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Peacekeeper Rail Garrison Vehicle Characterization Test of Triplet Cars, ATSF 90004 and 90006

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16. Abstract

Vehicle Characterization tests were performed on two of three commercial span bolsters cars (Triplet Cars) to gather data in support of the Train Dynamics Model (TDM) prediction of coupled span bolster car performance. The three vehicle characterization tests were: (1) static suspension characterization, (2) quasi-static suspension characterization, and (3) modal response testing.

Modal testing was performed to assess any resonant rigid or flexible body modes that may be encountered during track testing. Lower center roll at 0.9 Hz., Sway at 1.1 Hz., and bounce at 2.3 Hz were the only natural frequencies that would be expected to be encountered during operational test speeds over 39-foot wavelength perturbations for the ATSF 90006 car. These frequencies equate to 23, 29, and 61 mph, respectively. Lower center roll at 0.8 Hz. and bounce at 2.4 Hz were the only natural frequencies that would be encountered during operational test speeds for the ATSF 90004 car. These frequencies equate to 20 mph and 64 mph, respectively.

Quasi-static truck characterization tests were performed to characterize the vehicle suspension for input to the TDM. The ATSF 90006 car was equipped with 100-ton design ride control trucks. The average vertical stiffness and damping were 44.8 kips/inch and 10.7 kips for one spring nest. Lateral stiffness and damping were 40.6 kips/inch and 26.5 kips per spring nest. Truck roll rate was 75,386 kip-inches/radian. The ATSF 90004 car was equipped with 125-ton design ride control trucks. The average vertical stiffness and damping were 50.1 kips/inch and 10.7 kips per spring nest. Average lateral stiffness and damping were 42 kips/inch and 22.8 kips, per spring nest. Truck roll rate was 67,775 kip-inches/radian.

Static suspension characterization tests consisted of four subsets of air bearing table tests. They were: span bolster yaw moment, truck yaw moment, longitudinal stiffness, and axle yaw stiffness. Air bearing table test data appeared to be useable for TDM development.

17. Key Words

Depressed Center Flat Cars
Span Bolster
Suspension Characterization

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EXECUTIVE SUMMARY

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, contracted with the Federal Railroad Administration (FRA) to perform vehicle characterization tests on two commercial span bolster cars (Triplet Cars) prior to testing the Peacekeeper Rail Garrison (PKRG) consist. In general, enough data were measured to accurately assess the suspension and modal parameters of the cars. The Triplet Cars included two Atchison, Topeka and Sante Fe (ATSF) depressed center flat cars with two 36-inch wheel sets, and one ATSF depressed center flat car with 38-inch wheel sets. These cars were chosen for their ability to be loaded to simulate specific PKRG cars.

Vehicle characterization testing was performed to provide input data for the Train Dynamics Model (TDM). Identical designs of the two 36-inch wheel set cars allowed the assumption that both cars would have similar characteristics, thus, only one of the two 36-inch wheel set cars (ATSF 90006) was subjected to vehicle characterization testing. The 38 inch wheel set car (ATSF 90004), being of a different design, was also tested.

Modal testing was performed to assess any resonant rigid or flexible body modes that may be encountered during track testing. The natural frequencies for pitch, bounce, lower center roll, upper center roll, yaw, sway, lateral bending and vertical bending were all determined for the ATSF 90006 car. Lower center roll at 0.9 Hz, sway at 1.1 Hz, and bounce at 2.3 Hz were the only natural frequencies that would be expected to be encountered during operational test speeds over 39-foot wavelength track perturbations. These frequencies equate to 23, 29, and 61 mph, respectively. The natural frequencies for pitch, bounce, lower center roll, upper center roll, yaw, and lateral bending were located for the ATSF 90004 car. Lower center roll at 0.8 Hz and bounce at 2.4 Hz were the only natural frequencies that would be expected to be encountered during operational test speeds.

These frequencies equate to 20 mph and 64 mph, respectively.

Quasi-static truck characterization tests were performed to document the suspension characteristics for input to the TDM. The ATSF 90006 car was equipped with 100-ton ASF Ride Control trucks. Each truck was equipped with seven D-3 outer and five D-3 inner springs. The average vertical stiffness rate of 44.8 kips/inch was 16 percent higher than the calculated value of 38.6 kips/inch. The average vertical damping force of the spring nests was found to be 10.7 kips. Lateral stiffness rate and damping were 40.6 kips/inch and 26.5 kips, respectively. Truck roll rate was found to be 75,386 kip-inches/radian. The ATSF 90004 car was equipped with 125-ton ASF Ride Control trucks. Each truck was equipped with eight D-3 outer and eight D-3 inner springs. The average vertical stiffness rate of 50.1 kips/inch was 4 percent higher than the calculated value of 48.1 kips/inch. The average vertical damping for the spring nests was found to be 10.7 kips. Average lateral stiffness rate and damping were found to be 42 kips/inch and 22.8 kips, respectively. Truck roll rate was found to be 67,775 kip-inches/radian.

Static suspension characterization tests consisted of five subsets of air bearing table tests. They were span bolster yaw moment, truck yaw moment, longitudinal stiffness, and axle yaw stiffness. Longitudinal and axle yaw stiffness were both used. Span bolster yaw moment was approximately twice that of the individual truck yaw moment for both cars.

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1.0 INTRODUCTION

The Association of American Railroads (AAR), Transportation Test Center (TTC), Pueblo, Colorado, 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, of AAR's, M-1001, *Manual of Standards and Recommended Practices*. Chapter XI is attached as Appendix A.

Integral to this task is the development of an analytical tool, which is the Train Dynamics Model (TDM) that will make pre-test performance predictions for the PKRG train. Following the test program, the TDM may be used to examine operational regimes not considered by this test program, such as worn or failed components, unusual track conditions, or unforeseen operational requirements.

Before testing the actual PKRG cars as a train, vehicle characterization and track worthiness testing were performed with three commercial span bolsters cars (Triplet Cars) to document the performance of the coupled span bolster cars and to provide validation data for the TDM. The three vehicle characterization tests performed were (1) static suspension characterization, (2) quasi-static suspension characterization, and (3) modal response testing.

Two air bearing tables were used to conduct the static suspension characterization tests. The tests were conducted in the Urban Rail Building (URB). The Mini-Shaker Unit (MSU) was used as the quasi-static and modal response test apparatus. The test facility was the Rail Dynamics Laboratory (RDL).

The Triplet Cars were comprised of two depressed center flatcars loaded at 400,000 pounds with 36-inch wheel sets and one depressed center flatcar loaded at 560,000 pounds with 38-inch wheel sets. All three cars are eight axle span bolster cars and were loaded with concrete blocks.

This report will describe the test methods, discuss data reduction methods used, and give the results from the analysis of selected runs for the vehicle characterization tests.

2.0 OBJECTIVE

There were three objectives to the vehicle performance test. The first test objective was to measure the static suspension characteristics of two span bolster Triplet Cars:

ATSF 90006, a 36-inch wheel set car

ATSF 90004, a 38-inch wheel set car

The second objective was to measure the quasi-static suspension characteristics to include vertical and lateral stiffness, damping force, and roll rate of the same cars.

The third objective was to measure the modal parameters of the two cars to include:

Rigid Body Mode	Flexible Body Mode
• Pitch	• Vertical Bending
• Bounce	• Lateral Bending
• Roll	• Longitudinal Torsion (twist)
• Yaw	
• Sway	

All tests were conducted following procedures set forth in appendix B of Chapter XI.

3.0 PROCEDURES

Brief procedural outlines of the Air Bearing Table Test, Quasi-static Vehicle Characterization Test, and Modal Test are presented in this section. Detailed test procedures are contained in Appendixes B, C, and D.

3.1 AIR BEARING TABLE TEST

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

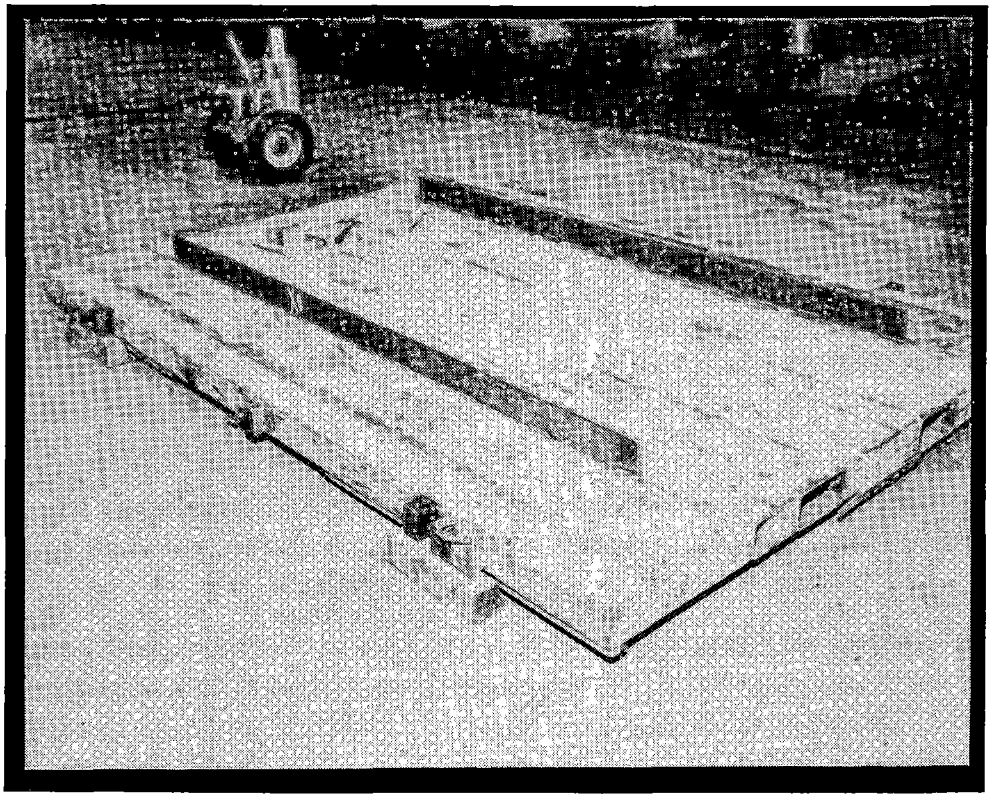


Figure 3.1 Air Bearing Table

The Air Bearing Table Test consisted of four subsets. They were (1) Span Bolster Yaw Moment, (2) Truck Yaw Moment, (3) Longitudinal Stiffness, and (4) Axle Yaw Stiffness.

3.1.1 Span Bolster Yaw Moment Test

The Span Bolster Yaw Moment Test was used to determine the torque necessary to rotate the span bolster about the car body center plate. This breakaway torque is related to the static friction between the center plate and center bowl. When the car enters a curve, the high lateral wheel forces cause the span bolster to break away and rotate. Figure 3.2 illustrates the basic test setup.

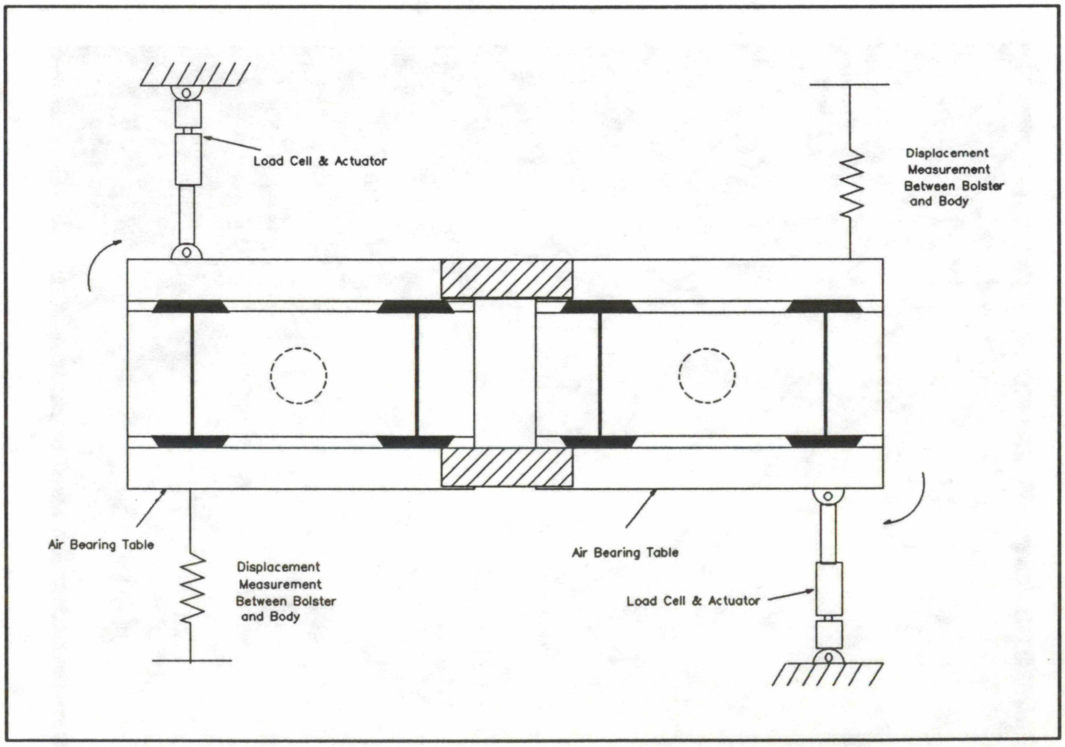


Figure 3.2 Span Bolster Yaw Moment Test Setup

One air bearing table was placed under each truck on the A-end of the car. The two tables were then bolted together. Actuators were attached at opposite corners of the table assembly. String potentiometers (string pots) were placed at the two free corners to measure rotational displacement. Force was applied equally and gradually with both actuators until the span bolster began to rotate. The test was stopped when the force versus displacement plot indicated the break-a-away torque had been reached, as shown in the sample below. The span bolster was then repositioned with chain hoists for a repeat of the test. The span bolster was rotated in clockwise (CW) and counterclockwise (CCW) directions during the test.

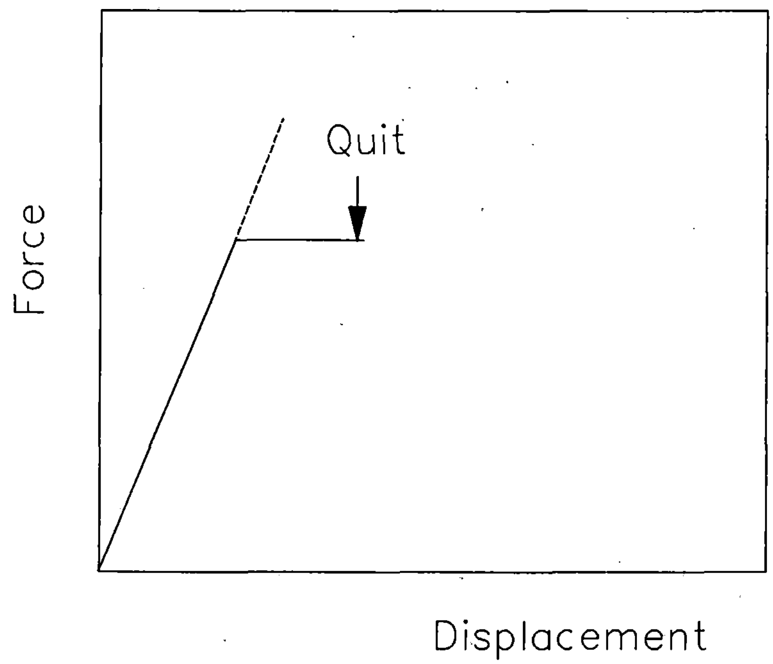


Figure 3.3 Force versus Displacement Plot

3.1.2 Truck Yaw Moment Test

The setup for the individual Truck Yaw Moment Test was very similar to the span bolster test. The tables were unbolted and the actuators and string pots were assembled on one table only (Figure 3.4).

The truck tests were performed in the same manner as the span bolster test. Each of the two trucks were tested in CW and CCW directions.

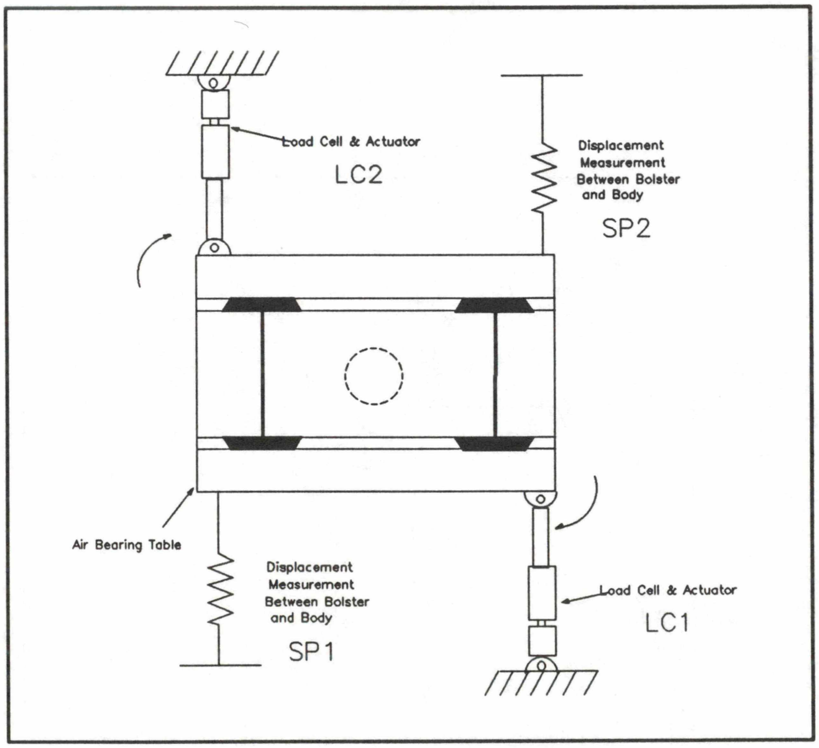


Figure 3.4 Truck Yaw Moment Test Setup

3.1.3 Truck Longitudinal Stiffness Test

The air tables were left in the same configuration for longitudinal stiffness as they were for the axle alignment tests. Actuators were connected to the ends of the axles via axle spuds bolted on the bearing end caps. The actuators were connected between the two axles on both sides of the truck, as shown in Figure 3.5.

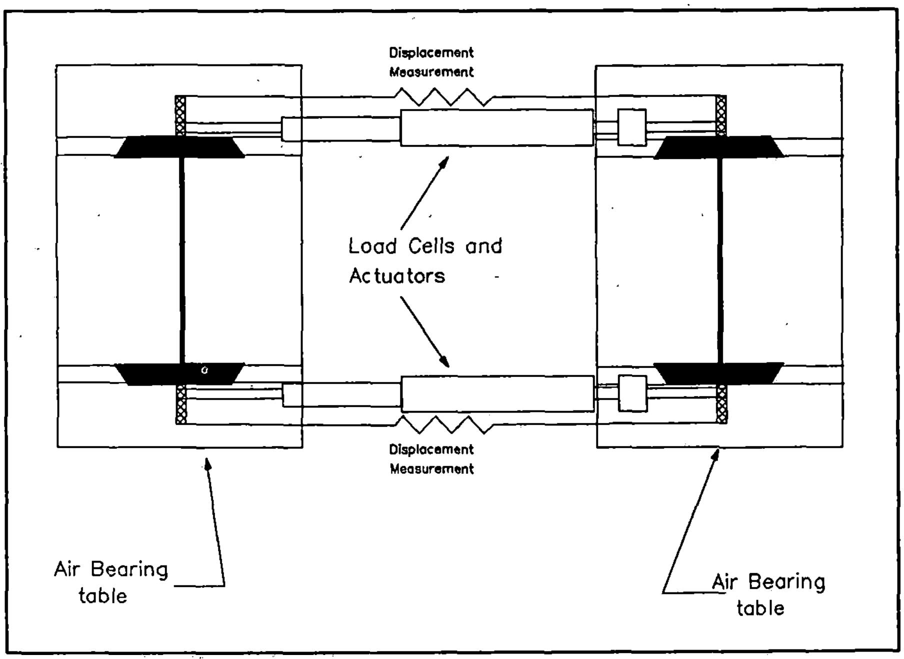


Figure 3.5 Truck Longitudinal Stiffness Test Setup

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 repeated on the second truck.

3.1.4 Truck Inter-axle Yaw and Bending Test

The Inter-axle Yaw and Bending 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 opposite side of the truck. Yaw restraint will affect curving and high speed stability performance.

