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U.S. Department
of Transportation
**Federal Railroad
Administration**

SUPPLEMENTAL TESTS FOR TRACK PANEL SHIFT INVESTIGATIONS

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Development
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Draft Letter Report

INTRODUCTION

Volpe National Transportation Systems Center (VNTSC) has created a model to predict, among other things, panel shift behavior of track structure. A series of tests was performed in October 1998 by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), in conjunction with VNTSC to validate that model. Funds for these tests were jointly provided by the Federal Railroad Administration (FRA) and the AAR under the Vehicle Track Systems (VTS)–Vehicle/Track Performance Strategic Research Initiative.

The October 1998 tests were conducted at the Balloon Loop of the Transportation Technology Center (TTC), Pueblo, Colorado, using TTCI's Track Loading Vehicle (TLV). This series consisted of two repeated passing panel shift tests. The tests were run at a speed of 5 mph over concrete ties. These runs helped to augment previous tests (July and September 1998) for FRA Task Order 102, Modification #8, Test Support for Track Stability Investigations.

After the September TLV tests for Task Order 102 were completed, a question was raised as to the accuracy of the TLV loads. Thus, the TLV was brought into the Rail Dynamics Lab (RDL) at TTC on October 6, 1998 to examine the accuracy of both the vertical and lateral forces using the Mini-shaker Unit (MSU) calibrated rail bars.

In addition, two types of panel shift trial tests were completed July 1998 at two locations (Sections 29 and 3) of the High Tonnage Loop (HTL). The first evaluation was a stationary test measuring tie/ballast coefficient of friction. The second was a repeated passing test designed to measure lateral track deformation. In this latter test, the TLV applied constant vertical and lateral loads while traveling over the test zone at approximately 5 mph. Section 29 of the HTL is a tangent track with wood ties and Section 3 is a 6-degree curve which includes sections with concrete ties. Testing in

Section 3 was performed such that the track was pushed toward the outside of the curve. These tests support the work planned under FRA Task Order 102.

OBJECTIVE

Volpe National Transportation Systems Center (VNTSC) has been developing a model to predict, among other things, track panel shift behaviors. At the request of the FRA, part of the VTS program is to validate this model. The following tests were conducted for this purpose.

- Tie/Ballast resistance under lateral loading and unloading using single tie push tests (STPTs)
- The nonlinear friction coefficient between loaded ties and ballast
- Vertical foundation modulus
- Track shift behavior for wood and concrete tie track with continuous welded rail during repeated passes of controlled axle loading

The tests discussed in this report have provided VNTSC with data for track shift behavior and nonlinear friction coefficients.

PROCEDURES

Supplemental Panel Shift Tests

TTCI used the TLV to perform a series of supplemental repeated passing tests on predetermined sections of track in the Balloon Loop. These repeated passing tests were performed on two concrete tie sections that were tamped shortly before testing. These sections, Sections 3 and 7, were used previously under Task Order 102 testing. The TLV team worked in cooperation with VNTSC technical staff over a two-day test period. The two tests were as follows:

- Oct. 27, 1998 - Balloon Loop Zone 3: 0.5 L/V, 27,500-pound (27.5-kip) lateral load, 55-kip vertical axle load; 44 passes
- Oct. 28, 1998 - Balloon Loop Zone 7: 0.6 L/V, 33-kip lateral load, 55-kip vertical axle load; 55 passes

The wayside track instrumentation consisted of eight linear variable differential transformers (LVDTs) spaced three ties apart in a 60-foot test zone. The test zone was divided up into three parts. The first 20-feet was used to ramp-up the lateral load while the TLV was in-motion before the first LVDT. The next area was the 60-foot test zone. The final 20-feet was used to ramp-down the lateral loads. The LVDTs were placed on the end of the ties opposite of the push direction. Displacement of the affected ties was measured as the ties were pushed away from the respective LVDT, both as the TLV passed directly over the affected tie(s) (dynamic deflection) and after the TLV had passed the test zone completely (residual deflection).

The instrumentation crew also documented the longitudinal force and temperature for both rails. The collected data was analyzed for plotting and post-processing of the dynamic and residual deflection data only.

Four-post-test single tie push tests (STPTs) were performed in each zone, two in the ramp-up and two in the ramp-down areas. Thermal loads (longitudinal) for both the inside and outside rails were within the prescribed ranges.

Weather conditions on the first day of testing (October 27, 1998) included rain just prior to testing and light rain during test runs 20 to 33.

Data from each LVDT was plotted as a group for each test zone for dynamic and residual deflection modes.

TLV Force Verification Tests

After completion of the September tests for Task Order 102, questions were raised concerning the TLV vertical and lateral loads and verification was necessary. Therefore, on October 6, 1998 the TLV was brought into TTC's Rail Dynamics Lab (RDL) to examine the accuracy of both the vertical and lateral forces.

The instrumentation used to verify the forces were two loading rails equipped with strain gages in both the vertical and lateral planes. These loading rails had been calibrated the day before testing began. The instrumented rails were mounted on a 2-inch thick steel plate and were bolted to the floor underneath the TLV load bogie. (See Figure X). The TLV load bogie was then positioned directly over the fixture and the wheel set was lowered onto the loading rails. The instrumented rail outputs were connected to the TLV's data collection system and zeroed while the bogie wheel set was in the air (no load).

Verification tests were performed in the following order:

- Vertical loads ramped from 0 to 50 kips (lateral force = 0)
- Vertical force kept at 27.5 kips per wheel, lateral loads ramped from 0 to 30 kips
- Vertical force kept at 45 kips per wheel, lateral loads ramped from 0 to 30 kips

The data was analyzed and plotted to show the graphical representation of the measured forces (instrumented rails) versus the applied forces (TLV). Graphs were also made showing the effect of the increasing lateral load on the constant vertical loads. A final graph was made showing the small vertical to lateral crosstalk inherent in the instrumented rails.

Preliminary Tie/Ballast Friction Coefficient Tests

These early trial tests were performed in June and July 1998 to develop the test method and hardware needed for performing the tie/ballast friction coefficient tests. After moving over a test zone, the rail between the TLV end trucks was cut and removed (Figure 1). The ballast shoulder was removed from the sides of all test ties. Each test tie was separated by one undisturbed tie. A wood tie test fixture, consisting of a steel switch plate approximately 8 feet long with two 10-inch, 136-pound rail sections clamped to it at a distance of 52 1/2 inches apart, was developed to allow the TLV to perform a lateral push on a single tie with varying vertical loads without risk of rail rollover.

