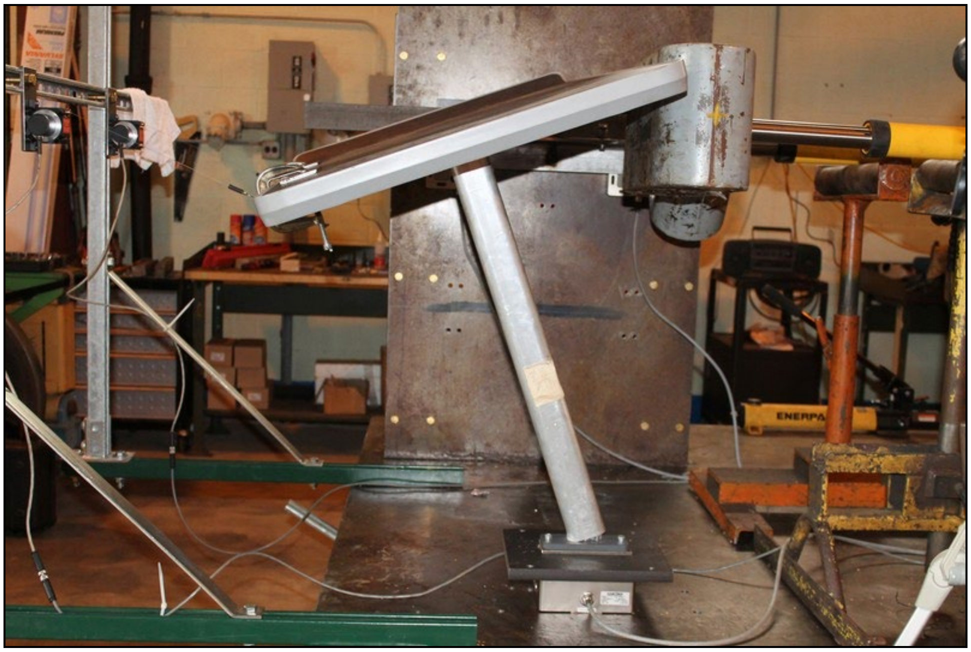


Figure 6 – Photo of Table A during Testing

Figure 7 shows the force versus displacement cross-plot of both body blocks for Table A. As seen in the plot, the maximum force applied by the wall block was 1,988 lbf. The maximum force experienced at the aisle block was 1,898 lbf.

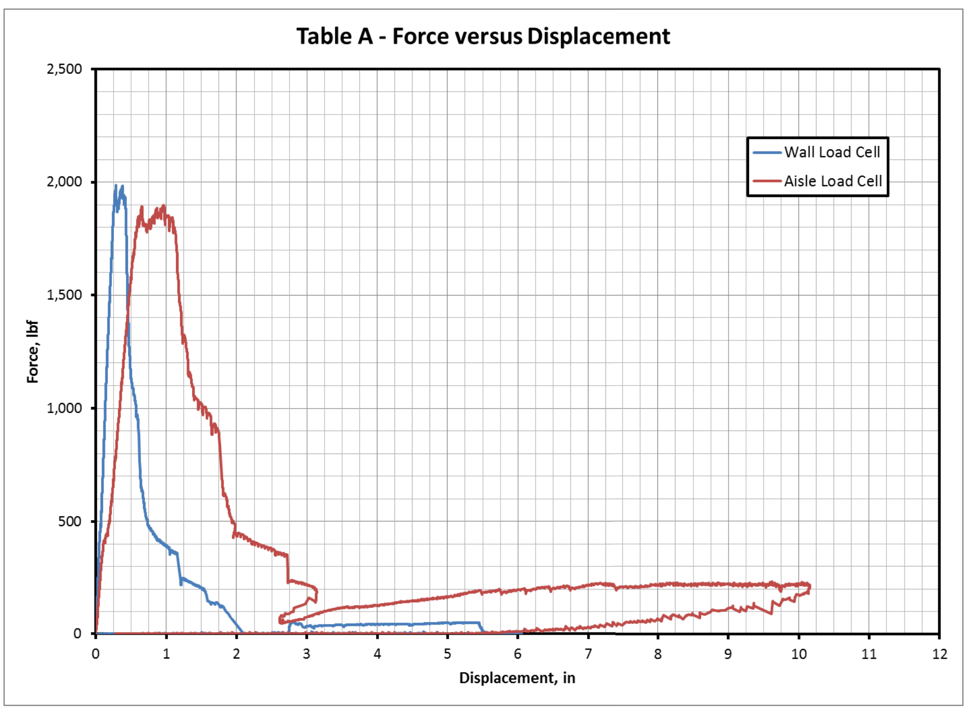


Figure 7 – Table A Force versus Displacement at Both Blocks

The Table A tri-axial load cell time histories are shown in Figure 8, Figure 9, and Figure 10.

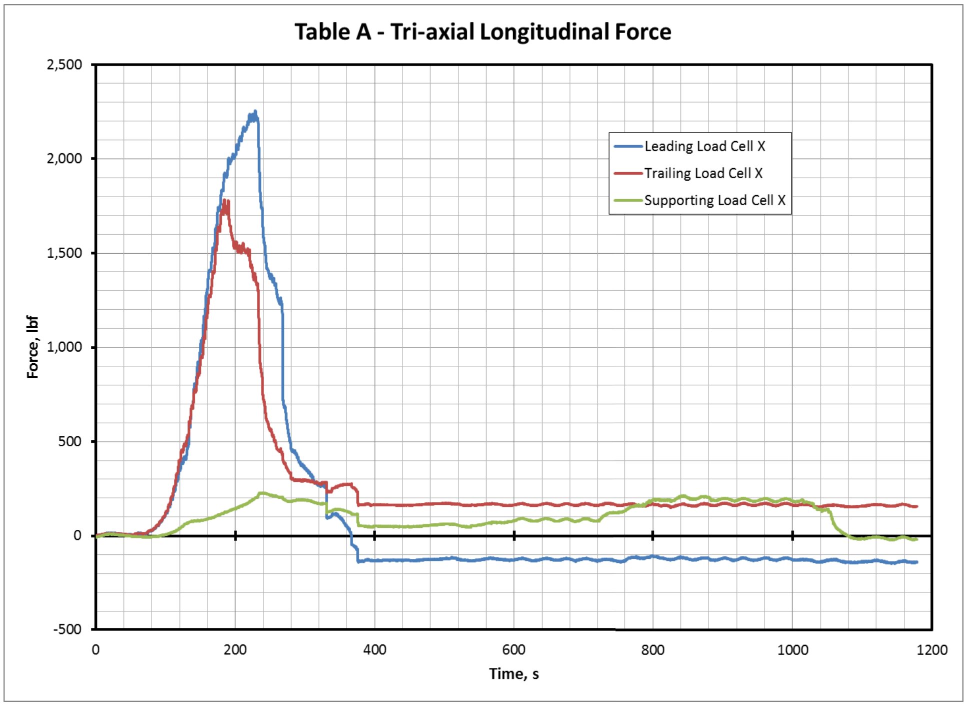


Figure 8 – Table A Longitudinal Force Time Histories from Tri-axial Load Cells

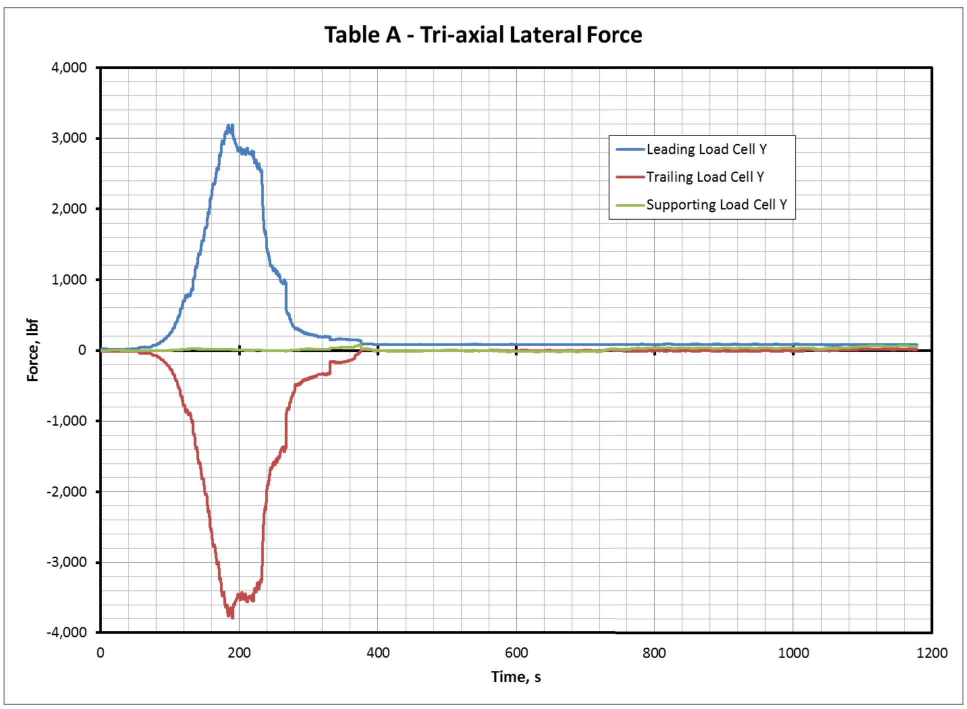


Figure 9 – Table A Lateral Force Time Histories from Tri-axial Load Cells

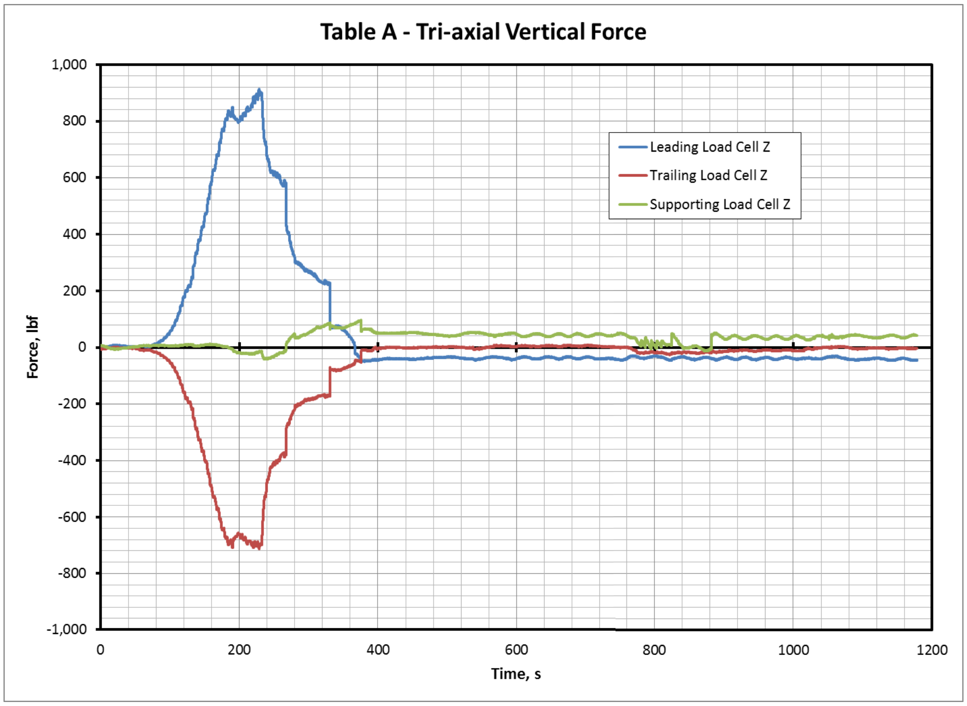


Figure 10 – Table A Vertical Force at Tri-axial Load Cells Time Histories

Figure 11 depicts the plastic energy absorbed as a function of displacement for both load cells.

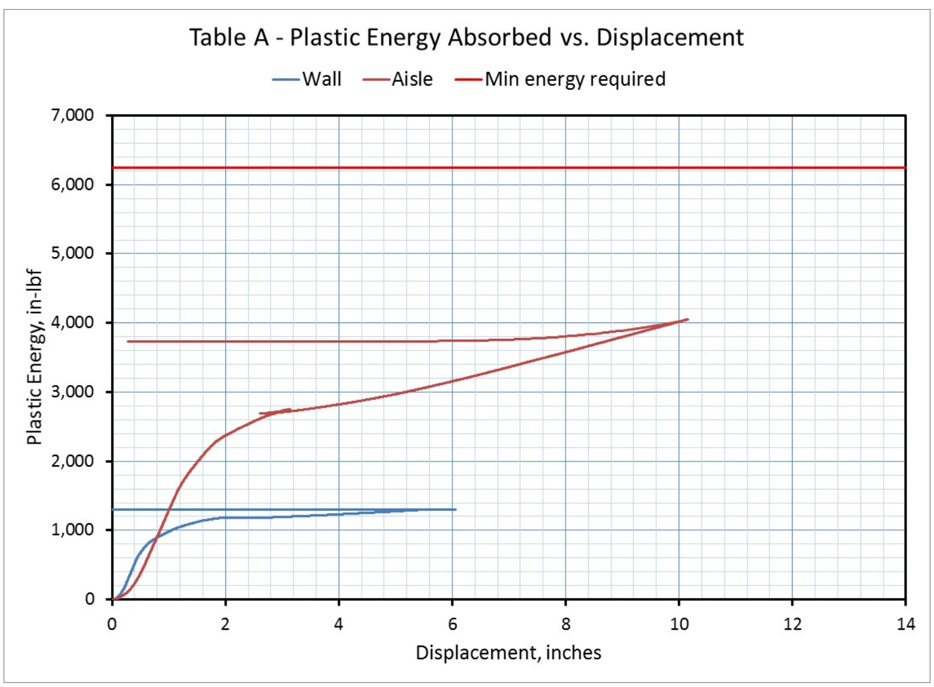


Figure 11 – Table A - Plastic Energy versus Displacement

Table 2 shows the maximum force and energy absorbed at each of the loading block locations for Table A.

Table 2 – Table A Test Results

Max Force on Load Cell, lbf		Final Plastic Energy Absorbed by Table, in-lbf		Longitudinal Space Preserved, inches	
Wall	Aisle	Wall	Aisle	Wall	Aisle
1,988	1,898	1,299	3,727	12.7	14.6

Due to the support failure as shown in Figure 6, loading the table any further would not have produced any meaningful results. Thus, testing for Table A was aborted before the load reached 2,250 lbf. As can be seen in Table 2, the energy absorbed by Table A did not achieve the target 6,250 in-lbf.

An overall performance evaluation is presented for Table A in Table 3.

Table 3 – Table A Performance Assessment

Requirement	Result	Pass/Fail
The table and any table components must remain attached to the test fixture.	See photo in Figure 6, depicting the table leg separated from the floor mounting.	Fail
A minimum of 15 inches of survivable space, measured post-test, must be preserved for facing occupants based on the predominant seat pitch used for seats surrounding tables.	15-inch minimum survival space was not preserved.	Fail
The energy absorbed by the plastic (permanent) table deformation at each seat position must be at least 6,250 in-lbf before the force reaches 2,250 lbf.	Fixture failure–test aborted before target energy could be reached.	Fail

4.3 Table B Results

Figure 12 shows the attachment of Table B to the wall, prior to testing. The test setup is identical to the previous test, with the exception of the location of the three tri-axial load cells in the mounting locations. In this test, all three tri-axial load cells were located at the attachment of the table to the wall, secured between the vertical side wall and rigid, steel plates–one slightly below the height of the table top, and two at the same height, near the bottom of the cantilever attachment. The approximate locations are denoted by green arrows.

Figure 12 – Table B Pre-Test Photo Depicting Locations of Load Cells

Figure 13 shows Table B during testing. This picture shows longitudinal displacement of the table structure relative to its support.

Figure 13 – Photo of Table B during Test

Figure 14 shows a picture of Table B after testing. Based on table drawings from the manufacturer, the nominal clearance is 19.9 inches between the table top and the opposing seat back. Therefore, table top displacement greater than 4.9 inches would encroach on the minimum clearance space of 15 inches. The survival space was breached as the resting position of the table encroached 2 to 3 inches into the passengers' survival space.

Figure 14 – Photo of Table B Post-Test

Figure 15 shows an under-table view of Table B after testing. As shown, the support frame had experienced high shear stresses (see deformation in circled area).

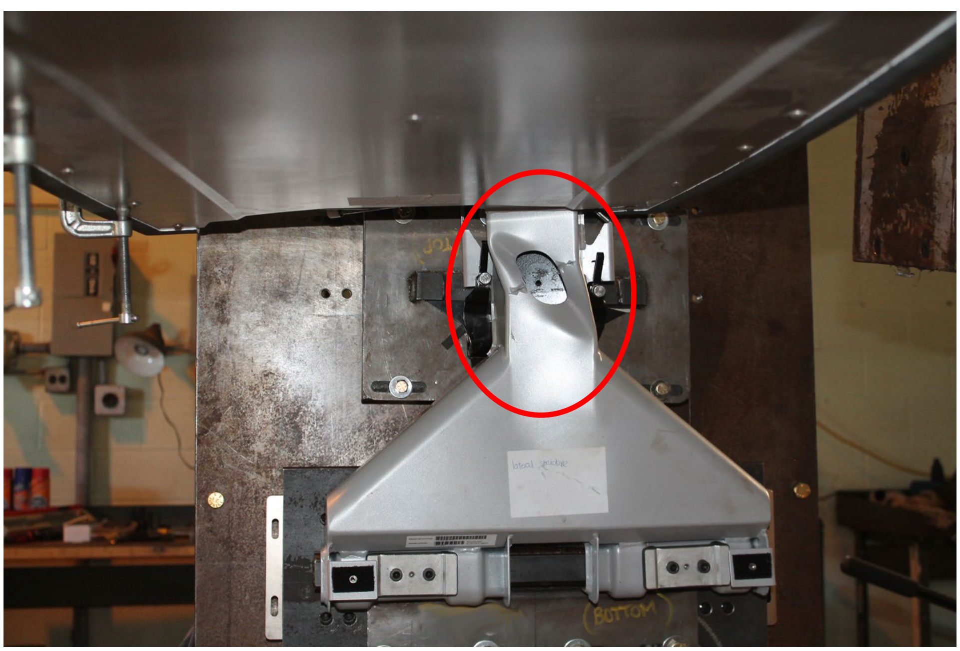


Figure 15 – Photo of Table B Post-Test Showing Support Frame Deformation

Figure 16 shows the force versus displacement cross-plot for both body blocks for Table B. As shown in the plot, the maximum force experienced at the wall block was 2,509 lbf. As the applied load was increasing quickly, the motion of the ram nearest the wall was not stopped until the applied load exceeded the limit of 2,250 lbf. When computing the plastic energy absorbed, the energy absorbed when the force was above the 2,250 lbf limit was subtracted from the total plastic energy. The highest force experienced at the aisle block was 920 lbf.