3.2 QUASI-STATIC CHARACTERIZATION TESTS

The quasi-static truck characterization tests were conducted on two 100-ton design trucks and two 125-ton design trucks. These trucks were utilized by the ATSF 90006, 36-inch wheel set car and the ATSF 90004, 38-inch wheel set car. The tests included vertical, roll, and lateral tests at low frequencies to determine the stiffness, truck roll rate, and damping characteristics of the trucks' suspension components. These parameters are required as input for the TDM. The tests were conducted in the sequence shown in Table 3.1. A more detailed log is given in Appendix E. These logs include run number, description, frequency, truck number, and burst time.

Prior to testing, rail forces were compared to actuator forces. The resulting 1:1 ratio indicates that both systems were working properly. This ratio also allows the option to use rail forces, actuator forces or both during data reduction.

Table 3.1 Quasi-static Truck Characterization Test Sequence

TRUCK NO. AND CAR	TEST DESCRIPTION
TRUCK NO. 4 ATSF 90006	VERTICAL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±C.P. Amplitude.
	ROLL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±2.0" Amplitude.
	LATERAL - Force Control, 0.1 and 0.25 Hz. Inputs, ± 10 kips to ± H.L.
TRUCK NO. 3 ATSF 90004	LATERAL - Force Control, 0.1 and 0.25 Hz. Inputs, ± 10 kips to ± H.L.
	VERTICAL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±C.P. Amplitude.
	ROLL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±2.0" Amplitude.
TRUCK NO. 3 ATSF 90006	VERTICAL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±C.P. Amplitude.
	ROLL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±2.0" Amplitude.
	LATERAL - Force Control, 0.1 and 0.25 Hz. Inputs, ± 10 kips to ± H.L.
TRUCK NO. 4 ATSF 90004	LATERAL - Force Control, 0.1 and 0.25 Hz. Inputs, ± 10 kips to ± H.L.
	VERTICAL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±C.P. Amplitude.
	ROLL - Stroke Control, 0.1 and 0.25 Hz. Inputs, ± 0.5" to ±2.0" Amplitude.

C.P. = Full Spring Compression
S.L. = 1/5 Vertical Static Load
H.L. = (S.L. - 10 Kips) + 10 Kips

3.2.1 Test Trucks

The four test trucks include two ASF 125-ton and two ASF 100-ton design ride control trucks. The springs used include (7) D-3 outer and (5) D-3 inners for ATSF 90006, and (8) D-3 outer and (8) D-3 inners for ATSF 90004.

3.2.2 Truck Break-In

The two trucks from the ATSF 90006 and the two trucks from the ATSF 90004 were tested as received.

3.2.3 Test Specimen and Test Apparatus

A Union Pacific gondola (UP31923) was used for the quasi-static characterization MSU tests. This car was loaded to approximate the average axle loads (73,566 lb) from the Missile Launch Car (MLC). Each of the two ATSF 90004, 125-ton design trucks were individually tested under the B-end of the UP gondola. Then the gondola was reconfigured to approximate the average axle loads (50,519 lb) from the Launch Control Car (LCC). Each of the two ATSF 90006, 100-ton design trucks were then individually tested under the gondola B-end.

The MSU utilized two 140-kip hydraulic actuators for vertical input excitation to the vehicle and one 140-kip actuator for lateral excitation. The actuators were attached to a reaction mass bolted to the floor of the RDL. The hydraulic actuators were connected between the car body and the ground with special brackets welded to the car structure. Sinusoidal input signals were provided to the actuators with a Hewlett-Packard (HP) 360 computer teamed with a programmable function generator. The actuators were driven with 0.1 and 0.25 Hz signals during quasi-static testing. Figures 3.6 and 3.7 show the MSU in the vertical and lateral test configurations, respectively.

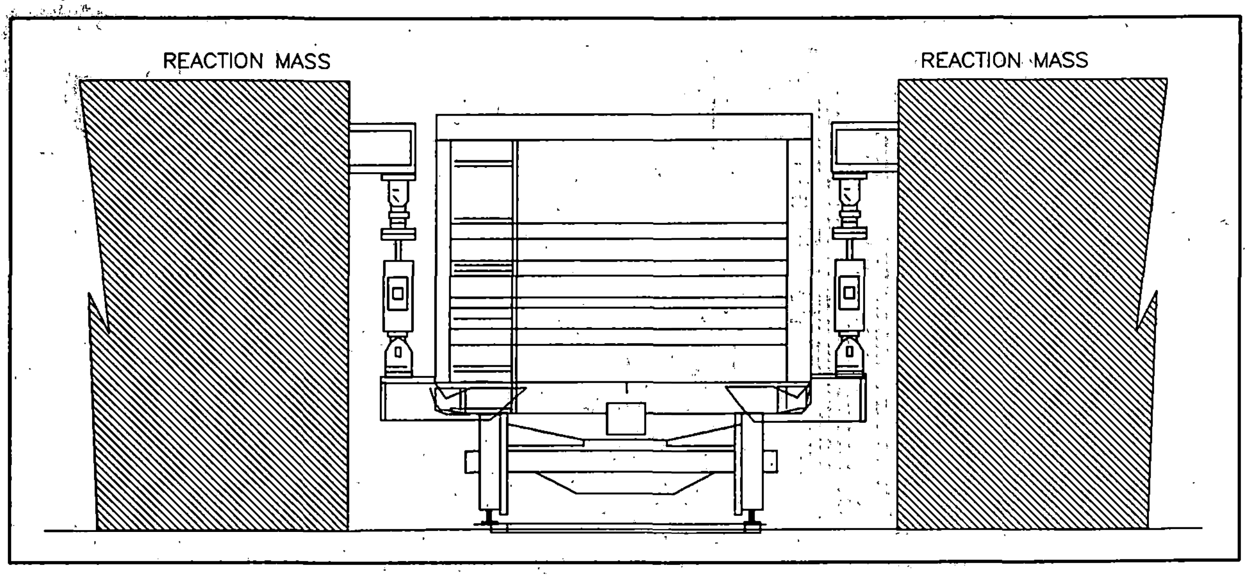


Figure 3.6 Vertical Test MSU Configuration

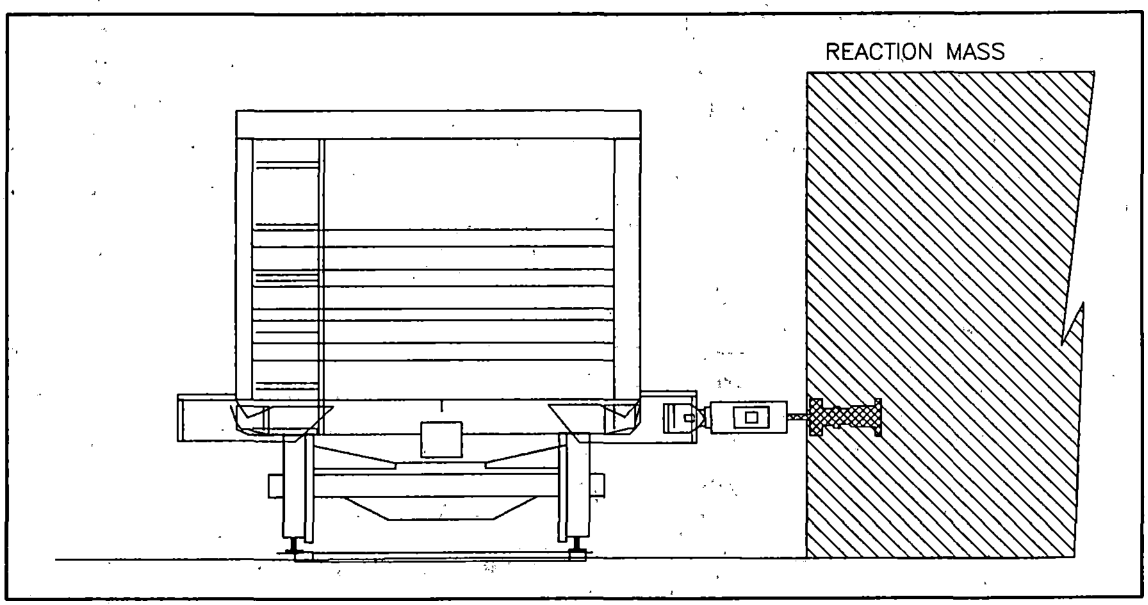
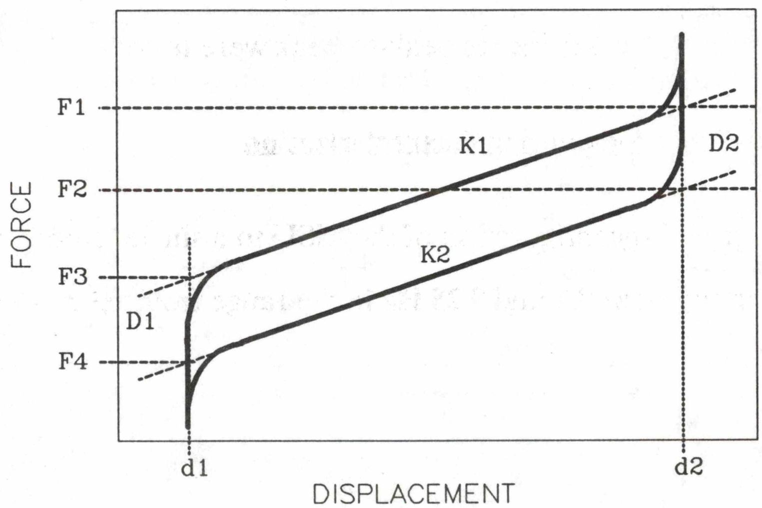


Figure 3.7 Lateral Test MSU Configuration

3.2.4 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 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. An actuator displacement of 4.0 inches peak-to-peak was determined during the test to be sufficient to fully compress the springs. Figure 3.8 is a force versus displacement hysteresis plot. The method used to determine stiffness and damping is also presented.



STIFFNESS	DAMPING
K1 = (F1 − F3) / (d2 − d1)	D1 = F3 − F4
K2 = (F2 − F4) / (d2 − d1)	D2 = F1 − F2

Figure 3.8 Stiffness and Damping Obtained from Hysteresis Plot

The two parallel lines of the curve (K1, K2) represent either the compression or extension of the suspension system (springs). The near vertical portion at each end of the cycle represents the full extension or compression of the spring. The stiffness greatly increases 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.

3.2.5 <u>Roll Quasi-Static Suspension Characterization</u>

The roll quasi-static characterization tests were very similar to the vertical characterization tests, except that the vertical actuators were operated 180 degrees out-of-phase. Actuator displacements up to 4.0 inches peak-to-peak were tested.

3.2.6 <u>Lateral Quasi-Static Suspension Characterization</u>

These tests required reconfiguration of the MSU to a single lateral actuator arrangement. The input was cycled at 0.1 and 0.25 Hz in the range from zero to 1/5 times the static load of the car.

3.2.7 Instrumentation and Data Acquisition

Test measurements for the quasi-static MSU tests consisted of input forces and displacements of the hydraulic actuators, response displacements measured across the various suspension elements, and vertical and lateral rail forces. Deflections across springs and side bearings were positive for extension and negative for compression.

Comprehensive pre-test and post-test calibrations were performed on all instrumentation channels. Included in these procedures are displacement transducer zero and cal, load cell and instrumented rail zero and RCAL, and load cell versus instrumented rail static comparison using load cell values of ±10-kip and ±30-kip.

The data were filtered at 30 Hz and collected at 256 samples per second with the 360 computer system. Appendix C contains quasi-static test procedures, with an attached measurement list.

3.3 DATA REDUCTION

The test data were reduced using AAR developed software on the HP computer system. The following is a list of the types of plots supplied to the United States Air Force and its contractors for review and analysis. Each type of plot has a letter label assigned to it. This letter corresponds to the far right column labeled "Data Reduction Option" in the condensed test logs given in Appendix D.

Table 3.2 Data Reduction Options

	VERTICAL DATA REDUCTION OPTIONS	DESCRIPTION
A.	Vertical Test Statistics	
B.	DZ14 vs. VAF1	Left side spring displacement across vertical suspension component vs. left side actuator force.
C.	DZ15 vs. VAF2	Same for the right side.
D.	VAFS vs. VRFS	Vertical actuator force vs. vertical rail force.
	ROLL DATA REDUCTION OPTIONS	**DESCRIPTION**
E.	Roll Test Statistics	
F.	DZ14 vs. VAF1	Same as vertical analysis
G.	DZ15 vs. VAF2	Same as vertical analysis
H.	RMNT vs. RANG Where: RMNT = (VAF1-VAF2) X 29.91 RANG=DZ14DZ15)/76 (in/in)	Displacement across vertical suspension vs. roll moment (inch-kips/radian)
	LATERAL DATA REDUCTION OPTIONS	**DESCRIPTION**
I.	Lateral Test Statistics	
J.	LAF1 vs. SMLR Where: SMLR = (LRF1 + LRF3 - LRF2 - LRF4)	Load cell force vs. lateral rail force
K.	DYO2 vs. LAF1	Displacement across lateral suspension components vs. lateral actuator force.
L.	DYO3 vs. LAF1	Displacement across lateral suspension components vs. lateral actuator force.

Note: Being that VAFS vs. VRFS = 1:1, actuator force sums may be replaced by rail force sums.

3.4 MODAL RESPONSE TEST

The Modal Response Test was performed on the 36-inch and 38-inch wheel set Triplet Cars to determine the resonant frequencies for the following modes:

Rigid Body Mode	Flexible Body Mode
• Pitch	• Vertical Bending
• Bounce	• Lateral Bending
• Roll	• Longitudinal Torsion (twist)
• Yaw	
• Sway	

3.4.1 Test Apparatus

The Modal Response Test was performed on the MSU in the RDL. The MSU utilized one 77 kip hydraulic actuator for vertical or lateral car body excitation.

The actuator was attached to the car body via a modal attachment fixture, which was welded to the car body (Figure 3.9).

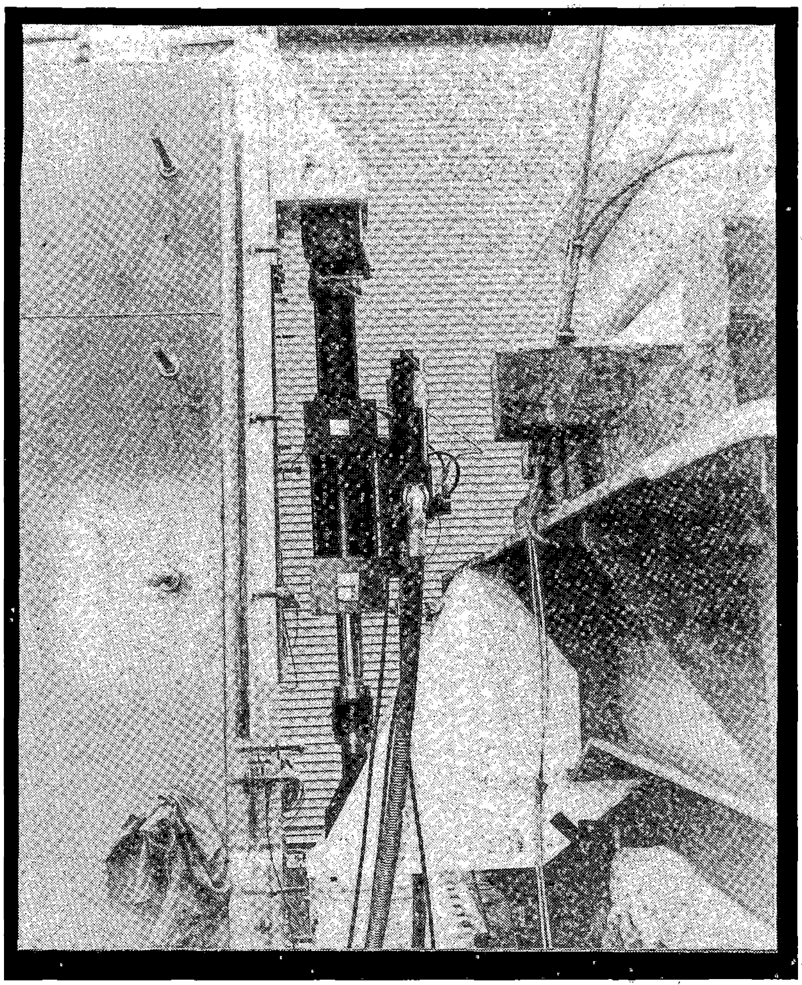


Figure 3.9 Modal Attachment Fixture

The actuator was attached to a reaction mass that rests on the floor of the RDL. Sinusoidal input signals were provided to the actuator control valves with an HP 360 desk top computer teamed with a programmable function generator. The 38-inch Triplet Car is shown on the MSU in Figure 3.10 and in the vertical configuration in Figure 3.11.

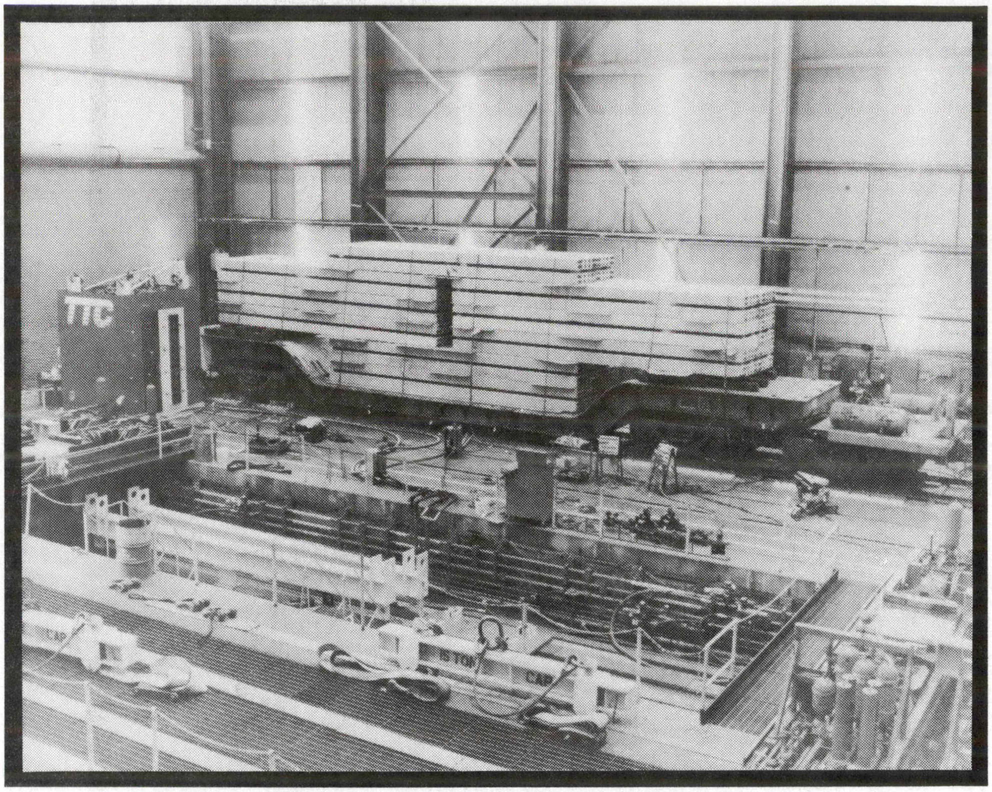


Figure 3.10 38-inch Triplet on the MSU

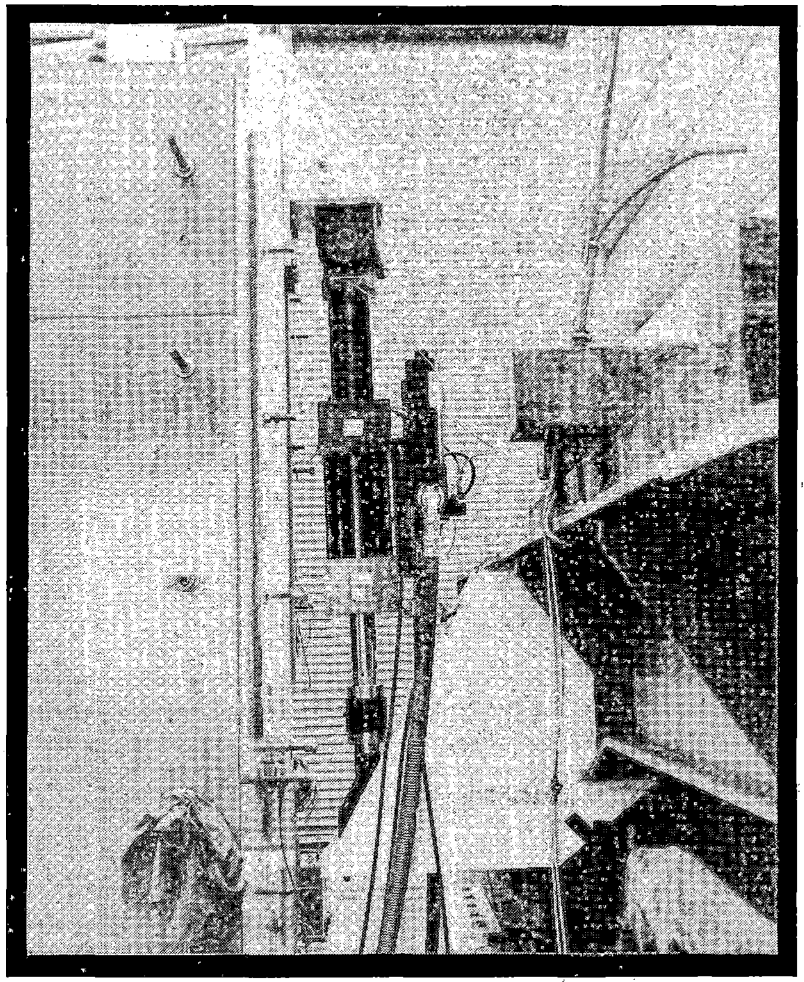


Figure 3.11 38-inch Triplet in the Vertical Test Mode

3.4.2 Triplet Instrumentation Setup

Rigid body modes were easily seen with displacement measurements. String pots on both cars were installed in the locations shown in Figure 3.12. From the string pot measurements, rigid body bounce, pitch, roll, yaw, and sway were initially determined. These modes were later verified with accelerometer data.

