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Peacekeeper Rail Garrison Test of Engineering Model Fuel Car

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16. Abstract

Tests were performed on the Peacekeeper Rail Garrison Fuel Car, according to specifications in Chapter XI of the Association of American Railroads (AAR), *Manual of Standards and Recommended Practices*. The car was tested in three discrete configurations: loaded, half-loaded, and unloaded. The unloaded Fuel Car was subjected to limited service worthiness testing. Tests performed in all configurations included vehicle characterization and track worthiness. These tests address vehicle safety performance for freight equipment. The primary measurement of safety, as described in Chapter XI, is the ratio of lateral to vertical wheel force (L/V ratio).

The Fuel Car track worthiness testing included portions of Chapter XI for each of the three configurations. Although the loaded configuration performed acceptably in most of the tests, the same tests proved to be difficult for some of the half-loaded and almost all of the unloaded operations. Primarily, the 35 foot 5 inch truck centers were the cause of this instability. Study of the sloshing effect of the fuel suggested some affect to the cars performance, although acceptable. The stiffness of the car body and the use of constant contact side bearings made curve negotiation difficult. The Fuel Car had no difficulty negotiating the Pitch and Bounce Test, the Hunting Test, and the Yaw and Sway Test; however, the yaw and sway facility had perturbations with 20 percent less amplitude than Chapter XI requires. The Fuel Car exceeded guideline criteria in all of the following track tests: Turnout and Crossover, Twist and Roll, Dynamic Curving, Constant Curving, and Spiral Negotiation.

No suspension separation, wheel lift, or permanent deformation of the car body was seen during the Curve Stability Test of the unloaded Fuel Car. Modal parameters were found for all three configurations. Truck Characterization was accomplished with the loaded Fuel Car.

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EXECUTIVE SUMMARY

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, conducted vehicle performance tests on the Peacekeeper Rail Garrison (PKRG) Engineering Model (EM) Fuel Car under contract with the Federal Railroad Administration (FRA). Tests were performed in accordance with test practices and criteria set forth in Chapter XI of the Association of American Railroad's (AAR), *Manual of Standards and Recommended Practices (M-1001)*. Fuel Car performance did not fall within Chapter XI criteria, especially for the half-loaded and unloaded configurations, indicating the possibility of unsafe car performance.

The overall objective of this test program was to examine the suitability of all prototype PKRG cars to railroad service through vehicle characterization, modeling, and static and dynamic on-track testing. The PKRG train includes two GP40 locomotives, a fuel car, a maintenance car, two security cars, two missile launch cars, and a launch control car. This report details the performance of the Fuel Car as tested and examines its suitability insofar as railroad service. All tests are summarized in the main body of this report; individual report documents, which contain the details of all tests, are included as attachments.

The PKRG Fuel Car is a 74,100 pound (unloaded) conventional tank car with a 21,644 gallon, 5/8-inch-thick shell tank that is intended to carry diesel fuel for the PKRG consist. The car was tested with the brake end of the car leading in three discrete configurations: (1) loaded, (2) half-loaded, and (3) unloaded. (Predictions for the loaded and unloaded test regimes were generated by the AAR's, New and Untried Car Analytic Regime Simulation (NUCARS) vehicle dynamics computer model.)

The Fuel Car track worthiness testing included portions of Chapter XI for loaded, half-loaded, and unloaded configurations (Document 1). Although the loaded configuration performed acceptably in most of the tests, the same tests proved to be difficult for some of the half-loaded and almost all of the unloaded operations.

The Fuel Car had no difficulty negotiating the Pitch and Bounce Test, the Hunting Test, and the Yaw and Sway Test; however, the yaw and sway facility had perturbations with 20-percent less amplitude than Chapter XI requires. The Fuel Car exceeded guideline criteria in all of the following on-track tests in at least one configuration:

- Turnout and Crossover
- Twist and Roll
- Dynamic Curving
- Constant Curving
- Spiral Negotiation

The static and quasi-static truck characterization data seemed reasonable based on experience with other types of three-piece trucks (Document 2). The static longitudinal stiffness and axle yaw stiffness were used for NUCARS predictions. The quasi-static examinations showed a lateral variation between the trucks; also, a variation between the right side damping and stiffness and the left side damping and stiffness was found. Modal parameters were found for all three configurations.

No suspension separation, wheel lift, or permanent deformation of the car body was seen during the Curve Stability Test of the unloaded Fuel Car.

The static brake tests showed that the Fuel Car braking system performance was within AAR specifications for both the air brake system and the hand brake system (Document 4).

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1.0 INTRODUCTION

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, has contracted with the Federal Railroad Administration (FRA) to perform vehicle performance tests on the Peacekeeper Rail Garrison (PKRG) rail cars according to specifications in Chapter XI, AAR's M-1001, *Manual of Standards and Recommended Practices.* These tests are designed to provide the FRA and United States Air Force (USAF) with structural and vehicle dynamic performance data for each car and for the assembled train.

This report describes tests performed on the PKRG Fuel Car. The Fuel Car was one of four PKRG cars tested at TTC.

These tests include static (air bearing) and quasi-static truck characterization, vehicle dynamic (modal) characterization, rail car service worthiness testing, and track worthiness testing. Static brake tests were also performed to verify the braking capabilities of the cars.

This is the final report of the Engineering Model (EM) PKRG Fuel Car (TBCX-90001) testing. All tests and results are summarized here; individual report documents, which contain the details of appropriate tests, are attached. The following documents will be referred to throughout this report.

- Document 1 Track Worthiness Report
- Document 2 Static and Quasi-Static Truck Characterization and Modal Response Report
- Document 3 Service Worthiness/Curve Stability Report
- Document 4 Static Brake Report
- Document 5 Report Procedures

The PKRG Fuel Car is a 74,100 pound (unloaded) conventional tank car with a 21,644 gallon, 5/8-inch-thick shell tank that is intended to carry diesel fuel for the PKRG consist. The car was tested with the brake end of the car as the reference in three discrete configurations: loaded, half-loaded, and unloaded. (Predictions for the loaded and unloaded test regimes were generated by the AAR's, New and Untried Car Analytic Regime Simulation (NUCARS) vehicle dynamics computer model.)

Figure 1.1 is a photograph of the Fuel Car (TBCX-90001).

Figure 1.1 Fuel Car (TBCX-90001)

2.0 OBJECTIVES

The following objectives were accomplished to complete the EM Fuel Car's testing.

The main objective was to document the Fuel Car's track worthiness in loaded, half-loaded and unloaded configurations, referencing criteria described by Chapter XI. The primary measurement of safety as described by Chapter XI is the ratio of the lateral to vertical wheel force (L/V ratio). The vehicles performance was monitored for the following test conditions:

- Lateral Stability on Tangent Track (Hunting)
- Constant Curving
- Spiral Negotiation
- Twist and Roll
- Pitch and Bounce
- Dynamic Curving
- Yaw and Sway
- Turnouts and Crossovers

Vehicle performance was compared to, but not limited by, Table 11.1 of Chapter XI.

A second objective was to characterize the car body and suspension in accordance with procedures set forth in Appendix B of Chapter XI.

Characterization tests were performed to measure the static suspension characteristics (air bearing) and the quasi-static suspension characteristics (truck characterization on Mini-Shaker Unit (MSU)) of the two 100-ton conventional three-piece trucks that were used under the Fuel Car (Document 2). The characteristics were used in NUCARS to predict on-track dynamic performance.

Characterization tests were also performed to determine the dynamic mode parameters of the Fuel Car (see modal response part of Document 2) to include:

- Pitch and Bounce
- Upper and Lower Centered Roll
- Yaw and Sway
- Vertical and Lateral Bending
- Longitudinal Torsion (Twist)
- Fuel Slosh Frequency

A further objective was to determine the static stability of the car under specified buff and draft loads in a curve; refer to the Service Worthiness / Curve Stability Report, Document 3.

Another objective was to determine static brake shoe forces when various brake cylinder pressures were applied; refer to the Static Brake Report, Document 4.

3.0 TEST DESCRIPTION/PROCEDURES

Test procedures are presented in the appropriate attached documents. The detailed (made for United States Air Force (USAF)) procedures for all tests are included in the Report Procedure, Document 5.

The criteria for the track worthiness testing is based upon lateral and vertical wheel forces, car body acceleration, and car body roll angle. These criteria are listed in Appendix A of the Track Worthiness Report, Document 1.

There are no criteria for the vehicle characterization tests.

The criteria for the Service Worthiness Test are visual.

The criteria for the Static Brake Tests are based on safety standards specified by the AAR Standard S-486.

4.0 INSTRUMENTATION

Instrumentation utilized for a particular test is included in the appropriate attached document.

5.0 RESULTS SUMMARY

5.1 TRACK WORTHINESS SUMMARY

The Fuel Car track worthiness testing included portions of Chapter XI for loaded, half-loaded, and unloaded configurations. Although the loaded configuration performed acceptably in most of the tests, the same tests proved to be difficult for some of the half-loaded and almost all of the unloaded operations. The results are summarized below:

1. **Hunting:**

   Half-loaded and unloaded conditions were tested and found to be within Chapter XI limits. The constant contact side bearings may have provided the influence necessary to establish the Fuel Car's lateral stability, especially in the unloaded case.

2. **Yaw and Sway:**

   Loaded and half-loaded conditions were tested and found to be within Chapter XI limits. The amplitudes of the perturbations of the Yaw and Sway facility are 20 percent less than required by Chapter XI; therefore, the indication of stability may be inconclusive.

3. **Pitch and Bounce:**

All configurations were tested and found to be within Chapter XI limits. Even though the perturbations are at 39-foot intervals and the truck center spacing of the Fuel Car was 35 feet 5 inches, the resonant speed produced only slight instability.

4. **Turnouts and Crossovers:**

In general, the "tighter" turnouts were more difficult to negotiate than the crossovers for all configurations. The unloaded configuration exceeded guideline criteria in most turnout and crossover runs, while the half-loaded car exceeded the criteria in turnouts. The loaded car met the criteria.

5. **Twist and Roll:**

All roll resonances agreed with calculations based on the natural roll frequencies found during modal response testing. The perturbations (39-foot staggered wavelengths) were effective in inducing roll resonance due to the truck center spacing of the car.

The loaded case did not exceed the criteria, but exhibited roll resonance at 24 mph, which corresponds to the roll frequency of about 0.9 Hz found in modal response testing.

A 1.6 percent minimum vertical wheel load for a duration of 50 millisecond at 28 mph, which corresponds to 1.125 Hz found in modal analysis, stopped the testing in the half-loaded case. There was a notable resonance at about 13 mph. This speed correlates to the first resonant fuel sloshing frequency (0.5 Hz) found in the modal response examination of the half-loaded car.

At 26 mph, the unloaded testing was stopped due to a 3 percent minimum vertical wheel load which exceeded criteria with a 51 millisecond duration. The expected critical speed was 33 mph due to the 1.25 Hz roll frequency found in modal analysis of the unloaded car; therefore, a wide band of instability from approximately 26 mph to approximately 40 mph existed for the unloaded car in the twist and roll test.

6. **Dynamic Curving:**

Dynamic curving combines twist and roll inputs, track gage variations, and curving inputs in a single test. The loaded car exceeded the criteria in this test scenario. Only three of the nine speed conditions tested did not exceed the axle sum L/V criterion.

The half-loaded condition was tested first in the counterclockwise (CCW) direction and then in the clockwise (CW) direction. An axle sum L/V of 1.52 at 10 mph cancelled further testing in the CCW direction. In the CW direction, guidelines were not surpassed; however, testing was terminated at 14 mph due to what appeared to be exceeded criteria.

Testing of the unloaded car was not planned. Due to twist and roll performance, it is probable that criteria would have been exceeded.

7. **Constant Curving 7.5-Degree:**

Loaded and half-loaded conditions were tested and found to be within Chapter XI limitations.

In the unloaded condition, although the 95th percentile limitation was not surpassed for wheel and axle sum L/V's, wheel lift did occur at 32 mph. Minimum vertical wheel load is not part of the official limiting criteria for constant curving, but wheel lift is judged to be unacceptable. The 7.5-degree curve rails are joined at staggered 39-foot spacings. The 32 mph wheel lift speed is very close to the 1.25 Hz resonant roll frequency (33 mph) found in the modal response testing of the unloaded Fuel Car.

8. **Constant Curving 12-Degree:**

No problems were found for the loaded and half-loaded configurations, but at 16 mph with the car half-loaded, the 95th percentile wheel L/V was 0.78 which is close to the 0.80 L/V limitation.

Testing was terminated after the first run at 16 mph during the unloaded test due to high wheel L/V occurrence.

9. Spiral Negotiation:

Curve entry and curve exit performances were acceptable in the 7.5-degree curve for all configurations of test.

In the 12-degree curve, the bunched spiral (BS) at exit (CW) produced a 0.89 wheel L/V with 150 milliseconds over the criteria in the loaded condition; the BS at entry (CCW) for the half-loaded configuration induced a wheel L/V of 0.86 with 50 milliseconds of exceeded criteria.

The half-loaded configuration in the 12-degree curve had a minimum vertical wheel load of 7 percent with 50 milliseconds of exceeded criteria in the conventional spiral (CS) at entry during the 32 mph CW run.

The 12-degree unloaded CW run at 16 mph exceeded L/V criteria several times at entry (CS) and in the BS at exit.

10. Uneven Wheel Loads Observed:

Throughout the track worthiness testing, an uneven wheel loading, in a twist manner, was witnessed in the car. This may have affected the car in track worthiness testing. A separate report, called the *Taguchi EM Fuel Car Experiment Report*, describes an investigation into the uneven wheel loading that was inherent in the Fuel Car car body; however, no conclusions were made about its affect to the car's track performance.

5.2 CHARACTERIZATION TESTING

There are no criteria limits set on the measured car body and suspension characteristics. These tests are done to determine engineering values for the suspension in support of the vehicle simulator computer program NUCARS. NUCARS will be used to make dynamic performance predictions for the Fuel Car track worthiness tests.

The characterization report is included as Document 2 of this report.

5.3 MODAL RESPONSE SUMMARY

Due to the fact that all of the Chapter XI perturbations are built with repeated 39-foot wavelength deviations, it is possible to predict the speed likely to excite resonance for each body mode. A natural frequency of 2.63 Hz would be induced due to a resonance at 70 mph. The speeds of interest, in track worthiness, are from about 10 mph to 70 mph; therefore, frequencies above 2.63 Hz would not induce resonance at any speeds tested and would not be of concern on track.

The modal analysis of the Fuel Car, utilizing Structural Measurement Systems' software, presented the following dynamic modes:

1. Bounce resonant frequencies were found at 2.0 (53 mph), 3.875, and 2.875 Hz for the loaded, unloaded, and half-loaded configurations, respectively.
2. Pitch approximate resonant frequencies were found at 4.5, 4.75, and 4.625 Hz for the loaded, unloaded, and half-loaded configurations, respectively.
3. Roll (lower center) was found at 1.00, 1.25, and 1.125 Hz for the loaded, unloaded, and half-loaded configurations, respectively. This would equate to resonance speeds of 26.5, 33.2, and 29.9 mph for the three conditions on the twist and roll track.
4. Roll (upper center), for all cases, was not determined.
5. Sway resonant frequencies were found at 1.5 Hz (40 mph) and 1.625 Hz (43 mph) for the loaded and half-loaded configurations, respectively. Sway was not found for the unloaded configuration.
6. Yaw was found at 5.625 and 5.0 Hz for the unloaded and half-loaded conditions, respectively. Yaw was not found in the half-loaded configuration.

7. The first car body vertical bending frequency was found at 10.6, 18.875, and 15.125 Hz for the loaded, unloaded, and half-loaded configurations, respectively. An unexpected vertical flex mode was found at 8.375, 16.25, and 11.875 Hz for the loaded, unloaded, and half-loaded configurations, respectively.
8. The first car body torsional frequency for all cases was not determined.
9. Lateral car body bending was found at 11.25, 19.0, and 14.625 Hz for the loaded, unloaded, and half-loaded configurations, respectively. An unexpected lateral flex mode was found at 8.75, 16.0, and 11.5 Hz for the loaded, unloaded, and half-loaded configuration, respectively.
10. Natural frequency of the diesel fuel sloshing was found to be 0.5 Hz. This corresponds to about 13 mph on the twist and roll track.

5.4 SERVICE WORTHINESS/CURVE STABILITY SUMMARY

The unloaded Fuel Car met guideline criteria for both buff and draft tests; there was no car body suspension separation or wheel lift.

5.5 STATIC BRAKE TEST SUMMARY

The braking ratio found during the instrumented brake shoe test showed the car to be acceptable for interchange.

6.0 CONCLUSIONS

1. The Fuel Car did not perform within the Chapter XI track worthiness guidelines in several test regimes. Chapter XI states that values worse than the criteria outlined in this report are regarded as indicating a higher likelihood of unsafe car performance. One main reason for such poor performance was the truck spacing. The twist and roll, yaw and sway, pitch and bounce, and dynamic curve test sections contain perturbations of 39-foot wavelengths. The Fuel Car, with 35-foot 5-inch truck centers, was very sensitive to those particular perturbated wavelengths. The sensitivity was compounded as the load of the car went from maximum to minimum.

2. The vehicle characterization data seemed reasonable and was similar to that obtained for other cars. The results of vehicle characterization were successfully integrated into NUCARS and the predictions for on-track testing were made. In general, predicted performance was better than measured performance.

3. The unloaded Fuel Car exhibited no wheel lift or suspension separation during the Curve Stability Test.

4. The static brake tests showed that the Fuel Car's braking system was within AAR specifications.

7.0 RECOMMENDATIONS

1. Post test modeling should be performed to reconcile measured and predicted performance, and to examine the car's performance in the testing scenarios which were terminated when testing exceeded Chapter XI criteria. Predictions should be made for yaw and sway, with the actual perturbations as input, and a correlation should be made between the predictions and the results that were found on the "as tested" yaw and sway track.

2. Improvements to the vehicle system, which would bring its performance to acceptable levels, should be determined.

3. The improved Fuel Car should be re-tested to verify performance.

DOCUMENT 1

FUEL CAR

TRACK WORTHINESS

"QUICKLOOK" REPORT

"QUICK LOOK" REPORT
PEACEKEEPER RAIL GARRISON

FUEL CAR
TRACK WORTHINESS TESTING

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August 17, 1991

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Tables

1.0 INTRODUCTION

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, has contracted with the Federal Railroad Administration (FRA) to perform vehicle performance tests on the Peacekeeper Rail Garrison (PKRG) rail cars according to specifications in AAR's, *Manual of Standards and Recommended Practices*, Chapter XI (M-1001). All tests are referenced to sections in Chapter XI.

These tests include static and quasi-static truck characterization, vehicle dynamic (modal) characterization, rail car service worthiness testing, and track worthiness testing. The vehicle characterization was covered in two separate reports. This report covers only the track worthiness testing of the PKRG Fuel Car (TBCX-90001).

The PKRG Fuel Car is a 74,100 pound (unloaded) conventional tank car with a 21,644 gallon, 5/8-inch-thick shell tank that is used to carry diesel fuel for the PKRG consist. The car was tested with the brake end of the car leading in three discrete configurations: loaded, half-loaded, and unloaded. At Air Force direction, predictions for the loaded and unloaded test regimes were generated by the AAR's, New and Untried Cars Analytic Regime Simulation (NUCARS) vehicle dynamics computer model to help predict the stability of the car in on-track regimes and to be used as a guide during on-track testing.

2.0 OBJECTIVE

The objective of track worthiness testing was to measure the performance of the Fuel Car as described by Chapter XI.

Chapter XI is designed to provide a severe but realistic test for freight vehicles. Individual tests have been tailored to excite the vehicle dynamic modes which have been associated with poor performance in the past. The test conditions in Chapter XI do not exceed those which can be encountered in normal railroad operation.

The vehicle performance will be referenced to published criteria set forth in table 11.1 of Chapter XI (see Appendix A) for the following test conditions:

- Lateral Stability on Tangent Track (Hunting)
- Constant Curving
- Spiral Negotiation
- Twist and Roll
- Pitch and Bounce
- Dynamic Curving
- Yaw and Sway
- Turnouts and Crossovers

3.0 PROCEDURE

Figure 3.1 shows the location of all of the Track Worthiness Test sections. Detailed Fuel Car Track Worthiness Test procedures may be found in Appendix B.

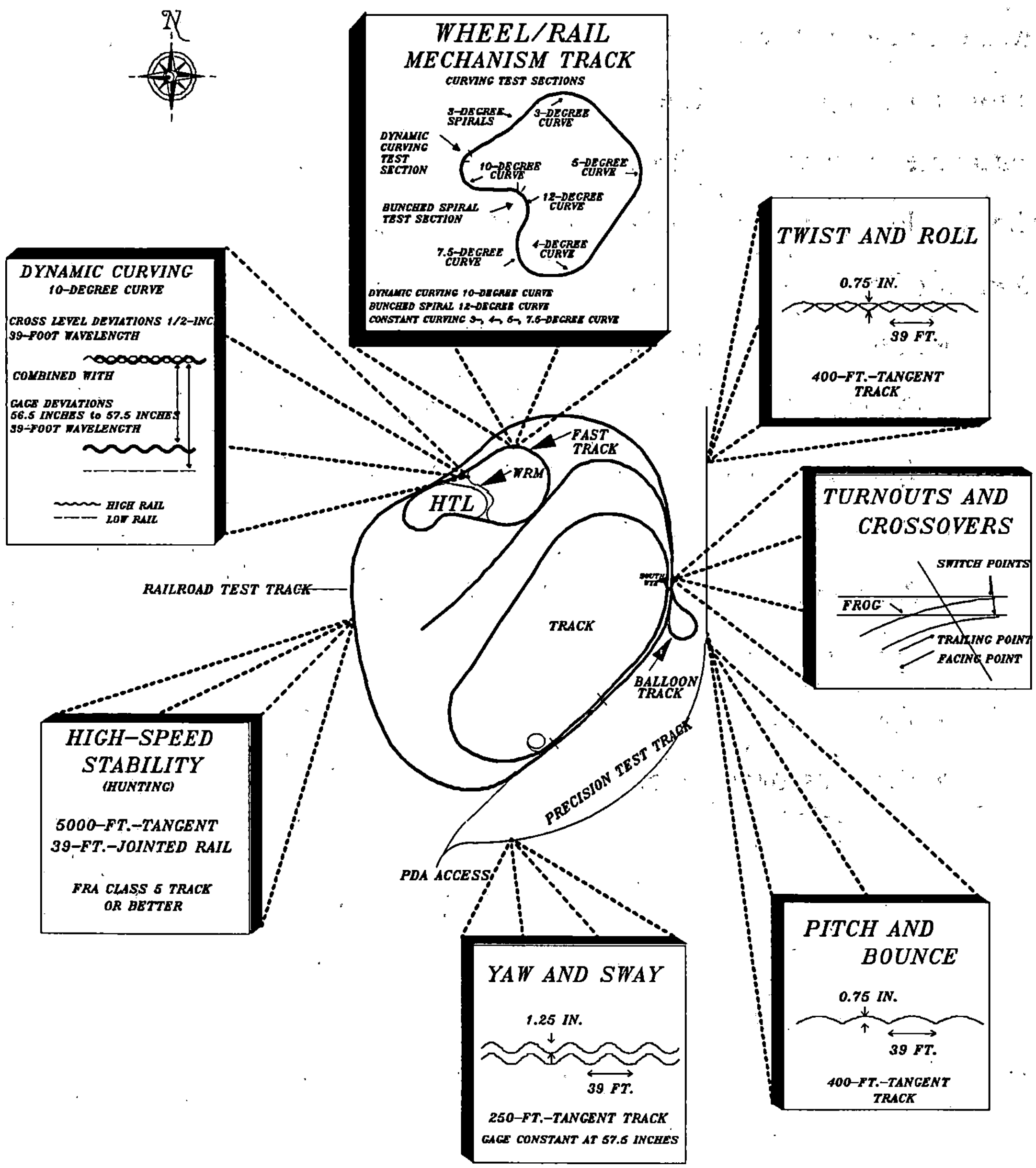

Figure 3.1 Chapter XI Track Worthiness Test Facilities

3.1 PITCH AND BOUNCE (LOADED, HALF-LOADED)

The Pitch and Bounce Test is designed to determine the dynamic pitch and bounce response of rail cars as they are excited by vertical inputs from the track. The criteria for this test is a minimum vertical wheel load of 10 percent of the static wheel load sustained for 50 milli-seconds.

The pitch and bounce testing was conducted on the Precision Test Track (PTT). The test section is between stations 1716+00 and 1719+90. This section of track is shimmed to represent parallel 0.75-inch vertical deviations at 39 foot intervals, shown in Figure 3.2. The Pitch and Bounce Test follows the procedure listed in Section 11.6.3 of Chapter XI.

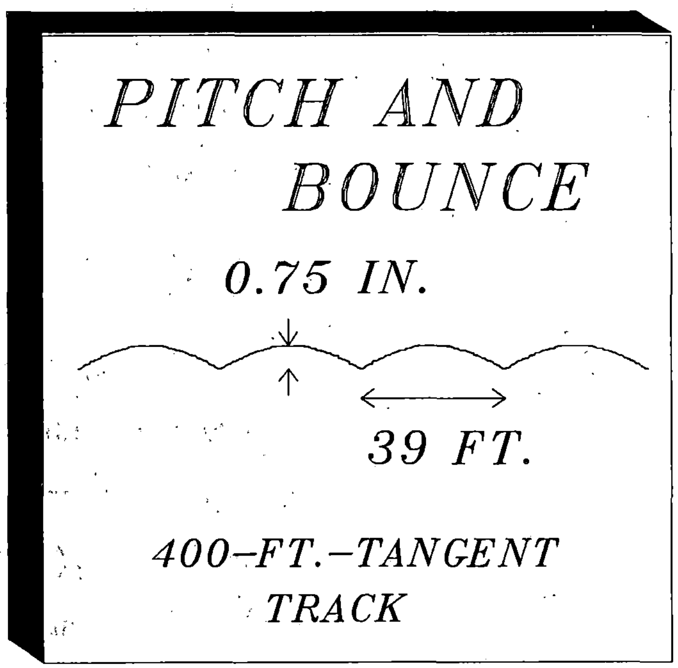

Figure 3.2 Pitch and Bounce Section

The test consist included one locomotive, the T-7 Instrumentation Car, the Fuel Car, and an empty flatcar (see Figure 3.3).

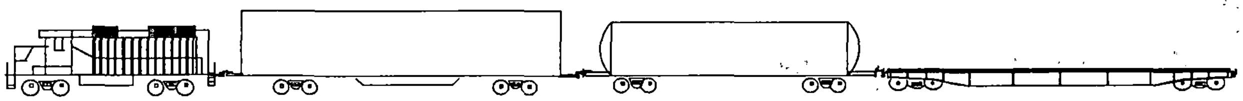

Figure 3.3 Pitch and Bounce Test Consist

Instrumented wheel sets were installed in the lead axle position of each truck of the Fuel Car. Vehicle resonance of the loaded Fuel Car was predicted by NUCARS at 55 mph. Test runs were performed at 30, 40, 50, 55, 60, 65, 67, and 70 mph in the loaded configuration and 30, 40, 50, and 60 mph in the half-loaded condition. Data collection began 100 feet before the perturbed track section and ended 100 feet after the section.

3.2 TWIST AND ROLL (LOADED, HALF-LOADED, UNLOADED)

Twist and Roll Tests are conducted to determine the cars ability to negotiate tangent track cross level deviations. These deviations were designed to excite the natural twist and roll motions of the car. Three criteria are given for this test: maximum roll angle of 6 degrees peak-to-peak, maximum axle sum lateral force over vertical force (L/V) of 1.3 sustained for 50 milliseconds, and a minimum vertical wheel load of 10 percent of the static wheel load sustained for 50 milliseconds.

The twist and roll testing followed Section 11.6.2 of Chapter XI and was conducted on the PTT at stations 1646+10 to 1650+90. These sections of the PTT were shimmed to represent staggered cross level deviations of 0.75 inches at 39-foot intervals (see Figure 3.4).

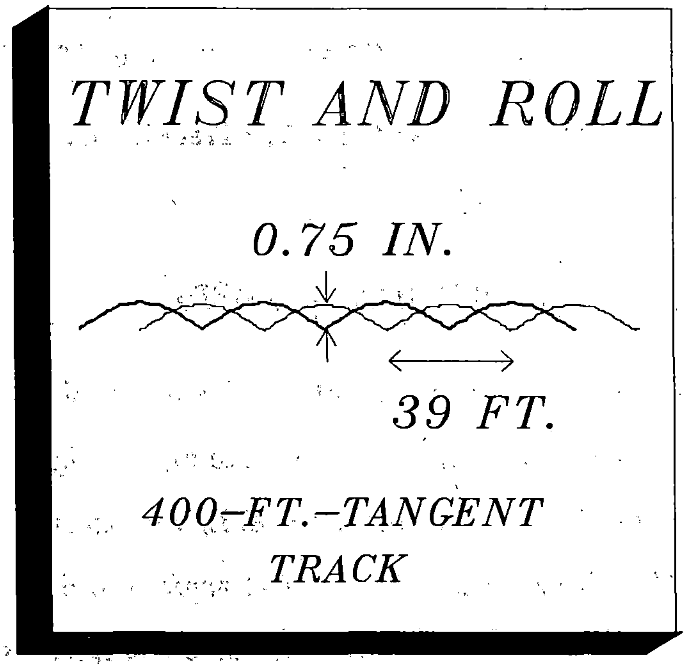

Figure 3.4 Twist and Roll Test Zone

Twist and roll testing was performed on the Fuel Car in all three configurations. Resonant speeds found from (laboratory) modal response testing were 24, 26, and 32 mph for the loaded, half-loaded, and unloaded configurations, respectively. Intended test speeds were 10, 14, 16, 18, 20, 22, 24, 26, 30, 40, 50, and 60 mph. Figure 3.5 shows the Twist and Roll Test consist.

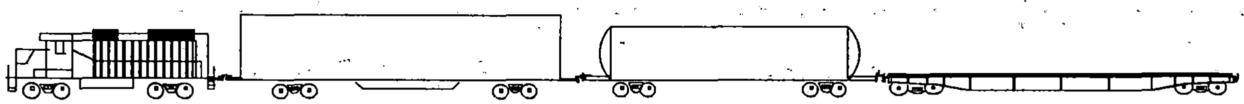

Figure 3.5 Twist and Roll Test Consist

3.3 DYNAMIC CURVING (LOADED, HALF-LOADED)

The Dynamic Curving Test is designed to determine the ability of the car to negotiate track with simultaneous cross level (vertical) and gage (lateral) misalignments in a curve. Four safety criteria are used for this test: maximum wheel L/V of 0.8 or maximum axle sum L/V of 1.3 sustained for 50 milliseconds, maximum roll angle of 6 degrees peak-to-peak, and minimum vertical wheel load of 10 percent of the static wheel load sustained for 50 milliseconds.

The dynamic curving tests were conducted on the 10-degree curve (station 1+00 to 3+50) of the Wheel/Rail Mechanisms (WRM) track. The 10-degree curve is shimmed to provide maximum cross level deviations of 0.5 inches combined with lateral perturbations giving a maximum gage of 57.5 inches and a minimum gage of 56.5 inches (Figure 3.6). The Dynamic Curve Test is performed according to Section 11.6.5 of Chapter XI.

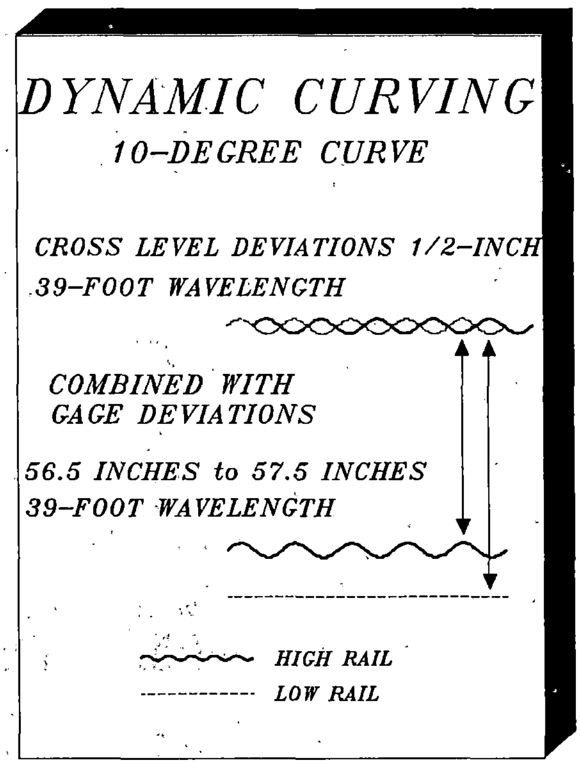

Figure 3.6 Dynamic Curving Test Facility

Dynamic curving was performed in the loaded and half-loaded configurations. Test runs were started at 10 mph and went up by increments of two mph to the particular critical speed of each configuration. A loaded gondola was used as the buffer car.

3.4 CONSTANT CURVING (LOADED, HALF-LOADED, UNLOADED)

The Constant Curving Test utilized the 12- and 7.5-degree curves of the WRM track (Figure 3.7). The procedure for the Constant Curving Test is found in Section 11.5.3 of Chapter XI.

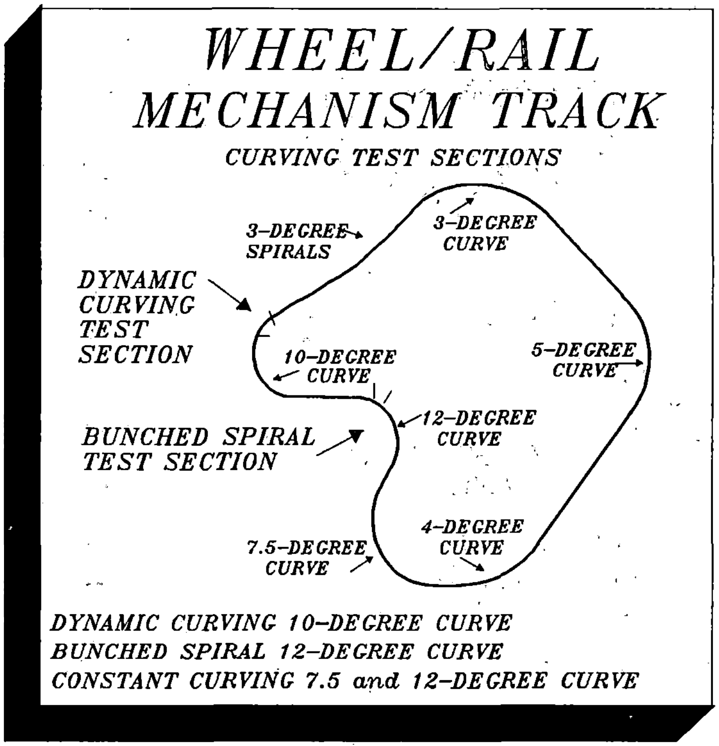

Figure 3.7 Constant Curving Test Facility

The Constant Curving Test is designed to determine the car's ability to negotiate normal track curves. The 95th percentile of maximum wheel L/V of 0.8 or maximum axle sum L/V of 1.3 (Chapter XI, Table 11.1) is the written criteria.

This test should verify that the car did not (1) have wheel climb, or (2) impart unusually high lateral forces to the rails during curving. Test runs were performed at 3 inches underbalance, balance, and 3 inches overbalance speed of each particular curve. Speeds were calculated with the following formula:

$$Speed = V = \sqrt{1480 \frac{(U+H)}{D}}$$

Where: U = unbalance in inches

H = superelevation in inches

D = curvature in degrees.

Table 3.1 shows balance speeds for each curve.

Table 3.1 Constant Curving Conditions

CURVE DEGREE	SUPER ELEVATION	BALANCE SPEED (mph)	+3 INCH SPEED (mph)	-3 INCH SPEED (mph)
7.5	3	24.0	32.0	14.0
12	5	25.0	32.0	16.0

Each test speed was performed in both clockwise (CW) and counterclockwise (CCW) directions. A loaded gondola was used as the buffer car.

3.5 SPIRAL NEGOTIATION (LOADED, HALF-LOADED, UNLOADED)

The Spiral Negotiation and Wheel Unloading Tests were performed in conjunction with the Constant Curving Test. A spiral is the transition from a curve to a tangent track. This transition includes changes in cross level and curvature. The purpose of the exaggerated bunched spiral is to twist the trucks and the car body as they would in transition from tangent track operation to curved track operation. A nominal spiral has constant changes in curvature and elevation with distance. The bunched spiral has all of the elevation change (5 inches) bunched in the middle one-hundred feet of the 200-foot long spiral.

Chapter XI states that the minimum acceptable vertical wheel load is 10 percent of the static wheel load and that the maximum wheel L/V is 0.8 sustained for 50 milliseconds. The data was monitored to verify that no wheel lift occurred and that no extreme wheel forces were measured. Test speeds were the same as those used on the 7.5- and 12-degree curves. As with constant curving, spiral negotiation was run in both CW and CCW directions. The entrance and exit spirals, including, but not limited to, the bunched spiral were analyzed. Chapter XI only specifies the bunched spiral for official testing.

3.6 TURNOUT AND CROSSOVER (LOADED)

Turnout and Crossover Tests are not listed in Chapter XI, but were conducted to determine if the car is able to negotiate standard turnouts and crossovers with a margin of safety in wheel/rail forces (Figure 3.8). A turnout is an arrangement of a switch and frog with closure rails, by which cars may be diverted from one track to another; while, a crossover as shown in Figure 3.9 is an arrangement of two turnouts with the track between the frogs arranged to allow passage between two parallel tracks. The wheel/rail forces determine if there is (1) a tendency for wheel climb, or (2) a tendency to induce unusually large lateral forces into the track.

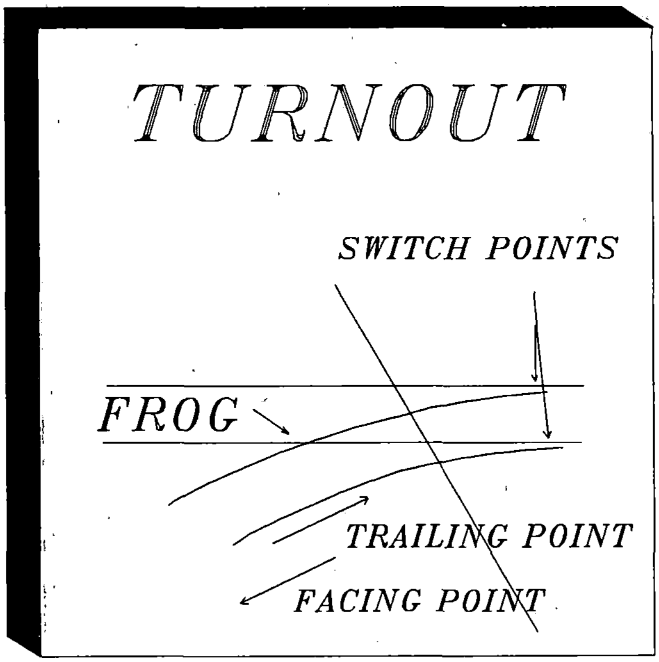

Figure 3.8 Turnout or 1/2 of a Crossover

A Track Conditioning Run (TCR) was conducted at 5 mph. Testing was conducted on the north turnout entering and exiting the Urban/Rail Building (URB) (Switch No. 704). Chapter XI criteria for axle and truck side L/V's were used as limitations for proper operation.

Switch No. 704 is a No. 8 turnout with a 15 mph speed limit. Test runs were performed at 10 mph and 15 mph in both directions.

The Crossover Test was performed on switch numbers 602A and B. The test zone is shown in Figure 3.9. Both were No. 15 turnouts with 35 mph speed limits. Test runs were performed at 15, 25, and 35 mph in both directions. The loaded gondola trailing buffer car was used for all tests.

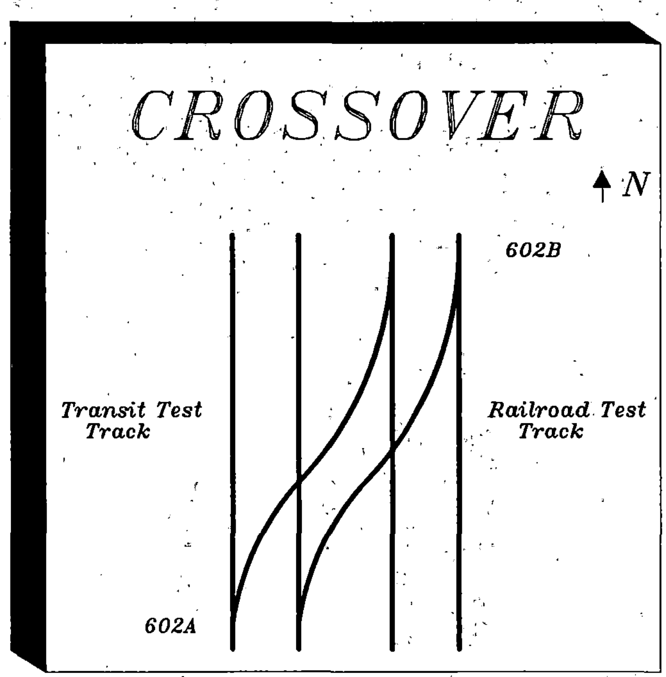

Figure 3.9 602A and B Crossover

3.7 YAW AND SWAY (LOADED)

The Yaw and Sway Test is conducted to determine the ability of a car to negotiate laterally misaligned track, which would excite the car in yaw and sway motions. The maximum allowable truck side L/V is 0.6 sustained for 50 milliseconds and the maximum allowable axle sum L/V is 1.3 sustained for 50 milliseconds (Chapter XI).

To obtain truck side L/V readings, instrumented wheel sets were installed at both axle locations under the leading truck for this test.

The Yaw and Sway Test was conducted in accordance with Section 11.6.4 of Chapter XI. Station 21+00 to 26+00 of the Precision Test Track (PTT) was the test site. This section had sinusoidal track alignment deviations of 39-foot wavelength and an amplitude of 1.00 inches peak-to-peak on both rails at a constant wide gage of 57.5 inches. These amplitudes were less than the 1.25 inches specified in Chapter XI. This was known before testing began, but it was impractical to adjust the perturbations due to cost and schedule. No trailing buffer car was used in the consist. Figure 3.10 shows the test zone with 1.25-inch perturbations.

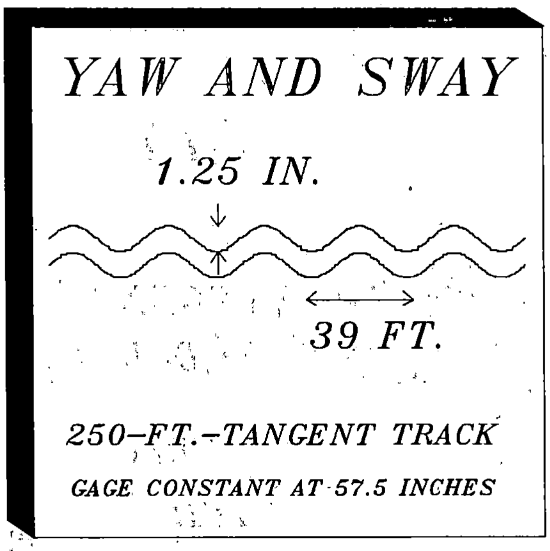

Figure 3.10 Yaw and Sway Test Track

3.8 LATERAL STABILITY (HUNTING) (HALF-LOADED, UNLOADED)

The High Speed Stability or Hunting Test is conducted to confirm that hunting (lateral oscillating instability of the trucks and/or carbody) does not occur within normal operating speeds. Chapter XI states that a car body center plate lateral acceleration (g) of 1.0 g sustained for 20 seconds indicates truck hunting. Hunting is inherent in some truck designs and is also seen in normally stable truck designs when components are allowed to wear beyond normal limits.

Procedures for the Hunting Test may be found in Section 11.5.2 of Chapter XI. This test is conducted on a 6,000-foot-tangent section (between R39-R33) of the Railroad Test Track (RTT). Refer to Figure 3.2 for site location and to Figure 3.11 for a description of the test track.

Test runs were performed at 30, 40, 50, 55, 60, 65, and 70 mph. No trailing buffer car was used.

Figure 3.11 Hunting Test Track

4.0 FUEL CAR DESCRIPTION

The test vehicle was Boeing's Peacekeeper Rail Garrison Fuel Car (TBCX-90001). Figure 4.1 shows the Fuel Car from the B-end, and Figure 4.2 shows the Fuel Car from the A-end. The Fuel Car is designed to be a 74,100 pound (unloaded) conventional tank car. The car, which uses two 100-ton trucks, has a 21,644 gallon, 5/8-inch thick outer shell tank that will be used to carry fuel for the PKRG consist. The car is an existing design, made by Procor and procured for the United States Air Force by Boeing. The 36-inch wheels arrived with AAR 1:20 profiles. All wheels were cut to the AAR-1B profile. The axle spacing within the truck is 70 inches. The truck center spacing is 35 feet 5 inches and the car length is 46 feet 4 inches over strikers.

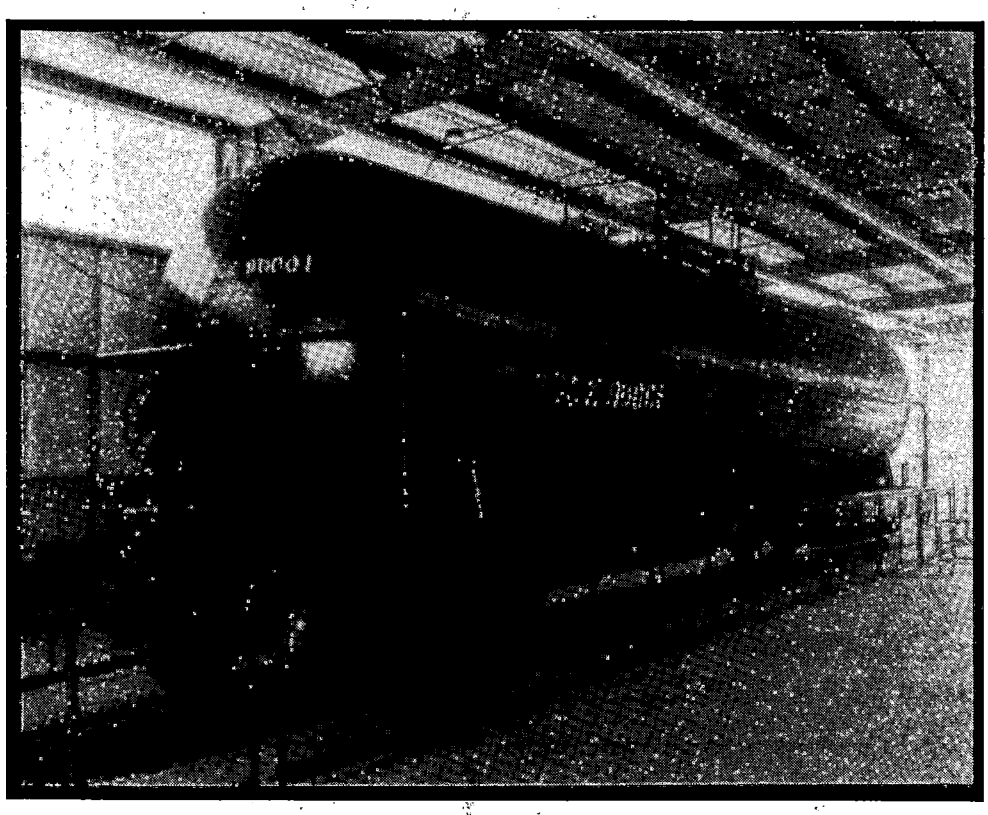

Figure 4.1 Fuel Car From B-End

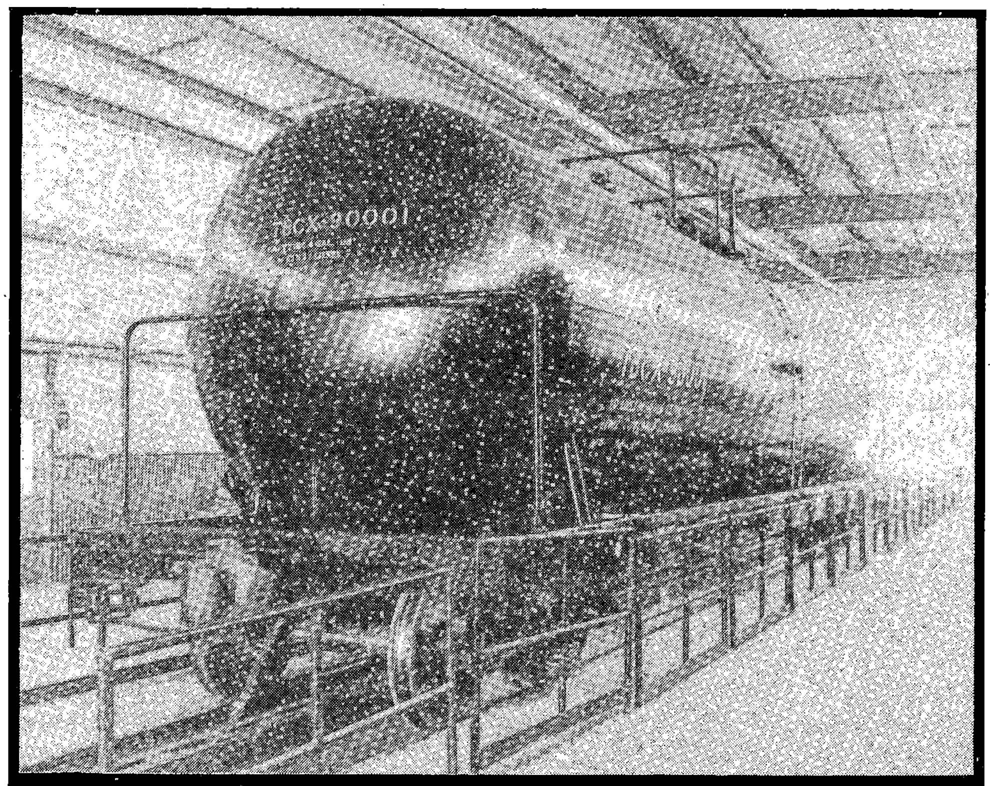

Figure 4.2 Fuel Car From A-End

4.1 RUNNING GEAR

Two American Steel Foundries' (ASF) 100-ton ride control trucks were utilized. The secondary suspension consisted of seven inner and eight outer D-7 springs. The spring configuration is shown in Figure 4.3. There was no primary suspension on the Fuel Car.

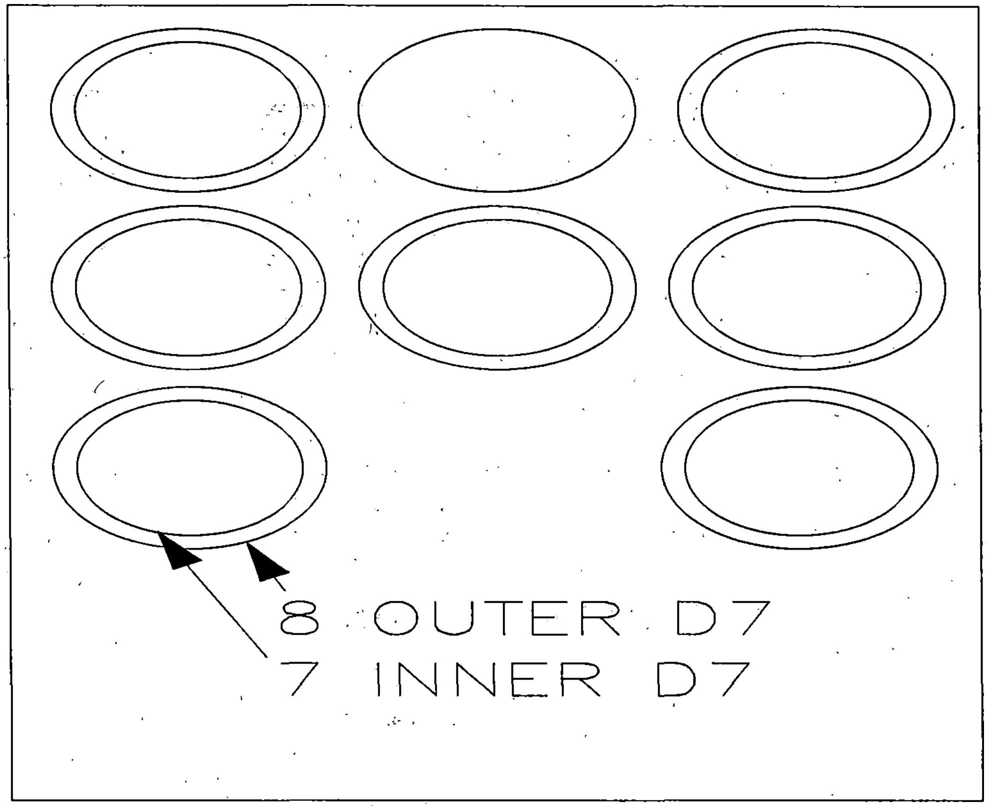

Figure 4.3 Fuel Car Spring Configuration

It is noted that Boeing indicated that the Operational Model (OM) Fuel Car will use five inner and nine outer D-7 springs in its secondary suspension.

Manufactured constant contact side bearings were used between the car body and truck bolster. The center bowl and pin are shown in Figure 4.4. Figure 4.5 shows the side bearing arrangement.

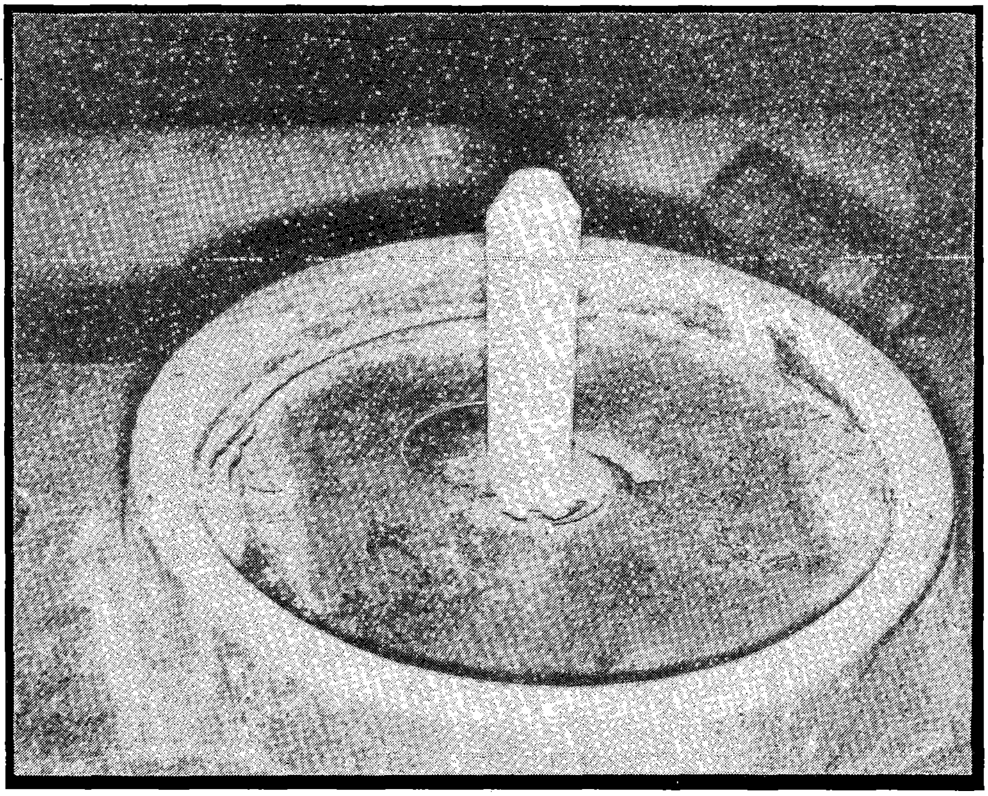

Figure 4.4 Fuel Car Truck Center Pin and Bowl

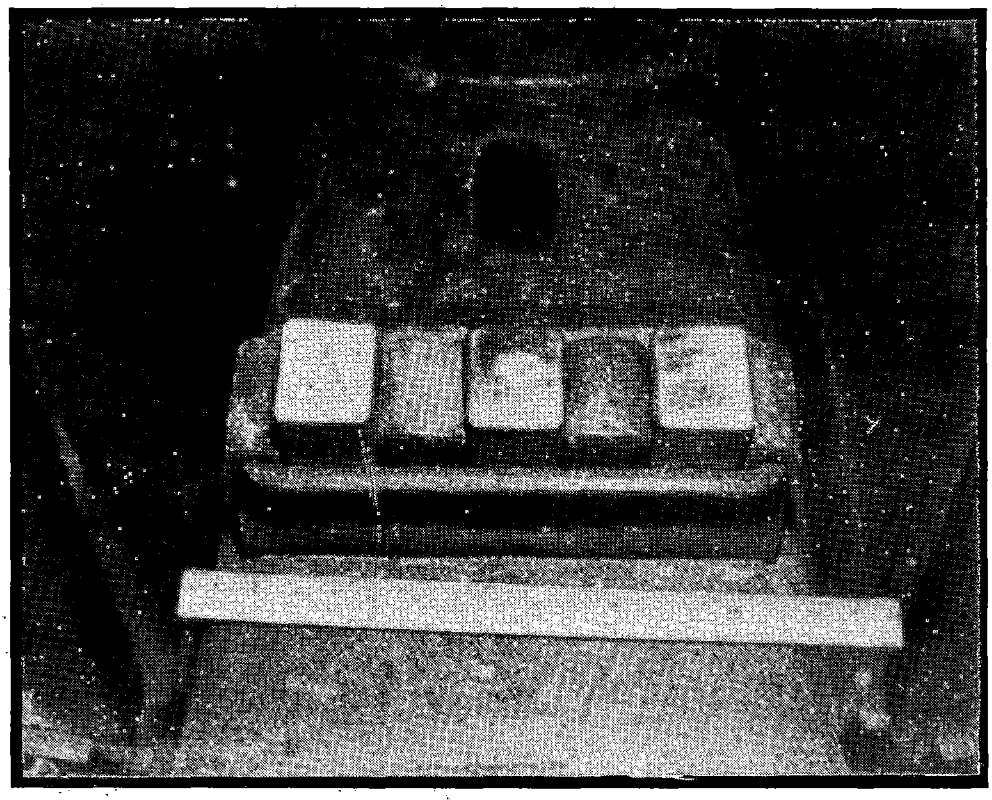

Figure 4.5 Fuel Car Constant Contact Side Bearing Arrangement

5.0 INSTRUMENTATION

5.1 INSTRUMENTED WHEEL SETS

Instrumented wheel sets (IWS) were provided to TTC for this test as Government Furnished Equipment (GFE). They were manufactured by the Illinois Institute of Technology Research Institute (IITRI). The instrumented wheel sets were conventional wheels and axles, machined smooth and strain gaged.

Each wheel has six strain gage bridges. Three bridges are used to measure vertical force; two bridges measure lateral force and one indicates lateral wheel tread position on the rail. The raw analog strain gage signals were digitized and acquired with a 386 based computer system. The signals were processed to produce digital output in the form of left and right side vertical wheel force, lateral wheel force, and axle torque. The digital signals were then converted to analog. Those analog signals were displayed on strip charts and acquired on a Hewlett-Packard (HP) Data Acquisition System (DAS) with the output from the rest of the transducers. Figure 5.1 shows an IITRI wheel set installed under a car.

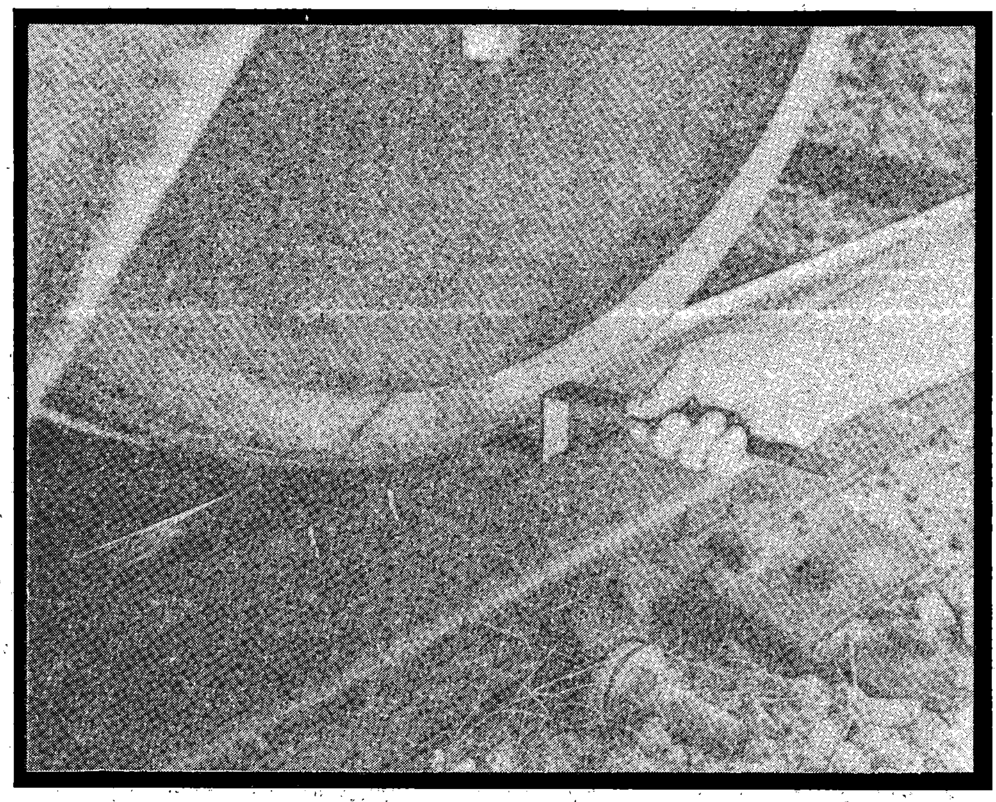

Figure 5.1 IITRI Instrumented Wheel Set

5.2 ROLL GYROS

Chapter XI requires the measurement of car body roll angle in twist and roll and dynamic curving. This was accomplished with two roll rate gyros. The gyros were installed on each end of the car at bottom tank level. Figure 5.2 shows a roll gyro.

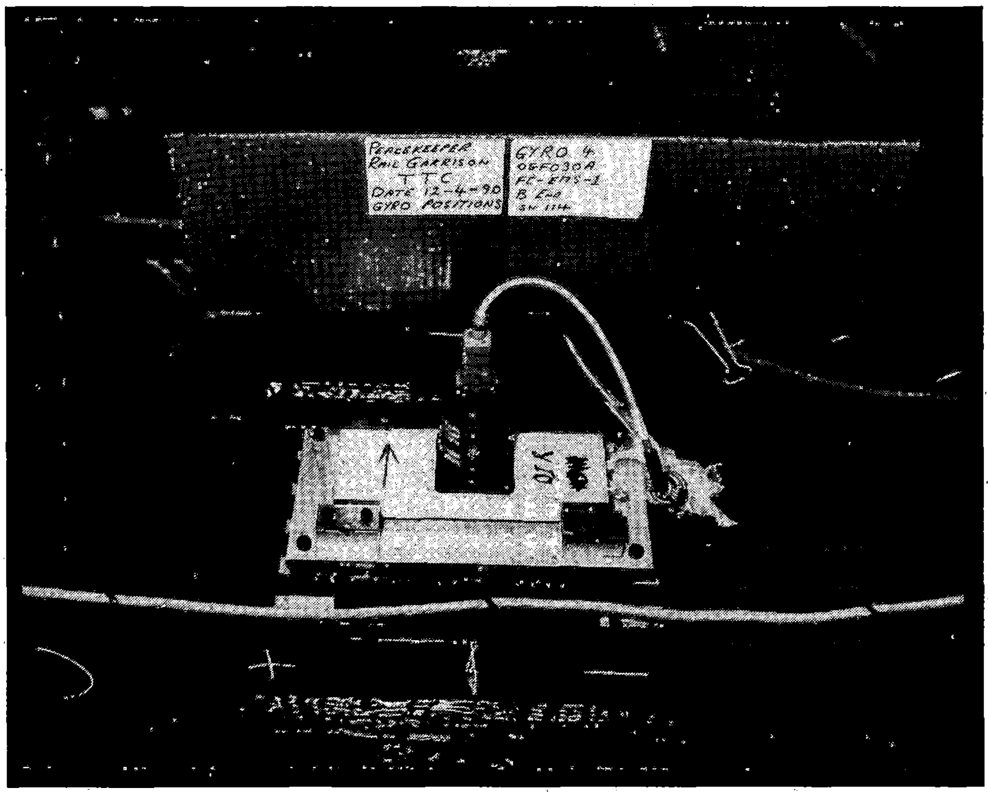

Figure 5.2 Roll Gyro

The output signal was a roll rate. This was electronically integrated and sent to the DAS as an analog voltage representing roll angle.

5.3 LATERAL ACCELEROMETERS

Endevco 25 g lateral accelerometers were installed on the A- and the B-end of the car, on the roll gyro base plates. They were utilized to measure car body accelerations for the Hunting Test.

5.4 ADDITIONAL MEASUREMENTS (BOEING REQUEST)

Accelerometers were installed in vertical, lateral, and longitudinal orientations at various positions on the car. Truck spring nest and side bearing displacements were also measured. All transducers are listed by channel number in the Measurement List (see Appendix C).