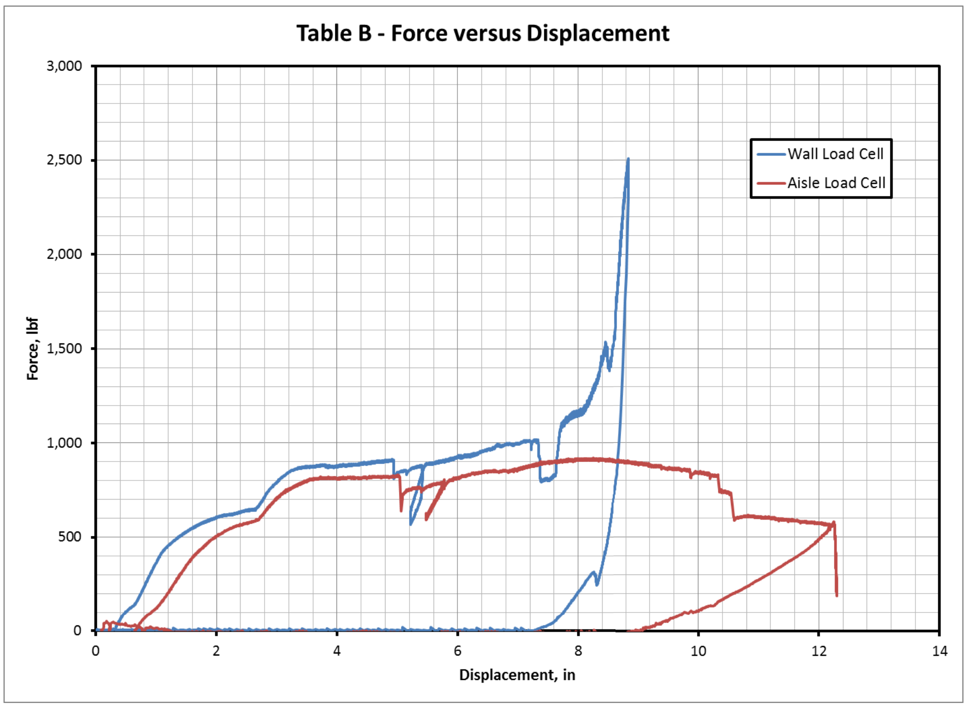


Figure 16 – Table B Force versus Displacement at Both Blocks

The Table B tri-axial load cell time histories are shown in Figure 17, Figure 18, and Figure 19.

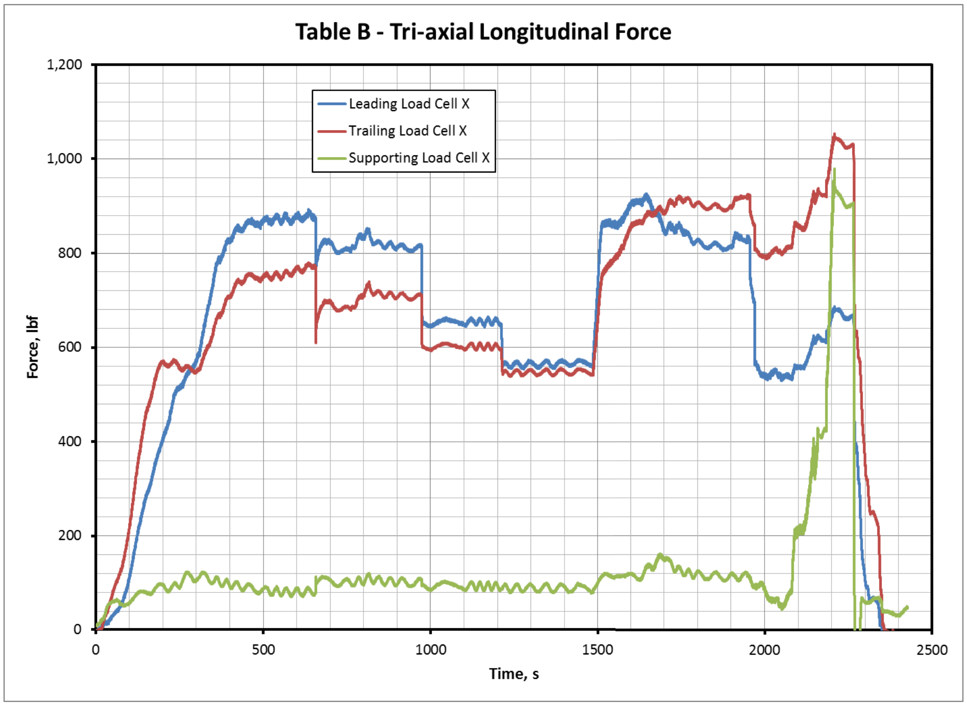


Figure 17 – Table B Longitudinal Force Time Histories from Tri-axial Load Cells

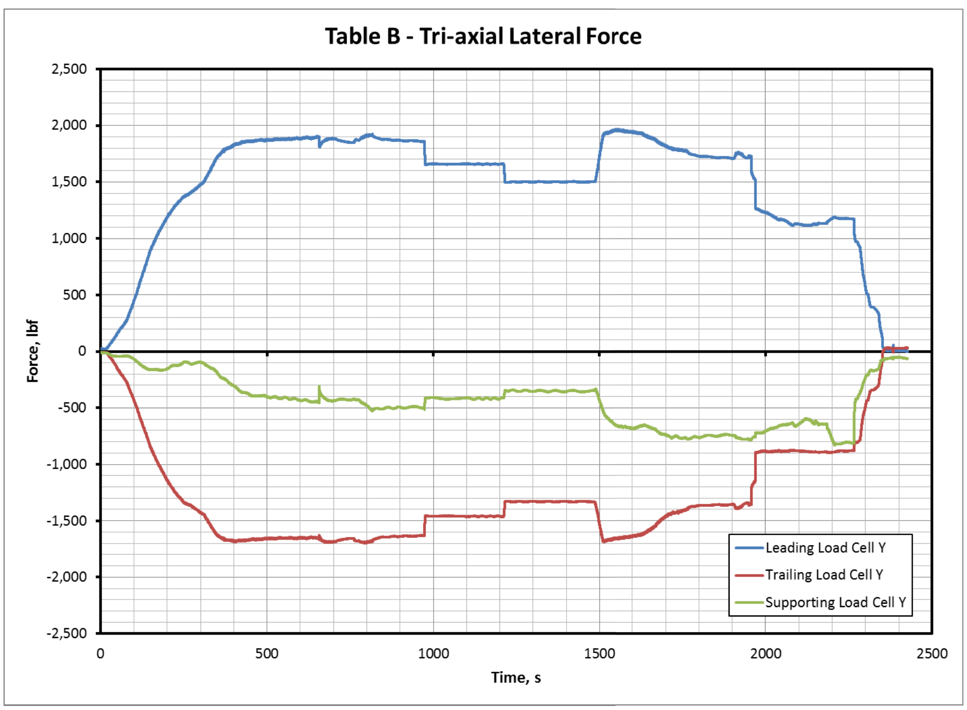


Figure 18 – Table B Lateral Force Time Histories from Tri-axial Load Cells

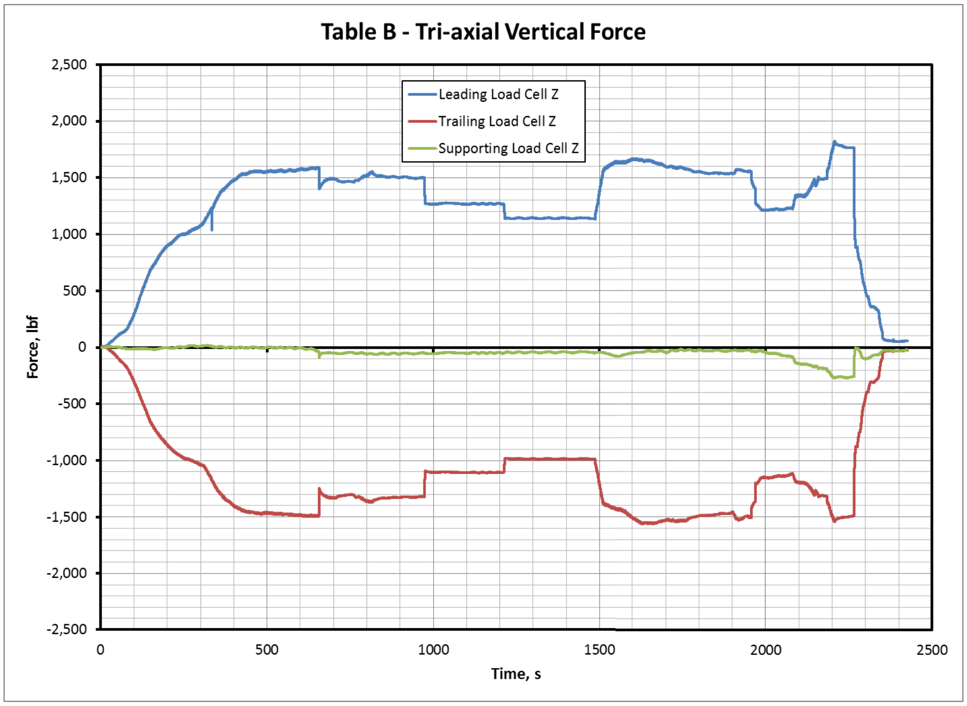


Figure 19 – Table B Vertical Force Time Histories from Tri-axial Load Cells

Figure 20 depicts the plastic energy absorbed as a function of displacement for both load cells.

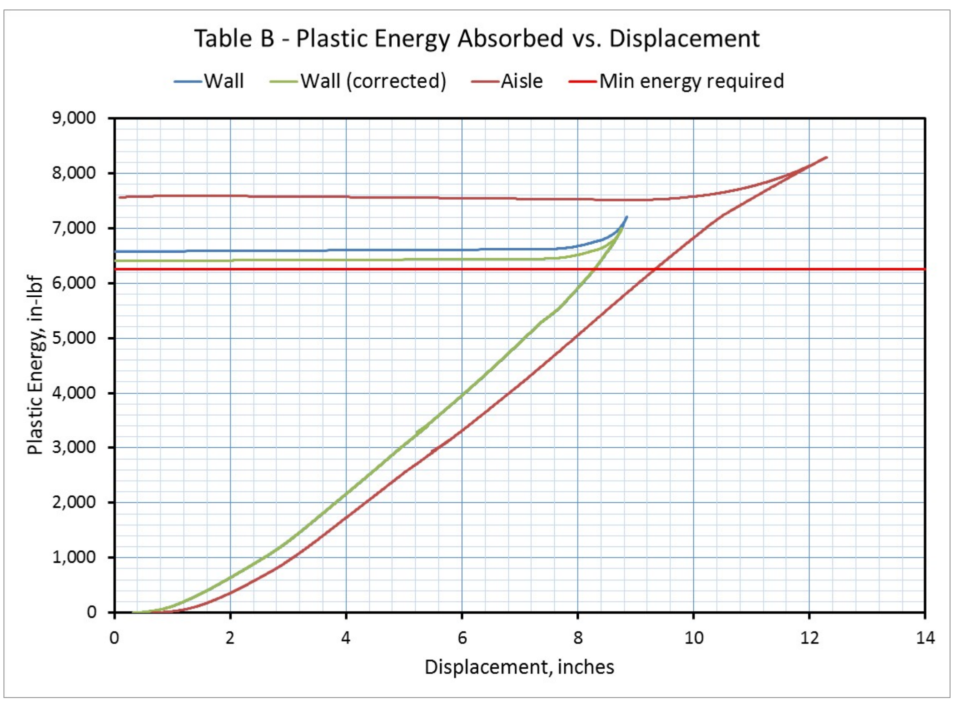


Figure 20 – Plastic Energy Absorbed Versus Displacement

At the load cell nearest the wall, the plastic energy absorbed by the table was 6,993 in-lbf. At the load cell nearest the aisle, the plastic energy absorbed by the table absorbed was 7,560 in-lbf. The plastic energy absorbed while the load was above 2,250 lbf was subtracted from the total plastic energy absorbed. In both cases, the table absorbed more plastic energy than the minimum of 6,250 in-lbf before the force reached 2,250 lbf.

Table 4 shows the maximum force and energy absorbed at each of the loading block locations for Table B.

Table 4 – Table B Test Results

Max Force on Load Cell, lbf		**Final Plastic Energy Absorbed by Table, in-lbf**		**Longitudinal Space Preserved, inches**	
Wall	Aisle	Wall	Aisle	Wall	Aisle
2,509	920	6,993	7,560	12.4	12.0

An overall performance evaluation is presented for Table B in Table 5.

Table 5 – Table B Performance Assessment

Requirement	**Result**	**Pass/Fail**
The table and any table components must remain attached to the test fixture.	See Figure 15; the table remained attached but the mounting yielded.	Pass
During and after crushing of the table, a minimum of 15 inches of survivable space must be preserved for facing occupants based on the predominant seat pitch used for seats surrounding tables.	12 to 12.4 inches of survival space preserved.	Fail
The energy absorbed by the plastic (permanent) table crush must be at least 6,250 in-lbf at each seat position before the force reaches 2,250 lbf.	The required plastic energy was absorbed on both the wall and aisle side of the table.	Pass

5. Conclusion

SA instrumented and performed a quasi-static test on two workstation tables for passenger rail cars from different manufacturers. Testing evaluated the tables in accordance with the requirements outlined in the APTA standard for fixed workstation tables. Each table was loaded longitudinally at the tabletop edge with hydraulic actuators at locations near the aisle and near the wall. Force and displacement measurements were collected at these locations, as were tri-axial load measurements at the supports.

Each performance criterion in the standard was addressed and evaluated for success based on the data collected and post-test visual inspection. Table A's attachment to the wall failed structurally prior to the table absorbing 6,250 in-lbf of energy. Table B was able to plastically absorb the required energy without the applied force exceeding 2,250 in-lbf; thus, Table B passed the energy absorption requirement. Post-test, neither table was able to preserve the minimum 15 inches of clearance required at the facing passengers' locations. Based on APTA performance requirements, both Table A and Table B failed to comply with all of the requirements.

6. References

1. American Public Transportation Association. (2015, October).Fixed Workstation Tables in Passenger Rail Cars. PR-CS-S-018-13, Rev. 1. Washington, DC.

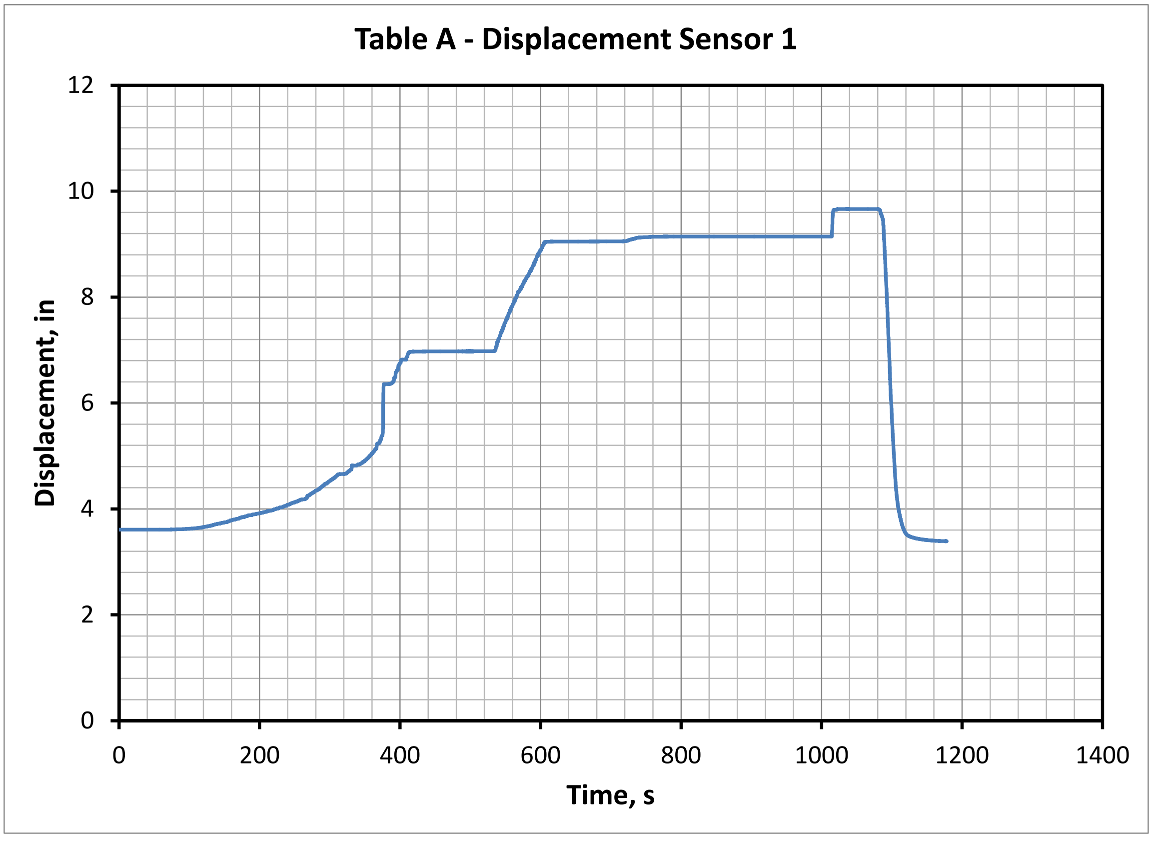
2. SAE International. (1995). Instrumentation for Impact Test—Part 1—Electronic Instrumentation. J211/1_201403. Warrendale, PA.

Abbreviations and Acronyms

Abbreviation or Acronym	Name
APTA	American Public Transportation Association
lbf	Pounds (force)
SA	Sharma & Associates, Inc.
SAE	Society of Automotive Engineers (now known as SAE International)
Volpe	Volpe National Transportation Systems Center

Appendix A–Time History Plots

See test schematics in Figure 4 for sensor locations.