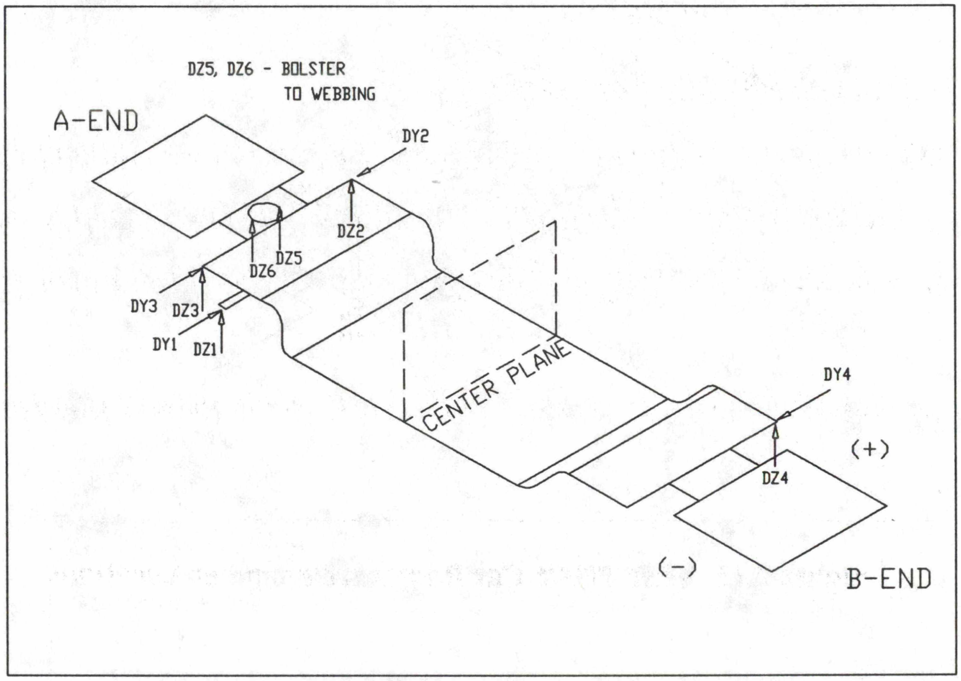


Figure 3.12 Car Body to Ground Displacements

The primary source of data for the flexible body (bending and twist) testing and final analysis of rigid body modes was the array of accelerometers shown in Figure 3.13. A large number of accelerometers were needed to clearly define the bending shape of the car.

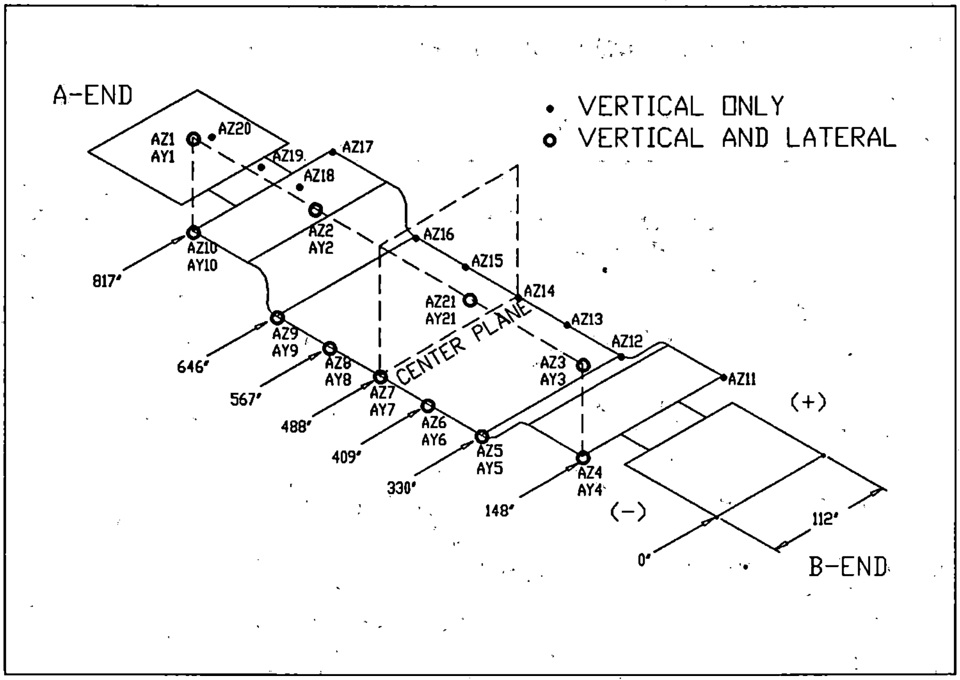


Figure 3.13 ATSF 90006 Car Body Accelerometer Locations

Vertical and lateral wheel forces were measured at each wheel on the A-end of the car via instrumented rail sections. Actuator force and displacement were also measured. Accelerometers and string pots were also installed on the A-end trucks and span bolster to help determine the role of the running gear during resonant modes of vibration. A complete measurement list is presented in the Modal Test Procedure in Appendix E.

3.4.3 Rigid Body Vertical Tests

The MSU was set up in the vertical test configuration as previously shown in Figure 3.11. The actuator was cycled in phase with 5, 10, 15, 25, and 30 kip sinusoidal inputs. The frequency increased from .2 Hz to 10 Hz in .1 Hz steps at 10 cycles per step. Pitch and bounce were determined by the phase relationship between the A- and B-end displacements or accelerations of the car body. Upper and lower center roll modes were determined by the phase relationship between left and right side vertical displacements or accelerations of the car body.

3.4.4 Flexible Body Vertical Tests

The MSU remained in the vertical test configuration. The actuator was in displacement control rather than force control. Displacement control was used for a constant g (acceleration) input. The sweeps were from 3 Hz to 30 Hz at constant g inputs of .1, .2, and .3. Additional sweeps of .4 g at 10-30 Hz and .5 g at 15-30 Hz were also performed. Vertical bending and twist were both determined from these tests.

3.4.5 Rigid Body Lateral Test

The MSU was reconfigured in the lateral test mode (Figure 3.14).

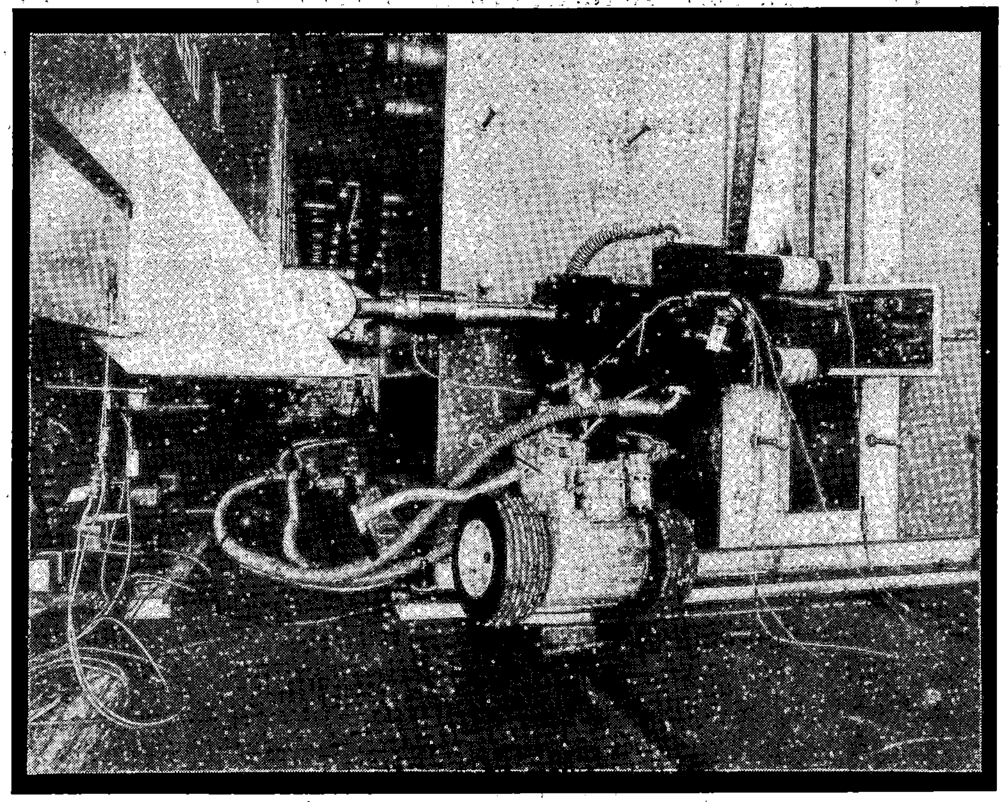


Figure 3.14 MSU Lateral Configuration

The Rigid Body Lateral Test was performed with the same sweeps as the Rigid Body Vertical Test. All input values were identical.

3.4.6 Flexible Body Lateral Test

The Flexible Body Lateral Test was performed with the same inputs as the Flexible Body Vertical Test, up to .4 g.

4.0 RESULTS

4.1 AIR BEARING TABLE TEST (ATSF 90006)

4.1.1 Span Bolster Yaw Moment Test

Figure 4.1 shows a typical force versus displacement plot.

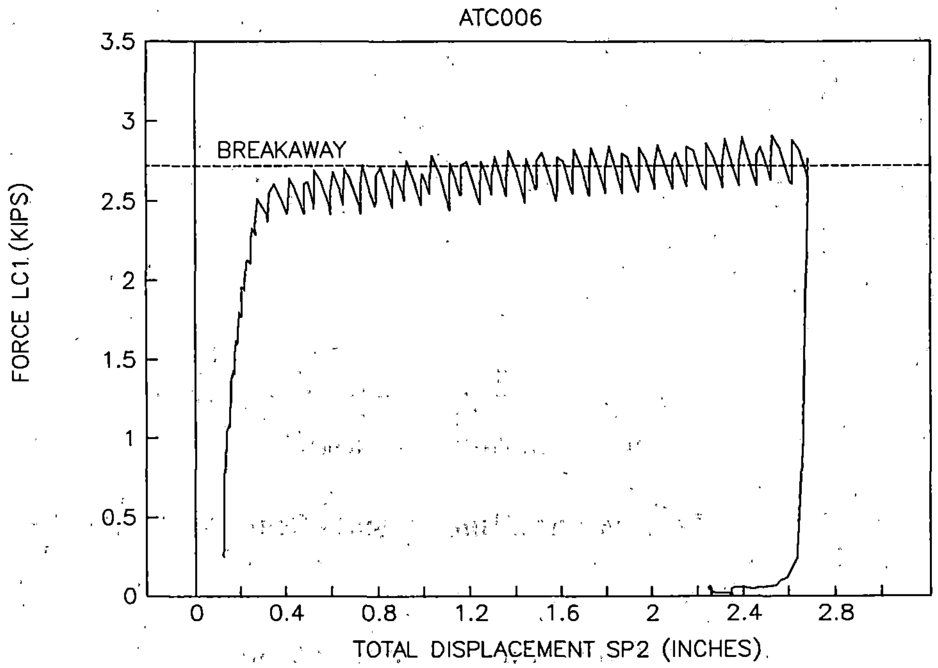


Figure 4.1 Force versus Displacement - Span Bolster Yaw Moment Test

The force increased with relatively small displacement until the static friction was overcome. At that point, the span bolster rotated with virtually no increase in force. This was called the breakaway point. Since two actuators were used, the actual breakaway torque or yaw moment was calculated by summing the two breakaway torques. Figure 4.2 is a force versus displacement plot for the second actuator.

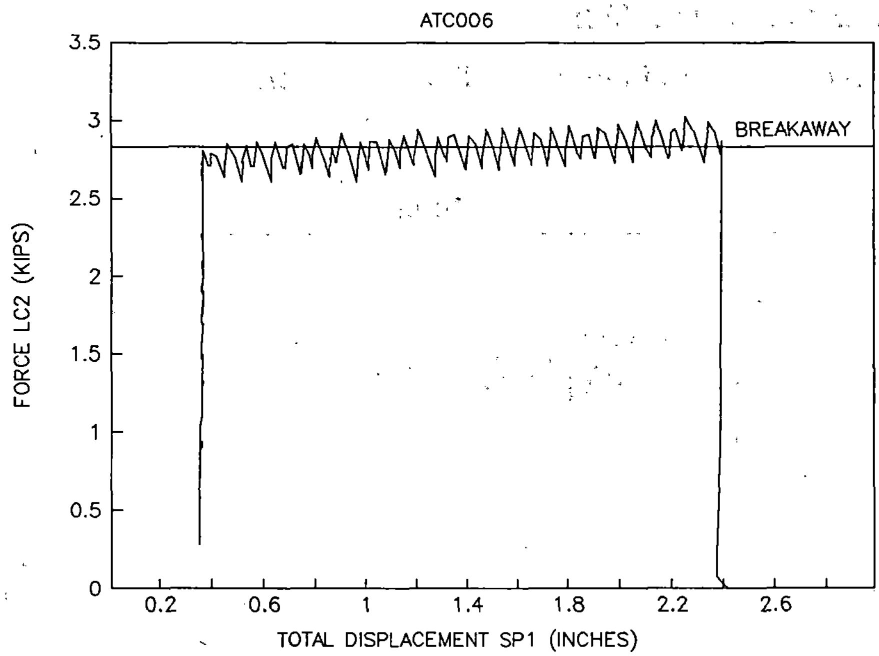


Figure 4.2 Second Actuator Force versus Displacement - Span Bolster Yaw Moment Test

In each case, the breakaway force on each actuator was slightly less than 3,000 pounds; 2,620 and 2,820 pounds, respectively. The serrated appearance of the line was caused by pumping the hydraulic actuators by hand. A line was drawn through the top of the fluctuations to imply the breakaway force value.

The perpendicular distance from each actuator to the span bolster center pin was 108 inches. The yaw moment or breakaway torque was then calculated by multiplying the sum of the two forces by the distance of 108 inches. The yaw moment for run ATC006, shown in the previous figures, was (2,620 + 2,820) X 108 = 587,520 in-lbs. Table 4.1 shows a summary of the Span Bolster Yaw Moment Test results.

Table 4.1 A-end Span Bolster Yaw Moment Test Results for ATSF 90006

DIR	RUN NO.	FORCE 1 (kips)	FORCE 2 (kips)	TOTAL (kips)	MOMENT (in-lbs)	AVERAGE (in-lbs)
CCW	ATC005	2.48	2.62	5.1	550,800	
	ATC006	2.62	2.82	5.44	587,520	569,160
CW	ATC012	3.2	3.2	6.4	691,200	
	ATC013	3.2	3.18	6.38	689,040	690,120
AVERAGE SPAN BOLSTER YAW MOMENT : 629,640 in-lbs						

Rotating the span bolster created a special set of problems. Car body motion and uneven floating of the tables were among a few. Although the data was repeatable, it is suspect.

4.1.2 <u>Truck Yaw Moment Test</u>

The test setup for this test was identical to the span bolster setup, except the distance from the actuators to the truck center pin was 36 inches. The breakaway for the truck was much less gradual than for the span bolster (Figures 4.3 and 4.4).

The force increased with almost no displacement until the truck broke away; then, the displacement increased with little or no increase in force.

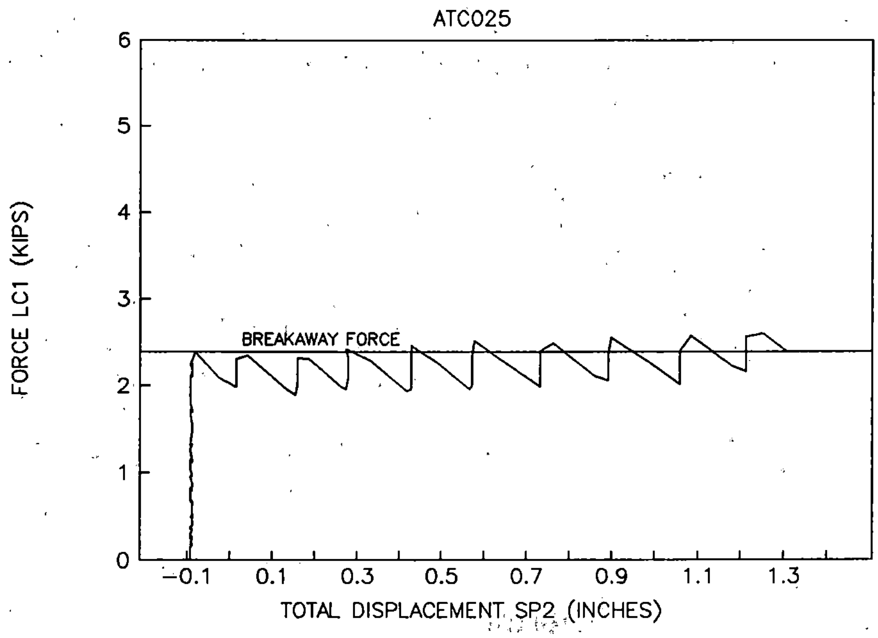


Figure 4.3 Force versus Displacement for Actuator 1

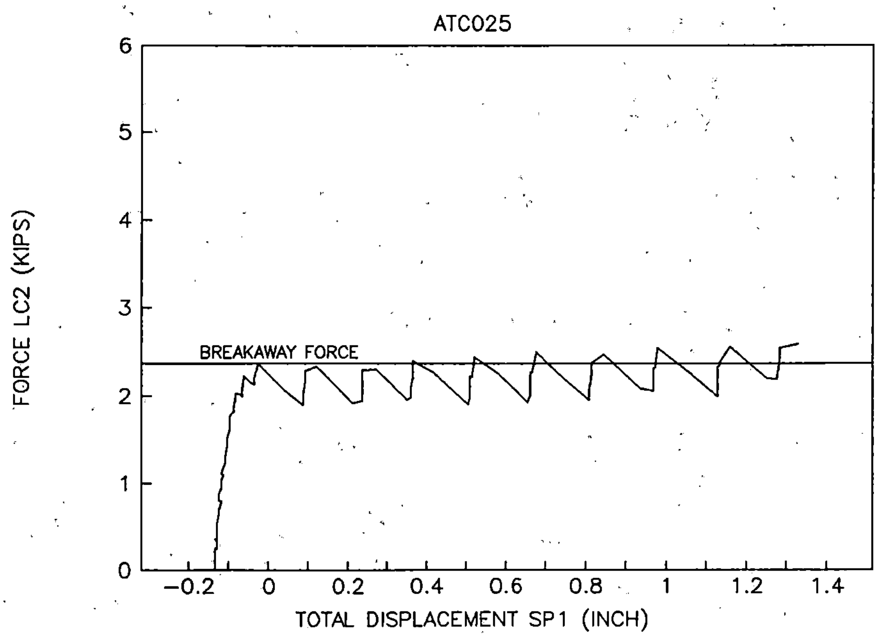


Figure 4.4 Force versus Displacement for Actuator 2

A tabulation of the Truck Yaw Moment Test results is presented in Table 4.2.