5.5 DATA ACQUISITION SYSTEM (DAS)

Analog signals from 69 signal conditioners were multiplexed and digitized with a HP 6944 multiprogrammer. Data was acquired with a HP 330 computer. AD counts were stored with their proper engineering unit conversions on one file for each test. Data was stored on a 650 megabyte optical disk.

5.6 CHART RECORDERS

All channels of required data were displayed real time on four Astro-Med strip charts.

6.0 RESULTS

Pre-test predictions were made with the NUCARS model for the loaded and unloaded Fuel Car track worthiness tests. Appropriate predictions are noted in each subsection. Predictions were presented in the Fuel Car Track Worthiness Test Readiness Review, given at TTC by Peter E. Klauser. Chapter XI criteria are used as guidelines to measure the performance of the Fuel Car and to indicate safe conduct of each test. **The tests were not performed to certify the Fuel Car.**

All results are shown as peak values and if a time duration is given, it is the duration that the Chapter XI limit, 0.8 wheel L/V for example, was surpassed.

6.1 PITCH AND BOUNCE (LOADED, HALF-LOADED)

The Chapter XI criterion for pitch and bounce is in reference to minimum vertical wheel load. The limit is 10 percent of the static wheel load sustained for 50 milliseconds.

The first step in data analysis is to determine the static wheel load for each instrumented wheel. Low speed tangent runs were analyzed to determine the rolling unperturbed static wheel load. These wheel loads were compared to the wheel loads calculated from weighing the Fuel Car on the Transit Maintenance Building's (TMB) track scale. The difference was negligible; hence, the scale weights were used in the minimum vertical wheel load calculations.

Table 6.1 shows the calculated wheel loads for the loaded, half-loaded, and unloaded configurations.

Table 6.1 Scale Weights for Fuel Car

LOADED LOADED	A-End B-End	107,700 lbs 108,800 lbs	Per Axle	Per Wheel
TOTAL		**216,500 lbs**	**54,125 lbs**	**27,062.5 lbs**
HALF-LOADED HALF-LOADED	A-End B-End	75,000 lbs 77,400 lbs	--	--
TOTAL		**192,400 lbs**	**38,100 lbs**	**19,050 lbs**
UNLOADED UNLOADED	A-End B-End	37,600 lbs 39,400 lbs	--	--
TOTAL		**77,000 lbs**	**19,250 lbs**	**9,625 lbs**

Tables 6.2(a) and (b) are tabulations of the actual and predicted minimum vertical wheel load percentages for the loaded and half-loaded pitch and bounce test runs, respectively.

Table 6.2(a) Loaded Pitch and Bounce Test Results Summary

SPEED (mph)	MINIMUM VERTICAL WHEEL LOAD (%)	PREDICTED MINIMUM VERTICAL WHEEL LOAD (%)
30	68	61
40	66	65
50	63	62
55	60	54
60	44	56
65	22	58
67	31	--
70	35	53

Table 6.2(b) Half-Loaded Pitch and Bounce Test Results Summary

SPEED (mph)	MINIMUM VERTICAL WHEEL LOAD (%)	PREDICTED MINIMUM VERTICAL WHEEL LOAD (%)
30	63	--
40	61	--
50	52	--
55	--	--
60	59	--
65	--	--
70	--	--

In the loaded configuration, the lowest vertical wheel load was 22 percent at 65 mph, this was higher than the specified limit of 10 percent of the static vertical wheel load; therefore, the loaded car performed within the Chapter XI criterion.

The worst case minimum vertical wheel load in the half-loaded case was 52 percent at 50 mph. This was higher than the specified 10 percent limit; hence, the half-loaded car also performed within the Chapter XI criterion.

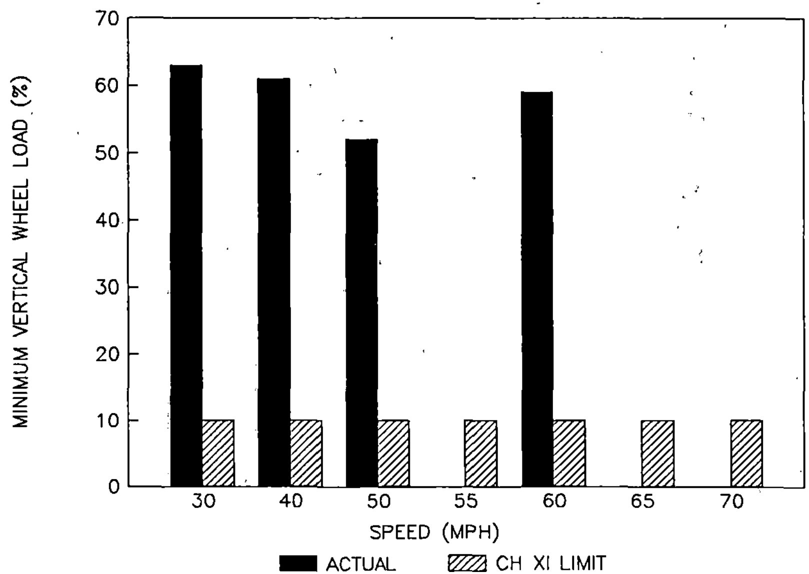

Figure 6.2 Half-Loaded Pitch and Bounce Minimum Wheel Load Results

Figures 6.1 and 6.2 show comparisons of actual and predicted values for minimum vertical wheel load test for loaded and half-loaded testing. The limiting value of 10 percent is also shown.

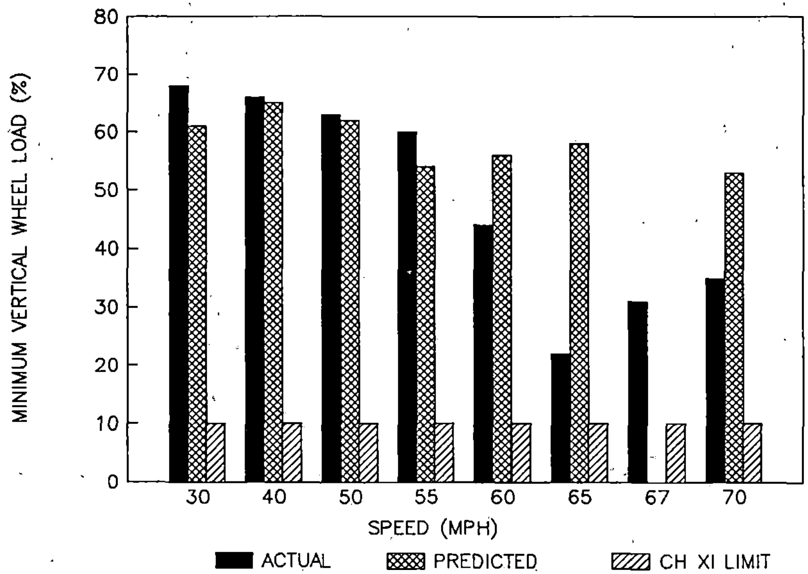

Figure 6.1 Loaded Pitch and Bounce Minimum Wheel Load Results

6.2 TWIST AND ROLL (LOADED, HALF-LOADED, UNLOADED)

Chapter XI specified three limiting criteria for twist and roll. The first was a 10 percent minimum vertical wheel load sustained for 50 milliseconds. The second was a 50 millisecond maximum axle sum L/V of 1.3, and the third was a maximum car body roll angle of 6 degrees peak-to-peak. Table 6.3(a) is a summary of the actual test data and predictions for each of the three criterion.

In the loaded condition there were no exceedences of Chapter XI, but the speed range of 22 mph to 30 mph showed some roll. At 24 mph, the minimum vertical wheel load was 14 percent and the peak-to-peak roll angle was 4.60 degrees. The 24 mph operation corresponds to the natural roll frequency of 0.9 Hz measured during modal analysis.

Table 6.3(a) Loaded Twist and Roll Results Summary

SPEED (mph)	MIN. VERT. WHEEL LOAD (%)	MIN. VERT. WHEEL LOAD PREDICTED (%)	ROLL ANGLE (DEG.)	ROLL ANGLE PREDICTED (DEG.)	AXLE L/V	AXLE L/V PREDICTED
10	56	--	1.40	--	0.29	--
14	43	79	2.24	0.8	0.38	--
16	32	80	2.80	0.7	0.42	--
18	41	79	2.84	0.9	0.43	--
20	36	76	2.96	1.1	0.46	--
22	16	75	4.40	1.3	0.55	--
24	14	74	4.60	1.3	0.60	--
26	18	--	4.16	--	0.57	--
30	25	72	4.10	1.3	0.53	--
40	30	75	3.32	0.9	0.41	--
50	44	75	2.52	0.8	0.42	--
60	49	74	2.48	0.9	0.39	--

Figures 6.3, 6.4, and 6.5 show comparisons of actual and predicted values for wheel load, roll angle, and axle sum L/V with the Chapter XI limiting values for the loaded twist and roll testing.

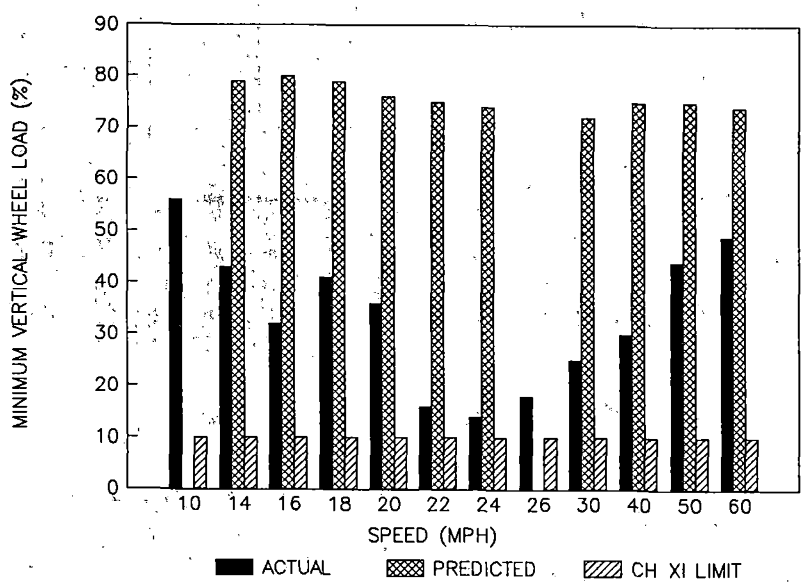

Figure 6.3 Loaded Twist and Roll Minimum Vertical Wheel Load

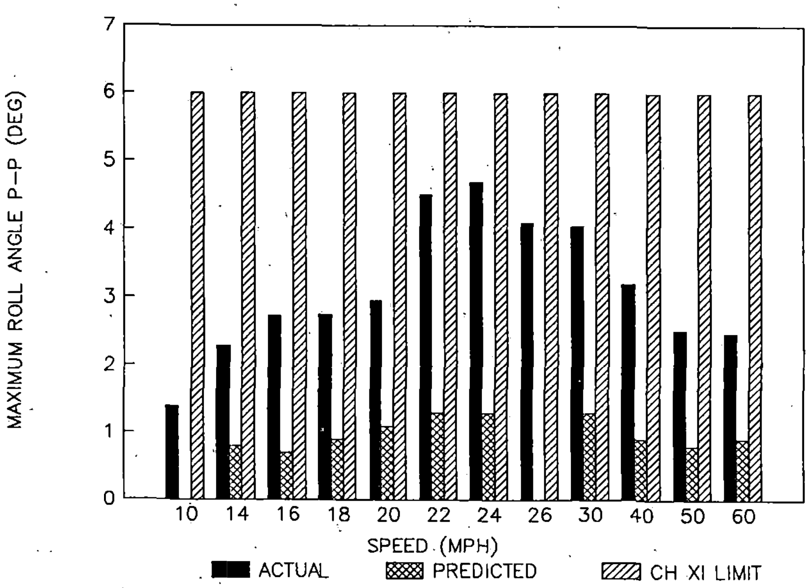

Figure 6.4 Loaded Twist and Roll Maximum Roll Angle (Peak-To-Peak)

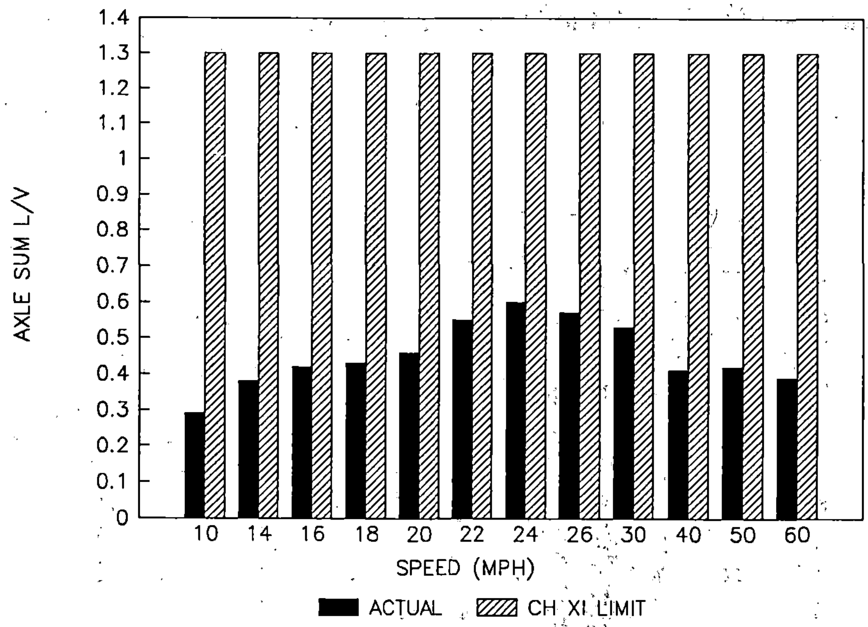

Figure 6.5 Loaded Twist and Roll Axle Sum L/V

The half-loaded condition had two definite critical speeds. At 12 mph, it appears that the sloshing of the fuel was pronounced; this correlates to the resonant frequency of the fuel (0.5 Hz) found in the modal response testing of the half-loaded Fuel Car. At 28 mph, an axle sum L/V of 1.52 and a minimum vertical wheel load of 1.6 percent (50 milliseconds) were recorded. Although testing was planned for speeds from 10 mph to 70 mph, the test was terminated by concurrence of Boeing and the AAR test engineer for reasons of safety. See Table 6.3(b) for the half-loaded results.

Table 6.3(b) Half-Loaded Twist and Roll Results Summary

SPEED (mph)	MIN. VERT. WHEEL LOAD (%)	MIN. VERT. WHEEL LOAD PREDICTED (%)	ROLL ANGLE (DEG.)	ROLL ANGLE PREDICTED (DEG.)	AXLE L/V	AXLE L/V PREDICTED
10	40	--	1.04	--	0.36	--
12	20	--	1.88	--	0.63	--
14	49	--	1.40	--	0.33	--
16	45	--	1.82	--	0.33	--
18	48	--	2.12	--	0.33	--
20	49	--	2.60	--	0.35	--
22	46	--	2.92	--	0.39	--
24	44	--	3.24	--	0.42	--
26	27	--	4.52	--	0.57	--
28	1.6 **50 msec**	--	5.44	--	1.52 **50 msec**	--

NOTE: Time values given are the length of time of exceedence.

Figures 6.6, 6.7, and 6.8 show comparisons of the actual values for wheel load, roll angle, and axle sum L/V with the Chapter XI limiting values for the half-loaded twist and roll testing.

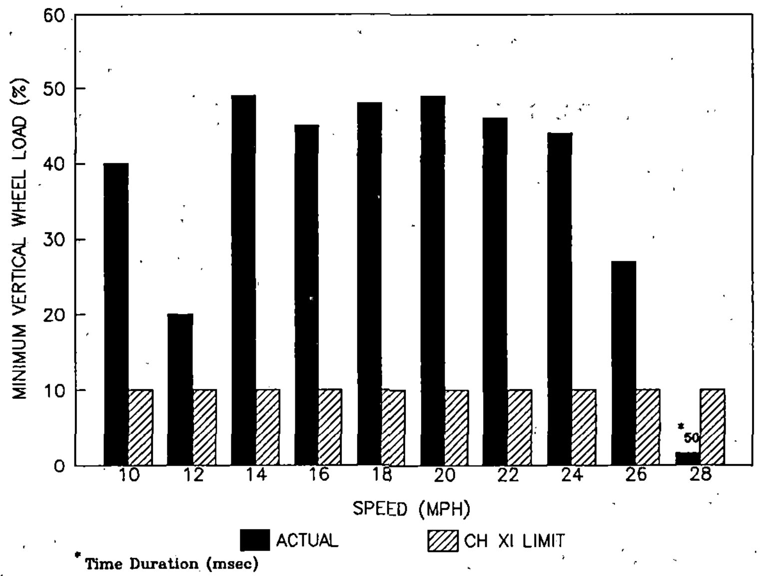

Figure 6.6 Half-Loaded Twist and Roll Minimum Vertical Wheel Load Testing Terminated at 28 mph

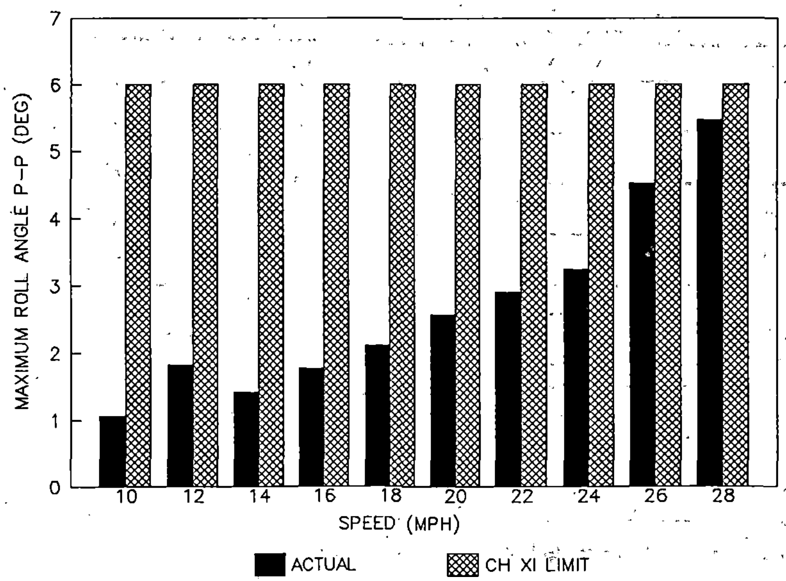

Figure 6.7 Half-Loaded Twist and Roll Maximum Roll Angle Testing Terminated at 28 mph

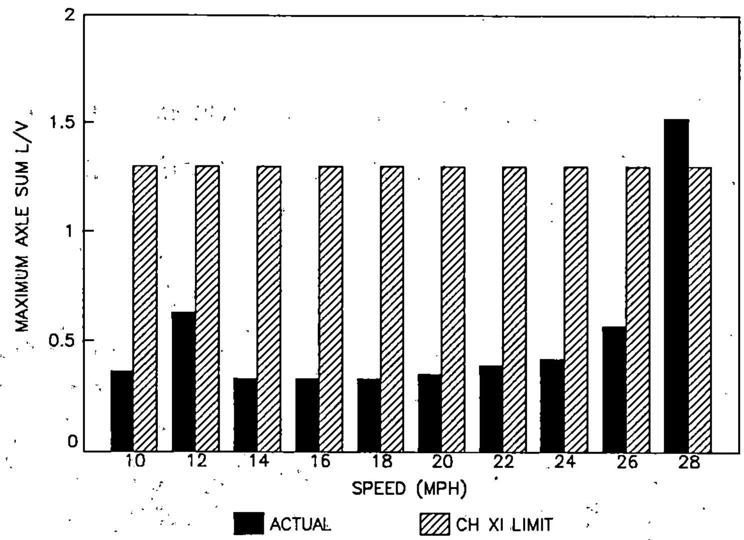

Figure 6.8 Half-Loaded Twist and Roll Axle Sum L/V Testing Terminated at 28 mph

The unloaded configuration was the most critical during twist and roll testing, and while the expected critical speed was 32 mph, testing was terminated at 26 mph due to a minimum vertical wheel load of 3 percent, see Figure 6.9.

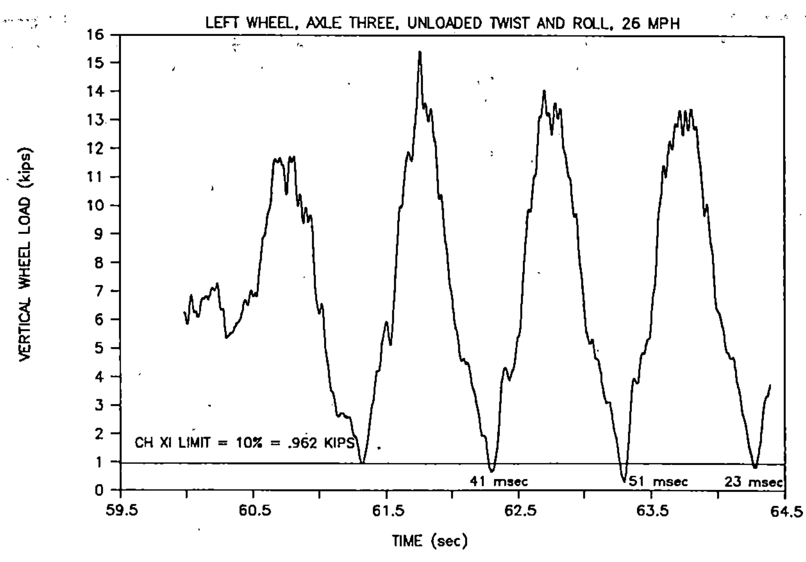

Figure 6.9 Time History of 26 mph Unloaded Car's Left Wheel, Third Axle

Table 6.3(c) shows that Chapter XI criteria was also exceeded at 24 mph. The 3.38 L/V at 26 mph was due primarily to wheel unloading. L/V ratios calculated at very low vertical wheel loads may not be accurate.

Table 6.3(c) Unloaded Twist and Roll Results Summary

SPEED (mph)	MIN. VERT. WHEEL LOAD (%)	MIN. VERT. WHEEL LOAD PREDICTED (%)	ROLL ANGLE (DEG.)	ROLL ANGLE PREDICTED (DEG.)	AXLE L/V	AXLE L/V PREDICTED
10	23	--	1.00	--	0.58	--
14	18	--	1.44	--	0.79	--
16	16	--	1.94	--	0.87	--
18	13	--	2.16	--	1.17	--
20	12	66	2.40	0.8	1.17	--
22	9	--	2.84	--	1.28	--
24	7	55	3.24	0.9	1.53	--
26	3 **51 msec**	56	4.48	0.9	3.38 **50 msec**	--

NOTE: Time values given are the length of time of exceedence.

Figures 6.10 and 6.11 show comparisons of actual and predicted values for wheel load and roll angle with the Chapter XI limiting values for the unloaded twist and roll testing.

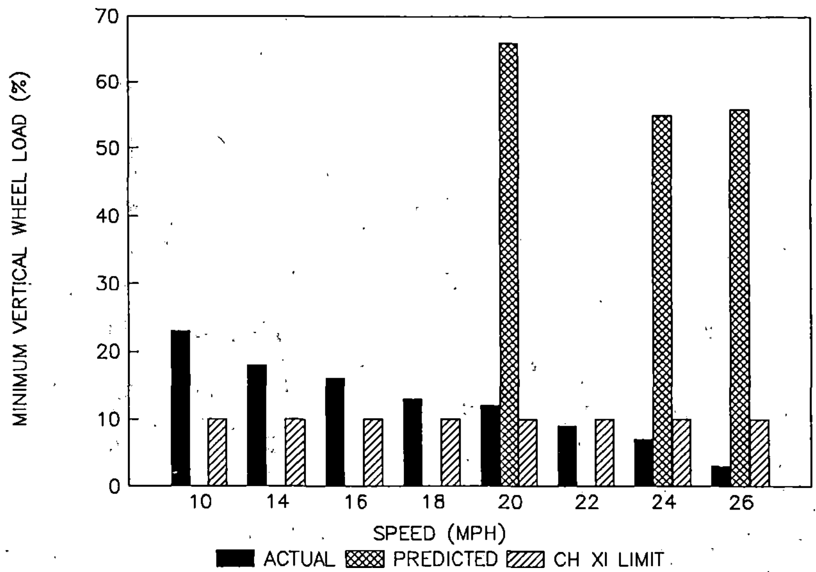

Figure 6.10 Unloaded Twist and Roll Minimum Vertical Wheel Load Testing Terminated at 26 mph

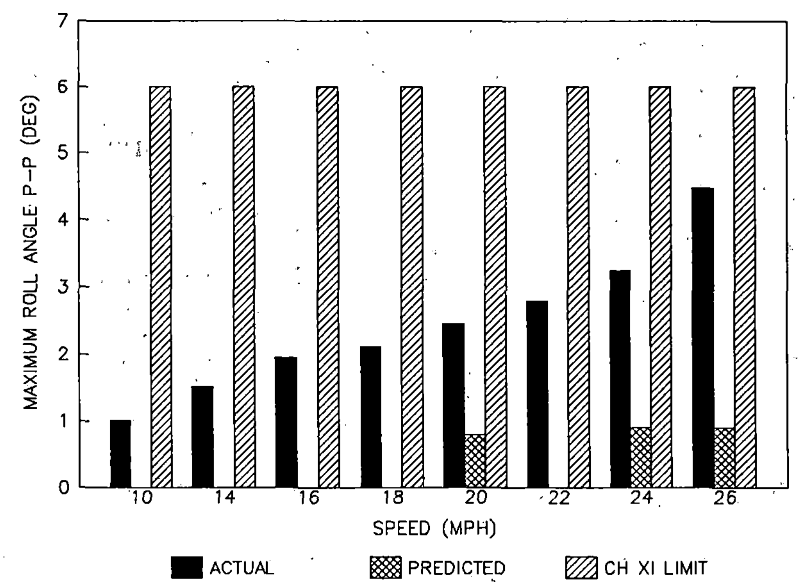

Figure 6.11 Unloaded Twist and Roll Maximum Roll Angle Testing Terminated at 26 mph

Figure 6.12 shows the comparisons of unloaded twist and roll axle sum L/V's with the Chapter XI limiting value for the unloaded twist and roll testing.

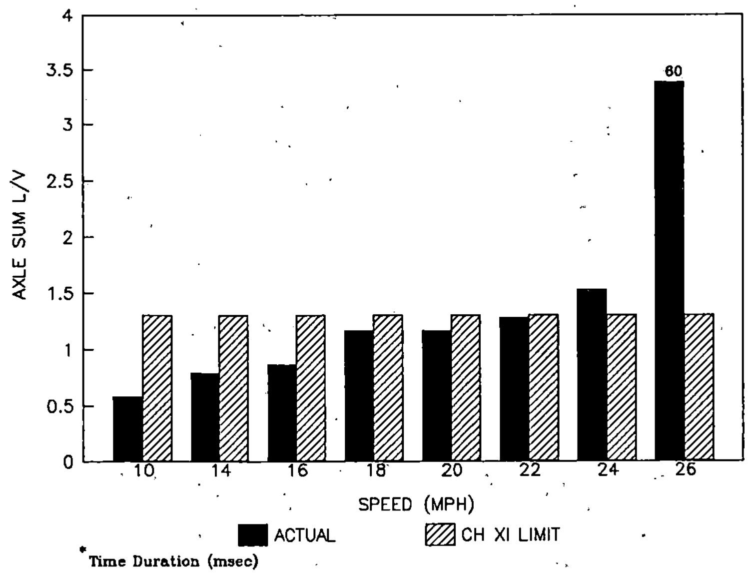

Figure 6.12 Unloaded Twist and Roll Axle Sum L/V Testing Terminated at 26 mph

6.3 DYNAMIC CURVING (LOADED, HALF-LOADED)

The dynamic curving limiting values specify four Chapter XI parameters: maximum wheel L/V of 0.8 and maximum axle sum L/V of 1.3 sustained for 50 milliseconds, maximum roll angle of 6 degrees peak-to-peak, and a minimum vertical wheel load of 10 percent sustained for 50 milliseconds.

The loaded dynamic curve testing was accomplished in the CCW direction. Testing speeds were terminated at 26 mph due to an occurrence of a 1.8 percent vertical wheel load. This exceeded the 10 percent guideline. Note, in Table 6.4(a), axle sum L/V's exceeded the 1.3 limit at all speeds tested with the lone exception being at 16 mph. Time histories of these L/V exceedences show that the 50 millisecond maximum time requirement was surpassed for all L/V's of 1.38 and greater.

Table 6.4(a) Loaded Dynamic Curving

SPEED (mph)	MIN. VERT. WHEEL LOAD (%)	MIN. VERT. WHEEL LOAD PREDICTED (%)	ROLL ANGLE (DEG.)	ROLL ANGLE PREDICTED (DEG.)	AXLE L/V & TIME DURATION	AXLE L/V PREDICTED
10	50	--	1.12	--	1.38 **50 msec**	--
12	48	67	1.28	1.1	1.41 **50 msec**	1.13
14	44	--	1.44	--	1.42 **50 msec**	--
16	32	68	1.84	1.0	1.24	1.13
18	36	70	1.44	0.9	1.47 **100 msec**	1.08
20	47	67	1.52	1.0	1.40 **50 msec**	1.08
22	40	62	1.76	1.8	1.33	1.26
24	12	62	3.12	1.7	1.31	1.27
26	1.8 **200 msec**	--	2.88	--	1.49 **50 msec**	--

NOTE: Time values given are the length of time of exceedence.

Figure 6.13 shows axle sum L/V comparisons for actual and predicted values with the Chapter XI limiting values for the loaded dynamic curve testing.

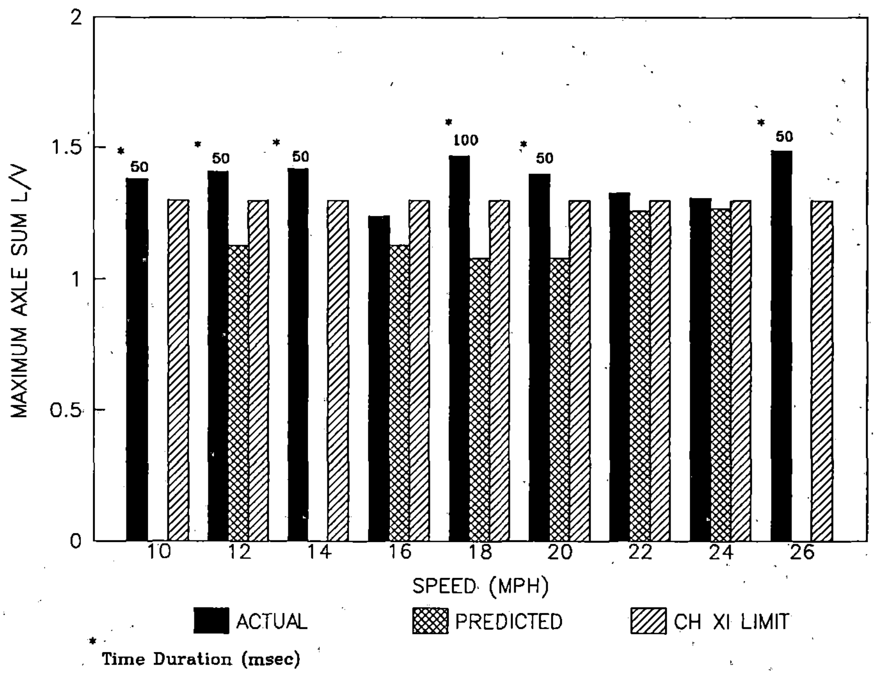

Figure 6.13 Loaded Dynamic Curving Axle Sum L/V

Dynamic curve testing in the half-loaded configuration was accomplished in the CW direction, as well as, the CCW direction. The CCW run was at 10 mph; an axle sum L/V of 1.52 for 55 milliseconds was noted. Boeing and the Air Force jointly agreed to stop testing in that direction and requested further testing in the CW direction. CW testing was accomplished at 10, 12, and 14 mph. The test was stopped by Boeing due to what appeared to be criteria exceedences in all three runs.

Table 6.4(b) shows the comparisons of wheel load, roll angle, and axle sum L/V data for the CCW half-loaded dynamic curving testing.

Table 6.4(b) Half-Loaded Dynamic Curving Results CCW

SPEED (mph)	MIN. VERT. WHEEL LOAD (%)	MIN. VERT. WHEEL LOAD PREDICTED (%)	ROLL ANGLE (DEG.)	ROLL ANGLE PREDICTED (DEG.)	AXLE L/V	AXLE L/V PREDICTED
10	38	--	1.24	--	1.52 **55 msec**	--
12 *	--	--	--	--	--	--
14 *	--	--	--	--	--	--

*** Subsequent speeds were not attempted**
NOTE: Time values given are the length of time of exceedence.

Table 6.4(b) shows the comparisons of wheel load, roll angle, and axle sum L/V data for the CW half-loaded dynamic curving testing.

Table 6.4(c) Half-Loaded Dynamic Curving Results CW

SPEED (mph)	MIN. VERT. WHEEL LOAD (%)	MIN. VERT. WHEEL LOAD PREDICTED (%)	ROLL ANGLE (DEG.)	AXLE L/V	TIME LENGTH EXCEEDENCE
10	52		1.28	1.38	**10 msec**
12	32	67	1.52	1.39	**25 msec**
14	57	--	1.04	1.31	**5 msec**

NOTE: Time values given are the length of time of exceedence.

6.4 CONSTANT CURVING (LOADED, HALF-LOADED, UNLOADED)

Tests were performed for loaded, half-loaded, and unloaded conditions in the CW and CCW directions on the 7.5- and 12-degree curves.

All Chapter XI tests, in which L/Vs are judged as critical in stability assessment, specify maximum values for 50 milliseconds as critical; however, in evaluating the constant curve test the criticality is addressed in Chapter XI as a 95th percentile criterion. This criterion states that the measured value cannot exceed the limit for more than 5 percent of the total constant curve test time. The maximum 95th percentile values show more stability than the maximum single occurrences because they are taken over the whole curve; for example, a particular critical situation may not be seen in the 95th percentile maximum but may indeed exist in single occurrences. The 50 millisecond values are reported here to show the possible criticality due to single occurrences.

The Fuel Car negotiated the 7.5-degree curve within Chapter XI limits in the loaded and half-loaded configurations. In the unloaded configuration, although the 95th percentile limitation was not surpassed for wheel and axle sum L/V's, wheel lift occurred at 32 mph. Minimum vertical wheel load is not part of the limiting criteria for constant curving because it is unusual to have a car exhibit roll resonance while in a constant curve test. Wheel load percentage is included in Table 6.5(c). Additional runs were made at 26, 28, and 30 mph to show the trend for vertical wheel unloading.

Table 6.5(a) shows the loaded car constant curving data for the 7.5-degree curve. The 95th percentile and 50 millisecond criteria were not exceeded in the test.

Table 6.5(a) 7.5-Degree Loaded Constant Curving Summary

DIRECTION	SPEED (mph)	STEADY STATE					
		PEAK WHEEL L/V	95TH PERCENTILE WHEEL L/V	PRED. WHEEL L/V	PEAK AXLE L/V	95TH PERCENTILE AXLE L/V	PRED. AXLE L/V
CCW	14	0.78	0.575	0.45	1.23	1.02	0.87
CCW	24	0.69	0.50	0.40	1.13	0.92	0.79
CCW	32	0.59	0.45	0.36	1.03	0.82	0.69
CW	14	0.64	0.505	0.45	1.04	0.88	0.87
CW	24	0.60	0.47	0.40	1.11	0.88	0.79
CW	32	0.56	0.45	0.36	1.00	0.36	0.69

Table 6.5(b) shows the half-loaded car constant curving data for the 7.5-degree curve. The 95th percentile criterion was not exceeded; however, there was a 0.93 wheel L/V with a 60 millisecond exceedence at 14 mph in the CCW direction.

Table 6.5(b) 7.5 Degree Half-Loaded Constant Curving Summary

DIRECTION	SPEED (mph)	STEADY STATE			
		PEAK WHEEL L/V	95TH PERCENTILE WHEEL L/V	PEAK AXLE L/V	95TH PERCENTILE AXLE L/V
CCW	14	0.93 **60 msec**	0.63	1.45 **60 msec**	1.15
CCW	24	0.78	0.59	1.29	1.05
CCW	32	0.66	0.55	1.16	0.99
CW	14	0.69	0.52	1.08	0.89
CW	24	0.65	0.48	1.03	0.83
CW	32	0.62	0.47	1.03	0.83

NOTE: Time values given are the length of time exceedence.

Table 6.5(c) shows the unloaded car constant curving data for the 7.5-degree curve. The 95th percentile criterion was not exceeded; however, there was a 0.98 wheel L/V with a 65 millisecond exceedence at 14 mph and wheel unloading for 50 milliseconds at 32 mph in the CW direction.

Table 6.5(c) 7.5-Degree Unloaded Constant Curving Summary

DIRECTION	SPEED (mph)	STEADY STATE						
		PEAK WHEEL L/V	95TH PERCENTILE WHEEL L/V	PRED. WHEEL L/V	PEAK AXLE L/V	95TH PERCENTILE AXLE L/V	MIN. PRED. AXLE L/V	WHEEL LOAD %
CW	14	0.73	0.57	0.48	1.25	1.125	0.91	42
CW	24	0.98 65 msec	0.62	0.43	1.62 65 msec	1.130	0.85	22
CW	26	0.76	0.56	--	1.29	0.950	--	19
CW	28	0.82	0.57	--	1.30	0.950	--	22
CW	30	0.78	0.56	--	1.23	0.965	--	14
CW	32	0.78	0.53	0.40	1.41	0.860	0.80	0 50 msec

Model Speeds = 10, 24, and 34 mph
NOTE: Time values given are the length of time of exceedence.

The 12-degree loaded constant curving summary shows no 95th percentile exceedences (see Table 6.6(a) below). There was a 0.86 wheel L/V with a 100 millisecond exceedence and a 1.35 axle sum L/V with 70 milliseconds exceedence at 16 mph in the CCW direction.

Table 6.6(a) 12-Degree Loaded Constant Curving Summary

DIRECTION	SPEED (mph)	STEADY STATE					
		PEAK WHEEL L/V	95TH PERCENTILE WHEEL L/V	PRED. WHEEL L/V	PEAK AXLE L/V	95TH PERCENTILE AXLE L/V	PRED. AXLE L/V
CCW	16	0.86 **100 msec**	0.74	0.53	1.35 **70 msec**	1.21	1.03
CCW	25	0.82	0.71	0.48	1.30	1.18	0.94
CCW	32	0.71	0.60	0.47	1.17	1.06	0.89
CW	16	0.85	0.74	0.53	1.40	1.23	1.03
CW	25	0.79	0.68	0.48	1.35	1.19	0.94
CW	32	0.77	0.61	0.47	1.32	1.15	0.89

Model Speeds = 15.5, 24.5, and 31 mph
NOTE: Time values given are the length of time of exceedence.

The half-loaded 12-degree curve summary (Table 6.6(b)) also shows no exceedences; however, at 16 mph the 95th percentile wheel L/V was 0.78, which is close to the 0.80 L/V limitation. There were "instantaneous" 50 millisecond exceedences for the 16 mph runs in both directions and one in the CCW direction at 32 mph. Minimum vertical wheel load percentage has been included in the table. A minimum vertical wheel load of 6 percent with a 20 millisecond duration was recorded at 32 mph.

Table 6.6(b) 12-Degree Half-Loaded Constant Curving Summary

DIRECTION	SPEED (mph)	STEADY STATE				
		PEAK WHEEL L/V	95TH PERCENTILE WHEEL L/V	PEAK AXLE L/V	95TH PERCENTILE L/V	WHEEL LOAD %
CCW	16	0.84 50 msec	0.78	1.38 50 msec	1.28	66
CCW	25	0.82	0.68	1.32	1.18	54
CCW	32	0.86 50 msec	0.66	1.36 50 msec	1.17	32
CW	16	0.85 55 msec	0.72	1.40 55 msec	1.20	60
CW	25	0.82	0.68	1.33	1.21	53
CW	32	0.75	0.64	1.31	1.17	6 20 msec

NOTE: Time values given are the length of time of exceedence.

In the unloaded case (Table 6.6(c)), an exceedence was recorded during the first 12-degree curve run at 16 mph; hence, testing was terminated.

Table 6.6(c) 12-Degree Unloaded Constant Curving Summary

DIRECTION	SPEED (mph)	STEADY STATE					
		PEAK WHEEL L/V	95TH PERCENTILE WHEEL L/V	PRED. WHEEL L/V	PEAK AXLE L/V	95TH PERCENTILE AXLE L/V	PRED. AXLE L/V
*CW	16	0.94 **200 msec**	0.83	0.51	1.65 **200 msec**	1.13	0.99
CW	25	--		0.49	--		0.98
CW	32	--		0.49	--		0.97

Model Speeds = 15.5, 24.5, and 31 mph
*** Test Terminated at 16 mph**
NOTE: Time values given are the length of time of exceedence.

Figure 6.14 shows the 95th percentile and maximum axle sum L/V's for both CW and CCW directions, of the loaded Fuel Car, on the 12-degree curve. Predicted of peak values and Chapter XI limitations are also shown.

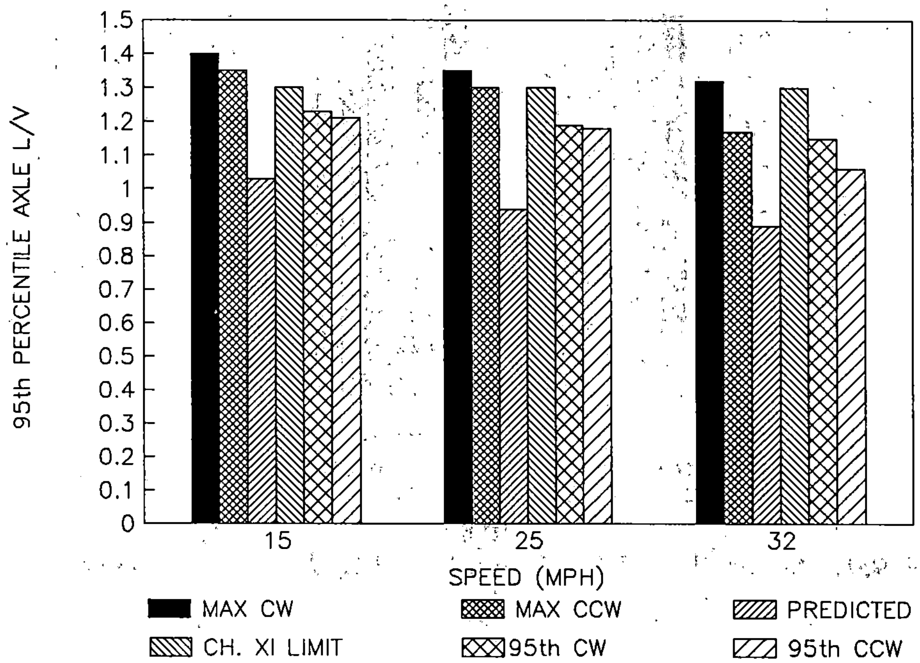

Figure 6.14 95th Percentile and Maximum Axle Sum L/V's for the Loaded 12-Degree Curve

Figure 6.15 shows the 95th percentile and maximum wheel L/V's for both directions on the 12-degree curve. Predictions of peak values and Chapter XI limit are also shown.

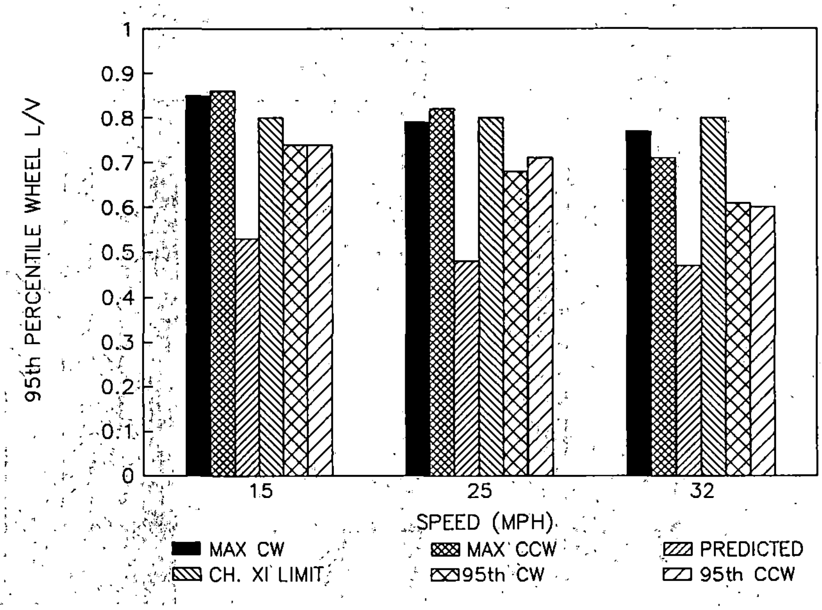

Figure 6.15 95th Percentile and Maximum Wheel L/V's for the Loaded 12-Degree Curve

Two things are noted in the two previous figures; 1) Steady state curve performance was similar in both directions and 2) The wheel L/V trends indicate a dry track and believable IWS results for three-piece truck performance. On dry track, a 0.8 flanging wheel L/V should be accompanied by approximately an 0.5 L/V on the opposite non-flanging wheel. This would yield a 1.3 axle sum. The L/V for the wheel that is not flanging should not exceed the static coefficient of friction.

6.5 SPIRAL NEGOTIATION (LOADED, HALF-LOADED, UNLOADED)

6.5.1 7.5-Degree Curve

Curve entry and curve exit performance in the 7.5-degree curve for all configurations of the Fuel Car were within Chapter XI guidelines. There were no exceedences.

In curve entry, the maximum wheel L/V's were 0.48 and 0.54 in the CCW and CW directions, respectively; in curve exit, the maximum wheel L\V's were 0.55 and 0.52 in the CCW and CW directions, respectively. Table 6.7(a) summarizes the data for the 7.5-degree loaded spiral negotiation testing.

Table 6.7(a) 7.5-Degree Loaded Spiral Negotiation Summary

DIR.	SPEED (mph)	CURVE ENTRY					CURVE EXIT				
		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL	
					ACT.	PRED.				ACT.	PRED.
CCW	14	0.40	0.54	0.64	54	64	0.55	0.47	1.00	62	67
CCW	24	0.46	0.48	0.86	60	71	0.49	0.40	0.87	57	70
CCW	32	0.48	0.42	0.90	54	65	0.44	0.35	0.88	52	59
CW	14	0.54	0.54	0.90	68	64	0.52	0.47	0.88	57	67
CW	24	0.40	0.48	0.70	73	71	0.45	0.40	0.84	64	70
CW	32	0.35	0.42	0.67	53	65	0.35	0.35	0.65	46	59

Model Speeds = 10, 24, and 34 mph

Table 6.7(b) shows the 7.5-degree half-loaded spiral negotiation testing summary. The most critical value seen was a 0.67 wheel L/V at 14 mph in the CCW direction.

Table 6.7(b) 7.5-Degree Half-Loaded Spiral Negotiation Summary

DIR.	SPEED (mph)	CURVE ENTRY					CURVE EXIT				
		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD	
					ACT.	PRED.				ACT.	PRED.
CCW	14	0.67	--	1.22	46	--	0.64	--	1.17	63	--
CCW	24	0.61	--	1.13	57	--	0.58	--	1.04	70	--
CCW	32	0.54	--	1.03	48	--	0.58	--	1.01	52	--
CW	14	0.48	--	0.82	59	--	0.47	--	0.89	54	--
CW	24	0.45	--	0.80	58	--	0.46	--	0.76	52	--
CW	32	0.42	--	0.78	54	--	0.42	--	0.72	44	--

Table 6.7(c) summarizes the 7.5-degree unloaded spiral negotiation. Due to the possible instability of the car in the 12-degree curve which leads into the 7.5-degree curve in the CCW direction, this test was run in the CW direction only. There were no exceedences of the Chapter XI guideline criteria.

Table 6.7(c) 7.5-Degree Unloaded Spiral Negotiation Summary

DIR.	SPEED (mph)	CURVE ENTRY					CURVE EXIT				
		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD	
					ACT.	PRED.				ACT.	PRED.
CW	14	0.50	--	0.84	44	--	0.67	--	1.20	30	--
CW	24	0.49	--	0.89	50	--	0.64	--	1.13	24	--
CW	32	0.57	--	1.00	19	--	0.40	--	0.69	14	--

Model Speeds = 10, 24, and 34 mph

6.5.2 12-Degree Curve

For all configurations, bunched spiral (BS) negotiation was curve entry in the CCW direction and curve exit in the CW direction on the 12-degree curve. A conventional spiral (CS) was at the opposite end of this curve.

In the loaded condition (Table 6.8(a)), the CW 16 mph curve exit (BS) showed a 150 millisecond exceedence for wheel L/V and a 100 millisecond exceedence for axle sum L/V, and the CW 32 mph curve entry (CS) gave a wheel L/V of 0.89 with 50 milliseconds of exceedence and axle sum L/V of 1.41 with 100 milliseconds of exceedence. The loaded car CCW spiral negotiation did not have exceedences.

Table 6.8(a) 12-Degree Loaded Spiral Negotiation Summary

DIR.	SPEED (mph)	CURVE ENTRY					CURVE EXIT				
		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL LOAD	
					ACT.	PRED.				ACT.	PRED.
CCW	16	0.76	0.70	1.26	61	57	0.80	0.78	1.24	55	48
CCW	25	0.79	0.62	1.24	50	54	0.75	0.60	1.21	37	54
CCW	32	0.80	0.57	1.21	31	49	0.70	0.50	1.18	17	46
CW	16	0.83	0.70	1.30	50	57	**0.89 150 msec**	0.78	**1.41 100 msec**	52	48
CW	25	0.80	0.62	1.28	37	54	0.69	0.60	1.14	63	54
CW	32	0.89 **50 msec**	0.57	1.32	9	49	0.61	0.50	1.18	44	46

Model Speeds = 15.5, 24.5, and 31 mph
NOTE: Time values given are the length of time of exceedence.

In the CCW direction, when half-loaded (Table 6.8(b)), the curve entry (BS) produced a wheel L/V exceedence at 16 mph. At 32 mph in the CW direction, the Fuel Car exhibited a minimum vertical wheel load of 7 percent (50 milliseconds) during curve entry, which is less than the 10 percent minimum vertical wheel load expressed in Chapter XI.

Table 6.8(b) 12-Degree Half-Loaded Spiral Negotiation Summary

DIR.	SPEED (mph)	CURVE ENTRY					CURVE EXIT				
		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL %		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL %	
					ACT	PRED				ACT	PRED
CCW	16	0.86 50 msec	--	1.33	60	--	0.86	--	1.34	54	--
CCW	25	0.85 50 msec	--	1.30	55	--	0.80	--	1.25	41	--
CCW	32	0.82	--	1.28	35	--	0.80	--	1.24	6	--
CW	16	0.76	--	1.14	51	--	0.59	--	1.06	48	--
CW	25	0.77	--	1.15	39	--	0.72	--	1.21	52	--
CW	32	0.82	--	1.27	7 50 msec	--	0.74	--	1.27	50	--

NOTE: Time values given are the length of time of exceedence.

The unloaded Fuel Car as tested in the CW direction (Table 6.8(c)) showed poor behavior in both curve entry (CS) curve exit (BS) of the 12-degree curve at 16 mph . The most severe was a wheel L/V of 1.26 with a 900 millisecond time exceedence in the curve exit (BS). Due to the CW results, CCW testing was not attempted.

Table 6.8(c) 12-Degree Unloaded Spiral Negotiation Summary

DIR.	SPEED (mph)	CURVE ENTRY					CURVE EXIT				
		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL %		MAX. WHEEL L/V	MAX. PRED. WHEEL L/V	MAX. AXLE L/V	MIN. VERT. WHEEL %	
					ACT	PRED				ACT	PRED
CW	16	1.07 **200 msec**	--	1.57 **150 msec**	20	--	1.26 **900 msec**	--	1.75 **750 msec**	35	--
CW	25	--	--	--	--	--	--	--	--	--	--
CW	32	--	--	--	--	--	--	--	--	--	--

For all configurations: 12-degree CCW curve entry is bunched spiral
12-degree CW curve exit is bunched spiral
NOTE: Time values given are the length of time of exceedence.

Figure 6.16 shows comparisons of the 12-degree actual and predicted wheel L/V for bunched spiral curve entry and exit maximum wheel L/V's for the loaded car operated in both directions.

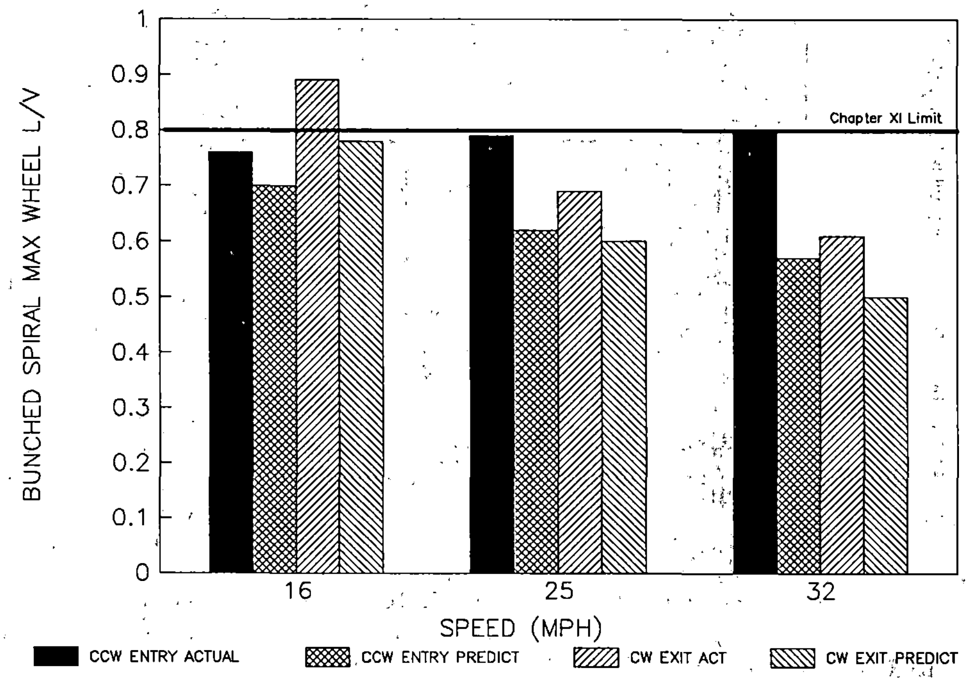

Figure 6.16 Loaded Fuel Car Spiral Negotiation Results 12-Degree CCW Bunched Spiral

Figure 6.17 shows comparisons of the 12-degree actual and predicted conventional spiral curve entry and exit maximum wheel L/V's for the loaded car operated in both directions.

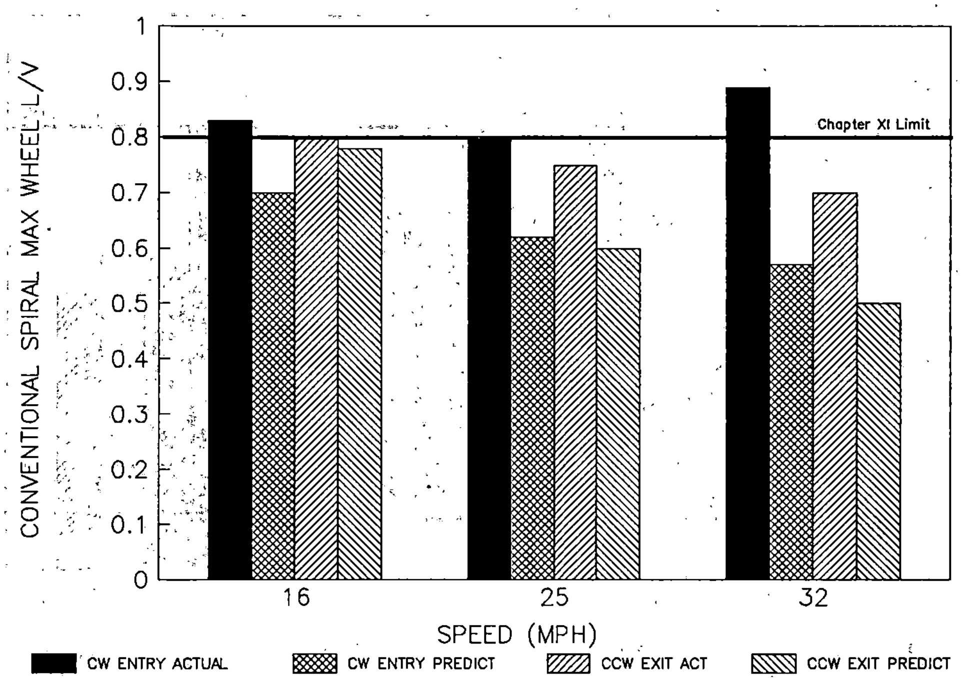

Figure 6.17 Loaded Fuel Car Spiral Negotiation Results 12-Degree CW Conventional Spiral

Figure 6.18 shows comparisons of the 12-degree bunched spiral curve entry and exit maximum wheel L/V's for the half-loaded car operated in both directions.

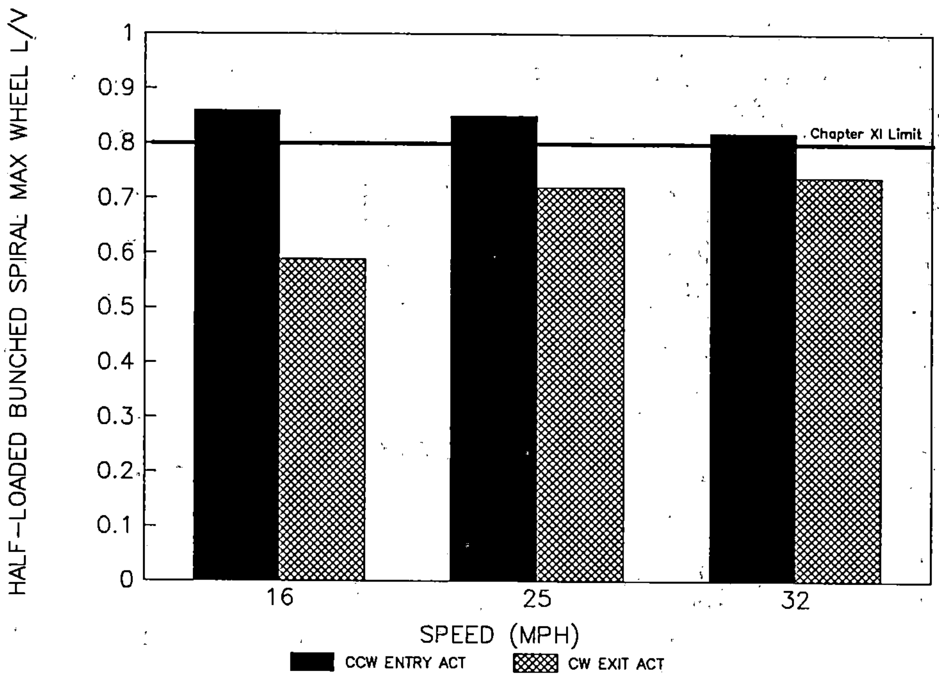

Figure 6.18 Half-Loaded Fuel Car Spiral Negotiation Results 12-Degree CCW Bunched Spiral

Figure 6.19 shows comparisons of the 12-degree conventional spiral curve entry and exit maximum wheel L/V's for the half-loaded car operated in both directions.

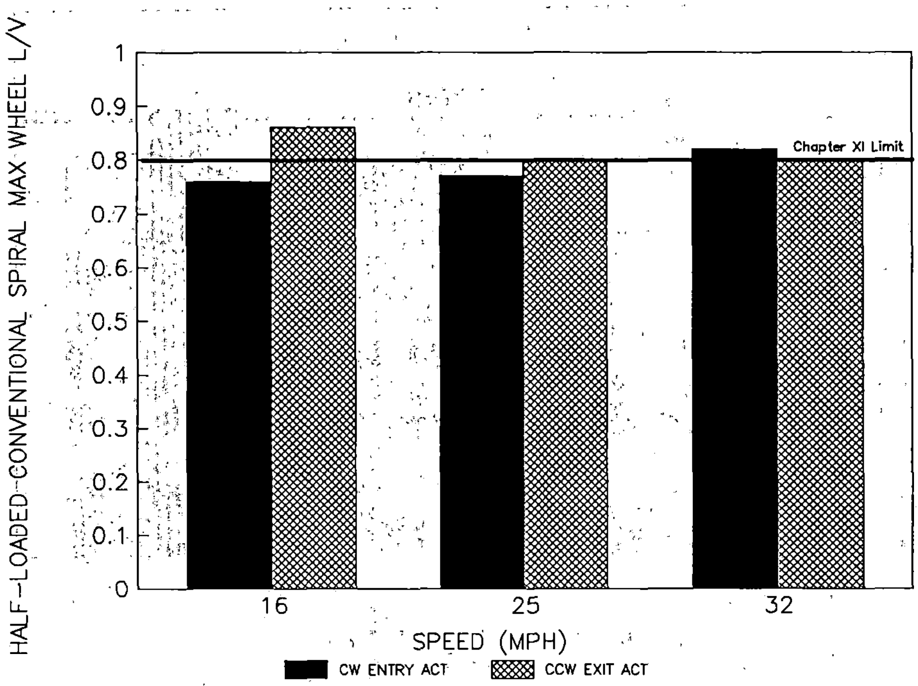

Figure 6.19 Half-Loaded Fuel Car Spiral Negotiation Results 12-Degree CW Conventional Spiral

The unloaded 12-degree spiral negotiation at 16 mph (CW entry and exit) was unstable, as shown in Table 6.8(c) and consisted of only one run; therefore, there will not be a bar chart summary for the 12-degree spiral negotiation of the unloaded car.

6.6 TURNOUT AND CROSSOVER (LOADED, HALF-LOADED, UNLOADED)

Turnout and crossover testing is not listed as an official Chapter XI Test; hence, there are no official limiting criteria. Wheel L/V's of 0.8 and a axle sum L/V's of 1.3 for 50 milliseconds, were used as guidelines. Results are summarized in Tables 6.9(a), (b), and (c) for the loaded, half-loaded, and unloaded configurations, respectively.

In general, the Fuel Car had difficulty negotiating turnouts and crossovers. The loaded condition was the least severe and the unloaded was the most severe.

An axle sum L/V of 1.31, for approximately 40 milliseconds, was the most severe result from the loaded testing (see Table 6.9(a)).

Table 6.9(a) Loaded Turnout and Crossover Results

TEST	DIRECTION	SPEED	MAXIMUM WHEEL L/V	MAXIMUM AXLE SUM L/V
Turnout	CCW	10	0.61	1.08
Turnout	CCW	15	0.78	1.31
Crossover	CCW	10	0.58	0.98
Crossover	CCW	15	0.63	0.99
Crossover	CCW	20	0.73	1.06
Turnout	CW	10	0.58	1.10
Turnout	CW	15	0.69	1.11
Crossover	CW	10	0.68	1.00
Crossover	CW	15	0.75	1.08
Crossover	CW	20	0.72	1.06

The tighter No. 8 turnouts (15 mph maximum speed) were more difficult to negotiate than the No. 15 crossovers (35 mph maximum speed) for the half-loaded Fuel Car as can be seen from Table 6.9(b). Wheel and axle sum L/V guidelines were exceeded for the 10 and 15 mph turnout negotiations.

Table 6.9(b) Half-Loaded Turnout and Crossover Results

TEST	DIRECTION	SPEED	MAXIMUM WHEEL L/V	MAXIMUM AXLE SUM L/V	MAXIMUM TIME LENGTH EXCEEDENCE
Turnout	CW	10	0.91	1.47	250msec
Turnout	CW	15	0.84	1.38	50msec
Crossover	CW	15	0.59	0.93	--
Crossover	CW	25	0.65	1.08	--
Crossover	CW	35	0.66	1.12	--
Crossover	CCW	15	0.63	0.97	--
Crossover	CCW	25	0.59	0.94	--
Crossover	CCW	35	0.69	0.99	--

In the unloaded condition, Table 6.9(c), the Fuel Car had difficulty in both turnout and crossover negotiation. Several exceedences of the guideline L/V were noted.

Table 6.9(c) Unloaded Turnout and Crossover Results

TEST	DIRECTION	SPEED	MAXIMUM WHEEL L/V	MAXIMUM AXLE SUM L/V	MAXIMUM TIME LENGTH EXCEEDENCE
Turnout	CW	10	0.92	1.31	--
Turnout	CW	15	0.96	1.52	**75msec**
Crossover	CW	15	0.70	1.58	**100msec**
Crossover *	--	25	--	--	--
Crossover *	--	35	--	--	--
Turnout	CCW	10	0.91	1.36	--
Turnout	CCW	15	0.97	1.38	**100msec**
Crossover	CCW	15	0.70	1.11	--
Crossover	CCW	25	0.71	1.19	--
Crossover	CCW	35	0.88	1.42	**50msec**

*** Not attempted due to results seen in previous run**

6.7 YAW AND SWAY (LOADED, HALF-LOADED)

Chapter XI specified two limiting criteria for yaw and sway testing. The first was a maximum absolute axle sum L/V of 1.3 for 50 milliseconds. The second limit was a maximum instantaneous truck side L/V of 0.6 for 50 milliseconds or 6 feet.