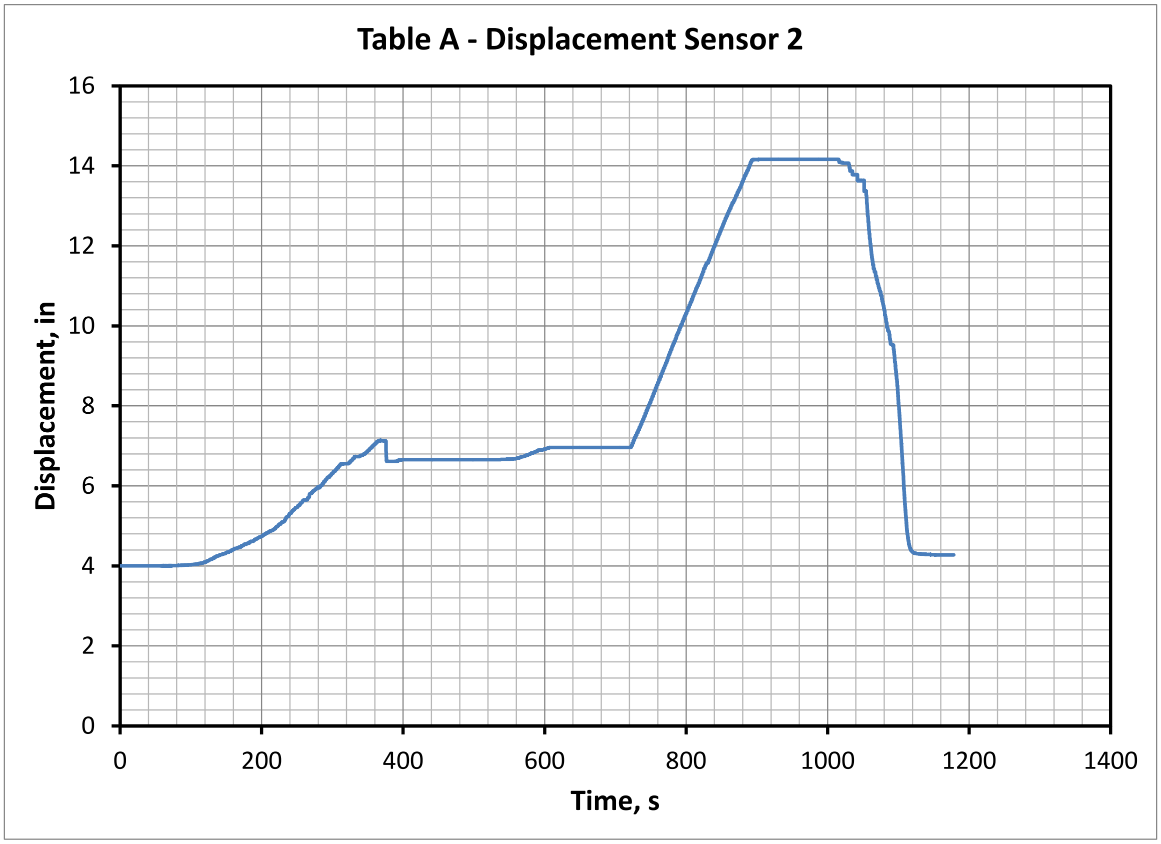


Table A - Displacement Sensor 2
16
14
12
10
8
6
4
2
0
Displacement, in
0
200
400
600
800
1000
1200
1400
Time, s

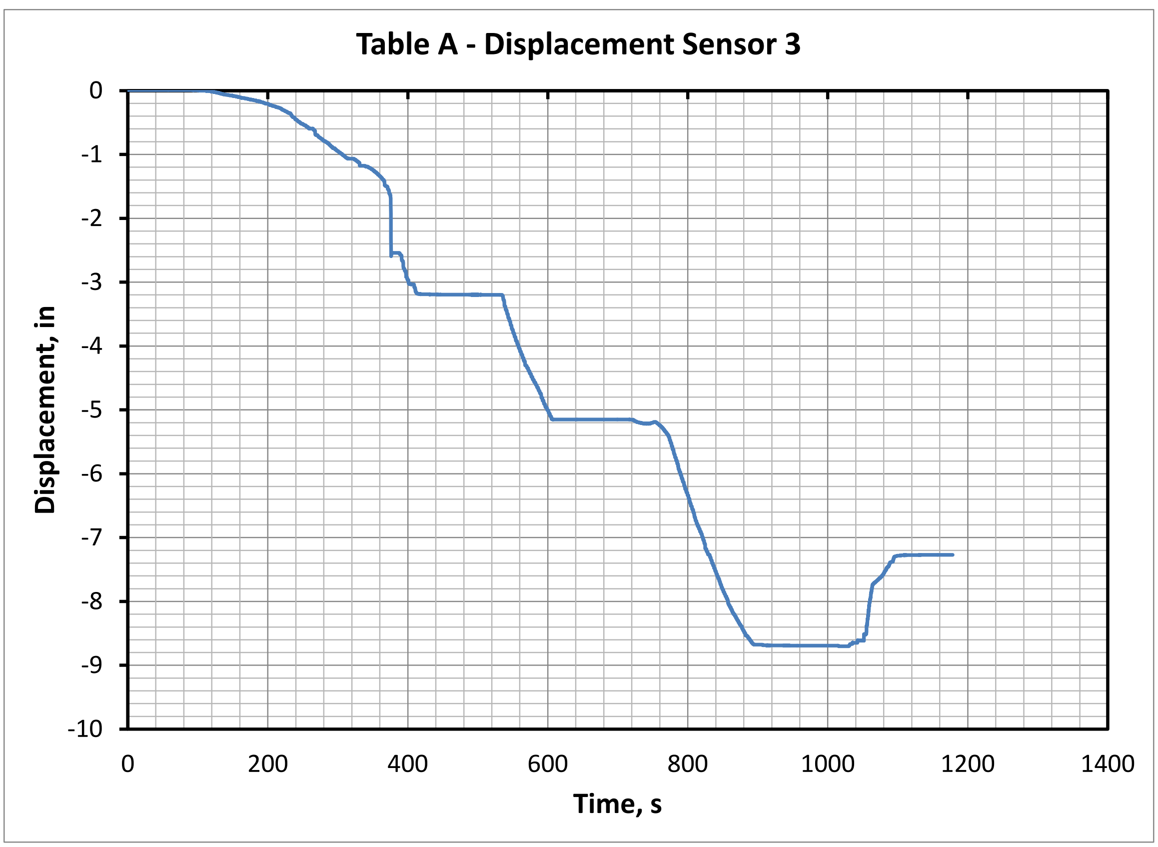


Table A - Displacement Sensor 3
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Displacement, in
0
200
400
600
800
1000
1200
1400
Time, s

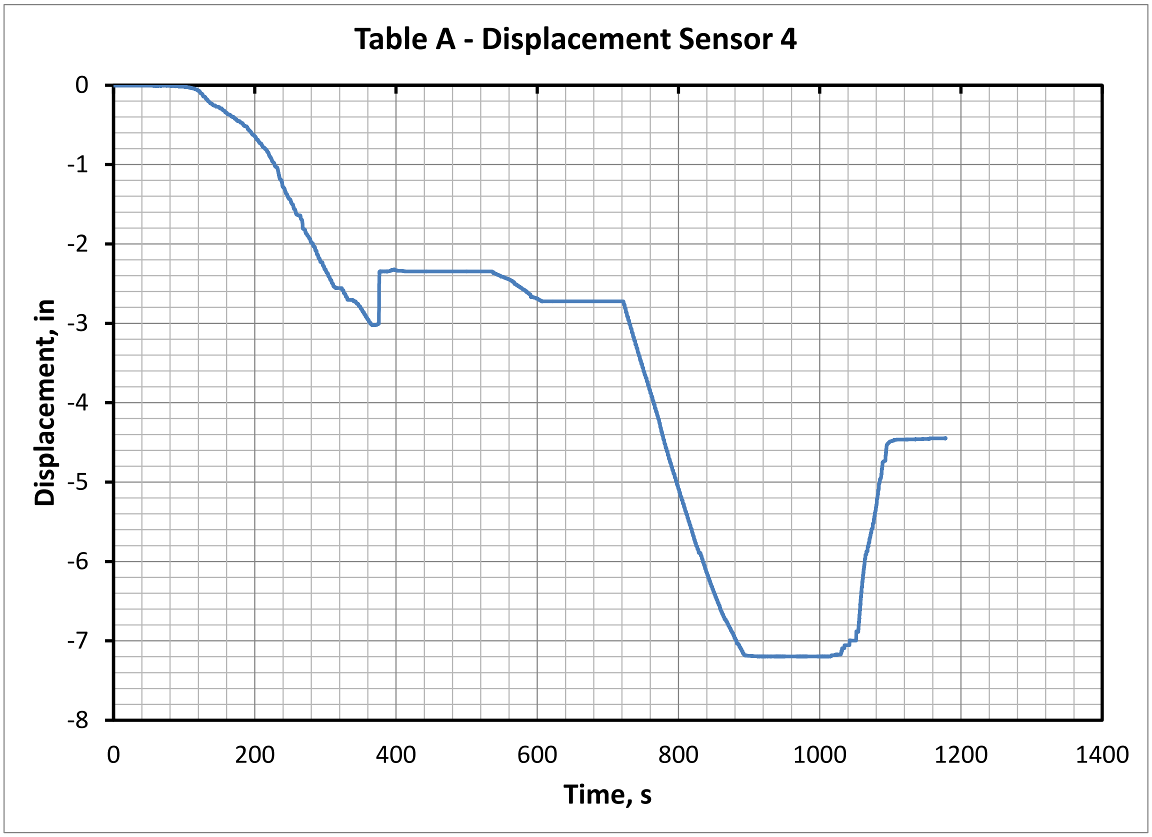


Table A - Displacement Sensor 4
Displacement, in
0
-1
-2
-3
-4
-5
-6
-7
-8
0
200
400
600
800
1000
1200
1400
Time, s

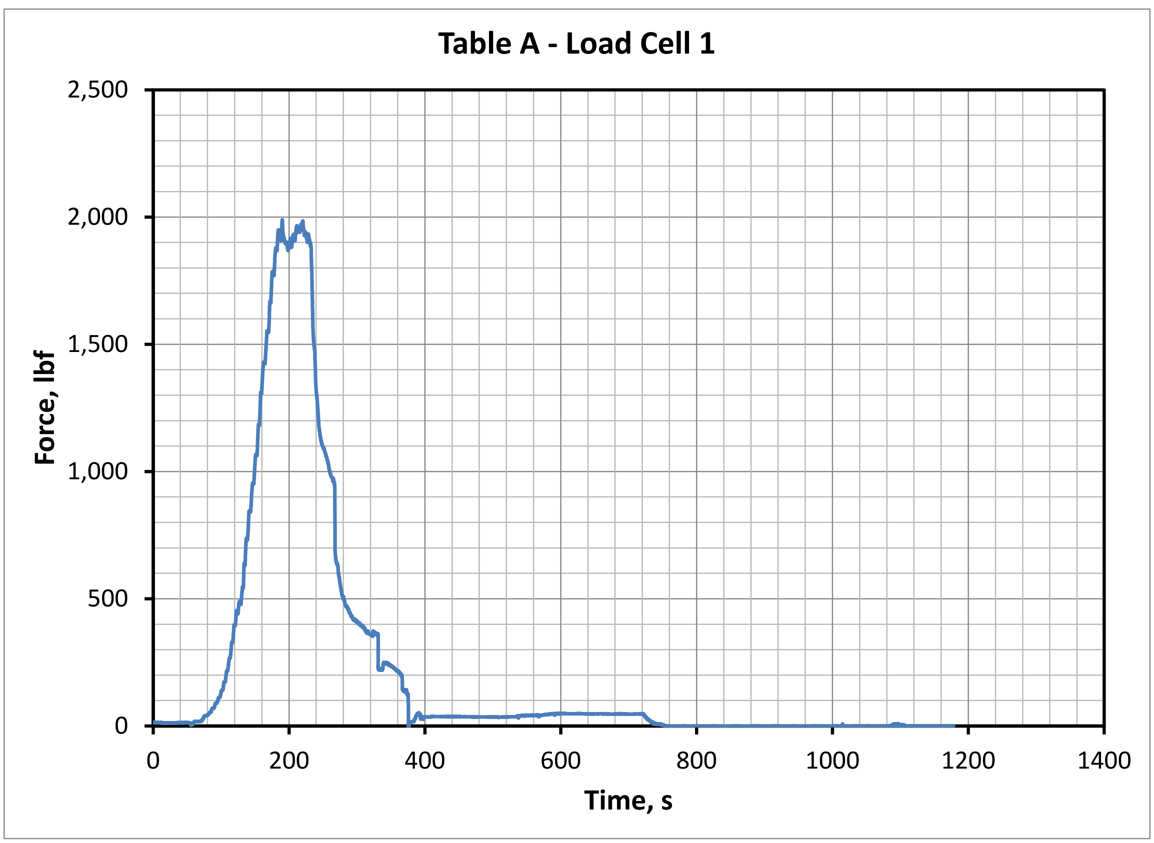


Table A - Load Cell 1
Force, lbf
2,500
2,000
1,500
1,000
500
0
0
200
400
600
800
1000
1200
1400
Time, s

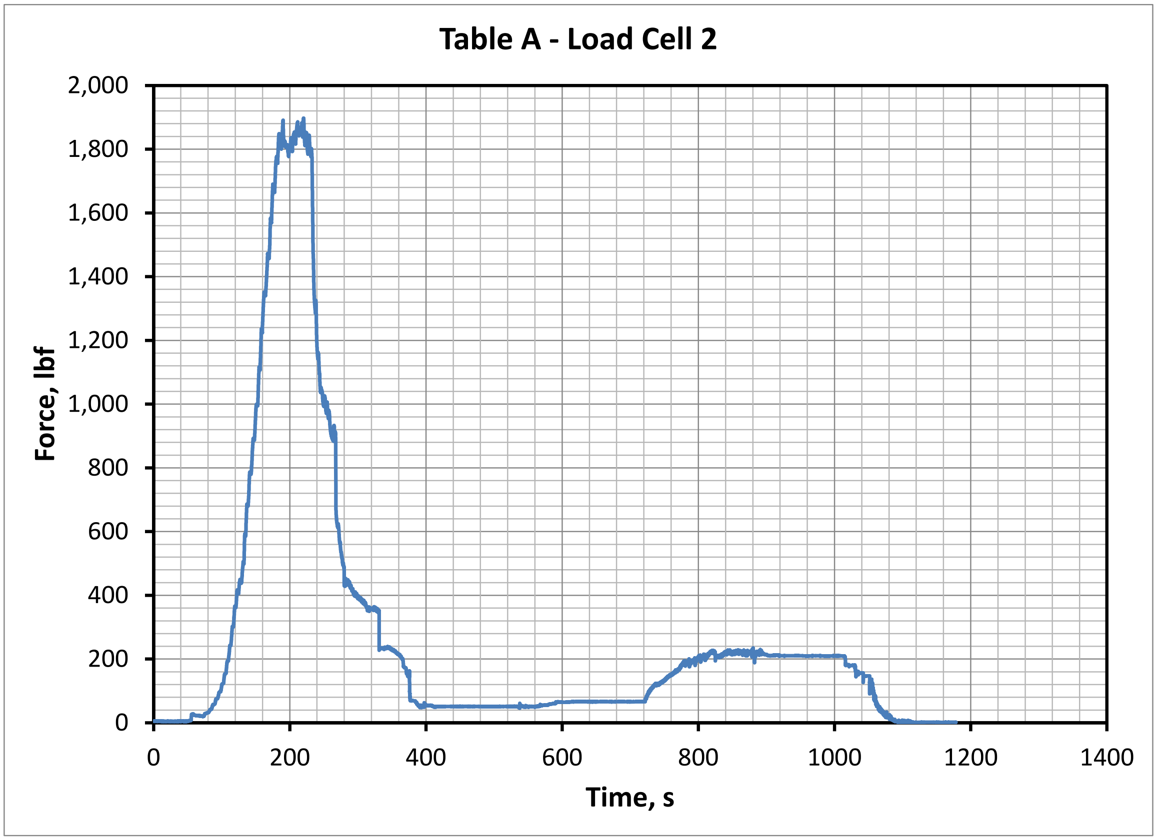


Table A - Load Cell 2
Force, lbf
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
Time, s

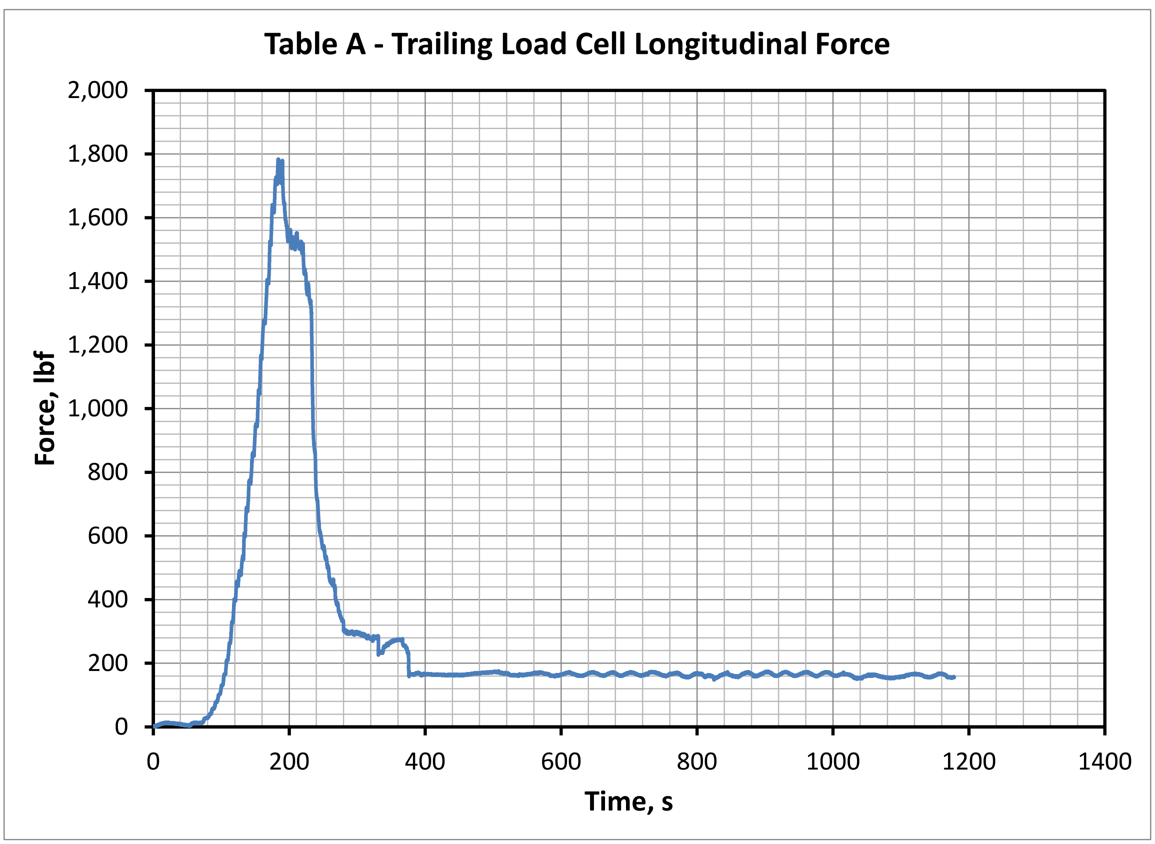


Table A - Trailing Load Cell Longitudinal Force
Force, lbf
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
Time, s

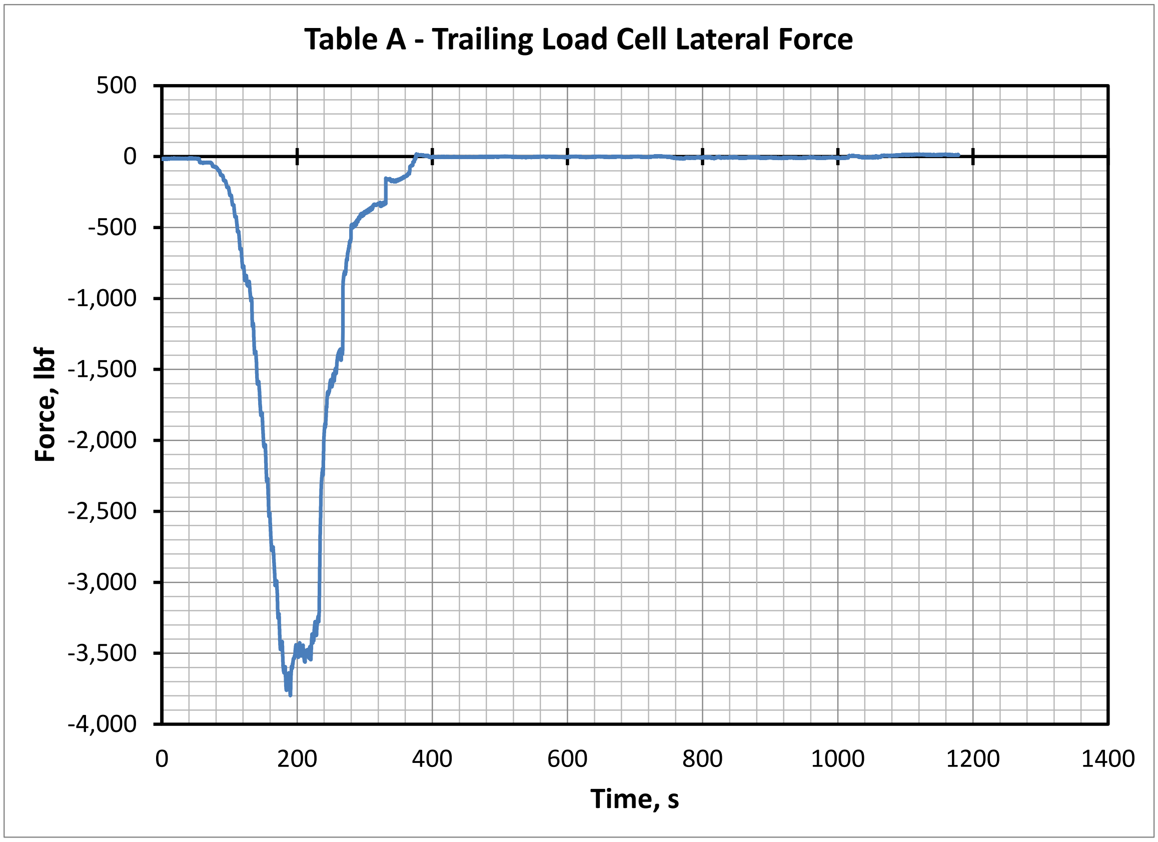


Table A - Trailing Load Cell Lateral Force
500
0
-500
-1,000
-1,500
-2,000
-2,500
-3,000
-3,500
-4,000
Force, lbf
0
200
400
600
800
1000
1200
1400
Time, s