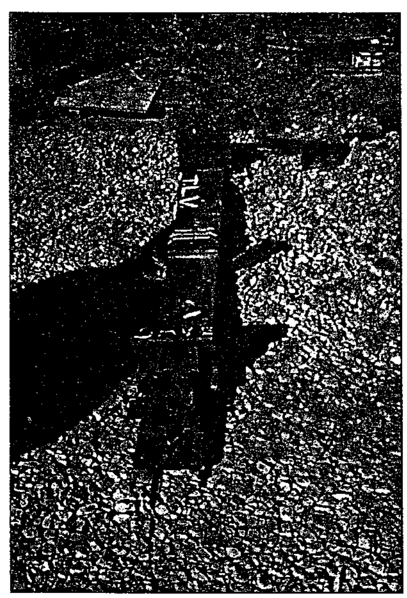


Figure 1. Tie Fixture Bolted to Wood Ties

In Section 29, the wood tie test fixture was fastened to the tie with screw spikes before each individual push. In Section 3, the concrete ties allowed two 10-inch, 136-pound rail sections to be fastened to the ties using only Pandrol clips, without the switch plate. This method was satisfactory below 20,000 pound vertical loads. At this vertical load, the TLV load bogie rolled the rail and derailed before the test was completed.

After the tie fixture was in place, the TLV load bogie was centered on the test tie, and the specified vertical load was applied. Starting at no-load, the lateral load was increased by 100 pounds per second. Displacement of the tie was measured by a wayside LVDT located on the end of the tie opposite of the push direction. The LVDT output signal was fed back to the TLV control program to stop the load application once the test tie displacement reached 2 inches. A total of six ties were tested with two tests being conducted at each of the following vertical loads:

- 5,000-pound vertical load
- 10,000-pound vertical load
- 20,000-pound vertical load

Preliminary Repeated Passing Tests

As with the friction coefficient trials, initial repeated passing tests were performed at the HTL to prepare for Task Order 102 work. Each repeated passing track panel shift test was conducted over a 100-foot long test section. Automatic location detectors (ALDs) were placed in the following locations:

- 20 feet before the beginning of the test section
- Beginning of the test section (LVDTs)
- Center of the test section (LVDTs)
- End of the test section (LVDTs)

The TLV was pulled over the test section at approximately 5 mph applying the specified constant vertical and lateral loads. The lateral force was ramped up from zero to the specified L/V and reached the required load before the first ALD was detected. Once the last ALD was detected, the lateral and vertical loads were ramped down to zero.

For this test, a total of 10 LVDTs, dispersed evenly throughout the test zone, were installed to measure lateral tie displacement. The LVDTs were placed on the end of the ties opposite of the push direction. A total of three zones were tested in each section with each of the following lateral/vertical load combinations:

- 55-kip vertical, 22-kip lateral load (0.4 L/V)
- 55-kip vertical, 33-kip lateral load (0.6 L/V)
- 50-kip vertical, 40-kip lateral load (0.8 L/V)

Each test consisted of 15 to 30 passes with the exception of the 0.8 L/V runs which exceeded the 0.5-inch displacement limits in under 10 runs.

RESULTS

See the appendix for results. The test data collected during these tests have been forwarded to VNTSC for further analysis.

APPENDIX

A-1: SUPPLEMENTAL PANEL SHIFT TEST RESULTS

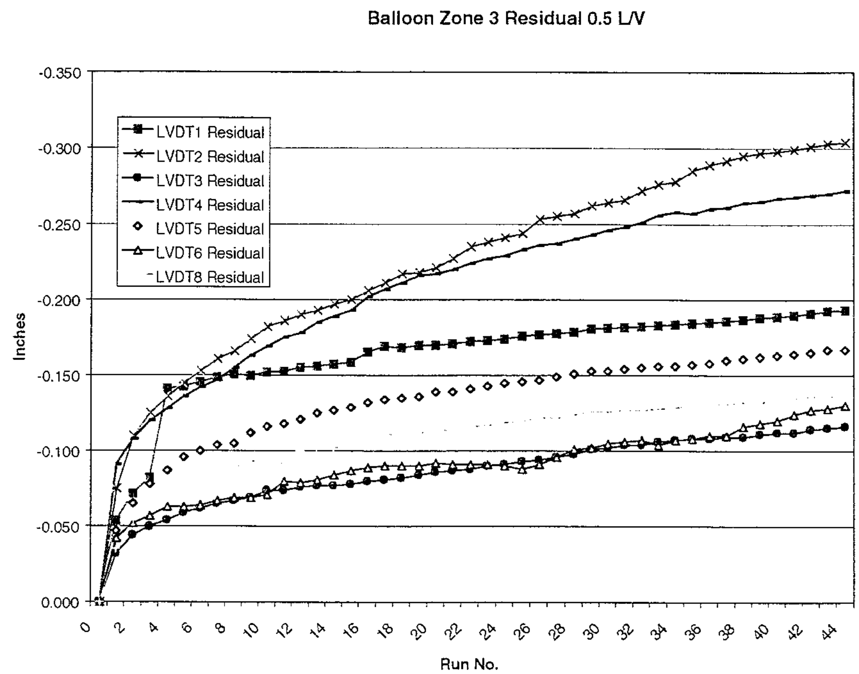


Figure A1. Cumulative Residual Deformation; Balloon Zone 3 55-kip Vertical Load, 27.5-kip Lateral Load (0.5 L/V)

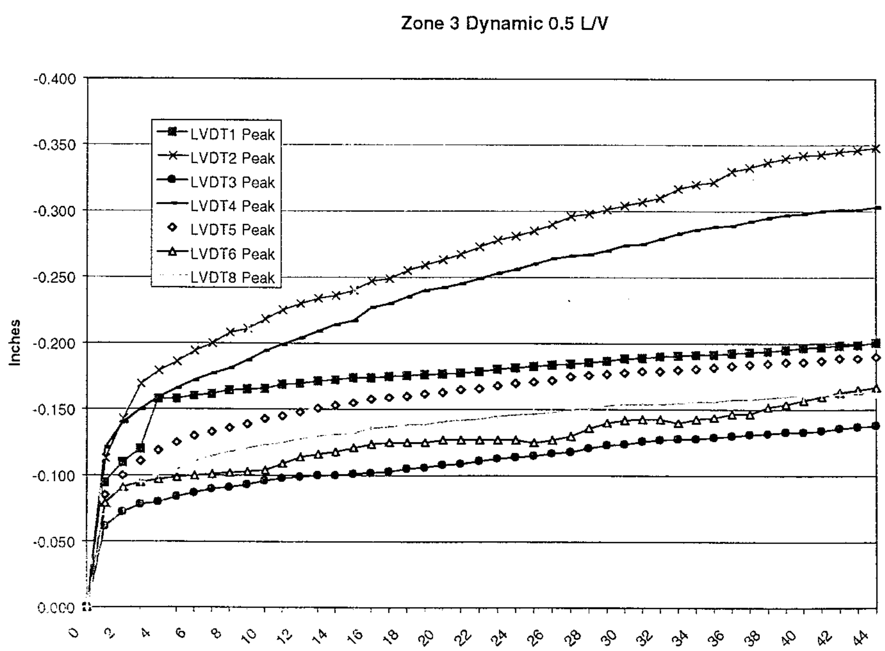


Figure A2. Cumulative Peak Deformation; Balloon Zone 3 (0.5 L/V)