Table 4.2 Truck Yaw Moment Test Results for ATSF 90006

DIR AND TRUCK NO.	RUN NO.	FORCE 1 (kips)	FORCE 2 (kips)	TOTAL FORCE (kips)	YAW MOMENT (in-lbs)	AVERAGE MOMENT (in-lbs)
CW 4	ATC017	2.4	2.35	4.75	171,000	
4	ATC018	2.3	2.27	4.57	164,520	
4	ATC020	2.3	2.23	4.53	163,080	
4	ATC021	2.38	2.3	4.68	168,480	167,020
CCW 4	ATC023	2.3	2.3	4.6	165,600	
4	ATC024	2.45	2.4	4.85	174,600	
TRUCK 4 AVERAGE TRUCK YAW MOMENT : 167,510 in-lbs						
4	ATC025	2.25	2.3	4.55	163,800	168,000
CCW 3	ATC028	2.7	2.85	5.55	198,800	
3	ATC029	2.7	2.8	5.5	198,000	
3	ATC030	2.8	2.9	5.7	205,200	
3	ATC031	2.65	2.75	5.4	194,400	199,000
CW 3	ATC032	2.6	2.65	5.25	189,000	
3	ATC033	2.7	2.74	5.44	195,840	
3	ATC034	2.65	2.65	5.3	190,800	191,880
TRUCK 3 AVERAGE TRUCK YAW MOMENT : 195,440 in-lbs						

The average truck yaw moment was 181,475 in-lbs. That value is considerably less than the average span bolster yaw moment of 629,640 in-lbs. This trend was expected, as in general, the static friction breakaway force is the product of the normal force and the coefficient of friction. Since the normal force on the span bolster was approximately twice the single truck normal force, and the area of friction decreased from a 22-inch span bolster center plate to a 16-inch truck center plate, the breakaway moment for the span bolster should be higher. However, a span bolster yaw moment over three times as high as the truck yaw moment is considered excessive. The values recorded for the truck rotation appear to be more realistic. One variable not monitored was the amount of lubrication in the center bowls. The overall scatter for both trucks and the span bolster is shown in Figure 4.5.

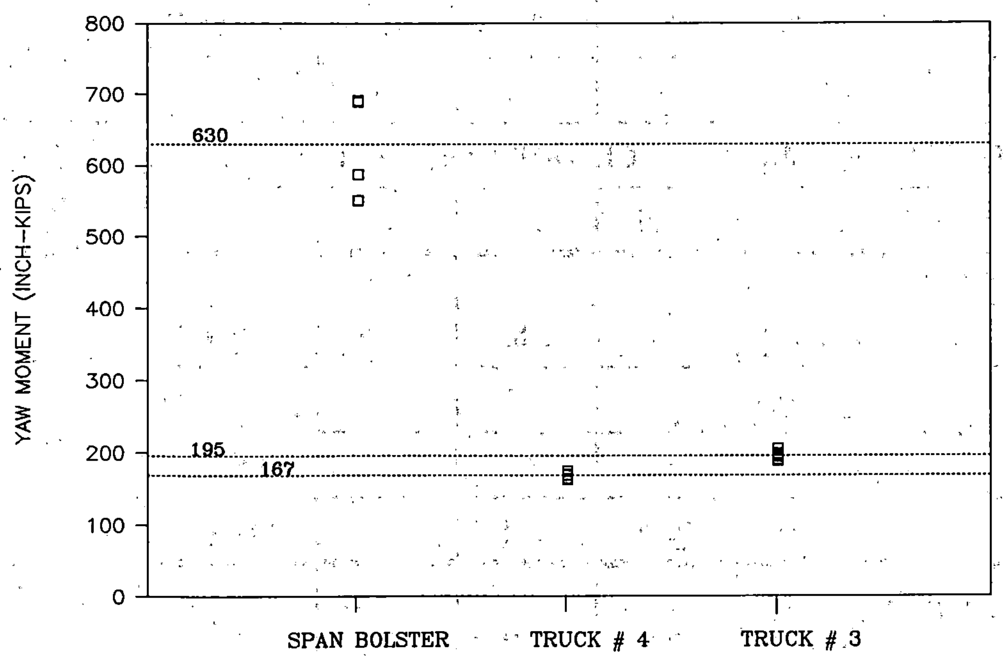


Figure 4.5 Yaw Moment Scatter Plot

The truck data showed a closer grouping than the span bolster; however, the span bolster data were still very reasonable. One final observation was that the first rotation of each truck and span bolster produced the highest yaw moment values.

4.1.3 Longitudinal Stiffness

Truck 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 (Figure 4.6).

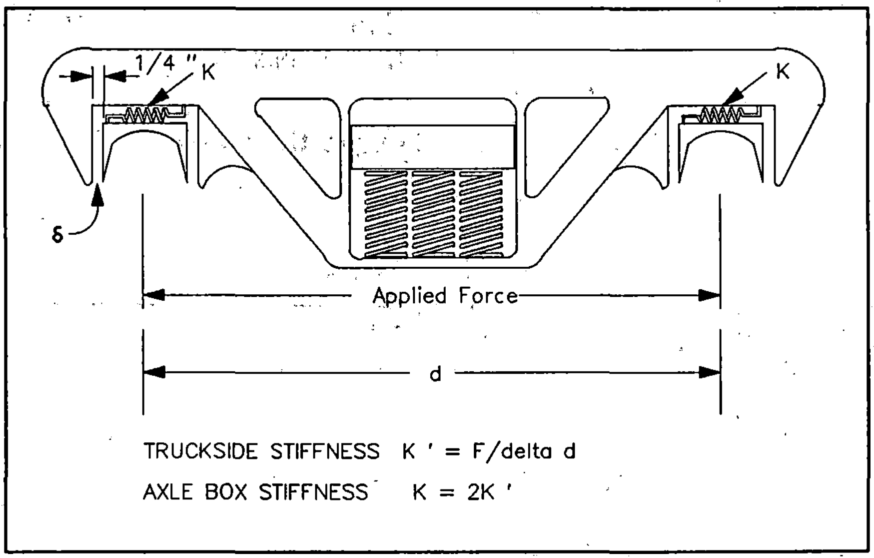


Figure 4.6 Longitudinal Stiffness Explanation

The computer program New and Untried Car Analytic Regime Simulation (NUCARS) required axle box stiffness rather than truck side stiffness. An assumption was made that the truck side was symmetric. Force versus displacement plots were produced for each truck side on all test runs. Typical plots, from run ATC039 in this case, are shown in Figures 4.7 and 4.8.

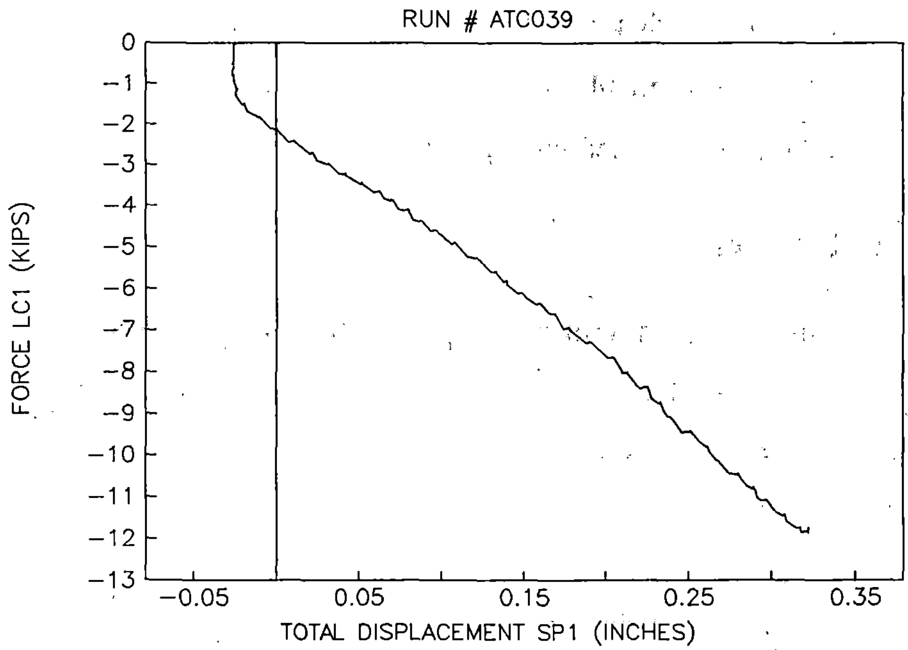


Figure 4.7 Right Truck Side Longitudinal Stiffness Plot

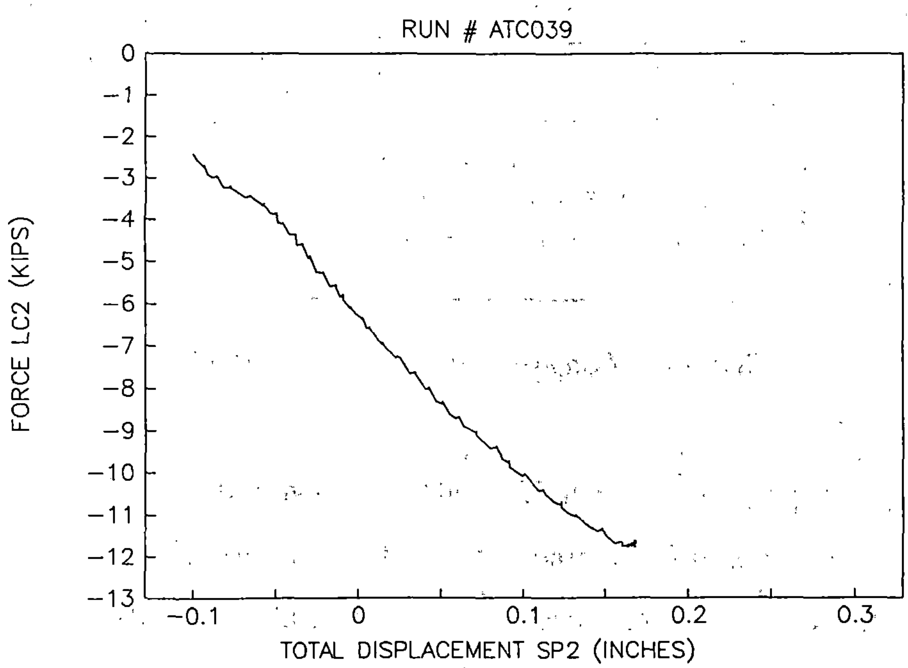


Figure 4.8 Left Truck Side Longitudinal Stiffness Plot

Table 4.3 is a tabulation of the truck side stiffness measurements. The first test run in each direction produced an exceptionally high value that was not representative of the rest of the data. For this reason, the first run in each direction was not considered in the average truck side longitudinal stiffness or axle box stiffness. The scatter plot for all runs is shown in Figure 4.9.

Table 4.3 Truck Side Longitudinal Stiffness Measurements

RUN NO.	TRUCK NO.	DIRECTION	RIGHT SIDE LC1 SLOPE (kips/in)	LEFT SIDE LC2 SLOPE (kips/in)
ATC035	3	Pulling	32.88*	42.62*
ATC037	3	Pulling	40.78	55.63
ATC038	3	Pulling	42.68	56.77
ATC039	3	Pushing	30.46*	37.75*
ATC040	3	Pushing	35.82	51.54
ATC041	3	Pushing	33.15	56.69
		AVERAGE :	**38.11**	**55.16**
ATC051	4	Pulling	34.78*	40.07*
ATC052	4	Pulling	48.49	47.58
ATC053	4	Pulling	49.2	48.47
ATC054	4	Pushing	29.43*	39.59*
ATC055	4	Pushing	39.28	50.06
ATC056	4	Pushing	40.55	51.45
		AVERAGE :	**44.38**	**49.39**

*** Not included in Average**

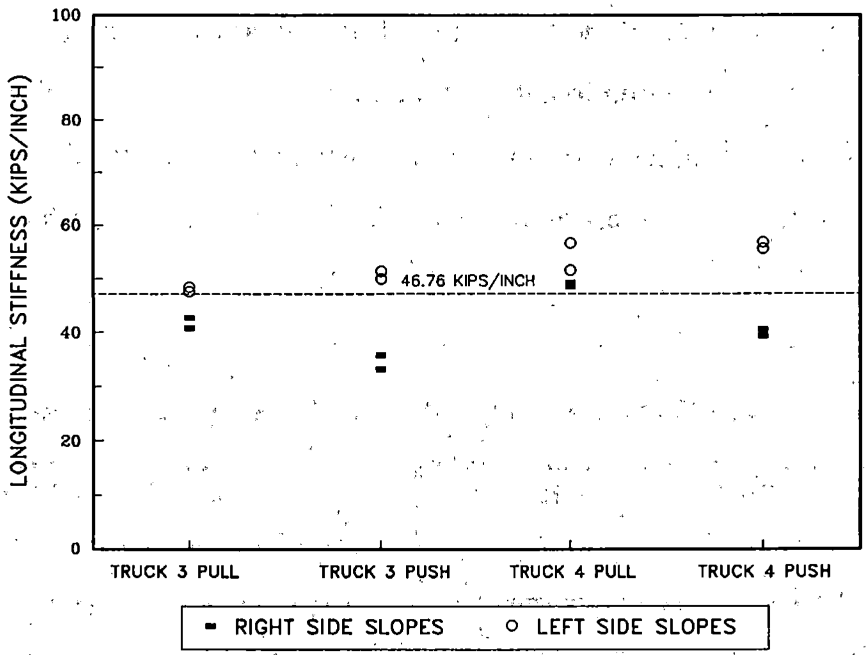


Figure 4.9 Longitudinal Stiffness Scatter

The average truck side longitudinal stiffness was 46.76 kips/inch. The truck side average was then doubled to give axle box stiffnesses. A final stiffness of 10^6 kips per inch will be used to represent the bearing adapter up against the side frame stops. This value has been used in a modified version of NUCARS to represent a very stiff connection. This value was never reached during testing. The second slope was extrapolated to a deflection of 1/4 inch at the stops, and the final slope was assumed to be 10^6 (Figure 4.10).

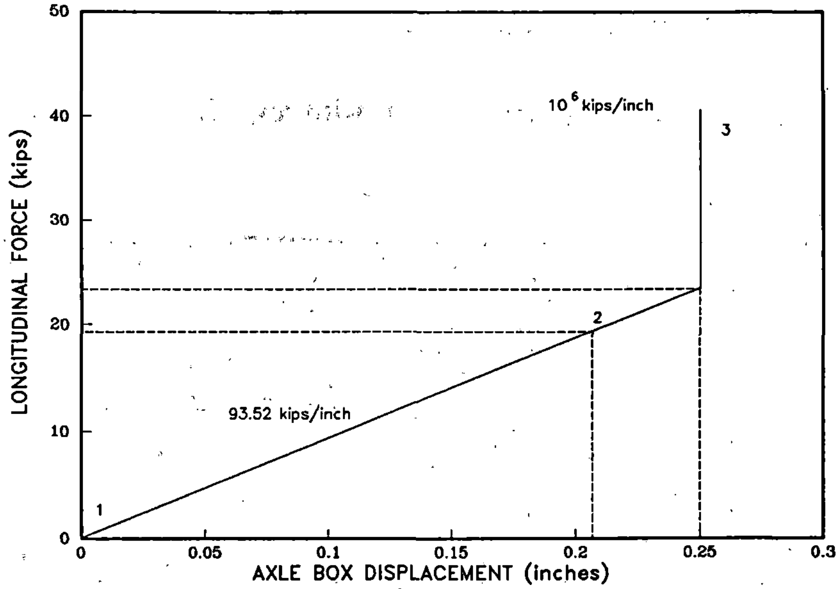


Figure 4.10 Axle Box Longitudinal Stiffness Profile

From the stiffness profile, a NUCARS axle box stiffness look-up table was created (Table 4.4).

Table 4.4 NUCARS Look-up Table for Axle Box Longitudinal Stiffness

	1	2	3
F	0	19.87	23.38
δ	0	0.2125	0.2500

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

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

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

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

4.1.4 Axle Yaw and Inter-axle Bending Stiffnesses

In curving, the axles have a tendency to yaw with respect to each other (Figure 4.11).

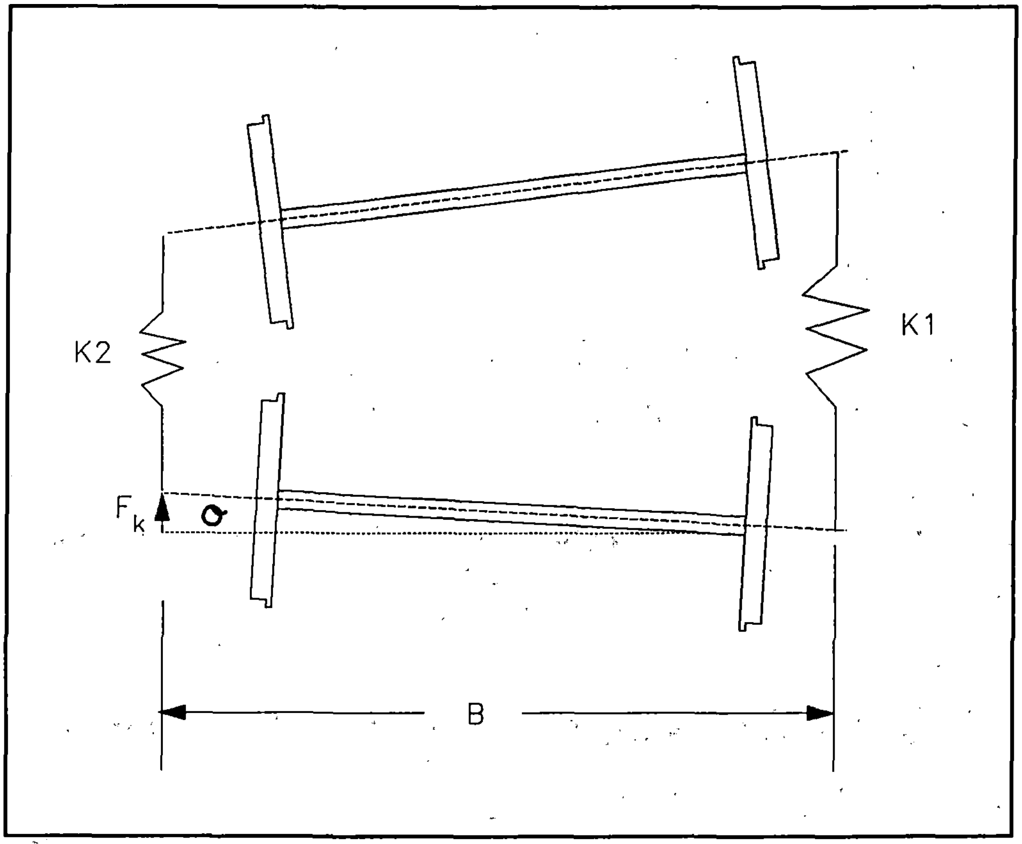


Figure 4.11 Axle Yaw and Inter-Axle Bending Diagram

The first step was to calculate the stiffnesses K1 and K2 in the same manner as longitudinal stiffness. Linear regressions were performed on graphs similar to the longitudinal stiffness plots.

Table 4.5 shows a summation of stiffness data for each test. The first run of each yaw direction was not representative of the overall yaw stiffness and was not considered when calculating averages.

Table 4.5 Axle Yaw Stiffness Summary Sheet

RUN NO.	TRUCK NO.	DIRECTION	RIGHT SIDE LC1 SLOPE (kips/in)	LEFT SIDE LC2 SLOPE (kips/in)
ATC043	3	LC1PUSH/LC2PULL	33.82	43.02
ATC044	3	LC1PUSH/LC2PULL	34.68	53.19
AVERAGE			**34.25**	**48.11**
ATC058	4	LC1PUSH/LC2PULL	40.14	47.49
ATC059	4	LC1PUSH/LC2PULL	39.56	45.35
ATC061	4	LC1PULL/LC2PUSH	39.44	47.12
ATC062	4	LC1PULL/LC2PUSH	40.26	47.47
AVERAGE			**39.85**	**46.86**
OVERALL AVERAGE			**37.05**	**47.48**

An axle yaw stiffness scatter plot from selected runs is shown in Figure 4.12.