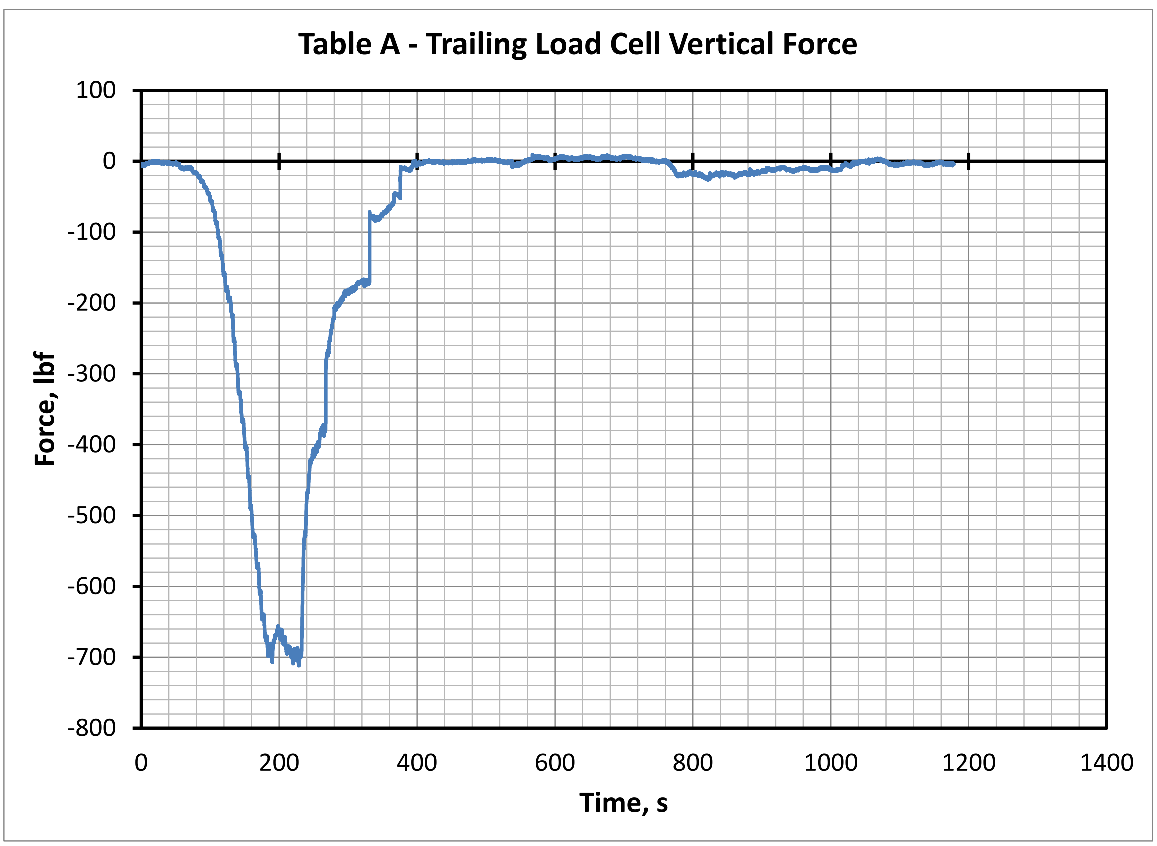


Table A - Trailing Load Cell Vertical Force
100
0
-100
-200
-300
-400
-500
-600
-700
-800
Force, lbf
0
200
400
600
800
1000
1200
1400
Time, s

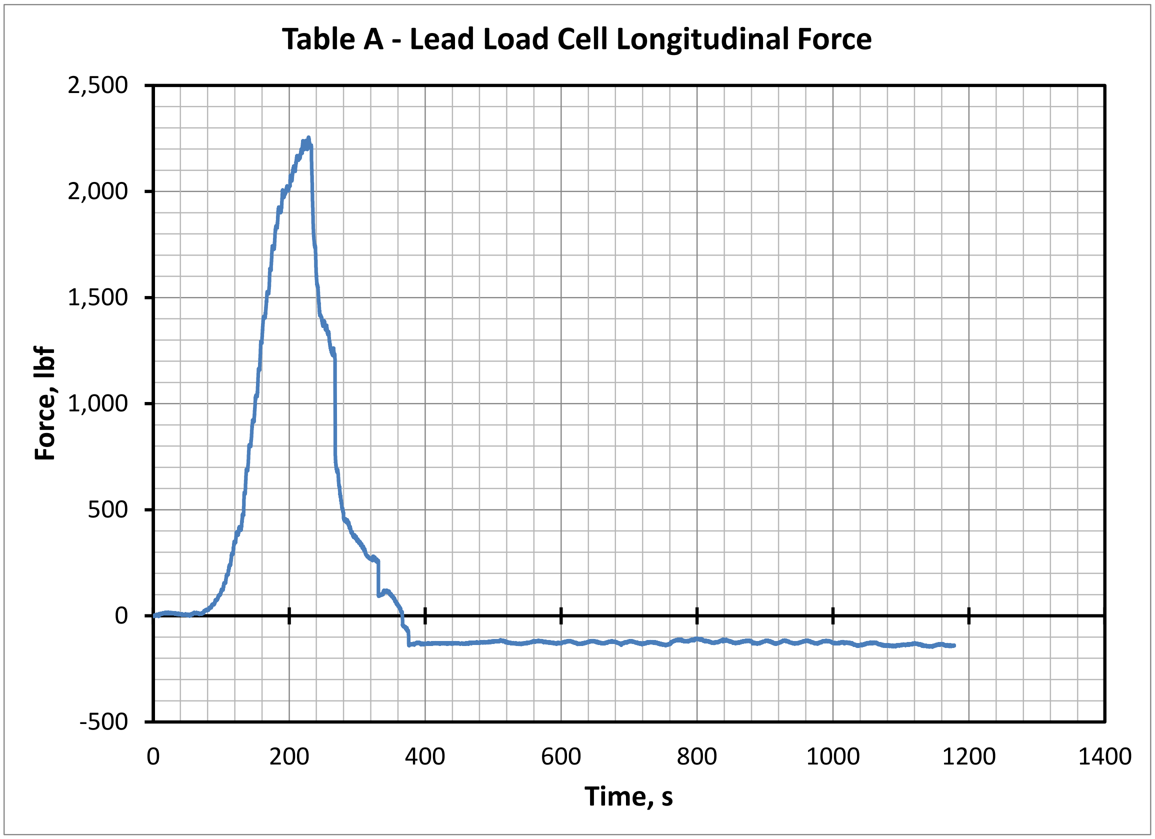


Table A - Lead Load Cell Longitudinal Force
Force, lbf
2,500
2,000
1,500
1,000
500
0
-500
0
200
400
600
800
1000
1200
1400
Time, s

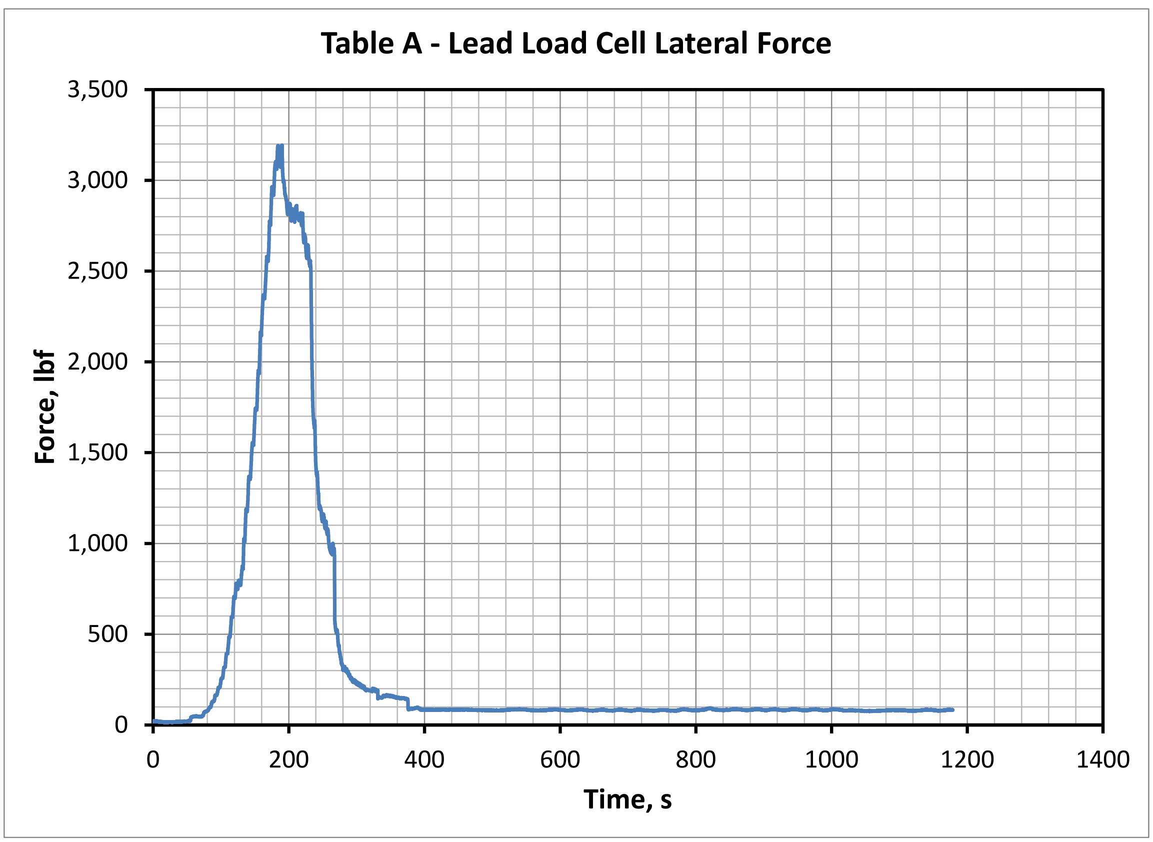


Table A - Lead Load Cell Lateral Force
Force, lbf
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
200
400
600
800
1000
1200
1400
Time, s

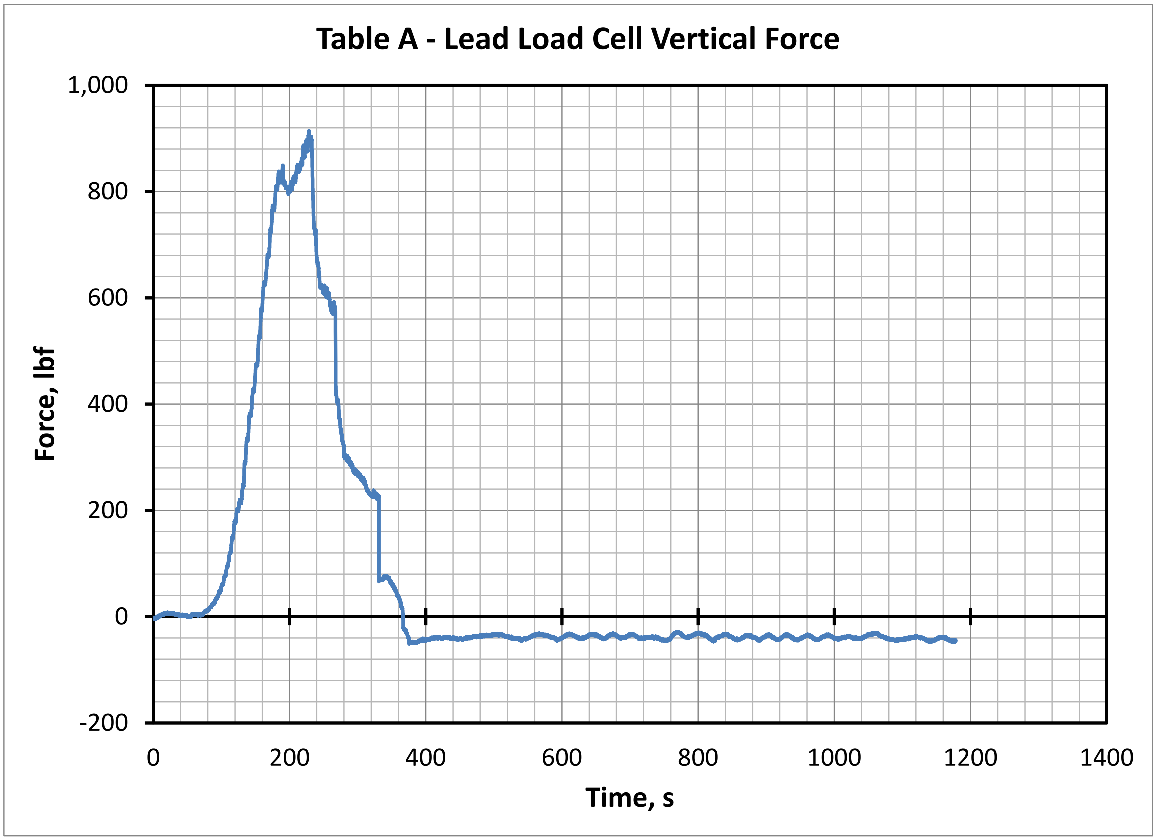


Table A - Lead Load Cell Vertical Force
1,000
800
600
400
200
0
-200
Force, lbf
0
200
400
600
800
1000
1200
1400
Time, s

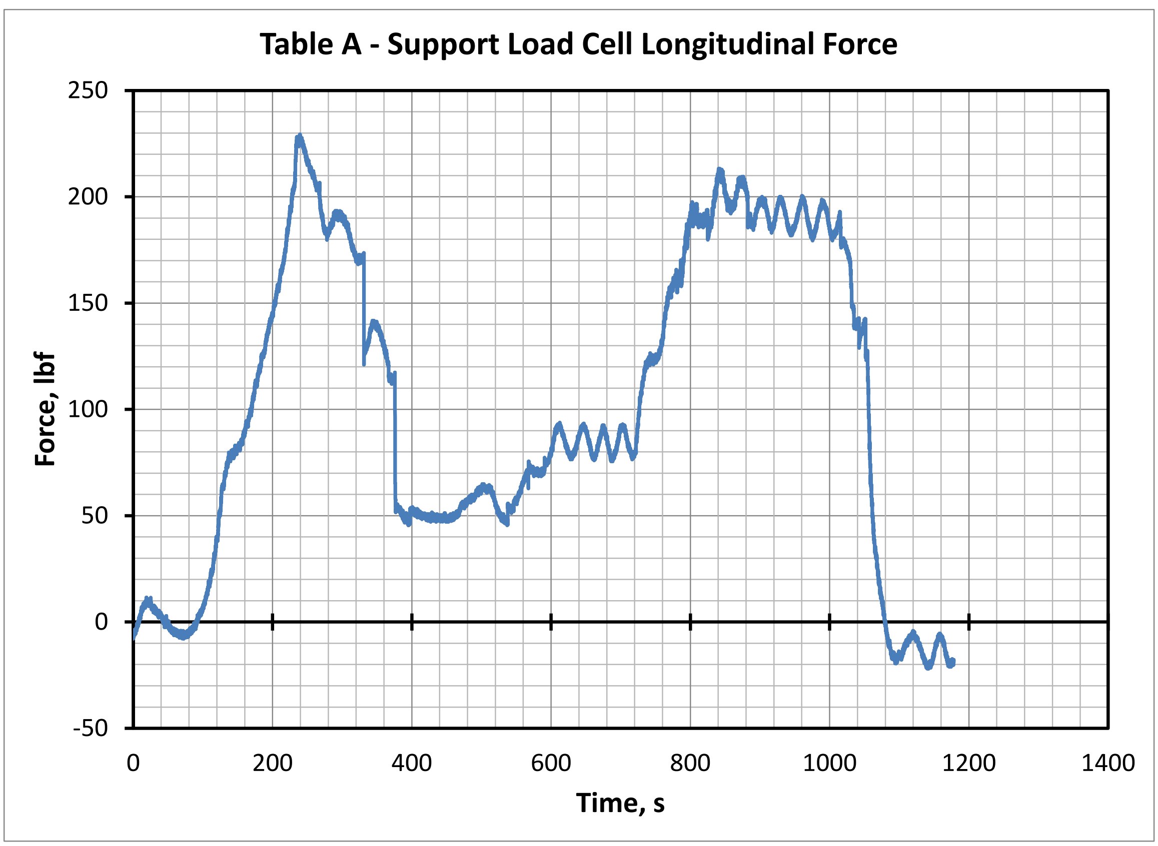


Table A - Support Load Cell Longitudinal Force
250
200
150
100
50
0
-50
Force, lbf
0
200
400
600
800
1000
1200
1400
Time, s

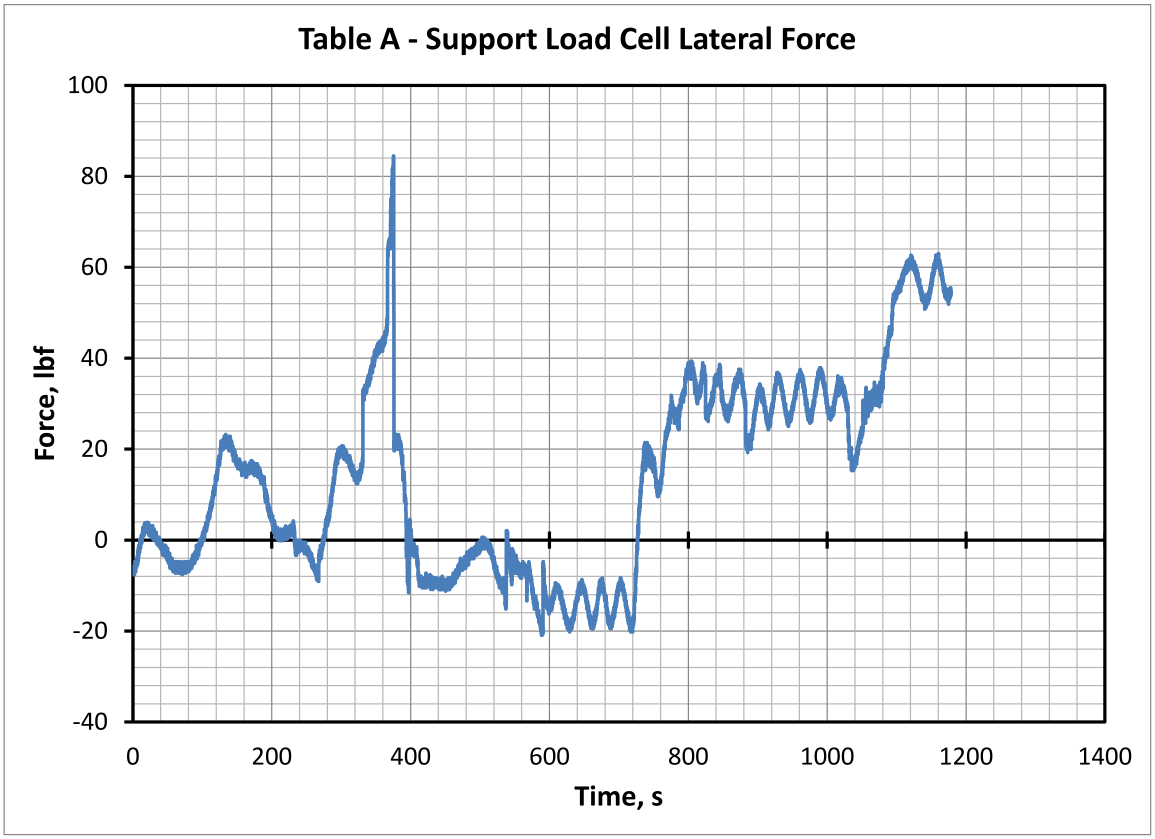


Table A - Support Load Cell Lateral Force
Force, lbf
100
80
60
40
20
0
-20
-40
0
200
400
600
800
1000
1200
1400
Time, s