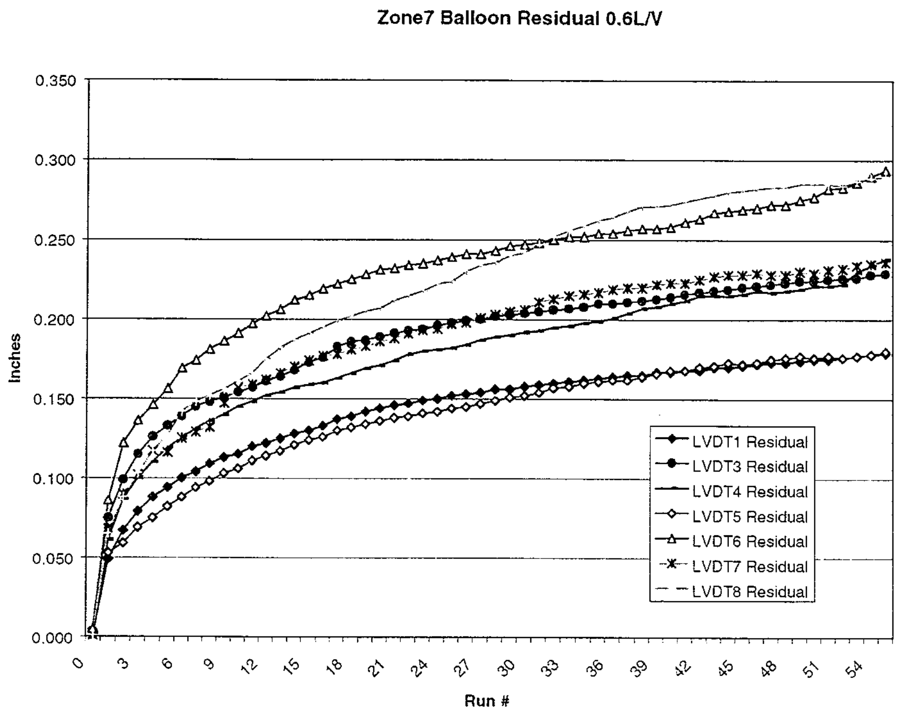


Figure A3. Cumulative Residual Deformation; Balloon Zone 7 55-kip Vertical Load, 33-kip Lateral Load (0.6 L/V)