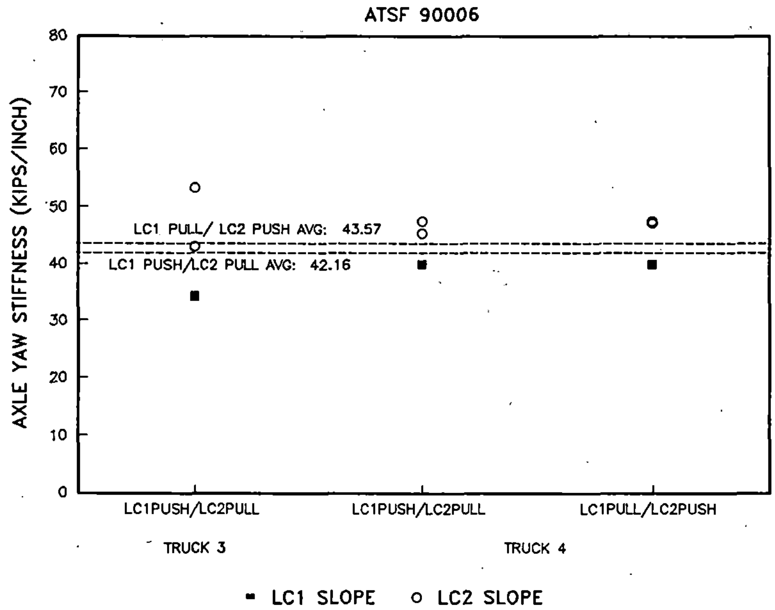


Figure 4.12 Axle Yaw Stiffness Scatter

The calculation for average axle yaw stiffness was calculated as:

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

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

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

$$K^1_{AY} = (43.57)(77.25)^2 = 260,007 inch-kips/rad = 260 inch-kips/mrad$$

$$K^2_{AY} = (42.16)(77.25)^2 = 251,592 inch-kips/rad = 252 inch-kips/mrad$$

See Figure 4.11 for explanations of F, B, and Theta.

The final calculation yielded an axle yaw stiffness of 256 in-kips/mrad. These values were compared to those calculated by the modified NUCARS program from the longitudinal stiffness inputs.

4.2 AIR BEARING TABLE TEST (ATSF 90004)

4.2.1 Span Bolster Yaw Moment Test

Figure 4.13 shows a typical force versus displacement plot.

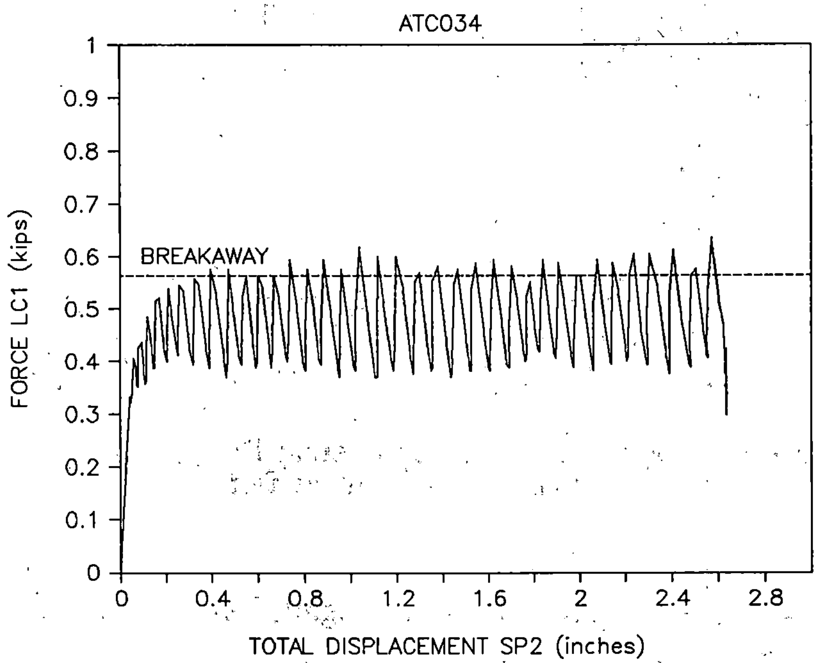


Figure 4.13 Force versus Displacement -- Span Bolster Yaw Moment Test

The force increased with relatively small displacement until the static friction was overcome. At that point, the span bolster rotated with virtually no increase in force. This was called the breakaway point. Since two actuators were used, the actual breakaway torque or yaw moment was calculated by summing the two breakaway torques. A plot similar to the one in Figure 4.13 is shown in Figure 4.14. This plot shows force versus displacement for the second actuator.

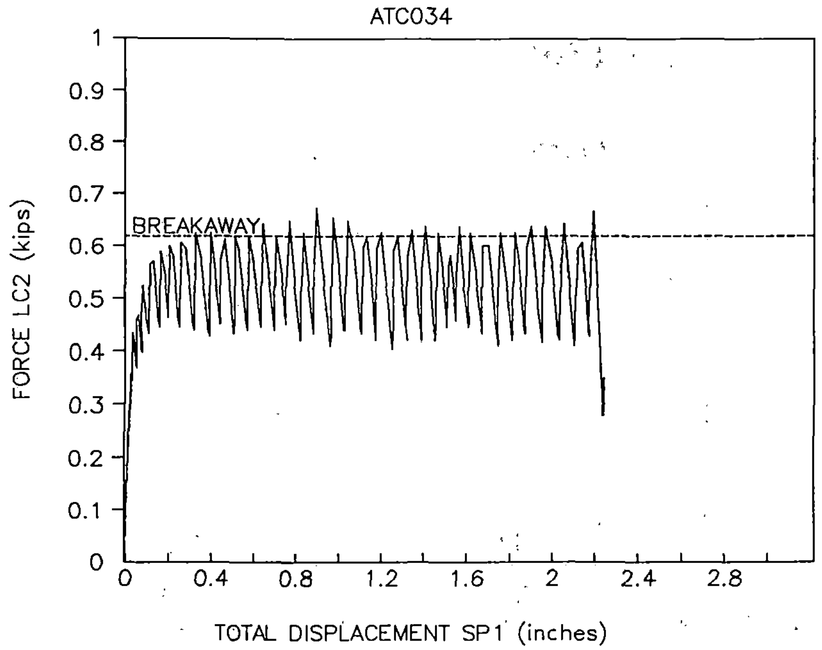


Figure 4.14 Second Actuator Force versus Displacement -- Span Bolster Yaw Moment Test

The breakaway force on each actuator was slightly less than 1,000 pounds; 550 and 610 pounds, respectively. The serrated appearance of the line was caused by pumping the actuators by hand. A line was drawn through the top of the fluctuations to imply the breakaway force value.

The perpendicular distance from each actuator to the span bolster center pin was 108 inches. The yaw moment or breakaway force was then calculated by multiplying the sum of the two forces by the distance of 108 inches. The yaw moment for run ATC033, shown in the previous figures, was (550 + 610) X 108 = 128,520 in-lbs. Table 4.6 shows a summary of the Span Bolster Yaw Moment Test results.

Table 4.6 A-end Span Bolster Yaw Moment Test Results for ATSF 90004

DIR	RUN No.	FORCE 1 (kips)	FORCE 2 (kips)	TOTAL (kips)	MOMENT (in-lbs)
CCW	ATC033	.63	.65	1.28	138,240
CCW	ATC034	.58	.61	1.19	128,520
CCW	AC035	.50	.53	1.03	111,240
CCW	ATC036	.63	.68	1.31	141,480
CCW	ATC041	.51	.52	1.03	111,240
CCW	ATC044	.50	.52	1.02	110,160
AVERAGE YAW MOMENT : 123,480 in-lbs					

Rotating the span bolster created a special set of problems. Car body motion and uneven floating of the tables were among a few. Due to difficulty controlling the air tables while rotating in the clockwise direction, only the counterclockwise direction was tested. Although the data was repeatable, it is suspect.

4.2.2 Truck Yaw Moment Test

A tabulation of the Truck Yaw Moment Test results is presented in Table 4.7.

Table 4.7 Truck Yaw Moment Test Result for ATSF 90004

RUN NO.	TRUCK NO.	DIR	FORCE 1 (kips)	FORCE 2 (kips)	TOTAL FORCE (kips)	YAW MOMENT (in-lbs)
ATC045	4	CCW	.63	.67	1.30	93,600
ATC046	4	CCW	.56	.59	1.15	82,800
ATC047	4	CCW	.51	.59	1.10	79,200
ATC048	4	CW	.50	.51	1.01	72,720
ATC049	4	CW	.43	.50	0.93	66,960
ATC050	4	CW	.42	.46	0.88	66,360
TRUCK 4 AVERAGE YAW MOMENT : 76,940 in-lbs						
ATC053	3	CW	.80	.86	1.66	119,520
ATC054	3	CCW	.89	.96	1.85	133,200
TRUCK 3 AVERAGE YAW MOMENT : 126,360 in-lbs						

The average yaw moment for truck 4 was 76,940 in-lbs, and truck 3 was 126,360. The large variation may be contributed to a difference in lubrication of the center bowls. Other factors, such as the amount of wear on the vertical wear liner, can cause a difference in friction, thus a different yaw moment value. The yaw moment value of truck 4 decreased with each consecutive run. This may be a test phenomena, and not characteristic of truck yaw moments.

The overall scatter for both trucks and the span bolster is shown in Figure 4.15.

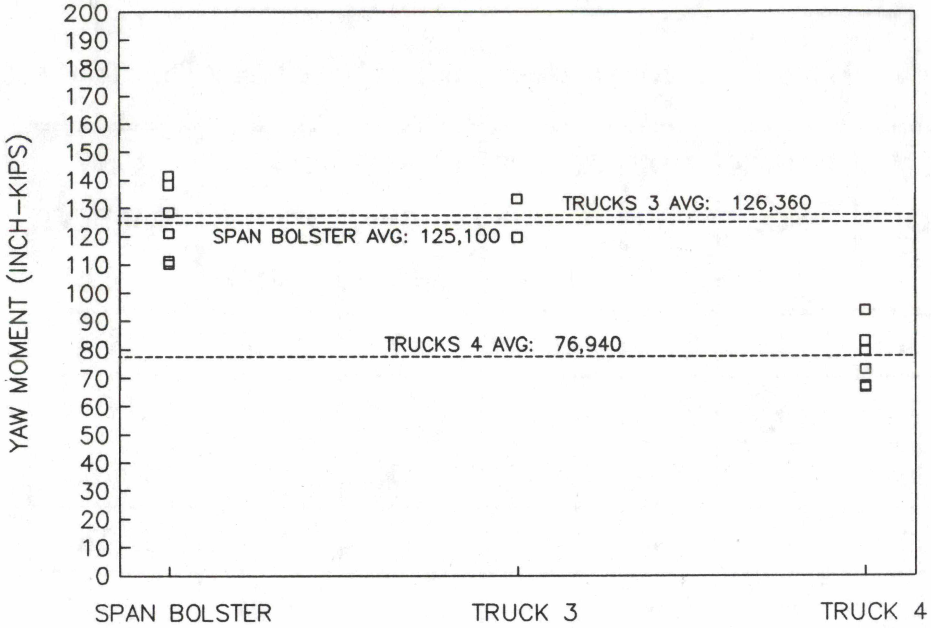


Figure 4.15 Yaw Moment Scatter Plot

4.2.3 Longitudinal Stiffness

Table 4.8 is a tabulation of the truck side stiffness measurements. The scatter for selected runs is shown in Figure 4.16.

Table 4.8 Truck Side Longitudinal Stiffness Measurements

RUN NO.	TRUCK NO.	DIRECTION	RIGHT SIDE LC1 SLOPE (kips/in)	LEFT SIDE LC2 SLOPE (kips/in)
ATC010	3	Pushing	91.76	111.70
ATC012	3	Pushing	91.31	107.54
		AVERAGE :	**93.23**	**111.36**
ATC019	4	Pulling	50.07	105.11
ATC020	4	Pulling	49.83	107.09
ATC028	4	Pushing	68.18	101.25
ATC029	4	Pushing	68.48	101.66
		AVERAGE :	**59.14**	**103.78**

Note: Overall Average 74.68 and 107.57 kips/inch

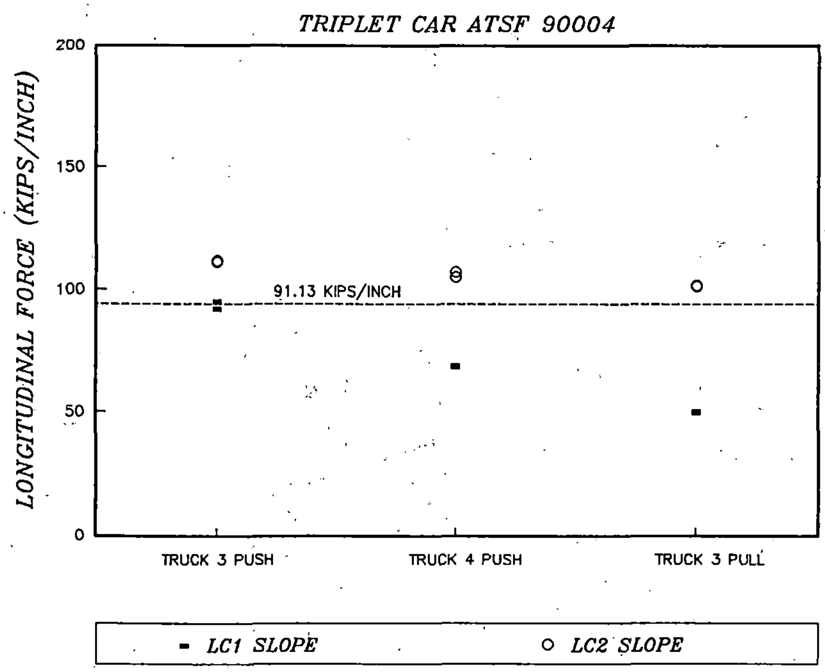


Figure 4.16 Longitudinal Stiffness Scatter

The average truck side longitudinal stiffness was 91.13 kips/inch. The truck side average was then doubled to give axle box stiffnesses. A final stiffness of 10^6 kips/in was chosen to represent the bearing adapter up against the stops. This value has been used in NUCARS to represent a very stiff connection. This value was never reached. The second slope was extrapolated to a deflection of 3/16-inch at the stops, and the final slope was assumed to be 10^6 (Figure 4.17).

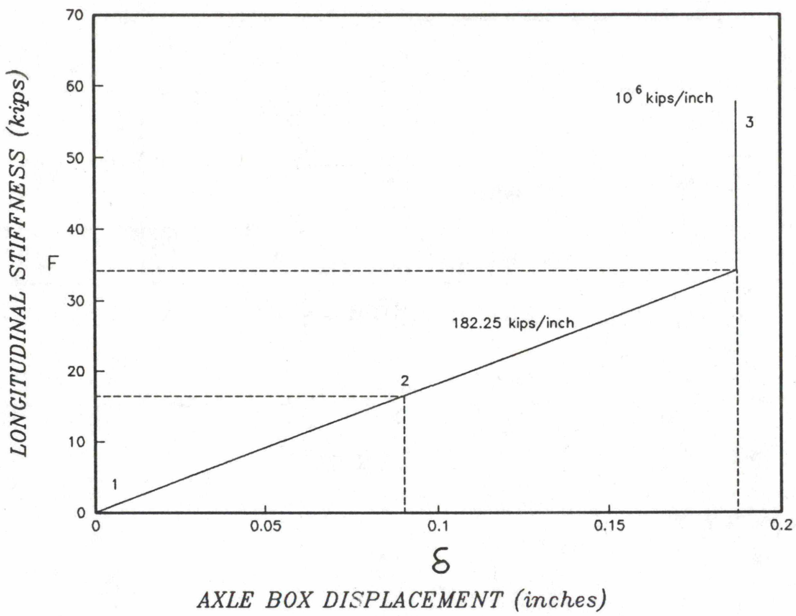


Figure 4.17 Axle Box Longitudinal Stiffness Profile

From the stiffness profile, a NUCARS axle box stiffness look-up table was created (Table 4.9).

Table 4.9 NUCARS Look-up Table for Axle Box Longitudinal Stiffness

	1	2	3
F	0	17.91	34.15
δ	0	0.0984	0.1875

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

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

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

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

4.2.4 Axle Yaw and Inter-axle Bending Stiffness

In curving, the axles have a tendency to yaw with respect to each other as previously illustrated in Figure 4.11. Table 4.10 shows a summation of stiffness data for each test.

Table 4.10 Axle Yaw Stiffness Summary Sheet

RUN NO.	TRUCK NO.	DIRECTION LC1 = RIGHT LC2 = LEFT	LC1 (RIGHT) SLOPE	LC2 (LEFT) SLOPE
ATC007	3	LC1PULL/ LC2PUSH	76.29	86.18
ATC008	3	LC1PULL/ LC2PUSH	82.58	99.67
ATC009	3	LC1PULL/ LC2PUSH	86.84	106.95
		AVERAGE	**81.90**	**97.60**
ATC022	4	LC1PUSH/ LC2PULL	64.52	94.95
ATC023	4	LC1PUSH/ LC2PULL	65.31	96.64
ATC025	4	LC1PULL/ LC2PUSH	43.20	90.2
ATC026	4	LC1PULL/ LC2PUSH	42.91	93.47
		AVERAGE	**53.98**	**93.81**

An axle yaw stiffness scatter plot from the summary sheet is shown in Figure 4.18.

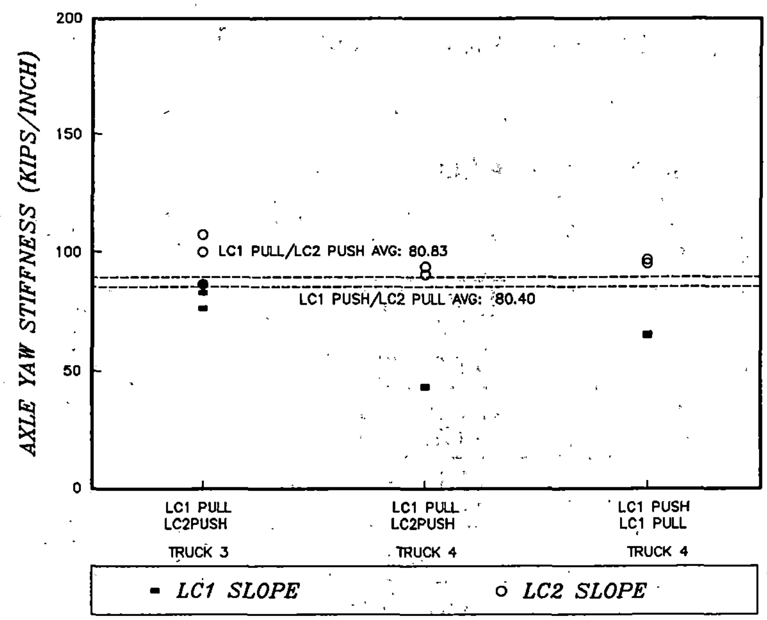


Figure 4.18 Axle Yaw Stiffness Scatter

The calculation for average axle yaw stiffness was calculated in the following way:

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

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

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

$$K_{AY}^1 = (80.40)(77.25)^2 = 479,792 inch-kips/rad = 480 inch-kips/mrad$$

$$K_{AY}^2 = (80.83)(77.25)^2 = 482,358 inch-kips/rad = 482 inch-kips/mrad$$

The final calculation yielded an average axle yaw stiffness of 481 in-kips/mrad. These values were compared to those calculated by the modified NUCARS program from the longitudinal stiffness inputs.

4.3 QUASI-STATIC TEST RESULTS

Each force versus displacement plot displays the hysteresis inherent in the particular suspension component being characterized. The x-axis corresponds to the displacement measurement; the y-axis corresponds to the rail-force or actuator force measurement. The upper and lower slopes of the curves correspond to the stiffnesses in kips/inch for the vertical, lateral and roll test runs. The damping corresponds to the vertical gap between the upper and lower sloped lines. This value is usually measured at each end of the hysteresis loop. Table 4.11 lists the runs selected for analysis.

Table 4.11 Runs Chosen for Data Analysis of A-end Span Bolster

RUN NUMBERS	TRUCK NO.	CAR	DESCRIPTION
TRIP_RN001 To TRIP_RN006	4	90006	VERTICAL± 0.5" to C.P. amplitude, 0.1 and 0.25 Hz Stroke Control
TRIP_RN040 To TRIP_RN047	3	90006	
TRIP_RN056 To TRIP_RN061	3	90004	
TRIP_RN094 To TRIP_RN099	4	90004	
TRIP_RN007 To TRIP_RN015	4	90006	ROLL± 0.5" to± 2.0" amplitude, 0.1 and 0.25 Hz Stroke Control Actuator 180 Degrees out-of-phase
TRIP_RN0048 To TRIP_RN055	3	90006	
TRIP_RN062 To TRIP_RN069	3	90004	
TRIP_RN100 To TRIP_RN107	4	90004	
TRIP_RN0016 To TRIP_RN027	4	90006	LATERAL± 10 kips to H.L., 0.1 and 0.25 Hz Force Control
TRIP_RN070 To TRIP_RN081	3	90004	
TRIP_RN029 To TRIP_RN039	3	90006	
TRIP_RN082 To TRIP_RN093	4	90006	

C.P. = Full Spring Compression
S.L. = 1/5 Vertical Static Load
H.L. = (S.L. - 10 Kips) + 10 Kips

The secondary suspension rates for the chosen vertical, roll, and lateral tests were determined. The damping was calculated for the vertical and lateral runs. Appendix F gives the force versus displacement plots used to determine the secondary suspension stiffnesses and damping for one chosen vertical and lateral run and for one truck roll stiffness rate run. Appendix F also contains a force versus force plot showing the relationship between the rail forces and the actuator forces. Tables 4.12 through 4.17 list the results of all the chosen runs. The slopes calculated from the force versus displacement plots are the result of hand-drawn approximations.