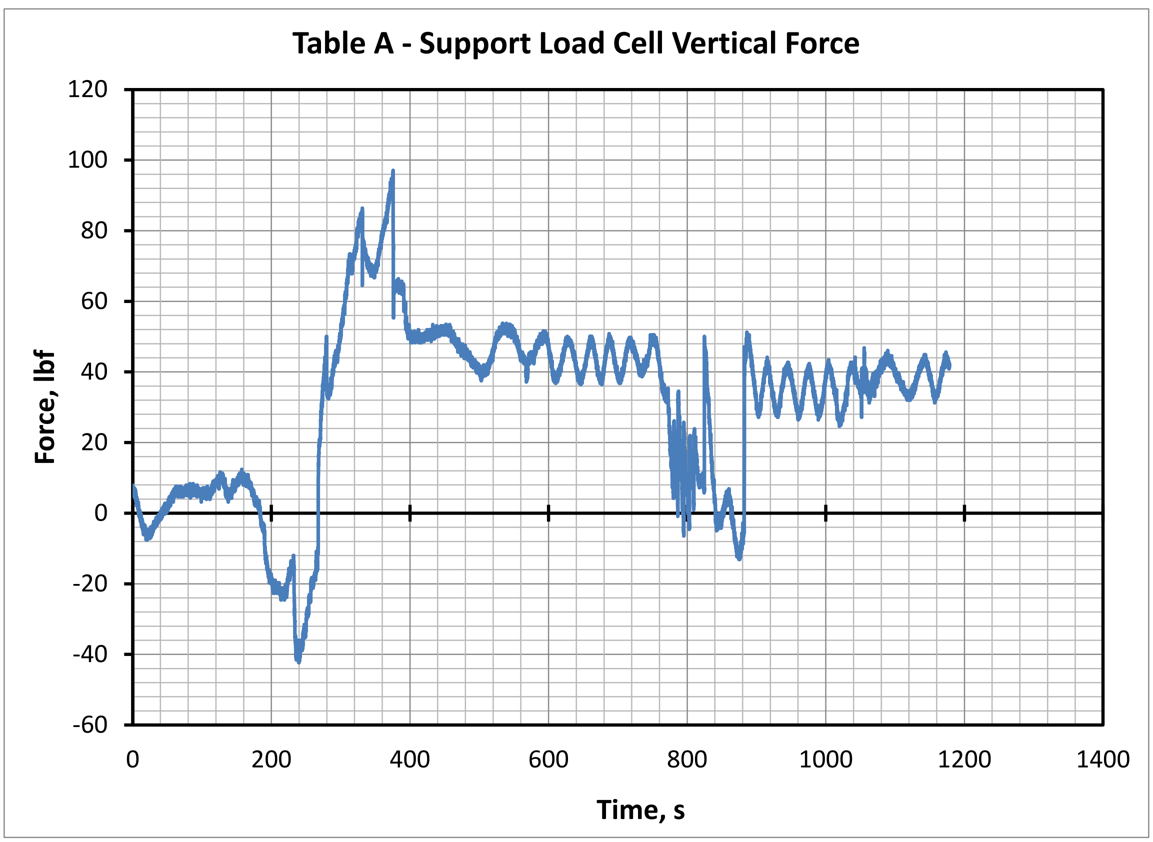


Table A - Support Load Cell Vertical Force
Force, lbf
120
100
80
60
40
20
0
-20
-40
-60
0
200
400
600
800
1000
1200
1400
Time, s

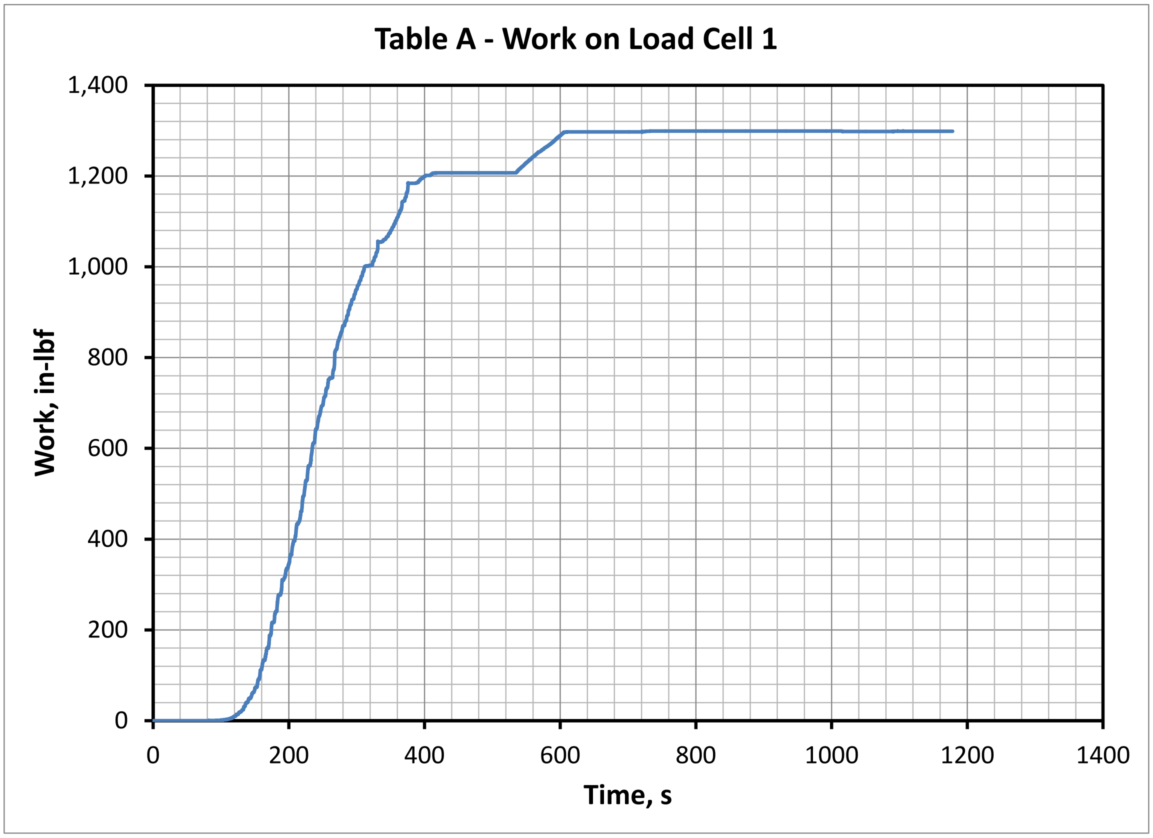


Table A - Work on Load Cell 1
Work, in-lbf
1,400
1,200
1,000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
Time, s

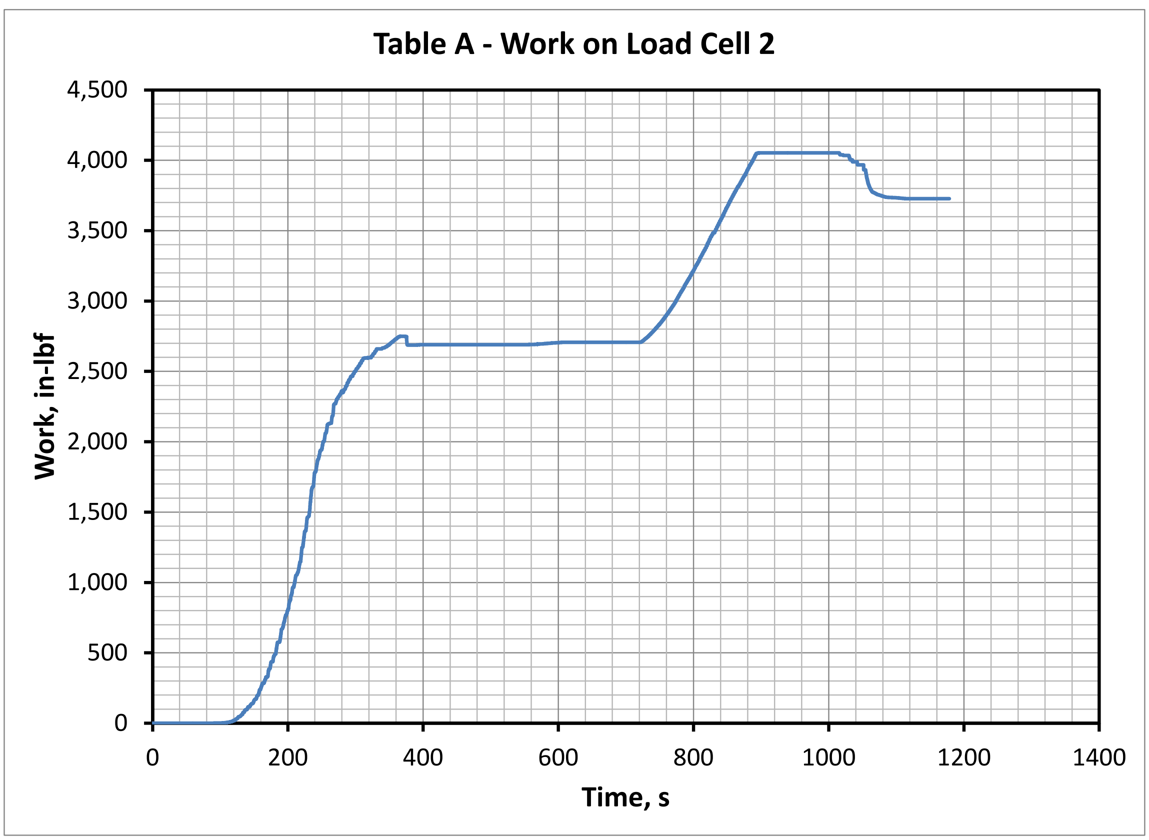


Table A - Work on Load Cell 2
Work, in-lbf
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
200
400
600
800
1000
1200
1400
Time, s

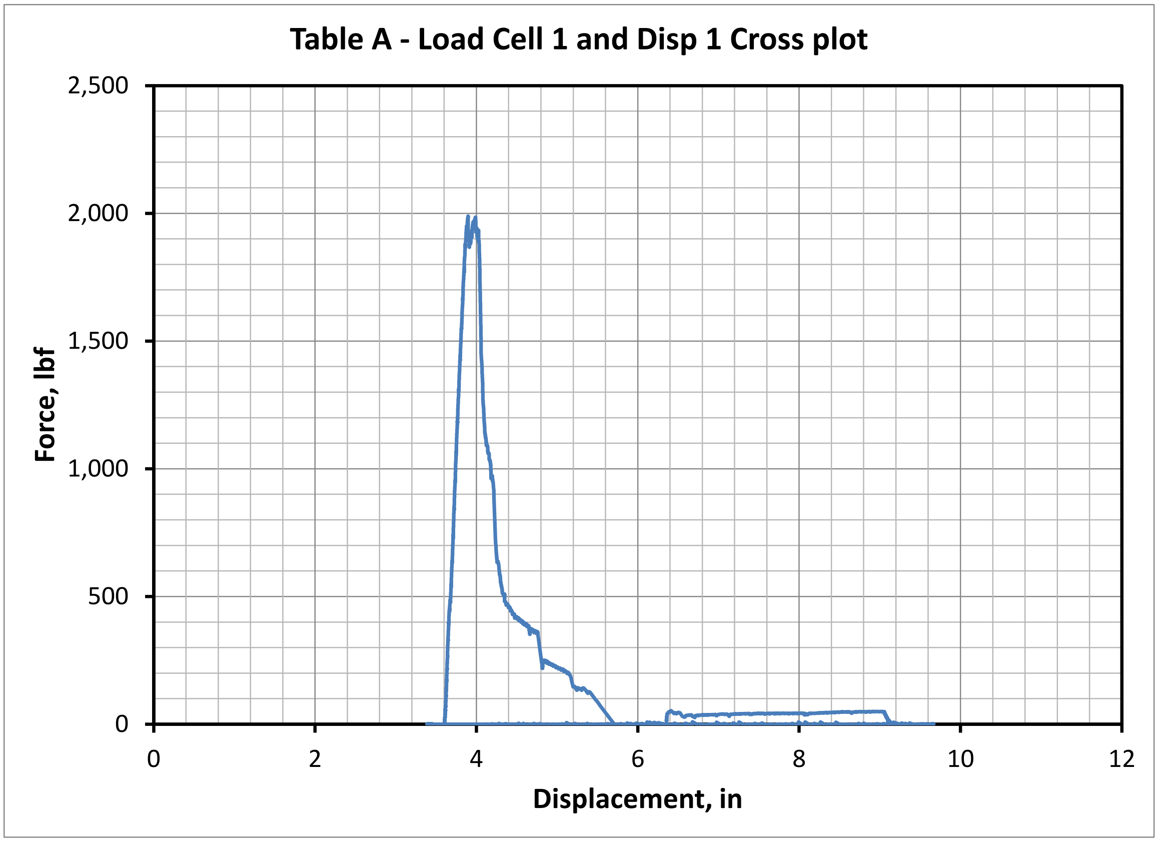


Table A - Load Cell 1 and Disp 1 Cross plot
2,500
2,000
1,500
1,000
500
0
Force, lbf
0
2
4
6
8
10
12
Displacement, in

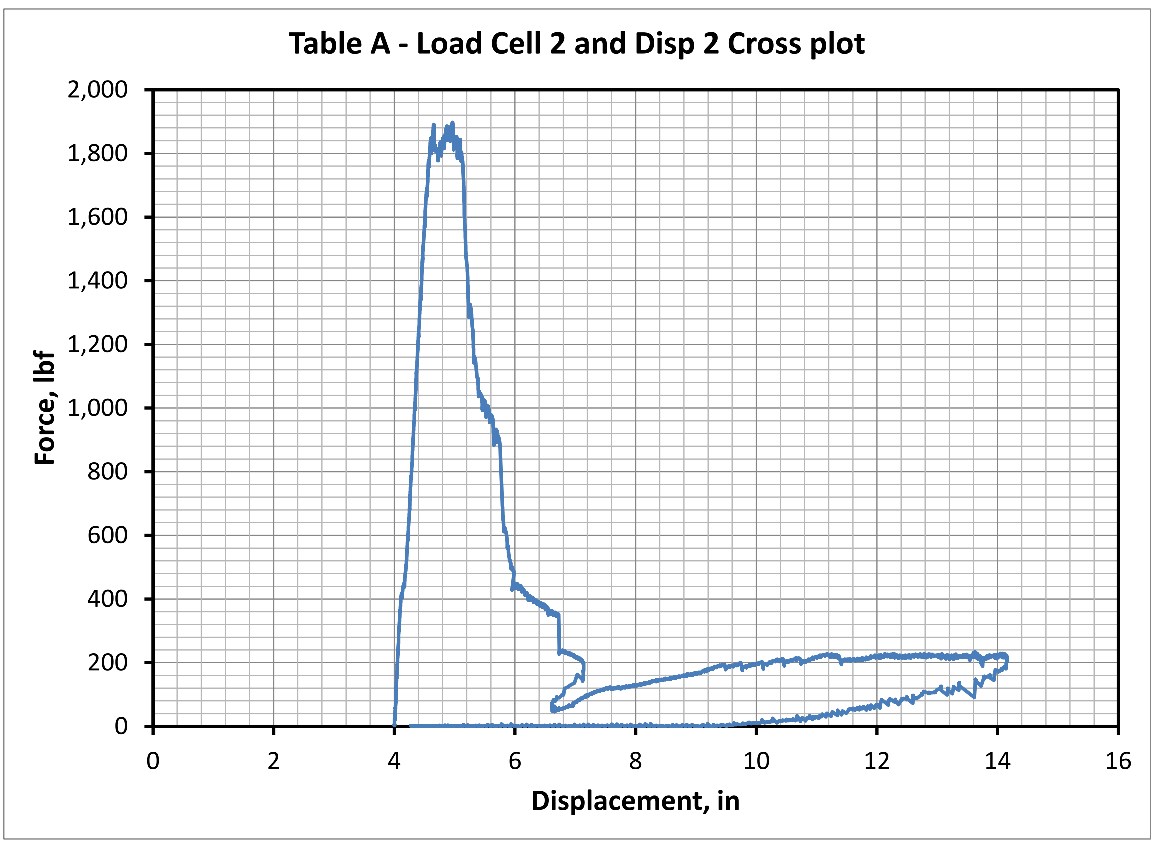


Table A - Load Cell 2 and Disp 2 Cross plot
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Force, lbf
0
2
4
6
8
10
12
14
16
Displacement, in

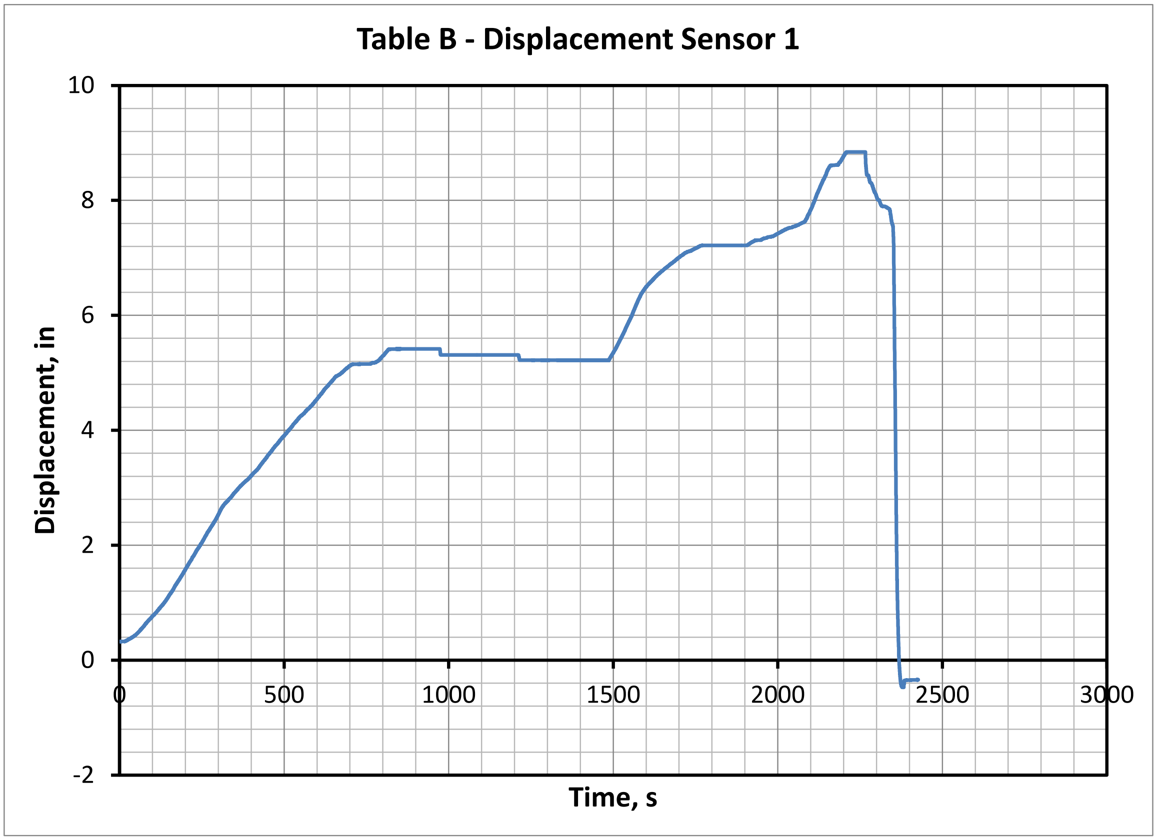


Table B - Displacement Sensor 1
10
8
6
4
2
0
-2
0
500
1000
1500
2000
2500
3000
Displacement, in
Time, s