In order to obtain truck side L/V's, one of the wheel sets had to be relocated. The leading axle (IWS) of the trailing truck was put into the trailing axle position of the leading truck.

NUCARS modeling predicted high L/V's and possible derailment. Past experience has indicted that NUCARS is unduly conservative in its predictions for the regime. Furthermore, the lateral perturbations on the track were approximately 0.25 inches less than the Chapter XI described 1.25 inches. This may also account for the difference between model predictions and measured data.

Loaded yaw and sway testing performance showed stability, as shown in Table 6.10(a).

Table 6.10(a) Loaded Yaw and Sway Results

SPEED	MAXIMUM AXLE SUM L/V	PREDICTED AXLE SUM	MAXIMUM TRUCK SIDE L/V	PREDICTED TRUCK SIDE L/V
30	0.53	1.34	0.20	0.53
35	0.78	--	0.29	--
40	0.63	1.41	0.25	0.70
45	0.85	--	0.36	--
50	0.87	1.45	0.35	0.82
55	0.94	--	0.39	--
60	0.93	2.79	0.41	0.97
70	--	2.85	--	0.96

Half-loaded yaw and sway testing also showed stability, as shown in Table 6.10(b).

Table 6.10(b) Half-Loaded Yaw and Sway Results

SPEED	MAXIMUM AXLE SUM L/V	PREDICTED AXLE SUM	MAXIMUM TRUCK SIDE L/V	PREDICTED TRUCK SIDE L/V
30	0.54	--	0.21	--
35	0.58	--	0.24	--
40	0.65	--	0.27	--
45	0.70	--	0.30	--
50	0.81	--	0.35	--
55	0.87	--	0.40	--
60	0.94	--	0.47	--

Yaw and sway truck side and axle sum L/V's were substantially lower than Chapter XI limiting criteria. Figures 6.20 and 6.21 show actual and predicted yaw and sway results for the loaded car compared to Chapter XI limits for axle sum L/V and truck side L/V, respectively.

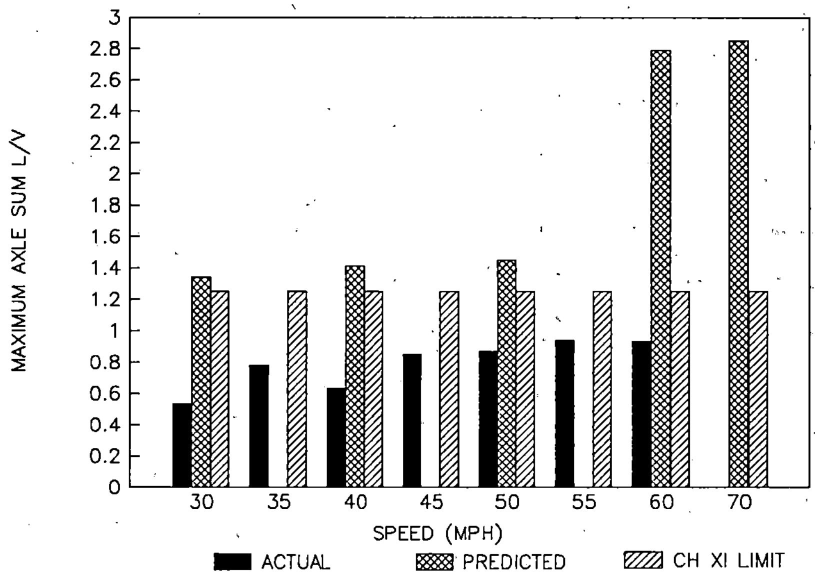

Figure 6.20 Loaded Yaw and Sway Axle Sum L/V Results

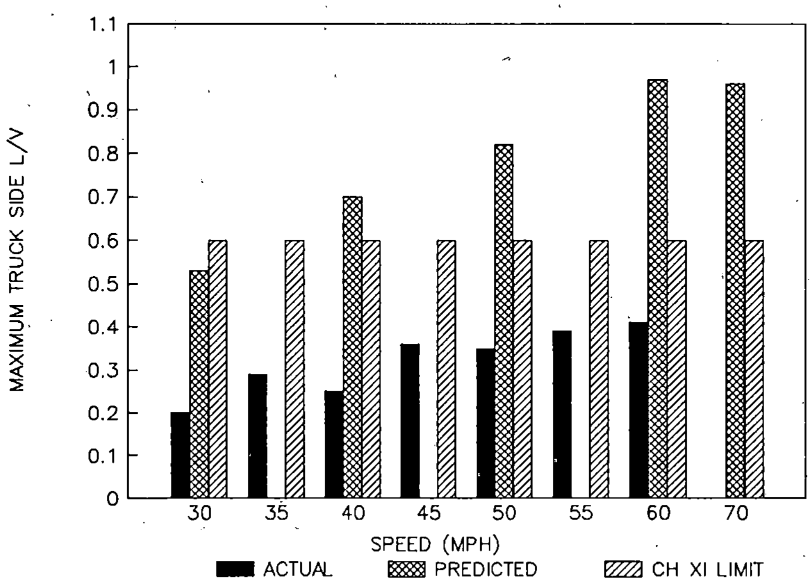

Figure 6.21 Loaded Yaw and Sway Truck Side L/V Results

Half-loaded truck side and axle sum L/V's were also lower than Chapter XI limiting criteria. Figures 6.22 and 6.23 show yaw and sway results for the half-loaded car compared to Chapter XI limits for axle sum L/V and truck side L/V, respectively.

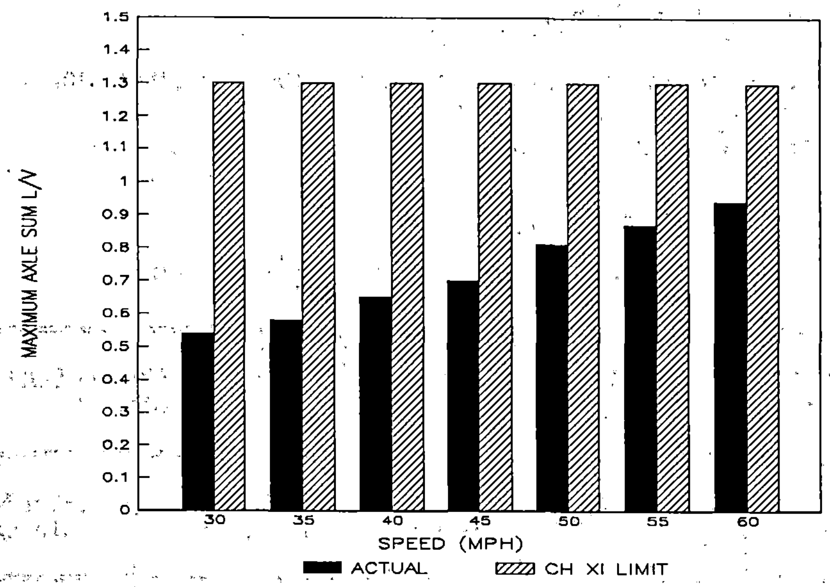

Figure 6.22 Half-Loaded Yaw and Sway Axle Sum L/V Results

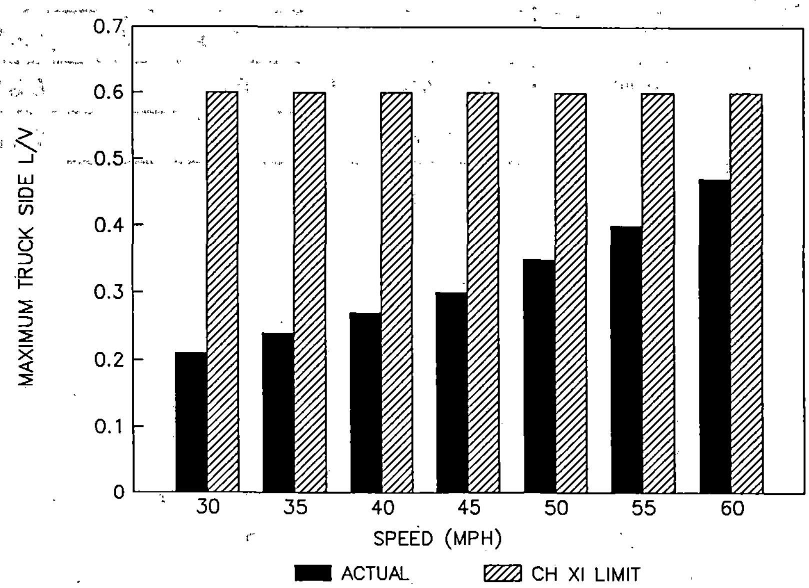

Figure 6.23 Half-Loaded Yaw and Sway Truck Side L/V Results

6.8 HUNTING (HALF-LOADED, UNLOADED)

There were two limiting criteria for the Hunting Test: maximum axle sum L/V of 1.3 for 50 milliseconds, and maximum peak-to-peak lateral acceleration of 1.0 g sustained for 20 seconds. The maximum test speed was 70 mph.

Table 6.11(a) is a tabulation of hunting results for the half-loaded configuration. No exceedences in the half-loaded test occurred.

Table 6.11(a) Lateral Stability Half-Loaded

SPEED (mph)	MAXIMUM PEAK-TO-PEAK LATERAL ACCELERATION		MAXIMUM AXLE ABSOLUTE SUM L/V	
	LEADING CENTERPLATE	TRAILING CENTERPLATE	LEADING TRUCK	TRAILING TRUCK
30	0.32	0.32	0.41	0.29
40	0.39	0.42	0.49	0.62
50	0.37	0.36	0.46	0.41
60	0.40	0.39	0.47	0.36
70	0.56	0.39	0.38	0.34

Table 6.11(b) is a tabulation of hunting results and predictions for the unloaded configuration. No exceedences occurred in the unloaded test.

Table 6.11(b) Lateral Stability Unloaded

SPEED (mph)	MAXIMUM PEAK-TO-PEAK LATERAL ACCELERATION				MAXIMUM AXLE ABSOLUTE SUM L/V			
	LEADING CENTERPLATE		TRAILING CENTERPLATE		LEADING TRUCK		TRAILING TRUCK	
	ACT.	PRED.	ACT.	PRED.	ACT.	PRED.	ACT.	PRED.
30	0.35	--	0.31	--	0.52	--	0.72	--
40	0.33	0.28	0.34	0.13	0.46	0.38	0.45	0.16
50	0.37	1.33	0.37	1.42	0.57	1.21	0.70	1.17
55	0.38	--	0.39	--	0.44	--	0.70	--
60	0.41	1.77	0.36	0.17	0.46	1.45	0.58	0.20
65	0.46	--	0.35	--	0.46	--	0.42	--
70	0.51	1.78	0.39	0.18	0.45	1.45	0.42	0.20

7.0 CONCLUSIONS

The Fuel Car track worthiness testing included portions of Chapter XI for loaded, half-loaded, and unloaded configurations. Although the loaded configuration performed acceptably in most of the tests, the same tests proved to be difficult for some of the half-loaded and almost all of the unloaded operations.

The results are summarized below:

1. **Hunting:**

   Half-loaded and unloaded conditions were tested and found to be within Chapter XI limits.

2. **Yaw and Sway:**

   Loaded and half-loaded conditions were tested and found to be within Chapter XI limits.

3. **Pitch and Bounce:**

   All configurations were tested and found to be within Chapter XI limits.

4. **Turnouts and Crossovers:**

   In general, the tighter turnouts were more difficult to negotiate than crossovers for all configurations.

   The unloaded configuration exceeded guideline criteria in most runs.

   The half-loaded configuration exceeded guideline criteria in turnouts.

   The loaded configuration met guideline criteria.

5. **Twist and Roll:**

All roll resonances agreed with calculations from the roll frequencies found during modal response testing.

The loaded case showed no exceedences, but exhibited resonance at 24 mph, which corresponds to the roll frequency of 0.9 Hz found in modal response testing.

A 1.6 percent minimum vertical load at 28 mph (1.0 Hz) stopped the testing in the half-loaded case.

A 3 percent minimum vertical load at 26 mph stopped the testing in the unloaded case.

The 1.2 Hz roll frequency found in modal response testing of the unloaded configuration would equate to a 32 mph roll speed. This speed was not attempted due to poor results at 26 mph and below. The twist and roll track contains perturbations of 39-foot wavelengths. The truck center spacing of the Fuel Car is 35 feet 5 inches, which is undoubtedly a major contributor to the cars poor performance in the twist and roll section.

6. **Dynamic Curving:**

The loaded car showed exceedences in this test scenario. Only three of the nine speed conditions tested did not exceed the axle sum L/V criterion.

The half-loaded condition was tested first in the CCW direction and then in the CW direction. An axle sum L/V of 1.52 at 10 mph cancelled further testing in the CCW direction. In the CW direction, exceedence did not occur; however, testing was terminated at 14 mph due to what appeared to be exceedences.

Testing of the unloaded car was not planned. Due to twist and roll performance, it is possible that criteria would have been exceeded.

7. **Constant Curving 7.5-Degree:**

Loaded and half-loaded conditions were tested and found to be within Chapter XI limitations.

In the unloaded condition, although the 95th percentile limitation was not surpassed for wheel and axle sum L/V's, wheel lift did occur at 32 mph. Minimum vertical wheel load is not part of the official limiting criteria for constant curving; but wheel lift is judged to be unacceptable. Rails are joined at staggered 39 foot spacings. The 32 mph wheel lift speed does in fact correlate to the 1.2 Hz resonant roll frequency found in the modal response testing of the unloaded Fuel Car.

8. **Constant Curving 12-Degree:**

No problems were found for the loaded and half-loaded configurations, but at 16 mph for the half-loaded case, the 95th percentile wheel L/V was 0.78 which is close to the 0.80 L/V limitation.

Testing was terminated after the first run at 16 mph during the unloaded test due to high wheel L/V occurrence.

9. ***Spiral Negotiation:***

Curve entry and curve exit in the 7.5-degree curve for all configurations of test were acceptable.

In the 12-degree curve, the BS at exit (CW) had a wheel L/V of 0.89 in the loaded condition; the BS at entry (CCW) for the half-loaded configuration showed a wheel L/V of 0.86.

The half-loaded configuration had a minimum vertical wheel load of 7 percent in the CS at entry of the 32 mph CW run.

The unloaded CW run at 16 mph had several exceedences at entry and in the BS at exit.

7.1 RECOMMENDATIONS

1. Due to poor performance in the half-loaded and empty testing, it was recommended that the fuel car not be tested with the full PKRG consist in the 7.3.1 Train Test, unless placed at the rear of the train. The Air Force authorized loaded (with water) car operation at normal fuel car position for full train testing.

2. The fuel car should be retested to determine if problems are related to specific car characteristics due to manufacturing tolerances.

3. If problems persist, design changes should be made.

APPENDIX A

CHAPTER XI

SERVICE WORTHINESS TESTS AND ANALYSIS FOR NEW FREIGHT CARS

CHAPTER XI
SERVICE-WORTHINESS TESTS AND ANALYSES FOR NEW FREIGHT CARS
Adopted 1987

11.1. PURPOSE AND SCOPE

This chapter presents guidelines for testing and analysis to ascertain the interchange-service worthiness of freight cars. The regimes of vehicle performance to be examined are divided into two sections. Section 1 covers structural static and impact requirements. Section 2 covers vehicle dynamic performance, with the following regimes to be examined: hunting, car body twist and roll, pitch and bounce, yaw and sway and longitudinal train action.

Braking performance, structural fatigue life, car handling, and other design considerations must be considered in accordance with requirements outlined by other chapters of this specification.

The methods presented provide acceptable approaches to the analysis and measurement of car parameters and performance. Other rational methods may be proposed at the time of submission for design approval. Their use and applicability must be agreed to by the Car Construction Committee.

11.2. STATIC AND IMPACT TEST REQUIREMENTS

Application for approval of new and untried types of cars, along with supporting data specified in paragraph 1.2.3, shall be submitted to the Director—Technical Committees Freight Car Construction prior to initiation of official AAR testing. A proposed testing schedule and testing procedures will be submitted sufficiently in advance of tests to permit review and approval of the proposal and assignment of personnel to witness tests as AAR observers. Tests will be in conformity with the following and all costs are to be borne by the applicant, including observers.

11.2.1. TEST CONDITIONS

11.2.1.1.

A car of the configuration proposed for interchange service must be utilized for all tests. Deviation from such configuration is only permitted with the explicit permission of the Car Construction Committee.

During impact tests, the test car will be the striking car and shall be loaded to AAR maximum gross rail load for the number and size of axles used under car (see 2.1.5.17). Exceptions to this procedure will be considered by the Car Construction Committee when justified by the applicant.

Cars designed for bulk loading shall have a minimum of 85% of the total volume filled.

Cars designed for general service, other than bulk loading, shall be loaded so that the combined center of gravity of car and loading is as close as practicable to the center of gravity computed in accordance with the requirements of 2.1.3, except that general service flat cars may be loaded by any practicable method. The loads shall be rigidly braced where necessary, and various types of loads should be used to test each component to its maximum load.

The test car may be equipped with any AAR-approved draft gear or any AAR-approved cushioning device for which the car was designed.

11.2.1.2.

The cars, other than the test car, shall be of seventy ton nominal capacity, loaded to the allowable gross weight on rails prescribed in 2.1.5.17. A high density granular material should be used to load cars to provide a low center of gravity, and the load should be well braced to prevent shifting. Such cars shall be equipped with draft gears meeting the requirements of AAR Specification M-901, except at the struck end where M-901E rubber friction gear shall be used.

Free slack between cars is to be removed, draft gears are not to be compressed. No restraint other than handbrake on the last car is to be used.

11.2.2. INSTRUMENTATION

The coupler force shall be measured by means of a transducer complying with AAR Specification M-901F, or other approved means. Instrumentation used for recording of other data shall be generally acceptable type properly calibrated and certified as to accuracy.

Speed at impact shall be recorded.

11.2.3. STATIC TESTS

11.2.3.1. COMPRESSIVE END LOAD

A horizontal compressive static load of 1,000,000 lbs, shall be applied at the centerline of draft to the draft system of car/unit structure interface areas, and sustained for a minimum 60 seconds. The car/unit structure tested shall simulate an axially loaded beam having rotation free-translation fixed end restraints. (See Figure 11.2.3.1).

No other restraints, except those provided by the suspension system in its normal running condition, are permissible. Multi-unit car must have each structurally different unit subjected to such test, also two empty units joined together by their connector shall undergo this test to verify the connectors compressive adequacy and its anti-jackknifing properties.

The test is to be performed with the car subjected to the most adverse stress or stability conditions (empty and/or loaded).

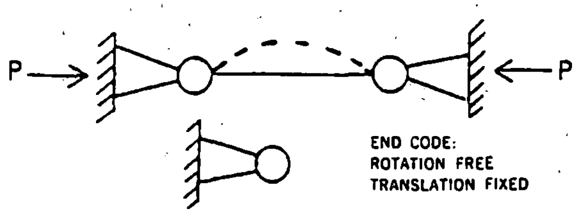

Figure 11.2.3.1

11.2.3.2. COUPLER VERTICAL LOADS

A vertical upward load shall be applied to the coupler shank immediately adjacent to the striker face or to the face of the cushion unit body at one end of the car, sufficient in magnitude to lift the fully loaded car free of the truck nearest the applied load, and held for sixty seconds. Cushion underframe cars having sliding sill are excluded from the requirements of this paragraph.

For cushion underframe cars having sliding sills, a vertical upward load shall be applied to the sliding sill in a plane as near the ends of the fixed center sills as practicable, sufficient in magnitude to lift the fully loaded car free of the truck nearest the applied load, and held for sixty seconds.

For all cars, a load of 50,000 pounds shall be applied in both directions to the coupler head as near to the pulling face as practicable and held for sixty seconds.

11.2.3.3. CURVE STABILITY

The test consist is to undergo a squeeze and draft load of 200,000 lbs. without car body-suspension separation or wheel lift. Load application shall simulate a static load condition and shall be of minimum 20 seconds sustained duration.

Cars consisting of more than two units shall be tested with a minimum of three units in the test consist. The number of units used shall generate maximum load in the critical L/V location of the car.

For the purpose of this test, wheel lift is defined as a separation of wheel and rail exceeding ⅛" when measured 2⅝" from the rim face at the inside of curve for buff and outside for draft.

Empty car shall be subjected to squeeze and draft load on a curve of not less than 10 degrees. The curve is to have ½" maximum superelevation. The test car is to be coupled to a "base car" as defined in paragraph 2.1.6.1. or a like car which ever is most severe and a "long car" having 90′ over strikers, 66′ truck centers, 60″ couplers and conventional draft gear.

The test consist shall have means for measuring and recording coupler forces.

11.2.3.4. RETARDER AND "HOT BOX" DETECTION

Cars with other than conventional 3 piece trucks must be operated while fully-loaded over a hump and through a retarder. Retarder shall be operated to determine capability to brake the test cars. Such cars must also demonstrate their compatibility with hot box detection systems or be equipped with on-board hot box detection systems.

11.2.3.5. JACKING

Vertical load capable of lifting a fully loaded car/unit shall be applied at designated jacking locations sufficient to lift the unit and permit removal of truck or suspension arrangement nearest to the load application points.

11.2.3.6. TWIST LOAD

Loaded car/unit shall be supported on the side bearings or equivalent load points only. Diagonally opposite bearing or load point support shall be lowered through a distance resulting from a calculated 3″ downward movement of one wheel of the truck or suspension system supporting it. No permanent deformation of car/unit structure shall be produced by this test.

11.2.4. IMPACT TESTS

These requirements apply to all cars except those exempted by other specification requirements.

11.2.4.1. SINGLE CAR IMPACT

The loaded car shall be impacted into a string of standing cars consisting of three nominal 70-ton capacity cars, loaded to maximum gross weight on rails as described in paragraph 2.1.5.17. with sand or other granular material, equipped with M-901E rubber-friction draft gear at the struck end and with the hand brake on the last car on the non-struck end of the string tightly set. Free slack between cars is to be removed; however, draft gears are not to be compressed. No restraint other than handbrake on the last car is to be used.

A series of impacts shall be made on tangent track by the striking car at increments of two miles per hour starting at six miles per hour until a coupler force of 1,250,000 pounds or a speed of fourteen miles per hour has been reached, whichever occurs first.

A car consisting of two or more units must also undergo impact testing as outlined above with the leading unit of the test car being empty for a two-unit car, or with the first two units being empty for a three (or more) unit car. No carbody-suspension disengagement or wheel lift is permitted during the partially loaded impact tests.

11.2.4.2. DYNAMIC SQUEEZE

(Optional–May be performed in lieu of or in addition to static end compression test if requested by the Car Construction Committee.)

The striking and standing car groups shall each consist of six cars, in which the test car may be the lead car in either group. All cars except the test car shall be as prescribed in 11.2.1.2. The brakes shall be set on all standing cars after all slack between cars has been eliminated. There shall be no precompression of the draft gears. The standing cars shall be on level tangent track. The striking cars, coupled together, shall be adjusted, if necessary, to restore the original conditions.

A series of impacts shall be made at increments of two miles per hour starting at six miles per hour until a coupler force of 1,250,000 pounds or a speed of fourteen miles per hour has been reached, whichever occurs first.

11.2.5. INSPECTION

A visual inspection of the test car shall be made after each static test and after each impact. Following the impact tests, the car shall be unloaded and inspected.

Any permanent damage to any major structural part of the car, found before or after all tests are completed, will be sufficient cause for disapproval of the design. Damage will be considered permanent when the car requires shopping for repairs.

11.3. TRACK-WORTHINESS ASSESSMENT

11.3.1. METHODOLOGY

Regimes are identified, representative of the performance of the car in service. Tests are defined for each regime. The results of the tests are an indication of the car's track-worthiness. In most regimes, analytic methods are also available to permit prediction to be made of the performance of the car, to the degree of accuracy required.

The characteristic properties of the car body and its suspension, required for the analysis, shall be supported by evidence of their validity. Characterization tests, such as those defined in Appendix A, are required to verify the values used in the analyses.

11.3.2. TRACK-WORTHINESS CRITERIA

The criteria applied to the analyses and tests are chosen from a consideration of the processes by which cars deviate from normal and required guidance. They are also subject to the requirement of observability in tests. Typical of these are lateral and vertical forces, the lateral over vertical force (L/V) ratios, dynamic displacements, and accelerations of the masses. These criteria are based on considerations of the processes of wheel climb, rail and track shift, wheel lift, coupler and component separation and structural integrity.

The values chosen for the criteria selected have been used in tests on cars presently in service. Those included in the body of this chapter are shown in Table 11.1. Values worse than these are regarded as having a high risk of unsafe behavior. Values better than these are regarded as indicating the likelihood of safe car performance.

Table 11.1 Criteria for Assessing the Requirements for Field Service

Regime	Section	Criterion	Limiting Value
Hunting (empty)	11.5.2	minimum critical speed (mph)	70
		maximum lateral acceleration (g)	1.0
		maximum sum L/V axle	1.3*
Constant curving (empty and loaded)	11.5.3	95th percentile maximum wheel L/V	0.8
		or	
		95th percentile maximum sum L/V axle	1.3
Spiral (empty and loaded)	11.5.4	minimum vertical load (%)	10 **
		maximum wheel L/V	0.8*
Twist, Roll (empty and loaded)	11.6.2	maximum roll (deg)***	6
		maximum sum L/V axle	1.3
		minimum vertical load (%)	10 **
Pitch, Bounce (loaded)	11.6.3	minimum vertical load (%)	10 **
Yaw, Sway (loaded)	11.6.4	maximum L/V truck side	0.6*
		maximum sum L/V axle	1.3*
Dynamic curving (loaded)	11.6.5	maximum wheel L/V	0.8*
		or	
		maximum sum L/V axle	1.3*
		maximum roll (deg) **	6
		minimum vertical load (%)	10 **
Vertical curve	11.7.2	to be added****	
Horizontal curve	11.7.3	to be added****	

* Not to exceed indicated value for a period greater than 50 milliseconds per exceedence
** Not to fall below indicated value for a period greater than 50 milliseconds per exceedence
*** Peak-to-peak
**** See the introduction to section 11.7.1

11.4. GLOSSARY OF TERMS

Radial misalignment of axles in a truck or car is the difference in yaw angle in their loaded but otherwise unforced condition. It causes a preference to curving in a given direction.

Lateral misalignment is the difference in lateral position between axles. It causes both axles to be yawed in the same direction on straight track.

Inter-axle shear stiffness, equivalent to the lozenge or tramming stiffness in 3-piece trucks, is the stiffness between axles in a truck or car found by shearing the axles in opposite directions along their axes, and measuring the lateral deflection between them.

Inter-axle bending stiffness is the stiffness in yaw between axles in a truck or car.

Bounce is the simple vertical oscillation of the body on its suspensions in which the car body remains horizontal.

Pitch of the body is the rotation about its transverse axis through the mass center.

Body yaw is the rotation of the body about a vertical axis through the mass center.

Body roll is the rotation about a longitudinal axis through the mass center.

Upper and lower center roll are the coupled lateral motion and roll of the body center of mass. They combine to give an instantaneous center of rotation above or below the center of mass. When below the center of mass, the motion is called lower center roll. When above, the motion is called upper center roll.

Sway is the coupled body mode in roll and yaw and it occurs where the loading is not symmetrical.

Unbalance is used in this chapter to mean the additional height in inches, which if added to the outer rail in a curve, at the designated car speed, would provide a single resultant force, due to the combined effects of weight and centrifugal force on the car, having a direction perpendicular to the plane of the track. Thus, the unbalance (U) is defined as:

$$\text{Unbalance } U = \frac{V^2 D}{1480} - H$$

where,
- D is the degree of the curve.
- V is the vehicle speed in mph.
- H is the height, in inches, of the outer rail over the inner rail in the curve.

Effective conicity, E, of a wheel on a rail is its apparent cone angle used in the calculation of the path of the wheel on the rail. It is defined as:

$$E = A\left(\frac{R_w}{R_w - R_R}\right)$$

where,
- A is the angle of the contact plane between the wheel and rail, to the plane of the track.
- R_w is the transverse profile radius of the wheel.
- R_R is the transverse profile radius of the rail.

The effective conicity of the modified Heumann wheel of Figure 8.1 on AREA 132 1b rail, under conditions of tight gage, is between 0.1 and 0.3.

Three ratios of lateral (L) to vertical (V) forces are used as criteria in the assessment of car performance. These are:

(1) **The individual wheel L/V**, (or wheel L/V). This is defined as the ratio of the lateral force to the vertical force between the wheel and rail on any individual wheel. It is used to assess the proximity of the wheel to climbing the rail.

(2) **The instantaneous sum of the absolute wheel L/V's on an axle**, (or sum L/V axle). This is defined as the sum of the absolute values of the individual wheel L/V's on the same axle, as given in the following algebraic equation. They must be measured at the same time.

$$\text{Sum L/V axle} = \left| \text{L/V (left whl)} \right| + \left| \text{L/V (right whl)} \right|$$

It is used to assess the proximity of the wheel to climbing the rail and is more appropriate where the angle of attack of the flanging wheel to the rail does not result in full slippage at the area of contact.

(3) **The truck side L/V**, (or L/V truck side). This is defined as the total sum of the lateral forces between the wheels and rails on one side of a truck divided by the total sum of the vertical forces on the same wheels of the truck, as given in the following algebraic expression.

$$\text{Truck side L/V} = \frac{\Sigma \text{L (truck side)}}{\Sigma \text{V (truck side)}}$$

It is used to indicate the proximity to moving the rail laterally.

11.5. SINGLE CAR ON UNPERTURBED TRACK

11.5.1. GENERAL

The regimes described in this section are chosen to test the track-worthiness of the car running on premium track. They are required to establish the safety of the car from derailment under conditions basic to its performance in service and are carried out under operating conditions similar to those found in normal service, but without the effects of dynamic variations due to adjacent cars or large perturbations associated with poor track.

The parameters used in the analysis shall be confirmed in characterization tests described in Appendix A. The results of the following analyses and tests shall be included for the consideration of approval by the Car Construction Committee.

11.5.2. LATERAL STABILITY ON TANGENT TRACK (HUNTING)

This requirement is designed to ensure the absence of hunting, which can result from the transfer of energy from forward motion into a sustained lateral oscillation of the axle between the wheel flanges, in certain car and suspension designs. The analyses and tests are required to show that the resulting forces between the wheel and rail remain within the bounds necessary to provide an adequate margin of safety from any tendency to derail.

11.5.2.1. PREDICTIONS AND ANALYSES

An analysis shall be made of the critical speed at which continuous full flange contact is predicted to commence, using a validated mathematical model and the parameters measured for the empty test car. This analysis shall include predictions on tangent and on 1/2 and 1 degree curves.

The analytic requirement is that no hunting be predicted for the empty car below 70 miles per hour assuming a coefficient of friction of 0.5 and an effective conicity of 0.15, for the modified Heumann wheel profile given in Figure 8.1 of Chapter VIII, on new AREA 136 lb. rail, for axle lateral displacements up to +/– 0.2 in. on track with standard gauge.

11.5.2.2. TEST PROCEDURE AND CONDITIONS

The empty test car shall be placed at the end of the test consist, behind a stable buffer car, and operated at speeds up to 70 miles per hour on tangent class 5 or better track, with dry rail.

All axles of the lead unit or car shall be equipped with modified Heumann profile wheels as shown in Figure 8.1 of Chapter VIII, with the machining grooves worn smooth on the tread.

The rail profile shall be new AREA 136 lb. or an equivalent which, with the Heumann wheel specified, gives an effective conicity of at least 0.15 for lateral axle displacements of +/– 0.2 inch from the track center. The track gage may be adjusted in order to achieve this minimum effective conicity. If hunting is predicted for curved track in section 11.5.2.1, a special hunting test in shallow curves may be requested.

11.5.2.3. INSTRUMENTATION AND CRITERIA

The leading axle of both trucks on an end unit or car, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets, and each truck location on the end unit or car shall be equipped with a lateral accelerometer on the deck above the center of the truck.

Sustained truck hunting shall be defined as a sustained lateral acceleration greater than 1 g peak-to-peak for at least 20 consecutive seconds. No occurrences of greater than 1.5 g peak-to-peak are permitted within the same time period. The instantaneous sum of the absolute values of the L/V ratios shall not exceed 1.3 on any instrumented axle. Components of the measured accelerations and forces having frequencies above 15 hertz are to be filtered out.

The car shall not experience sustained truck hunting during the test. A record of maximum lateral acceleration and the wheel L/V's on the same axle, against speed, at the worst location, shall be submitted as required test data.

11.5.3. OPERATION IN CONSTANT CURVES

This requirement is designed to ensure the satisfactory negotiation of track curves. The analyses and tests are required to show that the resulting forces between the wheel and rail are safe from any tendency to derail and to confirm other predictions of the car behavior relating to the guidance of the car and absence of interferences.

11.5.3.1. PREDICTIONS AND ANALYSES

An analysis shall be made of the wheel forces and axle lateral displacements and yaw angles on a single car, empty and fully loaded, using a validated mathematical model. The model shall include a fundamental representation of the rolling contact forces using the geometry of the profiles of the wheel and rail, and car parameters from the measurements described in Appendix A.

Either the individual wheel L/V shall be less than 0.8 on all wheels measured, or the instantaneous sum of the absolute wheel L/Vs on any axle shall be less than 1.3, for any curve up to 15 degrees. The range of unbalance assumed shall be –3 inches to +3 inches, with a coefficient of friction of 0.5 and modified Heumann profiled wheels on new AREA 132 lb. or 136 lb. rail.

11.5.3.2. TEST PROCEDURE AND CONDITIONS

The test car shall be operated at constant speeds equivalent to unbalances of −3, 0, and +3 inches. The tests shall be run with the test car in both empty and fully loaded conditions, between two heavy buffer cars, one of which may be replaced by an instrumentation car. A complete set of tests shall be carried out in both directions and with the test consist turned in each direction, on dry rail.

The wheels of the test car shall have less than 5000 miles wear on the new profiles specified for production, except that those on instrumented wheelsets shall have modified Heumann profiles. The rail profiles shall have a width at the top of the head not less than 95 percent of the original value when new. The test curve shall be of not less than 7 degrees with a balance speed of 20 to 30 mph, and with class 5 or better track.

11.5.3.3. INSTRUMENTATION AND CRITERIA

The leading axle of both trucks on an end unit or car, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets. The lateral and vertical forces and their ratio, L/V, shall be measured for the length of the body of the curve, which must be at least 500 ft., and their maxima and means computed. Measured force components having frequencies above 15 hertz are to be filtered out.

Either the individual wheel L/V shall be less than 0.8 on all wheels measured, or the instantaneous sum of the absolute wheel L/Vs on any axle shall be less than 1.3. A record of L/V on both wheels of the instrumented axles, for each test run, shall be submitted as required test data.

11.5.4. SPIRAL NEGOTIATION AND WHEEL UNLOADING

This requirement is designed to ensure the satisfactory negotiation of spirals leading into and away from curves. The analyses and tests are required to show that the resulting forces between the wheel and rail show an adequate margin of safety from any tendency to derail, especially under reduced wheel loading, and to confirm other predictions of the car behavior.

11.5.4.1. PREDICTIONS AND ANALYSES

An analysis shall be carried out of the lateral and vertical wheel forces on a single car, with the car loaded asymmetrically, consistent with AAR loading rules, to give maximum wheel unloading.

The analysis shall be made for a speed equivalent to a mean unbalance at the car center of −3 inches to +3 inches with a coefficient of friction of 0.5 and modified Heumann wheel and new AREA 132 lb. or 136 lb. rail profiles.

The predicted lateral-to-vertical force ratio shall not exceed 0.8, and no vertical wheel load shall be less than 10 percent of its static value, in a bunched spiral, with a change in superelevation of 1 inch in every 20 ft, leading into a curve of at least 7 degrees and a minimum of 3 inches superelevation.

11.5.4.2. TEST PROCEDURE AND CONDITIONS

This test may be carried out concurrently with the previous test, paragraph 11.5.3.2. The test car shall be operated, empty and fully loaded, between two heavy buffer cars, one of which may be an instrumentation car, at constant speeds equivalent to an unbalance of −3, 0, and +3 inches at the maximum curvature.

The wheels of the test car shall have less than 5000 miles wear on the new profiles specified for production, except that those on instrumented wheelsets shall have modified Heumann profiles. The rail profiles shall have a width at the top of the head not less than 95 percent of the original value when new.

The maximum curvature shall be not less than 7 degrees, with a minimum of 3 inches superelevation. A bunched spiral, with a change in superelevation of not less than 1 inch in every 20 ft., is required. The track shall be class 5 or better and dry. Tests shall be run in both directions and with the consist turned.

11.5.4.3. INSTRUMENTATION AND CRITERIA

The leading axle on both trucks on an end unit or car, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets.

The lateral and vertical forces and their ratio, L/V, shall be measured continuously through the bunched spiral, in both directions, and their maxima and minima computed. Measured force components having frequencies above 15 hertz are to be filtered out.

The maximum L/V ratio on any wheel shall not exceed 0.8, and the vertical wheel load shall not be less than 10 percent of the measured static value. A record of L/V's and vertical forces on both wheels of the two worst axles in a car, and car body roll angle, for each test, shall be submitted as required test data.

11.6. SINGLE CAR ON PERTURBED TRACK

11.6.1. GENERAL

The analyses and tests described in this section are designed to establish the track-worthiness of the car under conditions associated with variations in the track geometry. They include the dynamic response due to perturbations in the track but exclude the dynamic effects due to coupling with adjacent cars.

The investigations are designed to demonstrate that the car design provides an adequate margin of safety from structural damage and from any tendency to derail.

The tests shall be completed and their results found satisfactory by the AAR observers. The results identified shall be added as required data for the consideration of the Car Construction Committee.

11.6.2. RESPONSE TO VARYING CROSS-LEVEL (TWIST AND ROLL)

This requirement is designed to ensure the satisfactory negotiation of oscillatory cross-level excitation of cars, such as occurs on staggered jointed rail, which may lead to large car roll and twist amplitudes. The analyses and tests are required to show that the resulting forces between the wheel and rail show an adequate margin of safety from any tendency to derail.

11.6.2.1. PREDICTIONS AND ANALYSES

A review shall be made of any tests and analyses for the natural frequency and damping of the car body, in the roll and twist modes, in the empty and fully loaded conditions, and an estimate made of the speed of the car at each resonance.

The maximum amplitude of the carbody in roll and twist, the maximum instantaneous sum of the absolute values of the wheel L/V ratios on any axle, the minimum vertical wheel load, and the number of cycles to reach them, shall be predicted at resonant speed of 70 mph or below, on tangent track, with staggered jointed rails of 39 ft. length, and a maximum cross-level at the joints of 0.75 in. as shown in Fig. 11.1.

The instantaneous sum of the absolute values of the wheel L/V ratios on any axle shall be less than 1.3, the predicted roll angle of the carbody shall not exceed 6 degrees peak-to-peak, and the vertical wheel load shall not be less than 10 percent of its static value, within 10 rail lengths of the start, at any speed at or below 70 mph.

11.6.2.2. TEST PROCEDURE AND CONDITIONS

The test car shall be between two cars chosen for their stable performance. Tests shall be carried out with the test car empty and fully loaded.

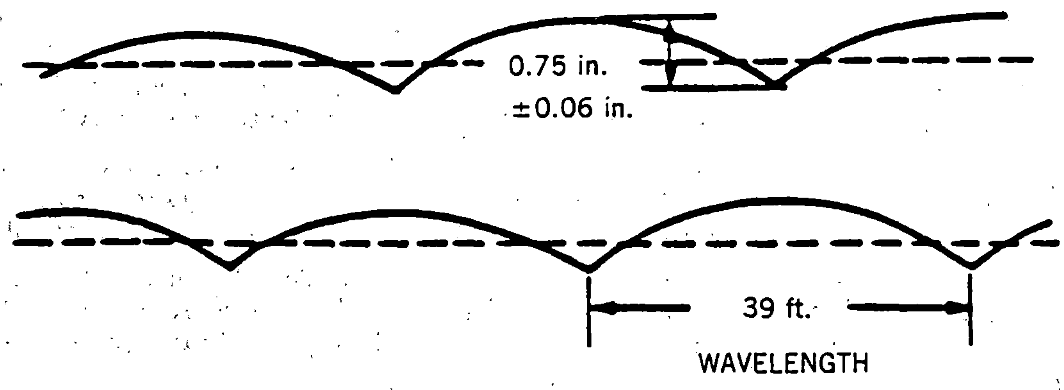

Figure 11.1.

TRACK CROSS LEVEL FOR THE TWIST AND ROLL TEST

The test shall be on tangent track with staggered 39 ft. rails on good ties and ballast, shimmed to a cross level of 0.75 in., low at each joint as shown in Fig. 11.1, over a test zone length of 400 ft., but otherwise held to class 5 or better.

The test shall be carried out at constant speed, increasing in 2 mph steps from well below any predicted resonance until it is passed, or approaching it from a speed above that expected to give a resonant condition. The test shall be stopped if an unsafe condition is encountered or if the maximum of 70 mph is reached. It shall be regarded as unsafe if a wheel lifts or if the car body roll angle exceeds 6 degrees, peak-to-peak.

11.6.2.3. INSTRUMENTATION AND CRITERIA

The leading axle of both trucks on an end unit or car, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets. The car body roll angle shall also be measured at a minimum of each end of an end unit.

The wheel forces, the mean roll angle and difference in roll between ends for each unit, shall be measured continuously through the test zone. Measured force components having frequencies above 15 hertz are to be filtered out.

The sum of the absolute values of wheel L/V on any instrumented axle shall not exceed 1.3, the roll angle of the carbody of any unit shall not exceed 6 degrees peak-to-peak and the vertical wheel load shall not be less than 10 percent of its static value at any speed tested.

A record of the vertical loads measured at the axle with the lowest measured vertical load, and the roll angles measured at each end of the most active unit of the car, taken at the resonant speeds for each car load, shall be submitted as required test data.

11.6.3. RESPONSE TO SURFACE VARIATION (PITCH AND BOUNCE)

This requirement is designed to ensure the satisfactory negotiation of the car over track which provides a continuous or transient excitation in pitch and bounce, and in particular the negotiation of grade crossings and bridges, where changes in vertical track stiffness may lead to sudden changes in the loaded track profile beyond those measured during inspection. The analyses and tests are required to show that the resulting forces between the wheel and rail show an adequate margin of safety from any tendency for the car to derail, to uncouple, or to show interference either between subsystems of the car or between the car components and track.

11.6.3.1. PREDICTIONS AND ANALYSES

A review shall be made of any tests and analyses for the natural frequency and damping of the car body, fully loaded, in the modes of pitch and bounce, and an estimate made of the resonant speed of the car when excited by a track wavelength of 39 feet.

The vertical wheel load shall be predicted at these speeds or at 70 mph, whichever is greater, for a continuous near sinusoidal excitation with a vertical amplitude to the track surface of 0.75 inches peak-to-peak and a single symmetric vertical bump in both rails; of the shape and amplitude shown in Fig. 11.2, predicted vertical wheel load shall not be less than 10 percent of its static value at any resonant speed at or below 70 mph, within 10 rail lengths of the start of the continuous sinusoid or following the single bump.

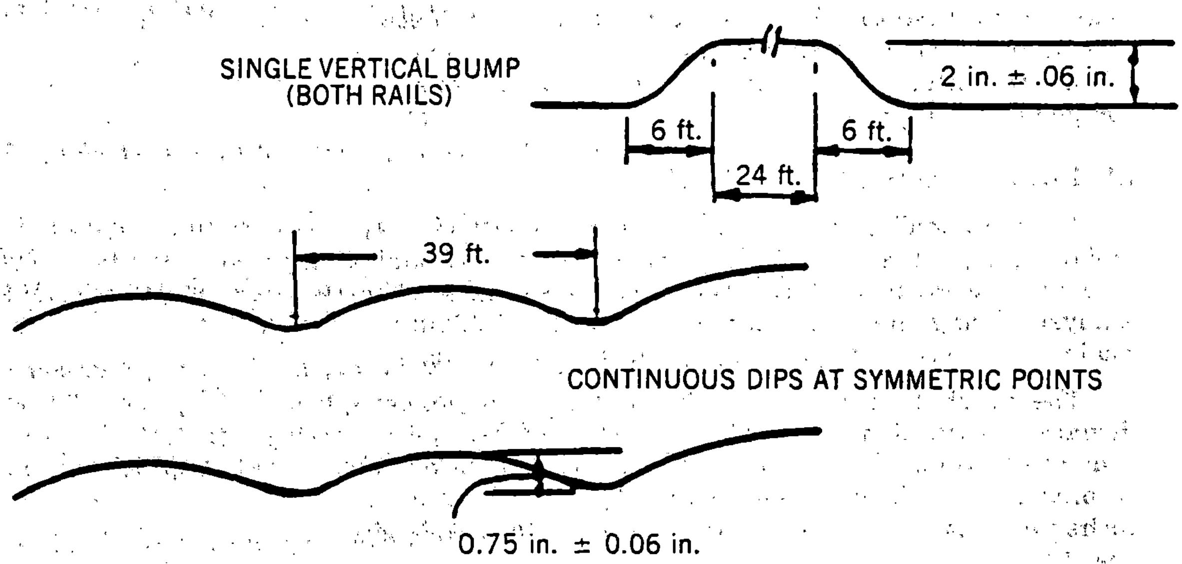

Figure 11.2.
TRACK SURFACE VARIATION FOR PITCH AND BOUNCE

11.6.3.2. TEST PROCEDURE AND CONDITIONS

The fully loaded test car shall be tested between two light cars that have at least 45 ft. truck center spacing.

Tests shall be carried out on tangent track with surface deviations providing a continuous, near sinusoidal, excitation with a vertical amplitude to the track surface of 0.75 inches peak-to-peak and a single symmetric vertical bump in both rails of the shape and amplitude shown in Fig. 11.2. These tests may be carried out separately, or together, with a separation of at least 100 feet. The track shall otherwise be held to class 5 or better.

Testing shall start at constant speed well below any predicted resonant speed, increasing in 5 mph steps until an unsafe condition is encountered, the resonance is passed, or the maximum of 70 mph is reached. The speed at which resonance is expected may be approached from a higher speed, using steps to decrease the speed. It shall be regarded as unsafe if any wheel lifts.

11.6.3.3. INSTRUMENTATION AND CRITERIA

The leading axle on both trucks on an end unit or car, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets. The vertical wheel forces shall be measured continuously through the test zone. Measured force components having frequencies above 15 hertz are to be filtered out.

The vertical wheel load shall not be less than 10 percent of its static value on any wheel at any speed tested. A record of the vertical loads measured on the axle with the lowest vertical load shall be submitted as required test data.

11.6.4. RESPONSE TO ALIGNMENT VARIATION ON TANGENT TRACK (YAW AND SWAY)

This requirement is designed to ensure the satisfactory negotiation of the car over track with misalignments which provide excitation in yaw and sway. The analyses and tests are required to show that the resulting forces between the wheel and rail show an adequate margin of safety from any tendency for the car forces to move the track or rail or to give interference either between subsystems of the car or between the car components and track.

11.6.4.1. PREDICTIONS AND ANALYSES

A review shall be made of the previous tests and analyses for the natural frequency and damping of the car body, fully loaded, in the yaw and roll modes. These may combine in a natural motion referred to as sway, which, if present, must be included in this analysis. Using the values for frequency and damping identified, an estimate shall be made of the resonant speed of the car, in each mode.

The car shall be assumed to be excited by a symmetric, sinusoidal track alignment deviation of wavelength 39 feet, on tangent track. The ratio of the sum of the lateral to that of the vertical forces on all wheels on one side of any truck shall be predicted at resonance or at 70 mph, whichever is greater, for a sinusoidal double amplitude of 1.25 inches peak-to-peak on both rails and a constant wide gage of 57.5 inches, as shown in Fig. 11.3.

The predicted truck side L/V shall not exceed 0.6, and the sum of the absolute values of L/V on any axle shall not exceed 1.3, at any speed at or below 70 mph, within 5 rail wavelengths of the start.

11.6.4.2. TEST PROCEDURE AND CONDITIONS

The fully loaded test car shall be placed at the end of the test consist, behind a buffer car of at least 45 feet truck center spacing, chosen for its stable performance.

Tests shall be carried out on dry tangent track, with symmetric, sinusoidal alignment deviations of wave length 39 feet, alignment amplitude 1.25 inches peak-to-peak and a constant wide gage of 57.5 inches, over a test zone of 200 feet as shown in Fig. 11.3. The track shall otherwise be held to class 5 or better.

The wheels of the test car shall have less than 5000 miles wear on the new profiles specified for production, except that those on instrumented wheelsets shall have modified Heumann profiles. The rail profiles shall have a width at the top of the head not less than 95 percent of the original value when new.

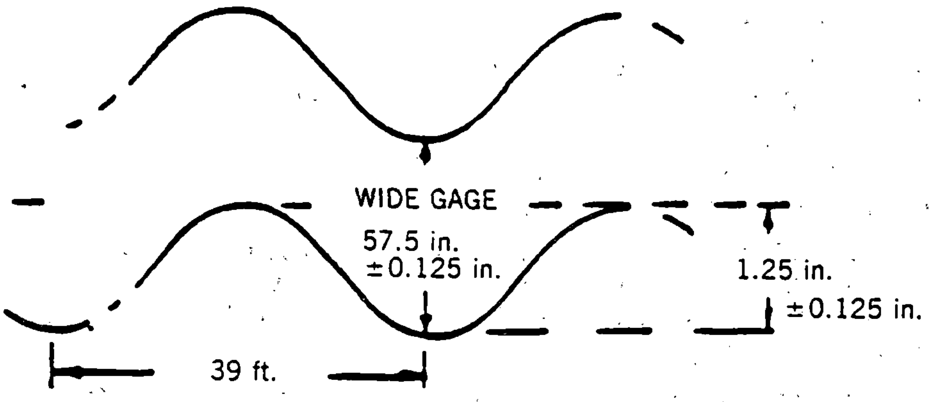

Figure 11.3.

TRACK ALIGNMENT VARIATIONS FOR YAW AND SWAY

Testing shall start at constant speed well below any predicted resonant speed, increasing in 5 mph steps until an unsafe condition is encountered, the resonance is passed, or the maximum of 70 mph is reached. It shall be regarded as unsafe if the ratio of total lateral to vertical forces, on any truck side measured, exceeds 0.6 for a duration equivalent to 6 feet of track.

11.6.4.3. INSTRUMENTATION AND CRITERIA

All axles on the truck estimated to provide the worst total truck side L/V, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets. The wheel forces shall be measured continuously through the test zone. Measured force components having frequencies above 15 hertz are to be filtered out.

The truck side L/V measured shall not exceed 0.6 for a duration equivalent to 6 feet of track, and the sum of the absolute values of L/V on any axle shall not exceed 1.3, at any speed at or below 70 mph. A record of the lateral and vertical loads, measured on the truck with the largest truck side L/V, shall be submitted as required test data.

11.6.5. ALIGNMENT, GAGE AND CROSS-LEVEL VARIATION IN CURVES (DYNAMIC CURVING)

This requirement is designed to ensure the satisfactory negotiation of the car over jointed track with a combination of misalignments at the outer rail joints and crosslevel due to low joints on staggered rails at low speed. The analyses and tests are required to show that the resulting forces between the wheel and rail show an adequate margin of safety from any tendency for the car forces to cause the wheel to climb the rail or to move the track or rail or to give unwanted interference, either between subsystems of the car, or between the car components and track.

11.6.5.1. PREDICTIONS AND ANALYSES

A review shall be made of the previous tests and analyses for the natural frequencies and response of the car body, fully loaded, in the yaw and roll modes.

No analysis is presently available, which can predict the results accurately for this test, for all possible designs. It is therefore necessary to provide additional safety features in the running of the test program to prevent unexpected derailments or unnecessary damage.*

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*Analyses suitable for predictions of new car performance in this test are under development and will be added later.

11.6.5.2. TEST PROCEDURE AND CONDITIONS

The test car shall be operated between two cars that are loaded to provide them with a low center of gravity. If suitable, an instrumentation car may be used as one of these cars.

Tests shall be carried out on dry rail, in a curve of between 10 and 15 degrees with a balance speed of between 15 and 25 mph, with the test car empty and fully loaded.

The wheels of the test car shall have less than 5000 miles wear on the new profiles specified for production, except that those on instrumented wheelsets shall have modified Heumann profiles. The rail profiles shall have a width at the top of the head not less than 95 percent of the original value when new.

The track shall consist of staggered rails, 39 feet long, on good ties and ballast, shimmed to provide a cross level of 0.5 inch, low at each joint, over the test zone length of 200 feet, as shown in Figure 11.4.

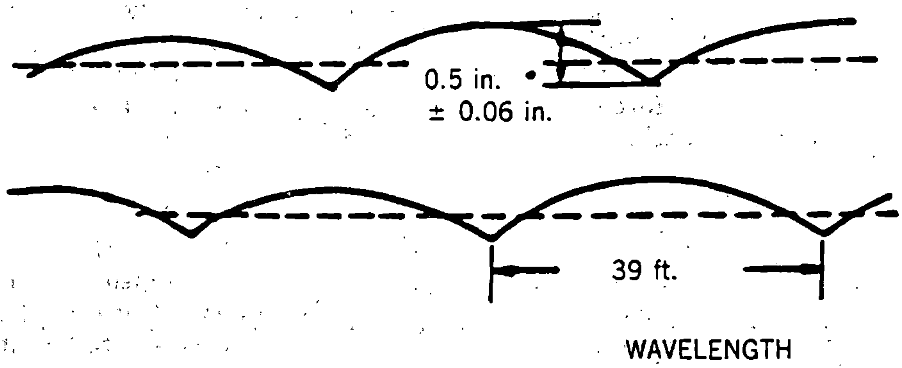


Figure 11.4.

CROSS LEVEL FOR DYNAMIC CURVING TESTS

Combined gage and alignment variation shall be provided in the test zone by shimming the outer rail in the form of an outward cusp, giving a maximum gage of 57.5 inches at each outer rail joint and a minimum gage of 56.5 inches at each inner rail joint, the inner rail being within class 5 standards for alignment in curves, as given in Figure 11.5.

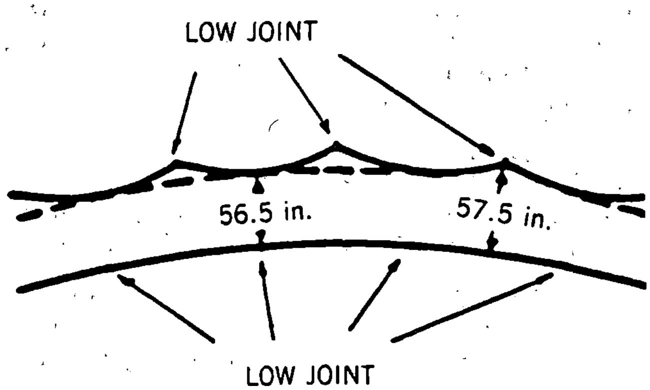


Figure 11.5.

GAGE AND ALIGNMENT VARIATION IN DYNAMIC CURVING

It is recommended that a guard rail be used to prevent unpredicted derailment; however, it must not be in contact with the wheel during normal test running. The test shall be carried out at constant speeds up to 3 inches of overbalance, increasing in 2 mph steps from well below any predicted lower center roll resonance until it is passed. The resonance may be approached from a speed above that predicted to give a lower center roll resonance.

The test shall be stopped if an unsafe condition is encountered or if the maximum unbalance is reached. It shall be regarded as unsafe if a wheel lifts, the instantaneous sum of the absolute L/V values of the individual wheels on any axle exceeds 1.3, or car body roll exceeds 6 degrees, peak-to-peak.

11.6.5.3. INSTRUMENTATION AND CRITERIA

The leading axle on both trucks on an end unit or car, or each axle on an end unit or car with single-axle trucks, shall be equipped with instrumented wheelsets. The car body roll angle shall also be measured at one end of the lead unit. The lateral and vertical wheel forces and the roll angle shall be measured continuously through the test zone. Measured force components having frequencies above 15 hertz are to be filtered out.

The maximum roll angle shall not exceed 6 degrees, peak-to-peak, the vertical wheel load shall not be less than 10 percent of its static value, the individual wheel L/V shall be less than 0.8, and the instantaneous sum of the absolute wheel L/Vs on any axle shall be less than 1.3, at any test speed.

A record of both wheel loads measured on the axle with the lowest measured vertical load and largest measured lateral load, and the roll angles measured, taken at the resonant speeds for each car load, shall be submitted as required test data.

11.7. COUPLED CARS AND UNITS

11.7.1. GENERAL

The tests described in this section will be designed to establish the track-worthiness of the car under conditions associated with the realistic operation of cars within a train. This may include severe transient forces due to coupling with adjacent cars. These forces may have a significant effect on the stability of cars and may lead to derailment. The investigations will be designed to demonstrate that the car design provides an adequate margin of safety from structural damage and from any tendency to derail.

11.7.2. VERTICALLY CURVED TRACK *

* This section to be added at a later date

11.7.3. HORIZONTALLY CURVED TRACK +

+ Investigations are currently underway which will allow the addition of this section in the near future.

APPENDIX A
VEHICLE CHARACTERIZATION
Adopted 1987

1.0. GENERAL

The characteristic properties of the car body and its suspension, required for analysis of its track-worthiness, must be supported by test results providing evidence of their validity. Forces and motions between suspension components and the body modal frequencies of the car, as assembled, can vary significantly from the values calculated or specified in the design, and may be important to the safe performance of the vehicle.

1.1. TEST CAR

It is important that characterizations be carried out on the particular car in the same condition that it is to be track tested so that accurate predictions of its performance can be made. For cars with more than one type of suspension, at least one of each type should be tested.

The tests apply to all new car suspensions, including trucks retrofitted with devices such as inter-axle connections, sideframe cross-bracing and additional suspension elements, which have not been tested previously.

Tests for horizontal characteristics of the suspension of trucks with at least two axles, may be carried out with the truck separated from the body. In this case static vertical loads must be applied to simulate those due to the body or bodies and the rotational and lateral characteristics between the truck and body must be measured separately.

Where connections exist between the truck and body that may affect the truck characteristics, such as with a truck steered through links to the body, and for all cars with single axle trucks, the suspension characteristics must be tested while connected to the body.

Where the truck is at the junction of two articulated bodies, both must be simulated or used in the suspension characterization tests specified.

1.2. TEST LOADS

Modal tests, and tests for the horizontal and vertical suspension characteristics are required with vertical loads equivalent to the car in the loaded condition required for the analyses in which the results will be used. This includes tests to measure the alignment of the axles to each other and to other elements in the system.

1.3. GENERAL PROCEDURE

In tests for the suspension characteristics, the recommended procedure is to load the suspension and to measure the load and displacement, or velocity, across the particular suspension element, in the required direction. These should be recorded up to the required maximum and down to the required minimum identified.

The loads may be applied, either through automatic cycling at an appropriate frequency or through manual increase and decrease of load through at least two complete cycles. If manual loading is used, delays and intermediate load reversals between measurements should be avoided. For the determination of stiffness and frictional energy dissipation, the frequency of cycling must be between 0.2 and 0.5 hertz.

Graphs of load versus displacement or velocity are desirable for the determination of the required stiffness or damping.

2.0. TESTS WITH THE WHEELS RESTRAINED

2.1. GENERAL

In the tests described in this section, the wheels are rigidly attached to the rails or supporting structure and the frame is moved relative to them.

The methods described are not suitable for trucks having steering links, which couple the lateral or roll motion of the body or truck frame to the yaw motion of the axles. In such a case, provision must be made for unrestrained longitudinal movement of the wheels, discussed in section 3. The steering links may be disconnected to measure the characteristics of suspension elements in the unsteered condition.

All tests require that the actuators and restraining links, other than those at the wheels, have the equivalent of ball joints at both ends to allow for motion perpendicular to their axis.

2.2. VERTICAL SUSPENSION STIFFNESS

For this test, equal measured vertical loads are applied across the spring groups in the range from zero to 1.5 times the static load, if possible, and at least to the static load of the fully loaded car. Vertical actuators are attached to each side of the body or the structure simulating it. The load may also be applied by adding dead load or a combination of both dead and actuator loads.

Vertical deflections are required across all significant spring elements under load. It is important to report any differences in the measurements taken between each axle and frame or sideframe.

2.3. TOTAL ROLL STIFFNESS

A roll test is required if the roll characteristic between the body and axle includes movement at or forces due to elements other than the vertical suspension, such as clearances at sidebearings, or anti-roll bars.

For the roll test, two vertical actuators are required as in the vertical test, but with the loads in the actuators in opposite directions. The range of roll moments, in inch-pounds, applied to the truck should be between plus and minus 30 times its static load, in pounds, or until the wheels lift. The roll angle across all suspension elements may be measured directly or deduced from displacements.

2.4. TOTAL LATERAL STIFFNESS

The lateral stiffness characteristic may be found by attaching an actuator to apply loads laterally to the body or bodies, which should be positioned as if on tangent track. If the lateral motion of the truck frame is coupled to its yaw through a steering mechanism, it should be disconnected to prevent the yaw resistance of the frame from affecting the measurement of lateral stiffnesses.

The minimum and maximum lateral loads applied per truck should be minus and plus one fifth of the static load carried. Measurements are required of the lateral displacements across all suspension elements.

2.5. INTER-AXLE TWIST AND EQUALIZATION

This test is carried out with only one axle fixed to the track. One wheel of the other axle in the car or truck is jacked up to a height of 3 inches, and the vertical load and displacement are measured. The stiffness between the axles in twist is the ratio of the load to the displacement multiplied by the square of the gage. It is a measure of the truck equalization.

3.0. TESTS WITH UNRESTRAINED WHEELS

3.1. GENERAL

These tests involve movements in the suspension system and axles relative to other elements of the system or to other axles, without restraint between the wheel and rail, but with the normal static vertical load.

The shear resistance between the rail and the wheel must be eliminated by the provision of a device having very low resistance, such as an air bearing, under each axle.

3.2. AXLE ALIGNMENT

Both radial and lateral misalignments may be deduced from measurements of the yaw angle of each axle from a common datum. The radial misalignment between axles is half the difference in their yaw angles, taken in the same sense, and the lateral misalignment is their mean yaw angle.

In the case of trucks which have significant clearance between the axle and frame, it may be necessary to establish the axle in the center of the clearance for the purpose of identifying the mean axle misalignments.

3.3. LONGITUDINAL STIFFNESS

A longitudinal load must be applied to the axle, equivalent to a single load at its center, and cycled between tension and compression up to half the static load on the axle.

The load may be applied directly between axles, or between the test axle and ground through an appropriate structure, with the body or truck frame restrained. The load may also be applied directly between the axle and frame, or in the case of a car with single axle trucks, between the axle and the body.

The longitudinal deflection across each spring element must be measured and the results plotted.

Where the load is applied directly between the axles of a truck or car, this measurement may be combined with the inter-axle shear test in section 3.4., or the inter-axle bending stiffness test in section 3.5.

3.4. AXLE LATERAL AND INTER-AXLE SHEAR STIFFNESS

The inter-axle shear stiffness may be found by shearing the axles, or moving them in opposite directions along their axes, and measuring the shear or lateral deflection between them. The shear force on each axle must be at least one tenth of the static vertical axle load.

This test may be combined with the inter-axle longitudinal test of section 3.3., where the required load can be achieved.

In the case of direct inter-axle loading, the locations of the applied force and restraint are such that they are equal and opposite, diagonally across the truck or car.

The actuator and restraint each provide two components of force on the axle to which they are attached. One component lies along the direction of the track and provides tension and compression, as in section 3.3., for the longitudinal stiffness. The other component lies along the axle and applies the required shear force bewteen axles. This component may be applied separately with a suitable arrangement of actuators and restraints.

Measurements are made of the lateral misalignment of the axles during the load cycle. The shear stiffness is the ratio of shear force to the lateral misalignment.

For single axle trucks, a test similar to that described above may be used to determine the lateral stiffness, with force applied laterally between ground and the axle with the body restrained, or with the truck frame restrained in the case of trucks having more than one axle. For trucks which also provide steering through coupling axle lateral motion to its yaw angle, this test may be preferred over the lateral test of section 2.4. for finding the lateral stiffness, since the axles are free to yaw.

3.5. AXLE YAW AND INTER-AXLE BENDING STIFFNESS

The inter-axle bending stiffness may be found by yawing the axles in the opposite directions and measuring the yaw angle between them. The yaw moment applied, in inch-pounds, must be at least equal to the axle load in pounds.

This test may be combined with the inter-axle longitudinal test of section 3.3. If this is done, the test is carried out by applying an effective force on the axle a known distance laterally from the truck centerline.

In the case of direct inter-axle loading the restraint must be applied to the axle, at the other end of the car or truck, on the same side as the applied force. The applied and restraining forces each provide a longitudinal force and a yaw moment on the axle to which they are attached. The force provides the tension and compression as in section 3.3. for the longitudinal stiffness and the moment is applied between the truck axles in yaw. This moment may be applied independently of the longitudinal force.

Measurements are made of the resulting radial mis-alignment of the axles during the load cycle. The bending stiffness is the ratio of applied bending moment to the radial misalignment.

A similar test of the axle yaw stiffness may be arranged with forces applied in yaw between a single axle and ground, with the body restrained, or with the truck frame restrained in the case of trucks having more than one axle.