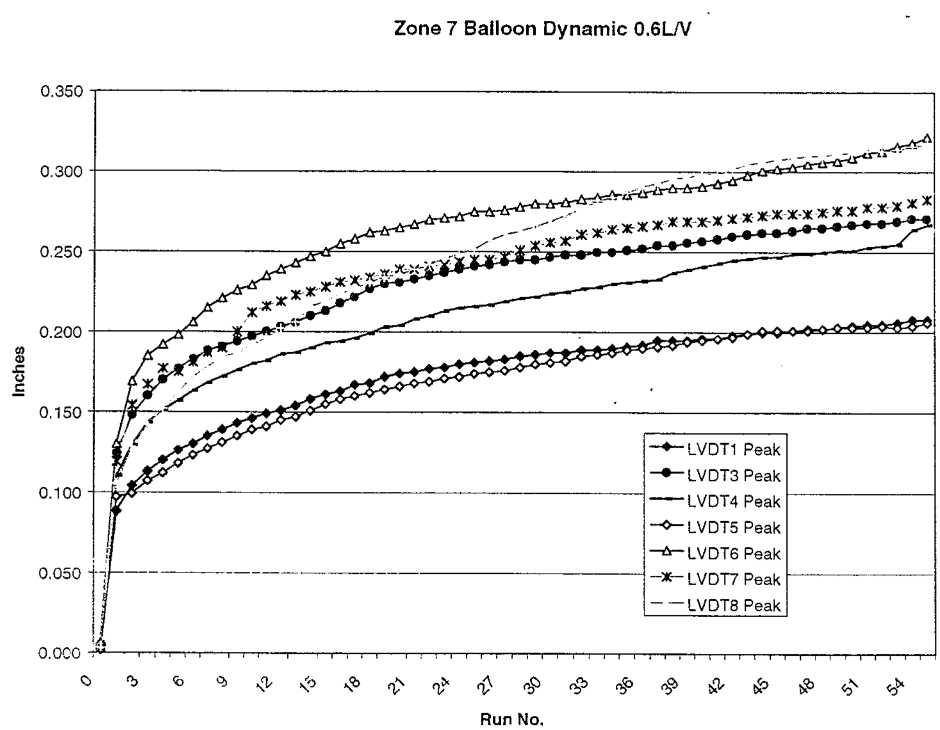


Figure A4. Cumulative Peak Deformation; Balloon Zone 7

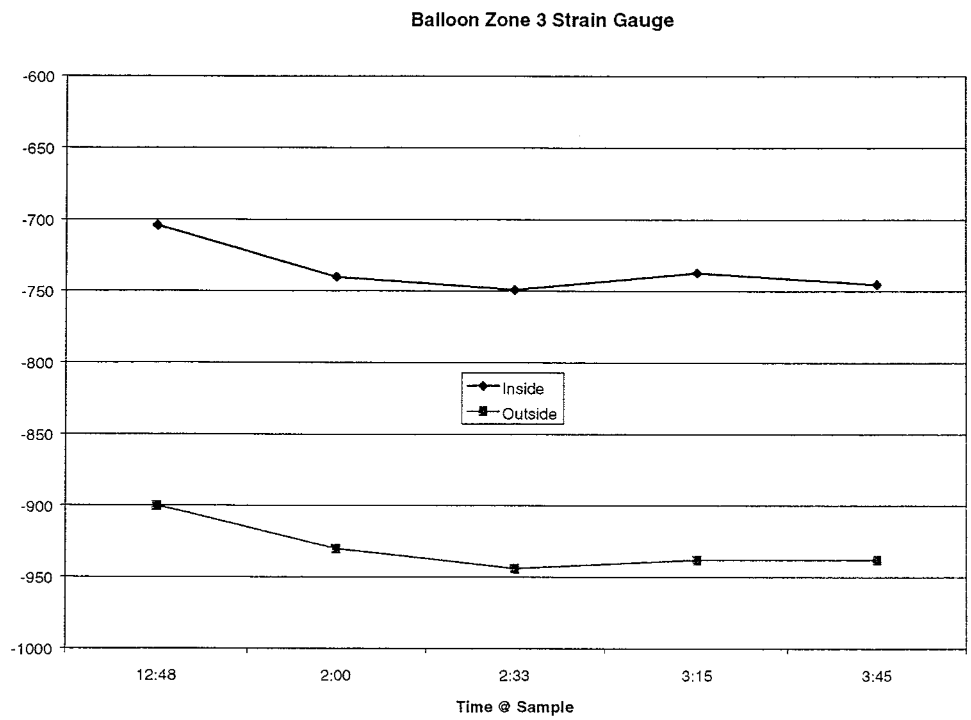


Figure A5. Longitudinal Force; Balloon Zone 3

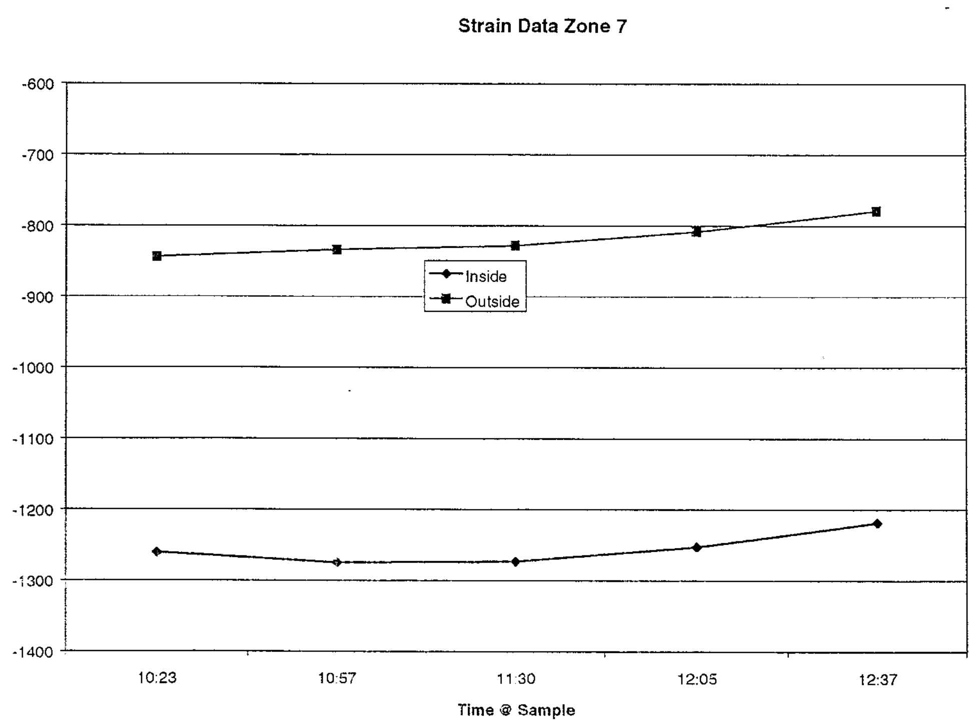
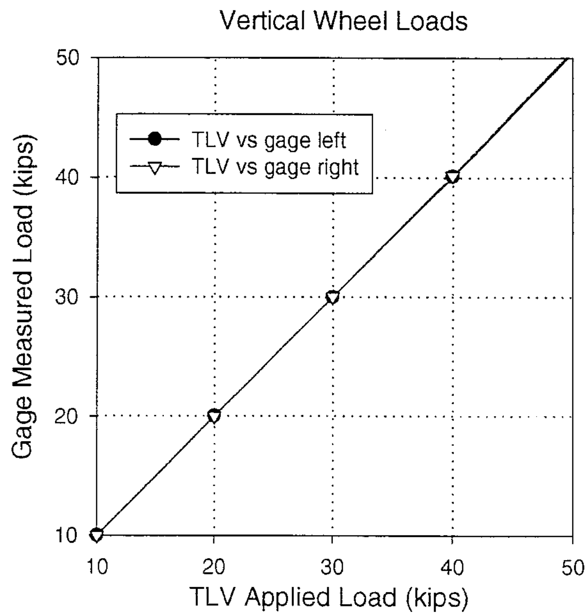