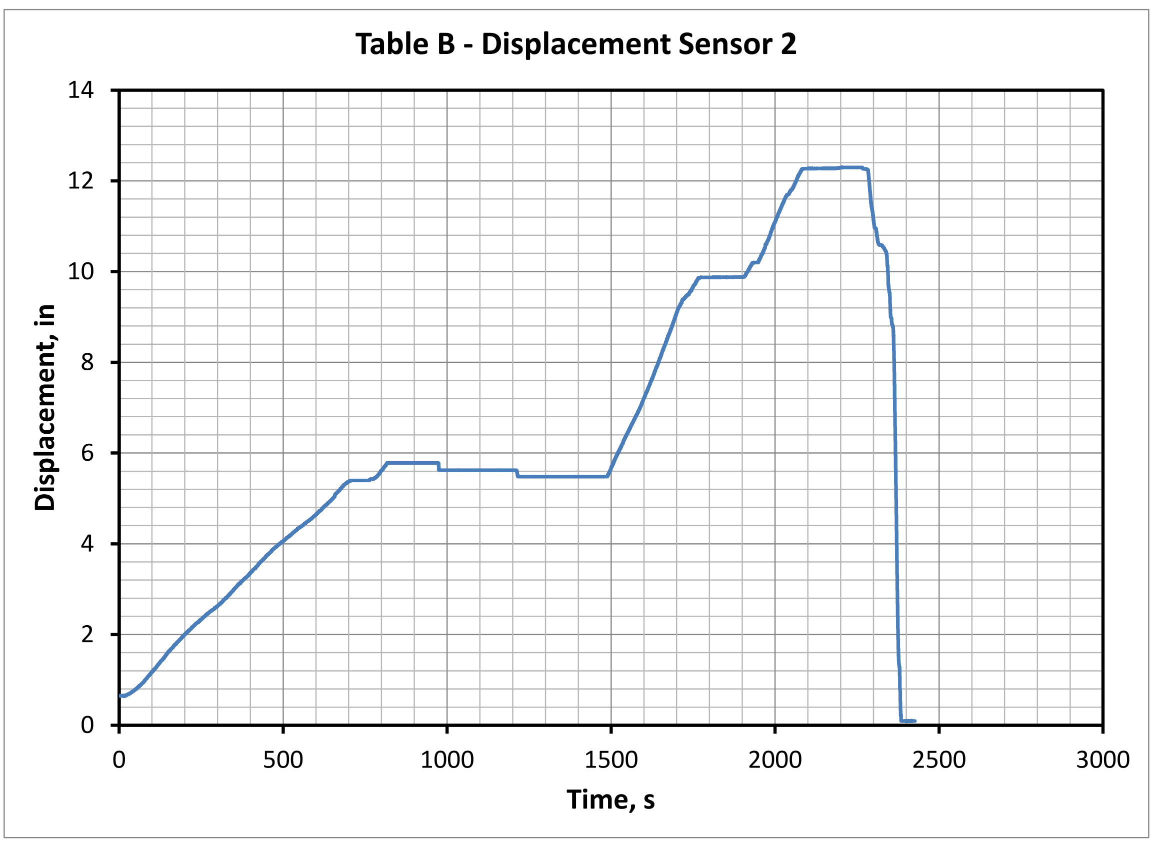


Table B - Displacement Sensor 2
14
12
10
8
6
4
2
0
0
500
1000
1500
2000
2500
3000
Displacement, in
Time, s

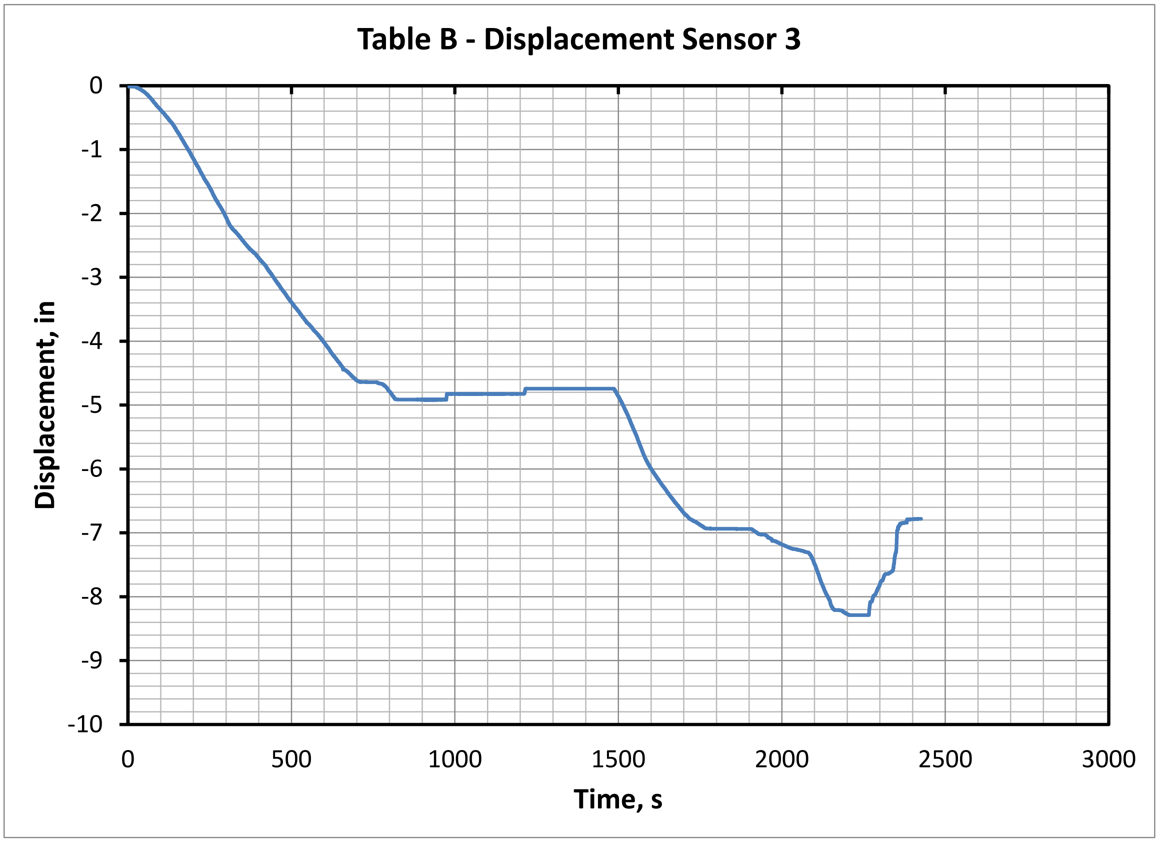


Table B - Displacement Sensor 3
Displacement, in
Time, s
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
0
500
1000
1500
2000
2500
3000

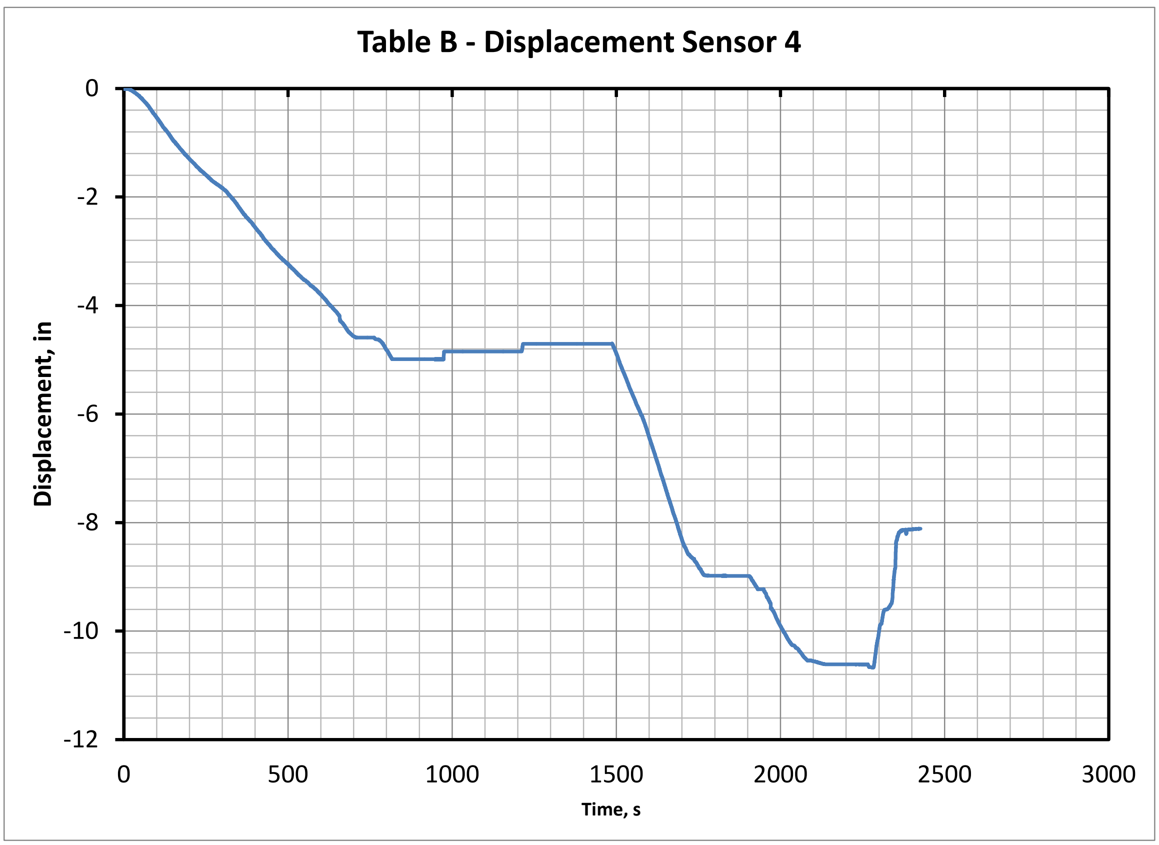


Table B - Displacement Sensor 4
Displacement, in
Time, s
0
-2
-4
-6
-8
-10
-12
0
500
1000
1500
2000
2500
3000

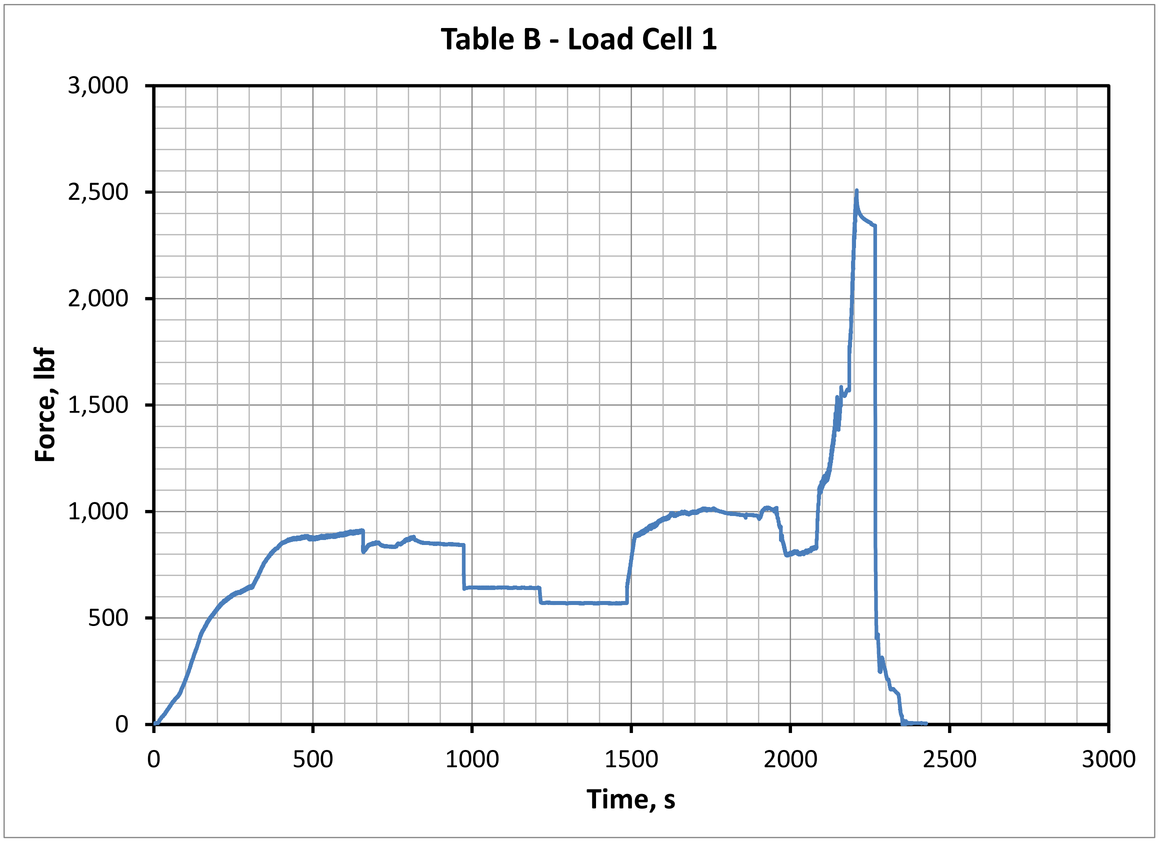


Table B - Load Cell 1
Force, lbf
3,000
2,500
2,000
1,500
1,000
500
0
0
500
1000
1500
2000
2500
3000
Time, s

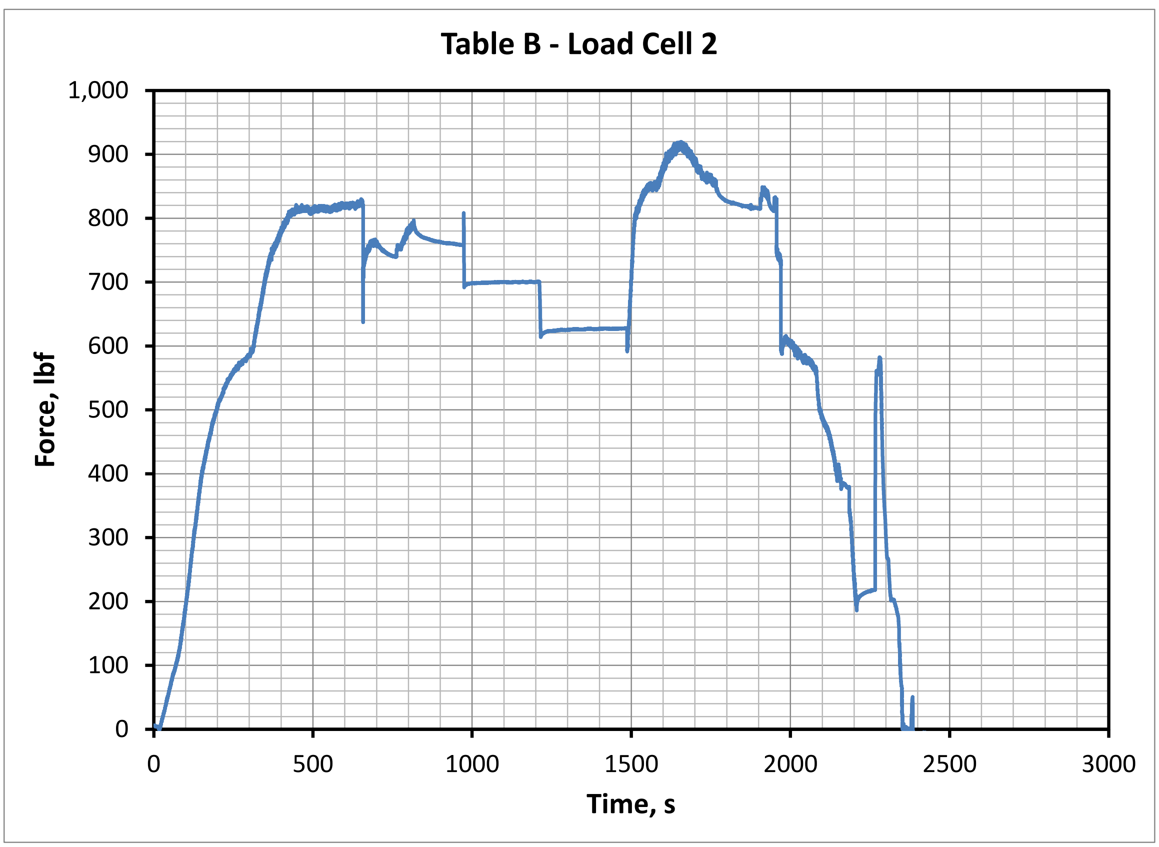


Table B - Load Cell 2
Force, lbf
1,000
900
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
Time, s

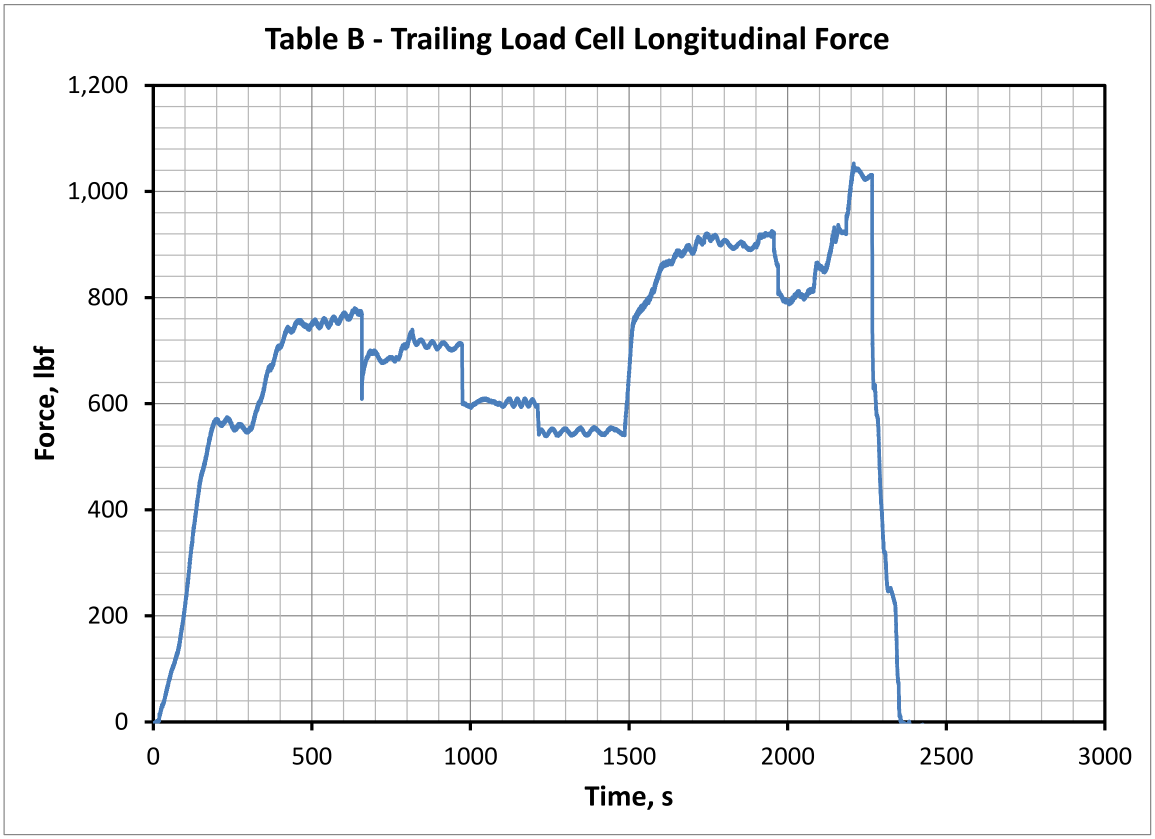


Table B - Trailing Load Cell Longitudinal Force
Force, lbf
1,200
1,000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
Time, s