3.6. YAW MOMENT BETWEEN THE SUSPENSION AND BODY

The required yaw stiffness and breakout torque between the car body and truck must be measured by applying a yaw moment, using actuators in equal and opposite directions at diagonally opposite corners of the truck to rotate the truck in yaw. The car body must be restrained.

The applied yaw moment must be increased until gross rotation is observed, representing the breakout torque, or to the limit recommended for the yaw of the secondary suspension.

The angle in yaw between the car body and truck bolster or frame must be measured.

4.0. RIGID AND FLEXIBLE BODY MODAL CHARACTERISTICS

4.1. GENERAL

Tests are required to identify the rigid and flexible body modal frequencies and damping. The rigid body modal frequencies may be compared to predictions using estimated or measured body masses, and inertias and the suspension parameters measured according to the requirements of sections 2. and 3. Tests and estimates should be made with the car in the empty and fully loaded state.

4.2. TEST CAR BODY

For cars consisting of more than one coupled unit, tests for body modes are required on one of each of the unit bodies having a different structural design. Dead loads may be added to give the required additional loading to any shared suspensions.

Where coupling exists between the modes of adjacent bodies, such as in roll or torsion, this may be examined in a dynamic analysis, validated for the case of tests without coupling.

The frequency and modal damping are only required for the flexible body modes which are predicted to have a natural frequency below 12 hertz.

4.3. GENERAL PROCEDURE

Transient or continuous excitation may be applied, using one or more actuators or dropping the car in a manner to suit the required mode of excitation.

The modal frequency and damping are required for an amplitude typical of the car running on class 2 track.

In the case of the rigid body modes, the actuators must be located at the rail level or the level of the truck frame with the body free to oscillate on its suspension. In the case of the flexible body modes, the excitation may be applied directly to the body.

The frequency in hertz may be determined from the wavelength in the transient test, or from the peak response, or from the 90 degree phase shift between the response and excitation where continuous excitation is used.

The percentage modal damping may be determined using the logarithmic decrement in transient tests or the bandwidth of the response from a range of frequencies.

4.4. RIGID BODY MODES

The rigid body modes for the car are:

Body bounce
Body pitch
Body yaw and sway
Lower center roll
Upper center roll

In the case where the normal load on the body is not centered between the suspensions, the body bounce mode may be coupled to the body pitch. The required measurement of bounce and pitch may be achieved by two vertical measurements at the ends of the car. Their weighted sum provides bounce and their weighted difference pitch. The weighting is dependent on their position relative to the center of mass.

Yaw and sway are deduced from lateral measurements made at each end of the body, a known distance from its mass center, similarly to the determination of pitch.

Measurement of the upper and lower center roll modes are determined from lateral displacements taken at two heights, or by a single lateral displacement and a roll angle measurement.

4.5. FLEXIBLE BODY MODES

The flexible body modes for the car are:

Torsion
Vertical bending
Lateral bending

Determination of the frequency and damping in the torsion mode requires excitation and measurement of roll at one end of the car.

The excitation is similar to that for roll but resonance occurs at a higher frequency. The response between the ends of the car is out of phase for modes number 1,3, and in phase for modes number 2,4, although it is unlikely that modes above 2 will be significant.

Vertical or lateral bending modes are measured as a response to the vertical or lateral excitation at one end or both ends of the car. The first bending mode has a maximum amplitude at or near the car center. The second bending mode has a node or point of minimum response at the center.

5.0. PARAMETER ESTIMATION*

* Tests are presently being conducted to examine this method.

APPENDIX B

SPECIFICATION FOR INSTRUMENTED WHEELSETS FOR CHAPTER XI (M-1001) TESTING

Adopted 1989

1.0. INTRODUCTION

Instrumented wheelsets to be used in acceptance testing of new and untried cars under Chapter XI of AAR Standard M-1001 must meet the requirements of this specification. Load measuring wheelsets are a critical transducer for a wide range of the Chapter XI vehicle dynamics tests. Calibrated wheelsets will be required to accurately measure lateral and vertical wheel/rail forces, as well as wheel lateral to vertical force (L/V) ratios. A verification of wheelset accuracy is performed through a three-step process consisting of calibration, analysis, and field procedures.

2.0. INSTRUMENTED WHEELSET SPECIFICATIONS

To be accepted for Chapter XI testing, a load measuring wheelset design must meet the following specifications:

2.1.

Vertical wheel load measurements must be within +/− 5 percent of the actual vertical load. This accuracy is to be maintained for loads ranging from 0 to 200 percent of the static wheel load. The minimum signal resolution is to be no less than 0.5 percent of the static wheel load.

2.2.

Lateral wheel load measurements must be within +/− 10 percent of the actual lateral load. This accuracy is to be maintained for loads ranging from 0 to 100 percent of the static (vertical) wheel load. The minimum signal resolution is to be no less than 0.5 percent of the static (vertical) wheel load.

2.3.

Maintain the above stated accuracy requirements, at all times, for:

2.3.1.

All potential load cases (longitudinal loads of up to 60 percent of the static (vertical) wheel load, lateral loads of up to 100 percent of the static (vertical) wheel load, and vertical loads of up to 200 percent of the static wheel load).

2.3.2.

All potential wheel/rail contact conditions including full flange contact, outside tread contact, two-point contact, and flange contact at high wheelset angles of attack.

2.3.3.

An operating speed (for dynamic wheelset output) of from 5 to 80 mph.

2.3.4.

Signals from 0 to 30 Hertz.

2.3.5.

Over a recommended operating ambient temperature range of 0 to 110 degrees Fahrenheit. Any restrictions in the operating temperature range are to be noted.

2.4.

Wheelset reprofiling or recalibration requirements due to profile wear are to be documented. Temperature compensation arrangements and operating limitations due to ambient temperature swings are to be detailed as well. The wheelsets are to be equipped with the modified Heumann profile shown in Figure 8.1 of Chapter VIII of AAR Standard M-1001.

3.0. VERIFICATION

Wheelset accuracy is to be substantiated through calibration, analysis, and testing. A minimum number of required wheelset static tests to calibrate and verify wheelset output are described. Since dynamic calibration of load measuring wheelsets has proven difficult, further verification of wheelset accuracy relies on required static and dynamic analyses. A limited set of simple experimental procedures are then prescribed to confirm proper wheelset function under field conditions.

3.1. STATIC CALIBRATION

Static tests to determine the wheelset calibration factors are required of all instrumented wheelsets. Documentation in support of the calibration tests is to include a complete description of the calibration stand and the calibration procedure. Calibration for vertical and lateral loads is to include testing for a minimum of six wheel rotational positions (0, 60, 120, 180, 240, and 300 degrees). Calibration for vertical loads is to include testing for a minimum of three contact point lateral positions (on tape line and one inch), respectively, to the flange and wheel face of the tape line. Each calibration sequence is to be repeated at least once to verify measurement repeatability.

The static calibration tests are as follows:

3.1.1.

Using an appropriate loading scheme, vertical loads ranging from 0 to 200 percent of the static wheel load are to be applied with a minimum of 5 equally spaced inputs (0, 50, 100, 150, and 200 percent of the static wheel load). Strain gauge output for both vertical and lateral force circuits is to be recorded.

3.1.2.

Using an appropriate loading scheme, lateral wheel loads are to be applied at the wheel tread ranging from −100 to 100 percent of the static wheel load with a minimum of 10 equally spaced inputs (+/− 20, 40, 60, 80, and 100 percent). A vertical force equivalent to the static wheel load is to be applied simultaneously. Both vertical and lateral force strain gauge outputs are to be recorded.

The static calibration report is to include raw measurement values and the derived calibration factors. The calibration report must also include a table comparing the applied forces and, given the calibration factors obtained during the testing, the measured forces. It is assumed here that the calibration factors will represent average values independent, for example, of wheelset rotational position.

3.2. ANALYSIS

The following theoretical analyses are required to verify theoretical wheelset accuracy for load combinations that cannot satisfactorily be applied using a conventional static loading frame. It is assumed that finite element or similar calculations will have been performed beforehand to obtain the theoretical wheelset calibration factors. Any variations in wheelset output or accuracy due to rotational position are to be described.

Static finite element or similar calculations to verify theoretical wheelset accuracy for the following scenarios:

3.2.1.

Single point contact at one inch toward the wheel face from the wheel tape line for a vertical load of 50 and 200 percent of the static wheel load in combination with a lateral load of −25 and 25 percent of the static wheel load (giving a total of four load combinations).

3.2.2.

Single point contact on the flange (defined as being at a point giving a rolling radius one-half inch greater than that obtained at the tape line) for a vertical load of 100 and 150 percent of the static wheel load in combination with a lateral load of 25, 50, and 75 percent of the static wheel load (giving a total of six load combinations).

3.2.3.

Single point contact at the wheel tape line for a vertical load equal to the static wheel load in combination with a longitudinal load of −50, −25, 25, and 50 percent of the static wheel load and a lateral load of 10 percent of the static wheel load (for a total of four load combinations). Note that a negative longitudinal load is defined here as a load directed in the sense of the wheel rotation.

3.2.4.

Single point contact at the flange for a vertical load of 75 percent of the static wheel load in combination with a longitudinal load of −50, −25, 25, and 50 percent of the static wheel load and a lateral load of 50 percent of the static wheel load (for a total of four load combinations).

3.2.5.

Two-point contact with the first point of contact at one-half inch toward the wheel face from the wheel tape line and the second point of contact at the flange and displaced −0.5, 0, and 0.5 inches longitudinally from the mid-plane axis of the wheelset. The loading at the tread contact is to be a vertical load of 50 percent of the static wheel load in combination with a longitudinal load of −25 percent and a lateral load of −10 percent of the static wheel load. The loading at the flange contact is to be a vertical load of 75 percent of the static wheel load in combination with a longitudinal load of 50 percent and a lateral load of 50 percent of the static wheel load (for a total of three calculation cases).

3.2.6.

Single point contact at the tape line for a wheel with a radius one-quarter inch less than nominal and a vertical load equal to the static wheel load in combination with a lateral load of 10 percent of the static wheel load.

3.2.7.

Single point contact at the flange for a wheel with a radius one-quarter inch less than nominal and a vertical load equal to 75 percent of the static wheel load in combination with a lateral load of 50 percent of the static wheel load.

Results for the twenty-three static calculation cases described above are to be given as the percent deviation of the predicted lateral and vertical force values from the applied values.

A single dynamic finite element or similar calculation to verify theoretical wheelset accuracy under dynamic conditions:

3.2.8.

This calculation is to verify that no wheelset vibration modes are present with natural frequencies below 30 Hertz. If such modes exist, a dynamic calculation is to be performed for the following wheelset input: single point contact at the wheel tape line for a vertical load equal to the static wheel load in combination with a time varying longitudinal load with an amplitude of 25 percent and a lateral load with an amplitude of 10 percent of the static wheel load. The mean longitudinal and lateral force are both to be zero. The calculation is to consider an input frequency ranging from 0 to 30 Hertz where the lateral and longitudinal force signals are 90 degrees out of phase. The boundary condition to be used for both this calculation and the wheelset natural frequency calculation is to fix the wheelset in the longitudinal, lateral, vertical, and rotational sense at the bearing centerline (axle top dead center).

The results of the dynamic calculation are to be given as the mean value and amplitude of the predicted lateral and vertical forces as functions of the wheelset rotational position.

3.3. TEST PROCEDURES

The following experimental analyses are required:

3.3.1.

A zero speed jacking test to set the wheelset zero followed by a slow speed roll (at ten, twenty, and thirty miles per hour) along tangent track to verify that wheel vertical load signals are within +/− 5 percent of the calibrated scale axle load for constant speed operation on level tangent track. Wheelset signals will be evaluated on the basis of mean values for a randomly chosen output segment having a minimum duration of ten seconds.

3.3.2.

A steady-state curving test to confirm that net truck or car lateral loads are within +/− 10 percent of the theoretical value for constant speed operation on constant radius track at speeds corresponding to +3, 0, and −3 inches cant deficiency. Both curvature and superelevation of the track need to be constant and accurate. Wheelset accuracy is to be verified on a sharp curve (7 degrees curvature and above) for curving with hard flange contact. Wheelset signals will be evaluated on the basis of mean values for a randomly chosen output segment having a minimum duration of ten seconds.

3.3.3.

As an alternative to this test a zero speed jacking test is suggested using equal and opposing lateral loads applied (via a hydraulic jack) to the wheel backs. Measured lateral loads are to be within +/− 5 percent of the applied value for loads ranging from 0 to 50 percent of the static (vertical) wheel load.

3.3.4.

A steady-state curving test to again confirm that total truck vertical loads are within +/− 5 percent of the theoretical value for constant speed operation on constant curvature track (for the test curve described above). Wheelset signals will be evaluated on the basis of mean values for a randomly chosen output segment having a minimum duration of ten seconds.

The test procedures prescribed above are also to be repeated and recorded at the start of each Chapter XI test series. A record of such results is to be kept for each Chapter XI certified wheelset. A minimum of the vertical load accuracy test is to be performed at the start of each daily test session.

4.0. RECORDS

4.1.

The theoretical analyses described are necessary only once for each wheelset design. The static calibration and field procedures must be performed for each wheelset produced to an accepted specification.

4.2.

An instrumented wheelset which has met these requirements will be so certified by the designated AAR representative.

4.3.

The designated AAR observer for Chapter XI testing will verify that the instrumented wheelsets to be used have been accepted for testing and the test procedures described in Section 3.3 above are completed satisfactorily.

APPENDIX B

TRACK WORTHINESS PROCEDURE

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-7000-FC
TRACK WORTHINESS TEST

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-7000-FC
TRACK WORTHINESS TESTS

1.0 DESCRIPTION

This procedure outlines the sequence of steps to conduct Track Worthiness Tests at TTC. The Track Worthiness Tests consist of seven sub-tests: Hunting Test, Constant Curving Test, Spiral Test, Rock and Roll Test, Pitch and Bounce Test, Dynamic Curving Test and Yaw and Sway Test; additionally tests have been added for the Rail Garrison program: Turnout and Crossover and Special Perturbations.

1.1 INDEX

1.2 EQUIPMENT LIST

a.	2ea.	IITRI Instrumented Wheel Sets
b.	2ea.	Single Roll Gyrometer
c.	2ea.	Lateral Accelerometer
d.	6ea.	Strip Chart Recorder
e.	1ea.	Digitizer
f.	4ea.	100-Ton Jacks
g.	1ea.	Hewett-Packard (HP) 360 Data Acquisition System
h.		Signal Conditioner
i.		All Safety Equipment As Required By TTC

1.3 FIGURE LIST

1.4 TABLE LIST

1.5 ATTACHMENT LIST

Attachment 1 Chapter XI Track Worthiness Test Facilities

1.6 REFERENCE LIST

PRKG 2100.... Truck Inspection Procedure

PKRG 3100.... Instrument Installation Procedure

M1001........ Manual of Standards and Recommended Practices

PKRG 3500....	Section C, Part II, Volume I, Chapter XI IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation
PKRG 3800....	Track Worthiness Test Instrumentation Setup
PKRG 7001....	Test Sequence Chart
PKRG 7002....	Daily Pre-Test Sign-Off Sheet
	Peacekeeper Rail Garrison Test Implementation Plan, (for appropriate test car), Chapter XI Testing
	ENSCO Operating Manual
	TTC Safety Rule Book

1.7 REFERENCE DOCUMENTATION

None

NOTE

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book.

2.0 PRE-TEST FOR ALL TESTS (EXCEPT YAW AND SWAY)

2.1 36-Inch Instrumented Wheel Set Installation

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Disconnect the hand brake chain and air brake line.	LDD____ UNLD____ HLD____
2.1.2	Ensure brake shoes and keys are removed from each wheel location.	________
2.1.3	Remove all slack adjusters.	________
2.1.4	Secure emergency brake chain.	________
2.1.5	Remove and secure all loose brake system components. Mark removed components defining location from which removed and store for later re-installation.	________
2.1.6	Chock all A-end wheels.	
2.1.7	Using two 100-ton jacks at the jacking pads, jack the B-end up approximately 12 inches.	

2.1.8 Roll out Truck 1.

2.1.9 Lift Truck 1 and remove the leading Axle 1 wheel set.

2.1.10 Replace the leading wheel set with the IITRI WS21 instrumented wheel set as illustrated in Figure 2-1 and in accordance with, PKRG-3500 IITRI 36-inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.

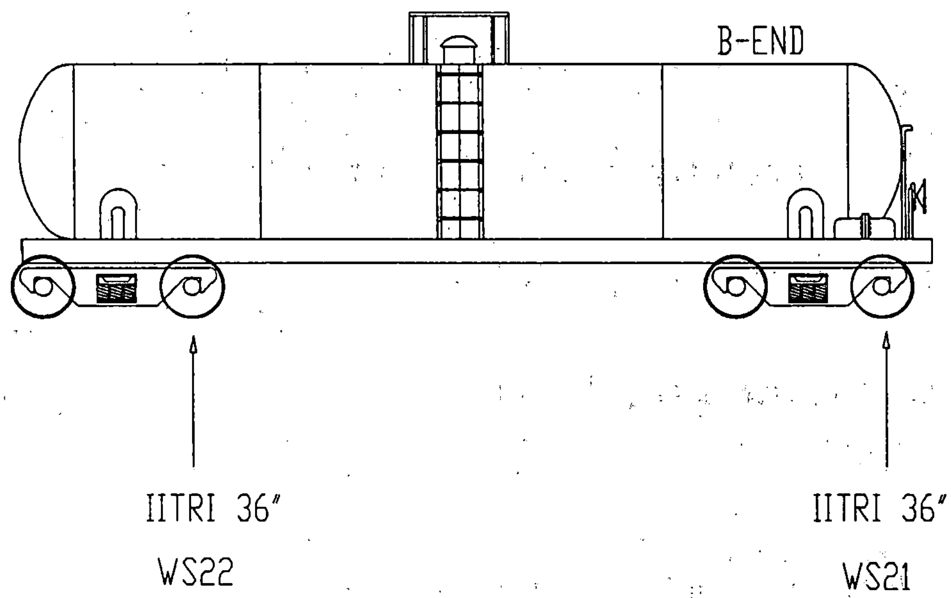


Figure 2-1 Instrumented Wheel Set Configuration

2.1.11 Roll the truck back under the car.

2.1.12 Lower the car.

2.1.13 Check Steps 2.1.1 through 2.1.5.

2.1.14 Chock all B-end wheels.

2.1.15 Using two 100-ton jacks at the jacking pads, jack the A-end up approximate 12 inches.

2.1.16 Roll out Truck 2.

2.1.17 Lift Truck 2 and remove Axle 3 (with respect to B-end) wheel set.

2.1.18 Replace Axle 3 wheel set with the ENSCO WS22 instrumented wheel set as illustrated in Figure 2-1 and in accordance with, PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.

2.1.19 Roll the truck back under the car.

2.1.20 Lower the jacks.

2.1.21 Quality verify the completion of the wheel set change out.

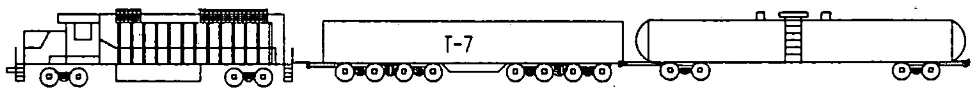
LDD____

UNLD____

HLD____

2.2 Coupling of the Test Car and the Instrumentation Car

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Couple the B-end of the test car behind the instrumentation car. Figure 2-2 shows the core test consist. Buffer cars may be added or removed as required for each test.	



Note: Additional buffer cars may be added as required

Figure 2-2 Core Test Consist

CAUTION

Restrict coupling speed to 3.5 mph

2.3 Instrumentation Checkout

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	Calibrate instrumentation in accordance with, PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	LDD____ UNLD___ HLD____
2.3.2	Quality verify coupling of the Fuel Car and the Instrumentation Car is complete.	LDD____ UNLD___ HLD____

NOTE

Test sequence is arbitrary. The test sequence may bedictated by track availability at TTC. Anticipated test sequence is shown in PKRG-7001 Test Sequence Procedure.

3.0 LATERAL STABILITY ON TANGENT TRACK (UNLOADED, HALF-LOADED)

3.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
3.1.1	Ensure that no buffer car is coupled to the core test consist shown in Figure 2-2.	
3.1.2	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	UNLD____ HLD____

3.2 On-Track Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Ensure that the instrumentation is checked-out in accordance with Section 3.1.1 and 3.1.2.	

NOTE

Test to be conducted on 5000 feet of dry tangent track on the RTT with Class 5 or better track (R39-R33).

CAUTION

Stop testing before lateral acceleration exceeds 1.0 g peak-to-peak or any maximum axle sum L/V exceeds 1.3.

3.2.1.1 Ensure applicable perturbations have been verified. ________

3.2.1.2 Ensure pre-test sign-off sheet PKRG-7002 has been completed.

3.2.2 During the initial 30 mph track conditioning run, keep the speed constant through the test zone.

3.2.3 Start taking lateral acceleration data 200 - 300 feet before reaching the test zone. The computer should be triggered by Automatic Location Device (ALD).

3.2.4 Stop data acquisition 200 - 300 feet beyond the test zone.

3.2.4.1 Review test, ensure data is acceptable and indicates that the test can be continued.

3.2.5 Repeat test once.

3.2.5.1 Compare maximum limiting values. Ensure readings are within 15% for instrumented wheel sets, 5% on roll gyros and accelerometers.

3.2.6 Increase speed in increments of ± 10 mph, ± 1 mph with each pair of test runs, until approachong a critiacl point (80 % of stop critiera, 0.8 g peak-to-peak, and 1.0 L/V); then, increase speed in increments of 2 mph until maximum test speed of 70 mph is reacded.

3.2.7	In the Test Engineers Log, note the speed at which the car sustains truck hunting if hunting occurs (Per Chapter XI criteria 1.0 g peak-to-peak for 20 seconds).	UNLD___ HLD____
3.2.8	Quality verify that the test is completed.	UNLD___ HLD____

3.3 Post Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Perform Post Test Cal per PKRG-3500 and 3800.	UNLD___ HLD____
3.3.2	Perform Post Test Visual Inspection.	UNLD___ HLD____

4.0 CONSTANT CURVING TEST (LOADED, UNLOADED, HALF-LOADED)

4.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
4.1.1	Instrumentation for this test should be as per Section 2.0.	

4.1.2	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	LDD____ UNLD____ HLD____
4.1.3	Place fully loaded 125-ton buffer car #UP31934 at the end of the core consist.	

CAUTION

Restrict coupling speed to 3.5 mph.

4.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
4.2.1	This test utilizes all of the different degrees of curvature and superelevation (7.5-, 10-, 12-degree with 3, 4 and 5 inches of superelevation respectively) available on the WRM track.	
4.2.1.1	Ensure applicable perturbations have been verified.	______
4.2.1.2	Ensure pre-test sign-off sheet PKRG-7002 has been completed.	
4.2.2	Determine the test run speed by equation:	

$$V = \sqrt{1480\frac{(U+H)}{D}}$$

Where: U = unbalance in inches
H = superelevation in inches
D = degree of curvature.

4.2.3 For U = -3, 0, and +3 inches of unbalance.

NOTE

Track speed may be lower than the calculated speed for the +3-inch run. If this condition exists use the track speed limit of 45 mph.

The speed calcuated for the -3-inch run may be zero or less. If this condition exists, use a negative difference from the balance equal to the positive difference for the +3-inch.

CAUTION

Stop testing before any L/V exceeds .8 or any axle sum L/V exceeds 1.3.

4.2.4 Operate the test consist at a constant speed for each condition shown in Table 3-1 ± 1 mph).

Table 3-1 Constant Curving Conditions

DEGREE	SUPER ELEVATION	BALANCE SPEED	+3 INCH	-3 INCH
7.5	3	24.0	32.0	14.0
10	4	24.0	32.0	12.0
12	5	25.0	32.0	16.0

4.2.5 With each test run, record data 200 - 300 feet before the curve and through the length of the body of the curve. The computer should be triggered by the ALD.

4.2.5.1 Repeat 4.2.4 for opposite direction.

4.2.6 QA verify that the test matrix is complete. LDD_____

HLD_____

5.0 SPIRAL NEGOTIATION AND WHEEL UNLOADING CONDITIONS

5.1 Test Requirements

TASK NUMBER	PROCEDURE	QA INITIAL
5.1.1	This test will run concurrently with the Constant Curving Test speed conditions.	
5.1.2	Record data while running through the spirals on the WRM during the curving test.	

CAUTION

Stop testing before the vertical wheel force is less than 10% static wheel load or any wheel L/V exceeds 0.8.

5.1.3	QA verify that the test is complete.	LDD_____ HLD_____

6.0 TWIST AND ROLL TEST (LOADED, UNLOADED, HALF-LOADED)

6.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
6.1.1	Couple a buffer car (UP31934) to the end of the core test consist.	

6.1.2	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	LDD____ UNLD____ HLD____

6.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
6.2.1.	Ensure applicable perturbations have been verified.	______
6.2.1.2	Ensure pre-test sign-off sheet PKRG-7002 has been completed.	
6.2.2	This test will be performed on the Precision Test Track (PTT) as shown in Attachment 1.	
6.2.3	Approach the test zone at a constant speed of 10 mph, ± 1 mph.	
6.2.4	Record the wheel forces, mean roll angle and differences in roll between the ends for each truck for approximately 200 feet before the test zone and continuously through the test zone.	

CAUTION

Stop testing before the car body peak-to-peak roll exceeds 6 degrees, any single wheel L/V exceeds 0.8, any axle sum L/V exceeds 1.3 or any vertical wheel load measures less than 10 % of its static wheel load.

6.2.5 Run tests at constant speeds, increasing in increments of 5 mph, $\pm$ 1 mph then increasing at increments of 2 mph until resonance is passed; then, increase speeds in increments of 5 mph.

6.2.6 Make two runs at each speed. In the Test Engineers Log, note the speed at which resonance is reached. LDD____

UNLD___

HLD____

6.2.7 Stop testing if an unsafe condition is encountered or when the maximum speed of 70 mph is reached. LDD____

UNLD___

HLD____

6.2.8 Quality verify that the Twist and Roll Test is completed. LDD____

UNLD___

HLD____

6.3 Test Tear-Down

TASK NUMBER	PROCEDURE	QA INITIAL
6.3.1	Remove the loaded buffer car from the test consist (if applicable).	
6.3.2	Quality verify that the Test Tear-down is completed.	LDD____ UNLD___

7.0 PITCH AND BOUNCE TEST (LOADED, HALF-LOADED)

7.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
7.1.1	This test is to be performed on the PTT located between stations 1716+00 and 1719+90 as shown in Attachment 1.	
7.1.2	Place a light car (TTX479303 empty flat) that has at least 45 ft. truck center spacing at the end of the consist directly behind the test car.	
7.1.3	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	LDD_____ HLD_____

7.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
7.2.1	Approach the test section at a constant speed of 30 mph, $\pm$1 mph. Start recording test data approximately 100 feet before the test section and continuously through the test section.	
7.2.2	Using the computer, record the vertical wheel forces.	

CAUTION

Stop testing when any wheel shows a vertical load of 10 % or less of its static load.

7.2.3 Run the test twice at each speed.

7.2.4	Increase speed in increments of 10 mph until unsafe conditions are encountered, the resonance is passed, or a maximum of 60 mph is reached. Increments may be reduced to 2 mph when nearing resonance. Resonance to be determined prior to testing.	LDD____ HLD____
7.2.5	Quality verify that the Pitch and Bounce Test is completed.	LDD____ HLD____

8.0 DYNAMIC CURVING TEST (LOADED, HALF-LOADED)

8.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
8.1.1	This test is to be conducted on the 10-degree curve (station 1+00 to 3+50) of the wheel/rail mechanism (WRM) track, as shown in Attachment 1.	
8.1.2	Place a loaded buffer car (UP 31934) at the end of the core consist coupled directly to the test car.	
8.1.3	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	

8.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL

CAUTION

It shall be regarded as unsafe and the test will be stopped if a wheel lifts, if any wheel L/V exceeds 0.8, if the instantaneous sum of the absolute L/V values of the individual wheels on any axle exceeds 1.3, or the car body roll exceeds 6 degrees peak-to-peak or minimum wheel load of 10% static.

8.2.1	Approach the test zone at a constant speed of 5 mph.	
8.2.2	Start acquiring test data approximately 200 feet before the test zone. Record the lateral and vertical wheel forces and the roll angle.	
8.2.3	Increase speed in increments of 2 mph until a maximum speed of 32 mph is reached or an unsafe condition is encountered.	LDD____ HLD____
8.2.4	Quality verify that the Dynamic Curving Test is completed.	LDD____ HLD____

8.3 Test Tear-down

TASK NUMBER	PROCEDURE	QA INITIAL
8.3.1	Remove the loaded buffer car from the test consist if applicable.	
8.3.2	Quality verify that the Test Tear-down is completed.	LDD____ HLD____

9.0 TURNOUT AND CROSSOVER TEST (LOADED, UNLOADED, HALF-LOADED)

9.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
9.1.1	Use whatever configuration the consist is in while traversing from one test section to the other.	
9.1.2	This test will be performed on the turnouts and crossover of the RTT and TTT near Post 85 (Attachment 1).	
9.2	The Fuel Car shall be run at 10 mph 15 mph through a #8 turnout and also shall be run at 15, 25, 35 through 602A and B crossover.	
9.3	Quality verify Turnout and Crossover Test completed.	LDD____ UNLD____ HLD____

10.0 SPECIAL PERTURBATIONS

10.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
10.1.1	If necessary, the consist may be run through special perturbations to be identified at a later time.	

10.1.2 Test setup will be defined at that time.

10.2 On-track Test

TASK NUMBER	PROCEDURE	QA INITIAL
10.2.1	Test procedure and stop criteria will be identified at a later time.	

11.0 YAW AND SWAY TEST (LOADED, HALF-LOADED)

11.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
11.1.1	Disconnect cables between T-7 and the Fuel Car. Uncouple the Fuel Car from T-7.	
11.1.2	Using four 100-ton jacks at the jacking pads, jack the test car up approximately 12 inches.	
11.1.3	Roll both trucks away from the car.	

11.1.4 Remove the trailing axle of Truck 1 (Axle 2) and the leading axle of Truck 2.

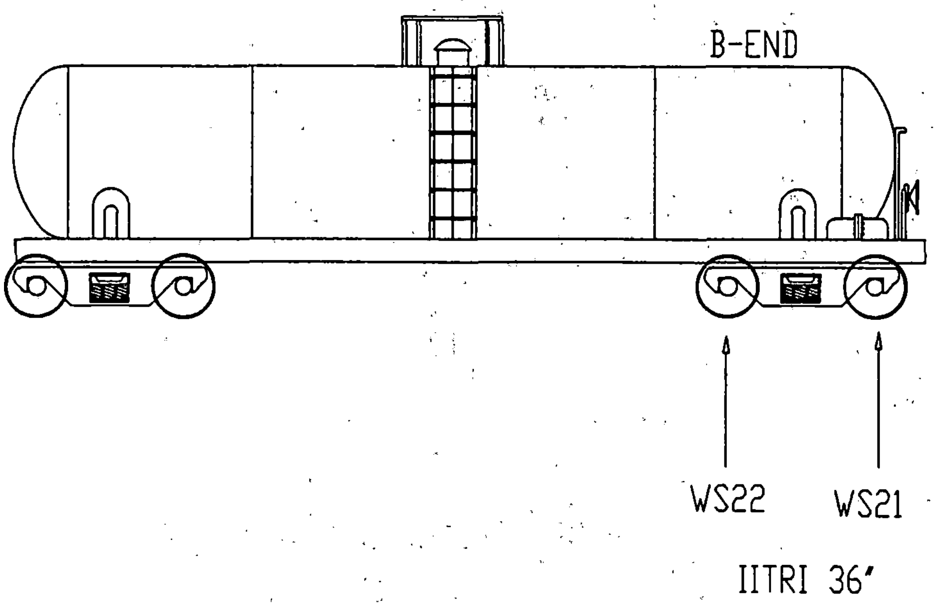


Figure 11-1 Instrumented Wheel Set Configuration

11.1.5 Place the instrumented wheel set from Truck 2 in the trailing axle position of Truck 1, as shown in Figure 11-1. LDD____

HLD____

11.1.6 Place the old trailing axle from Truck 1 under Truck 2 (Axle 3).

11.1.7 Roll the trucks back under the car.

11.1.8 Lower the jacks.

11.1.9 Quality verify that the wheel sets have been changed over. LDD____

HLD____

11.1.10 Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup. LDD____ HLD____

11.1.11 Place the test car at the end of the consist behind the T-7 Instrument Car. Reconnect instrumentation cables per procedure PKRG-3500 and 3800.

11.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
11.2.1	This test is to be conducted on Section 21+00 to 26+00 of the PTT, as shown in Figure 3-1 (Attachment 1).	
11.2.2	The initial test run is to be conducted at a constant speed of 20 mph and increasing in increments of 5 mph, ± 1 mph until resonance is passed and top speed is accomplished.	
11.2.3	Begin test data acquisition approximately 200 feet before reaching the test section.	

CAUTION

It shall be regarded as unsafe and the test will be stopped if the ratio of the total lateral forces on any one side measured exceeds 0.6 for a duration equivalent to 6 ft. or any axle sum L/V exceeds 1.3.

11.2.4	Repeat the test at speed increments of 2 mph, $\pm$ 1 mph. The test will continue until an unsafe condition is encountered, the resonance is passed or the maximum speed of 60 mph is reached. Speed may be increased in increments of 5 mph when resonance has passed.	LDD_____ HLD_____
11.2.5	Quality verify that the Yaw and Sway Test is completed.	LDD____ HLD____

12.0 CONFIGURATION TEST REQUIREMENTS

TASK NUMBER	PROCEDURE	QA INITIAL
12.0.1	Repeat applicable tests in half-loaded and loaded conditions.	

13.0 TEST TEAR-DOWN

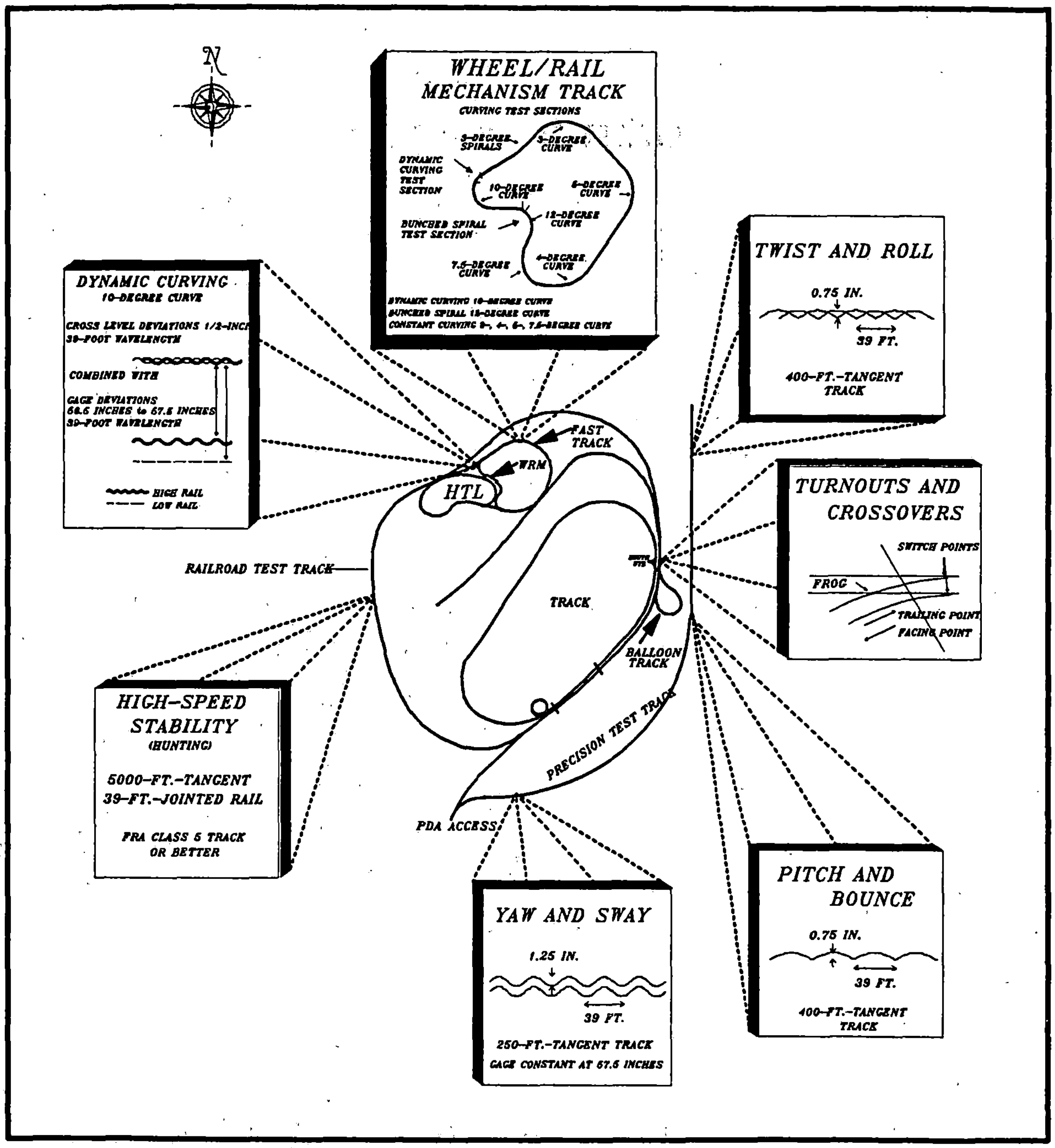
TASK NUMBER	PROCEDURE	QA INITIAL
13.0.1	The procedure for tear down of the IITRI 36-Inch Instrumented Wheel Sets is located in PKRG-3500, Section 5.0 through 5.1. Refer to this procedure and the applicable section to complete test tear-down.	LDD____ UNLD___ HLD____

14.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
14.0.1	Quality Verify that Procedure PKRG-7000-FC is complete and closed.	
14.0.2	Authorized QA signature ______________________________.	

ATTACHMENT 1

CHAPTER XI TRACK WORTHINESS TEST FACILITIES



APPENDIX C

MEASUREMENT LIST

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FUEL CAR DATE 7-23-90 W.O. 87560 LOC.

INSTR. ENGR./TECH. TEST ENGR. BRABB QA

SOFTWARE/VERSION RECORDER I.D. NO. SET-UP FILE

SAMPLE RATE ENCODER/DIGITIZER I.D. NO.

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	TRANSDUCER S.N.	TRANSDUCER SENS.	TRANSDUCER LOC.	TRANSDUCER CAL VOID DATE	AMPLIFIER CH. NO.	AMPLIFIER EXC.-L/R	AMPLIFIER GAIN FIX/VAR	AMPLIFIER R-CAL RES.	AMPLIFIER CAL. E.U. & VOLTS	AMPLIFIER S.N. CAL VOID DATE	FILTER NO.	FILTER FREQ	FILTER GAIN	FILTER CAL VOID DATE	SYSTEM AO (E.U.)	SYSTEM AI (E.U./VOLT)	SYSTEM ENGR. UNITS	RECORDER CH. NO.	RECORDER SENS. (E.U./DIV.)	COMMENTS
ALD	0	0	XBX 001A	WARNER		20 MS PULSE	X= Y= Z=												0	1 EVENT / 10V	EVENT			ALD
TSPD	1	1	RDV 001A	AIR. PAX		64 PULSE/REV	X= Y= Z=												0	10 MPH / V	MPH			SPEED
FVIL	2	2	LBV 001A	IITRI	21A	CALC	X= 964 Y= 28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	1		IVS TRK-1 LEAD AXLE VERT LEFT
FVIR	3	3	LBV 002A	IITRI	21B	CALC	X= 964 Y= -28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	2		IVS TRK-1 LEAD AXLE VERT RIGHT
FLIL	4	4	LBV 003A	IITRI	21A	CALC	X= 964 Y= 28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	3		IVS TRK-1 LEAD AXLE LAT LEFT
FLIR	5	5	LBV 004A	IITRI	21B	CALC	X= 964 Y= -28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	4		IVS TRK-1 LEAD AXLE LAT RIGHT
LVIL	6	6	LBV 005A	IITRI	21A	CALC	X= 964 Y= 28.5 Z= 18									15 Hz	1		0	.5 L/V / V	L/V	5		IVS TRK-1 LEAD AXLE L/V LEFT
LVIR	7	7	LBV 006A	IITRI	21B	CALC	X= 964 Y= -28.5 Z= 18									15 Hz	1		0	.5 L/V / V	L/V	6		IVS TRK-1 LEAD AXLE L/V RIGHT
FT1	8	8	LBV 007A	IITRI	21	CALC	X= 964 Y= 0 Z= 18									15 Hz	1		0	5.0 KIPS / V	KIPS	7		IVS TRK-1 LEAD AXLE TORQUE
FV3L	9	9	LBV 008A	IITRI	22A	CALC	X= 964 Y= 28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	9		IVS TRK-2 LEAD AXLE VERT LEFT

NOTES:

ACAD FILE: FC1OF7.DWG

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FUEL CAR DATE ______ W.O. 87560 LOC. ______

INSTR. ENGR./TECH. ______ TEST ENGR. BRABB QA ______

SOFTWARE/VERSION ______ RECORDER I.D. NO. ______ SET-UP FILE ______

SAMPLE RATE ______ ENCODER/DIGITIZER I.D. NO. ______

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER					AMPLIFIER						FILTER				SYSTEM			RECORDER		COMMENTS
				MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. / CAL VOID DATE	NO.	FREQ	GAIN	CAL VOID DATE	A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	CH. NO.	SENS. (E.U./DIV.)	
FV3R	10	10	LBV 009A	IITRI	22B	CALC	X= 1392 Y= -28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	10		IVS TRK-2 LEAD AXLE VERT RIGHT
FL3L	11	11	LBV 010A	IITRI	22A	CALC	X= 1392 Y= -28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	11		IVS TRK-2 LEAD AXLE LATERAL LEFT
FL3R	12	12	LBV 011A	IITRI	22B	CALC	X= 1392 Y= -28.5 Z= 18									15 Hz	1		0	10.246 K / V	KIPS	12		IVS TRK-2 LEAD AXLE LATERAL RIGHT
LV3L	13	13	LBV 012A	IITRI	22A	CALC	X= 1392 Y= -28.5 Z= 18									15 Hz	1		0	.5 L/V / V	L/V	13		IVS TRK-2 LEAD AXLE L/V LEFT
LV3R	14	14	LBV 013A	IITRI	22B	CALC	X= 1392 Y= -28.5 Z= 18									15 Hz	1		0	.5 L/V / V	L/V	14		IVS TRK-2 LEAD AXLE L/V RIGHT
FT3	15	15	LBW 014A	IITRI	22	CALC	X= 1392 Y= -28.5 Z= 18									15 Hz	1		0	5.0 KIPS / V	KIPS	15		IVS TRK-2 LEAD AXLE TORQUE
AY1A	16	16	Y001A	7290	AE 74	196.4 mv/G	X= 958 Y= 0 Z= 41		K	15V	2 FIX	VSUB	.888 G 3.333 V			15 Hz	1		0	2.5458 / V	G	17		ACCEL LATERAL B-END CARBODY FLOOR PLATE 5/5
AY2A	17	17	Y002A	7290	AC 58	201.9 mv/G	X= 1470 Y= 0 Z= 41		K	15V	2 FIX	VSUB	.888 G 3.333 V			15 Hz	1		0	2.4765 / V	G	18		ACCEL LATERAL A-END CARBODY FLOOR PLATE 5/5
543A AY3A	18	18	Y003A	ENDEVCO 7265-HS	BP 90	27.59 mv/G	X= 964 Y= 44 Z= 24		H	10 V	100 FIX	29.8 K	4.0 V 3.6 G			15 Hz	1		0	3.6245 / V	G	19		ACCEL LATERAL TRK-1 AXLE 1 LEFT WHEEL ADPT 25/5
AY4A	19	19	Y004A	ENDEVCO 7265-HS	BM 38	23.53 mv/G	X= 1034 Y= 44 Z= 24		H	10 V	100 FIX	29.8 K	4.0 V 3.6 G			15 Hz	1		0	4.2499 / V	G	20		ACCEL LATERAL TRK 1 AXLE 2 LEFT WHEEL ADPT 25/5

NOTES:

*b230W

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 3 OF ____

TEST NAME FUEL CAR DATE ______ W.O. 87560 LOC. ______
INSTR. ENGR./TECH. ______ TEST ENGR. BRABB QA ______
SOFTWARE/VERSION ______ RECORDER I.D. NO. ______ SET-UP FILE ______
SAMPLE RATE ______ ENCODER/DIGITIZER I.D. NO. ______

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	TRANSDUCER S.N.	TRANSDUCER SENS.	TRANSDUCER LOC.	TRANSDUCER CAL VOID DATE	AMPLIFIER CH. NO.	AMPLIFIER EXC. L/R	AMPLIFIER GAIN FIX/VAR	AMPLIFIER R-CAL RES.	AMPLIFIER CAL. E.U. & VOLTS	AMPLIFIER S.N. CAL VOID DATE	FILTER NO.	FILTER FREQ	FILTER GAIN	FILTER CAL VOID DATE	SYSTEM A0 (E.U.)	SYSTEM A1 (E.U./VOLT)	SYSTEM ENGR. UNITS	RECORDER CH. NO.	RECORDER SENS. (E.U./DIV.)	COMMENTS
277A AX1A	20	20	X001A	ENDEVCO 7265	BT 36	25.76 mv/G	X= 1000 Y= 0 Z= 46		H	10 V	100 FIX	29.88 K				15 Hz	1			3.8820 V	G	21		ACCEL LONG B-END ABOVE TRK-1 CTR PLATE
273A AX2A	21	21	X002A	ENDEVCO 7265	BR 11	27.80 mv/G	X= 1426 Y= 0 Z= 46		H	10 V	100 FIX	29.88 K				15 Hz	1			3.5971 V	G	22		ACCEL LAT A-END ABOVE TRK-2 CTR PLATE
276A AY5A	22	22	Y005A	ENDEVCO 7265	BP 43	22.80 mv/G	X= 1000 Y= 0 Z= 46		H	10 V	100 FIX	29.88 K				15 Hz	1			4.3859 V	G	23		ACCEL LATERAL B-END ABOVE TRK-1 CTR PLATE
275A AZ1A	23	23	Z001A	ENDEVCO 7265	BP 82	27.38 mv/G	X= 1000 Y= 0 Z= 46		H	10 V	100 FIX	29.88 K				15 Hz	1		0	3.6523 V	G	24		ACCEL VERT B-END ABOVE TRK-1 CTR PLATE
272A AZ2A	24	24	Z002A	ENDEVCO 7265	BP 20	26.30 mv/G	X= 1426 Y= 0 Z= 46		H	10 V	100 FIX	29.88 K				15 Hz	1		0	3.8023 V	G	25		ACCEL VERT A-END ABOVE TRK-2 CTR PLATE
AZ3A	25	25	Z003A	ENDEVCO 7265	BR 33	24.75 mv/G	X= 1213 Y= 0 Z= 50		H	10 V	100 FIX	29.88 K				15 Hz	1		0	4.0404 V	G	26		ACCEL VERT CTR OF CAR FLOOR
545A AY8A	26	26	Y008A	ENDEVCO 7265 HS	BP 25	24.20 mv/G	X= 1389 Y= 41 Z= 24			10 V	100 FIX	29.88 K.				15 Hz	1			4.1322 V		27		ACCEL LAT TRK-2 AXLE 3 WHEEL CAP
544A AY6A	27	27	Y006A	ENDEVCO 7265 HS	BP 04	21.68 mv/G	X= 1000 Y= 41 Z= 31			10 V	100 FIX	29.88 K				15 Hz	1			4.6125 V		28		ACCEL LAT TRK-1 LEFT SIDE FRAME CTR
546A AY7A	28	28	Y007A	ENDEVCO 7265 HS	BR 32	23.00 mv/G	X= 1426 Y= 41 Z= 31			10 V	100 FIX	29.88 K				15 Hz	1			4.3478 V		29		ACCEL LAT TRK-2 LEFT SIDE FRAME CTR
AZ4A	29	29	Z004A	CELESCO	A 45607	622.6 mv/G	X= 1000 Y= 48 Z= 20		K	10 V	2 FIX	VSUB				15 Hz	1		0	.803 in/v	inch			DISPLACEMENT VERT SPRING NEST TRK-1 LEFT

NOTES:

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PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FUEL CAR DATE ________ W.O. 87560 LOC. ____________

INSTR. ENGR./TECH. ____________ TEST ENGR. BRABB QA ________

SOFTWARE/VERSION ____________ RECORDER I.D. NO. ____________ SET-UP FILE

SAMPLE RATE ________ ENCODER/DIGITIZER I.D. NO. ____________ ____________

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER					AMPLIFIER						FILTER				SYSTEM			RECORDER		COMMENTS
				MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. / CAL VOID DATE	NO.	FREQ.	GAIN	CAL VOID DATE	A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	CH. NO.	SENS. (E.U./DIV.)	
JBX1A	30	30	JBX 001A	HUMPREY	101	4.052 deg/v	X= 930 Y= 0 Z= 46		K	10 V	1 FIX	VSUB				15 Hz	1		0	1.008 / deg/V	deg	30		C/L B-END CARBODY ROLL ANGLE 8/8
JBX2A	31	31	JBX 002A	HUMPREY	102	4.087 deg/v	X= 1484 Y= 0 Z= 46		K	10 V	1 FIX	VSUB				15 Hz	1		0	1.018 / deg/v	deg	31		C/L A-END CARBODY ROLL ANGLE 8/8
AZ5A	32	32	Z005A	CELESCO	A 45608	623.0 mv/G	X= 1426 Y= 48 Z= 20		K	10 V	2 FIX	VSUB				15 Hz	1		0	.803 / in/v	inch			DISPLACEMENT VERTICAL SPRING NEST TRK-2 LEFT SIDE
AZ6A	33	33	Z006A	CELESCO	A 45609	622.4 mv/G	X= 1000 Y= -48 Z= 20		K	10 V	2 FIX	VSUB				15 Hz	1		0	.803 / in/v	inch			DISPLACEMENT VERTICAL SPRING NEST TRK-1 RIGHT SIDE
AZ7A	34	34	Z007A	CELESCO	A 45610	622.4 mv/G	X= 1426 Y= -48 Z= 20		K	10 V	2 FIX	VSUB				15 HZ	1		0	.803 / in/v	inch			DISPLACEMENT VERTICAL SPRING NEST TRK-2 RIGHT SIDE
	35	35	SLZ1A	GEMS 36460-60	700 121	161.9 mv/in	X= 1426 Y= 35 Z= 73		K	10 V	1 FIX	20 K	6.0			15 Hz	1			0.515′ / V				SLOSH GAUGE A-END CAR FLOOR RIGHT SIDE
	36	36	SLZ2A	GEMS 36460-60	700 122	161.9 mv/in	X= 1426 Y= -35 Z= 73		K	10 V	1 FIX	20 K	6.0			15 Hz	1			0.515′ / V				SLOSH GAUGE A-END CAR FLOOR LEFT SIDE
	37	37	SLZ3A	GEMS 36460-60	700 123	161.9 mv/in	X= 1213 Y= 35 Z= 73		K	10 V	1 FIX	20 K	6.0			15 Hz	1			0.515′ / V				SLOSH GAUGE CTR OF TANK RIGHT SIDE
	38	38	SLZ4A	GEMS 36460-	700 124	161.9 mv/in	X= 1213 Y= -35 Z= 73		K	10 V	1 FIX	20 K	6.0			15 Hz	1			0.515′ / V				SLOSH GAUGE CTR OF CAR ABOVE LEFT SIDE
	39	39	SLZ5A	GEMS 36460-	700 125	161.9 mv/in	X= 1000 Y= 35 Z= 73		K	10 V	1 FIX	20 K	6.0			15 Hz	1			0.515′ / V				SLOSH GAUGE B-END RIGHT SIDE

NOTES:

ACAD FILE: FC4OF7.DWG

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 5 OF ____

TEST NAME FUEL CAR   DATE ____ W.O. 87560 LOC. ____

INSTR. ENGR./TECH. ____   TEST ENGR. BRABB   QA ____

SOFTWARE/VERSION ____   RECORDER I.D. NO. ____   SET-UP FILE ____

SAMPLE RATE ____   ENCODER/DIGITIZER I.D. NO. ____

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	TRANSDUCER S.N.	TRANSDUCER SENS.	TRANSDUCER LOC.	TRANSDUCER CAL VOID DATE	AMPLIFIER CH. NO.	AMPLIFIER EXC.-L/R	AMPLIFIER GAIN FIX/VAR	AMPLIFIER R-CAL RES.	AMPLIFIER CAL. E.U. & VOLTS	AMPLIFIER S.N. CAL VOID DATE	FILTER NO.	FILTER FREQ	FILTER GAIN	FILTER CAL VOID DATE	SYSTEM A0 (E.U.)	SYSTEM A1 (E.U./VOLT)	SYSTEM ENGR. UNITS	RECORDER CH. NO.	RECORDER SENS. (E.U./DIV.)	COMMENTS
	40	40	SLZ6A	GEMS 36460-	700 126	161.9 mv/in	X= 1000 Y= -35 Z= 73		K	10 V	1 FIX	20 K	6.0			15 Hz	1							SLOSH GAUGE B-END LEFT SIDE
	41	41	IRIG				X= Y= Z=																	
V21A	42	42	V21AA				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
V21B	43	43	V21AB				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
V21C	44	44	V21AC				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
L21A	45	45	L21AA				X= Y= Z=			15	200	118 K	1.535			200	1			1				
L21B	46	46	L21AB				X= Y= Z=			15	200	118 K	1.535			200	1			1				
VA/B/C21	47	47	V21BA				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
VB21	48	48	V21BB				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
VC21	49	49	V21BC				X= Y= Z=			15	1000	681 K	1.980			200	1			1				

NOTES:

ACAD FILE: FC5OF7.DWG

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FUEL CAR DATE ______ W.O. 87560 LOC. ______

INSTR. ENGR./TECH. ______ TEST ENGR. BRABB QA ______

SOFTWARE/VERSION ______ RECORDER I.D. NO. ______ SET-UP FILE ______

SAMPLE RATE ______ ENCODER/DIGITIZER I.D. NO. ______

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER					AMPLIFIER						FILTER				SYSTEM			RECORDER		COMMENTS
				MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. / CAL VOID DATE	NO.	FREQ.	GAIN	CAL VOID DATE	A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	CH. NO.	SENS. (E.U./DIV.)	
LA21	50	50	L21BA				X= Y= Z=			15	200	118 K	1.535			200	1			1				
LB21	51	51	L21BB				X= Y= Z=			15	200	118 K	1.535			200	1			1				
	52	52	JBX3A				X= Y= Z=																	ROLL RATE B-END RAW GYRO
P21A	53	53	P21AA				X= Y= Z=			15	1000	815 K	1.095			200	1			1				
P21B	54	54	P21BA				X= Y= Z=			15	1000	815 K	1.095			200	1			1				
V22A	55	55	V22AA				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
V22B	56	56	V22AB				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
V22C	57	57	V22AC				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
L22A	58	58	L22AA				X= Y= Z=			15	200	118 K	1.535			200	1			1				
L22B	59	59	L22AB				X= Y= Z=			15	200	118 K	1.535			200	1			1				

NOTES:

ACAD FILE: FC6OF7.DWG

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 7 OF ____

TEST NAME FUEL CAR DATE ________ W.O. 87560 LOC. ________

INSTR. ENGR./TECH. ________ TEST ENGR. BRABB QA ________

SOFTWARE/VERSION ________ RECORDER I.D. NO. ________ SET-UP FILE ________

SAMPLE RATE ________ ENCODER/DIGITIZER I.D. NO. ________

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER					AMPLIFIER						FILTER				SYSTEM			RECORDER		COMMENTS
				MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	NO.	FREQ.	GAIN	CAL VOID DATE	AO (E.U.)	AI (E.U./VOLT)	ENGR. UNITS	CH. NO.	SENS. (E.U./DIV.)	
VA22	60	60	V22BA				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
VB22	61	61	V22BB				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
VC22	62	62	V22BC				X= Y= Z=			15	1000	681 K	1.980			200	1			1				
LA22	63	63	L22BA				X= Y= Z=			15	200	118 K	1.535			200	1			1				
LB22	64	64	L22BB				X= Y= Z=			15	200	118 K	1.535			200	1			1				
JBX4A	65	65					X= Y= Z=																	ROLL RATE A-END RAV GYRO
P22A	66	66	P22AA				X= Y= Z=			15	1000	815 K	1.095			200	1			1				
P22B	67	67	P22BA				X= Y= Z=			15	1000	815 K	1.095			200	1			1				
							X= Y= Z=																	
							X= Y= Z=																	

NOTES:

ACAD FILE: FC7OF7.DWG

DOCUMENT 2

FUEL CAR
STATIC AND QUASI-STATIC
TRUCK CHARACTERIZATION AND MODAL RESPONSE
REPORT

PEACEKEEPER RAIL GARRISON

EM FUEL CAR

VEHICLE CHARACTERIZATION TESTS

David C. Brabb

Association of American Railroads
Transportation Test Center
Pueblo, CO 81001

October 1991

Table of Contents

Table of Figures

Tables

1.0 INTRODUCTION

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, has contracted with the Federal Railroad Administration (FRA) to perform vehicle performance tests on the Peacekeeper Rail Garrison (PKRG) rail cars according to specifications in Chapter XI, AAR's M-1001, *Manual of Standards and Recommended Practices.* These tests are designed to provide the FRA and United States Air Force (USAF) with structural and vehicle dynamic performance data for each car and for the assembled train.

This document describes the PKRG Engineering Model (EM) Fuel Car's vehicle characterization testing which includes static truck characterization (Air Bearing), quasi-static truck characterization (Mini-Shaker Unit (MSU)), and vehicle dynamic characterization (MSU modal).

The PKRG Fuel Car is a 74,100 pound (unloaded) conventional tank car with a 21,644 gallon, 5/8-inch-thick shell tank that is intended to carry diesel fuel for the PKRG consist.

2.0 OBJECTIVES

The objective of this test program was to determine the car body and suspension characteristics of the EM Fuel Car. These characteristics were used to generate vehicle dynamic performance predictions for an on-track test program scheduled for the Fuel Car in August of 1990.

The first test objective was to measure the static suspension characteristics of the two 100-ton three-piece trucks that were used under the Fuel Car to include:

- Truck Yaw Moment
- Axle Alignment
- Axle Box Longitudinal Stiffness
- Axle Yaw and Inter-axle Bending Stiffness

The second objective was to measure the quasi-static suspension characteristics of the two 100-ton trucks to include:

- Secondary Suspension Vertical Stiffness and Damping
- Secondary Suspension Lateral Stiffness and Damping
- Secondary Suspension Truck Roll Stiffness

The third objective was to measure the modal response parameters of the Fuel Car in loaded, half-loaded, and unloaded conditions, to include:

- Pitch and Bounce
- Upper and Lower Center Roll
- Yaw and Sway
- Vertical and Lateral Bending
- Longitudinal Torsion (Twist)
- Fuel Slosh Frequency

3.0 PROCEDURES

These tests were performed following procedures specified in Appendix B of Chapter XI.

3.1 AIR BEARING TABLE TEST

Static truck characterization was performed using air bearing tables. These tables utilized six air bearings to float an object off the ground on a cushion of air. This effectively eliminated the friction between the wheels and the rail. Figure 3.1 shows an air bearing table.

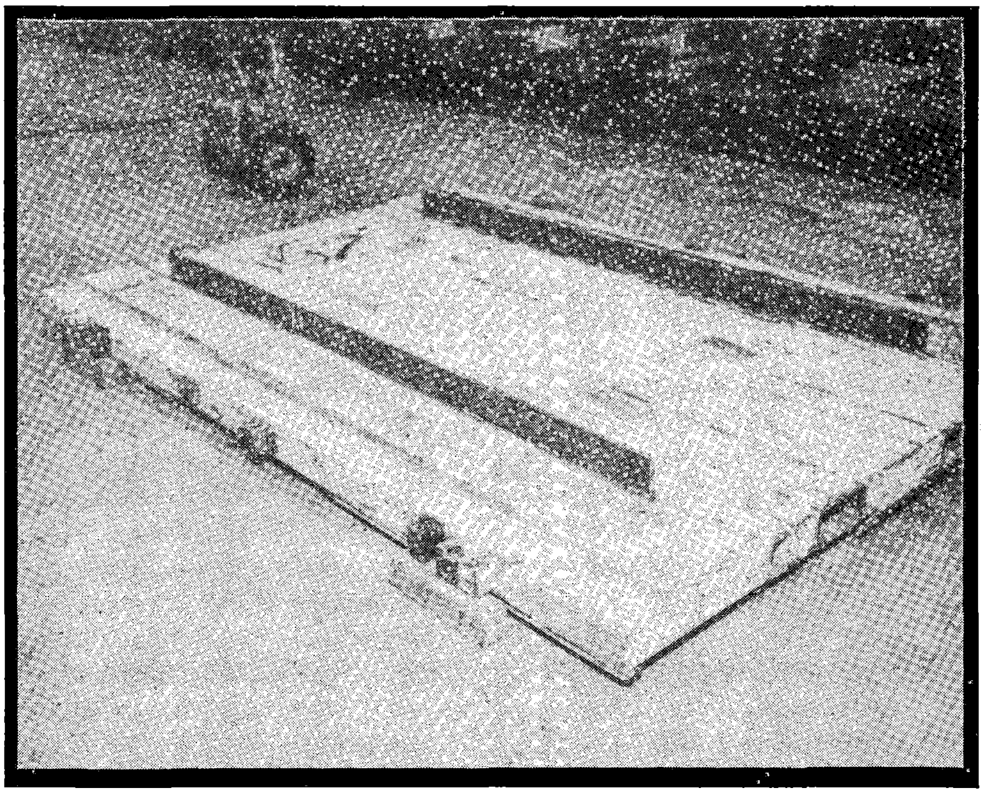


Figure 3.1 Air Bearing Table

The Air Bearing Table Test consisted of the following four sub-tests described in Appendix A of Chapter XI:

- Truck Yaw Moment
- Axle Alignment
- Axle Box Longitudinal Stiffness
- Axle Yaw and Inter-axle Bending Stiffness

3.1.1 Truck Yaw Moment Test

The Truck Yaw Moment Test was used to determine the force necessary to break static friction and rotate the truck about the car body center plate. Truck rotation is resisted by friction in the center plate and side bearing mating surfaces of the truck bolster, and the vehicle car body. The value desired in this test is the breakaway torque.

An air bearing table was placed under the truck being tested. Actuators were attached at opposite corners of the table to induce the forces necessary for rotation. String pots were placed at the two free corners to measure the rotational displacement. The force was applied equally and gradually with both actuators until the truck broke away. Chain hoists were used to reposition the truck for re-test. Both of the trucks were tested in clockwise and counter-clockwise rotations.

The actuators and string pots, for the Truck Yaw Moment Test, were assembled as shown in Figure 3.2.

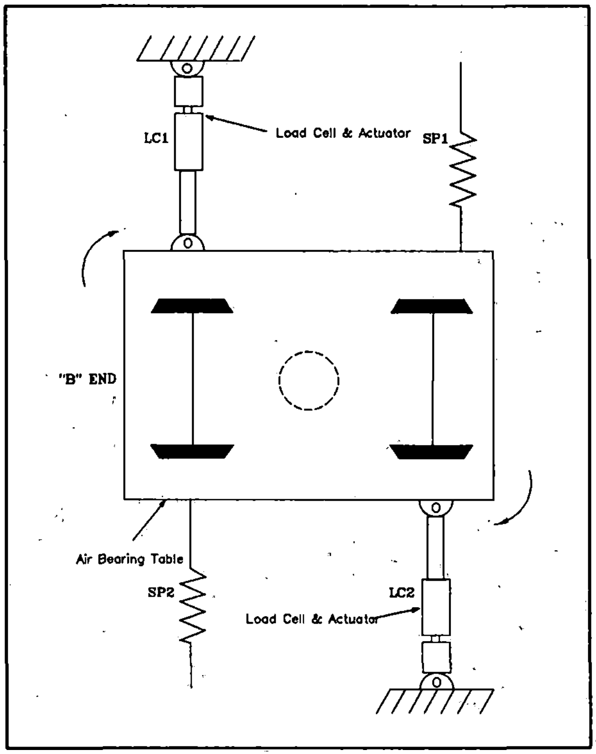


Figure 3.2 Truck Yaw Moment Test Setup

3.1.2 Axle Alignment Test

The Axle Alignment Test was performed to determine the lateral or radial misalignment between the two axles in a truck.

Since both axles in the truck needed to move independently for this test, the air table arrangement had to be changed. Two air tables were placed under one truck, one under each axle.

In order to measure radial and lateral misalignments, an optical transit and four precision scales were used in the arrangement shown in Figure 3.3.