Figure A6. Longitudinal Force; Balloon Zone 7

A-2: TLV FORCE VERIFICATION TEST RESULTS



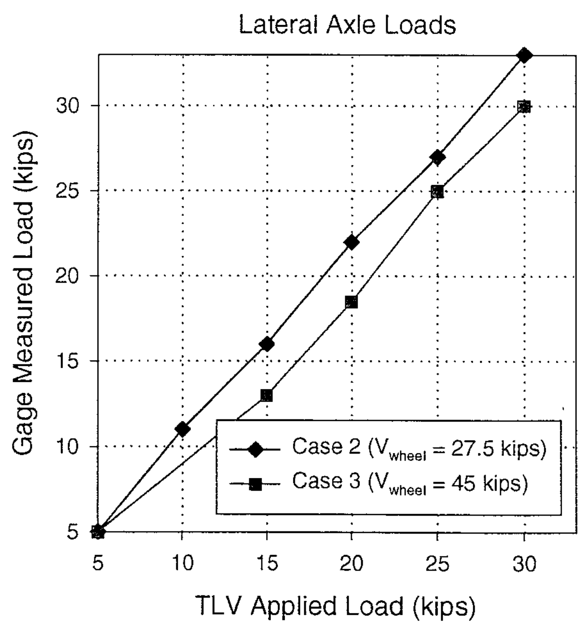


Figure A7. Summary of Vertical and Lateral Load Check-out Results

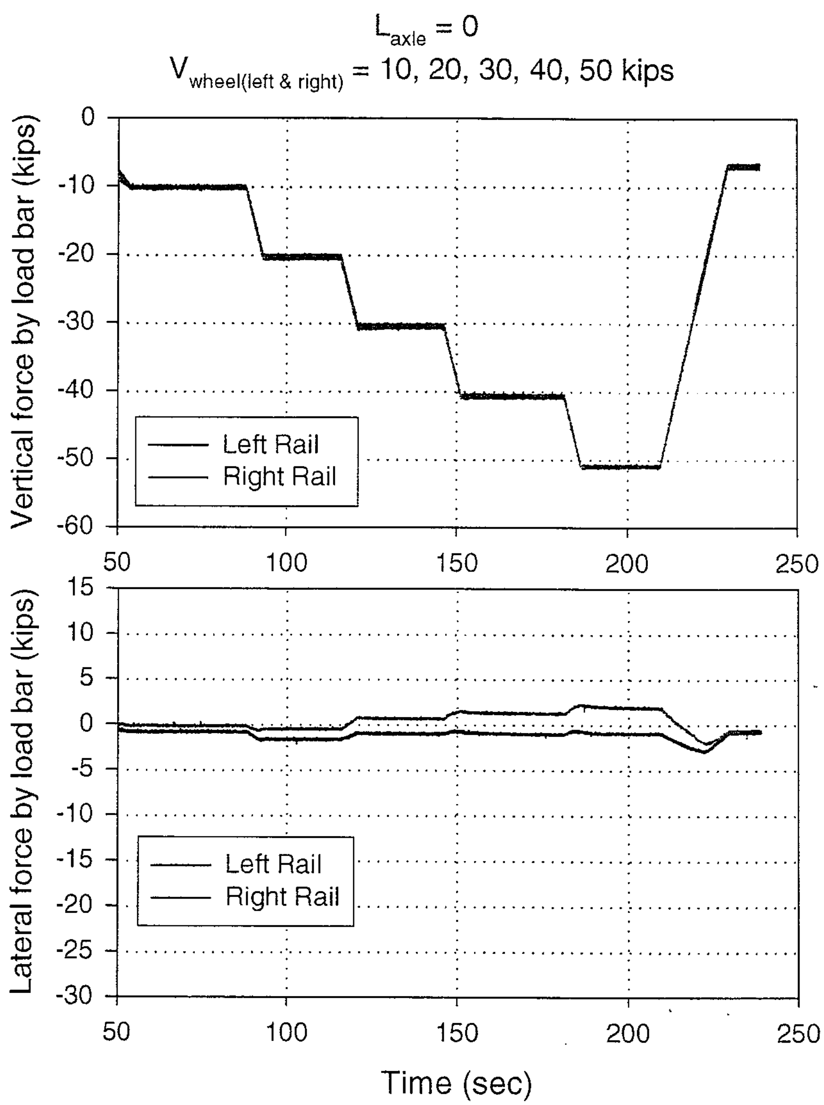


Figure A8. Case 1, TLV Applied Loads

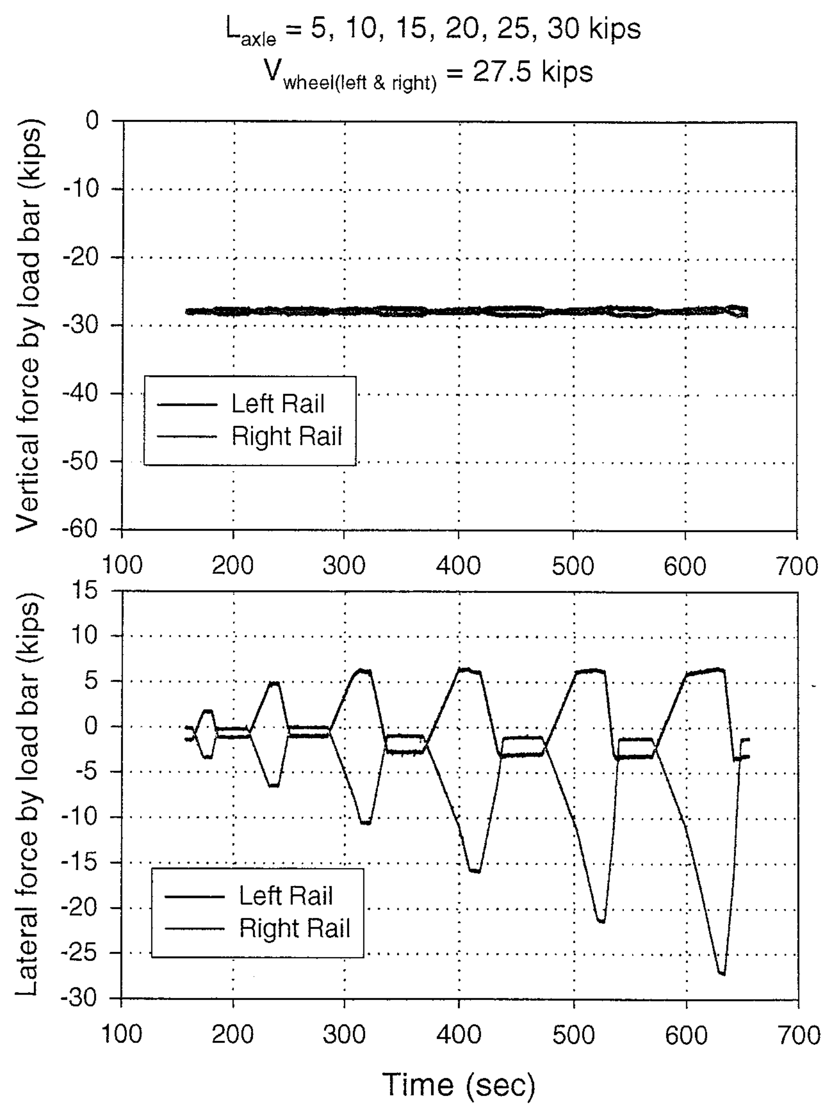


Figure A9. Case 2, TLV Applied Loads

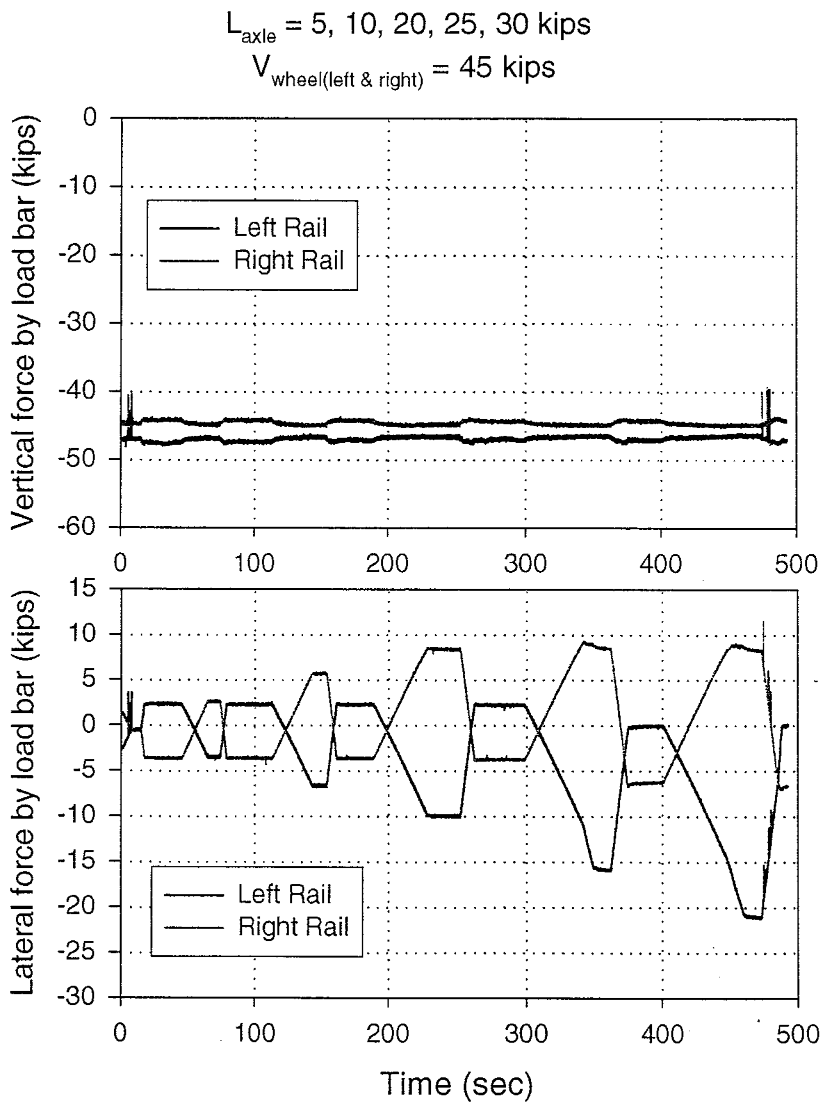


Figure A10. Case 3, TLV Applied Loads