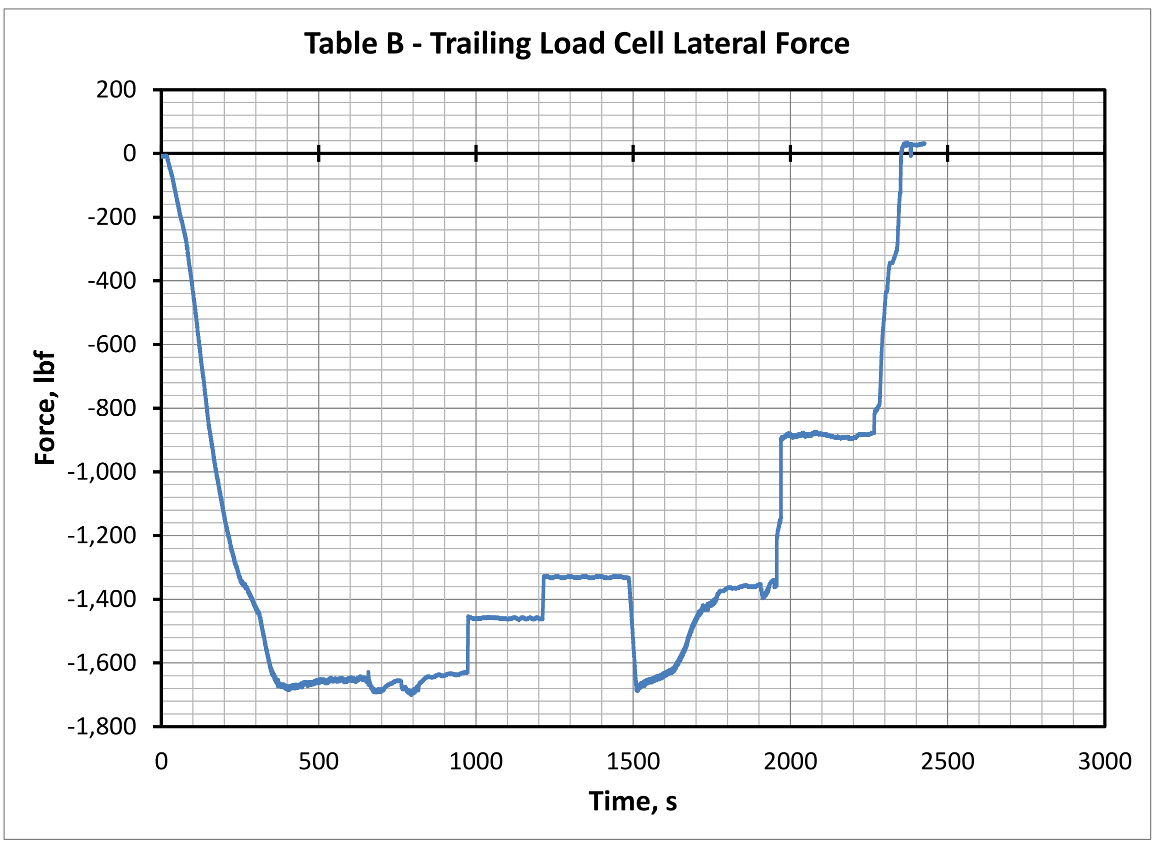


Table B - Trailing Load Cell Lateral Force
Force, lbf
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
0
500
1000
1500
2000
2500
3000
Time, s

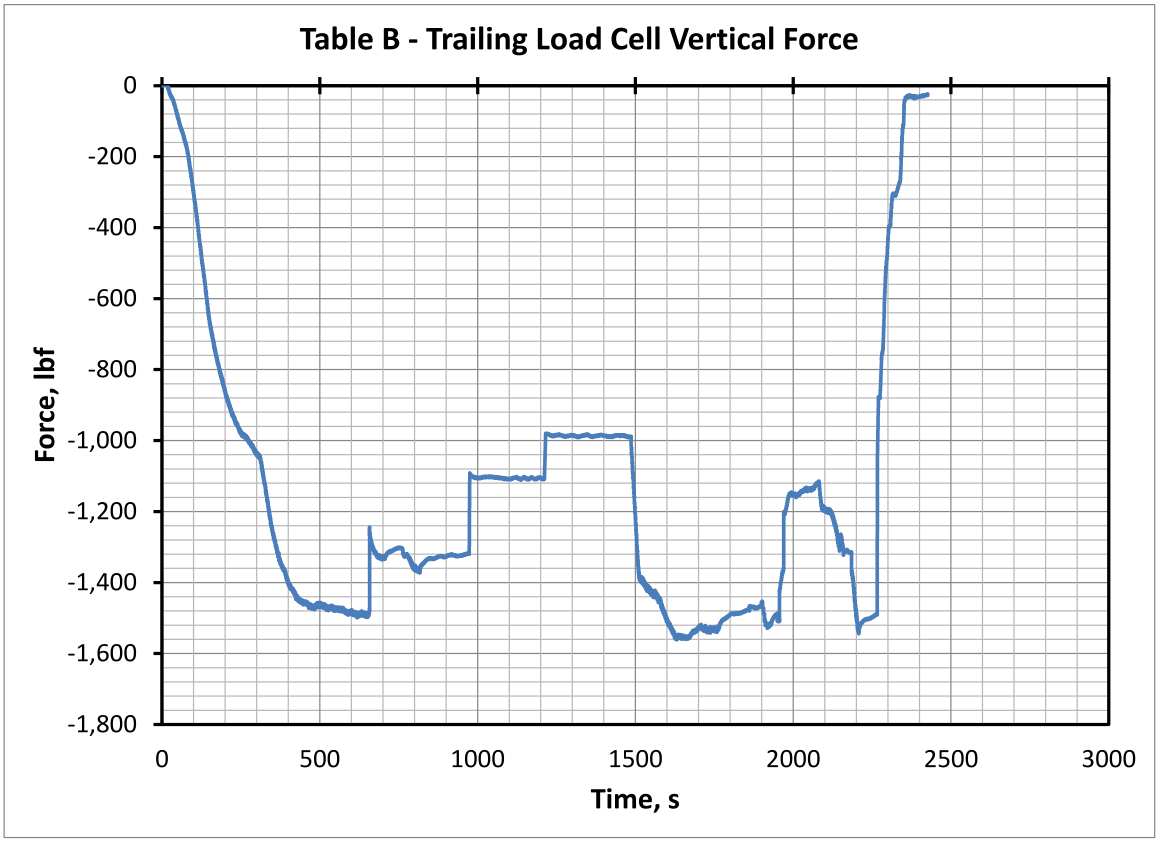


Table B - Trailing Load Cell Vertical Force
Force, lbf
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
0
500
1000
1500
2000
2500
3000
Time, s

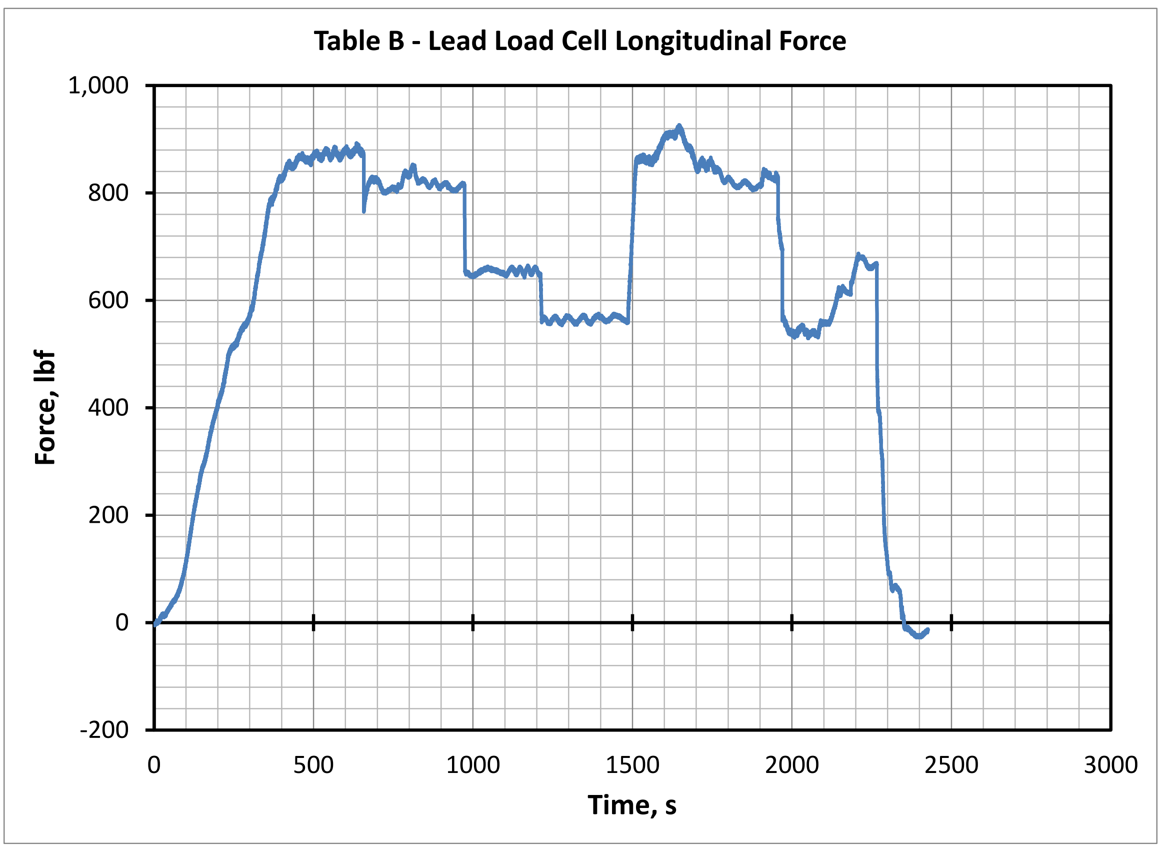


Table B - Lead Load Cell Longitudinal Force
Force, lbf
1,000
800
600
400
200
0
-200
0
500
1000
1500
2000
2500
3000
Time, s

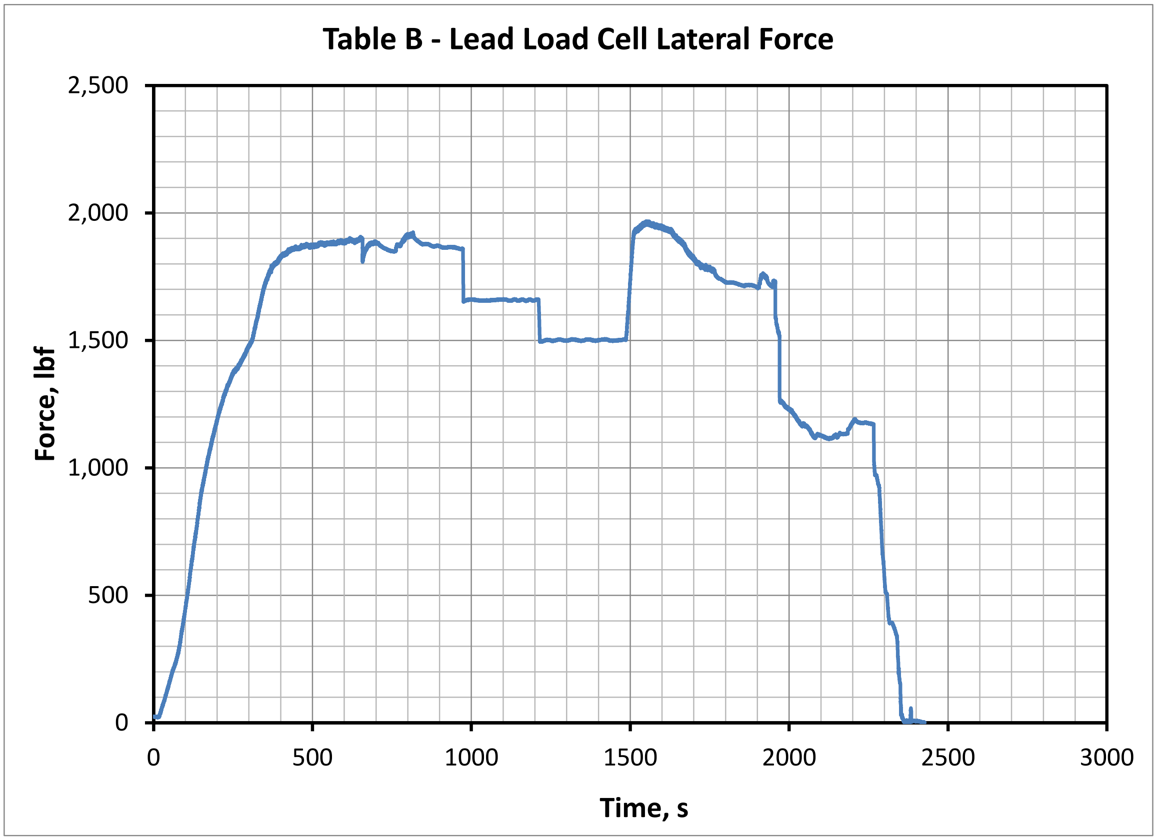


Table B - Lead Load Cell Lateral Force
Force, lbf
2,500
2,000
1,500
1,000
500
0
0
500
1000
1500
2000
2500
3000
Time, s

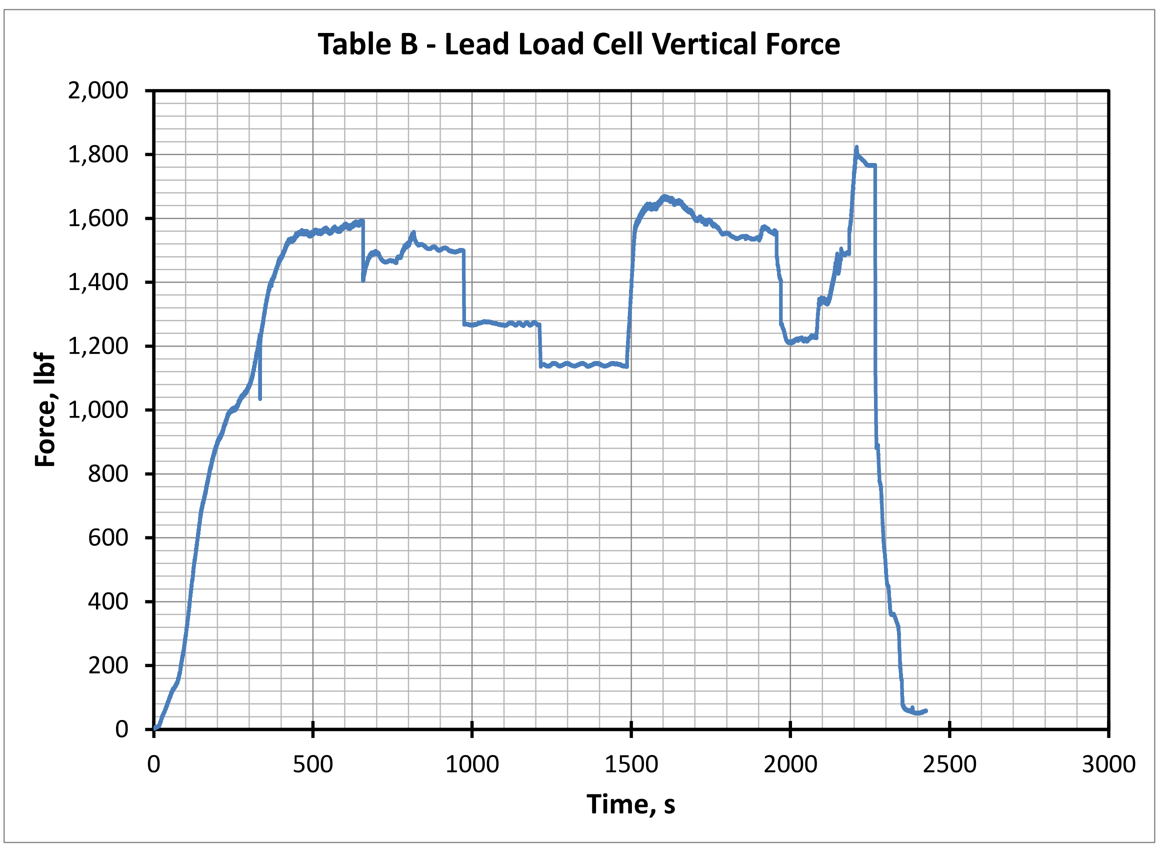


Table B - Lead Load Cell Vertical Force
Force, lbf
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
Time, s

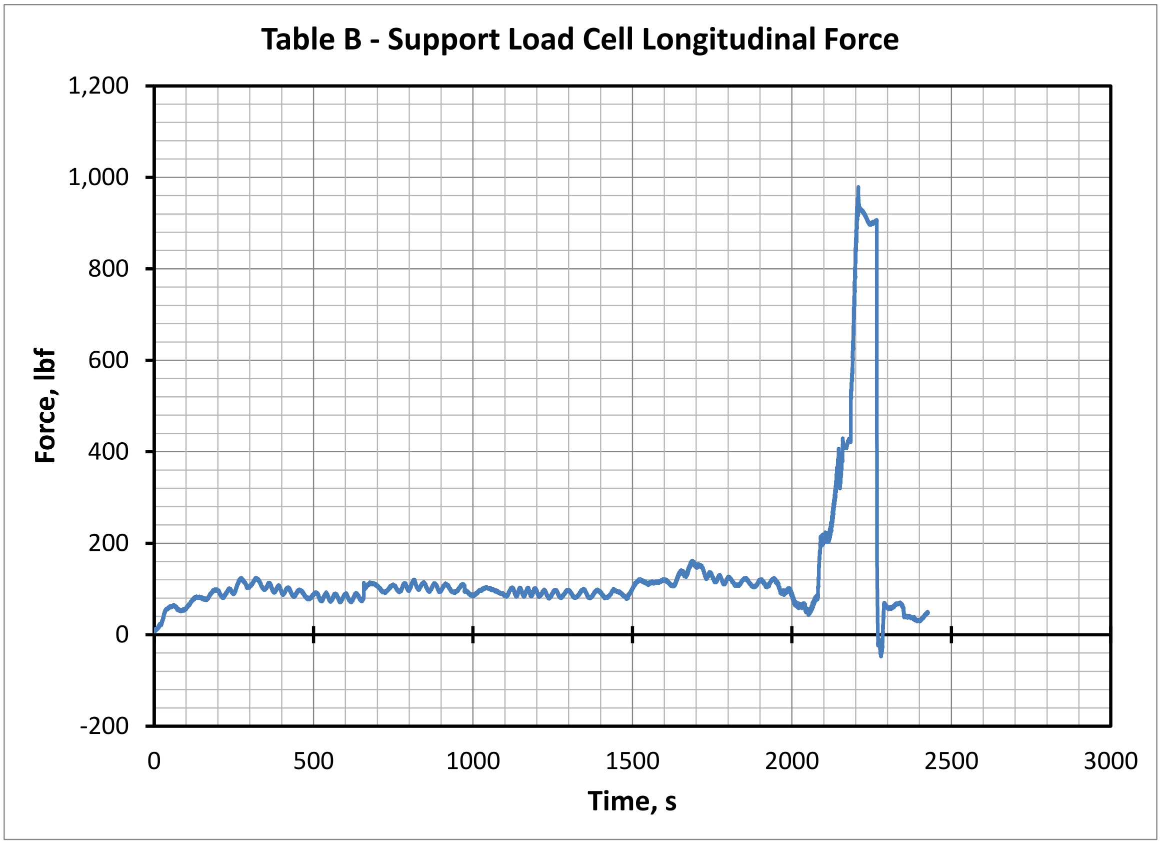


Table B - Support Load Cell Longitudinal Force
Force, lbf
1,200
1,000
800
600
400
200
0
-200
0
500
1000
1500
2000
2500
3000
Time, s