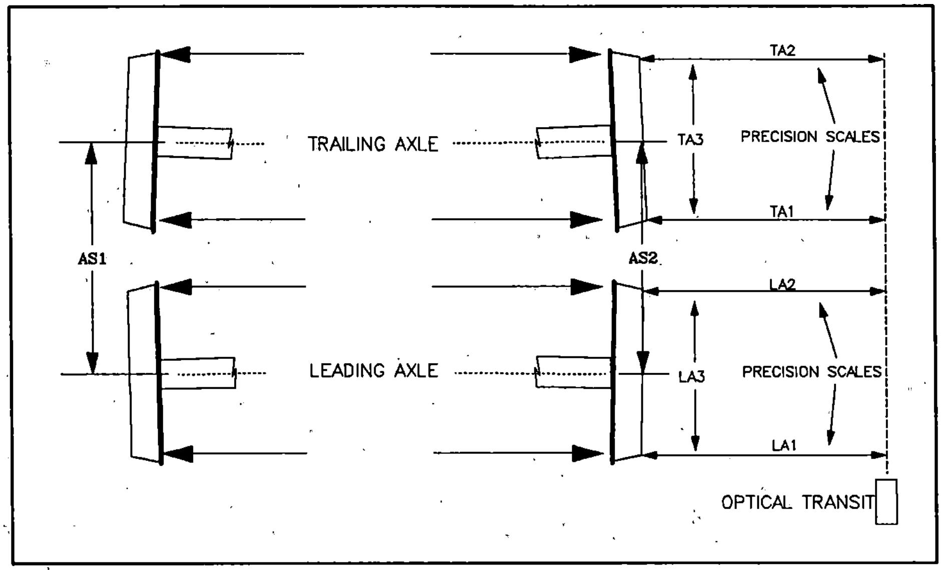


Figure 3.3 Axle Alignment Test Setup

Each time the tables were floated and set back down, the axle spacing on each side of the truck was measured. The scales were then put in place and the misalignments calculated. This test was performed three times on both of the trucks.

3.1.3 Longitudinal Stiffness Test

For this test the air tables were left in the same configuration as they were for axle alignment test. Actuators were connected to the ends of the axles via axle spuds bolted on the bearing end caps. The actuators and string pots were connected between the two axles on both sides of the truck, as shown in Figure 3.4.

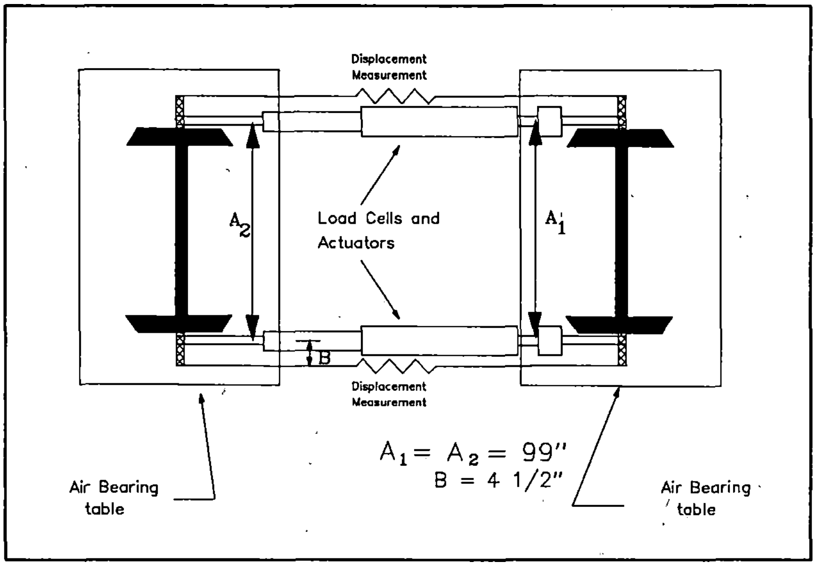


Figure 3.4 Longitudinal Stiffness Test Setup

String pots were used to measure displacement between the two axles on each side of the truck. The axles were pushed apart and pulled together to determine the longitudinal stiffness. This test was accomplished on both trucks.

3.1.4 Axle Yaw and Inter-axle Bending Stiffness Test

The Axle Yaw and Inter-axle Bending Stiffness Test was performed in conjunction with the Longitudinal Stiffness Test. The axles were yawed by pushing them apart on one side of the truck while pulling them together on the other side of the truck.

3.2 MINI-SHAKER UNIT TRUCK CHARACTERIZATION TEST

The quasi-static truck characterization tests, described in Appendix A of Chapter XI, were conducted to find the vertical and lateral suspension characteristics of the two American Steel Foundries' (ASF) 100-ton design ride control trucks. Both trucks were equipped with eight D-7 outer springs and seven D-7 inner springs, the center outside spring pockets were empty. The trucks were individually tested under the B-end of a Union Pacific gondola (UP31923). The gondola was loaded to approximate the average axle load (59,000 lbs.) of the Fuel Car. The tests included vertical, lateral, and roll tests at low frequencies to determine the stiffness and damping characteristics of the truck suspension components. These parameters were required as input for a mathematical model, New and Untried Car Analytic Regime Simulation (NUCARS), used to predict rail car performance. All of the characteristics used were for the secondary suspension because the truck design did not have primary suspension.

3.2.1 Test Specimen and Test Apparatus

The MSU utilized two 140-kip hydraulic actuators for vertical input excitation to the vehicle and one 140-kip hydraulic actuator for lateral excitation. The actuators were attached to reaction masses bolted to the floor of the Rail Dynamics Laboratory (RDL). Each actuator was connected between the car body and a reaction mass with special brackets that were welded to the car structure. Sinusoidal input signals were provided to the actuator control valves with a Hewlett Packard (HP) 360 desktop computer teamed with a programmable function generator. The actuators were controlled with 0.1 and 0.25 Hertz (Hz) signals during the quasi-static tests. Figures 3.5 and 3.6 show the MSU in the vertical and lateral test configurations, respectively.

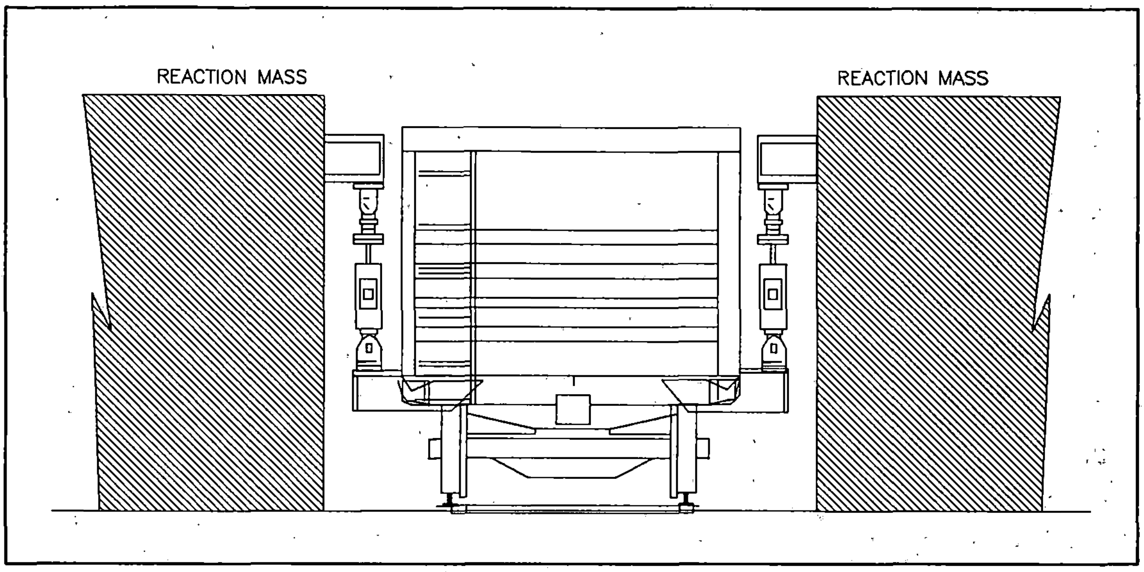


Figure 3.5 MSU Vertical Test Configuration

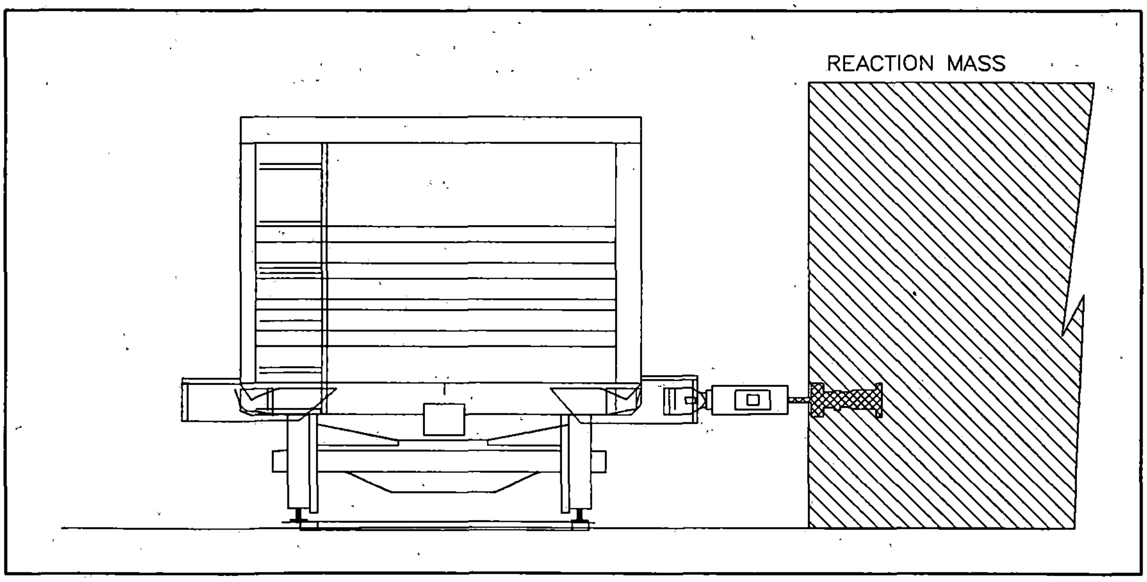


Figure 3.6 MSU Lateral Test Configuration

3.2.2 EM Fuel Car Instrument Setup

MSU applied measurements consisted of input forces and displacements of the hydraulic actuators. Response displacements were measured across the various suspension elements. Vertical and lateral wheel/rail forces were measured by strain gaged rail. String pots were installed as shown in Figure 3.7 and Figure 3.8. The vertical and lateral stiffness and damping were determined from those locations. A general measurement list is presented in Table 3.1. A complete measurement list is included in the "MSU Truck Characterization Procedure" found in Appendix E of the final report.

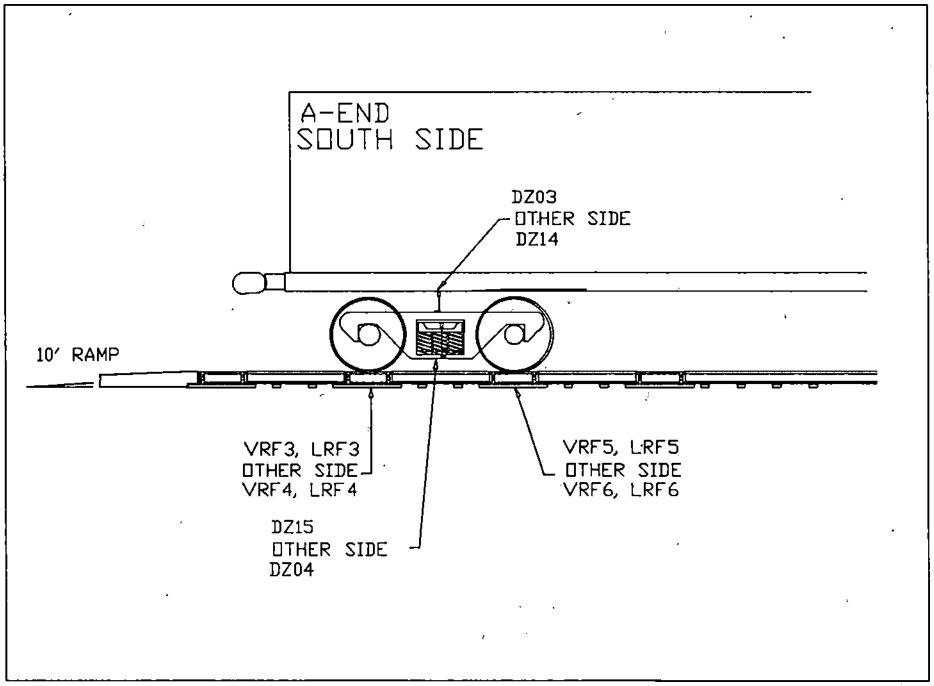


Figure 3.7 Quasi-Static Displacement and Instrumented Rail Location

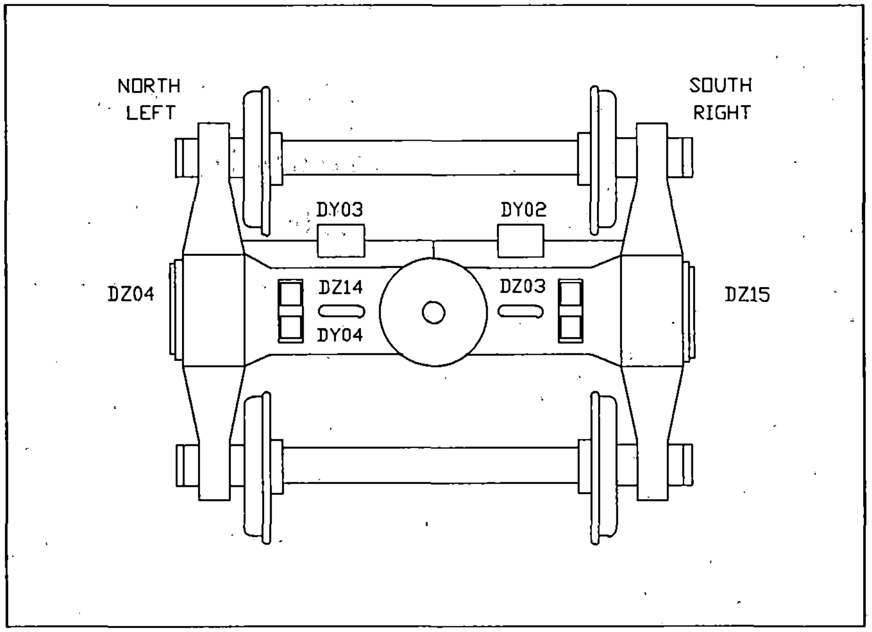


Figure 3.8 Quasi-Static Truck and Car Instrumentation Locations

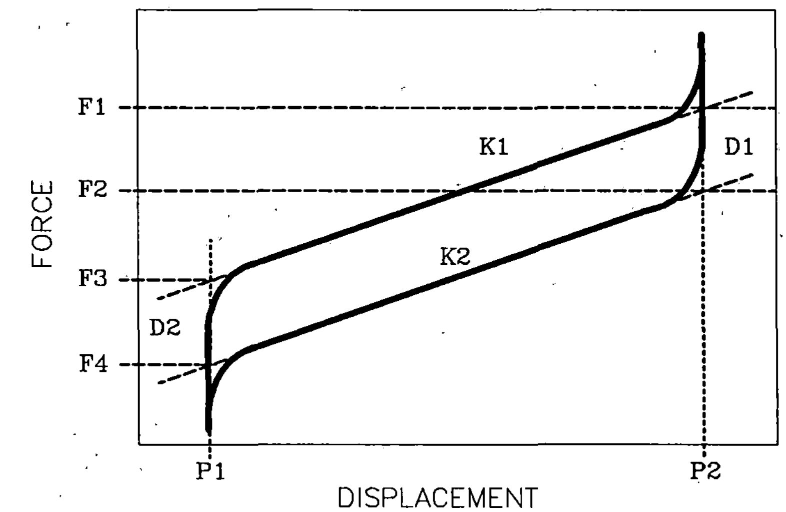
Table 3.1 Truck Characterization Measurement Descriptions

MEASUREMENT NAME	MEASUREMENT DESCRIPTION
VRF3	Vertical Wheel/Rail Force - Lead Axle Right
LRF3	Lateral Wheel/Rail Force - Lead Axle Right
VRF4	Vertical Wheel/Rail Force - Lead Axle Left
LRF4	Lateral Wheel/Rail Force - Lead Axle Left
VRF5	Vertical Wheel/Rail Force - Trail Axle Right
LRF5	Lateral Wheel/Rail Force - Trail Axle Right
VRF6	Vertical Wheel/Rail Force - Trail Axle Left
LRF6	Lateral Wheel/Rail Force - Trail Axle Left
DZ03	Vertical Displacement - Right Car Body to Truck Bolster
DZ04	Vertical Displacement - Left Side Spring Group
DZ14	Vertical Displacement - Left Car Body to Truck Bolster
DZ15	Vertical Displacement - Right Side Spring Group
DY01	Lateral Actuator Displacment
DY02	Lateral Displacement - Right Side Frame to Truck Bolster
DY03	Lateral Displacement - Left Side Frame to Truck Bolster
DY04	Lateral Displacement - Car Body to Truck Bolster

3.2.3 Test Descriptions (Vertical, Roll, and Lateral Inputs)

3.2.3.1 Vertical Quasi-static Suspension Characterization

The vertical quasi-static characterization tests were conducted by cycling both vertical actuators in-phase at frequencies of 0.1 Hz and 0.25 Hz. The actuators were extended and retracted to the full extent of the spring travel and to various levels below the maximum spring travel. It was determined, during the tests, that approximately 4 inches of actuator displacement was sufficient to fully compress the springs. Figure 3.9 is a force versus displacement hypothesis plot. The method used to find stiffness and damping is also displayed.



STIFFNESS	DAMPING
K1 = (F1 − F3) / (P2 − P1)	D1 = F1 − F2
K2 = (F2 − F4) / (P2 − P1)	D2 = F3 − F4

Figure 3.9 Stiffness and Damping Obtained from Hysteresis Plot

The straight line portions of the curve in Figure 3.9 represent either the compression or extension of the suspension system (springs). The near vertical portion at each end of the cycle represent the full extension or compression of the spring. The stiffness increases greatly due to steel on steel contact when components run up against the stops. The difference in force at any given displacement on this plot represents the frictional component of the total force. The slope represents the stiffness while the difference between the slopes represents damping.

3.2.3.2 Roll Quasi-static Suspension Characterization

The roll quasi-static characterization tests were very similar to the vertical characterization tests, with exceptions being that the vertical actuators were operated 180 degrees out-of-phase and actuator displacements were tested at ± 2 inches.

3.2.3.3 Lateral Quasi-static Suspension Characterization

The lateral quasi-static characterization tests required reconfiguration of the MSU to a single lateral actuator arrangement. The input was cycled at 0.1 Hz and 0.25 Hz in the range from ± 10 kip to ± $^1/_5$ times the vertical static load of the car (± 20 kips), which is the AAR Chapter XI criterion.

3.2.4 Test Prerequisites / Test Sequence

Prior to the Fuel Car's arrival at TTC, the car had derailed twice in Chicago. Maintenance personnel in Chicago greased the ride control assembly to, supposedly, increase the cars stability for interchange to TTC.

Before a truck was tested, the ride control assembly was inspected and degreased, the pre-compression on the constant contact side bearings was checked, the center plates and wear liners were inspected and photographed, and the D7 springs from the center outside spring pockets were removed to provide an 8 outer and 7 inner spring configuration. The trucks also underwent a warm-up period to wear-in the friction snubbers. In this wear-in period each truck was cycled in the vertical setup for one hour. The wear-in was done before the vertical quasi-static characterization tests.

The vertical, roll, and lateral quasi-static characterization tests were performed on Truck 1. Truck 2 was then placed in the MSU and was tested first in the lateral and then in the vertical and roll configuration.

3.3 MODAL RESPONSE TEST

The Modal Response Test was performed on the Fuel Car to determine the first natural frequencies for the following modes:

- Pitch and Bounce
- Upper and Lower Center Roll
- Yaw and Sway
- Vertical and Lateral Bending
- Longitudinal Torsion (Twist)
- Fuel Slosh Frequency

3.3.1 Test Apparatus

The modal response tests were performed on the Fuel Car in loaded, unloaded, and half-loaded configurations utilizing the MSU in the RDL. The test apparatus used for the modal response test was almost identical to that used for the quasi-static truck characterization test. The only difference was that the MSU was equipped with 55 kip hydraulic actuators instead of 140 kip hydraulic actuators.

The actuators were connected between reaction masses and the car body via attachment fixtures welded to the car.

3.3.2 Fuel Car Instrumentation Setup

Rigid body and flexible body modes were assessed with the array of accelerometers shown in Figure 3.10. String pots were installed in the locations shown in Figure 3.11. From those measurements, rigid body bounce, pitch, upper and lower center roll, and yaw and sway were determined.

Slosh gages were installed inside the tank (see Figure 3.12). The gages were Gems 36000 Series tank level indicating transmitters. They allowed calculation of the resonant frequency of the fuel during the half-loaded MSU Testing.

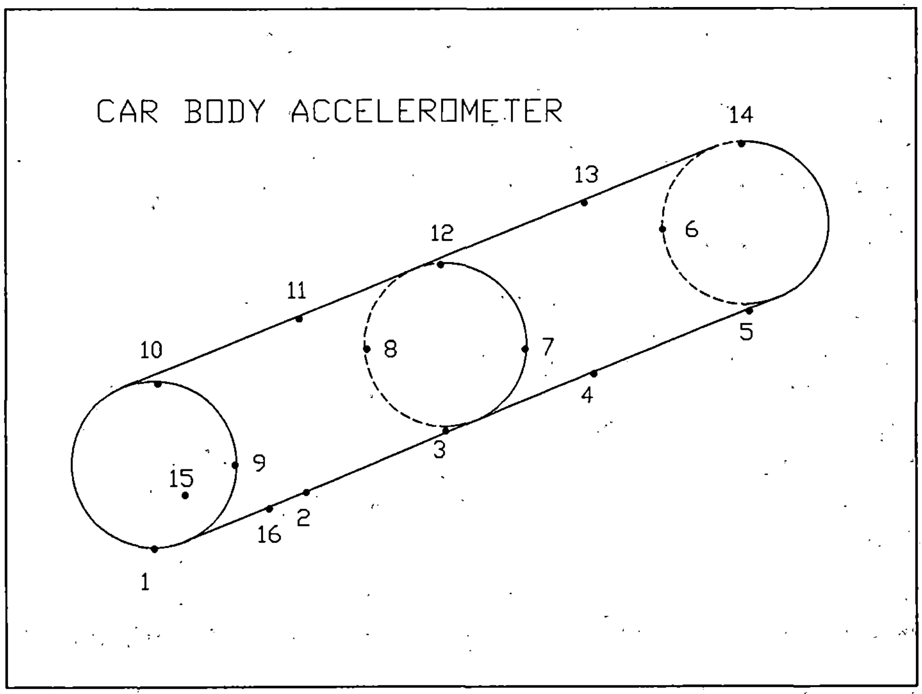


Figure 3.10 Car Body Accelerometer Locations

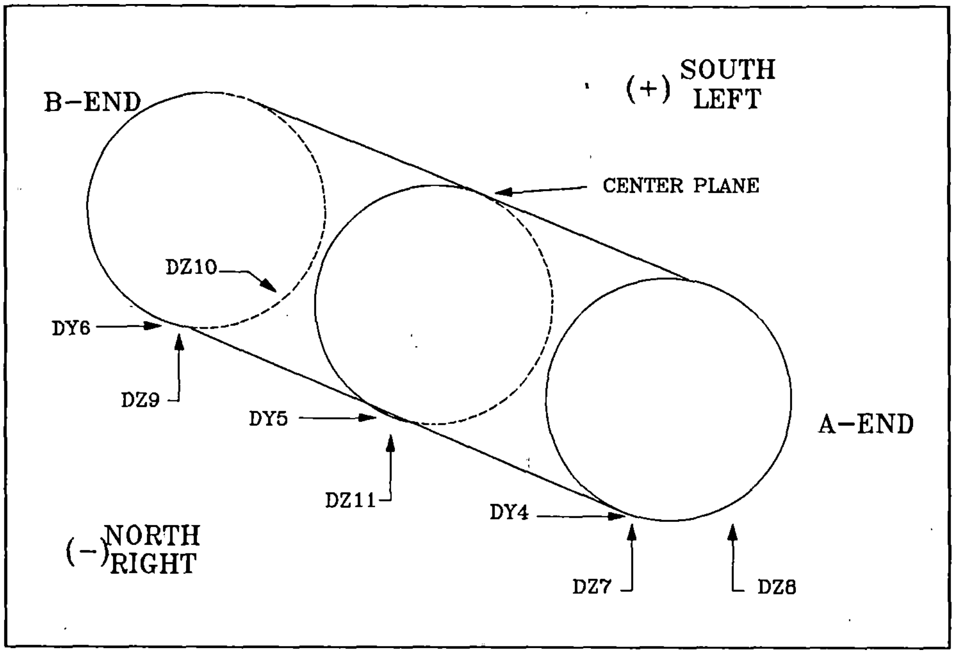


Figure 3.11 Car Body To Ground Displacements

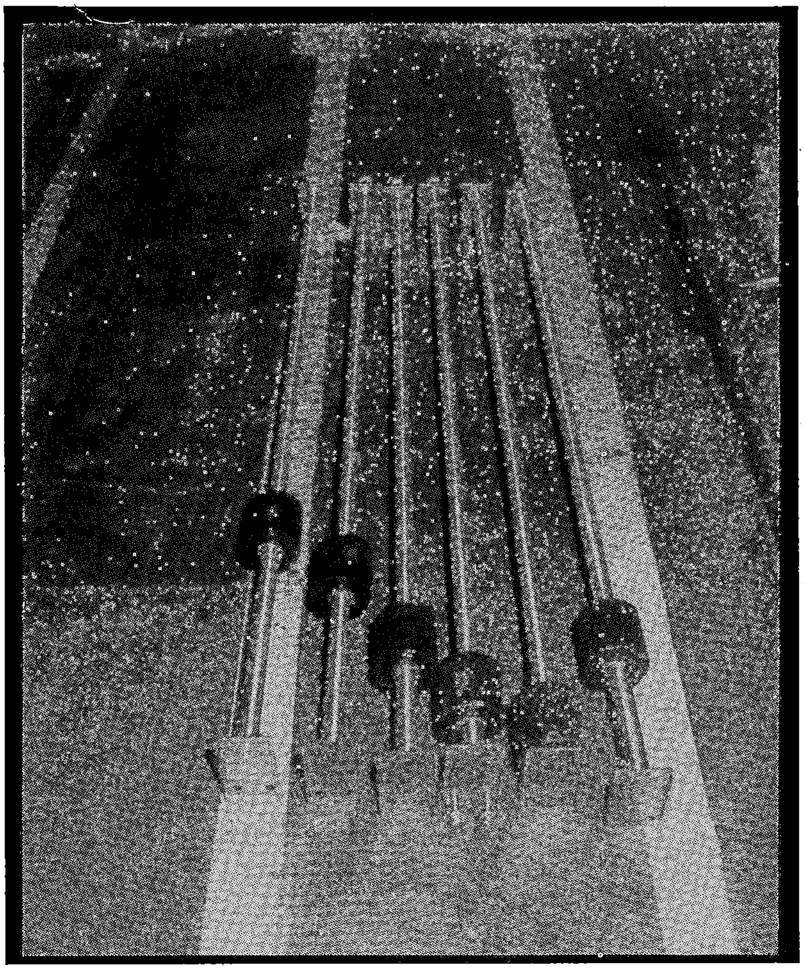


Figure 3.12 Slosh Gages

Vertical and lateral loads were measured at each wheel on the A-end of the car via instrumented rail sections. Actuator force and displacement was also measured. Accelerometers and string pots were installed on the A-end trucks. A complete measurement list is presented in the "Modal Test Procedure" in Appendix E of the final report.

3.3.3 Rigid Body Vertical Test

The MSU was set up in the vertical test configuration as shown in Figure 3.10. The actuators were cycled in-phase with 5, 10, and 15 kip sinusoidal inputs. The frequency increased from .2 Hz to 5.0 Hz in .1 Hz steps at 10 cycles per step.

3.3.4 Rigid Body Roll Test

The MSU setup remained in the vertical configuration; however, the actuators were cycled 180 degrees out-of-phase with each other.

3.3.5 Flexible Body Vertical Test

The MSU remained in the vertical test configuration. The actuators were cycled in-phase, but they were in displacement control rather than force control. Displacement control was used for a constant acceleration (g) input. The sweeps were from 3 Hz to 30 Hz at constant acceleration inputs of .1, .2, and .3 g. Additional sweeps, depending on the configuration of the Fuel Car, were also performed if deemed necessary.

3.3.6 Flexible Body Twist Test

The Flexible Body Twist Test was also performed in the vertical configuration with the actuators 180 degrees out-of-phase with respect to each other.

3.3.7 Rigid Body Lateral Test

The MSU was configured to the lateral test setup as shown in Figure 3.13.

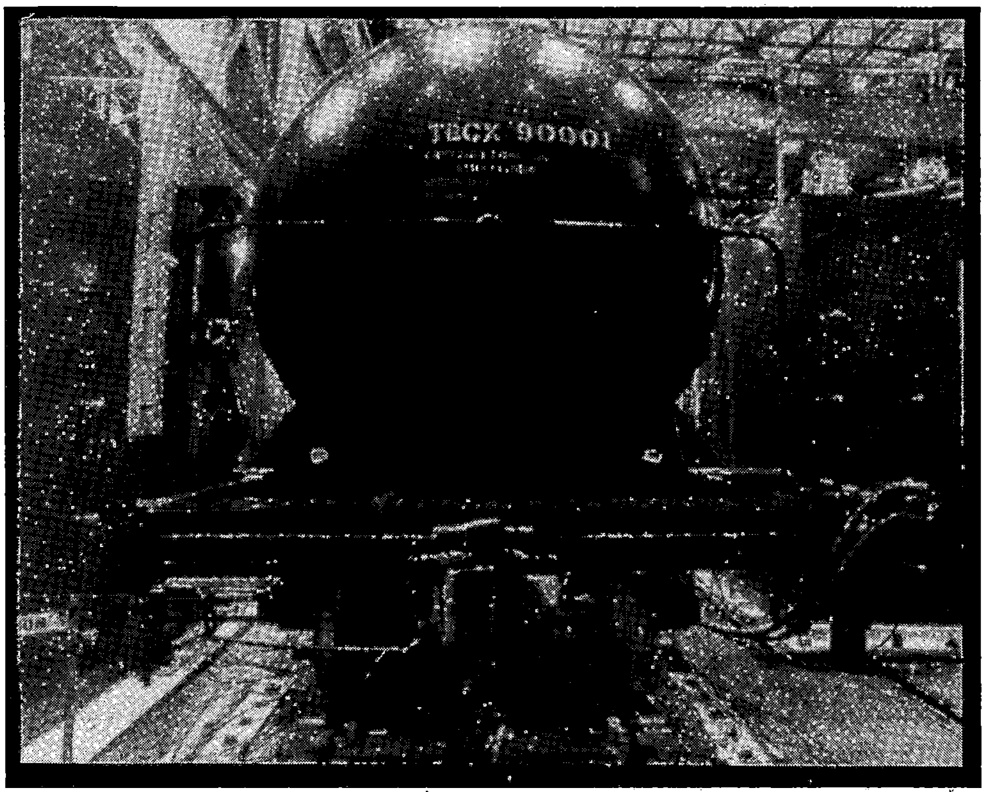


Figure 3.13 MSU Lateral Configuration

The Rigid Body Lateral Test was performed with basically the same frequency sweeps as the Rigid Body Vertical Test but with only one actuator in the lateral direction.

3.3.8 Flexible Body Lateral Test

The Flexible Body Lateral Test was performed with the same type of inputs as the Flexible Body Vertical Test. This was also done with just one actuator in the lateral direction.

4.0 RESULTS

4.1 AIR BEARING TEST RESULTS

4.1.1 100-Ton Truck Yaw Moment

Force versus displacement was plotted for each actuator after each test. Figure 4.1 shows a typical force versus displacement plot.

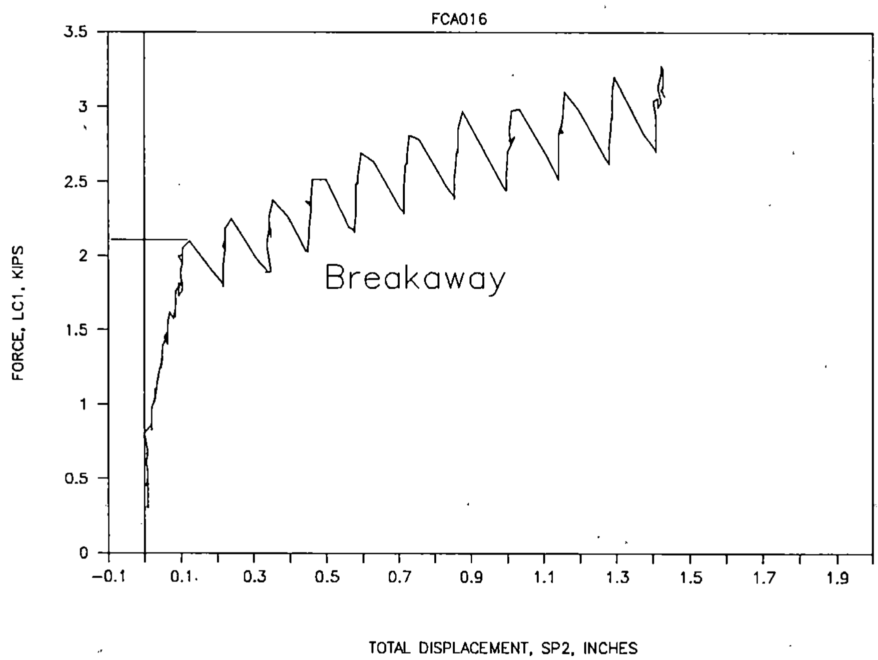


Figure 4.1 First Actuator Force versus Displacement, Yaw Moment Test

The force increased with relatively small displacement until the static friction was overcome. At that point, the truck rotated with very little increase in force. This was called the breakaway point. It should be noted that the Fuel Car had constant contact side bearings.

Since two actuators were used, the actual breakaway torque or yaw moment was calculated by summing the two breakaway torques. Force versus displacement for the second actuator is shown in Figure 4.2 and is very similar to Figure 4.1.

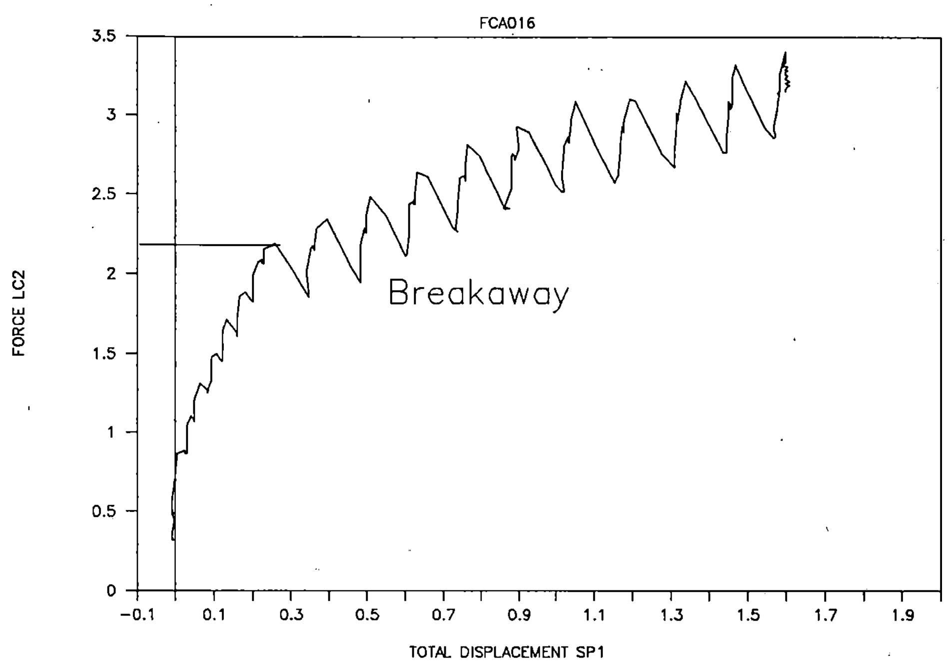


Figure 4.2 Second Actuator Force versus Displacement, Yaw Moment Test

In this case, the breakaway force on each actuator was slightly more than 2,000 pounds. The plots are not smooth because a hand pump was used to drive the actuators. After the breakaway point, friction still exists; this can be seen by the smaller but positive slope of the characteristic line.

The perpendicular distance from each actuator to the truck center pin was approximately 36 inches. The yaw moment or breakaway force was then calculated by multiplying the sum of the two forces by the distance of 36 inches. The yaw moment for run FCA016, shown in the previous figures, was (2,150 + 2,050) X 36 = 144,000 in-lbs. The yaw moment is generally largest during the first test. The overall yaw moment average of both trucks was 108,300 in-lbs.

The clockwise breakaway torque of Truck 2 was affected by the fact that the brakes were inadvertently left on; hence, that data was not used in the averages. Tables 4.1 and 4.2 show a summary of the Yaw Moment Test results.

Table 4.1 Yaw Moment Test Results For Truck 1

DIRECTION	RUN NO.	FORCE 1 (kips)	FORCE 2 (kips)	TOTAL (kips)	MOMENT (in-lbs)	AVERAGE (in-lbs)	STD DEV
CCW	016	2.0	2.0	4.0	144,000 *	--	--
CCW	017	1.5	1.6	3.1	111,600	--	--
CCW	018	1.5	1.5	3.0	108,000	109,800	3,600
CW	019	1.6	1.65	3.25	117,000	--	--
CW	020	1.4	1.4	2.8	100,800	--	--
CW	021	1.425	1.425	2.85	102,600	106,800	8,879
AVERAGE YAW MOMENT : 108,300 in-lbs							

* NOT USED IN AVERAGE

Table 4.2 Yaw Moment Test Results For Truck 2

DIRECTION	RUN NO.	FORCE 1 (kips)	FORCE 2 (kips)	TOTAL (kips)	MOMENT (in-lbs)	AVERAGE (in-lbs)	STD DEV
CCW	025	1.4	1.5	2.9	104,400	--	--
CCW	026	1.6	1.6	3.2	115,200	--	--
CCW	027	1.4	1.5	2.9	104,400	108,000	6,235
CW	022	2.5	2.5	5.0	*180,000	--	--
CW	023	2.7	2.8	5.5	*198,000	--	--
CW	024	2.7	2.8	5.5	*198,000	*192,000	10,392
AVERAGE YAW MOMENT : 108,000 in-lbs							

* Values affected by hand brake were not used for averages.

4.1.2 Axle Alignment Test

The radial misalignment and the lateral misalignments of the individual axles in a truck were the subject of this investigation. Six measurements, described in Table 4.3, were made during each test and are shown in Figure 4.3.

Table 4.3 Axle Alignment Measurements

MEASUREMENT NAME	DESCRIPTION
AS1	Right Side Axle Spacing Measured Directly From Caliper
AS2	Left Side Axle Spacing Measured Directly From Caliper
LA1	Leading Axle Lateral Alignment - Leading Half of Wheel
LA2	Leading Axle Lateral Alignment - Trailing Half of Wheel
TA1	Trailing Axle Lateral Alignment - Leading Half of Wheel
TA2	Trailing Axle Lateral Alignment - Trailing Half of Wheel

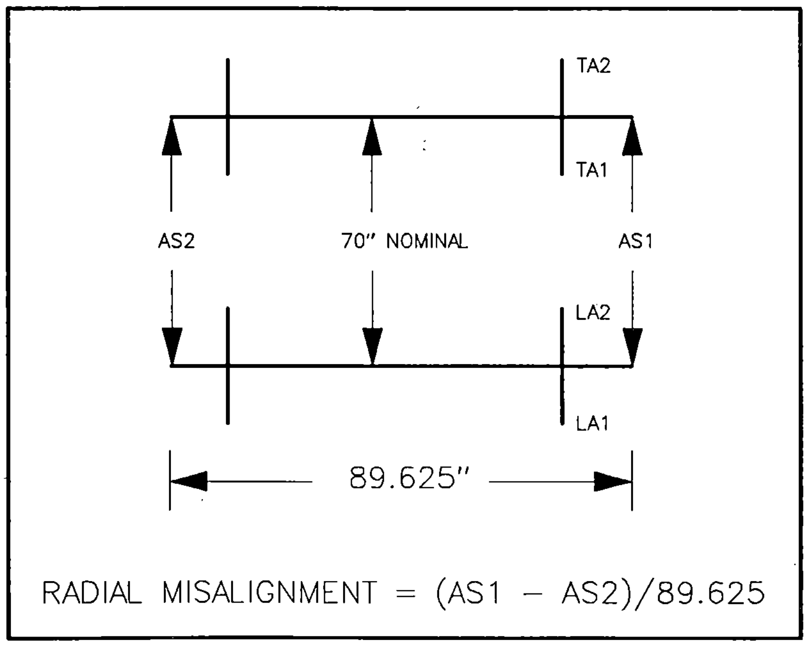


Figure 4.3 Axle Alignment Measurements

Axle radial misalignment was calculated with the axle spacing values AS1 and AS2 as shown in the equation in Figure 4.3. Axle lateral misalignment was calculated with the leading axle and trailing axle measurements LA1, LA2, TA1, and TA2, respectively. Those numbers were read from rulers with a Brunson Optical Transit. The transit was first rotated until LA1 was equal to TA2. It was then translated so that LA1 and TA2 were on a round number. LA2 and TA1 were measured and then delta LA's and TA's were calculated. The transit was parallel to the side frame when LA1 and TA2 were equal. The lateral misalignment could be implied from the deltas. Table 4.4 is a tabulation of alignment measurements from both trucks.

Table 4.4 Axle Alignment Data

TRUCK NO.	RUN NO.	AS1 (IN.)	AS2 (IN.)	RADIAL MIS. (MRAD)	DELTA LA (IN.)	DELTA TA (IN.)
1	1	69.968	70.000	0.3	+0.100	+0.107
1	2	70.036	70.038	0.0	+0.041	+0.013
1	3	70.034	70.101	0.7	+0.044	+0.026
2	29	70.056	70.026	0.3	-0.100	-0.081
2	30	70.063	69.988	0.8	-0.106	-0.082
2	31	70.077	70.017	0.6	-0.100	-0.094

The variations were consistent and typical for a conventional three-piece truck design, and should have little affect on the on-track performance of the Fuel Car. No further analysis was performed.

4.1.3 Axle Box Longitudinal Stiffness

Axle box longitudinal stiffness is related to the ability of the axles to move longitudinally independently of each other. In standard three-piece trucks, the longitudinal stiffness is very high once the bearing adapters run up against the side frame stops. In trucks with primary suspension components, there is some stiffness associated with the stretching of the suspension before the bearing adapters run up against the stops. The Fuel Car has no primary suspension. Figure 4.4 is a side view representation of the components to be investigated during the Longitudinal Stiffness Test.

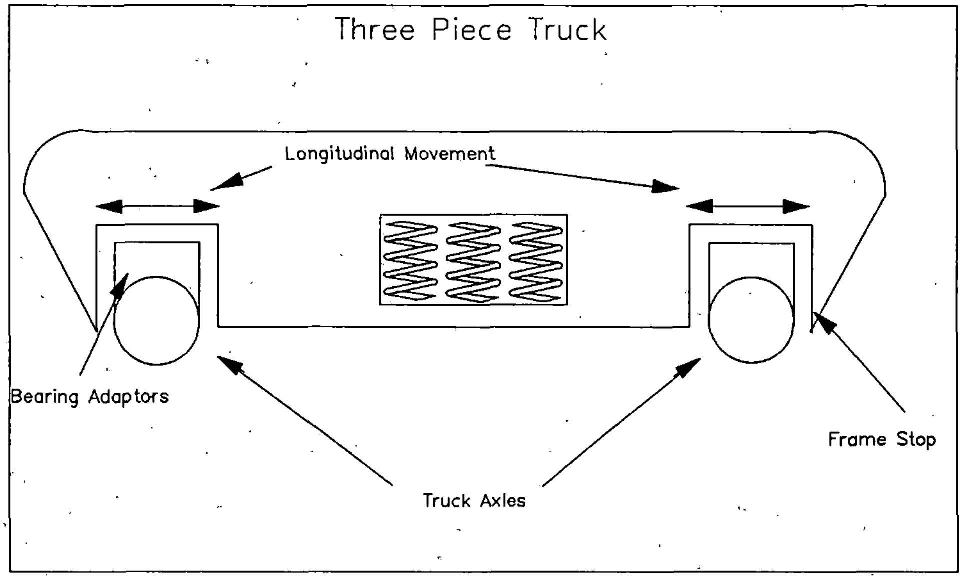


Figure 4.4 Longitudinal Stiffness Theory

NUCARS requires axle box stiffness rather than truck side stiffness. It was assumed that the truck side was symmetric. Force versus displacement plots were produced for each truck side on all test runs. Typical plots, run FCA015 in this case, are shown in Figures 4.5 and 4.6. The stiffness slope was calculated with linear regression.

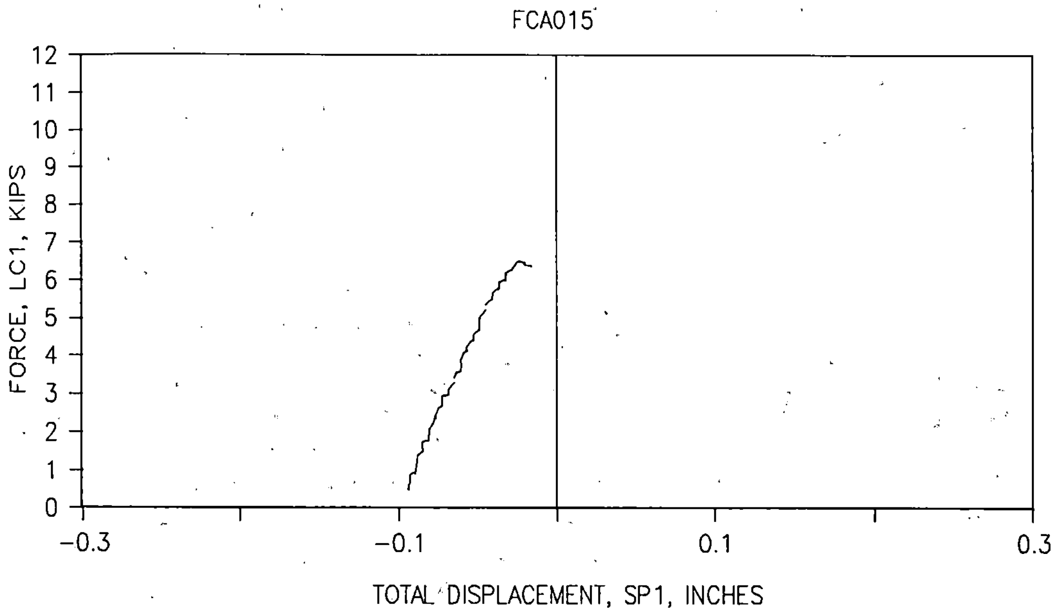


Figure 4.5 Right Truck Side Stiffness Plot

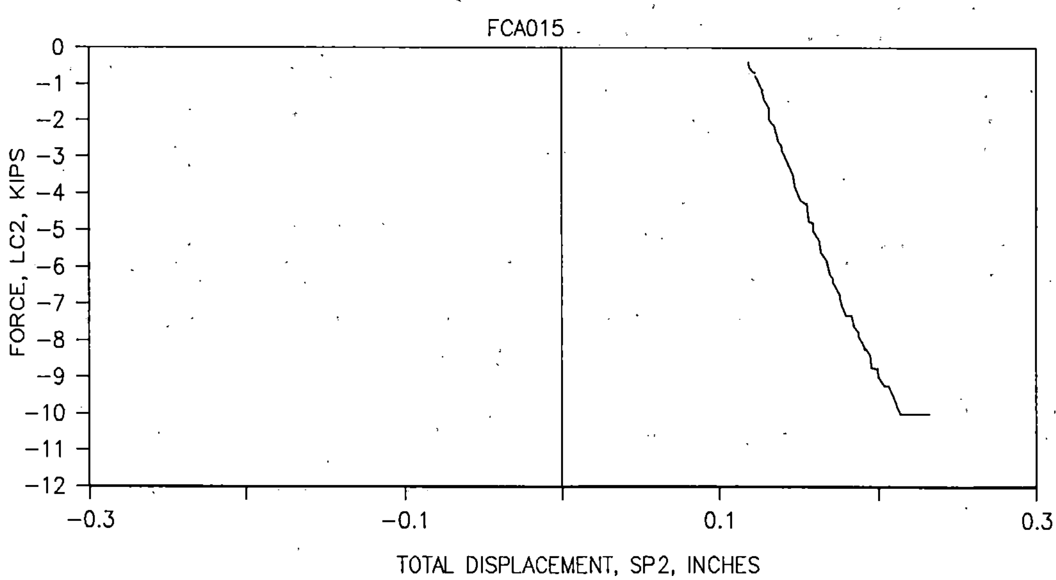


Figure 4.6 Left Truck Side Stiffness Plot

Linear regression was performed on each graph. Table 4.4 is a tabulation of the truck side stiffness measurements. The overall average truck side longitudinal stiffness was 73.33 kips/inch. This stiffness is due to sliding friction between the bearing adapter and side frame.

Table 4.4 Truck Side Longitudinal Stiffness Measurements

RUN NO.	TRUCK NO.	DIRECTION	LC1 SLOPE (KIPS/INCH)	LC2 SLOPE (KIPS/INCH)
005	1	Pulling	71.6	65.5
006	1	Pulling	65.2	76.9
007	1	Pulling	59.4	61.7
008	1	Pushing	53.3	51.1
009	1	Pushing	83.7	95.4
010	1	Pushing	78.1	89.5
		AVERAGE :	68.6	73.35
		STANDARD DEVIATION :	11.5	17.04
032	2	Pulling	60.51	60.83
033	2	Pulling	84.72	*108.46
034	2	Pushing	76.30	94.90
035	2	Pushing	*45.95	77.74
036	2	Pushing	78.93	97.73
037	2	Pulling	76.20	96.81
		AVERAGE :	75.33	71.33
		STANDARD DEVIATION :	8.97	16.08
OVERALL AVERAGE : 73.33 kips/inch				
OVERALL STANDARD DEVIATION : 8.9 kips/inch				

* Not used in calculations

The truck side averages were then doubled to give axle box stiffnesses. A final stiffness of 10^3 kips/inch was estimated to represent the bearing adapter up against the stops. Contact was never made in the test. The axle needed to displace 1/8-inch before that would happen (see Figure 4.7).

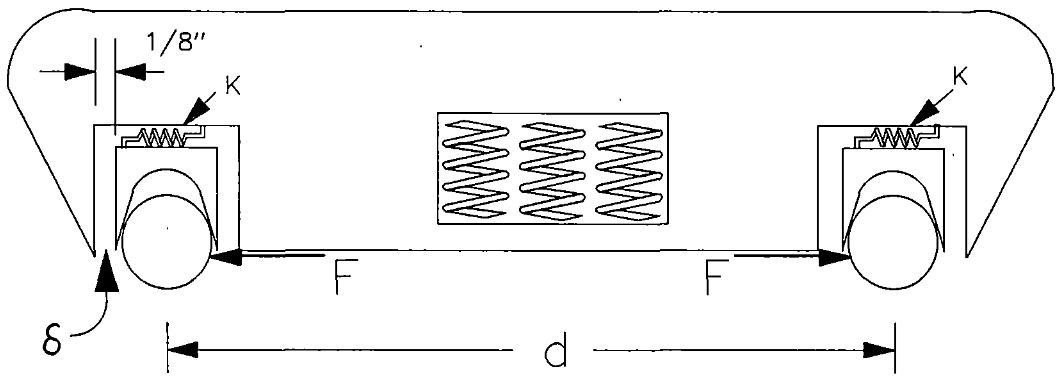


Figure 4.7 Axle Box Stiffness Test Measurements

It was necessary to provide a complete force versus displacement profile in the form of a look-up table for NUCARS. The first slope was extrapolated to a deflection of 1/8 inch, point 2, and the second slope was assumed to be 10^3 kips/inch as shown in Table 4.6 and Figure 4.8.

The equations used to extrapolate the stiffness data are shown below.

$$F_z = K_{(1-2)} * \delta_2$$

$$\delta_3 = F_3 - F_2 / K_{(2-3)} + \delta_2$$

Table 4.6 NUCARS Look-up Table For Axle Box Stiffness

	1	2	3
F	0	18.4	50.0
δ	0	0.125	0.156

F = Force In KIPS
δ = Displacement In Inches

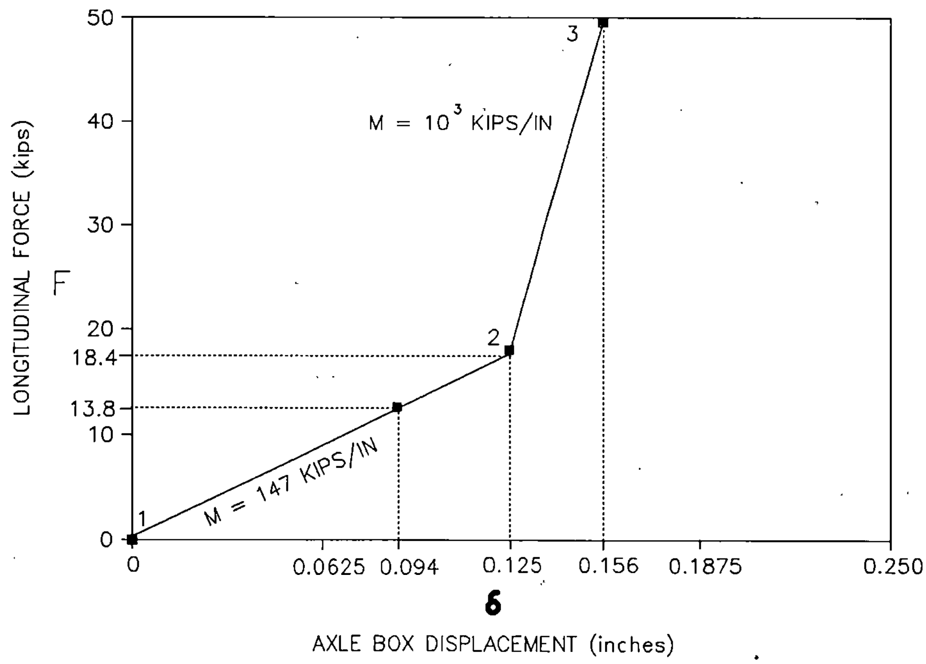


Figure 4.8 Axle Box Stiffness Graph

4.1.4 Axle Yaw And Inter-axle Bending Stiffnesses

In curving, the axles have a tendency to yaw with respect to each other as shown in Figure 4.9.

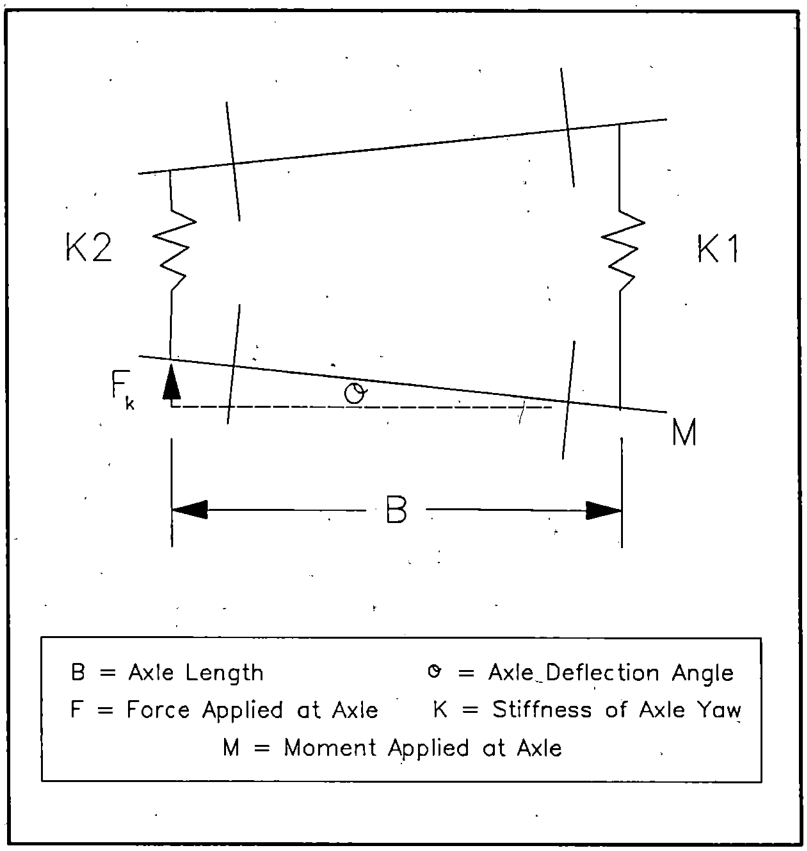


Figure 4.9 Axle Yaw Stiffness Theory

The first step in finding axle yaw stiffness was to calculate the stiffnesses K1 and K2 in the same manner as longitudinal stiffness.

Table 4.7 shows a summation of stiffness data for each test.

Table 4.7 Axle Yaw Stiffness Summary Sheet

RUN NO.	TRUCK NO.	DIRECTION	LC1 SLOPE 1	LC1 SLOPE2
011	1	LC1PUSH/LC2PULL	80.9	48.2
012	1	LC1PUSH/LC2PULL	85.8	92.6
013	1	LC1PUSH/LC2PULL	*41.2	71.3
014	1	LC1PULL/LC2PUSH	98.7	106.6
015	1	LC1PULL/LC2PUSH	90.3	103.0
		AVERAGE :	88.9	84.34
		STANDARD DEVIATION :	7.56	15.86
K1 = AVERAGE PUSH STIFFNESS LC1 and LC2 : 83.50 kips/inch K2 = AVERAGE PULL STIFFNESS LC1 and LC2 : 80.22 kips/inch				
038	2	LC1PULL/LC2PUSH	76.1	83.6
039	2	LC1PULL/LC2PUSH	77.5	104.4
040	2	LC1PULL/LC2PUSH	71.5	99.3
041	2	LC1PUSH/LC2PULL	*41.2	88.1
042	2	LC1PUSH/LC2PULL	81.7	87.5
043	2	LC1PUSH/LC2PULL	83.0	84.4
		AVERAGE :	77.96	91.21
		STANDARD DEVIATION :	4.6	8.58
K1 = AVERAGE PUSH STIFFNESS LC1 and LC2 : 80.87 kips/inch K2 = AVERAGE PULL STIFFNESS LC1 and LC2 : 82.20 kips/inch				

* Not included in calculations

The calculation for average axle yaw stiffness is shown below. Refer to Figure 4.9 for the definitions of the variables.

$$F_k = 2(K_1 + K_2)B\theta$$

$$M = F_k B = (K_1 + K_2)B^2\theta$$

$$K_{AY} = AXLE \quad YAW\,STIFFNESS = \frac{M}{\theta} = (K_1 + K_2)B^2$$

$$K^1_{AY} = (83.50 + 80.22)(79)^2 = 1{,}021{,}776\,INCH - kips/RAD = 1021\,INCH - kips/MRAD$$

$$K^2_{AY} = (80.87 + 82.20)(79)^2 = 1{,}017{,}719\,INCH - kips/RAD = 1017\,INCH - kips/MRAD$$

The final calculation yielded axle yaw stiffnesses of 1021 and 1017 in-kips/mrad for trucks one and two, respectively. The average of 1019 in-kips/mrad was to be compared to NUCARS calculations of yaw stiffness from the longitudinal stiffness inputs. The axle box stiffness of 147 kips/inch obtained in the longitudinal stiffness test would yield an axle yaw stiffness of 918 inch-kips/mrad, 10 percent lower than the axle yaw test results.

4.2 MSU TRUCK CHARACTERIZATION TEST RESULTS

The test data was reduced using AAR developed software on an HP 360 computer system. Plots were made to display stiffness and damping in the particular suspension component. The x-axis corresponds to the displacement measurement; the y-axis corresponds to the rail-force measurement (the rail forces, not the load cells, were used for these plots). The upper and lower slopes of the curves correspond to the stiffness in kips/inch for the vertical and lateral runs, and inch-kips/radian for the roll runs. The damping corresponds to the vertical gap (hysteresis) between the upper and lower sloped lines. Figure 4.10 is a typical hysteresis plot. In this case the sum of the right vertical rail forces is plotted versus the sum of the right vertical spring displacement. Table 4.8 lists the test runs that were analyzed.

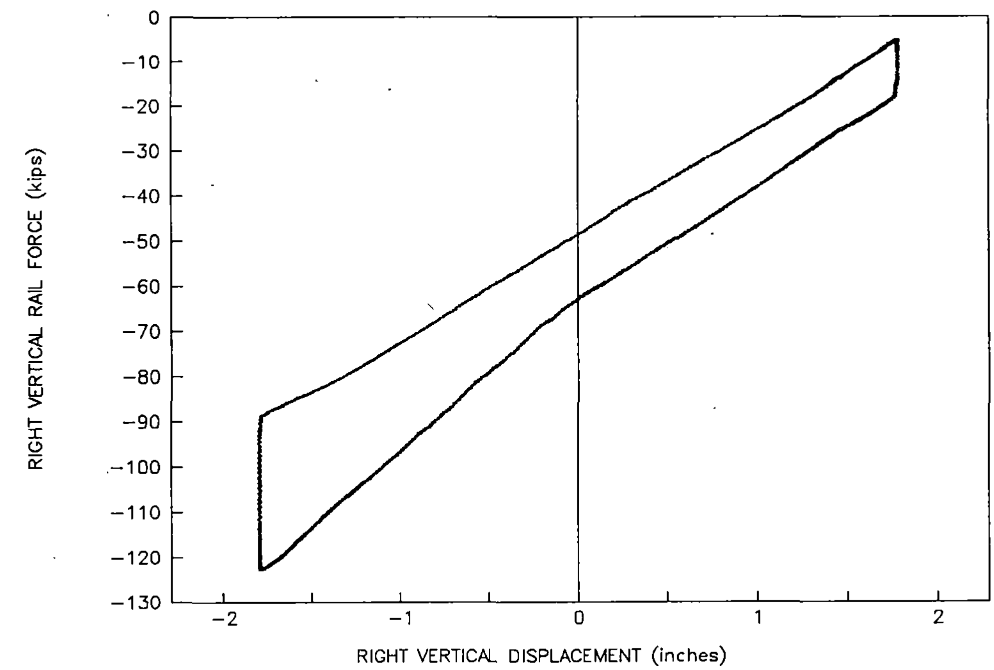


Figure 4.10 Force versus Displacement Plot Showing Vertical Stiffness and Damping (Hysteresis) for the Right Side Truck Secondary Suspension

Table 4.8 Quasi-static Test Runs

RUN NAME	DESCRIPTION	FREQUENCY	TRUCK NO.	TEST
FC01_RN003	Stroke Control± *C.P"	0.1 Hz	1	Vertical
FC01_RN006	Stroke Control± C.P"	0.25 Hz	1	Vertical
FC01_RN010	Stroke Control± 2.0"	0.1 Hz	1	Roll
FC01_RN014	Stroke Control± 2.0"	0.25 Hz	1	Roll
FC01_RN017	Force Control ± *SL kip north	0.1 Hz	1	Lateral
FC01_RN020	Force Control ± SL kip north	0.25 Hz	1	Lateral
FC01_RN023	Force Control ± SL kip south	0.1 Hz	1	Lateral
FC01_RN026	Force Control ± SL kip south	0.25 Hz	1	Lateral
FC02_RN003	Stroke Control± C.P"	0.1 Hz	2	Vertical
FC02_RN006	Stroke Control± C.P"	0.25 Hz	2	Vertical
FC02_RN010	Stroke Control± 2.0"	0.1 Hz	2	Roll
FC02_RN014	Stroke Control± 2.0"	0.25 Hz	2	Roll
FC02_RN017	Force Control ± SL kip north	0.1 Hz	2	Lateral
FC02_RN020	Force Control ± SL kip north	0.25 Hz	2	Lateral
FC02_RN023	Force Control ± SL kip south	0.1 Hz	2	Lateral
FC02_RN026	Force Control ± SL kip south	0.25 Hz	2	Lateral

* C.P = Full Compressed Spring Distance
* SL = $^1/_5$ Vertical Static Load

The secondary suspension rates for the chosen vertical, roll, and lateral tests were determined. Damping was calculated for the vertical and lateral runs. The stiffness and damping values were averaged for each truck in the vertical, roll, and lateral configurations. Tables 4.9(a) and 4.9(b) give the vertical secondary suspension average stiffness and damping for the vertical test runs at 0.1 and 0.25 Hz respectively. When observing the vertical and roll data a consistently higher stiffness (approx. 7%) and damping (approx. 30%) for the right side over the left side on both trucks can be seen. This caused an investigation into the test setup. Truck 2 was rotated and tested. It was found that the stiffness and damping also reversed. This clearly showed the vertical characteristics of both trucks were indeed asymmetric. No further investigation was considered necessary at that time.