A-3: PRELIMINARY TIE/BALLAST FRICTION COEFFICENT TEST RESULTS

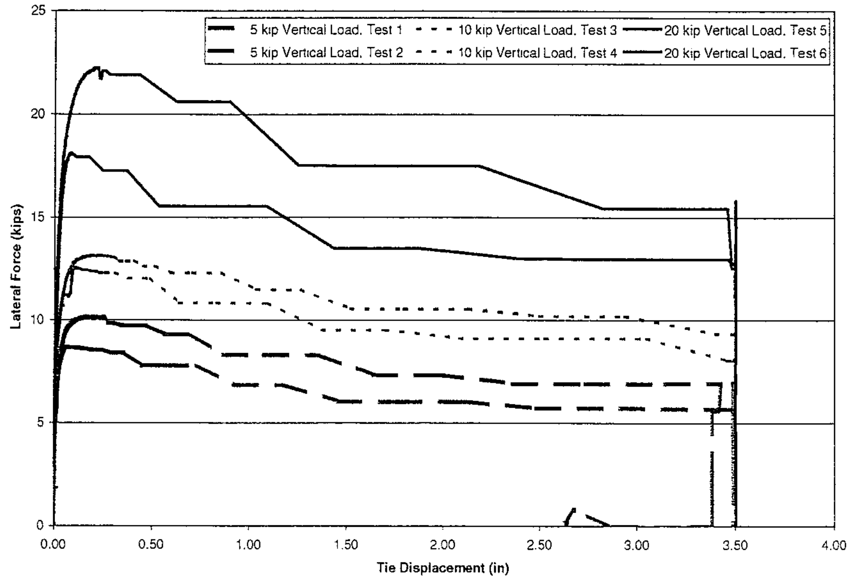


Figure A11. Displacement/Force Plot, HTL Section 3

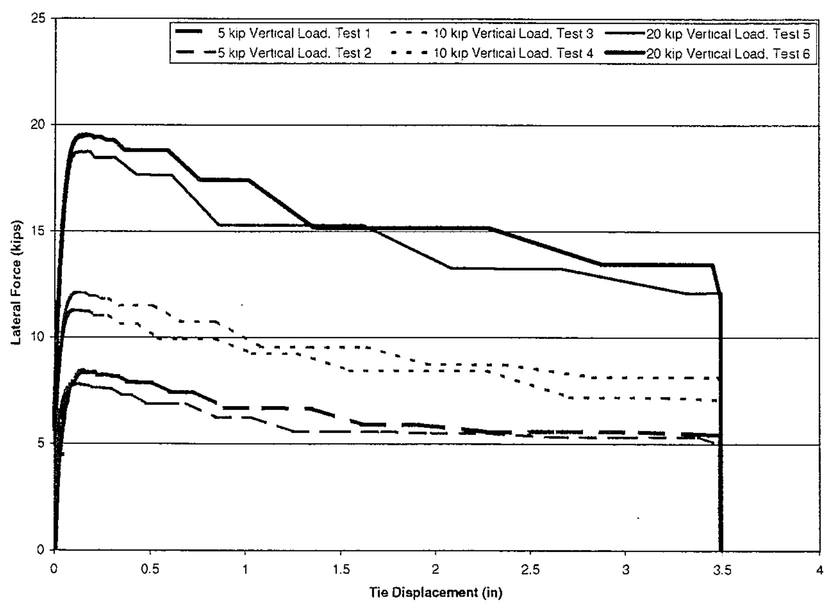


Figure A12. Displacement/Force Plot, HTL Section 29

A-4: PRELIMINARY REPEATED PASSING TEST RESULTS

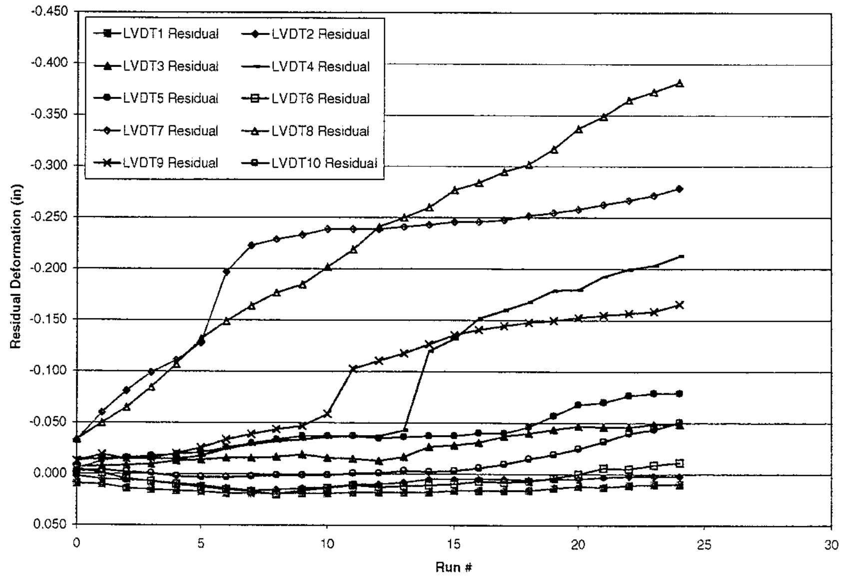


Figure A13. Cumulative Residual Deformation
HTL Section 3, 55-kip Vertical Load, 22-kip Lateral Load (0.4 L/V)