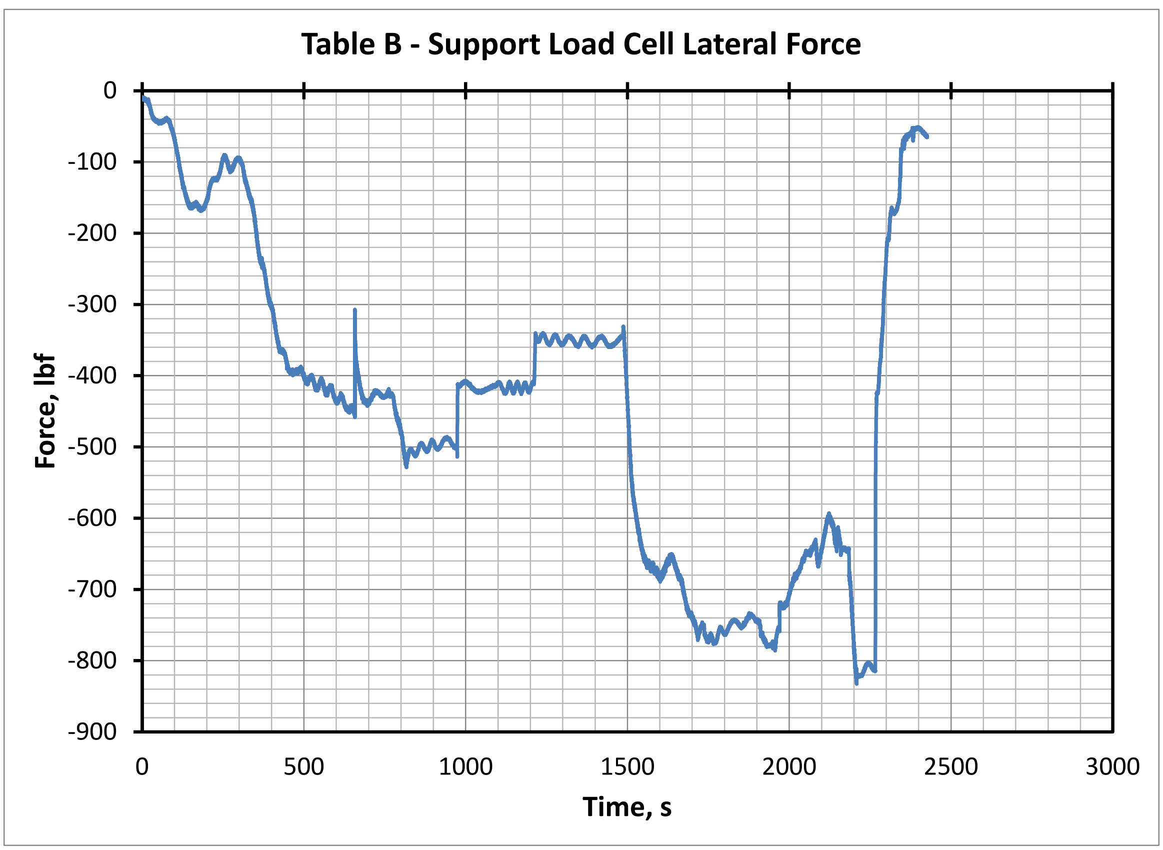


Table B - Support Load Cell Lateral Force
Force, lbf
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
0
500
1000
1500
2000
2500
3000
Time, s

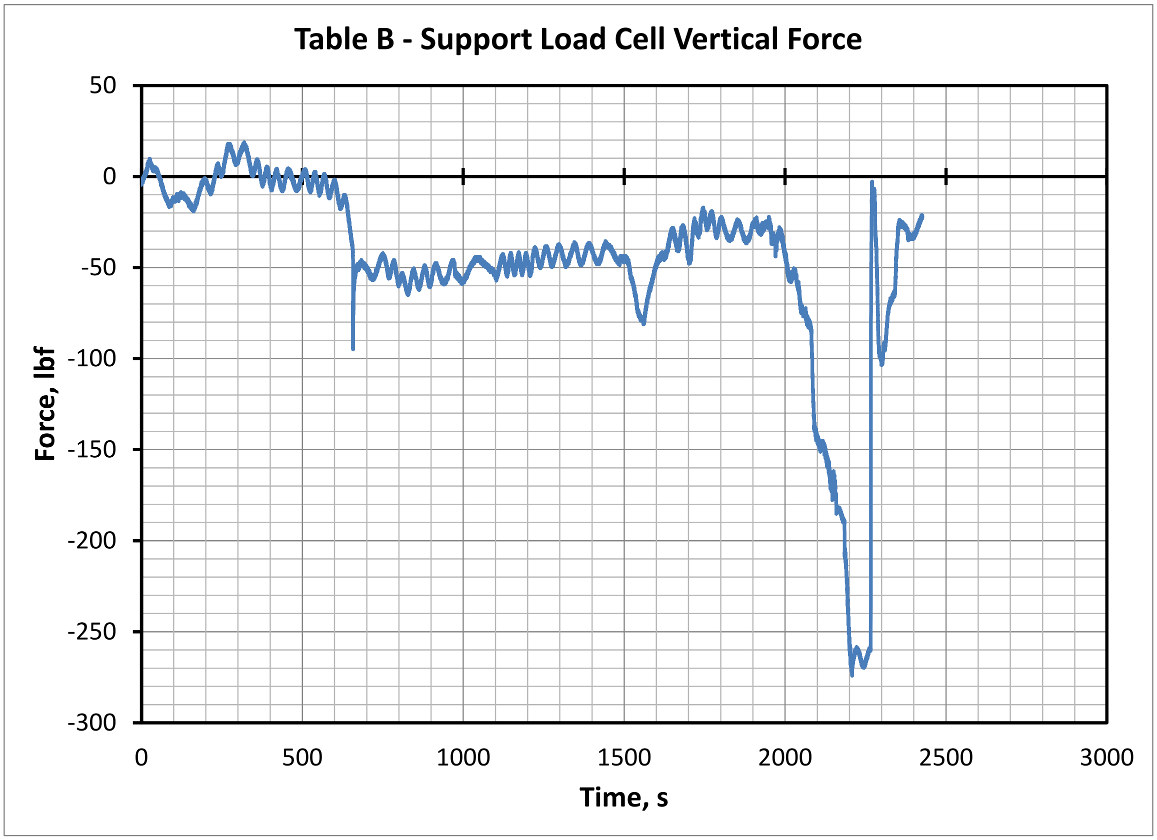


Table B - Support Load Cell Vertical Force
50
0
-50
-100
-150
-200
-250
-300
Force, lbf
0
500
1000
1500
2000
2500
3000
Time, s

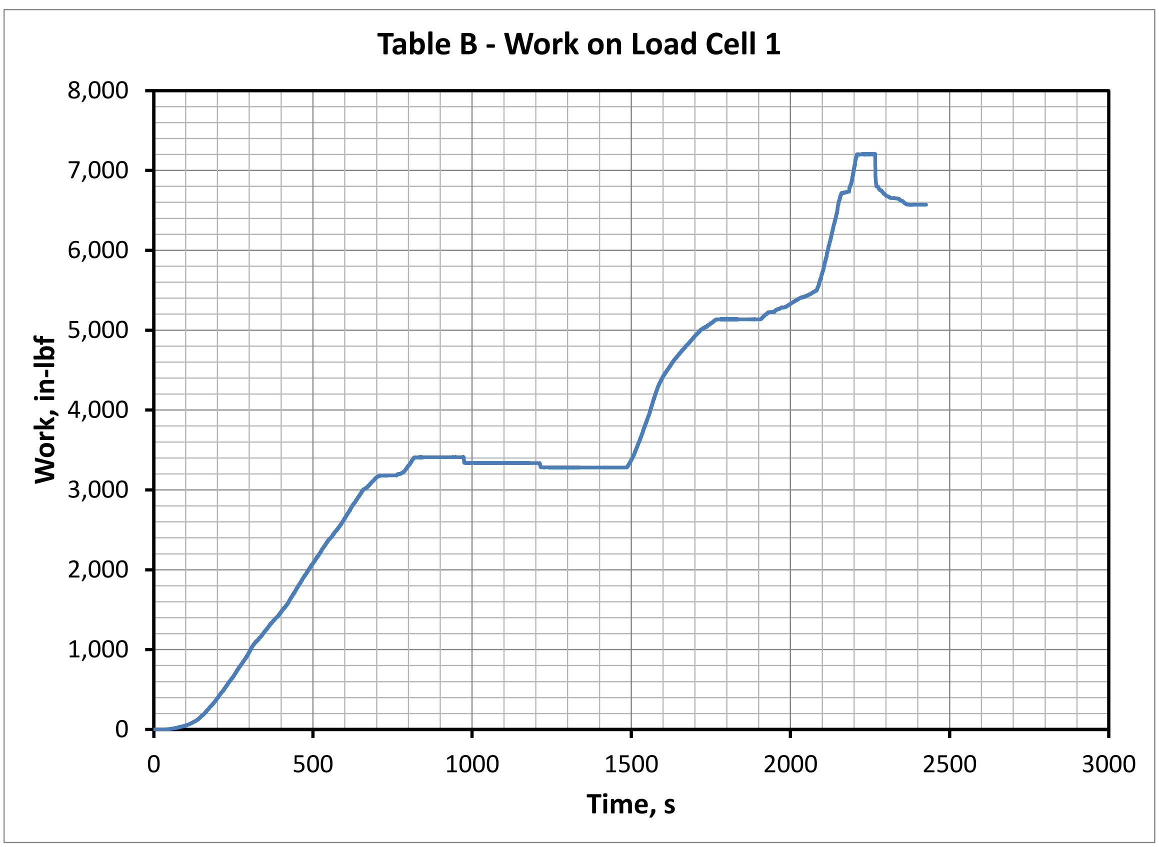


Table B - Work on Load Cell 1
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Work, in-lbf
0
500
1000
1500
2000
2500
3000
Time, s

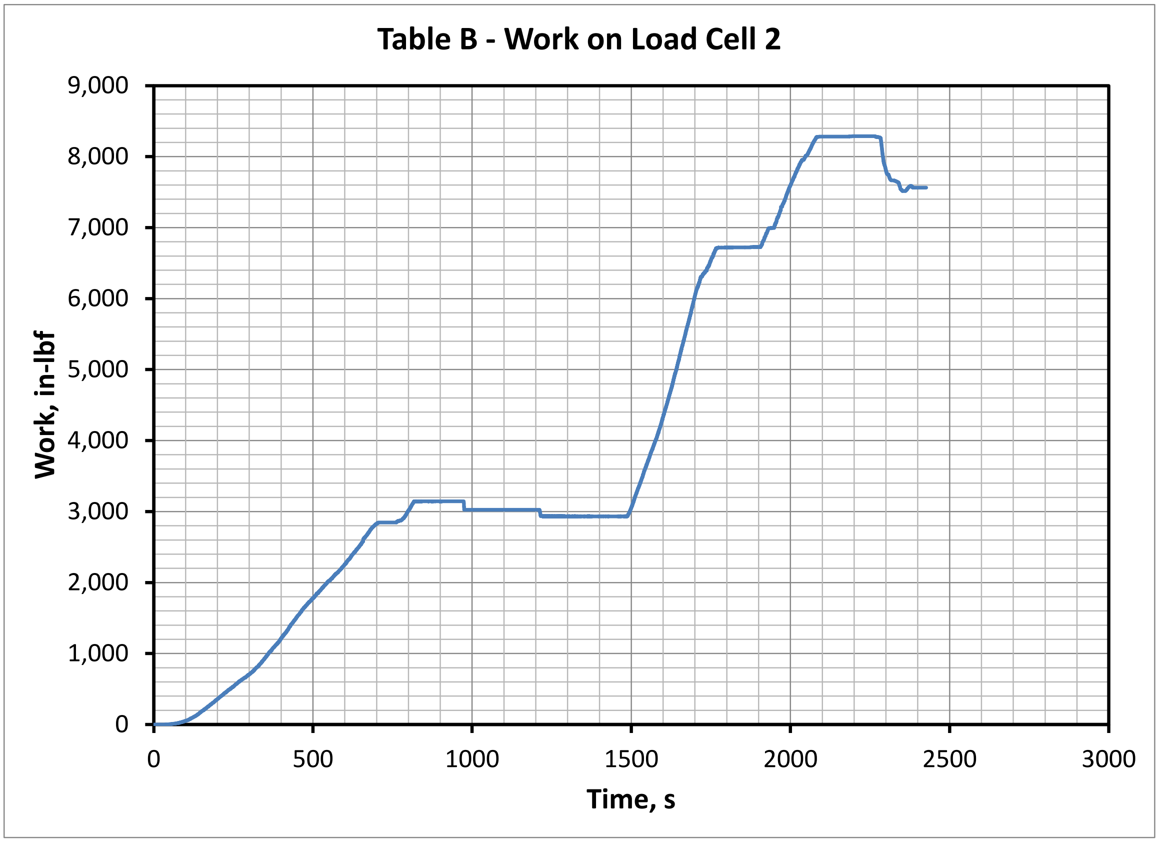


Table B - Work on Load Cell 2
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Work, in-lbf
0
500
1000
1500
2000
2500
3000
Time, s

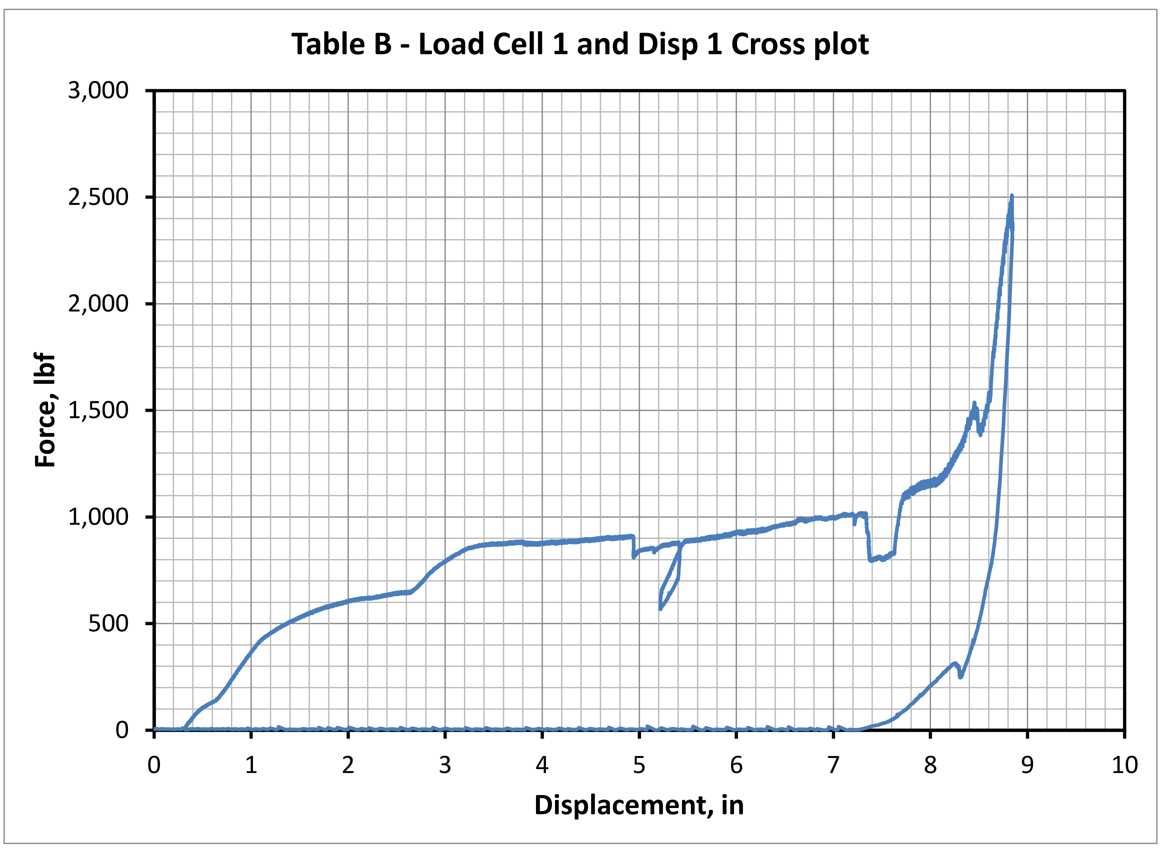


Table B - Load Cell 1 and Disp 1 Cross plot
3,000
2,500
2,000
1,500
1,000
500
0
Force, lbf
0
1
2
3
4
5
6
7
8
9
10
Displacement, in

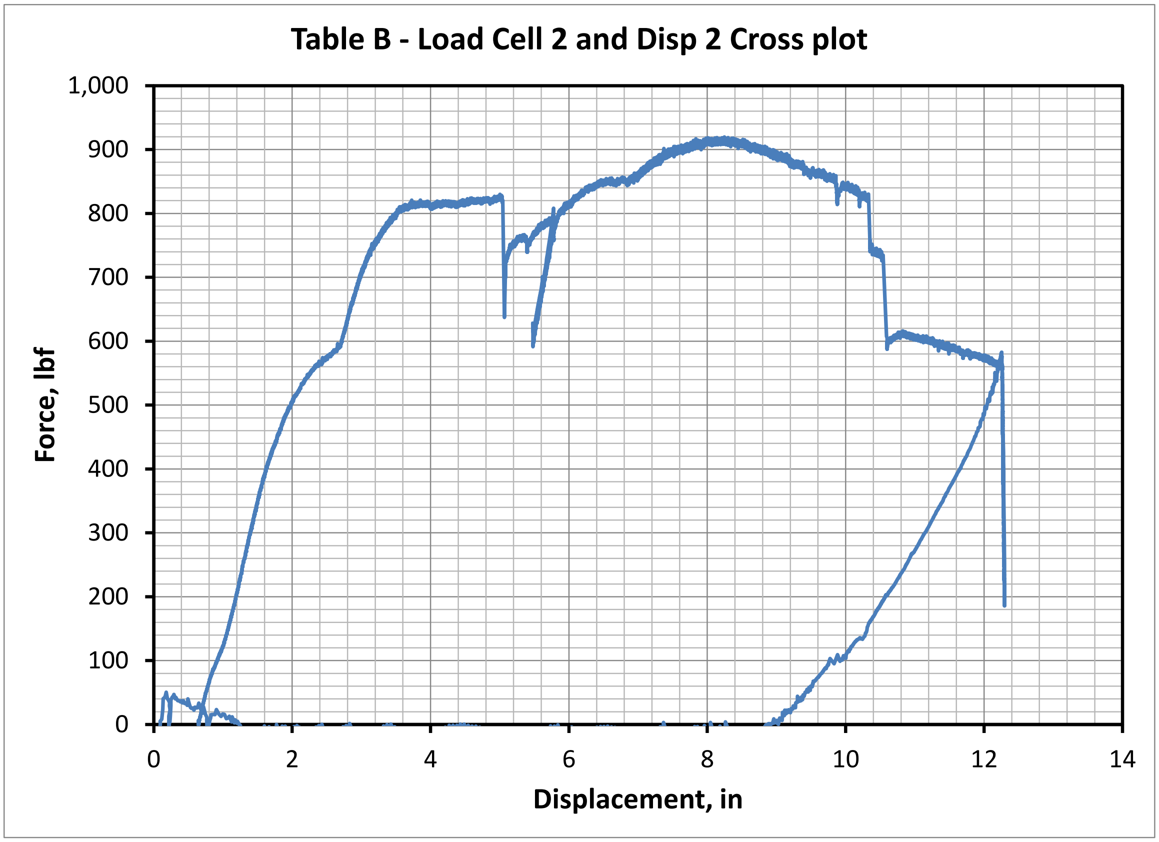


Table B - Load Cell 2 and Disp 2 Cross plot
Force, lbf
1,000
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
Displacement, in