Table 4.9(a) Secondary Suspension Average Vertical Stiffness and Damping for Test Runs @ 0.1 Hz

TRUCK	LEFT SIDE AVERAGE VERTICAL DATA		RIGHT SIDE AVERAGE VERTICAL DATA	
	STIFFNESS	DAMPING	STIFFNESS	DAMPING
1	24.39 kips/in.	10.78 kips	25.00 kips/in.	16.00 kips
2	24.37 kips/in.	11.05 kips	27.40 kips/in.	11.60 kips

Table 4.9(b) Secondary Suspension Average Vertical Stiffness and Damping for Test Runs @ 0.25 Hz

TRUCK	LEFT SIDE AVERAGE VERTICAL DATA		RIGHT SIDE AVERAGE VERTICAL DATA	
	STIFFNESS	DAMPING	STIFFNESS	DAMPING
1	24.23 kips/in.	10.65 kips	24.72 kips/in.	15.84 kips
2	24.41 kips/in.	09.95 kips	26.27 kips/in.	15.34 kips

Table 4.10 lists the secondary suspension average roll stiffness for each truck in the roll case.

Table 4.10 Secondary Suspension Average Roll Stiffness

TRUCK NO.	AVERAGE TRUCK ROLL STIFFNESS
1	67,502 inch-kips/radian
2	65,275 inch-kips/radian

Tables 4.11(a) and 4.11(b) list the lateral secondary suspension average stiffness and damping for both trucks in the lateral case at 0.1 and 0.25 Hz, respectively. As the tables show, Truck 1 had approximately two times the lateral stiffness of Truck 2.

Table 4.11(a) Secondary Suspension Average Stiffness and Damping for Test Runs @ 0.1 Hz.

TRUCK	LEFT SIDE AVERAGE LATERAL DATA		RIGHT SIDE AVERAGE LATERAL DATA	
	STIFFNESS	DAMPING	STIFFNESS	DAMPING
1	45.57 kips/in.	36.85 kips	46.67 kips/in.	38.14 kips
2	26.40 kips/in.	27.20 kips	27.30 kips/in.	26.20 kips

Table 4.11(b) Secondary Suspension Average Lateral Stiffness and Damping for Test Runs @ 0.25 Hz.

TRUCK	LEFT SIDE AVERAGE LATERAL DATA		RIGHT SIDE AVERAGE LATERAL DATA	
	STIFFNESS	DAMPING	STIFFNESS	DAMPING
1	43.18 kips/in.	38.08 kips	46.51 kips/in.	38.15 kips
2	26.95 kips/in.	28.70 kips	26.10 kips/in.	28.83 kips

Please note that the lateral stiffnesses are taken from the forces seen on all four instrumented rails; therefore, they must be divided by two to give the rates of the individual spring groups.

4.3 MODAL RESPONSE TEST ANALYSIS

Modal analysis was performed with Structural Measurements System's (SMS) software. Transfer functions for each point shown in Figure 4.11 were created with AAR analysis software and imported into the SMS model.

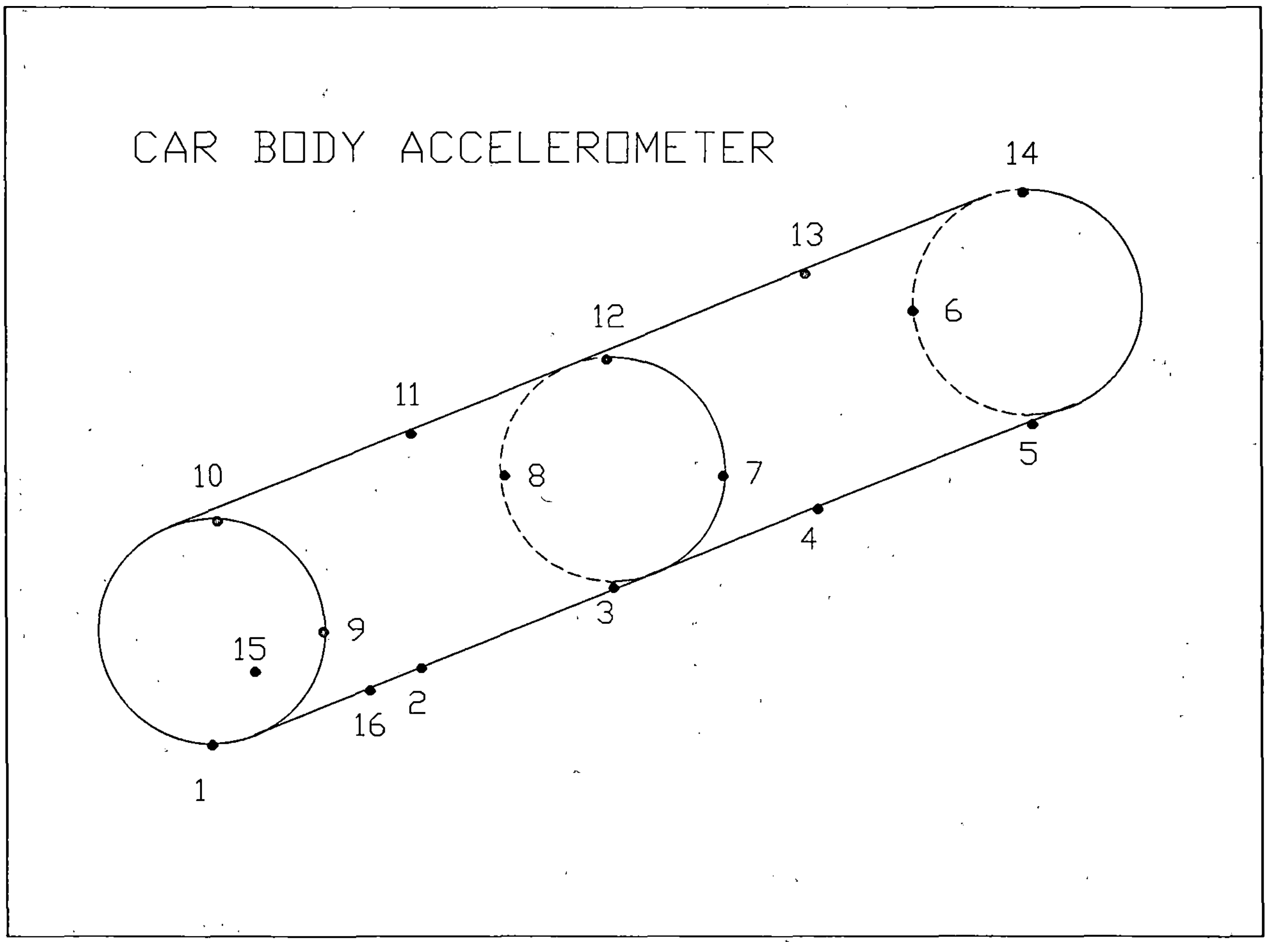


Figure 4.11 Car Body Accelerometer Location

4.3.1 Rigid Body Vertical

Data from runs RN017, RN031, RN043, and RN077 were analyzed to obtain pitch and bounce in the loaded, unloaded, and half-loaded configurations.

Figure 4.12(a) shows the loaded car's transfer function between the actuator input force and a vertical accelerometer at the B-end of the car. From the peaks in the transfer function and simulation by SMS modal software, it was postulated that the loaded car's bounce natural frequency was 2.0 Hz.

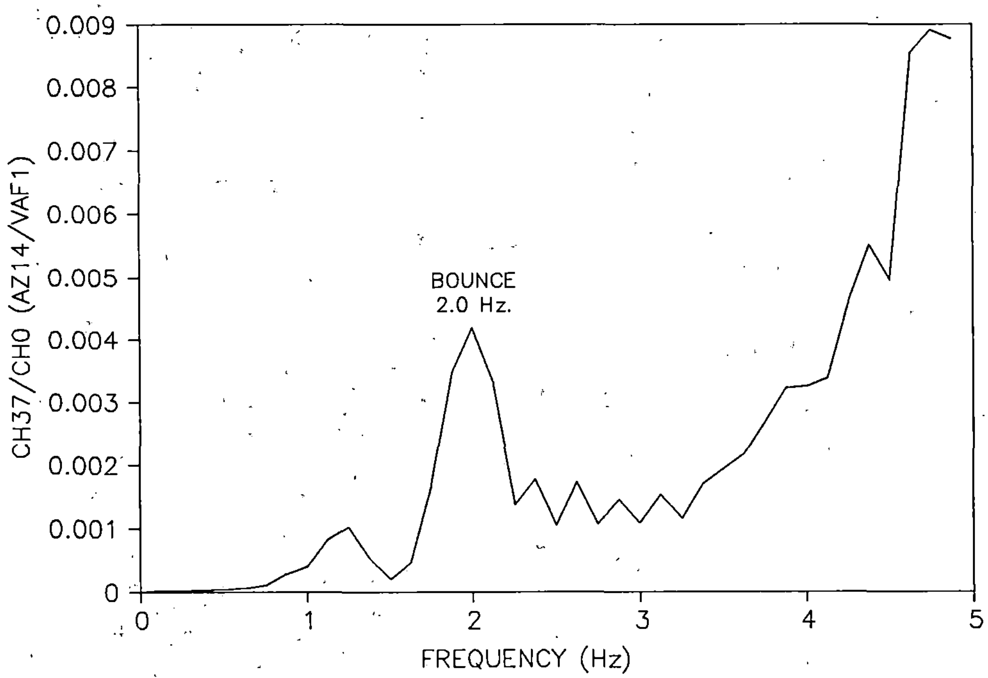


Figure 4.12(a) Loaded Bounce Transfer Function

Figure 4.12(b) shows phase relationship of transducers located at each end of the car. Bounce describes the frequency at which the car has in-phase vertical response along the car. The phase relationship at the 4.75 Hz peak in the transfer function does not correspond to bounce.

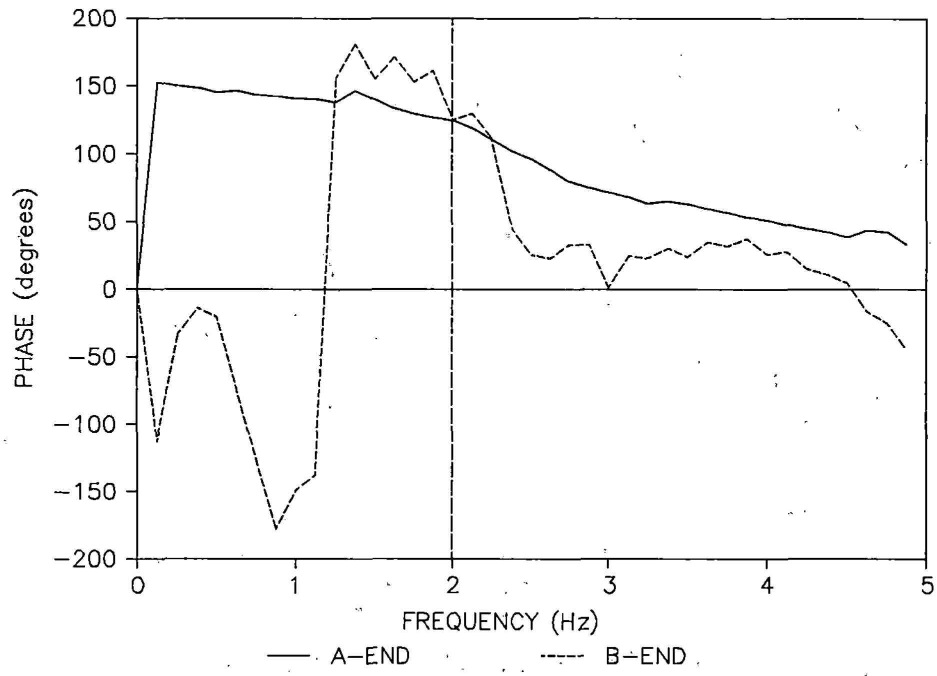


Figure 4.12(b) Loaded Bounce Phase Relationships

Transfer functions and phase relationships were analyzed, in the same manner, for the half-loaded and unloaded configurations. The natural bounce frequencies found for the half-loaded and unloaded cases were 2.875 Hz and 3.875 Hz, respectively.

Pure pitch was not found in any of the configurations; however, approximate pitch frequencies were found.

Figures 4.13(a) shows the transfer function between the actuator input force and a transducer mounted on the bottom B-end of the car. The pitch frequency found from the peak in the transfer function and SMS was 4.5 Hz.

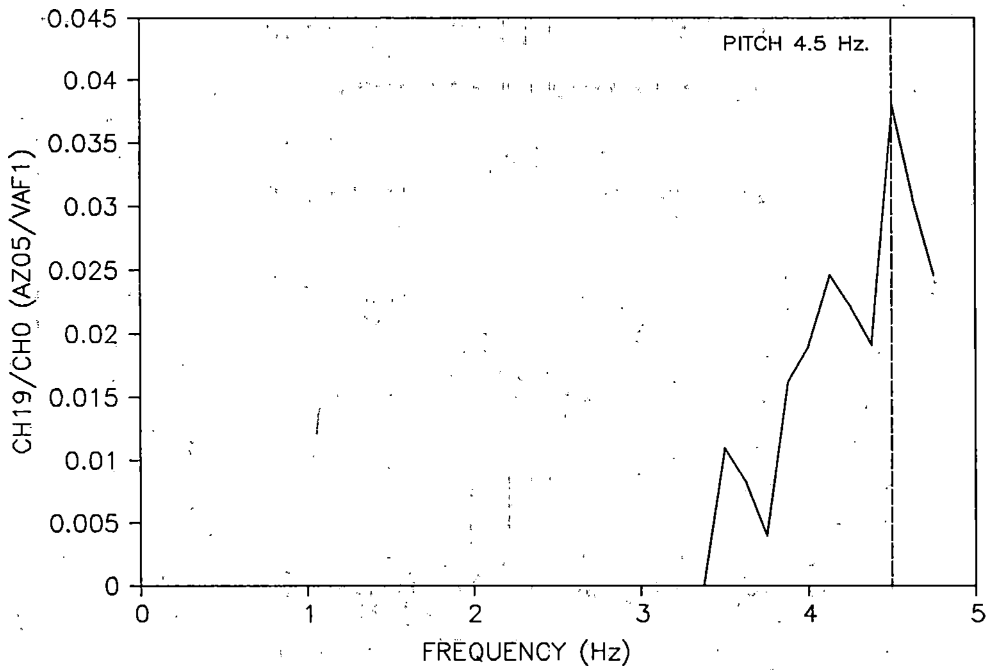


Figure 4.13(a) Pitch Transfer Function

Figure 4.13(b) shows the phase relationship of transducers mounted at each ends of the loaded car. Pitch is when the vertical response of a car body is 180 degrees out-of-phase between the ends of the car. The phase difference found was 215 degrees.

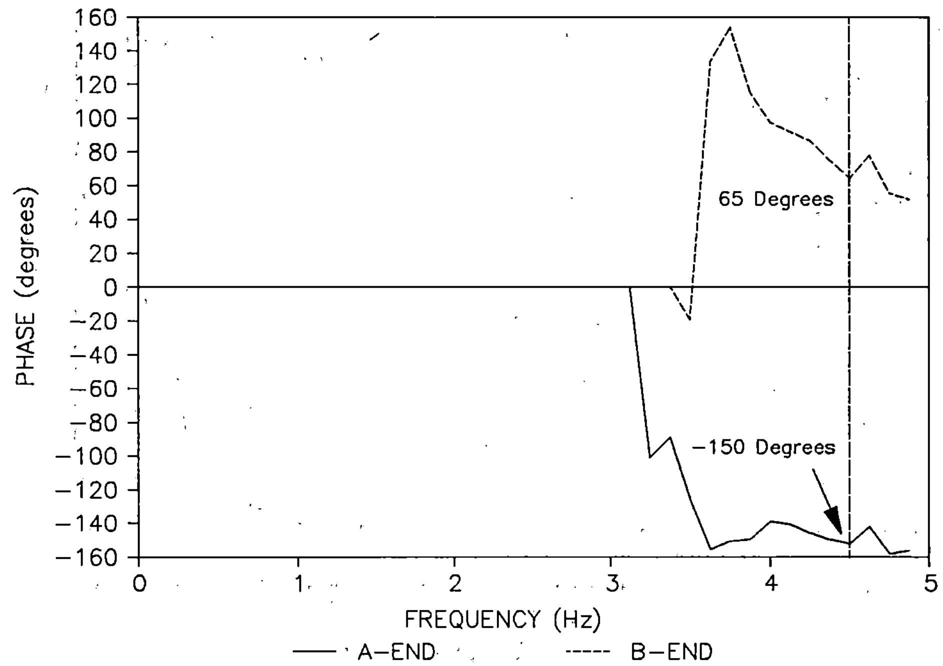


Figure 4.13(b) Pitch Phase Relationships

The matrix below is a summary of the pitch and bounce modes identified. Half-loaded pitch was near 4.6 Hz and unloaded pitch was near 4.75 Hz.

MODE	LOADED	HALF-LOADED	UNLOADED
Bounce	2.0 Hz	2.875 Hz	3.875 Hz
• Pitch	4.5 Hz	4.625 Hz	4.75 Hz

• Approximate pitch frequencies

4.3.2 Rigid Body Lower Center Roll

Data from runs RN024, RN045, and RN080 were analyzed to obtain lower center roll in the loaded, half-loaded, and unloaded configurations.

Figure 4.14(a) shows the loaded car's transfer function between the actuator input force and a transducer near the center of the car at the sides. Lower center roll is begins at 1 Hz as shown by the beginning of the peak in the transfer function. This was substantiated by the mode being seen in SMS.

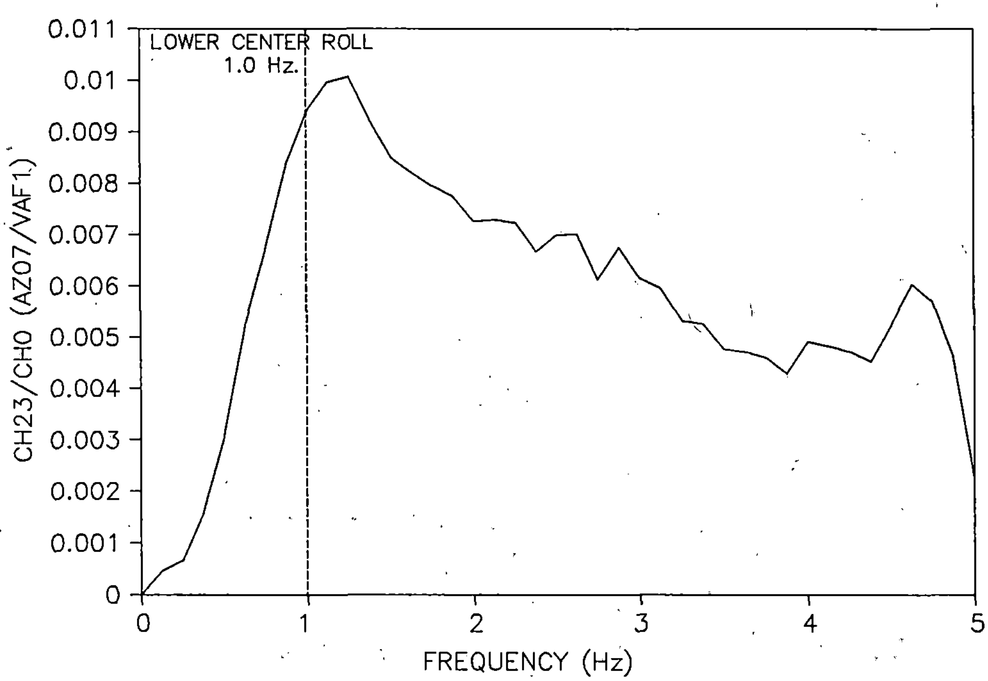


Figure 4.14(a) Loaded Lower Center Roll

The phase relationship of transducers mounted on the right and left side of the car are shown in Figure 4.14(b). Even though lower center roll begins at 1 Hz the sides of the car are nearly 180 degrees out-of-phase at all frequencies.

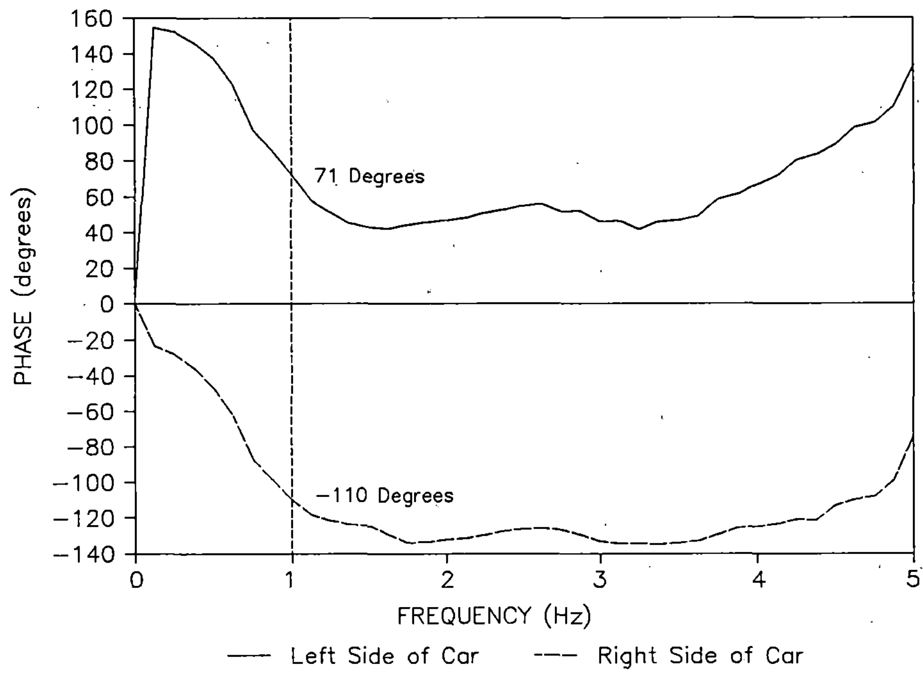


Figure 4.14(b) Loaded Lower Center Roll Phase Relationships

Transfer functions and phase relationships were analyzed, in the same manner, for the half-loaded and unloaded configurations. The lower center roll frequencies found for the half-loaded and unloaded cases were 1.125 Hz and 1.25 Hz, respectively. The matrix below is the summary of the lower center roll frequencies found.

MODE	LOADED	HALF-LOADED	UNLOADED
L-Roll	1.00 Hz	1.125 Hz	1.25 Hz

4.3.3 Rigid Upper Center Roll

Data from runs RN005, RN062, and RN069 were analyzed in an attempt to obtain upper center roll in the loaded, unloaded, and half-loaded configurations. A pure upper center roll frequency was not determined.

4.3.4 Flexible Body Vertical

Data from runs RN031, RN054, and RN085 were analyzed to obtain first vertical bending in the loaded, half-loaded, and unloaded configurations.

Figure 4.15(a) shows the loaded car's transfer function between the actuator input force and a vertical accelerometer near the middle of the car used to find first vertical bending at 11.0 Hz. A mode that was not expected, which we will call the vertical flex mode, was also found at 8.375 Hz.

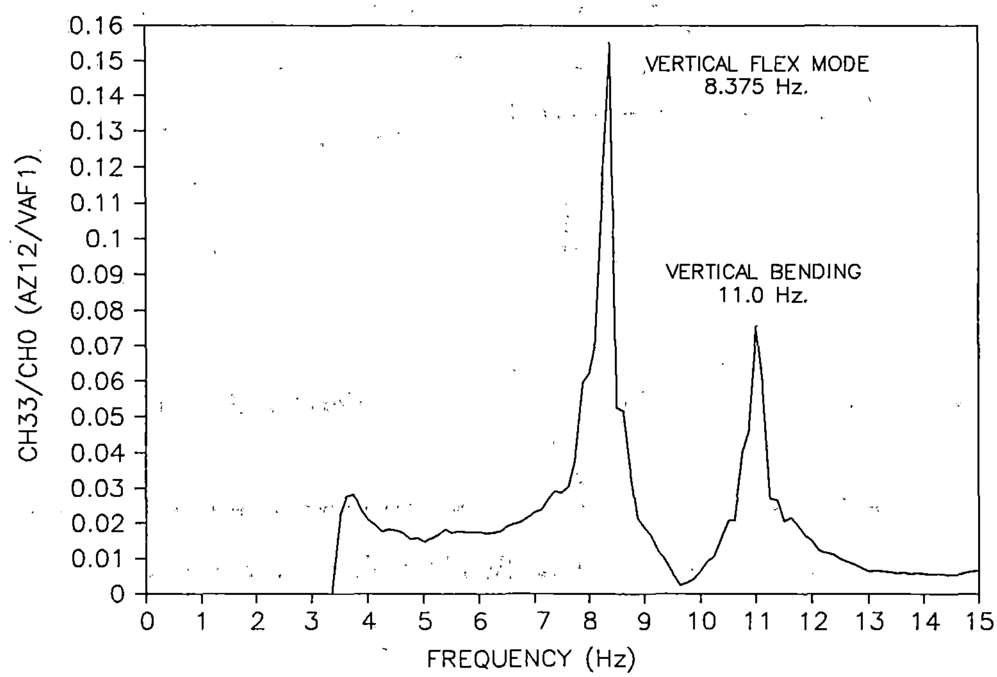


Figure 4.15(a) Loaded Flexible Body Vertical

Figure 4.15(b) is a side view representation and shows the motion on the top of the car is in-phase with the motion on the bottom of the car in vertical bending; while, in the vertical flex mode the motion on the top of the car is 180-degrees out-of-phase with the motion on the bottom of the car.

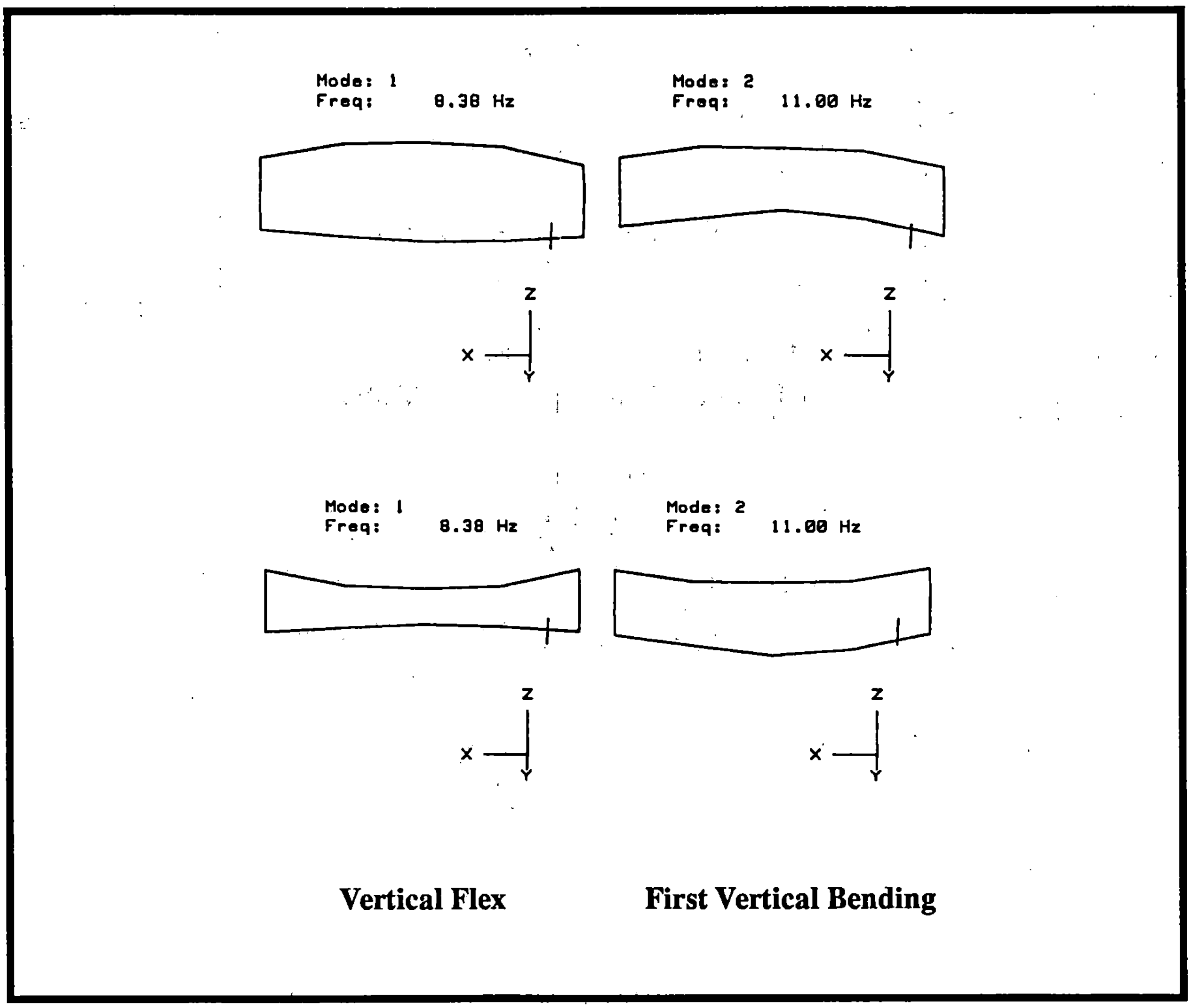


Figure 4.15(b) Vertical Bending Shape Illustration

Transfer functions and phase relationships were also analyzed to find vertical bending for the half-loaded and unloaded configurations. Again, in both cases, the vertical flex mode appeared. The results are summarized in the matrix below.

MODE	LOADED	HALF-LOADED	UNLOADED
Vertical Flex	8.375 Hz	11.875 Hz	16.25 Hz
Vertical Bending	11.0 Hz	15.125 Hz	18.875 Hz

4.3.5 Flexible Body Torsion (Twist)

Data from runs RN039, RN054, and RN090 were analyzed in an attempt to obtain first twist in the loaded, half-loaded, and unloaded configurations.

Possibly due to a large inherent stiffness associated with a cylinder (tank), twist was not found.

4.3.6 Rigid Body Lateral

Data from runs RN009, RN058, and RN069 were analyzed in an attempt to determine the natural yaw and sway frequencies for the loaded, unloaded, and half-loaded Fuel Car.

Figure 4.16(a) shows the transfer function between actuator input force and a lateral accelerometer at a bottom of the car at one end.

From the peaks in the transfer function and simulation by the SMS software it was postulated that the sway natural frequency was 1.5 Hz. No obvious yaw frequency was determined.

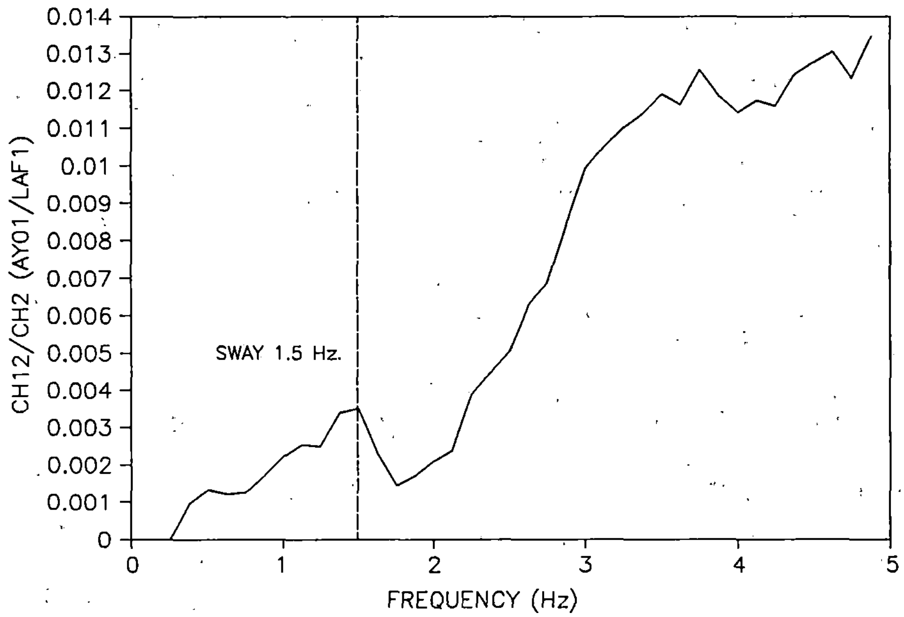


Figure 4.16(a) Loaded Yaw and Sway

Figure 4.16(b) shows the phase relationships of accelerometers mounted at either end of the car at the bottom.

At 1.5 Hz the car's ends were 50 degrees out-of-phase indicating sway. In pure sway the car's ends would be in-phase.

The ends of the car were out-of-phase laterally from 2.3 Hz to 4.8 Hz. Out-of-phase motion could be indicative of yaw; however, no dominate frequency was determined.

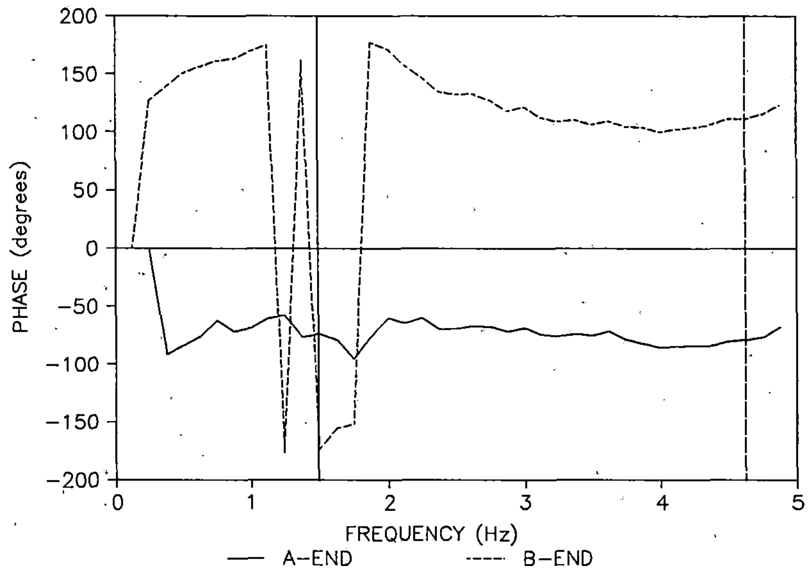


Figure 4.16(b) Loaded Yaw and Sway Phase Relationships

Transfer functions and phase relationships were analyzed, in the same manner, to find yaw and sway for the half-loaded and unloaded configurations. The unloaded sway frequency was not determined. The results are summarized in the matrix below.

MODE	LOADED	HALF-LOADED	UNLOADED
Sway	1.5 Hz	1.625 Hz	Not Found
Yaw	Not Found	Not Found	Not Found

4.3.7 Flexible Body Lateral

Data from run numbers RN009, RN063, and RN074 were analyzed to obtain first lateral bending in the loaded, half-loaded, and unloaded configurations.

Figure 4.17(a) shows the loaded car's transfer function between the actuator input force and the top middle of the car at the top, used to find first lateral bending, and another unexpected mode that we'll call the lateral flex mode. The transfer function shows first lateral bending in it's peak at 11.25 Hz, and the lateral flex mode at 8.875 Hz.

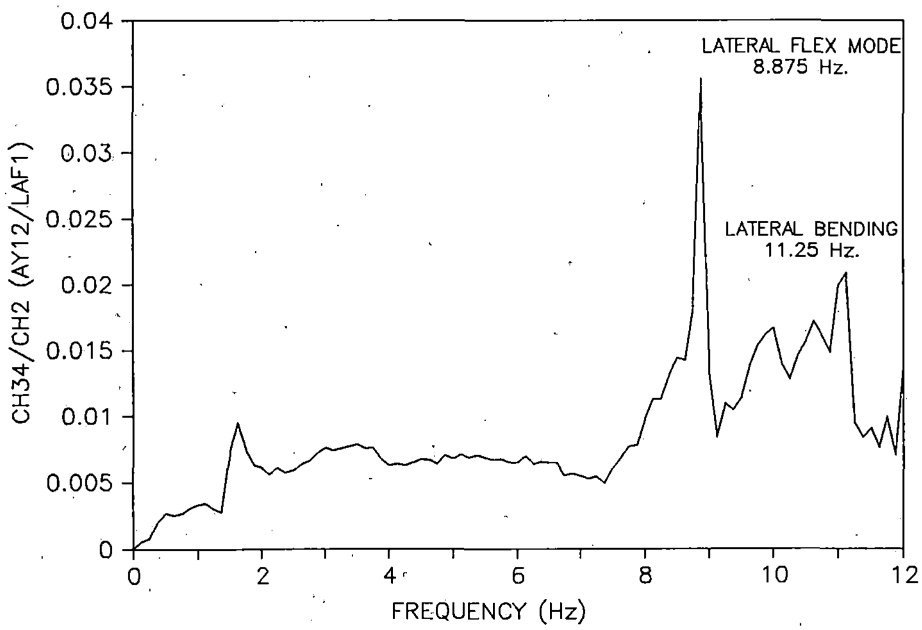


Figure 4.17(a) Loaded Flexible Body Lateral

In Figure 4.17(b) (top view), first lateral bending is shown on the right hand side. The motion of the top and bottom center lines of the car are generated from accelerometer data that are in-phase; while, the lateral flex mode is shown on the left side of Figure 4.17(b), as the motion of the top and bottom lines of the car that are out-of-phase (flexing). The lateral flex mode representation has been exaggerated to show the bending of the car. The lateral flex figure also appears to have a roll component as shown by the gap between the top and bottom of the car.

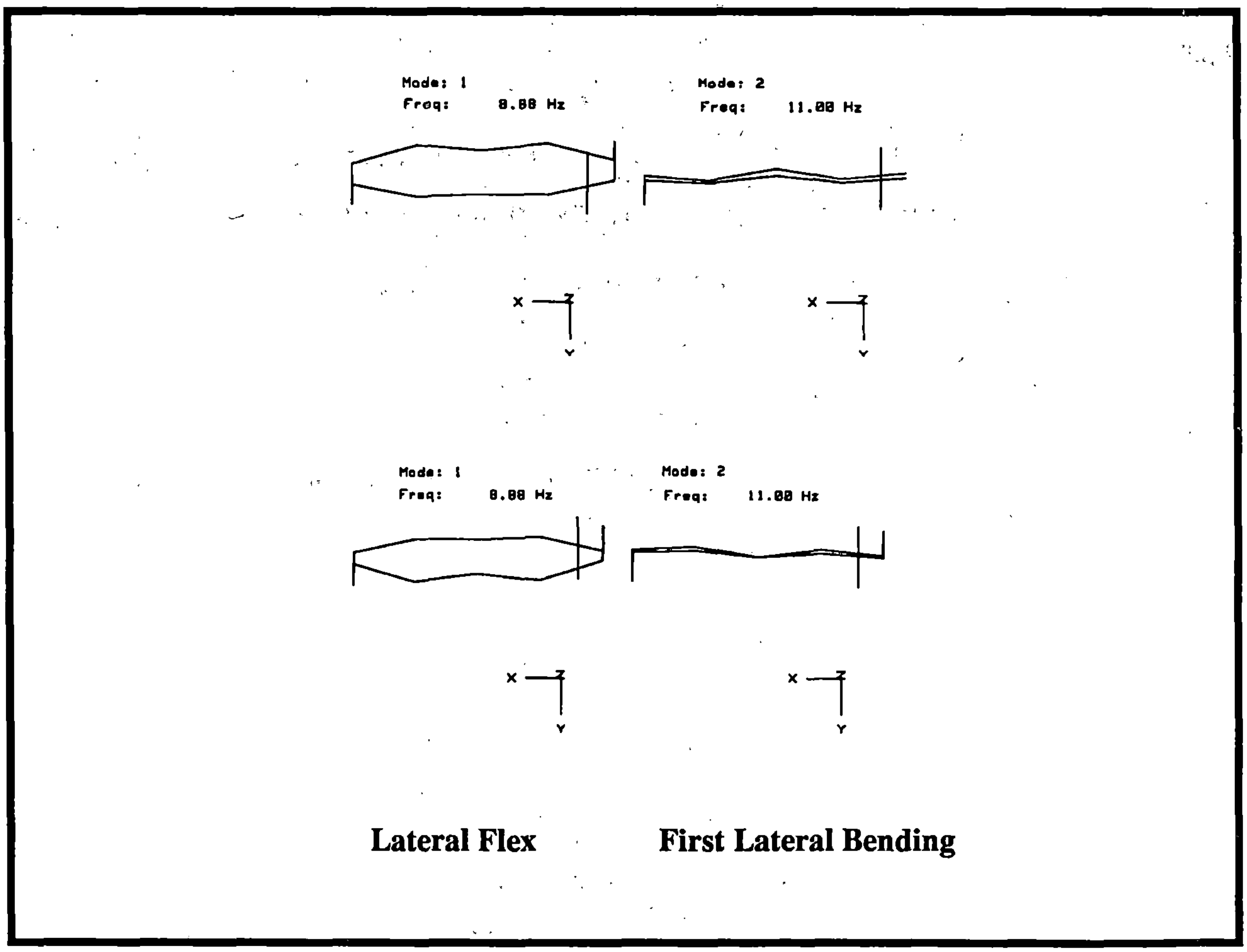


Figure 4.17(b) Lateral Bending Shape Illustration

Transfer functions and phase relationships were also analyzed to find lateral bending for the half-loaded and unloaded configurations. Again, in both cases, the lateral flex mode appeared. The results are summarized in the following matrix.

MODE	LOADED	HALF-LOADED	UNLOADED
LATERAL FLEX	8.875 Hz	11.5 Hz	16.0 Hz
LATERAL BENDING	11.25 Hz	14.625 Hz	19.0 Hz

4.3.8 Fuel

Data from the rigid half-loaded runs showed the resonant frequency of the fuel slosh to be 0.5 Hz. Figure 4.18 is a Power Spectral Density (PSD) of one of the six slosh gauges (vertical displacement floats) that were installed inside the tank of the car.

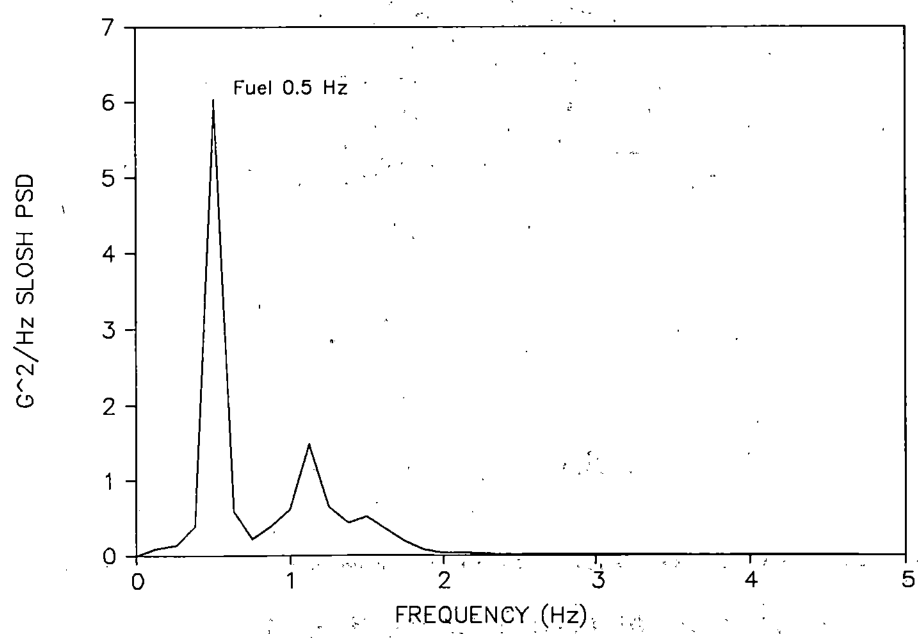


Figure 4.18 Half-loaded Rigid Fuel

4.4 RESULTS SUMMARY

Tables 4.12 and 4.13 present a summary of characterization data which was provided for NUCARS.

Table 4.12 Truck Characterization Summary

PARAMETER	VALUE	
	STIFFNESS	DAMPING
Secondary Suspension Vertical	25.1 kips/in	6.3 kips
Secondary Suspension Lateral	18.04 kips/in	16.3 kips
Truck Roll Rate	66,388 in-kips/rad	
Truck Yaw Moment	108,300 in-lbs	
Axle Alignment	No Effect	
Axle Box Longitudinal Stiffness	147 kips/inch	
Inter Axle Yaw and Bending Stiffness	1,019 in-kips/mrad	

Table 4.13 Modal Summary

PARAMETER	FREQUENCY		
	LOADED	HALF-LOADED	UNLOADED
Bounce Frequency	2.0 Hz	2.875 Hz	3.875 Hz
Pitch Frequency	4.5 Hz	4.625 Hz	4.75 Hz
Roll Frequency Lower Center	1.00 Hz	1.125 Hz	1.25 Hz
Roll Frequency Upper Center	*	*	*
Sway Frequency	1.5 Hz	1.625 Hz	*
Yaw Frequency	*	*	*
First Vertical Bending Frequency	10.6 Hz	15.125 Hz	18.875 Hz
Vertical Flex	8.375 Hz	11.875 Hz	16.25 Hz
First Torsional Frequency	*	*	*
First Lateral Bending Frequency	11.25 Hz	14.625 Hz	19.0 Hz
Lateral Flex	8.875 Hz	11.5 Hz	16.0 Hz

* NOT FOUND

5.0 CONCLUSIONS

1. In general, the characterization data seemed reasonable.

2. Axle alignment test data will not be used.

3. Longitudinal stiffness test data will be used in NUCARS.

4. A lateral variation in the trucks existed; also, on both trucks the vertical right side stiffness and damping are higher than the left side stiffness and damping.

5. The rigid body modes of lower center roll, sway, and bounce, have correlated track speeds that will be seen in operations of less than 60 mph on 39-foot wavelength perturbations. Close attention should be observed when near those speeds. The following is a list of the tests and speeds that should be closely observed while in the track worthiness test regime:
   - Lower center roll 25 to 38 mph, depending on vertical loading
   - Sway 39 to approximately 50 mph, depending on vertical loading
   - Bounce 50 to 55 mph in the loaded condition

6. All modes found above 2.63 Hz (70 mph) should not be excited in the Track Worthiness Test.

DOCUMENT 3

FUEL CAR
SERVICE WORTHINESS/CURVE STABILITY
REPORT

PEACEKEEPER RAIL GARRISON

EM FUEL CAR
SERVICE WORTHINESS TESTING
CURVE STABILITY

David C. Brabb

Association of American Railroads
Transportation Test Center
Pueblo, Colorado 81001

October 1991

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1.0 INTRODUCTION

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, has contracted with the Federal Railroad Administration (FRA) to perform vehicle performance tests on the Peacekeeper Rail Garrison (PKRG) rail cars according to specifications in AAR's, *Manual of Standards and Recommended Practices*, Chapter XI (M-1001).

These tests include static (air bearing) and quasi-static truck characterization, vehicle dynamic (modal) characterization, rail car service worthiness testing, and track worthiness testing. Static brake tests were also performed to verify the braking capability of the cars.

This is the report on the service worthiness testing of the Engineering Model (EM) PKRG Fuel Car (TBCX-90001). Service worthiness consists of a variety of tests; however, only the Curve Stability Test was performed with the EM Fuel Car because the car was assumed to be a proven structural design.

The PKRG Fuel Car is a 74,100 pound (unloaded) conventional tank car with a 21,644 gallon, 5/8-inch-thick shell tank that could be used to carry diesel fuel for the PKRG consist.

2.0 OBJECTIVE/DESCRIPTION

The objective of the Curve Stability Test was to place the Fuel Car on a 10-degree-curve track that had less than 1/2 inch superelevation and have it undergo buff and draft loads of 200,000 pounds without car body suspension separation or wheel lift. The loads had to be sustained for a minimum of 20 seconds for the vehicle to pass the test.

3.0 PROCEDURE

The test was done on the Urban Rail Building's south wye. Extremely short and long cars were connected adjacent to the Fuel Car on either side of it to simulate the worst case situation. Car body suspension separation and wheel lift were monitored at 100 kips and at 200 kips.

For the purpose of this test Chapter XI states that wheel lift is defined as a separation of wheel and rail exceeding 1/8 inches when measured 2 and 5/8 inches from the rim face at the inside of the curve for buff and outside for draft. Figure 3.1 shows a feeler gage being used to check for wheel lift.

Figure 3.1 Feeler Gage

4.0 INSTRUMENTATION

The following is a list of the instrumentation and materials used in the Curve Stability Test:

- 200 kip Actuator
- Instrumented Coupler, Conditioner
- Strip Chart
- Steel Chocks
- 23 Car Consist

5.0 SERVICE WORTHINESS/CURVE STABILITY RESULTS

No car body suspension separation or wheel lift occurred on the Fuel Car during the Curve Stability Test.

DOCUMENT 4

FUEL CAR
STATIC BRAKE
REPORT

PEACEKEEPER RAIL GARRISON

FUEL CAR

STATIC BRAKE TEST

David C. Brabb

Association of American Railroads
Transportation Test Center
Pueblo, Colorado 81001

October 1991

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Tables

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These tests include static (air bearing) and quasi-static truck characterization, vehicle dynamic (modal) characterization, rail car service worthiness testing, and track worthiness testing. Static brake tests were also performed to verify the braking capabilities of the cars.

This is the brake test report of the Engineering Model (EM), PKRG Fuel Car (TBCX-90001). The PKRG Fuel Car is a 74,100 pound (unloaded) conventional tank car with a 21,644 gallon, 5/8-inch-thick shell tank that could be used to carry diesel fuel for the PKRG consist.

2.0 OBJECTIVES

The objective of the Static Brake Test was to determine static brake shoe forces at various brake cylinder pressures. This information was compared to accepted braking standards and was also used to ensure the compatibility of all car brake systems in the PKRG train.

3.0 TEST DESCRIPTION/PROCEDURES

The Static Brake Test was performed by the AAR with assistance from Blaine Consulting Services. The brake test was performed to ensure compliance with existing AAR and FRA rules and regulations.

A Single Car Test was performed on the EM Fuel Car, following specifications from the Westinghouse Air Brake Company instruction pamphlet entitled, *Single Car Testing Device Code of Tests for Freight Equipment, No. 5039-4 Sup. 1*, Standard S-486, April 1987.

A Net Shoe Force Test was performed as part of the Static Brake Test. Instrumented brake shoe load cells were installed at each wheel/brake interface. Brake shoe forces were then read from a digital readout for a series of different brake pipe reductions.

A Hand Brake Net Shoe Force Test was also performed with the instrumented brake shoes in both trucks. The hand brake was applied in 1,000 pound (horizontal chain force) increments and the brake shoe forces were recorded.

4.0 INSTRUMENTATION/MATERIALS

The following is a list of instrumentation and materials that was used in the Static Brake Test:

- Single Car Test Device and Attachments
- Air Gage and Attachments (200 psi)
- Instrumented brake shoes (static), Conditioner and readout
- Instrumented clevis pin, Conditioner/Indicator
- Torque Wrench (115 ft-lbs), tools/hammers
- Clean dry Air Supply (110 psi)

5.0 STATIC BRAKE TEST RESULTS

Two static brake tests were performed on the EM Fuel Car. The first test was done in 1990 with the assistance of Blaine Consulting Services. The second was done by the AAR in 1991. The results of both tests were similar. The 1991 data is presented here. The Static Brake Test consisted of a single car test and net shoe force tests.

Instrumented brake shoes were installed at each brake/wheel interface in place of the brake pads. Data was obtained with the brake rigging tapped and untapped (3-pound hammers). The tapped rigging simulates the rigging response due to track inputs; hence, the tapped values were used for the following analysis.

Figure 5.1 shows the sum of the shoe forces from both trucks for each test. A linear regression was performed for the Net Shoe Force of the car and its equation is given as follows:

$$Net\ Shoe\ Force = (426 * Brake\ Cylinder\ Pressure) - 990$$

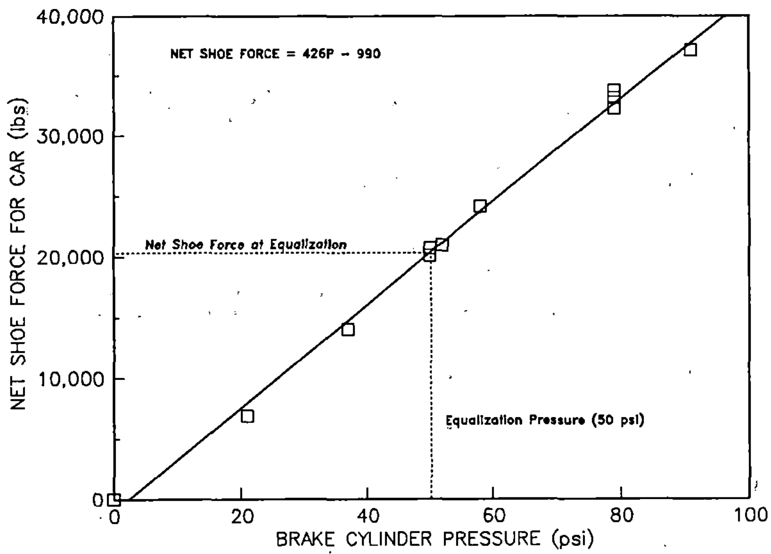


Figure 5.1 Fuel Car Static Brake Test Results

Braking performance is based on net shoe force and car weight. The net braking ratio percentage, which is the net shoe force divided by the car weight and times one-hundred, is the parameter regulated by the AAR. The loaded net braking ratio must be within 6.5 percent minimum and 10 percent maximum at a brake cylinder pressure of 50 pounds per square inch (psi) (equalization pressure) according to AAR Standard S-486. The following equation shows the net braking ratio calculation.

*Net Braking Ratio % = (Net Shoe Force / Weight of Car) * 100*

By AAR specification, the weight of the car should be **Designed Gross Rail Load.** The designed gross rail load of 100 ton trucks is 263,000 pounds.

The net brake ratio percentage at 50 psi for the designed gross rail load was 7.7 which is within the specification. There also exists a specification for unloaded cars. The maximum brake ratio percentage for an unloaded car is 30. When the Fuel Car is unloaded, it weighs approximately 77,000 pounds and the braking ratio percentage is 26, which also falls within specification. Therefore, the car falls within AAR standards.

Brake cylinder pressure is dependent on the train line pressure and the amount of pressure bled off (reduction). Since the operational train line pressure could be between 70 and 110 psi, Table 5.1 was developed to show brake ratios for various brake cylinder pressures with realistic (218,000 lbs.) loading of the car. The car weight, filled with diesel fuel, is approximately 218,000 pounds but could be 263,000 pounds at maximum allowed gross rail load.

Table 5.1 Loaded (218,000 lbs.) Fuel Car Net Braking Ratio Summary

EXPLANATION	BRAKE CYLINDER PRESSURE (psi)	NET BRAKING RATIO (%)
Full Service Reduction at 70 psi Train Line	50	9.3
Full Service Reduction at 90 psi Train Line	64	12.0
Full Service Reduction at 110 psi Train Line	78	14.7
Emergency at 70 psi Train Line	60	11.2
Emergency at 90 psi Train Line	77	14.5
Emergency at 110 psi Train Line	93	17.7

The hand brake net shoe force tests were also performed. Hand brake chain forces from 1,000 pounds to 6,000 pounds were tested in 1,000 pound increments. Practically, a 6,800 pound force should be obtained in the horizontal chain after the first sheave with a 125-pound application at the hand brake wheel on a high power (HP) hand brake. The instrumented pin used to measure chain force was only rated for 6,000 pounds so the test was halted at that point. Net shoe force versus chain force was plotted and a linear regression was performed. Figure 5.2 shows the plotted points and the linear regression best fit line and associated equation. The net braking ratio percentage equation is as follows.

Net Braking Ratio % due to Hand Brake =

*(((5.2 * Horizontal Chain Force) - 792) / Weight of Car) * 100*

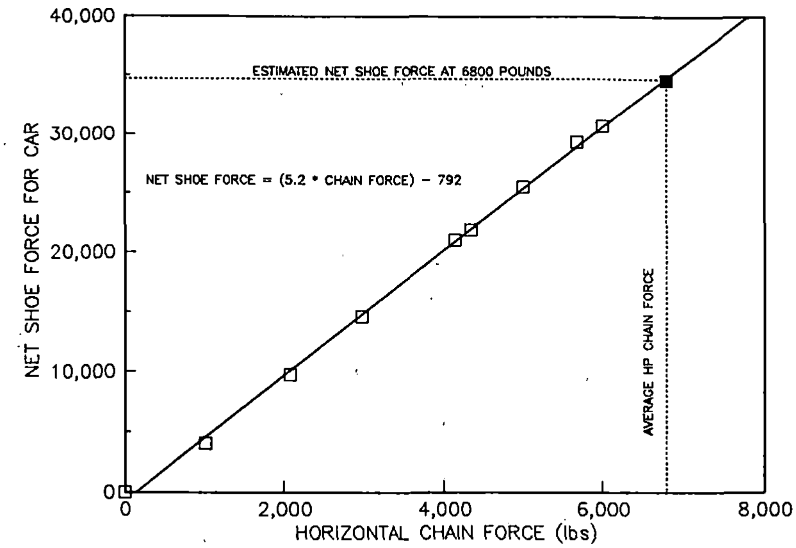


Figure 5.2 Fuel Car Hand Brake Results

A horizontal chain force of 6,800 pounds would have yielded a net shoe force (due to the hand brake) of 34,568 pounds and a net braking ratio percentage of 15.8 when the car's weight is 218,000 pounds. This value is well above the AAR minimum of 11 percent for a loaded car. The net braking ratio percentage of the designed gross rail load (263,000 lbs.) is 13.1, which is also above the AAR minimum.

DOCUMENT 5

FUEL CAR

REPORT PROCEDURES

1. TRACK WORTHINESS
2. MODAL RESPONSE
3. TRUCK CHARACTERIZATION
4. SERVICE WORTHINESS
5. STATIC BRAKE

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-7000-FC
TRACK WORTHINESS TEST

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-7000-FC
TRACK WORTHINESS TESTS

1.0 DESCRIPTION

This procedure outlines the sequence of steps to conduct Track Worthiness Tests at TTC. The Track Worthiness Tests consist of seven sub-tests: Hunting Test, Constant Curving Test, Spiral Test, Rock and Roll Test, Pitch and Bounce Test, Dynamic Curving Test and Yaw and Sway Test; additionally tests have been added for the Rail Garrison program: Turnout and Crossover and Special Perturbations.

1.1 INDEX

1.2 EQUIPMENT LIST

a.	2ea.	IITRI Instrumented Wheel Sets
b.	2ea.	Single Roll Gyrometer
c.	2ea.	Lateral Accelerometer
d.	6ea.	Strip Chart Recorder
e.	1ea.	Digitizer
f.	4ea.	100-Ton Jacks
g.	1ea.	Hewett-Packard (HP) 360 Data Acquisition System
h.		Signal Conditioner
i.		All Safety Equipment As Required By TTC

1.3 FIGURE LIST

1.4 TABLE LIST

1.5 ATTACHMENT LIST

Attachment 1 Chapter XI Track Worthiness Test Facilities

1.6 REFERENCE LIST

PRKG 2100.... Truck Inspection Procedure

PKRG 3100.... Instrument Installation Procedure

M1001........ Manual of Standards and Recommended Practices

PKRG 3500....	Section C, Part II, Volume I, Chapter XI IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation
PKRG 3800....	Track Worthiness Test Instrumentation Setup
PKRG 7001....	Test Sequence Chart
PKRG 7002....	Daily Pre-Test Sign-Off Sheet
	Peacekeeper Rail Garrison Test Implementation Plan, (for appropriate test car), Chapter XI Testing
	ENSCO Operating Manual
	TTC Safety Rule Book

1.7 REFERENCE DOCUMENTATION

None

NOTE

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book.

2.0 PRE-TEST FOR ALL TESTS (EXCEPT YAW AND SWAY)

2.1 36-Inch Instrumented Wheel Set Installation

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Disconnect the hand brake chain and air brake line.	LDD____ UNLD___ HLD____
2.1.2	Ensure brake shoes and keys are removed from each wheel location.	________
2.1.3	Remove all slack adjusters.	________
2.1.4	Secure emergency brake chain.	________
2.1.5	Remove and secure all loose brake system components. Mark removed components defining location from which removed and store for later re-installation.	________
2.1.6	Chock all A-end wheels.	
2.1.7	Using two 100-ton jacks at the jacking pads, jack the B-end up approximately 12 inches.	

2.1.8 Roll out Truck 1.

2.1.9 Lift Truck 1 and remove the leading Axle 1 wheel set.

2.1.10 Replace the leading wheel set with the IITRI WS21 instrumented wheel set as illustrated in Figure 2-1 and in accordance with, PKRG-3500 IITRI 36-inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.

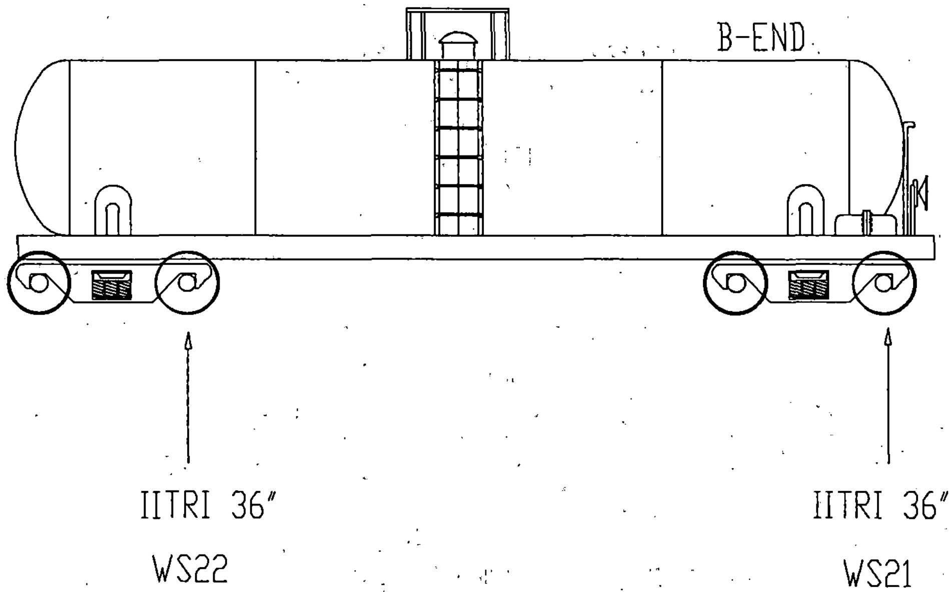


Figure 2-1 Instrumented Wheel Set Configuration

2.1.11 Roll the truck back under the car.

2.1.12 Lower the car.

2.1.13 Check Steps 2.1.1 through 2.1.5.

2.1.14 Chock all B-end wheels.

2.1.15 Using two 100-ton jacks at the jacking pads, jack the A-end up approximate 12 inches.

2.1.16 Roll out Truck 2.

2.1.17 Lift Truck 2 and remove Axle 3 (with respect to B-end) wheel set.

2.1.18 Replace Axle 3 wheel set with the ENSCO WS22 instrumented wheel set as illustrated in Figure 2-1 and in accordance with, PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.

2.1.19 Roll the truck back under the car.

2.1.20 Lower the jacks.

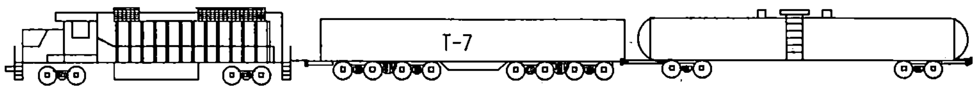
2.1.21 Quality verify the completion of the wheel set change out. LDD____

UNLD____

HLD____

2.2 Coupling of the Test Car and the Instrumentation Car

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Couple the B-end of the test car behind the instrumentation car. Figure 2-2 shows the core test consist. Buffer cars may be added or removed as required for each test.	



Note: Additional buffer cars may be added as required

Figure 2-2 Core Test Consist

CAUTION

Restrict coupling speed to 3.5 mph

2.3 Instrumentation Checkout

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	Calibrate instrumentation in accordance with, PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	LDD____ UNLD____ HLD____
2.3.2	Quality verify coupling of the Fuel Car and the Instrumentation Car is complete.	LDD____ UNLD____ HLD____

NOTE

Test sequence is arbitrary. The test sequence may bedictated by track availability at TTC. Anticipated test sequence is shown in PKRG-7001 Test Sequence Procedure.

3.0 LATERAL STABILITY ON TANGENT TRACK (UNLOADED, HALF-LOADED)

3.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
3.1.1	Ensure that no buffer car is coupled to the core test consist shown in Figure 2-2.	
3.1.2	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	UNLD____ HLD_____

3.2 On-Track Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Ensure that the instrumentation is checked-out in accordance with Section 3.1.1 and 3.1.2.	

NOTE

Test to be conducted on 5000 feet of dry tangent track on the RTT with Class 5 or better track (R39-R33).

CAUTION

Stop testing before lateral acceleration exceeds 1.0 g peak-to-peak or any maximum axle sum L/V exceeds 1.3.

3.2.1.1 Ensure applicable perturbations have been verified. ________

3.2.1.2 Ensure pre-test sign-off sheet PKRG-7002 has been completed.

3.2.2 During the initial 30 mph track conditioning run, keep the speed constant through the test zone.

3.2.3 Start taking lateral acceleration data 200 - 300 feet before reaching the test zone. The computer should be triggered by Automatic Location Device (ALD).

3.2.4 Stop data acquisition 200 - 300 feet beyond the test zone..

3.2.4.1 Review test, ensure data is acceptable and indicates that the test can be continued.

3.2.5 Repeat test once.

3.2.5.1 Compare maximum limiting values. Ensure readings are within 15% for instrumented wheel sets, 5% on roll gyros and accelerometers.