Table 4.12 is a tabulation of A-end vertical stiffness and damping force for the ATSF 90004 car with 125-ton design trucks.

Table 4.12 Secondary Suspension Average ATSF 90004

TRUCK NO.	RUN NO.	LEFT SIDE AVERAGE VERTICAL DATA		RIGHT SIDE AVERAGE VERTICAL DATA	
		STIFFNESS	DAMPING	STIFFNESS	DAMPING
4	TRIP_RN094	52.40	9.75	48.17	8.50
4	TRIP_RN095	51.48	10.50	47.04	9.60
4	TRIP_RN096	51.75	10.50	52.00	11.00
4	TRIP_RN097	52.00	12.80	47.94	9.50
4	TRIP_RN098	46.80	12.60	51.85	15.2
	AVERAGE :	**50.88**	**11.23**	**49.40**	**10.76**
3	TRIP_RN56	52.25	10.45	49.67	11.10
3	TRIP_RN57	51.67	10.50	48.33	11.10
3	TRIP_RN58	51.88	10.00	48.43	9.50
3	TRIP_RN59	51.33	11.00	48.28	11.25
3	TRIP_RN60	50.77	10.40	48.00	9.60
	AVERAGE :	**51.58**	**10.47**	**48.54**	**10.51**

The ATSF 90004 car had eight D-3 outer and eight D-3 inner springs per spring nest. The calculated spring nest stiffness was 48.06 kips/inch. The average tested value was 50.1 kips/inch.

Table 4.13 is a tabulation of vertical stiffness and damping force for the ATSF 90006 car.

Table 4.13 Secondary Suspension Average ATSF 90006

TRUCK NO.	RUN NO.	LEFT SIDE AVERAGE VERTICAL DATA		RIGHT SIDE AVERAGE VERTICAL DATA	
		STIFFNESS	DAMPING	STIFFNESS	DAMPING
3	TRIP_RN40	48.75	9.60	46.50	--
3	TRIP_RN041	49.12	11.10	46.13	10.50
3	TRIP_RN042	47.27	12.80	43.81	9.38
3	TRIP_RN043	43.93	11.25	42.83	12.25
3	TRIP_RN044	46.25	12.00	45.62	8.00
3	TRIP_RN045	45.77	11.50	44.17	10.5
3	TRIP_RN046	44.00	--	44.54	10.00
3	TRIP_RN047	43.98	12.75	44.00	11.90
	AVERAGE :	**46.13**	**11.57**	**44.70**	**10.36**
4	TRIP_RN001	45.35	10.25	45.32	9.50
4	TRIP_RN002	45.00	10.5	44.36	10.35
4	TRIP_RN003	44.88	11.48	43.10	--
4	TRIP_RN004	45.31	12.75	42.92	8.20
4	TRIP_RN005	45.28	11.62	42.77	--
4	TRIP_RN006	44.37	12.5	41.3	--
	AVERAGE :	**45.03**	**11.52**	**43.30**	**9.35**

The ATSF 90006 car had seven D-3 outer and five D-3 inner springs per spring nest. The calculated spring nest stiffness was 46.66 kips/inch. The average tested value was 44.85 kips/inch.

Table 4.14 is a tabulation of average roll stiffness for the A-end trucks of the ATSF 90004 car.

Table 4.14 Truck Roll Stiffness - Selected Roll Test Runs ATSF 90004

TRUCK NO.	RUN NO.	AVERAGE TRUCK ROLL STIFFNESS
3	TRIP_RN062	72,600 kip-in/rad
3	TRIP_RN063	65,400 kip-in/rad
3	TRIP_RN064	65,200 kip-in/rad
3	TRIP_RN066	61,779 kip-in/rad
3	TRIP_RN068	61,389 kip-in/rad
	AVERAGE	**65,274 kip-in/rad**
4	TRIP_RN100	80,400 kip-in/rad
4	TRIP_RN101	73,200 kip-in/rad
4	TRIP_RN102	64,200 kip-in/rad
4	TRIP_RN103	70,800 kip-in/rad
4	TRIP_RN104	67,992 kip-in/rad
4	TRIP_RN106	67,134 kip-in/rad
4	TRIP_RN107	67,930 kip-in/rad
	AVERAGE	**70,237 kip-in/rad**

Table 4.15 is a tabulation of average roll stiffness of the A-end trucks for the ATSF 90006 car.

Table 4.15 Truck Roll Stiffness - Selected Roll Test Runs
ATSF 90006

TRUCK NO.	RUN NO.	AVERAGE TRUCK ROLL STIFFNESS
3	TRIP_RN048	65,888 kip-in/rad
3	TRIP_RN050	72,800 kip-in/rad
3	TRIP_RN051	61,285 kip-in/rad
3	TRIP_RN052	82,758 kip-in/rad
3	TRIP_RN053	77,419 kip-in/rad
3	TRIP_RN054	64,639 kip-in/rad
3	TRIP_RN055	59,294 kip-in/rad
	AVERAGE	**69,154 kip-in/rad**
4	TRIP_RN009	73,125 kip-in/rad
4	TRIP_RN011	72,965 kip-in/rad
4	TRIP_RN013	75,849 kip-in/rad
	AVERAGE	**73,939 kip-in/rad**

Table 4.16 is a tabulation of lateral stiffness and damping force for the A-end trucks of the ATSF 90004 car.

Table 4.16 Stiffness and Damping - Selected Lateral Test Runs ATSF 90004

TRUCK NO.	RUN NO.	LEFT SIDE AVERAGE LATERAL DATA		RIGHT SIDE AVERAGE LATERAL DATA	
		STIFFNESS	DAMPING	STIFFNESS	DAMPING
4	TRIP_RN084	47.14	23.60	45.00	23.40
4	TRIP_RN085	40.31	24.68	36.17	24.7
4	TRIP_RN086	43.87	21.30	46.95	21.6
4	TRIP_RN087	38.63	21.90	34.88	21.9
4	TRIP_RN090	44.45	22.20	44.87	22.60
4	TRIP_RN091	39.75	23.70	42.70	23.80
4	TRIP_RN092	44.25	22.20	45.00	23.1
4	TRIP_RN093	38.25	23.40	36.00	23.40
	AVERAGE	**42.08**	**22.87**	**41.45**	**23.06**
3	TRIP_RN072	46.29	25.10	48.57	24.80
3	TRIP_RN073	43.34	25.00	43.57	25.40
3	TRIP_RN074	44.33	19.5	48.75	19.80
3	TRIP_RN075	32.62	20.10	33.00	21.00
3	TRIP_RN078	49.17	24.6	57.91	25.10
3	TRIP_RN079	36.00	25.20	41.00	23.20
3	TRIP_RN080	46.71	20.70	52.83	19.20
3	TRIP_RN081	32.63	23.7	33.00	21.00
	AVERAGE	**41.39**	**22.99**	**44.83**	**22.44**

Table 4.17 is a tabulation of lateral stiffness and damping force for the A-end trucks of the ATSF 90006 car.

Table 4.17 Stiffness and Damping - Selected Lateral Test Runs ATSF 90006

TRUCK NO.	RUN NO.	LEFT SIDE AVERAGE LATERAL DATA		RIGHT SIDE AVERAGE LATERAL DATA	
		STIFFNESS	DAMPING	STIFFNESS	DAMPING
4	TRIP_RN018	37.50	21.90	41.82	23.40
4	TRIP_RN019	40.00	26.40	42.85	25.60
4	TRIP_RN020	41.67	25.25	42.44	25.25
4	TRIP_RN021	36.67	26.00	35.50	17.75
4	TRIP_RN024	40.73	25.40	44.44	24.80
4	TRIP_RN025	33.33	27.4	35.55	27.20
4	TRIP_RN026	41.47	26.25	42.73	25.63
	TRIP_RN027	39.01	27.00	35.93	26.75
	AVERAGE	**38.78**	**25.70**	**40.16**	**24.55**
3	TRIP_RN030	51.30	27.09	48.00	25.56
3	TRIP_RN031	36.90	28.01	33.00	27.00
3	TRIP_RN032	44.50	29.50	44.80	28.40
3	TRIP_RN033	36.40	29.90	35.38	29.20
3	TRIP_RN036	51.20	28.50	48.00	27.36
3	TRIP_RN037	41.14	28.80	35.20	27.84
3	TRIP_RN038	45.63	30.30	43.00	29.00
3	TRIP_RN039	38.00	30.00	34.09	29.70
	AVERAGE	**43.13**	**27.76**	**40.18**	**28.00**

4.4 TRIPLET CAR MODAL RESPONSE TEST (ATSF 90006)

Modal analysis was performed with Structural Measurements Systems (SMS) modal analysis software. Transfer functions for each point shown in Figure 4.19 were created with AAR analysis software and imported into the SMS model.

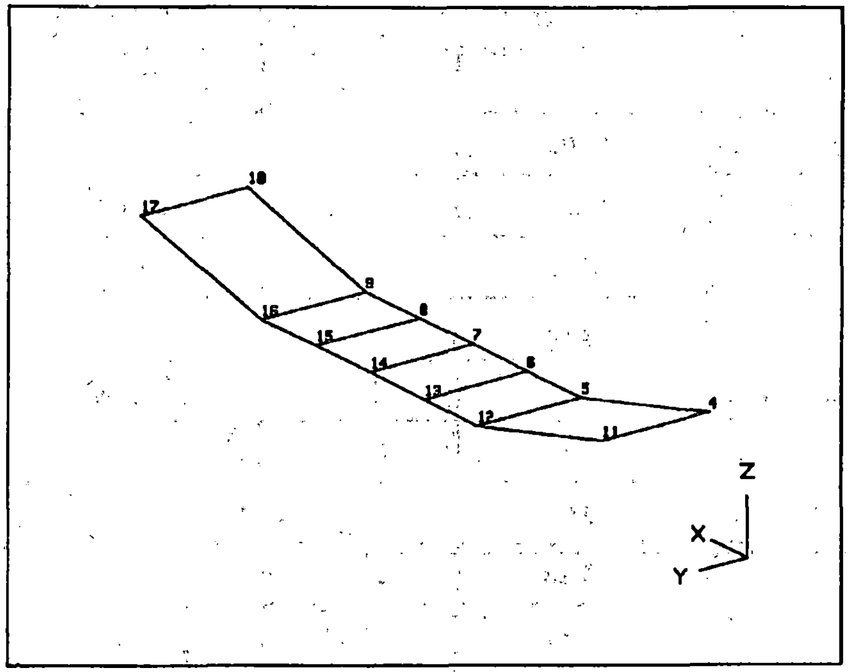


Figure 4.19 SMS Model of ATSF 90006

Points 11 through 17 in the model were receiving vertical measurements only, therefore, these points were laterally constrained to their counterparts on the other side of the car. In roll, those points were constrained 180 degrees out of phase with the other side of the car. Magnitude and phase were compared at each peak in the transfer functions and a mode shape was calculated and displayed by SMS.

4.4.1 Rigid Body Vertical

Data from run TRIP_RN146 were analyzed to obtain pitch and bounce resonant frequencies.

MODE	FREQUENCY
Pitch	5.75 Hz
Bounce	2.25 Hz

A 25 kip sinusoidal load was applied to the actuator. The sine wave was swept from .5-10 Hz. A transfer function between the actuator input force and acceleration at the A-end edge of the depressed center of the car body is shown in Figure 4.20.

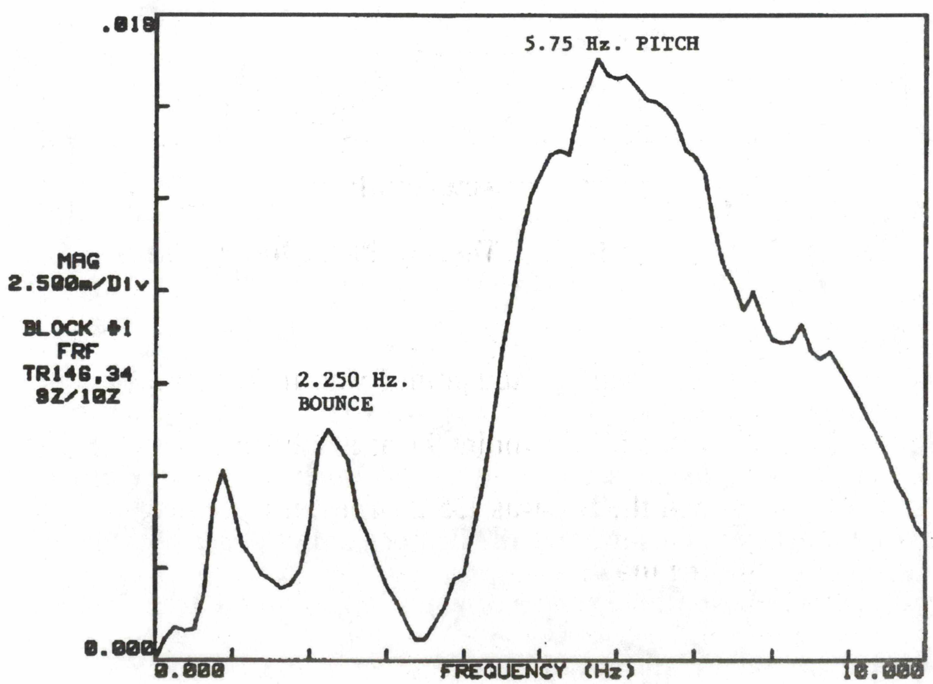


Figure 4.20 Pitch and Bounce Transfer Function

Pitch and bounce were determined by the phase relationship between the A-end and the B-end vertical accelerations. Figure 4.21 shows the phase of point 9 near the A-end and point 5 near the B-end, top to bottom plots, respectively. The two vertical lines represent the frequency at which the two peaks were found on the previous transfer function.

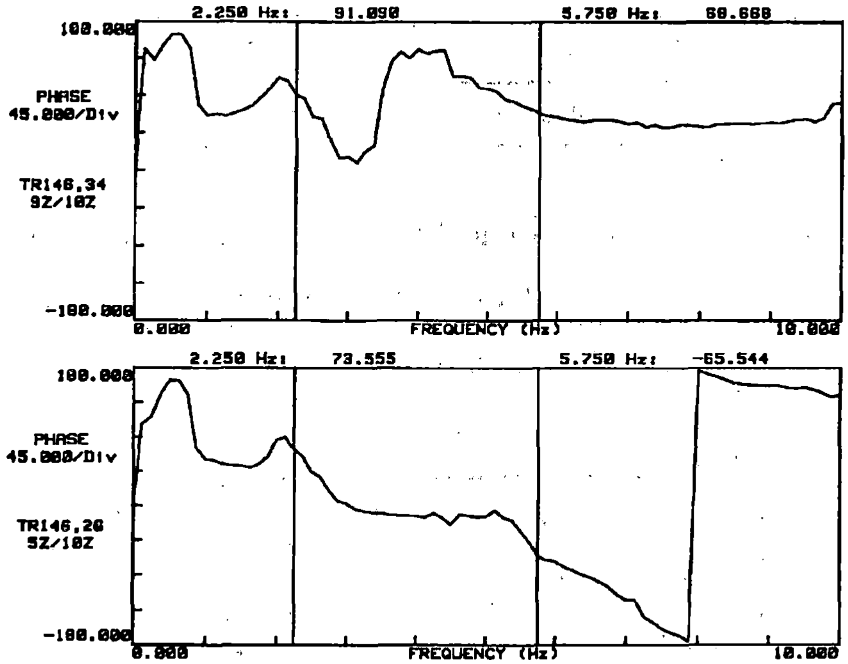


Figure 4.21 A- and B-end Vertical Phase Relationship

At 2.25 Hz point 9 was at 91 degrees and point 5 was at 74 degrees, essentially in phase, indicating body bounce. At 5.75 Hz point 9 was at 69 degrees and point 5 was at -66 degrees. The difference between the two was 135 degrees, essentially 180 degrees out of phase, which indicates a pitching motion.

Figure 4.22 shows the bounce mode as displayed with vectors by SMS. The base of the car is shown. Other points were removed for clarity. The small lines are the vectors indicating relative amplitude and direction of motion for each point. The MSU utilized one 77 kip hydraulic actuator for car body excitation.

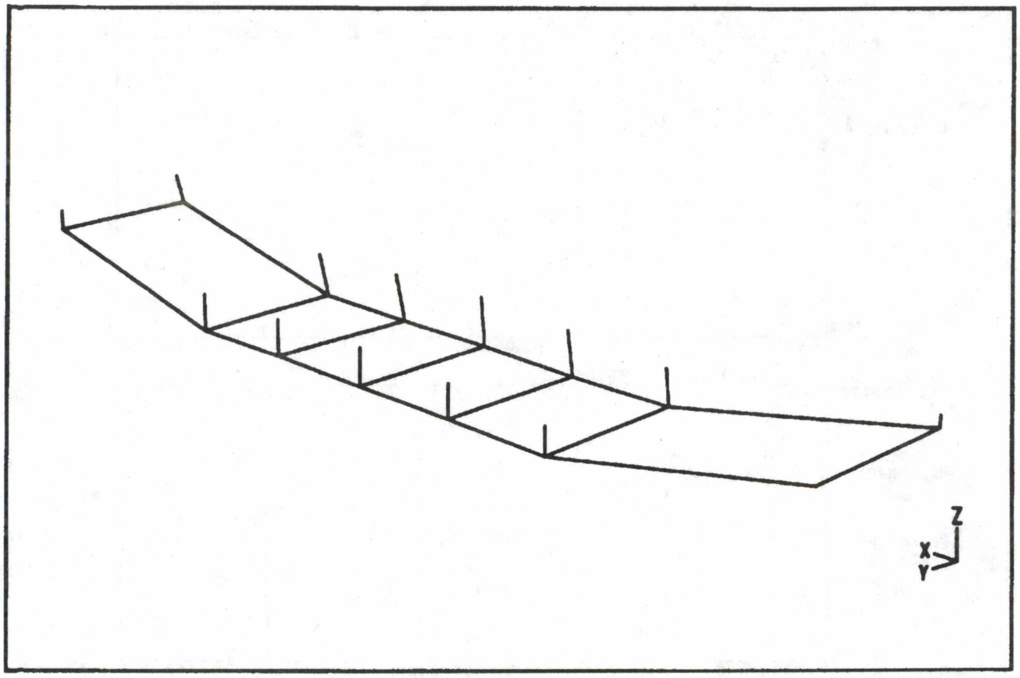


Figure 4.22 Bounce Displayed with Vectors

A pure bounce mode would show all points along the car moving vertically in the same direction with the same amplitude. The case shown here is typical of that excited by the MSU.

Figure 4.23 shows the vector plot for pitch.