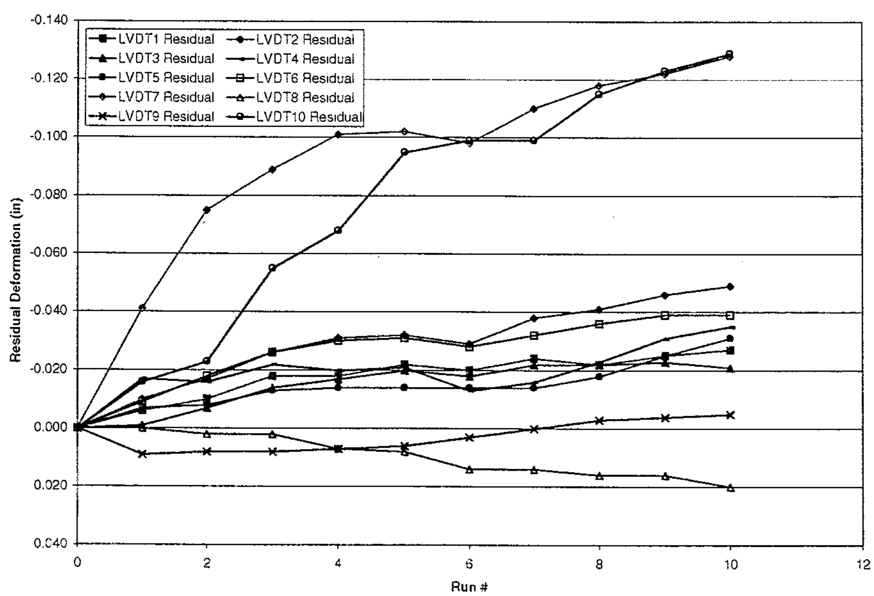


Figure A14. Cumulative Residual Deformation
HTL Section 29, 50-kip Vertical Load, 40-kip Lateral Load (0.8 L/V)

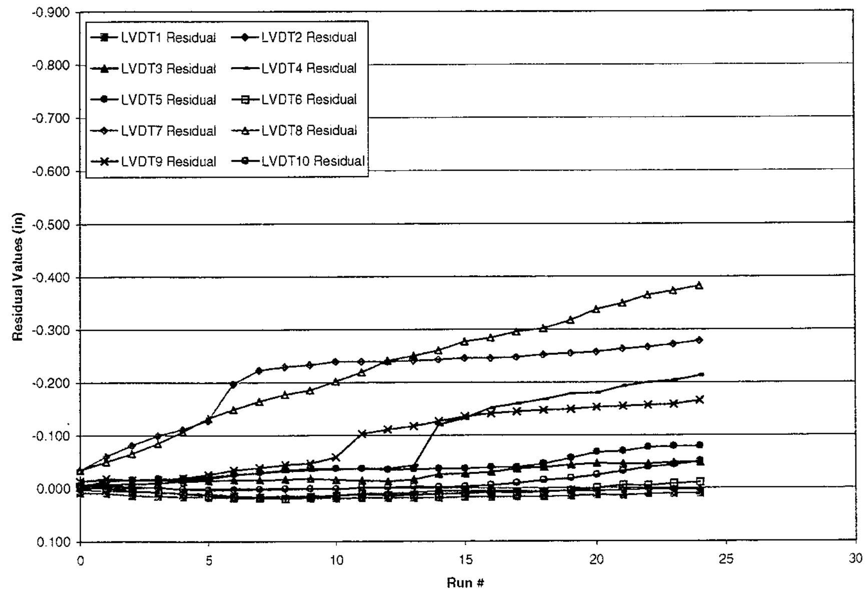


Figure A15. Cumulative Residual Deformation
HTL Section 3, 55-kip Vertical Load, 22-kip Lateral Load (0.4 L/V)

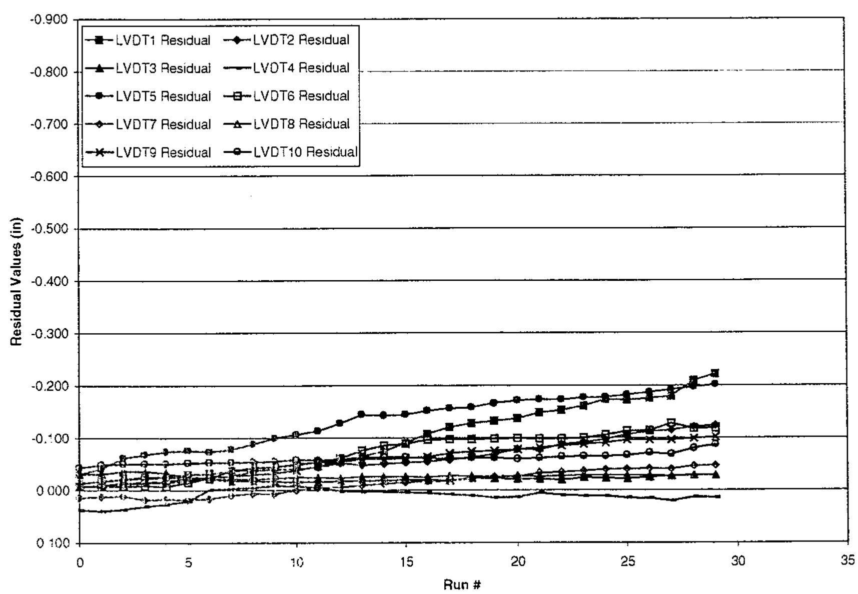


Figure A16. Cumulative Residual Deformation
HTL Section 3, 55-kip Vertical Load, 33-kip Lateral Load (0.6 L/V)