3.2.6 Increase speed in increments of $\pm$ 10 mph, $\pm$ 1 mph with each pair of test runs, until approachong a critiacl point (80 % of stop critiera, 0.8 g peak-to-peak, and 1.0 L/V); then, increase speed in increments of 2 mph until maximum test speed of 70 mph is reacded.

3.2.7	In the Test Engineers Log, note the speed at which the car sustains truck hunting if hunting occurs (Per Chapter XI criteria 1.0 g peak-to-peak for 20 seconds).	UNLD____ HLD_____
3.2.8	Quality verify that the test is completed.	UNLD____ HLD_____

3.3 Post Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Perform Post Test Cal per PKRG-3500 and 3800.	UNLD____ HLD_____
3.3.2	Perform Post Test Visual Inspection.	UNLD____ HLD_____

4.0 CONSTANT CURVING TEST (LOADED, UNLOADED, HALF-LOADED)

4.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
4.1.1	Instrumentation for this test should be as per Section 2.0.	

4.1.2 Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup. LDD____ UNLD____ HLD____

4.1.3 Place fully loaded 125-ton buffer car #UP31934 at the end of the core consist.

CAUTION

Restrict coupling speed to 3.5 mph.

4.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
4.2.1	This test utilizes all of the different degrees of curvature and superelevation (7.5-, 10-, 12-degree with 3, 4 and 5 inches of superelevation respectively) available on the WRM track.	
4.2.1.1	Ensure applicable perturbations have been verified.	______
4.2.1.2	Ensure pre-test sign-off sheet PKRG-7002 has been completed.	
4.2.2	Determine the test run speed by equation: $V = \sqrt{1480 \frac{(U+H)}{D}}$ Where: U = unbalance in inches; H = superelevation in inches; D = degree of curvature.	
4.2.3	For U = -3, 0, and +3 inches of unbalance.	

NOTE

Track speed may be lower than the calculated speed for the +3-inch run. If this condition exists use the track speed limit of 45 mph.

The speed calcuated for the -3-inch run may be zero or less. If this condition exists, use a negative difference from the balance equal to the positive difference for the +3-inch.

CAUTION

Stop testing before any L/V exceeds .8 or any axle sum L/V exceeds 1.3.

4.2.4 Operate the test consist at a constant speed for each condition shown in Table 3-1 ± 1 mph).

Table 3-1 Constant Curving Conditions

DEGREE	SUPER ELEVATION	BALANCE SPEED	+3 INCH	-3 INCH
7.5	3	24.0	32.0	14.0
10	4	24.0	32.0	12.0
12	5	25.0	32.0	16.0

4.2.5 With each test run, record data 200 - 300 feet before the curve and through the length of the body of the curve. The computer should be triggered by the ALD.

4.2.5.1 Repeat 4.2.4 for opposite direction.

4.2.6 QA verify that the test matrix is complete. LDD____

HLD____

5.0 SPIRAL NEGOTIATION AND WHEEL UNLOADING CONDITIONS

5.1 Test Requirements

TASK NUMBER	PROCEDURE	QA INITIAL
5.1.1	This test will run concurrently with the Constant Curving Test speed conditions.	
5.1.2	Record data while running through the spirals on the WRM during the curving test.	

CAUTION

Stop testing before the vertical wheel force is less than 10% static wheel load or any wheel L/V exceeds 0.8.

5.1.3	QA verify that the test is complete.	LDD____ HLD____

6.0 TWIST AND ROLL TEST (LOADED, UNLOADED, HALF-LOADED)

6.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
6.1.1	Couple a buffer car (UP31934) to the end of the core test consist.	

6.1.2 Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.

LDD____

UNLD____

HLD____

6.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
6.2.1.	Ensure applicable perturbations have been verified.	______
6.2.1.2	Ensure pre-test sign-off sheet PKRG-7002 has been completed.	
6.2.2	This test will be performed on the Precision Test Track (PTT) as shown in Attachment 1.	
6.2.3	Approach the test zone at a constant speed of 10 mph, $\pm$ 1 mph.	
6.2.4	Record the wheel forces, mean roll angle and differences in roll between the ends for each truck for approximately 200 feet before the test zone and continuously through the test zone.	

CAUTION

Stop testing before the car body peak-to-peak roll exceeds 6 degrees, any single wheel L/V exceeds 0.8, any axle sum L/V exceeds 1.3 or any vertical wheel load measures less than 10 % of its static wheel load.

6.2.5 Run tests at constant speeds, increasing in increments of 5 mph, ± 1 mph then increasing at increments of 2 mph until resonance is passed; then, increase speeds in increments of 5 mph.

6.2.6 Make two runs at each speed. In the Test Engineers Log, note the speed at which resonance is reached. LDD____ UNLD____ HLD____

6.2.7 Stop testing if an unsafe condition is encountered or when the maximum speed of 70 mph is reached. LDD____ UNLD____ HLD____

6.2.8 Quality verify that the Twist and Roll Test is completed. LDD____ UNLD____ HLD____

6.3 Test Tear-Down

TASK NUMBER	PROCEDURE	QA INITIAL
6.3.1	Remove the loaded buffer car from the test consist (if applicable).	
6.3.2	Quality verify that the Test Tear-down is completed.	LDD____ UNLD____

7.0 PITCH AND BOUNCE TEST (LOADED, HALF-LOADED)

7.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
7.1.1	This test is to be performed on the PTT located between stations 1716+00 and 1719+90 as shown in Attachment 1.	
7.1.2	Place a light car (TTX479303 empty flat) that has at least 45 ft. truck center spacing at the end of the consist directly behind the test car.	
7.1.3	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	LDD____ HLD____

7.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
7.2.1	Approach the test section at a constant speed of 30 mph, $\pm$1 mph. Start recording test data approximately 100 feet before the test section and continuously through the test section.	
7.2.2	Using the computer, record the vertical wheel forces.	

CAUTION

Stop testing when any wheel shows a vertical load of 10 % or less of its static load.

7.2.3	Run the test twice at each speed.	
7.2.4	Increase speed in increments of 10 mph until unsafe conditions are encountered, the resonance is passed, or a maximum of 60 mph is reached. Increments may be reduced to 2 mph when nearing resonance. Resonance to be determined prior to testing.	LDD____ HLD____
7.2.5	Quality verify that the Pitch and Bounce Test is completed.	LDD____ HLD____

8.0 DYNAMIC CURVING TEST (LOADED, HALF-LOADED)

8.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
8.1.1	This test is to be conducted on the 10-degree curve (station 1+00 to 3+50) of the wheel/rail mechanism (WRM) track, as shown in Attachment 1.	
8.1.2	Place a loaded buffer car (UP 31934) at the end of the core consist coupled directly to the test car.	
8.1.3	Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup.	

8.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL

CAUTION

It shall be regarded as unsafe and the test will be stopped if a wheel lifts, if any wheel L/V exceeds 0.8, if the instantaneous sum of the absolute L/V values of the individual wheels on any axle exceeds 1.3, or the car body roll exceeds 6 degrees peak-to-peak or minimum wheel load of 10% static.

TASK NUMBER	PROCEDURE	QA INITIAL
8.2.1	Approach the test zone at a constant speed of 5 mph.	
8.2.2	Start acquiring test data approximately 200 feet before the test zone. Record the lateral and vertical wheel forces and the roll angle.	
8.2.3	Increase speed in increments of 2 mph until a maximum speed of 32 mph is reached or an unsafe condition is encountered.	LDD____ HLD____
8.2.4	Quality verify that the Dynamic Curving Test is completed.	LDD____ HLD____

8.3 Test Tear-down

TASK NUMBER	PROCEDURE	QA INITIAL
8.3.1	Remove the loaded buffer car from the test consist if applicable.	
8.3.2	Quality verify that the Test Tear-down is completed.	LDD____ HLD____

9.0 TURNOUT AND CROSSOVER TEST (LOADED, UNLOADED, HALF-LOADED)

9.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
9.1.1	Use whatever configuration the consist is in while traversing from one test section to the other.	
9.1.2	This test will be performed on the turnouts and crossover of the RTT and TTT near Post 85 (Attachment 1).	
9.2	The Fuel Car shall be run at 10 mph 15 mph through a #8 turnout and also shall be run at 15, 25, 35 through 602A and B crossover.	
9.3	Quality verify Turnout and Crossover Test completed.	LDD____ UNLD____ HLD____

10.0 SPECIAL PERTURBATIONS

10.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
10.1.1	If necessary, the consist may be run through special perturbations to be identified at a later time.	

10.1.2 Test setup will be defined at that time.

10.2 On-track Test

TASK NUMBER	PROCEDURE	QA INITIAL
10.2.1	Test procedure and stop criteria will be identified at a later time.	

11.0 YAW AND SWAY TEST (LOADED, HALF-LOADED)

11.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
11.1.1	Disconnect cables between T-7 and the Fuel Car. Uncouple the Fuel Car from T-7.	
11.1.2	Using four 100-ton jacks at the jacking pads, jack the test car up approximately 12 inches.	
11.1.3	Roll both trucks away from the car.	

11.1.4 Remove the trailing axle of Truck 1 (Axle 2) and the leading axle of Truck 2.

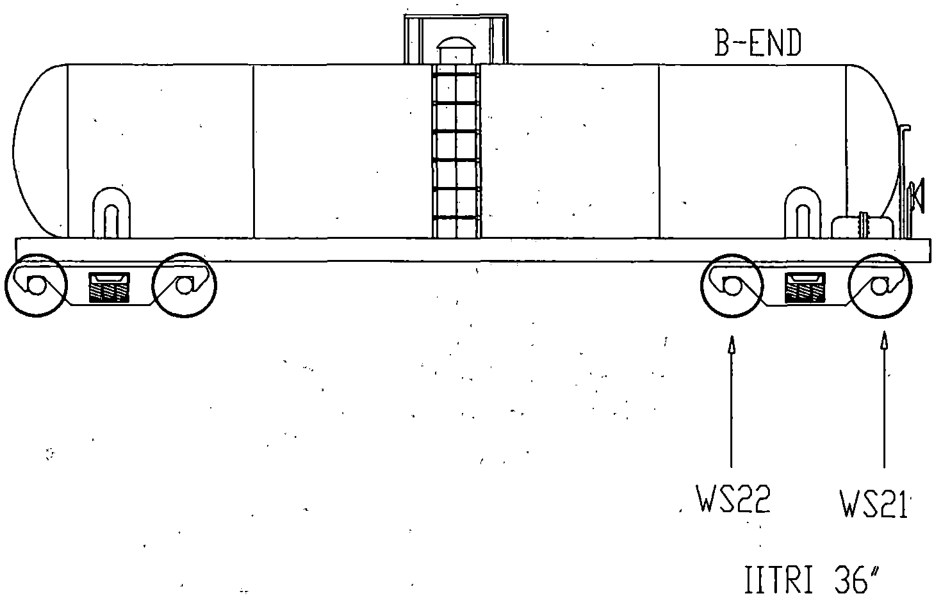


Figure 11-1 Instrumented Wheel Set Configuration

11.1.5 Place the instrumented wheel set from Truck 2 in the trailing axle position of Truck 1, as shown in Figure 11-1. LDD____ HLD____

11.1.6 Place the old trailing axle from Truck 1 under Truck 2 (Axle 3).

11.1.7 Roll the trucks back under the car.

11.1.8 Lower the jacks.

11.1.9 Quality verify that the wheel sets have been changed over. LDD____ HLD____

11.1.10 Ensure that instrumentation meets the requirements outlined in PKRG-3500 IITRI 36-Inch Instrumented Wheel Set Installation, Calibration and Operation, and PKRG-3800 Track Worthiness Test Setup. LDD____ HLD____

11.1.11 Place the test car at the end of the consist behind the T-7 Instrument Car. Reconnect instrumentation cables per procedure PKRG-3500 and 3800.

11.2 On-track Testing

TASK NUMBER	PROCEDURE	QA INITIAL
11.2.1	This test is to be conducted on Section 21+00 to 26+00 of the PTT, as shown in Figure 3-1 (Attachment 1).	
11.2.2	The initial test run is to be conducted at a constant speed of 20 mph and increasing in increments of 5 mph, $\pm$ 1 mph until resonance is passed and top speed is accomplished.	
11.2.3	Begin test data acquisition approximately 200 feet before reaching the test section.	

CAUTION

It shall be regarded as unsafe and the test will be stopped if the ratio of the total lateral forces on any one side measured exceeds 0.6 for a duration equivalent to 6 ft. or any axle sum L/V exceeds 1.3.

11.2.4	Repeat the test at speed increments of 2 mph, ± 1 mph. The test will continue until an unsafe condition is encountered, the resonance is passed or the maximum speed of 60 mph is reached. Speed may be increased in increments of 5 mph when resonance has passed.	LDD____ HLD____
11.2.5	Quality verify that the Yaw and Sway Test is completed.	LDD____ HLD____

12.0 CONFIGURATION TEST REQUIREMENTS

TASK NUMBER	PROCEDURE	QA INITIAL
12.0.1	Repeat applicable tests in half-loaded and loaded conditions.	

13.0 TEST TEAR-DOWN

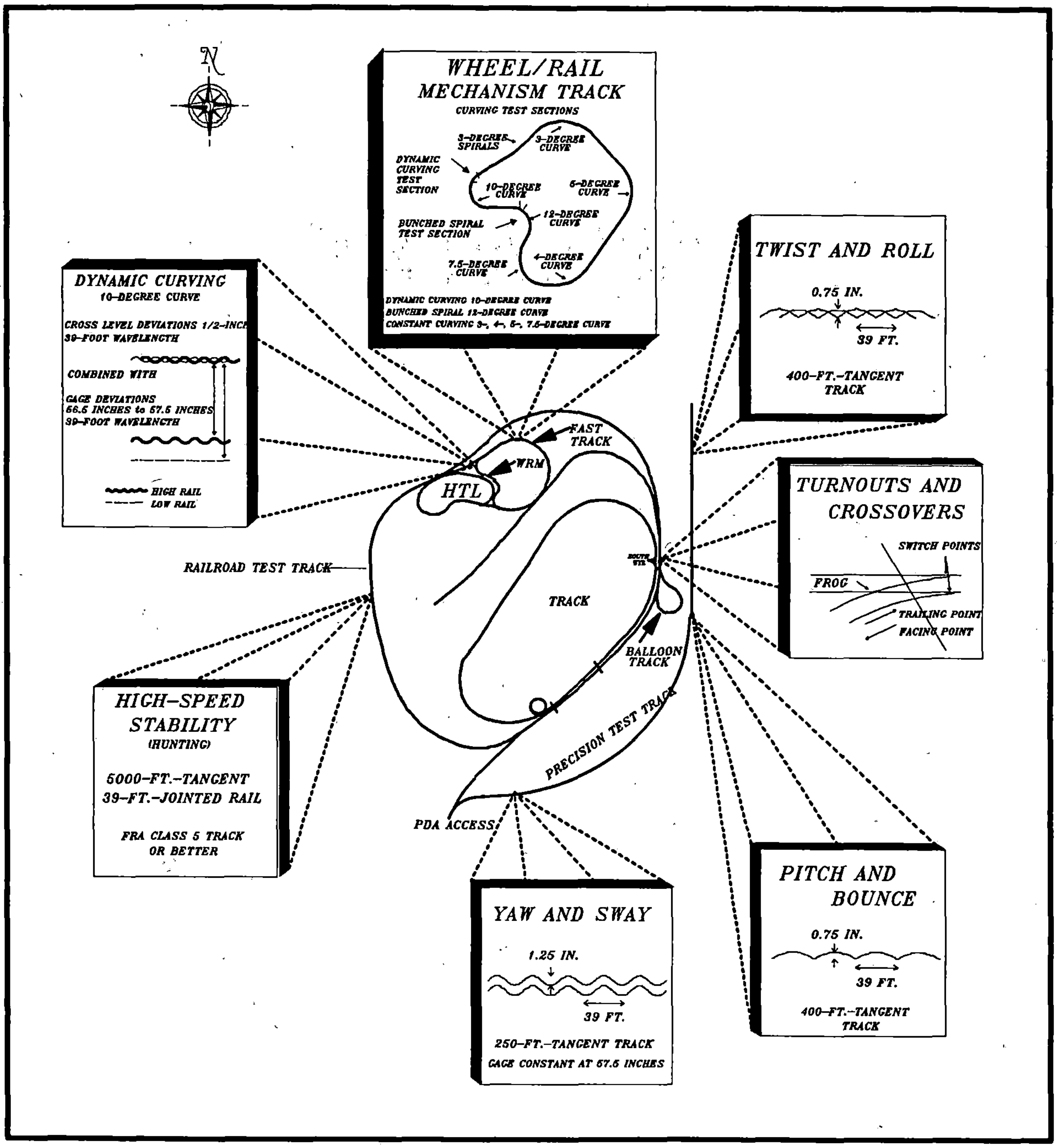
TASK NUMBER	PROCEDURE	QA INITIAL
13.0.1	The procedure for tear down of the IITRI 36-Inch Instrumented Wheel Sets is located in PKRG-3500, Section 5.0 through 5.1. Refer to this procedure and the applicable section to complete test tear-down.	LDD____ UNLD____ HLD____

14.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
14.0.1	Quality Verify that Procedure PKRG-7000-FC is complete and closed.	
14.0.2	Authorized QA signature ______________________________.	

ATTACHMENT 1

CHAPTER XI TRACK WORTHINESS TEST FACILITIES



PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-5100-FC
MODAL RESPONSE TEST

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-5100-FC
MODAL RESPONSE TEST

1.0 DESCRIPTION

The purpose of this procedure is to outline the sequence of steps for the Rail Garrison Modal Response Test to be performed on the Rail Garrison Fuel Car. The Modal Response Test consists of six sub-tests, they are: Rigid Body Vertical Test, Twist/Roll (Rigid Body) Test, Flexible Body Vertical Test, Flexible Body (Twist) Test, Rigid Body Lateral Test and Flexible Body LateralTest. The tests will be conducted in three configurations, full, empty and half-full.

1.1 INDEX

4.0 Test Tear Down
5.0 Quality Verification

1.2 EQUIPMENT LIST

a.	2 ea.	55 KIP Actuators
b.	2 ea.	Load Cell, 0-100k Range
c.	8 ea.	Instrumented Rails, 0-100k Vertical Range 0-60k Lateral Range
d.	2 ea.	Displacement Transducer (LVDT), +/- 5" Range
e.	4 ea.	String Pot, +/- 4" Range
f.	2 ea.	Strong Pot, +/- 1" Range
g.	14 ea.	String Pot, +/- 5" Range
h.	27 ea.	Accelerometer, +/-5G Range
i.	1 ea.	Hewlett Packard (HP) 9000, Model 360 Computer System
j.	1 ea.	Hewlett Packard (HP) 6944a Multi-Programmer
k.	As needed	Safety Equipment as required by Rail Dynamics Lab (RDL)
l.	2 ea.	90-87560-XXX Attachment Fixture
m.	1 ea.	Hewlett Packard (HP) 3325B Function Generator
n.	1 ea.	MTS Control System
o.	77 ea.	Signal Conditioners
p.	77 ea.	Filters (0-50Hz)

1.3 FIGURE LIST

1.4 ATTACHMENT LIST

(1) Applicable PSD'S

(2) Instrumentation Placement (3 sheets)

  (a) Truck And Bolster Instrumentation

  (b) Car Body Accelerometer

  (c) Car Body To Ground Displacements

(3) Test Configuration Data Sheets

1.5 REFERENCE LIST

PKRG-2200	Car Inspection Procedure
PKRG-3100	Instrumentation Installation Procedure
PKRG-3200	Instrumentation Verification Procedure
M1001	Manual of Standards and Recommend Practices, Section C, Part II, Volume I, Chapter XI
	TTC Operation Rules for the Transportation Test Center, Pueblo, Colorado, AAR, November 1, 1989
	Peacekeeper Rail Garrison Test Implementation Plan, Fuel Car Chapter XI Testing
PKRG-5110	FC Modal Test Car Attachment Fixture Installation Procedure
PKRG-5115	FC Weld Magnaflux Test Procedure
PKRG 5120	Modal Test Car Attachment Fixture Removal
	AAR/TTC Fueling Procedure

NOTE

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book.

2.0 MODAL TEST PROCEDURES

2.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL

NOTE

The following tests are to be conducted using three configurations: fully loaded, empty and half-loaded. Testing will start with the fully loaded configuration.

2.1.1 Move test car onto the RDL mini-shaker as illustrated in Figure 2-1. Comply with TTC Operating Rules. FL____

HLF____

EPT____

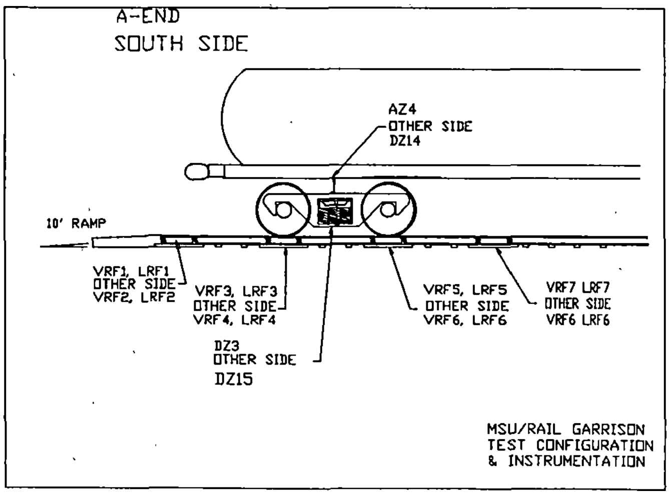


Figure 2-1 MSU/Rail Garrison Test Configuration And Instrumentation

2.1.2 Install car attachment fixtures per PKRG-5110-FC, Modal Test Car. Attachment Fixture Installation Procedure. FL____

HLF___

EPT___

NOTE

Calibration procedures will be accomplished at the start of each test day for all the following tasks except for the instrumented rail procedure. The instrumented rail procedure will be accomplished every third consecutive test day.

2.2 Load Cell Calibration Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	This calibration procedure is for all load cell channels.	
2.2.2	Refer to Procedure PKRG-3100 for completing the Attachment (3) Test Configuration Data Sheet, PKRG-3100 Section 5.1 through 5.8.	
2.2.3	Refer to Attachment (2) Instrumentation Placement Sheets for instrumentation location.	
2.2.4	Verify loads are zero by checking appropriate load cell.	
2.2.5	Zero the load cells by adjusting the zero knob on the north and south MTS 443 DC conditioners, (+/- 10 mV).	
2.2.6	Print checkout values and label Pre-test Load Cell Zeros.	

2.2.7 RCAL the load cells by pressing the CAL button on the DC conditioners and compare the values with the Test Configuration Data Sheet, tolerance should be +/- 5 percent.

2.2.8 Print checkout values and label Pre-test Load Cell RCAL.

2.2.9 Quality verify load cell calibration completed. FL___

HLF___

EPT___

2.3 LVDT Calibration (Accomplish during L.C. Zero)

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	LVDT, this calibration procedure is for all LVDT Channels.	
2.3.2	Refer to Procedure PKRG-3100 for completing the Attachment (3) Test Configuration Data Sheet, PKRG-3100 Section 5.1 through 5.8.	
2.3.3	Refer to Attachment (2) Instrumentation Placement Sheets for instrumentation location.	
2.3.4	Zero all LVDT's using the knob labeled ZERO on the AC conditioner located inside the MTS443 hydraulic control system +/- 10 mV.	
2.3.5	Print calibration values and label Pre-test LVDT Zeros.	
2.3.6	Under static hydraulic control move actuators at 1-inch increments up to 4 inches and verify output with depth dial indicator. Output (EU's) should correspond to assigned channels per Test Configuration Data Sheet.	

NOTE

If output doesn't match, adjust gage factor knob on the AC conditioner and repeat Steps 2.3.4 through 2.3.6.

2.3.7 Quality verify LVDT's calibration completed. FL____

HLF___

EPT___

2.4 Instrumented Rail Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.4.1	This calibration procedure is for all instrumented rail data channels.	
2.4.2	Remove hydraulic actuators.	
2.4.3	Move the test car forward until clear of instrumented rail assembly.	
2.4.4	Refer to Procedure PKRG-3100 for completing the Attachment (3) Test Configuration Data Sheet, PKRG-3100 Section 5.1 through 5.8.	
2.4.5	Refer to Attachment (2) Instrumentation Placement Sheets for intrumentation location.	
2.4.6	At patch panel 0738A8, patch T27 to T31.	
2.4.7	Zero out the DC offset of the conditioner amplifier, + /- 10 mV.	
2.4.8	Adjust the balance control (i.e. BAL) for a bridge null.	

2.4.9 Set the CAL knob to the + 100 position.

2.4.10 Adjust the amplifier gain for proper calibration engineering units per Test Configuration Data Sheet (ensure CAL knob is positioned to + 100).

2.4.11 Place CAL knob to OPR position.

2.4.12 Place B and F calibration controller into Mode O record data for 60 seconds. Label data file as Pre-test Instrumented Rail Zero.

2.4.13 Place B and F Calibration Controller into Mode I, record data for 60 seconds. Label data file as Pre-test Instrumented Rail CALS.

2.4.14 Place B and F Calibration Controller into Mode 5.

2.4.15 Move test car back onto instrumented rail assembly.

2.4.16 Install hydraulic actuators in the vertical test configuration, as illustrated in Figure 2-2.

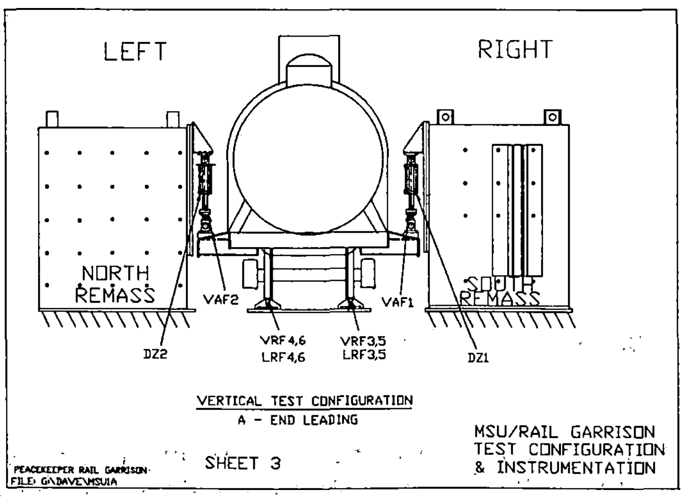


Figure 2-2 Vertical Test Configuration

2.4.17 Quality verify instrumented rail calibration completed. FL____

HLF____

EPT____

2.5 Accelerometer Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.5.1	This calibration procedure is for all piezo resistive accelerometer channels.	
2.5.2	Refer to procedure PKRG-3100 for completing the Attachment (3) Test Configuration Data Sheet, PKRG-3100 Section 5.1 through 5.8.	
2.5.3	Refer to Attachment (2) Instrumentation Placement Sheets for instrumentation location.	
2.5.4	Install accelerometers in accordance with AAR/TTC instrumentation SOP NO. 024 9/89.	
2.5.5	Push the EXCIT button on the signal conditioner and adjust excitation voltage for + 10.0 VDC +/- 10.0 mV using the SPAN control.	
2.5.6	Zero out the DC offset of the conditioner amplifier, +/- 10 mV.	
2.5.7	Adjust the balance control (i.e. BAL) for a bridge null.	
2.5.8	Set the CAL knob to the + 100 position.	
2.5.9	Adjust the amplifier gain for proper calibration engineering units per Test Configuration Data Sheet (ensure CAL knob is positioned to + 100).	

2.5.10 Place CAL knob to OPR position.

2.5.11 Push the ZERO button on the amplifier and null the output at the zero adjust pot.

2.5.12 Using a manual adjustment tool, null the BAL pot on the signal conditioner +/- 10 mV.

2.5.13 Set the CAL switch to + 100% and adjust the amplifier course and fine gain, adjust for the output to correspond to the system EU/VOLT section and the Configuration Data Sheet.

2.5.14 Quality verify accelerometer calibration completed. FL____

HLF___

EPT___

2.6 String Pot Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.6.1	This calibration procedure is for all string pot channels.	
2.6.2	Refer to Procedure PKRG-3100 for completing the Attachment (3) Test Configuration Data Sheet, PKRG-3100 Section 5.1 through 5.8.	
2.6.3	Refer to Attachment (2) Instrumentation Placement Sheets for instrumentation location.	
2.6.4	Attach string pots in accordance with AAR/TTC Instrumentation SOP NO. 024 9/89.	

2.6.5 Push the EXCIT button on the signal conditioner and adjust excitation voltage for + 10.0 VDC +/- 10.0 mV using the SPAN control.

2.6.6 Zero out the DC offset of the conditioner amplifier, +/- 10 mV.

2.6.7 Adjust the balance control (i.e. BAL) for a bridge null.

2.6.8 Set the CAL knob to the + 100 position.

2.6.9 Adjust the amplifier gain for proper calibration engineering units per Attachment (3) Test Configuration Data Sheet (ensure CAL knob is positioned to + 100).

2.6.10 Place CAL knob to OPR position.

2.6.11 Place B and F calibration controller into Mode O record data for 60 seconds. Label data file as Pre-test Instrumented Rail Zero.

2.6.12 Place B and F Calibration Controller into Mode I, record data for 60 seconds. Label data file as Pre-test Instrumented Rail CALS.

2.6.13 Place B and F Calibration Controller into Mode 5.

2.6.14 Zero the amplifier, +/- 10 mV.

2.6.15 Reposition CAL knob to OPR position

2.6.16 Quality verify string pot calibration completed. FL____

HLF___

EPT___

3.0 MODAL TEST

3.1 Rigid Body Vertical Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.1.1	Setup computer and control system for Rigid Body Vertical Modal Test. A. At the 443 Control System Panel, set MODE switches to the positive position to place actuators in phase. B. At the Data Acquisition System (DAS) (HP 360 Data Acquisition and Control) set the following parameters: 1. Load (KIP) — 5 KIP 2. Displacement (stroke) — .2" 3. Freq. Range (Hz) — .2-5Hz a. Dwell Points (cycles/step) — 10 b. Frequency Steps (Hz) — .1 c. Constant G — N/A 4. Sweep Duration (sec) — 350	
3.1.2	Start data acquisition and control program.	
3.1.3	Test will stop when parameters are satisfied. Save file.	
3.1.4	Calculate a Power Spectral Density (PSD) (see Attachment 1) for test data. Examine for pitch and bounce resonant frequencies.	
3.1.4.1	Quality verify 5 KIP test parameters are satisfied.	FL____ HLF___ EPT___
3.1.5	Repeat Steps 3.1.1 through 3.1.4 with force control settings of 10 KIP and 15 KIP if it is determined safe after previous test.	

3.1.5.1 Quality verify that test parameters are satisfied for:

10 KIP ________
15 KIP ________

3.2 Twist/Roll Modal Test Procedure (Rigid Body)

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Setup the HP 360 data acquisition and control computer for Twist/Roll Test.	

A. At the Control System Panel, set the top MODE switch to the positive position and the lower MODE switch to the negative position to achieve 180 degree out of phase.
B. At the Data Acquisition System (DAS) set the following parameters:

1. Load (KIP)	5
2. Displacement (stroke)	N/A
3. Frequency Range	.2-5Hz
a. Dwell Points (cycles/step)	10
b. Frequency Steps (Hz)	.1
c. Constant G	N/A
4. Sweep Duration (sec)	350

3.2.2 Start data acquisition and control program to begin test.

3.2.3 Save file when test stops.

3.2.4 Calculate a PSD's (see Attachment 1) for test data. Examine for twist/roll resonant frequencies.

3.2.5 Quality verify 5 KIP twist/roll test parameters are satisfied.

FULL
5 KIP
10 KIP
15 KIP

EMPTY
5 KIP
6 KIP
7 KIP

FL____

HLF___

EPT___

3.2.7 Repeat Steps 3.2.1 through 3.2.6 for force control settings of 6 and 7 KIPS if it is determined safe after previous test.

3.2.7.1 Quality verify that test data for twist/roll test parameters are satisfied at:

10 KIP
15 KIP

FL____

HLF___

EPT___

3.3 Flexible Body Vertical Modal Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Disconnect all string pots.	FL____ HLF___ EPT___

3.3.2 Setup computer and control system for Flexible Body Vertical Modal Test.

A. At the 443 Control System Panel, set MODE switches to the positive position to place actuators in phase.
B. Set the following parameters on the HP 360 data acquisition and control computer for displacement control with constant G:

1. Load (KIP)	N/A
2. Displacement (stroke)	.2"
3. Freq. Range (hz)	3-30Hz
a. Dwell Points (cycles/step)	N/A
b. Frequency Steps (Hz)	N/A
c. Constant G	.10
4. Sweep Duration (sec)	300

3.3.3 Start data acquisition and control program to begin test.

3.3.4 Save file when test stops.

3.3.5 Calculate PSD's (see Attachment 1) for test data. Examine for vertical bending (first, second and third if possible) frequencies.

3.3.6 Quality verify acceptable constant G level at .10. FL_____

HLF__

EPT__

3.3.7 Repeat Steps 3.2.3 through 3.2.6 for constant G levels of .15, .20 and .30 at 10 -30 Hz, .40g at 5 -30 Hz and .50g at 10 -30 Hz, if it is determined safe after previous test.

3.3.7.1 Quality verify acceptable constant G level at:

FULL	FL____
.15	
.20	HLF___
.30	
.40 at 5-30 Hz	EPT___
EMPTY	FL____
.15	
.20	HLF___
.30	
.40 at 5-30 Hz	EPT___

NOTE:

Test Runs may be at different frequencies if deemed necessary.

3.4 Flexible Body (Twist) Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.4.1	Disconnect all string pots.	FL____ HLF___ EPT___

3.4.2 Setup the HP 360 data acquisition and control computer for Flexible Body Twist Modal Test.

A. At the Control System Panel, set the top MODE switch to the positive position and the lower MODE switch to the negative position to achieve 180 degree out of phase.

B. At the HP 360 data acquisition and control computer set the following parameters with constant G.

1. Load (KIP)	N/A
2. Displacement (stroke)	.2" max
3. Freq. Range (Hz)	3-30
a. Dwell Points (cycles/step)	N/A
b. Frequency Steps (Hz)	N/A
c. Constant G	.10
4. Sweep Duration (sec)	300

3.4.3 Start data acquisition and control program to begin test.

3.4.4 Save file when test stops.

3.4.5 Calculate PSD's (see Attachment 1) for test data. Examine for twist (first, second and third if possible) frequencies.

3.4.6 Quality verify acceptable constant G level at .10.

FL____

HLF___

EPT___

3.4.7 Repeat Steps 3.2.3 thru 3.2.6 for constant G levels of .15, .20, .3g at 3 - 30 Hz and .4g at 10 - 30 Hz if it is determined safe after previous test.

3.4.7.1 Quality verify acceptable constant G level at:

FULL FL____
.15
.20 HLF___
.30
.40 at 5-30 Hz EPT___

EMPTY FL____
.15
.20 HLF___
.30
.40 at 5-30 Hz EPT___

3.5 Rigid Body Lateral Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.5.1	Setup hydraulic actuators for rigid and flexible body lateral test configuration as shown in Figure 3-1. Reconnect string pots.	

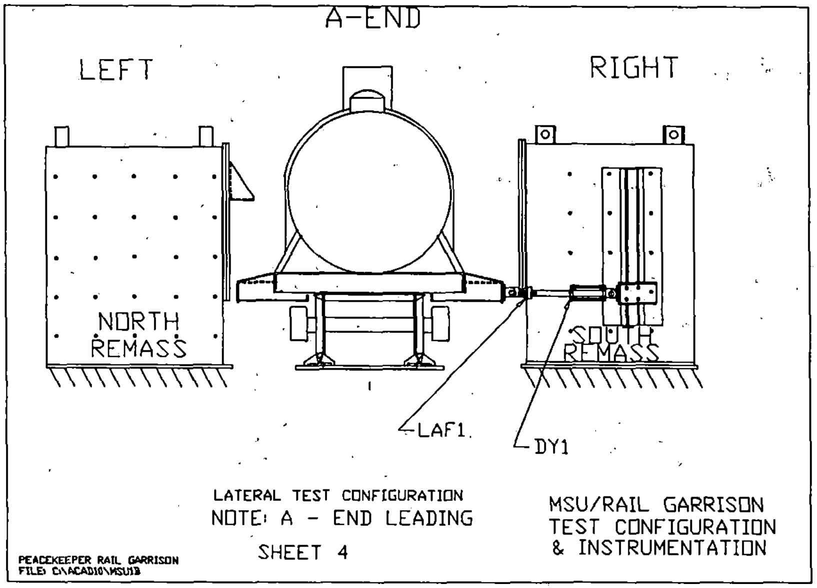


Figure 3-1 Lateral Test Configuration

3.5.2	Ensure all instrumentation is connected for Lateral Modal Testing.	FL____ HLF___ EPT___
3.5.3	At the 443 Control System Panel, ensure the top MODE switch is in the positive position.	
3.5.4	At the HP 360 data acquisition and control computer set the following parameters:	

1. Load (KIP)	5
2. Displacement (stroke)	2.5 KIP (Empty)
3. Freq. Range (Hz)	.2-5
a. Dwell Points (cycles/step)	10
b. Frequency Steps (Hz)	.1
c. Constant G	N/A
4. Sweep Duration (sec)	350

3.5.5 Start data acquisition and control program to begin test.

3.5.6 Save file when test stops.

3.5.7 Calculate a PSD's (see Attachment 1) for test data. Examine for lateral rigid body resonant frequencies.

3.5.7.1 Quality verify 5 KIP rigid body lateral is acceptable.

FL____

HLF___

EPT___

3.5.8 Repeat Steps 3.5.4 through 3.5.7 with force control settings of 10 and 15 KIP if it is determined safe after previous test.

3.5.8.1 Quality verify acceptable rigid body laterals at:

10 KIP FL____
15 KIP

HLF___

EPT___

3.6 Flexible Body Lateral Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.6.1	Disconnect all string pots.	FL____ HLF____ EPT____
3.6.2	Setup the HP 360 data acquisition and control computer for Flexible Body Lateral Modal Test. A. At the 443 Control System Panel, set the top MODE switches to the positive position. B. At the HP 360 data acquisition and control computer set the following parameters for displacement with constant G: 1. Load (KIP) — N/A 2. Displacement (stroke) — .2"max 3. Frequency Range — 3-30 a. Dwell Points (cycles/step) — N/A b. Frequency Steps (Hz) — N/A c. Constant G — .10 4. Sweep Duration (sec) — 300	
3.6.3	Start data acquisition and control program to begin test.	
3.6.4	Save file when test stops.	
3.6.5	Calculate PSD's (see Attachment 1) for test data. Examine for lateral bending (first, second and third if possible) frequencies.	
3.6.6	Quality verify acceptable constant G level at .10 (d max = .1082).	FL____ HLF____ EPT____

3.6.7 Repeat Steps 3.2.3 through 3.2.6 for constant G levels of .15 and .20 at 3 - 30 Hz, .30g at 10 - 30 Hz and .40g at 15 - 30 Hz if it is determined safe after previous test.

3.6.7.1 Quality verify acceptable constant G levels at.

FULL FL____
.1600
.2200 HLF___
.0242
.0173 EPT___

EMPTY
.13-30Hz FL____
.15 5-30Hz
.2 5-30Hz HLF___
.3 5-30Hz
.4 9-30Hz EPT___

NOTE

Any one or more of these to be used for extra data points if deemed necessary.

4.0 TEST TEAR DOWN

TASK NUMBER	PROCEDURE	QA INITIAL
4.0.1	Remove instrumentation from car.	
4.0.2	Remove car from MSU following TTC operating procedures.	
4.0.3	Remove car attachment fixtures per PKRG-5120-FC Modal Response Test Fixture Removal.	FL____ HLF___ EPT___

4.0.4 Perform car and truck inspection per PKRG-2200. FL____

HLF____

EPT____

4.0.5 Repeat Steps 2.0 through 5.0 for empty and halfloaded conditions of Fuel Car.

5.0 Quality Acceptance

TASK NUMBER	PROCEDURE	QA INITIAL
5.1	Quality verified that PKRG-5100-FC is complete and closed.	
5.2	Authorized QA signature________________________________	

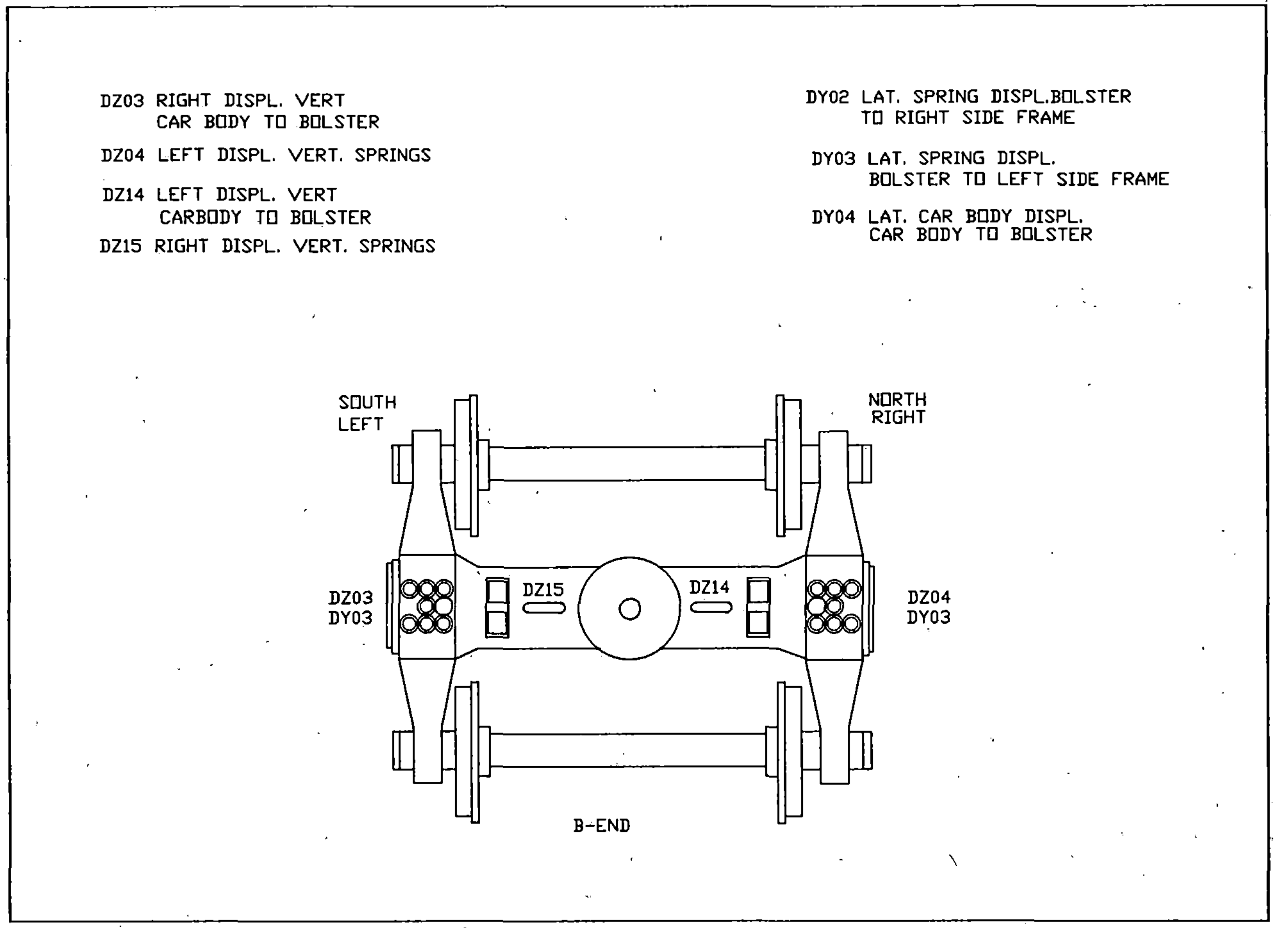
ATTACHMENT 1

APPLICABLE PSD'S TO BE REVIEWED BEFORE CONTINUING TEST

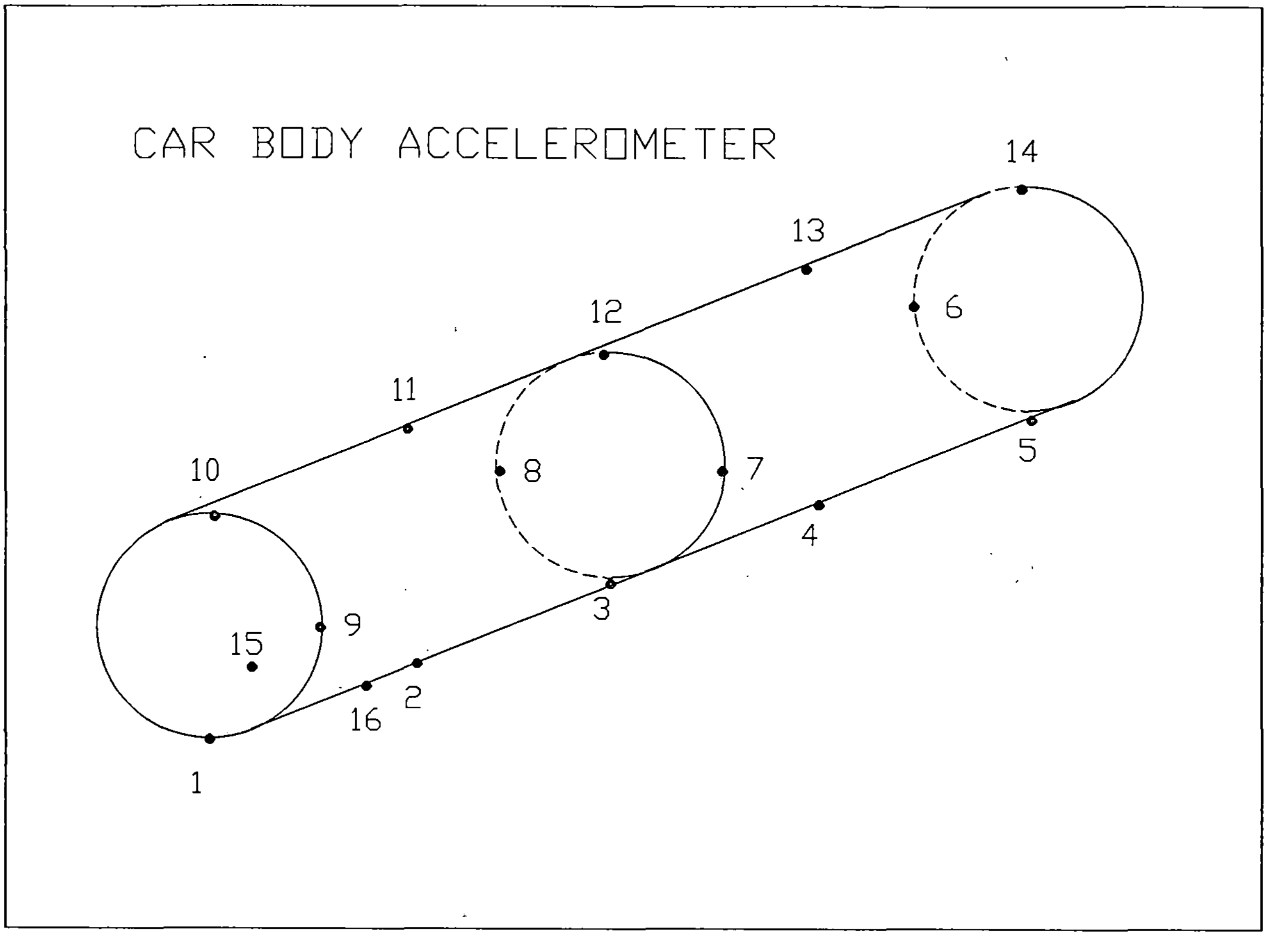
TEST	PERTINENT PSD CHANNEL
* RIGID VERTICAL	AZ1, AZ3, AZ4, AZ5, AZ8, DZ7, DZ11, DZ12
* RIGID ROLL	DZ7, DZ8, DZ11, DZ9, DY4, DY5
FLEXIBLE VERTICAL	AZ4, AZ5, AZ8, AZ11, AZ12, AZ15,
FLEXIBLE TWIST	AZ4, AZ16, AY4, AY16, AZ8, AY8, AZ14, AY15
RIGID LATERAL	DY4, DY5, DY6
FLEXIBLE LATERAL	AY4, AY15, AY8, AY12, AY16, AY03, AY05, AY11, AY13
* Also determine peak spring displacement to ensure springs are not bottoming out.	

ATTACHMENT 2

INSTRUMENTATION PLACEMENT SHEETS

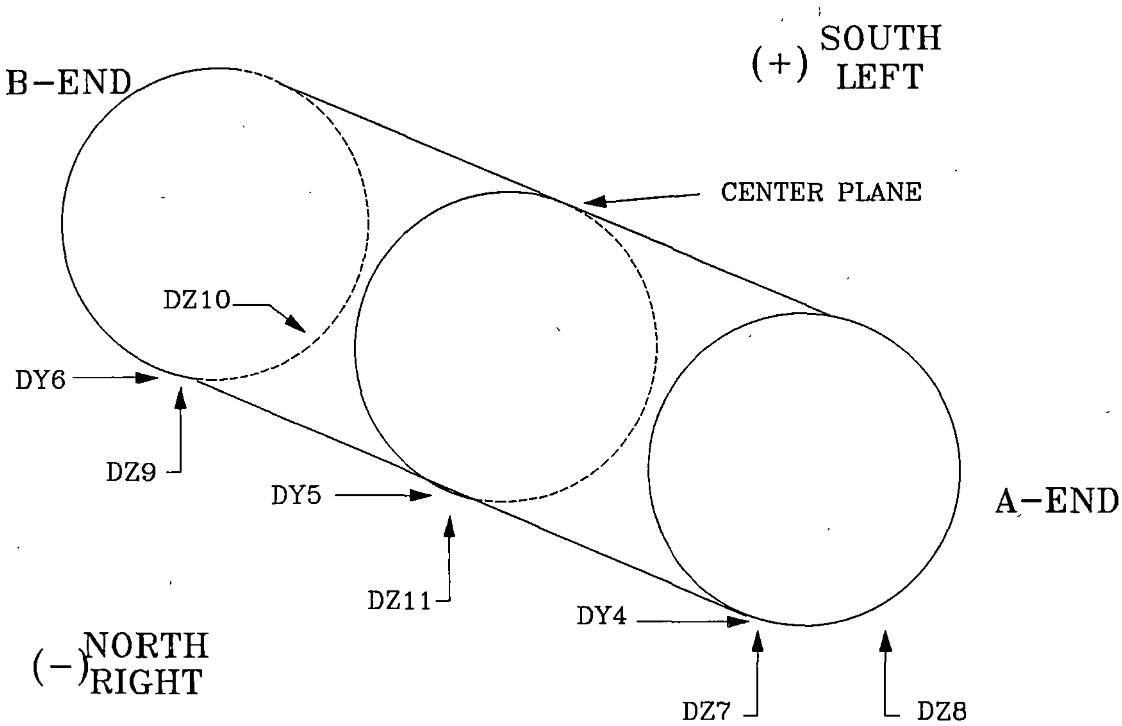


(a) Truck And Bolster Instrumentation



(b) Car Body Accelerometer

CAR BODY TO GROUND BODY DISPLACEMENTS



(c) Car Body To Ground Displacements

ATTACHMENT 3

TEST CONFIGURATION DATA SHEETS

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FC-MODAL DATE APR 90 W.O. 87560 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. ______ QA ______

SOFTWARE/VERSION XGNRL_AQ8A/MIF_FC RECORDER I.D. NO. HP-360 SET-UP FILE ______

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP-69444

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER					AMPLIFIER						FILTER				SYSTEM			RECORDER		COMMENTS
				MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	NO.	FREQ	GAIN	CAL VOID DATE	A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	CH. NO.	SENS. (E.U./DIV.)	
	0	49	VAF1	INTERFA	9978 26538	0.41022 MV/KLBS	X= Y= Z=	5-JUL-90	MTS SOUTH		V	59.88 K	35585lbs 6.47V		ITH 1	50	1	2-OCT-90	0.0	5.5647 klbs/v	klbs	1-1		VERTICAL ACTUATOR FORCE, LEFT, A-END SOUTH
	1	50	VAF2	INTERFA	9979 26630	0.40573 MV/KLBS	X= Y= Z=	5-JUL-90	MTS NORTH		V	59.88 K	25025lbs 4.55V		ITH 2	50	1	2-OCT-90	0.0	5.5612 klbs/v	klbs	1-2		VERTICAL ACTUATOR FORCE, RIGHT, A-END NORTH
	2	49	LAF1	INTERFA	9978 26538	0.41022 MV/KLBS	X= Y= Z=	5-JUL-90	MTS SOUTH		V	59.88 K	35585lbs 6.47V		ITH 1	50	1	2-OCT-90	0.0	5.5647 klbs/v	klbs	1-1		LATERAL ACTUATOR FORCE, LEFT, A-END SOUTH
A41	3	37	VRF3	TTC	3	68.413 MV/KLBS	X= Y= Z=	5-JAN-91	R40 124	15V R	1000 V	499 K	76.886klbs 5.26V		ITH 3	50	1	2-OCT-90	0.0	14.617 klbs/v	klbs			VERTICAL RAIL LOAD AXLE 4, LEFT, SOUTH A-END, TRUCK 2
A45	4	39	VRF4	TTC	4	71.559 MV/KLBS	X= Y= Z=	5-JAN-91	R42 126	15V R	1000 V	499 K	72.667klbs 5.20V		ITH 4	50	1	2-OCT-90	0.0	13.974 klbs/v	klbs			VERTICAL RAIL LOAD AXLE 4, RIGHT, NORTH A-END, TRUCK 2
A49	5	41	VRF5	TTC	5	76.577 MV/KLBS	X= Y= Z=	5-JAN-91	R44 128	15V R	1000 V	499 K	69.277klbs 5.305V		ITH 5	50	1	2-OCT-90	0.0	13.059 klbs/v	klbs			VERTICAL RAIL LOAD AXLE 3, LEFT, SOUTH A-END, TRUCK 2
A53	6	43	VRF6	TTC	6	78.416 MV/KLBS	X= Y= Z=	5-JAN-91	R46 130	15V R	1000 V	499 K	66.823klbs 5.24V		ITH 6	50	1	2-OCT-90	0.0	12.752 klbs/v	klbs			VERTICAL RAIL LOAD AXLE 3, RIGHT, NORTH A-END, TRUCK 2
A43	7	38	LRF3	TTC	3	183.637 MV/KLBS	X= Y= Z=	5-JAN-91	R41 125	15V R	1000 V	499 K	29.025klbs 5.33V		ITH 7	50	1	2-OCT-90	0.0	5.446 klbs/v	klbs			LATERAL RAIL LOAD AXLE 4, LEFT, SOUTH A-END, TRUCK 2
A47	8	40	LRF4	TTC	4	165.574 MV/KLBS	X= Y= Z=	5-JAN-91	R43 127	15V R	1000 V	499 K	32.131klbs 5.32V		ITH 8	50	1	2-OCT-90	0.0	6.040 klbs/v	klbs			LATERAL RAIL LOAD AXLE 4, RIGHT, NORTH A-END, TRUCK 2
A51	9	42	LRF5	TTC	5	173.419 MV/KLBS	X= Y= Z=	5-JAN-91	R45 129	15V R	1000 V	499 K	30.331klbs 5.26V		ITH 9	50	1	6-OCT-90	0.0	5.766 klbs/v	klbs			LATERAL RAIL LOAD AXLE 3, LEFT, SOUTH A-END, TRUCK 2

NOTES:

FILE:\ACAD\MODAL1

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FC-MODAL DATE ______ W.O. 87560 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. ______ QA ______

SOFTWARE/VERSION xGNRL_AQ8A/MIF_FC RECORDER I.D. NO. HP-360 SET-UP FILE

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP-69444

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	AMPLIFIER CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	FILTER NO.	FREQ	GAIN	CAL VOID DATE	SYSTEM A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	RECORDER CH. NO.	SENS. (E.U./DIV.)	COMMENTS
A55	10	44	LRF6	TTC	6	145.765 mv/klbs	X= Y= Z=	5-jan-91	r47 131	15v R	1000 V	499 K	35.880 klbs 5.23 v		ITH 10	50	1	6-OCT-90	0.0	6.860 klbs/v	klbs			LATERAL RAIL LOAD AXLE 3, RIGHT, NORTH A-END, TRUCK 2
C41	11	115	AZ01	ENDVECO	PA16 21026	11.14 MV/G	X= Y= Z=	25-JAN-91	Q1 0	10v R	179.53 V	100			ITH 11	50	1	6-OCT-90	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, A-END; C/L UNDERSIDE
C43	12	116	AY01	ENDVECO	KR88 21025	12.90 MV/G	X= Y= Z=	25-JAN-91	Q2 1	10v R	155.04 V	100			ITH 12	50	1	6-OCT-90	0.0	0.5 G/V	G	3-1		LATERAL CAR BODY ACCEL, A-END, C/L UNDERSIDE
C45	13	117	AZ02	ENDVECO	MY28 21024	11.67 MV/G	X= Y= Z=	25-JAN-91	Q3 2	10v R	171.38 V	100			ITH 13	50	1	6-OCT-90	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, A-END (3/4) C/L, UNDERSIDE
C47	14	118	AY02	ENDVECO	TG93	10.09 MV/G	X= Y= Z=	8-AUG-90	Q4 3	10v R	198.22 V	100			ITH 14	50	1	6-OCT-90	0.0	0.5 G/V	G	3-2		LATERAL CAR BODY ACCEL, A-END, (3/4) C/L, UNDERSIDE
C49	15	119	AZ03	ENDVECO	ML36 21027	12.23 MV/G	X= Y= Z=	25-JAN-91	Q5 4	10v R	163.53 V	100			ITH 15	50	1	6-OCT-90	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, CENTER (1/2) C/L, UNDERSIDE
C51	16	120	AY03	ENDVECO	TG91 21812	12.31 MV/G	X= Y= Z=	30-JUN-90	Q6 5	10v R	162.47 V	100			ITH 16	50	1	6-OCT-90	0.0	0.5 G/V	G	3-3		LATERAL CAR BODY ACCEL, CENTER (1/2) C/L, UNDERSIDE
C53	17	121	AZ04	ENDVECO	RW99 21525	9.282 MV/G	X= Y= Z=	3-JUL-90	Q7 6	10v R	215.47 V	100			ITH 17	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, B-END (1/4) C/L, UNDERSIDE
C55	18	122	AY04	ENDVECO	NZ07 13738	8.613 MV/G	X= Y= Z=	30-JUN-90	Q8 7	10v R	232.21 V	100			ITH 18	50	1	23-JAN-91	0.0	0.5 G/V	G	3-4		LATERAL CAR BODY ACCEL, B-END (1/4) C/L, UNDERSIDE
C57	19	123	AZ05	ENDVECO	NN23 12642	11.95 MV/G	X= Y= Z=	30-JUN-90	Q9 8	10v R	167.36 V	100			ITH 19	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, B-END, C/L UNDERSIDE

NOTES:

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PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FC-MODAL DATE ______ W.O. 87560 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. ______ QA ______

SOFTWARE/VERSION xGNRL_AQ8A/MIF_FC RECORDER I.D. NO. HP-360 SET-UP FILE ______

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP-69444

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	AMPLIFIER CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	FILTER NO.	FREQ.	GAIN	CAL VOID DATE	SYSTEM A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	RECORDER CH. NO.	SENS. (E.U./DIV.)	COMMENTS
C59	20	124	AY05	ENDVECO	MG10 12625	9.43 MV/G	X= Y= Z=	29-JUN-90	Q10 9	10V R	212.09 V	100			ITH 20	50	1	23-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, B-END, C/L UNDERSIDE
C61	21	97	AZ06	ENDVECO	KY10 20491	12.22 MV/G	X= Y= Z=	29-JUN-90	Q11 10	10V R	163.67 V	100	39.8 MV 3.257G 6.514V		ITH 21	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, B-END, RIGHT C/L, MIDWAY
C63	22	98	AY06	ENDVECO	RW85 21524	9.564 MV/G	X= Y= Z=	3-JUL-90	Q12 11	10V R	209.12 V	100	39.3MV 4.109G 8.218V		ITH 22	50	1	23-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, B-END, RIGHT C/L, MIDWAY
D33	23	99	AZ07	ENDVECO	MR84 12630	9.31 MV/G	X= Y= Z=	29-JUN-90	Q13 12	10V R	214.82 V	100	39.5MV 4.243G 8.485V		ITH 23	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, CENTER, LEFT C/L, MIDWAY
D35	24	100	AY07	ENDVECO	NF15 12639	12.85 MV/G	X= Y= Z=	30-JUN-90	Q14 13	10V R	155.64 V	100	39.7MV 3.089G 6.179V		ITH 24	50	1	23-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, CENTER, LEFT C/L, MIDWAY
D37	25	101	AZ08	ENDVECO	LD24 20936	12.06 MV/G	X= Y= Z=	29-JUN-90	Q15 14	10V R	165.84 V	100	40.1MV 3.325G 6.650V		ITH 25	50	1	22-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, CENTER, RIGHT C/L, MIDWAY
D39	26	102	AY08	ENDVECO	MR29 12627	8.95 MV/G	X= Y= Z=	29-JUN-90	Q16 15	10V R	223.46 V	100	39.5MV 4.413G 8.827V		ITH 26	50	1	22-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, CENTER, RIGHT C/L, MIDWAY
D41	27	103	AZ09	ENDVECO	EY98 13580	22.91 MV/G	X= Y= Z=	24-JAN-91	Q17 16	10V R	87.30 V	100	39.7MV 1.733G 3.466V		ITH 27	50	1	22-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, A-END, LEFT C/L, MIDWAY
D43	28	104	AY09	ENDVECO	EY97 8834	25.05 MV/G	X= Y= Z=	23-JAN-91	Q18 17	10V R	79.84 V	100	39.7MV 1.585G 3.170V		ITH 28	50	1	22-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, A-END, LEFT C/L, MIDWAY
D45	29	105	AZ10	ENDVECO	GT42 13579	28.80 MV/G	X= Y= Z=	24-JAN-91	Q19 18	10V R	69.44 V	100	39.9MV 1.385G 2.771V		ITH 29	50	1	22-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, A-END, C/L TOP

NOTES:

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FC-MODAL DATE ______ W.O. 87560 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. ______ QA ______

SOFTWARE/VERSION xGNRL_AQ8A/MIF_FC RECORDER I.D. NO. HP-360 SET-UP FILE ______

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP-69444

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	AMPLIFIER CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	FILTER NO.	FREQ.	GAIN	CAL VOID DATE	SYSTEM A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	RECORDER CH. NO.	SENS. (E.U./DIV.)	COMMENTS
D47	30	106	AY10	ENDVECO	RH83 21510	20.92 MV/G	X= Y= Z=	25-JAN-91	Q20 19	10V R	95.60 V	100	39.9MV 1.907G 3.814V		ITH 30	50	1	22-JAN-91	0.0	0.5 G/V	G	3-6		LATERAL CAR BODY ACCEL, A-END, C/L TOP
D49	31	107	AZ11	ENDVECO	JQ78 9991	24.17 MV/G	X= Y= Z=	24-JUAN-91	Q21 20	10V R	82.75 V	100			ITH	50	1	22-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, A-END (3/4) C/L, TOP
D51	32	108	AY11	ENDVECO	JQ66 9990	19.36 MV/G	X= Y= Z=	24-JUAN-91	Q22 21	10V R	103.31 V	100			ITH	50	1	22-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, A-END (3/4) C/L, TOP
D53	33	109	AZ12	ENDVECO	FM79 8816	21.03 MV/G	X= Y= Z=	24-JUAN-91	Q23 22	10V R	95.10 V	100			ITH	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, CENTER (1/2) C/L, TOP
D55	34	110	AY12	ENDVECO	JQ54 9989	24.69 MV/G	X= Y= Z=	24-JUAN-91	Q24 23	10V R	81.00 V	100			ITH	50	1	23-JAN-91	0.0	0.5 G/V	G	3-7		LATERAL CAR BODY ACCEL, CENTER (1/2) C/L, TOP
D57	35	111	AZ13	ENDVECO	CW96 7091	10.91 MV/G	X= Y= Z=	28-JUN-90	Q25 24	10V R	183.32 V	100			ITH	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, B-END (1/4) C/L, TOP
D59	36	112	AY13	ENDVECO	HF67 13575	23.82 MV/G	X= Y= Z=	24-JAN-91	Q26 25	10V R	83.96 V	100			ITH	50	1	23-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, B-END, C/L TOP
D61	37	113	AZ14	ENDVECO	EH18 7084	9.30 MV/G	X= Y= Z=	29-JUN-90	Q27 26	10V R	215.05 V	100			ITH	50	1	23-JAN-91	0.0	0.5 G/V	G			VERTICAL CAR BODY ACCEL, B-END, C/L TOP
A15	38	114	AY14	ENDVECO	EZ49 13579	18.63 MV/G	X= Y= Z=	24-JAN-91	Q28 27	10V R	107.35 V	100			ITH	50	1	23-JAN-91	0.0	0.5 G/V	G			LATERAL CAR BODY ACCEL, B-END, C/L TOP
A1	39	65	AZ15	ENDVECO	RH68 21509	20.06 MV/G	X= Y= Z=	25-JAN-91	Q29 28	10V R	99.70 V	100	39.5 MV 1.969 G 3.938 V		ITH 39	50	1	23-JAN-91	0.0	0.5 G/V	G	1-5		VERTICAL CAR BODY ACCEL, RIGHT, NORTH ACTUATOR INTERFACE

NOTES:

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PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FC-MODAL DATE ______ W.O. 87560 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. ______ QA ______

SOFTWARE/VERSION xGNRL_AQ8A/MIF_FC RECORDER I.D. NO. HP-360 SET-UP FILE ______

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP-69444

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	AMPLIFIER CH. NO.	EXC. L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	FILTER NO.	FREQ.	GAIN	CAL VOID DATE	SYSTEM A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	RECORDER CH. NO.	SENS. (E.U./DIV)	COMMENTS
A3	40	66	AY15	ENDVECO	KR29 20937	12.80 MV/G	X= Y= Z=	29-JUN-90	Q30 29	10V R	156.25 V	100	39.9 MV 3.117 G 6.234 V		ITH 40	50	1	23-JAN-91	0.0	0.5 G/V	G	1-6		LATERAL CAR BODY ACCEL, RIGHT, NORTH ACTUATOR INTERFACE
A5	41	67	AZ16	ENDVECO	FP90 13582	17.24 MV/G	X= Y= Z=	24-JAN-91	Q31 30	10V R	116.01 V	100	39.6 MV 2.297 G 4.594 V		ITH 41	50	1	22-JAN-91	0.0	0.5 G/V	G	1-7		VERTICAL CAR BODY ACCEL, LEFT, SOUTH ACTUATOR INTERFACE
A7	42	63	AY16	ENDVECO	KE52 20942	12.44 MV/G	X= Y= Z=	29-JUN-90	Q32 31	10V R	160.77 V	100	39.8 MV 3.199 G 6.399 V		ITH 42	50	1	22-JAN-91	0.0	0.5 G/V	G	1-8		LATERAL CAR BODY ACCEL, LEFT, SOUTH ACTUATOR INTERFACE
	43	51	DZ01	MTS	21708		X= Y= Z=		MTS SOUTH 2	ACV	V				65 ITH 43	50	1	22-JAN-91	0.0	0.05 IN/V	INCH	1-3		VERTICAL ACTUATOR DISPLACEMENT, LEFT SOUTH, A-END
	44	52	DZ02	MTS	21709		X= Y= Z=		MTS NORTH 2	ACV	V				66 ITH 44	50	1	22-JAN-91	0.0	0.05 IN/V	INCH	1-4		VERTICAL ACTUATOR DISPLACEMENT, RIGHT NORTH, A-END
B33	45	55	DZ03	CELESCO	14233	0.94751 V/IN	X= Y= Z=	22-JUL-90	Q51 50	10V R	2.11 V	500	3.684 IN 7.369 V		67 ITH 45	315	1	22-JAN-91	0.0	0.5 IN/V	INCH			VERTICAL SPRING DISPLACEMENT, BOLSTER TO LEFT SIDE FRAME, TRK 2
B35	46	56	DZ04	CELESCO	10063	0.9383 V/IN	X= Y= Z=	28-JUL-90	Q52 51	10V R	2.13 V	500	3.670 IN 7.340		68 ITH 46	315	1	22-JAN-91	0.0	0.5 IN/V	INCH			VERTICAL SPRING DISPLACEMENT, BOLSTER TO RIGHT SIDE FRAME TRK 2
B41	47	58	DZ07	CELESCO	10071	0.94418 V/IN	X= Y= Z=	26-JUL-90	Q56 55	10V R	2.12 V	500	3.654 IN 7.308 V		69 ITH 47	315	1	22-JAN-91	0.0	0.5 IN/V	INCH	2-1		VERTICAL CAR BODY DISPLACEMENT, A-END LOWER, RIGHT TO GROUND
B43	48	59	DZ08	CELESCO	10075	0.94263 V/IN	X= Y= Z=	20-JUN-90	Q57 56	10V R	2.12 V	500	3.635 IN 7.270 V		70 ITH 48	315	1	22-JAN-91	0.0	0.5 IN/V	INCH	2-2		VERTICAL CAR BODY DISPLACEMENT, A-END LOWER, LEFT TO GROUND
B45	49	127	DZ09	CELESCO	10076	0.93878 V/IN	X= Y= Z=	20-JUN-90	Q58 57	10V R	2.13 V	500	3.647 IN 7.294 V		KI 1	31	1	16-JUL-90	0.0	0.5 IN/V	INCH	2-3		VERTICAL CAR BODY DISPLACEMENT, B-END LOWER, RIGHT TO GROUND

NOTES:

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PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME FC-MODAL DATE ______ W.O. 87560 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. ______ QA ______

SOFTWARE/VERSION xGNRL_AQ8A/MIF_FC RECORDER I.D. NO. HP-360 SET-UP FILE ______

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP-69444

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	AMPLIFIER CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. CAL VOID DATE	FILTER NO.	FREQ.	GAIN	CAL VOID DATE	SYSTEM A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	RECORDER CH. NO.	SENS. (E.U./DIV.)	COMMENTS
B47	50	128	DZ10	CELESCO	10079	0.9400 V/IN	X= Y= Z=	23-SEP-90	Q59 58	10V R	2.13 V	500	3.631 IN 7.261		RI 2	31	1	16-JUL-90	0.0	0.5 IN/V	INCH	2-4		VERTICAL CAR BODY DISPLACEMENT, B-END COVER, LEFT TO GROUND
B49	51	95	DZ11	CELESCO	10364	0.93074 V/IN	X= Y= Z=	22-JUL-90	Q60 59	10V R	2.15 V	500	3.592 IN 7.185 V		RI 3	31	1	16-JUL-90	0.0	0.5 IN/V	INCH			VERTICAL CAR BODY DISPLACEMENT, MIKKLE UNDER, C/L TO GROUND
B55	52	62	DZ14	CELESCO	14232	0.94768 V/IN	X= Y= Z=	30-JUL-90	R3 62	10V R	2.11 V	500	3.583 IN 7.165 V		RI 4	31	1	16-JUL-90	0.0	0.5 IN/V	INCH			VERTICAL BOLSTER DESPLACEMENT, A-END RIGHT, BOLSTER TO CAR BODY
B57	53	63	DZ15	CELESCO	10081	0.93758 V/M	X= Y= Z=	30-JUL-90	R4 63	10V R	2.11 V	500	3.657 IN 7.313 V		RI 5	31	1	16-JUL-90	0.0	0.5 IN/V	INCH			VERTICAL BOLSTER DISPLACEMENT, A-END LEFT, BOLSTER TO CAR BODY
	54	54	DY01	MTS	21708		X= Y= Z=		MTS SOUTH 2	ACV	V				RI 43	50	1	22-JAN-91	0.0	0.05 IN/V	INCH	1-3		LATERAL ACTUATOR DISPLACEMENT, LEFT SOUTH, A-END
B63	55	93	DY02	CELESCO	14240	4.7746 V/IN	X= Y= Z=	30-JUL-90	R7 66	10V R	2.09 V	500	.7091 7.091		RI 6	31	1	16-JUL-90	0.0	0.1 IN/V	INCH			LATERAL SPRING DISPLACEMENT, LEFT TRUCK 2, A-END, SOUTH
C33	56	53	DY03	CELESCO	14238	4.7537 V/IN	X= Y= Z=	30-JUL-90	R8 67	10V R	2.10 V	500	.7087 7.087 V		RI 7	31	1	16-JUL-90	0.0	0.1 IN/V	INCH			LATERAL SPRING DISPLACEMENT, RIGHT TRUCK 2, A-END, NORTH
C35	57	54	DY04	CELESCO	10367	0.94576 V/IN	X= Y= Z=	20-JUL-90	R12 71	10V R	2.11 V	500	3.586 IN 7.173 V		RI 8	31	1	16-JUL-90	0.0	0.5 IN/V	INCH	2-6		LATERAL CAR BODY DISPLACEMENT, A-END LOWER BEAM, RIGHT
C37	58	93	DY05	CELESCO	10074	0.94331 V/IN	X= Y= Z=	31-JUL-90	R10 69	10V R	2.12 V	500	3.629 IN 7.259 V		RI 9	31	1	16-JUL-90	0.0	0.5 IN/V	INCH	2-7		LATERAL CAR BODY DISPLACEMENT, CENTER LOWER BEAM, RIGHT
C39	59	126	DY06	CELESCO	10062	0.94309 V/IN	X= Y= Z=	23-SEP-90	R11 70	10V R	2.12 V	500	3.611 IN 7.223 V		RI 10	31	1	16-JUL-90	0.0	0.5 IN/V	INCH	2-8		LATERAL CAR BODY DISPLACEMENT, B-END LOWER BEAM, RIGHT

NOTES:

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PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-4200-FC
TRUCK CHARACTERIZATION -- AIR-BEARING TABLE TEST

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-4200-FC
TRUCK CHARACTERIZATION -- AIR-BEARING TABLE TEST

1.0DESCRIPTION

The purpose of this procedure is to outline the sequence of steps to conduct truck characterization tests on the Air-bearing Tables located in the Urban Rail Building (urb). The Truck Characterization Test consists of four sub-tests: Yaw Moment Test, Axle Alignment Test, Longitudinal Stiffness Test and Axle Yaw Stiffness Test.