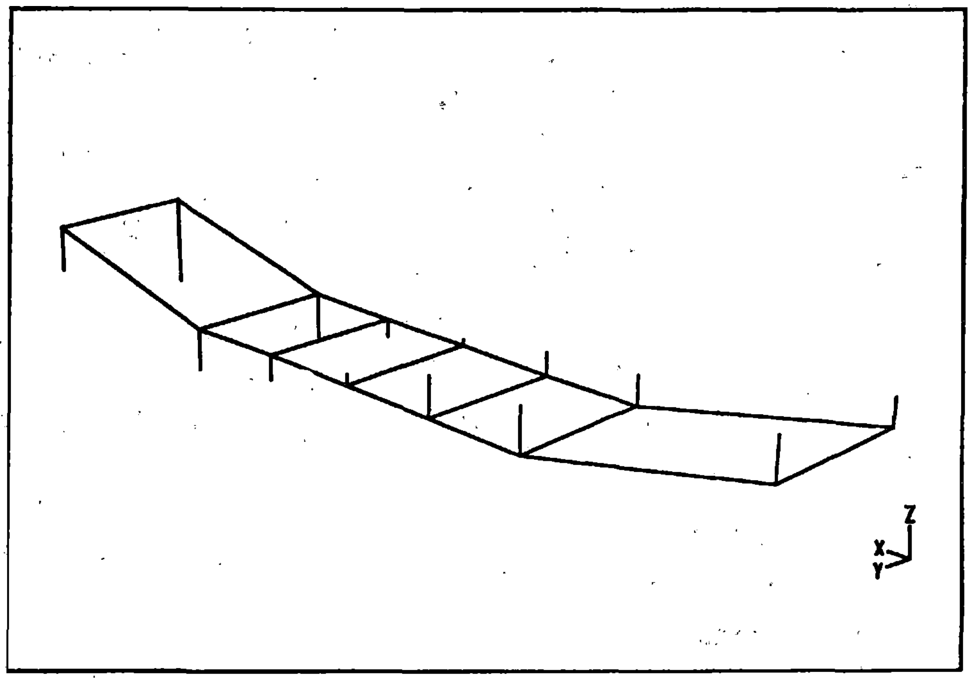


Figure 4.23 Pitch Displayed with Vectors

The relative magnitude of motion decreased toward the center of the car then increased again toward each end. At the A-end, the direction of motion is in the negative z direction, while the B-end is moving in the positive z direction. The center is hardly moving as shown by the very small vectors. This indicates vertical pitch about the center of the car.

4.4.2 Rigid Body Roll

Data from run TRIP_RN146 were analyzed to obtain the lower center roll resonant frequency. The matrix below shows the lower center roll resonant frequency.

MODE	FREQUENCY
Lower Center Roll	0.87 Hz

A 25 kip sinusoidal load was applied to the car. The sine wave was swept from .5-10 Hz. Due to the fact that only one vertical actuator was used, the roll modes as well as vertical modes were excited. A transfer function between the actuator input force and acceleration at the A-end edge of the depressed center of the car body is shown in Figure 4.24.

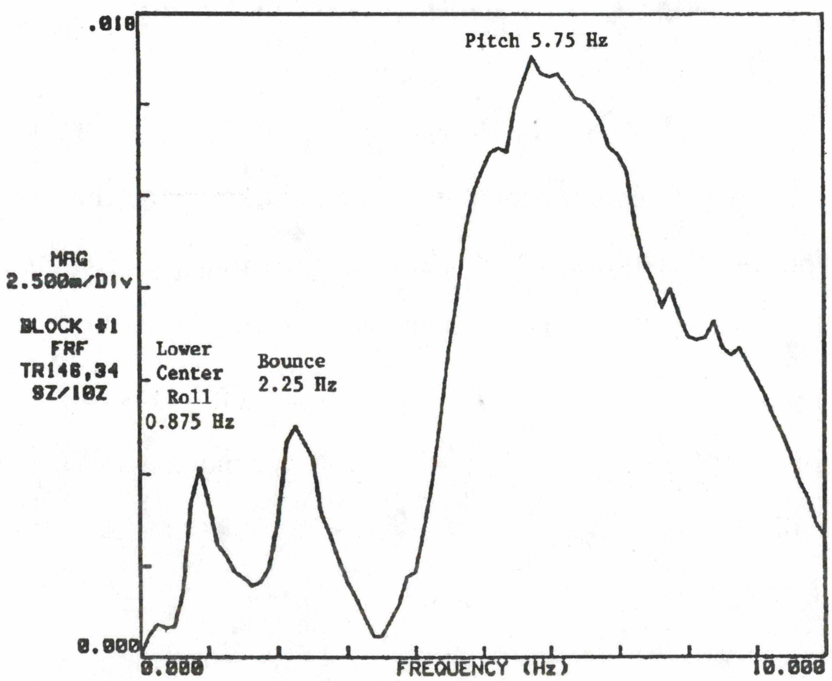


Figure 4.24 Lower Center Roll Transfer Function

The phase relationship between right and left side vertical accelerations was examined to determine if roll was present. Figure 4.25 shows the phase of the A-end right vertical accelerometer (9) and the A-end left vertical accelerometer (16). The vertical line indicates the frequency at which the peak was observed on the previous transfer function.

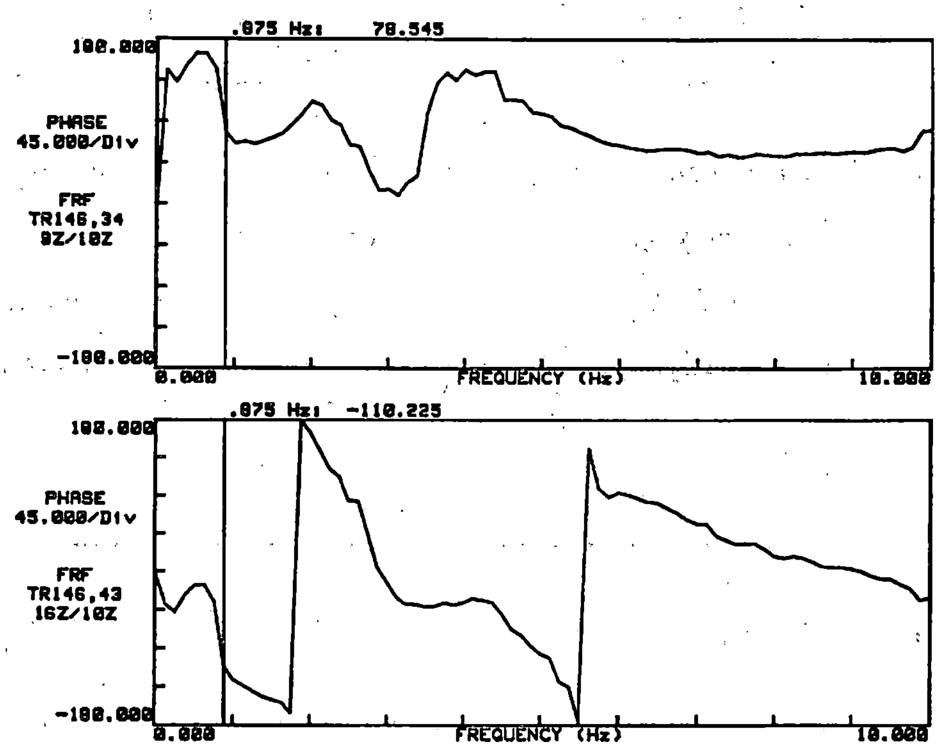


Figure 4.25 Right and Left Side Vertical Phase Showing Roll

At 0.875 Hz, the right side was 78 degrees and the left was -110 degrees. The difference was 188 degrees. This shows that the right side was moving up when the left side was moving down, indicating roll or twist. The B-end phases were also examined to ensure that the phase relationship was similar to the A-end. If the car was twisting, the A- and B- end right side accelerometers would have been out of phase. The A-end would have been rolling right while the B-end was rolling left. This was not the case.

Figure 4.26 shows the A-end acceleration measurements on the left and right corners of the car. When a line is drawn between these points in SMS, it represents the width of the car. Vectors at points (9) and (16) indicate the relative magnitude and direction of motion at 0.875 Hz. The small angle in the vectors indicate that the car was rolling about some point beneath the car body.

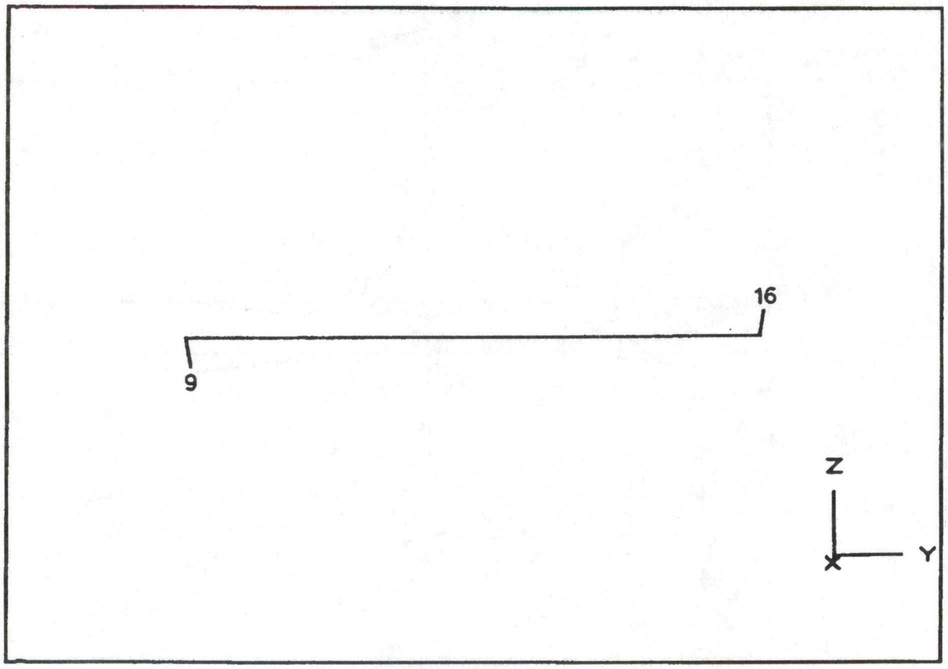


Figure 4.26 Vector Display of Lower Center Roll at A-End

Figure 4.27 is an A-end view of points 9 and 16 at 0.875 Hz. This is a two frame depiction of the rolling motion of the car. The first frame is point 9 (left A-end corner) at its lowest point, while point 16 (right A-end corner) is at its highest point. The second frame is the two points in opposite translation. Superimposed, they demonstrate the full range of car body roll.

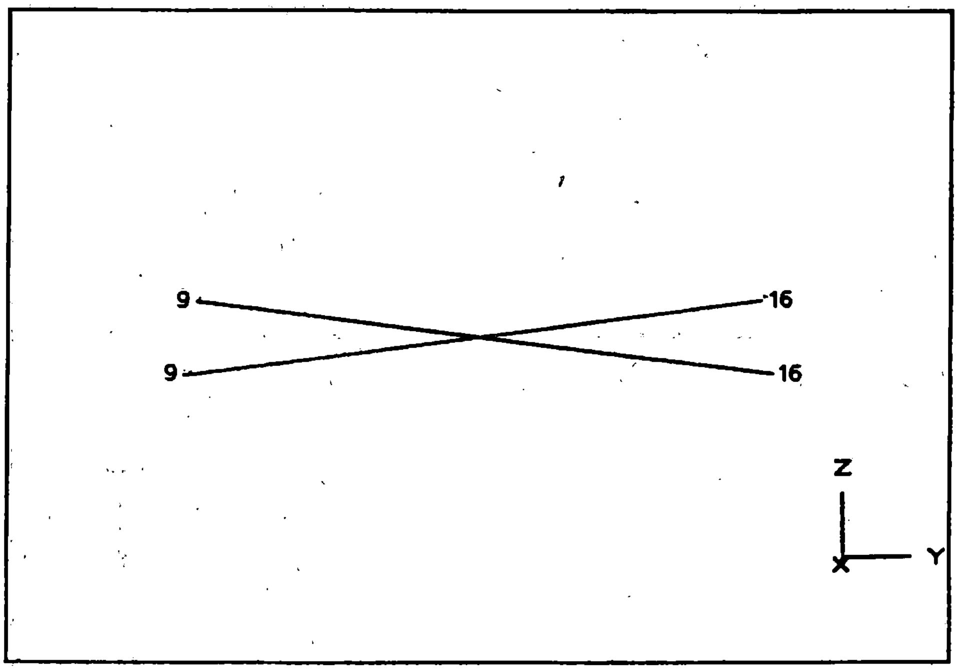


Figure 4.27 A-End View of Lower Center Roll Motion

4.4.3 Flexible Body Vertical

Data from runs similar to TRIP_RN151 were analyzed to obtain the first vertical bending frequency and mode shape. The matrix below shows the first vertical bending resonant frequency.

MODE	FREQUENCY
First Vertical Bending	10.6 Hz

A constant 0.5 g input was used in a 8-30 Hz sine sweep. The constant g input was actually implied from a matrix of displacement control parameters. The displacement was reduced as the frequency increased, thus keeping the acceleration level constant.

Figure 4.28 is a transfer function between the actuator input force and vertical acceleration at the edge of the opposite side of the car at the center line.

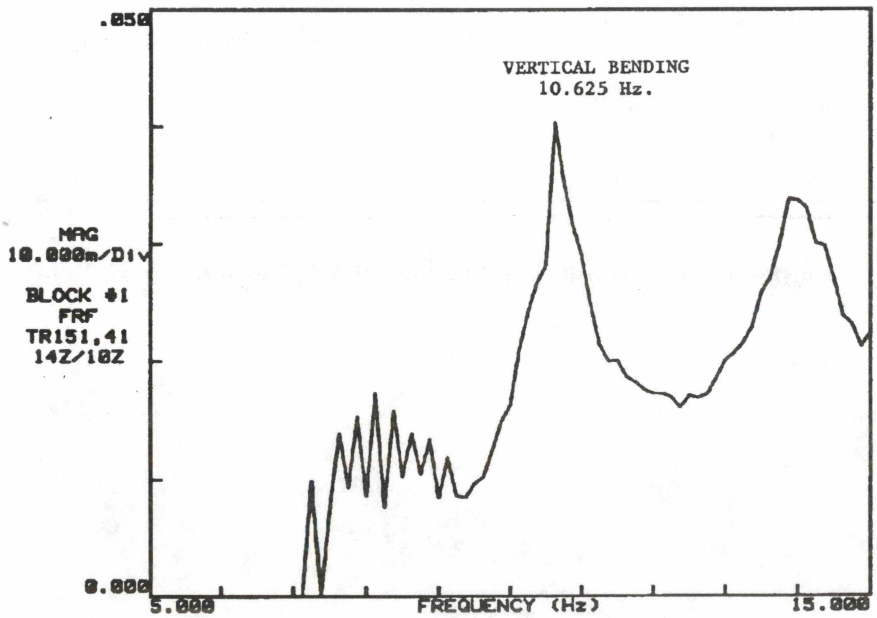


Figure 4.28 Vertical Bending Transfer Function

Other frequencies were examined for vertical bending including 14 Hz, which is also prevalent in Figure 4.28. The mode shape created for 14 Hz clearly showed a non-uniform vertical bending of the car body. Figures 4.29 and 4.30 show the maximum bending in the upward directions at 10.6 Hz using an exaggerated amplitude and vectors to illustrate the bending shape, respectively.

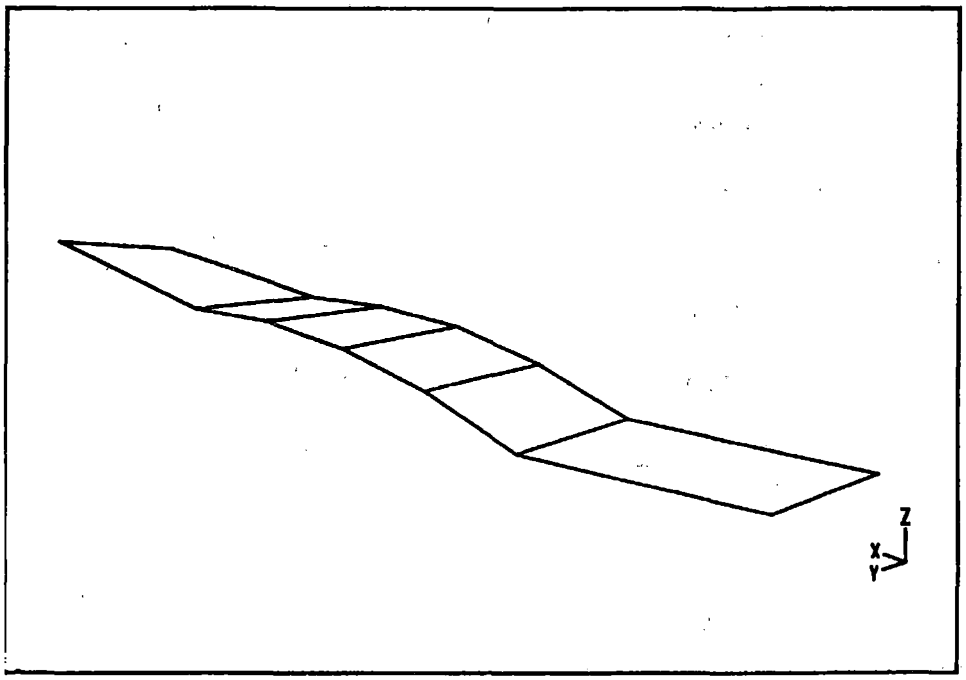


Figure 4.29 Upward Vertical Bending Shape Exaggerated

The vectors near the ends of the car point down where the vectors near the center of the car point up. This implies that the center of the car was out of phase with the ends, indicating first vertical bending.

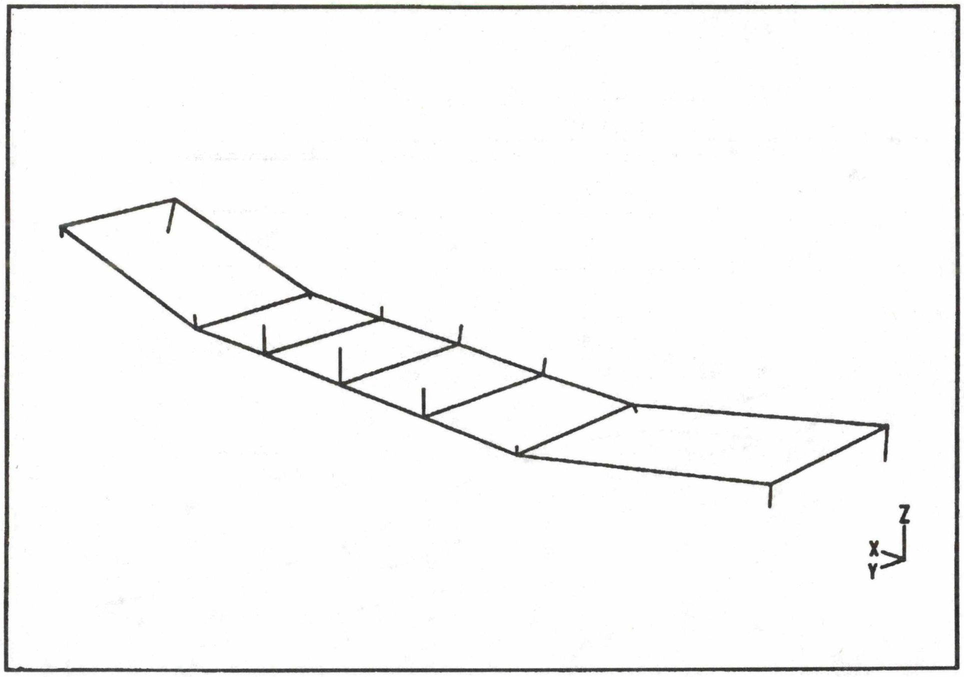


Figure 4.30 Upward Vertical Bending Shape Displayed with Vectors

4.4.4 Flexible Body Torsion

Flexible body torsion (twist) was not found.

4.4.5 Rigid Body Lateral

Rigid body modes of yaw and sway are best defined with large force inputs; therefore, runs with a 30 kip lateral input force, such as TRIP_RN139, were analyzed for yaw and sway resonant frequencies. The matrix below shows the yaw and sway resonant frequencies.

MODE	FREQUENCY
Sway	1.1
Yaw	9.8

Figure 4.31 shows a transfer function between input force and A-end lateral acceleration.

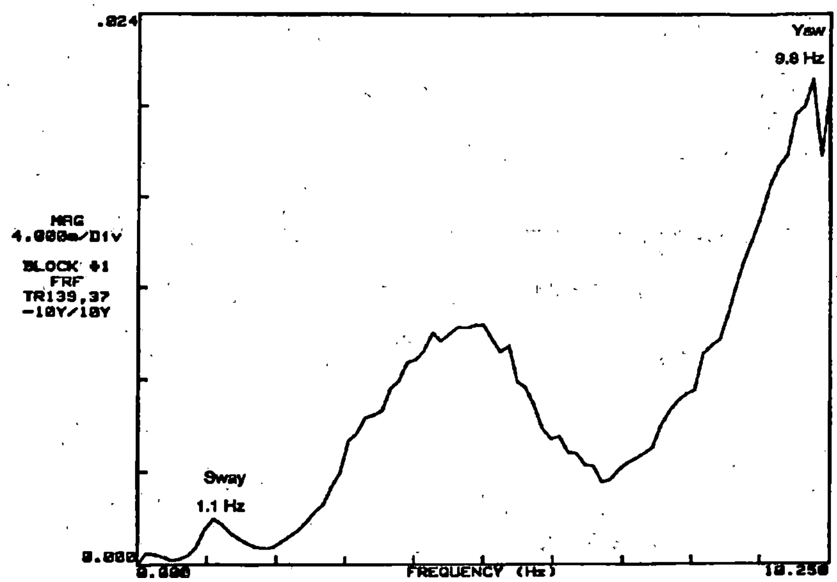


Figure 4.31 A-End Lateral Car Body Acceleration Transfer Function

Upon close examination of the car body behavior at 1.1 Hz, it was determined that the motion was sway coupled with some roll. Completely eliminating roll proved to be difficult when exiting the car with one actuator. The mode at 5 Hz was the result of a testing phenomenon and should not be considered a valid natural mode.