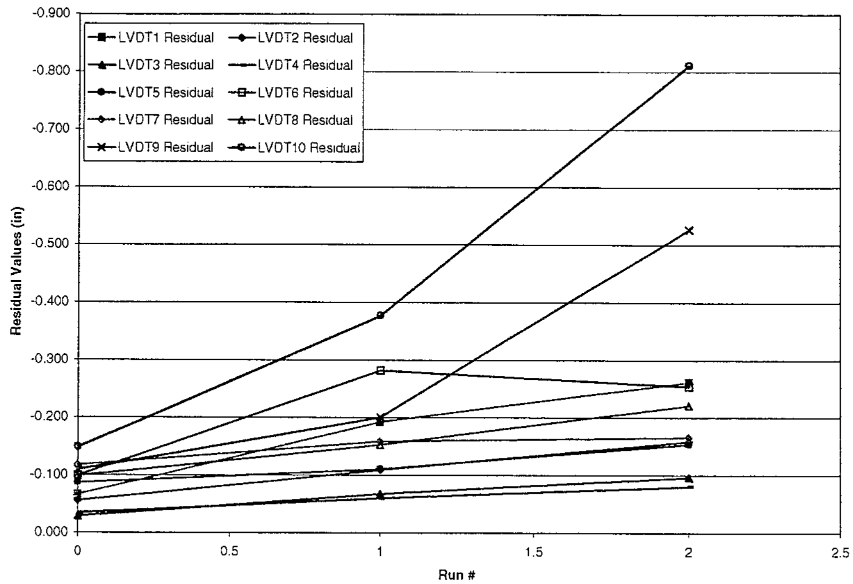


Figure A17. Cumulative Residual Deformation
HTL Section 3, 50-kip Vertical Load, 40-kip Lateral Load (0.8 L/V)

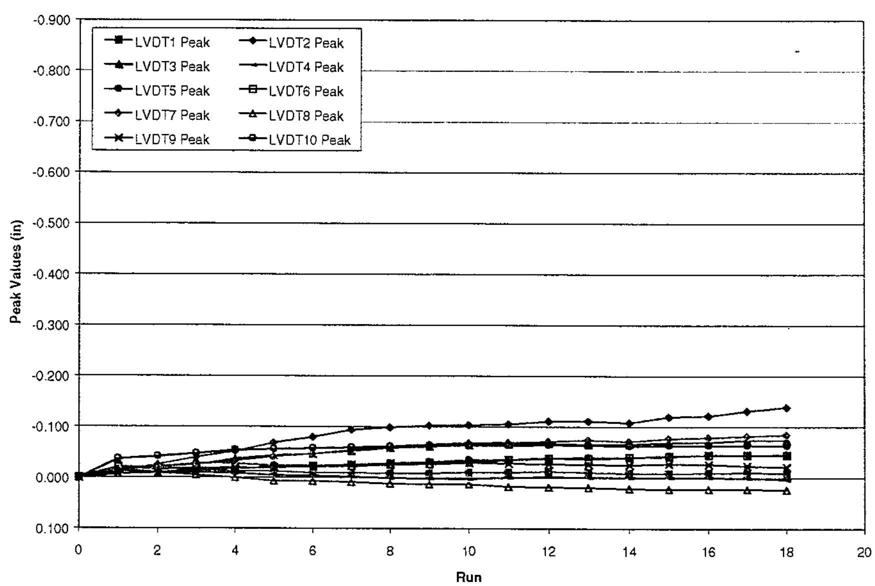


Figure A18. Cumulative *Peak Deformation
HTL Section 29, 55-kip Vertical Load, 22-kip Lateral Load (0.4 L/V)
***No Residual Data Available**

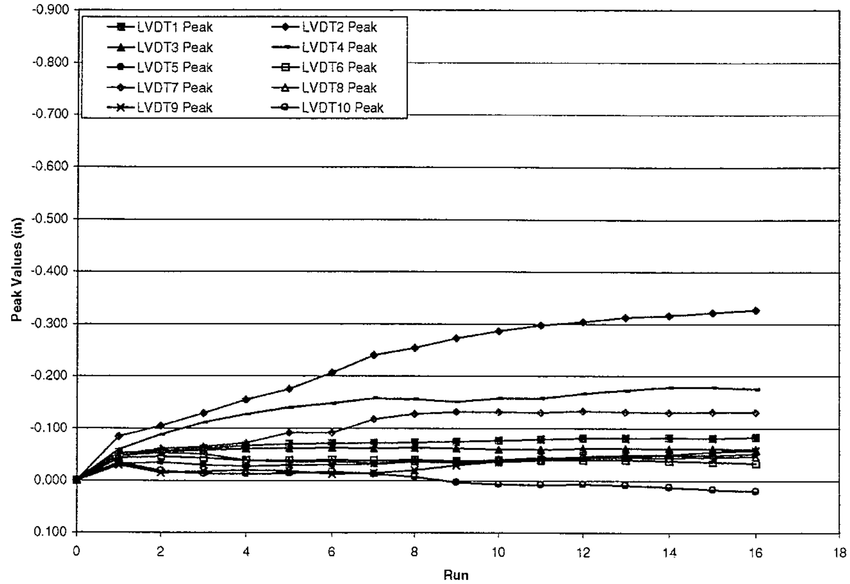


Figure A19. Cumulative *Peak Deformation
HTL Section 29, 55-kip Vertical Load, 33-kip Lateral Load (0.6 L/V)
***No Residual Data Available**

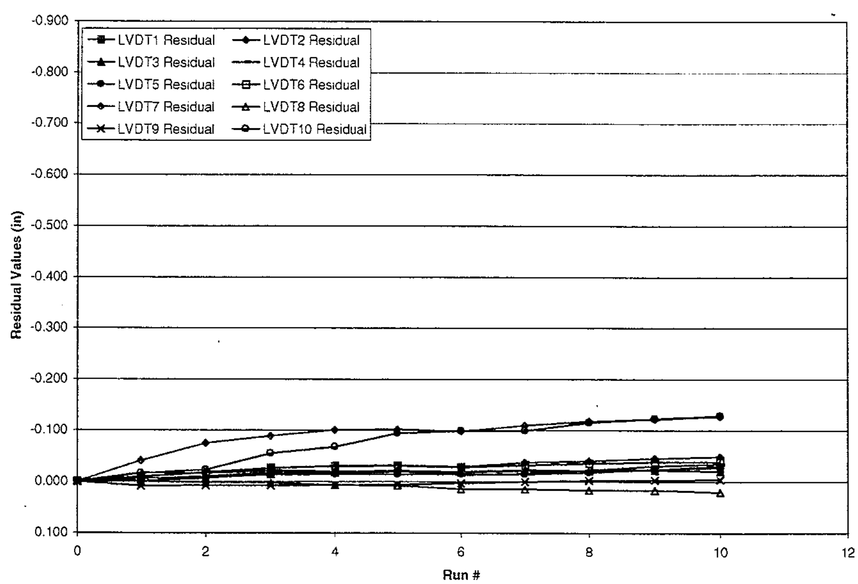


Figure A20. Cumulative Residual Deformation
HTL Section 29, 50-kip Vertical Load, 40-kip Lateral Load (0.8 L/V)