1.1 INDEX

1.2 EQUIPMENT LIST

a.	6ea	Machinists Scale (0-48")
b.	2ea	Load Cell (10 KIP) with Accessories
c.	2ea	Celesco String Pot (+/- 5")
d.	2ea	Celesco String Pot (+/- 10")
e.	2ea	20 Kip Load Cell
f.	2ea	Enerpac Hydraulic Cylinder (6" throw) with Accessories
g.	2ea	Axle Spud kit
h.	1ea	String Pot Magnetic Bases
i.	4ea	Transit Square, Brunson Optical
j.	2ea	Machine Scale Support Stand
k.	2ea	Air-bearing Tables ((120"x82"x7.5")
l.	4ea	Air Compressor with Accessories (750 cfm)
m.	1ea	100-ton Jack (15" base)
n.	8ea	Chains and Clevis Kit
o.	1ea	Wheel Blocks (lead)

p.	10ea	6' Tape Measure
q.	8ea	Aluminium Sheets (12' X 4')
r.	2ea	Keepers, Axle
s.	1ea	Reacting Fixture
t.	2ea	X-Y-Y Plotter
u.	1ea	IBM PC with Metrabyte DAS 16F Card
v.	4ea	Actuator (20 kip)
w.	1ea	Signal Conditioners
a.a.	1ea	Caliper, Vernier, 80 inch
b.b.	1ea	Torque Wrench, TBD

1.3 FIGURE LIST

1.4 TABLE LIST

1.5 REFERENCE LIST

PKRG 2200....	Car Inspection Procedure
PKRG 3100....	Instrument Installation Procedure
M1001........	Manual of Standards and Recommended Practices, Section C, Part II, Volume I, Chapter XI
	TTC Operation Rules for the Test Transportation Test Center, Pueblo, Colorado, AAR, November 1, 1989.
	Peacekeeper Rail Garrison Test Implementation Plan, (for appropriate test car), Chapter XI testing
	TTC Safety Rule Book

1.6 REFERENCE DOCUMENTATION

1.6.1 Test Events Log

The Test Engineer will maintain a Test Events Log throughout the testing process. The log will be used to record;

a. Time of completion for each major phase of the test procedure.

b. Any unexpected or unusual circumstances, anomalies, or delays.

c. Any event that potentially impacts the validity of the evaluation or test results.

Upon completion of this procedure, the Test Events Log will be permanently filed in the appropriate case file.

1.6.2 Test Run Matrix

As test runs are completed, the Test Engineer will record the time of completion of each run on the Test Run Matrix. The Test Run Matrix will be placed in the appropriate case file upon completion of this procedure.

1.6.3 Test Configuration Data Sheet

The Test Configuration Data Sheet is produced by performance of Procedure PKRG-3100, Instrumentation Installation. It will be permanently filed in the appropriate case file upon completion of this test procedure.

1.6.4 Data Disk

Data will be developed in Lotus Spreadsheet format for each test. Copies of each disk will be provided to the ASCON.

1.6.5 Run Statistics Printout X-Y-Y Plots

X-Y Plots will be made in Lotus format during testing. Copies will be provided to ASCON.

1.6.6 Quality Control Checklist

The Quality Control Checklist will be completed and permanently filed in the appropriate case file upon completion of this procedure.

NOTE

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book.

2.0 YAW MOMENT TEST PROCEDURES

2.1 Test Setup

Perform the following steps to prepare test car for the Yaw Moment Test:

NOTE

Ensure all test equipment that requires calibration is current and in useable condition.

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Ensure test area is clean and secure from outside interference.	_______
2.1.2	Measure and record side bearing and bolster clearance. Ensure side bearing top to bolster is 5 1/16 +/- 1/16-inch. Ensure car is level.	_______
2.1.3	Position test car so that test end lead axle is centered on the center of the first reaction fixture (see Figure 2-1).	_______

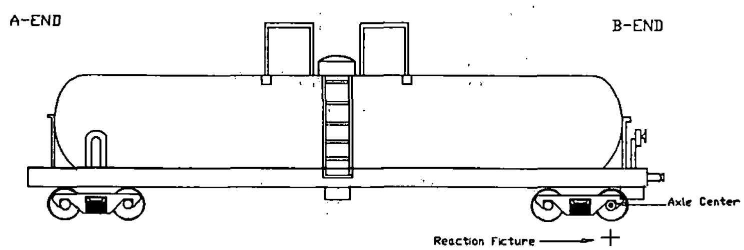


Figure 2-1 FC located at Reaction Fixture

2.1.4 Chock all non-test wheels. Disconnect hand brake chain and air brake line.

2.1.5 Using two 100-ton jacks at jacking pad, jack the test end of the test car with the truck chained up to the car test end.

2.1.6 Insert aluminum sheets beneath and around the test car, see Figure 2-2.

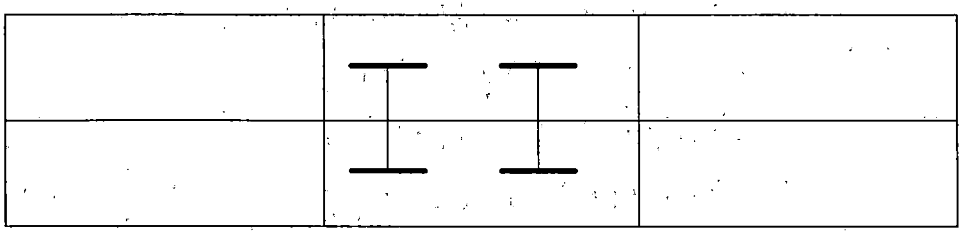


Figure 2-2 Aluminum Sheet Placement

2.1.7 Float air bearing table under car.

2.1.8 Place truck onto table see Figure 2-3.

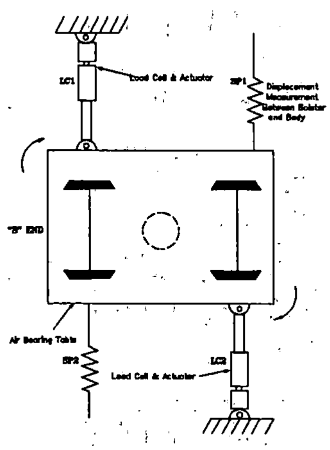


Figure 2-3 Truck Yaw Moment Test Setup

2.1.9 Ensure spring group is in its correct position.

2.1.10 Lower test car onto air bearing table, and remove jacks from test end of test car.

2.1.11 Level test car:

Step a. Apply air to air bearing table (float test end).

Step b. At test end of car measure from bottom of bolster (center) to floor.

Step c. At non-test end of car measure from bottom of bolster (center) to floor.

Step d. Adjust non-test end jacks so that non-test end height equals the test end height +/- 1/2-inch or insert Rail Height Adjusters under non-test end trucks.

2.1.12 Connect reaction fixtures to facility floor.

NOTE

Actuators must be in-line with lead and trail axle respectively.

2.1.13 Connect string pots, actuators and load cells between air bearing table and reaction fixtures.

2.1.14 Connect transducer cables (string pots and load cells) through signal conditioners to the Data Acquisition System (DAS).

2.1.15	Measure initial force at actuator for both tables. Ensure that actuators are at less than 500 lbs..	_______

NOTE

Do not re-zero Load Cells at this time.

2.2 Yaw Moment Test

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1.	Ensure initial pre-load on actuators is less than 500 lbs.. Mark initial table location if different than previous test.	_______
2.2.2	Start acquisition program, slowly apply force to actuators while observing X-Y plotter to ensure the force values rise together. The displacent will increase suddenly as the truck begins to rotate. At this point stop force application. Record break-away force and cross check with measurement acquired on PC.	_______
2.2.3	Realign truck using two come-a-longs.	
2.2.4	Repeat Steps 2.2.1 through 2.2.3 twice, record load cell readings in Test Events Log.	_______
2.2.5	Reconfigure actuators to repeat test in opposite direction. Steps 2.3.1 through 2.3.3.	
2.2.6	Repeat Steps 2.2.1 through 2.2.4	
2.2.7	Quality verify Yaw Moment Test is complete.	_______

2.3 Test Tear Down

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	Remove string pots and load cells with actuators.	
2.3.2	Lower non-test end of car, chock non-test end wheels, jack test end of car off of the Air Bearing Table.	
2.3.3	Apply air and float table away from car.	
2.3.4	Reverse Steps 2.1.5 through 2.1.14.	
2.3.5	Lower both jacks evenly from side to side. Attach cut lever and place Bad Order Tag on car for non-functioning brakes.	
2.3.6	Quality Assurance will verify test tear down is complete.	______

3.0 AXLE ALIGNMENT TEST

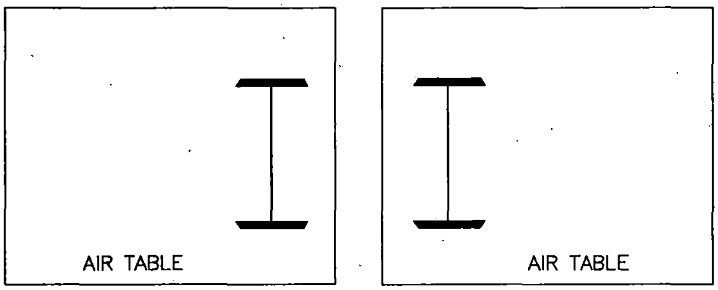
3.1 Test Setup

Perform the following steps to prepare test car for the Axle Alignment Test:

NOTE

Ensure all test equipment that require calibration is current and in useable condition

TASK NUMBER	PROCEDURE	QA INITIAL



Figur 3-1 Axle Alignment

3.1.1 Chain truck to car, chock non-test end wheels.

3.1.2 Jack up test end of car.

3.1.3 Position air bearing tables under test end truck (one table per axle). See Figure 3-1.

3.1.4 Lower test car onto the air bearing tables, and remove jacks from the test end of the car.

3.1.5 Ensure spring group is in its correct location.

3.1.6 Level test car and apply air to the air bearing tables (float test end).

3.2 Axle alignment test

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Position transit as illustrated in Figure 3-2, and set transit elevation to center of wheel. Float car and release air.	

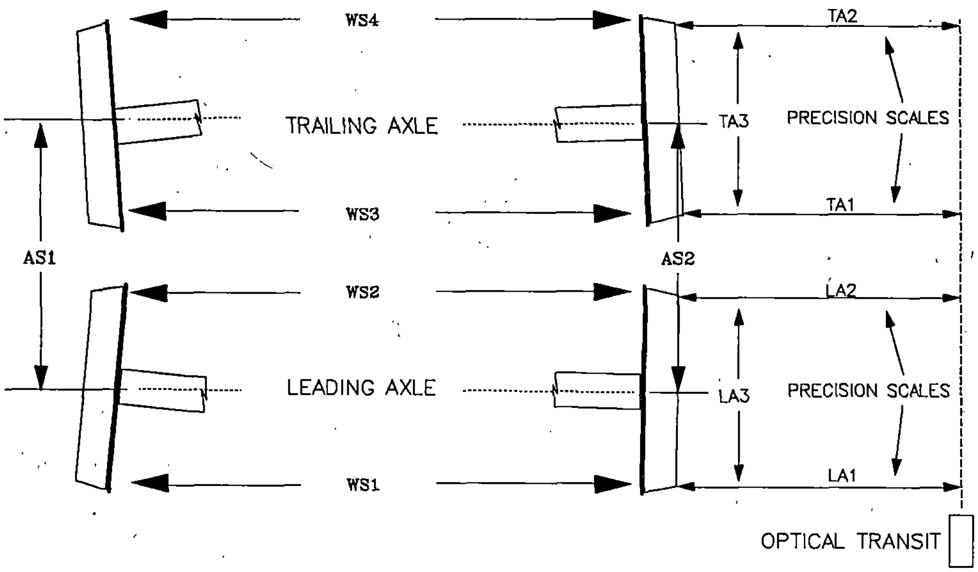


Figure 3-2 Axle Alignment Test Configuration

3.2.2	Mark a level with 4 lines, one pair at 20 inches and the other at 22 inches apart.	______
3.2.3	Trace the top of the level at the points on the wheel where the 20-inch marks lines up at the inside rim, yet remain level.	______
3.2.4	Measure back 1-inch from the inside rim and make a 1/4-inch long vertical line (at the 22-inch marks).	______
3.2.5	Place machinists scales in holders.	______

3.2.6 Place a scale and holder at each mark. The bottom of the scale should be at the horizontal line and the scale should be on the vertical line.

3.2.7 Ensure that the scales are square with the wheel by equating the diagonals (+/- 1/8-inch). ______

3.2.8 Repeat Steps 3.2.2 through 3.2.7 for axle #2.

CAUTION

End Caps should be re-torqued to 360 - 390 ft.-lbs..
DO NOT permit wheels to rotate while caps are off.

3.2.9 Remove End Caps on all four bearings.

3.2.10 Measure axle spacing on the both sides of the Truck with vernier calipers.

3.2.11 Measure inside wheel spacing for each axle. Take two measurements per axle.

3.2.12 Align Transit (rotationally) until front most and rear most rulers read within 1/100th of an inch of each other.

3.2.13 Read all scales to a 1/1000th of an inch and record them on the Data Sheet. ______

3.2.14 Reinstall end caps and torque to 360 - 390 ft/lbs. ______

3.2.15 Perform axle alignment test three times per truck. ______

3.3 Test Tear Down

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Remove scales and transit	______

4.0 LONGITUDINAL STIFFNESS TEST

4.1 Test Setup Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
4.1.1	Ensure Steps 3.1.1 through 3.1.5 have been complished.	______
4.1.2	Install Axle Spud Kit as illustrated in Figure 4-1 and in accordance with AAR Wheel Axle Manual, torque bolts to 360 - 390 ft.-lbs..	______

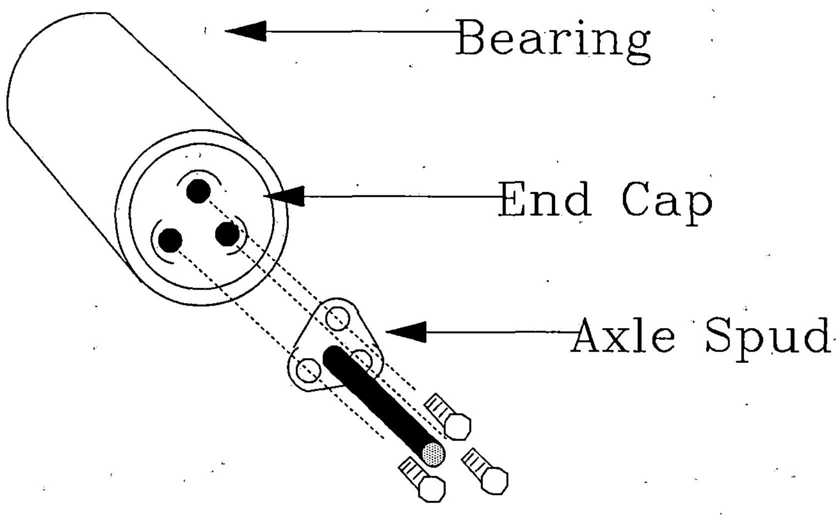


Figure 4-1 Axle Spud Kit Installation

CAUTION

Ensure axles do not rotate with End Caps removed.

4.1.2.1 Install actuators and string pots as illustrated in Figure 4-2. ______

4.1.2.2 Connect load cell and string pot cables to the signal conditioners and to the DAS.

4.1.2.3 C-clamp and shim bar (actuator and loadcell) to the truck to prevent any motion other than linear.

4.1.2.4 Check zero and RCAL on each load cell, check excitation and zero stringpots.

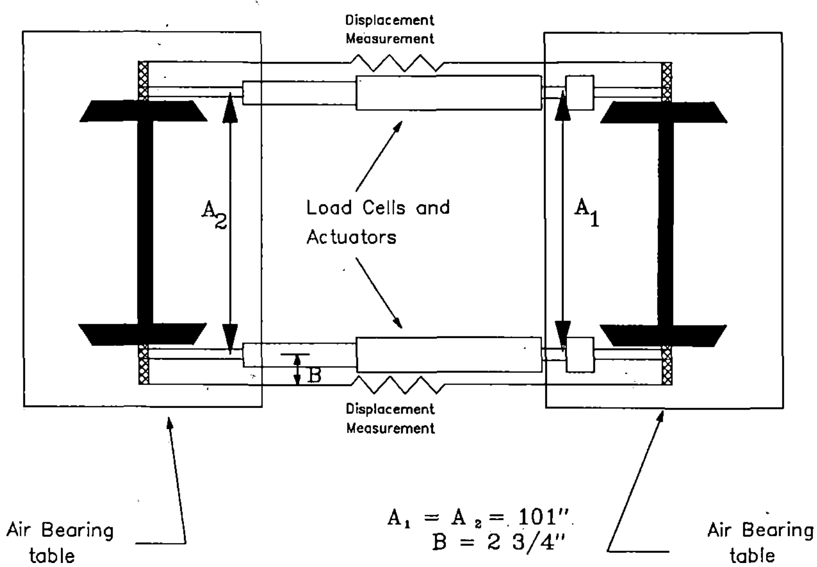


Figure 4-2 Longitudinal Stiffness, Axle Yaw and, Inter-axle Bending Test Setup

4.2 Longitudinal Stiffness Test

TASK NUMBER	PROCEDURE	QA INITIAL
4.2.1	Start Test with whatever force exists in the load cells and actuators, providing the force is less than 400 lbs.. DO NOT re-zero the load cells.	________
4.2.2	Start Data Acquisition Program	

WARNING

Do not exceed a maximum force of 20,000 lbs.

4.2.3	Continue applying tension load until force versus displacement is no longer linear, refer to Figure 4-3.	________

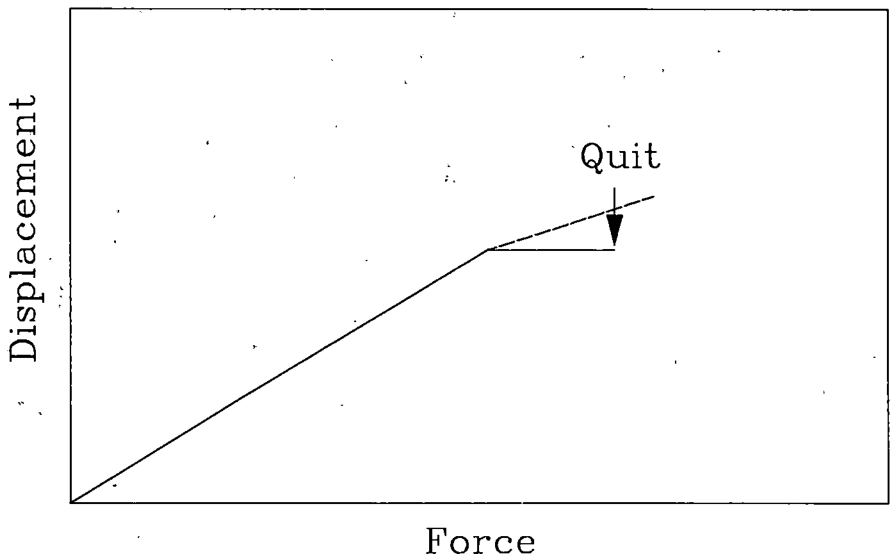


Figure 4-3 Force Versus Displacement Sample

4.2.4 Ensure axle is centered in pedestal before proceeding with testing, by, allowing axles to come to rest in their normal position. Repeat test two additional times. _______

4.2.5 Reverse actuators and repeat Stepss 4.2.1 through 4.2.3 three times. _______

4.3 Test Tear Down

TASK NUMBER	PROCEDURE	QA INITIAL
4.3.1	Test tear down is not required at this point in order to continue this Truck Characterization Test.	

5.0 AXLE YAW AND INTER-AXLE BENDING STIFFNESS TEST

5.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
5.1.1	Check zero and RCAL of each channel before testing.	_______
5.1.2	Ensure trucks are unchained.	

5.2 Axle Yaw and Inter-axle Bending Stiffness Test

TASK NUMBER	PROCEDURE	QA INITIAL
5.2.1	Apply a compressive load to actuator #1 and a tensile load to actuator #2. The same pre-loading as Step 4.2.1 should be used Force will be applied at separate rates through the same pump.	_______

5.2.2 Start Data Acquisition Program.

5.2.3 Continue applying force to both actuators until force versus displacement is no longer linear as illustrated in Figure 4-3 ______

5.2.4 Repeat test two times and record data.

5.2.5 Reverse hydraulic pump and repeat Steps 5.2.1 through 5.2.4. ______

5.3 Test Tear Down

TASK NUMBER	PROCEDURE	QA INITIAL

CAUTION

Torque End Cap Bolts to 360 - 390 ft.-lbs.

5.3.1 Remove actuators, load cells, string pots, and spud kit. ______

5.3.2 Apply end plates with new information and torque bolts to 360 - 380 ft.-lbs. Record torque Serial # ______________ ______

6.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
6.1	Quality verified that PKRG-4200-FC is complete and closed.	
6.2	Authorized QA signature________________________________.	

TABLE LIST 1

AIR BEARING TEST MEASUREMENT LIST

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 1 OF 2

TEST NAME TRUCK ROTATION DATE JUNE 90 W.O. A5B300 LOC. URB AIR TABLES
INSTR. ENGR./TECH. BRABB TEST ENGR. BRABB QA K. FELLER
SOFTWARE/VERSION ______ RECORDER I.D. NO. ______ SET-UP FILE ______
SAMPLE RATE ______ ENCODER/DIGITIZER I.D. NO. ______

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	TRANSDUCER S.N.	TRANSDUCER SENS.	TRANSDUCER LOC.	TRANSDUCER CAL VOID DATE	AMPLIFIER CH. NO.	AMPLIFIER EXC.-L/R	AMPLIFIER GAIN FIX/VAR	AMPLIFIER R-CAL RES.	AMPLIFIER CAL. E.U. & VOLTS	AMPLIFIER S.N. / CAL VOID DATE	FILTER NO.	FILTER FREQ.	FILTER GAIN	FILTER CAL VOID DATE	SYSTEM A0 (E.U.)	SYSTEM A1 (E.U./VOLT)	SYSTEM ENGR. UNITS	RECORDER CH. NO.	RECORDER SENS. (E.U./DIV.)	COMMENTS
		1	LC1	Interface	8875	.4024 V/KIP	X= Y= Z=	9-16-90	1	10 VDC	100F		7.257K 2.92V	14855 / 9-23-90	H	15	1	9-23-90						LEFT SIDE 10K LOAD CELL
		2	LC2	Interface	7861	.41104 V/KIP	X= Y= Z=	9-15-90	2	10 VDC	100F		7.155K 2.94V	14901 / 9-29-90	H	15	1	9-29-90						RIGHT SIDE 10K LOAD CELL
		3	SP1	Celesco	A46550	.474 V/IN	X= Y= Z=	10-23-90	3	10 VDC	1F			14953 / 10-12-90	K	15	1	10-12-90						LEFT SIDE 20' STRING POT
		4	SP2	Celesco	A45654	.473 V/IN	X= Y= Z=	10-23-90	4	10 VDC	1F			14858 / 9-28-90	K	15	1	9-28-90						RIGHT SIDE 20' STRING POT
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	

NOTES:

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PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 2 OF ____

TEST NAME LONGITUDINAL STIFFNESS DATE JUNE 90 W.O. A5B300 LOC. URB AIR TABLES

INSTR. ENGR./TECH. BRABB TEST ENGR. BRABB QA K. FELLER

SOFTWARE/VERSION ____ RECORDER I.D. NO. ____ SET-UP FILE ____

SAMPLE RATE ____ ENCODER/DIGITIZER I.D. NO. ____

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER					AMPLIFIER						FILTER				SYSTEM			RECORDER		COMMENTS
				MFG.	S.N.	SENS.	LOC.	CAL VOID DATE	CH. NO.	EXC.-L/R	GAIN FIX/VAR	R-CAL RES.	CAL. E.U. & VOLTS	S.N. / CAL VOID DATE	NO.	FREQ.	GAIN	CAL VOID DATE	A0 (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	CH. NO.	SENS. (E.U./DIV.)	
		1	LC1	Interface	8875	.4024 V/KIP	X= Y= Z=	9-16-90	1	10 VDC	100F		7.257K 2.92V	14855 9-23-90	H	15	1	9-23-90						LEFT SIDE 10K LOAD CELL
		2	LC2	Interface	7861	7861 V/KIP	X= Y= Z=	9-15-90	2	10 VDC	100F		7.155K 2.94V	14901 9-29-90	H	15	1	9-29-90						RIGHT SIDE 10K LOAD CELL
		3	SP1	RI	1675	4.5416 V/IN	X= Y= Z=	9-20-90	3	10 VDC	1F		-1.1 IN 4.996V	14953 10-12-90	K	15	1	10-12-90						LEFT SIDE 20' STRING POT
		4	SP2	RI	3681	4.8332 V/IN	X= Y= Z=	8-15-90	4	10 VDC	1F		.187 IN .904 V	14858 9-28-90	K	15	1	9-28-90						RIGHT SIDE 20' STRING POT
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	

NOTES:

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PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-6000-FC
SERVICE WORTHINESS TEST

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-6000-FC
SERVICE WORTHINESS TEST

1.0 DESCRIPTION

This procedure outlines the sequence of steps to conduct service worthiness tests on the Peacekeeper Rail Garrison Fuel Car (FC). The Service Worthiness Test consists of the Curve Stability Test.

1.1 INDEX

1.2 EQUIPMENT LIST

a. 1 ea Generator, Portable Model 30KW

b. 1 ea Instrumented Coupler (200,000)

c. 1 ea Strain Gage, Daytronic 3270

d. 1 ea X-Y Recorder

e. 4 st Wheel Chocks

f. 1 ea 100-Ton Hopper Car (modified)

g. 1 ea Coupler Adapter (Squeeze Fixture)

h. 1 ea Hewlett Packard (HP) 300 Series Data Acquisition System

i. 20 2702 Instrum Signal Conditioner

j. 1 ea Western Graphic Strip Chart or Equivalent

k. 2 ea Feeler Gages

1.3 FIGURE LIST

1.4 TABLE LIST

None

1.5 REFERENCE LIST

None

1.6 ATTACHMENTS

1 Test Measurement List

NOTE

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book.

2.0 CURVE STABILITY TEST

2.1 Test Setup

NOTE

The test car will be in the unloaded condition for the following test.

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Place the test car in a consist as illustrated in Figure 2-1.	

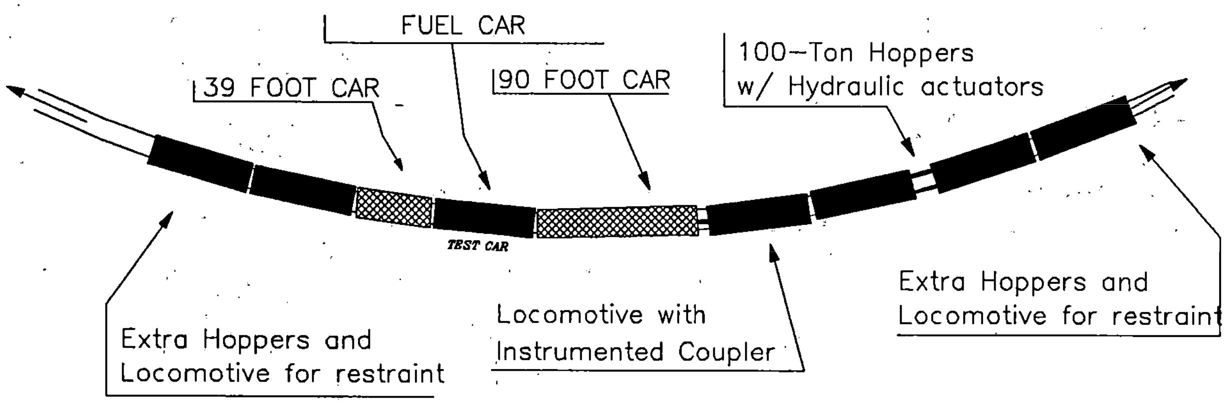

Figure 2-1 Curve Stability Test Facility

2.1.2	The consist will be placed on the South Wye of the Urban Rail Building access track.	

2.1.3 Quality verify proper setup for the Curve Stability Test. ______

2.2 Instrumentation Installation, Calibration and Operation

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Refer to the Test Measurement List (Attachment 1) for instrumentation installation location.	
2.2.2	Refer to Procedure PKRG-3100 for completing the Test Configuration Data Sheet.	
2.2.3	Instrumented Coupler Setup.	
2.2.3.1	Monitor the signal conditioner excitation to the transducer for a minimum of five minutes.	
2.2.3.2	Verify that the 3270 indicator switch, located on the rear panel, is set to 20,000.	______
2.2.3.3	Verify that the display switches 1,2,3, and 6 are closed.	______
2.2.3.4	Verify that the display switches 4 and 5 are open.	______
2.2.3.5	Adjust the course and then the fine balance potentiometers for 0.00 on the display indicator.	

2.2.3.6 Calculate shunt calibration reading using the following formula:

$$X = \frac{2500 R_b}{K(R_c + R_b)}$$

X = Indicator Reading
R_b = Bridge Resistance (typical 350 ohm)
K = mV/V Sensitivity
R_c = Shunt Cal Resistor Value (29.88 K typical)

Typical X (96.5 % or 193 K)

2.2.3.7 Adjust the course and then the fine span to the value calculated in Step 2.2.3.6.

2.2.3.8 Repeat Steps 2.2.3.5 and 2.2.3.6 as necessary.

2.2.4 X-Y Recorder Setup

2.2.4.1 Connect the output of the 3270 to the Y input of the X-Y recorder.

2.2.4.2 Set the X axis to the time mode at 50 sec per CM rate.

2.2.4.3 Adjust the Y axis zero to the first major division on the chart paper.

2.2.4.4 Depress the Cal button on the 3270 conditioner and adjust the Y axis span for five major divisions of deflection.

2.2.4.5 Repeat Steps 2.2.4.3 and 2.2.4.4 as necessary.

2.2.4.6 Quality verify installation and calibration is complete. ________

2.3 Curve Stability Testing

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	With the test consist positioned at the Curve Stability Test site as outlined in Section 2.1 and the instrumentation operating as outlined in Section 2.2, begin applying a buff load (compressive) using the actuators illustrated in Figure 2-1.	
2.3.2	Continue applying the buff load until a maximum load of 100,000 lbs. is applied.	
2.3.3	The test car will be held in place for a 20 second sustained duration while under the maximum load (+5000 -0 lbs).	
2.3.4	The test car will be monitored for the following conditions: wheel lift, any separation of the trucks and car body.	
2.3.4.1	Check wheel lift with feeler gauges. Wheel lift should not exceed 1/8-inch when measured 2 5/8-inch from the rim face at the inside of curve for buff and outside for draft.	
2.3.4.2	Repeat Steps 2.3.2 through 2.3.4.1 applying buff load to 200,000 lbs.	
2.3.5	Reverse the X-Y recorder and install new paper.	

2.3.6 Repeat Steps 2.3.1 through 2.3.4.2 using a draft (tensile) load.

2.3.7 Quality verify that the Curve Stability Test is complete. ______

3.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
3.0.1	Quality verify that PKRG 6000-FC is complete and closed.	
3.0.2	Authorized QA signature ______________________________.	

ATTACHMENT 1

TEST MEASUREMENT LIST

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 1 OF ____

TEST NAME FC CHAPTER XI SW DATE 6-12-90 W.O. 87560 LOC. ____
INSTR. ENGR./TECH. ____ TEST ENGR. BRABB QA ____
SOFTWARE/VERSION ____ RECORDER I.D. NO. ____ SET-UP FILE
SAMPLE RATE ____ ENCODER/DIGITIZER I.D. NO. ____

INST INIT	DAS CH	PP CH	MEAS. CODE	TRANSDUCER MFG.	TRANSDUCER S.N.	TRANSDUCER SENS.	TRANSDUCER LOC.	TRANSDUCER CAL VOID DATE	AMPLIFIER CH. NO.	AMPLIFIER EXC.-L/R	AMPLIFIER GAIN FIX/VAR	AMPLIFIER R-CAL RES.	AMPLIFIER CAL. E.U. & VOLTS	AMPLIFIER S.N. / CAL VOID DATE	FILTER NO.	FILTER FREQ.	FILTER GAIN	FILTER CAL VOID DATE	SYSTEM A0 (E.U.)	SYSTEM A1 (E.U./VOLT)	SYSTEM ENGR. UNITS	RECORDER CH. NO.	RECORDER SENS. (E.U./DIV.)	COMMENTS
	1	1	02N	MINER	24	1.5017 mv/v	X= Y= Z=	2-3-91	1	5V	1000 FIX	19.88	1.009 K lbs 7.5 v			360 Hz	1		0	133.2 K	lbs			ANVIL CAR COUPLER
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
							X= Y= Z=																	
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NOTES:

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PEACEKEEPER RAIL GARRISON
TEST PLAN FOR STATIC TESTING OF BRAKE SYSTEMS ON INDIVIDUAL CARS AND LOCOMOTIVES PROCEDURE

PEACEKEEPER RAIL GARRISON
TEST PLAN FOR STATIC TESTING OF BRAKE SYSTEMS ON INDIVIDUAL CARS AND LOCOMOTIVES
PROCEDURE

1.0 DESCRIPTION

This procedure outlines the sequence of tests to provide reasonable assurance that the train brake system will perform as intended, providing satisfactory slowdown, stopping ability and able to hold the train stationary on level or expected track gradients. These tests include static (vehicle standing) tests of the air brake system to ensure compliance with existing AAR and FRA rules and regulations. Other tests are conducted other than those that are strictly in accordance with AAR and FRA rules to ensure the brake system on each car will be compatible and perform as uniformly as possible when coupled together.

1.1 INDEX

1.2 EQUIPMENT LIST

a.	1ea.	Standard AAR Single Car Test Device for Freight
b.	as needed	FS-5 Plugged Dummy Hose Coupling With Double #80 Choke
c.	as needed	LS-5 Plugged Dummy Coupling
d.	2ea.	0-160 psi or 0-200 psi 3-1/2" Dia. Air Brake Test Air Gauges
e.	1ea.	1/8" Wire Braided armored Hoses 18" Long
f.	1ea.	Filling piece 1/16-3/32"
g.	2 sets	Four Strain Gaged "JIM SHOES"
h.	as needed	Batteries
i.	1ea.	Portable Bellofram Adjustable Control Air Valve
j.	1ea	Hose 1/8" or 1/4" of Ample Size
k.	2ea.	3 Lb. Blacksmith Hammers
l.		All Safety Equipment As Required By TTC

1.3 FIGURE LIST

1.4 TABLE LIST

None

1.5 REFERENCE LIST

PRKG 2100....	Truck Inspection Procedure
PKRG 3100....	Instrument Installation Procedure
M1001........	Manual of Standards and Recommended Practices, Section C, Part II, Volume I, Chapter XI
	TTC Operation Rules for the Transportation Test Center, Pueblo, Colorado, AAR, November 1, 1989.
	Peacekeeper Rail Garrison Test Implementation Plan, (for appropriate test car), Chapter XI Testing
	TTC Safety Rule Book
	AAR Single Car Test Code (IP No. 5039-4 Sup. 1)
	Canadian Pacific Instructions and Methods

1.7 ATTACHMENT LIST

None

NOTE

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book.

2.0 CAR AIR AND HANDBRAKE SYSTEM

2.1 Material and Equipment Requirements

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	<u>IN DATE</u> Standard AAR Single Car Test Device for Freight, complete with FS-5 FS-5 hose coupling with double #80 choke.	
2.1.1.1	LS-5 dummy coupling, plugged, to insert at brake pipe hose at end car brake pipe hose coupling.	
2.1.2	Two 0-160 psi or 0-200 psi 3-1/2" dia. Air Brake Test air gauges each attached to a 1/8" wire braided armored hoses approximately 18" long with a very thin filling piece (1/16" - 3/32") to insert between brake cylinder pipe or reservoir pipe flange fitting and flange fitting mounting bracket, in order to read pressure in these pipes, see Figure 2.1.	

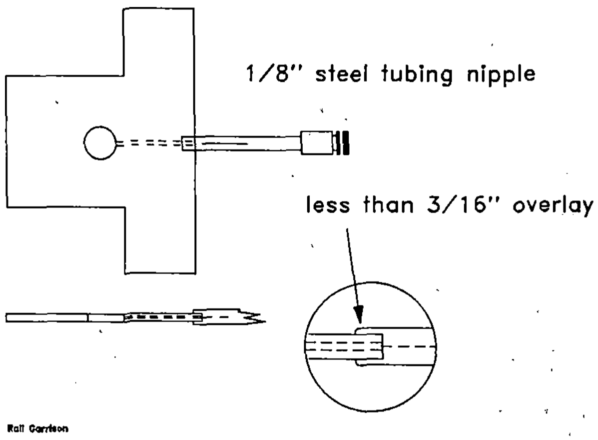

Figure 2.1 Weld Setup

2.1.3 One, preferably two, sets of four strain gaged "JIM SHOE". They are the type of calibrated brake shoes for measuring actual brake shoe force during various applications of the brakes. These sets should be complete with electronic direct readout of brake shoe force.

2.1.4 New batteries to be installed with spares available.

2.1.5 Portable Bellofram adjustable control air valve with suitable air supply.

2.1.6 Delivery hoses (1/8" or 1/4" size) of ample length to vary and control brake cylinder pressure during calibrated shoe force tests.

2.1.7 One, preferably two, 3-lb. Blacksmith's hammers to perform rapping during calibrated brake shoe tests.

2.1.8 Currently effective copy of AAR Single Car Test Code booklet, IP No. 5039-4 Sup. 1. This is AAR STANDARD S-486.

2.2 Single Car Test On Cars

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Install Test air gage filling piece and hose in brake cylinder pipe associated with each ABDW control valve.	
2.2.2	If car has two ABDW control valves, one on each span bolster controlling only the brake cylinders on the two four wheel trucks. Separate brake cylinders on the two four wheel trucks and separate brake pipe length into two sections, if possible, when testing for control valve performance.	

2.2.3 Measure the effective brake pipe length on the control valve being tested or use the complete run of brake pipe through car, measuring and recording the total length including end hose.

2.2.4 Cut out and drain the other ABDW control valve, its auxiliary and emergency reservoirs.

2.2.5 Follow applicable tests in AAR Single Car Test Code, IP No. 5039-4 Sup. 1, Test 3.1.

2.2.6 Attach single car tester to the brake pipe end hose on the car on which the control valve being tested is located.

2.2.7 Install plugged FS-5 dummy coupling at rear end or opposite end of brake pipe hose after determining that air is flowing freely from "rear end" with single car tester in #1 or release position (AAR Single Car Test Code, IP No. 5039-4 Sup. 1), Test 3.1.3.

2.2.8 Cut out the operative ABDW control valve, completely drain its reservoirs and proceed with Test 3.2 to determine brake pipe leakage.

2.2.9 If car does not pass this test, inspect complete length of brake pipe and hoses using soap suds or acceptable leak detector fluid. Correct leakage found.

2.2.10 If there are no detectable or significant leaks in the brake pipe, angle cocks or hoses. Pull reservoir release rod and hold it open to see if there is any air pressure in reservoirs. Do this for the first control valve and then for the other control valve. If there is pressure now it indicates a leaking 1" branch pipe cut out cock.

2.2.10.1 Change out 1" branch pipe cut out cock and dirt collector assembly as required with a new one or one known to be in good condition.

2.2.10.2 Repeat Test 3.2 to ensure BP leakage is satisfactory.

2.2.11 If car is equipped with an A-1 Reduction Relay Valve or an Emergency Brake Pipe Vent perform AAR Single Car Test Code, IP No. 5039-4 Sup. 1, Test 3.3.

2.3 Hand Brake Inspection

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	Chock wheels so car will not roll.	
2.3.2	Determine that shoes connected to handbrake release have effective force on them.	
2.3.3	Release handbrake.	
2.3.4	Check that the chain is "loose" but still is in line with sheave wheels and not jam or foul when reapplied.	

2.4 System Leakage Test

TASK NUMBER	PROCEDURE	QA INITIAL
2.4.1	Cut in ABDW control valve on end nearest single car tester and allow to charge.	
2.4.2	Leave other ABDW control valve cut out with its reservoirs drained.	

2.4.3	Perform AAR Single Car Test Code, IP No. 5039-4 Sup. 1, Test 3.5.	
2.4.4	When test is satisfactory proceed with remainder of applicable tests on ABDW control valve at this end of car.	

2.5 Piston Travel And Rigging

TASK NUMBER	PROCEDURE	QA INITIAL
2.5.1	Perform AAR Single Car Test Code, IP No. 5039-4 Sup. 1, Test 3.6.	
2.5.2	When making this test make service BP reduction carefully, noting the brake pipe pressure at which service brake cylinder pressure (BCP) reaches its maximum. Record these values.	
2.5.3	Brake cylinder pressure must be between 48 and 52 psi with reduction made accurately, set and fully charged 70 psi in system.	
2.5.4	Check piston travel on all brake cylinders controlled by this ABDW valve.	
2.5.5	If brake cylinder pressure is outside the 48 to 52 psi range try resetting piston travel to bring BCP within this range.	

2.6 Minimum Application And Brake Cylinder Leakage And Slow Release

TASK NUMBER	PROCEDURE	QA INITIAL
2.6.1	Perform AAR Single Car Test Code, IP No. 5039-4 Sup. 1, Tests 3.7 and 3.8 in accordance with the effective BP length on the car.	

2.6.2 Following successful passing of Test 3.7 and 3.8 recharge the equipment.

2.6.3 Make approximately 10 psi BP reduction by reducing the setting of the reducing valve on the single car test device.

2.6.4 Note brake cylinder and brake pipe pressure and monitor this for 10 minuets. Pipe pressure should remain steady.

2.6.5 Increase in BCP over appx. 2 psi and particularly if it is a steady rise, which may mean there is brake pipe pressure leaking into brake cylinder, probably past quick service limiting valve "O" rings in the service portion.

2.6.6 If brake pipe pressure leaking occurs, the service portion will have to be changed out and a new or COT'D portion applied.

2.6.8 If there is brake pressure leaking recharge equipment and repeat Tests 3.5, 3.6, 3.7 and 3.8.

2.7 Service Stability, Emergency, Release After Emergency ABDW Application And Manual Release Valve Tests

TASK NUMBER	PROCEDURE	QA INITIAL
2.7.1	Perform The following Test(s): Service Stability, Emergency, Release After Emergency ABDW Application and Manual Release Valve as per AAR Single Car Test Code, IP No. 5039-4 Sup. 1. 1.	
2.7.2	Record the emergency equalization pressure and the piston travel at each brake cylinder.	

2.8 Tests On Second ABDW Control Valve (If Equipped)

TASK NUMBER	PROCEDURE	QA INITIAL
2.8.1	On car equipped with a second ABDW valve and second set of brake cylinders cut out the first control valve previously tested and drain its reservoirs completely.	
2.8.2	Cut in the second ABDW on the span bolster at other end of car.	

NOTE

It will not be necessary to preform the BP leakage test or auxiliary brake pipe reduction device tests if the complete BP was previously tested.

TASK NUMBER	PROCEDURE	QA INITIAL
2.8.3	Repeat Sections 2.4 - 2.7.	

3.0 NET SHOE FORCE TESTS WITH CALIBRATED BRAKE SHOES

TASK NUMBER	PROCEDURE	QA INITIAL
3.0.1	Arrange to introduce pressure into brake cylinder pipe independently from the ABDW control valve(s).	
3.0.2	A thin piece of shim stock should be used to blank off the brake cylinder pipe (#3 port) at the AB pipe bracket.	
3.0.2	The bellofram adjustable reducing valve should be connected to the single car tester supply line and the delivery hose into the tee under the test air gage hose assembly. The supply pressure should be 90 to 100 psi.	

3.0.3 Remove brake shoes and install a "JIM SHOE" in each brake head key bridge.

3.0.4 Follow "JIM SHOES" instruction for zeroing and calibrating the circuits of the electronic readout device.

3.0.5 Make actual ("net") shoe force readings at the following pressures, set with the Bellofram adjustable reducing valve:

* 10 psi, 20 psi, 30 psi and 40 psi actual service equalization pressure from 70 psi, 80 psi and 80 psi.

NOTE

Do not back off or reduce pressure if actual turns out a psi or too different from that desired. Use the pressure attained such as 22 or 43 psi and make all force reading at this particular pressure.

3.0.6 Make a full set of pressure and force readings with the rigging at each truck rapped with the 3-lb blacksmith's hammer.

3.0.7 Hit each pin or clevis joint on each side of brake beam not more than three times.

3.0.8 Following this release of BCP, reapply to the specific service equalization pressure previously determined and make accrual force readings without rapping the rigging.

3.0.9 Calculate the efficiency of the rigging on each truck and the Net Braking Ratio (NBR) of the service equalization pressure at 50 psi.

NOTE

These overall values @ 50 psi on the total gross weight of the car should not be over 10% and must not be less than 6.5%. At empty weight of the car the NBR must not exceed 30% @ 50 psi.

4.0 HAND BRAKE NET SHOE FORCE TESTS

TASK NUMBER	PROCEDURE	QA INITIAL
4.0.1	Install suitable load cell or Strain Sert pin, preferably in the vertical chain coming down out of the geared hand brake or the closest horizontal chain.	
4.0.2	Install Strain Sert pins at the delivery end pin of each TMB hand brake lever (Ellcon National) or the hand brake clevis connection to the BC push rod Thrall TMB.	
4.0.3	Apply geared hand brake to its specified vertical chain force or slightly above if exact force cannot be obtained.	
4.0.4	Make net shoe force reading on each "JIM SHOE": 1. Without rapping rigging. 2. With rapping reading.	
4.0.5	If force is above specified vertical chain force release and reapply to a force somewhat less and repeat Steps 4.0.3 - 4.0.4	
4.0.6	Handbrake net braking ratio must be a minimum of 11% of the gross rail load of the complete vehicle. Preferably the empty weight net braking ratio should not be more than 50% of the empty weight on the handbrake trucks.	

5.0 TESTS OF LOCOMOTIVE BRAKE SYSTEM

5.1 Basic Braking Ratio Of Locomotive

TASK NUMBER	PROCEDURE	QA INITIAL
5.1.1	Determine the leverage ratio associated with each brake cylinder.	
5.1.2	Determine the size of each brake cylinder.	
5.1.3	Check lever lengths and compare with locomotive builder recommendations/specifications.	
5.1.4	The above Step 5.1.2 may require removing and measuring one truck side set of levers. Then hopefully comparative outside measuring points can be found so that the others can be checked.	
5.1.5	The condition of the pins and bushings should be carefully inspected on the locations where parts are removed.	
5.1.6	Worn or broken pins and bushings should be replaced in the truck frame, levers and brake head assemblies.	
5.1.7	Apply independent brake making sure that all shoes are line up with and contact the normal tread of each wheel.	
5.1.8	If a shoe overhangs the outside rim of a wheel, release brake and push rigging laterally to determine if pins and bushings are worn. Remedy the situation.	

CAUTION

Overhanging shoes are a Federal defect.

5.1.9 With the weight of locomotive known, either light, with fuel or with supplies ready to run, calculate the gross braking ratio of the locomotive @ 50 psi.

5.1.10 If locomotive is equipped with a J-1.6-16 brake cylinder relay, calculate gross braking ratio at 80 psi BCP and for independent brake at 50 psi Independent and Release Pipe pressure.

NOTE

Normally these should be in the range of 26-28% @ 80 psi with AAR high friction composition shoes.

5.2 Net Shoe Force Tests

TASK NUMBER	PROCEDURE	QA INITIAL
5.2.1	With rigging installed and operable with independent brake valve, remove brake shoes and install calibrated "JIM SHOES" at the location controlled by each brake cylinder on the truck.	
5.2.2	Make actual or net shoe force reading each 10 psi up to 80 psi with rigging rapped.	
5.2.3	Make unrapped tests at 30, 50 and 80 psi.	
5.2.4	Calculate rigging efficiency and determine net braking ratios.	

5.2.5 On front truck or that equipped with handbrake, arrange to install Strain Sert pin or load cell preferably in vertical chain and apply handbrake to manufactures specified force.

5.2.6 Make "JIM SHOE" reading of actual shoe force at each shoe operated by the handbrake mechanism. DO NOT rap the rigging.

5.2.7 Calculate net braking ratio.

5.3 Air Brake System Tests

TASK NUMBER	PROCEDURE	QA INITIAL
5.3.1	Ensure that all cab air gages are checked and meet master air gauge within + or - psi.	

5.4 Main Reservoir Pressures And Leakage

TASK NUMBER	PROCEDURE	QA INITIAL
5.4.1	Partially open main reservoir (MR) drain cock in 2nd main reservoir and note the pressure where the Compressor Control Switch (CCS) causes the air compressor to "cut-in" and start pumping. This should be between 125 and 130 psi. Note the pressure where the CCS causes the air compressor to "cut out" and stop pumping at between 135 and 145 psi.	
5.4.2	Install LS-5 plugged dummy coupling at front and rear MR hose couplings.	
5.4.3	Open MR cut out cocks (usually reachable through end steps).	

5.4.4 Close MR drain cock tightly and deactivate automatic drain valves.

5.4.5 Close MR cut out cock leading to brake equipment, generally downstream from air filter.

5.4.6 When compressor next cuts out, stop the diesel engine.

5.4.7 Measure the amount of MR pressure drop for three minutes. Maximum allowed pressure drop is 9 psi or 3 psi per minute average. If greater than this locate source (s) of leakage and eliminate.

5.4.8 Restart engine and repeat Steps 5.4.2 - 5.4.7.

5.4.9 Close MR cut out cocks at front and rear.

5.4.10 Remove LS-5 Dummy Couplings.

5.4.11 Restart engine and continue with tests.

5.5 Brake Pipe Leakage Test

TASK NUMBER	PROCEDURE	QA INITIAL
5.5.1	Install FS-5 dummy couplings in front and rear BP end hose coupling.	
5.5.2	Open angle cocks or 1-1/4" cut out cocks (reachable through end steps).	

5.5.3 Check and set 26-C automatic brake valve (ABV) BP regulating valves if necessary to 90 psi as read on BP cab air gauge.

5.5.4 Allow time for BP pressure to readjust and close the cut out cock in branch pipe leading to 26-F control valve (under floor).

5.5.5 Cut out 26-C ABV.

5.5.6 Wait a few minutes and then check BP pressure drop for 3 minutes.

NOTE

BP leakage rate must not exceed 3 psi in one minute.
If leakage exceeds this rate, locate source(s) and repair.
Repeat Steps 5.5.1 - 5.5.6.

5.5.7 "Cut In" 26-C ABV and open branch pipe cut out cock leading to 26-F control valve.

5.5.8 Close angle cocks or 1-1/4" BP cut out cocks and remove LS-5 dummy couplings from front and rear BP end hoses.

5.6 Brake Cylinder Equalization Or Independent Application And Release Pipe Leakage

TASK NUMBER	PROCEDURE	QA INITIAL
5.6.1	Install HS-2 plugged Dummy couplings, one with test air gauge to front and rear BC air hose couplings and then open 1/2" BC line cut out cocks at front and rear.	
5.6.2	Apply Independent Brake Valve (IND) to maximum.	

5.6.3 Adjust pressure to read 80 psi on cab air gauge, if necessary, allowing time for pressure to adjust. BC test air gauge should read appx. 50 psi.

5.6.4 Close the "double ported MU cut out cock" or place MU-2A valve in Trail position.

5.6.5 Check leakage for three minutes, rate should not exceed 5 psi per minute.

5.6.6 Close end BC cut out cocks, remove dummy couplings, open double ported cut out cock or place MU valve in Lead position.

5.7 Pressure Maintaining Capacity Test

TASK NUMBER	PROCEDURE	QA INITIAL
5.7.1	Install special pressure maintaining dummy coupling on coupling of rear BP hose.	
5.7.2	Open adjacent angle cock or 1-1/4" cut out cock under front steps.	

NOTE

In cab it may be necessary to increase engine speed to hold 90 psi BP setting on cab air gauge against flow out of the 3/16" orifice. 90 psi must be maintained against the orifice.

5.7.3	Close 1-1/4" BP cut out cock and remove test dummy coupling.	

5.8 Calibration Test For Brake Pipe Flowmeter

TASK NUMBER	PROCEDURE	QA INITIAL
5.8.1	If locomotive is so equipped, follow instructions of the manufacturer of the flowmeter to properly calibrate or check calibration of the particular flowmeter. See Canadian Pacific Instructions and Method for the WABCO B-1 Flowmeter and the WABCO.	

5.9 Equalizing Reservoir (ER) Leakage

TASK NUMBER	PROCEDURE	QA INITIAL
5.9.1	Make Approximately a 10 psi ER and BP reduction with 26-C ABV, then place BV cut off valve in "OUT" position.	
5.9.2	ER pressure should show no leakage for a period of one minute.	
5.9.3	Correct any leakage found and repeat Steps 5.9.1 - 5.9.2.	

5.10 Service Brake Application And Release

TASK NUMBER	PROCEDURE	QA INITIAL
5.10.1	Move 26-C ABV handle to minimum reduction position.	

NOTE

The equalizing reservoir and brake pipe should respond and drop appx. 6 to 8 psi. Also brake cylinder pressure should respond.

5.10.2 Depress IND handle and BC pressure must exhaust to atmosphere.

5.10.3 Release and recharge.

5.10.4 Move 26-C ABV into service zone making approximately a 10 psi reduction, note brake responds.

5.10.5 Increase BP reduction in two or three appx. 2 psi steps and note brake cylinder pressure increases.

5.10.6 Move to the right hand end of the service quadrant, note ER and BP reduction increases to appx. 24-26 psi.

NOTE

Brake cylinder pressure should have increased to the setting of the service limiting valve in the 26-F control valve which should nominally be 60 psi maximum.

5.10.7 Move to the next notch or Suppression Position and then partly into the overreduction quadrant noting the ER and BP pressure reduce further from the 24-26 psi in effect in suppression position and that there is no increase in BC pressure.

5.10.8 Move the automatic brake valve handle to the left past suppression and into the service quadrant to about the position of a 10 psi reduction. Note the ER and BC pressure do not increase and BC pressure holds steady.

5.10.9 Move the ABV handle further left to release position. Note that the ER and BP pressures rise to 90 psi and BC pressure exhausts completely.

5.10.10 Release and recharge.

5.11 Emergency Application

TASK NUMBER	PROCEDURE	QA INITIAL
5.11.1	From engineman's brake valves. With system fully charged, quickly move 26-C ABV handle to far right of Emergency Position. Note that "PC" light illuminates, BP pressure quickly reduces to zero and that ER pressure steadily reduces to zero.	
5.11.1.1	BC pressure should quickly rise to appx. 75 psi. Record BC pressure.	
5.11.1.2	Power and dynamic brake are nullified.	
5.11.1.4	Release and recharge brake system.	
5.11.2	From other side of cab emergency brake valve. With system fully charged and 26-C ABV in release position, quickly open the 1-1/4" Emergency Brake Valve.	
5.11.2.1	Check that BP quickly drops to zero, 26-C ABV is cut off from suppling BP pressure and PC light illuminates after 26-C ABV is moved to emergency position.	
5.11.2.2	Timed sanding may operate if locomotive is equipped. This indicates that the A-1 charging cut off pilot valve is operating; timed sanding may also operate, if locomotive is so equipped. Power and dynamic brake are nullified.	
5.11.3	From train brake pipe emergency. With system fully charged and 25 ABV in release position, quickly open the rear end angle or BP cut out cock. Note that BP quickly reduces to zero, BC pressure quickly builds up to normal emergency BC pressure and PC light illuminates.	

5.12 Penalty Brake Application

TASK NUMBER	PROCEDURE	QA INITIAL
5.12.1	With system fully charged and 26-ABV in release position, lift or release foot pressure from the foot pedal.	
5.12.2	After 4 to 6 seconds and warning signal, note that penalty application results and produces appx. 24-26 psi BP reduction and brake cylinder pressure builds up to appx. 60 psi.	
5.12.3	Place 26-C ABV handle in suppression position and wait appx. 1 minute.	
2.12.4	Move ABV handle to release position and note that penalty application is reduced to zero. This indicates proper operation of the P-2-A brake application valve.	

5.13 Suppression Of Penalty Application

TASK NUMBER	PROCEDURE	QA INITIAL
5.13.1	Apply independent to about 10 psi BCP, release foot pedal and note alarm sounds, quickly increase pressure to above 25 psi, note alarm silences and no penalty application results.	

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