The yaw mode was verified at 9.7 Hz by comparing the phase of the A-and B-end lateral accelerations as in Figure 4.32.

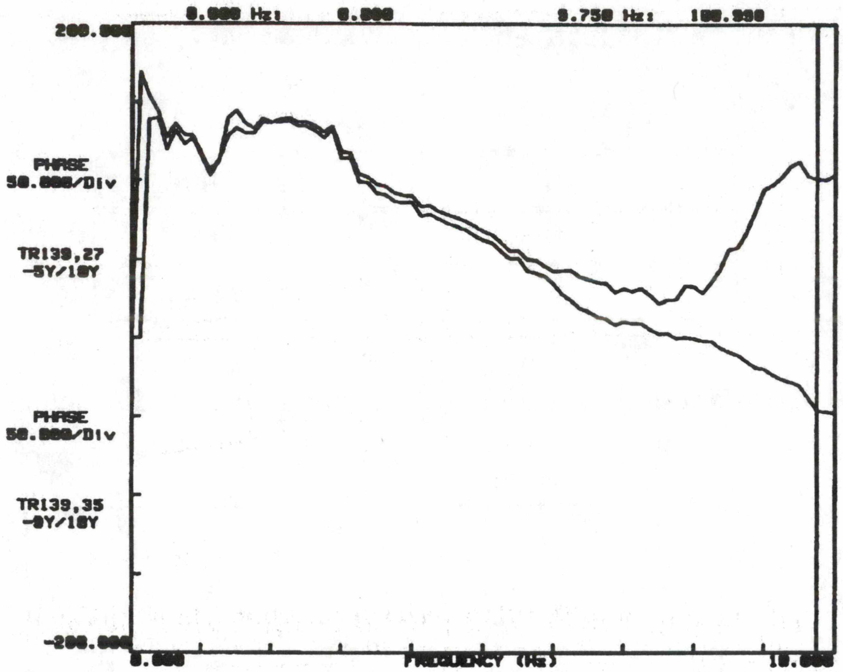


Figure 4.32 A-and B-End Phase Comparison Showing Yaw

The top line of the graph represents the phase at the A-end (point 5) and the bottom line of the graph represents the phase at the B-end (point 9). The vertical line at 9.75 Hz indicates the frequency at which yaw is suspected. Note the two points stay in phase until 9.75 Hz, then shift almost 180 degrees out of phase, indicating yaw.

Figure 4.33 is a top view of the car floor showing yaw in a relative displacement format. The single horizontal line shows the normal orientation of the car.

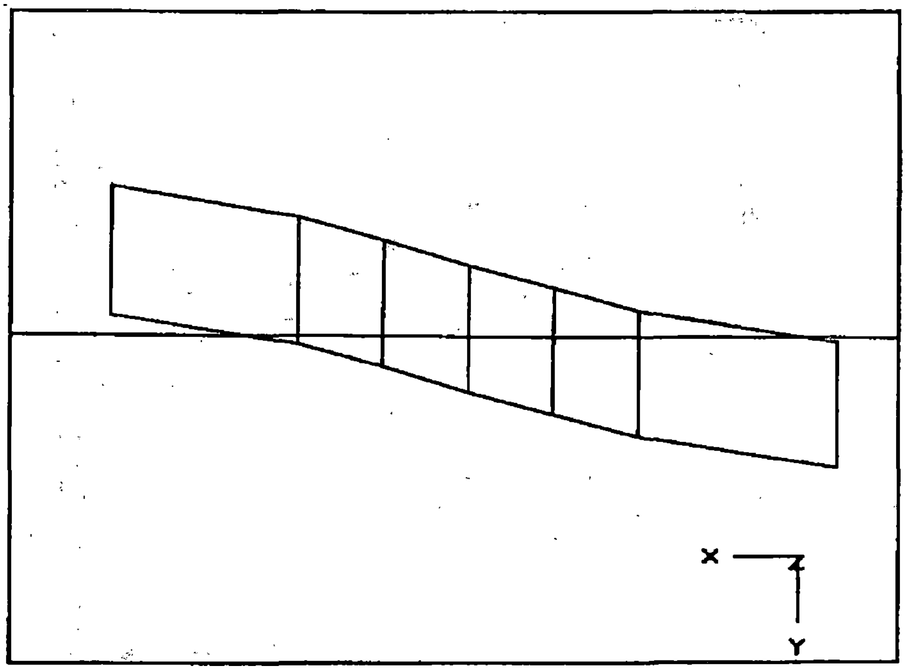


Figure 4.33 Yaw Mode Shape in Top View

During examination of the lateral modes, upper center roll was noted at 6.1 Hz, which couples with pitch at 5.8 Hz. Figure 4.34 shows the A-end of the car with acceleration measurements 9 and 16 shown as vectors to indicate the relative magnitude and direction of motion at 6.1 Hz.

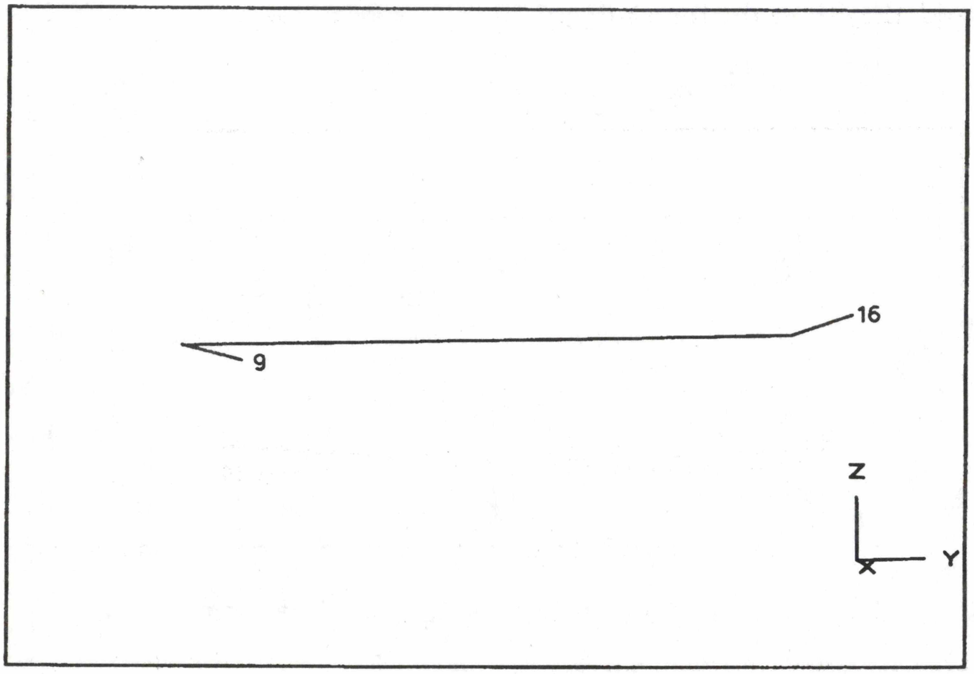


Figure 4.34 A-End Upper Center Roll Displayed with Vectors

Vectors 9 on the A-end left side, is moving down and inward while vector 16 is moving up and outward, indicating a roll motion about a point above the horizontal center line.

The primary difference between lower and upper center roll is the point which the car rolls about. Figure 4.35 is an A-end view which shows the upper center roll motion of the car at 6.1 Hz. This figure is a two frame depiction of the rolling motion of the car. The first frame is point 9 (left A-end corner) at its lowest point, while point 16 (right A-end corner) is at its highest point. The second frame is the two points in opposite translation. Superimposed, they show the full rolling motion of the car body.

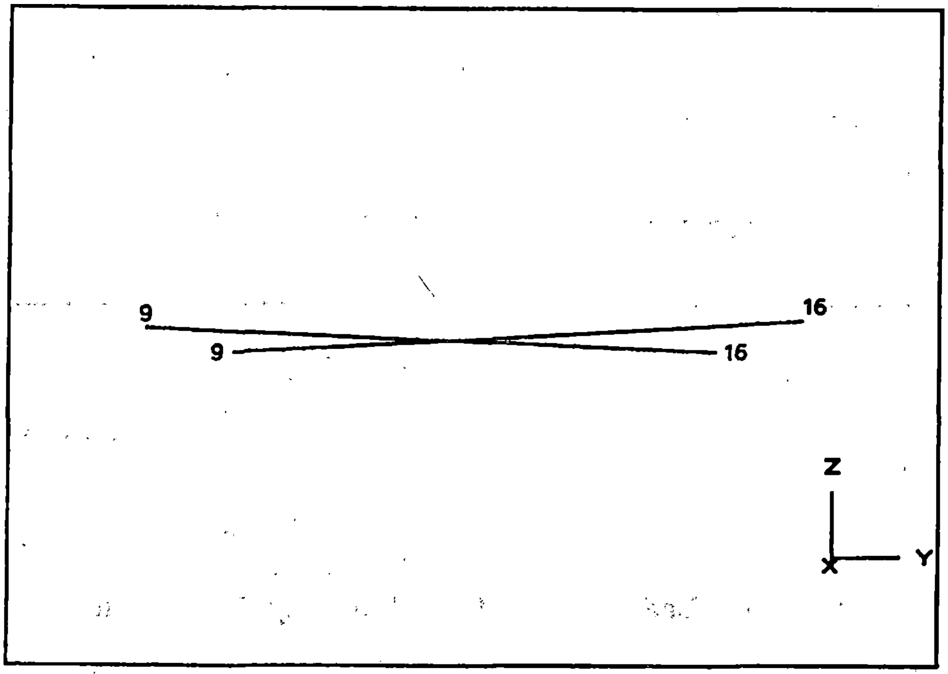


Figure 4.35 A-End Upper Center Roll Motion

4.4.6 Flexible Body Lateral

Data from run TRIP_RN143 were analyzed to obtain first lateral bending. The matrix below shows the first lateral bending resonant frequency.

MODE	FREQUENCY
First Lateral Bending	13.6 Hz

Runs with a lateral input of .2 to .4 g swept from 5 Hz to 30 Hz were analyzed for the first lateral bending mode. The first large spike in the transfer function at the center of the car was at 13.6 Hz (Figure 4.36). The spike at 6.1 was upper center roll.

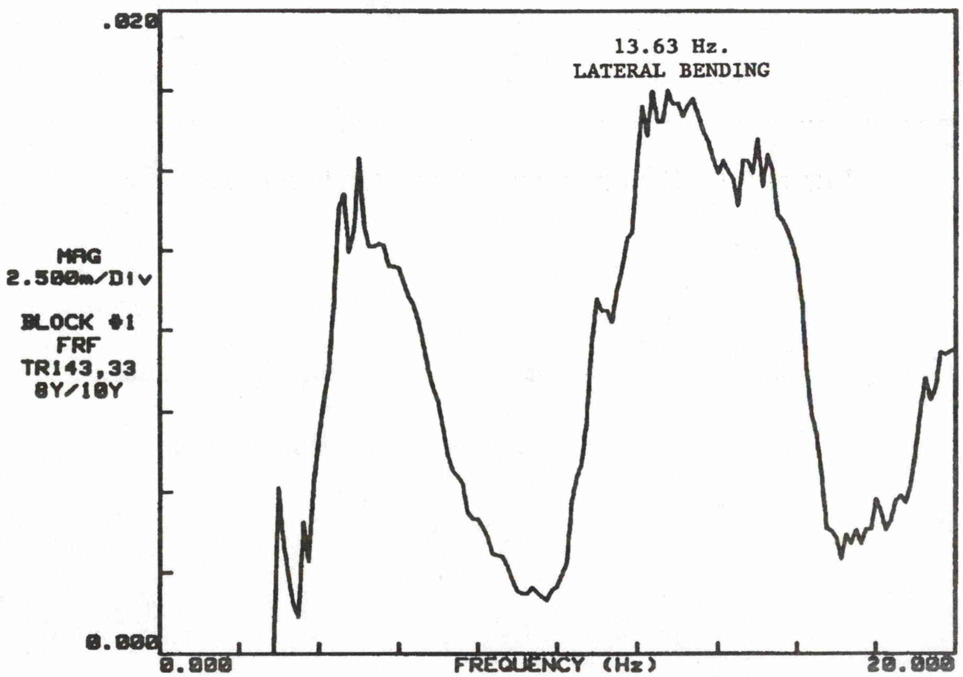


Figure 4.36 Mid Car Lateral Acceleration Transfer Function

A mode shape was developed for 13.6 Hz, which was unquestionably lateral bending. Figure 4.37 shows the exaggerated lateral bending mode shape.

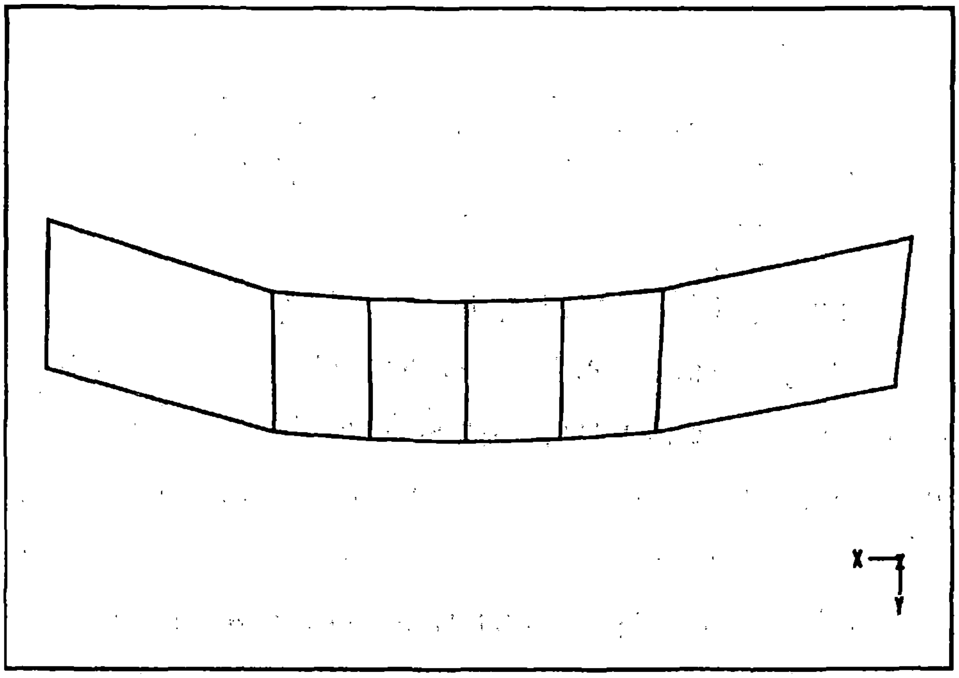


Figure 4.37 Exaggerated Lateral Bending Mode Shape

4.5 TRIPLET CAR MODAL RESPONSE TEST (ATSF 90004)

Modal analysis was performed with (SMS) modal analysis software. Transfer functions for each point shown in Figure 4.38 were created with AAR analysis software and imported into the SMS model.

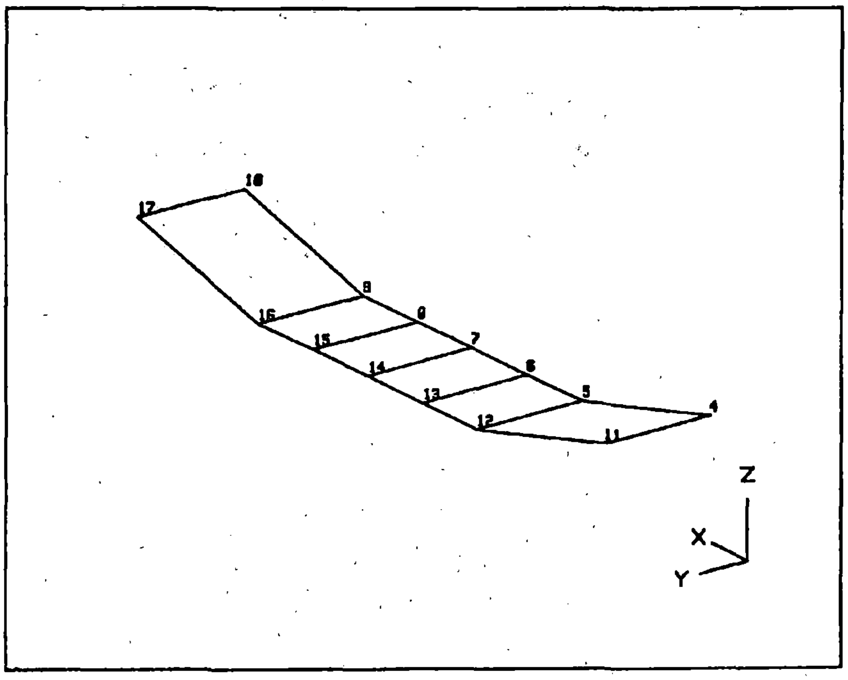


Figure 4.38 SMS Model of ATSF 90004

Points 11 through 17 in the model were receiving vertical accelerations only, therefore, these points were laterally constrained to their counterparts on the other side of the car. In roll those points were constrained 180 degrees out of phase with the other side of the car. Magnitude and phase were compared at each peak in the transfer functions and a mode shape was calculated and displayed by SMS.

4.5.1 Rigid Body Vertical

Data from runs similar to TRIP_RN113 were analyzed to obtain pitch and bounce resonant frequencies.

MODE	FREQUENCY
Pitch	6.0 Hz
Bounce	2.4 Hz

A 30 kip sinusoidal load was applied to the actuator. The sine wave was swept from .2-10 Hz. A transfer function between the actuator input force and acceleration at the A-end edge of the depressed center of the car body is shown in Figure 4.39.

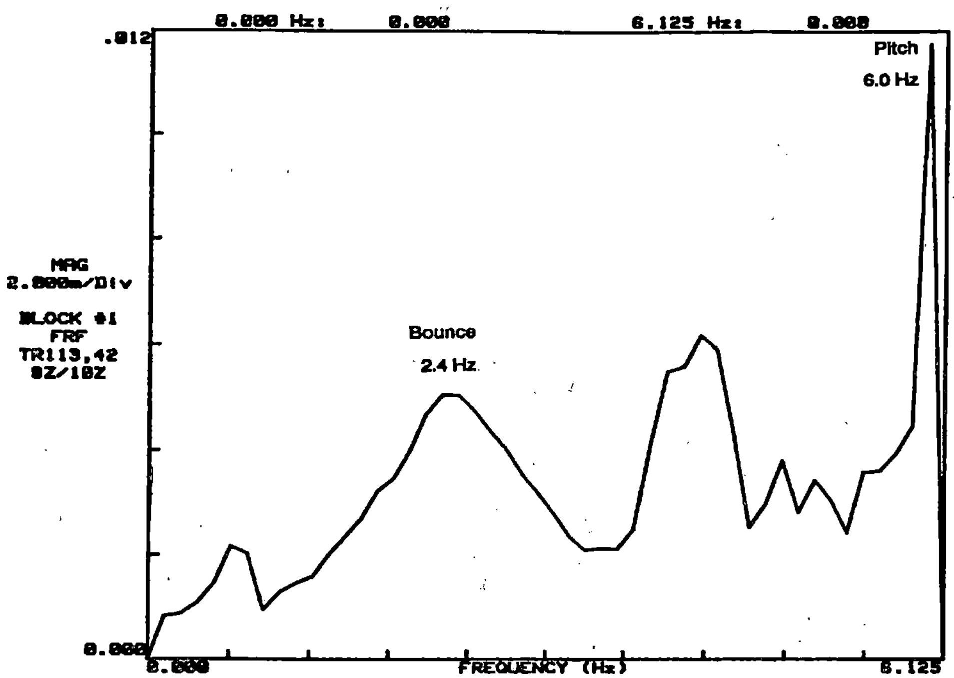


Figure 4.39 Pitch and Bounce Transfer Function

Pitch and bounce were determined by the phase relationship between the A-end and the B-end vertical accelerations. Figure 4.40 shows the phase of a point (9) near the A-end and a point (5) near the B-end, top to bottom plot respectively. The two vertical lines represent the frequency at which the two peaks were found on the previous transfer function.

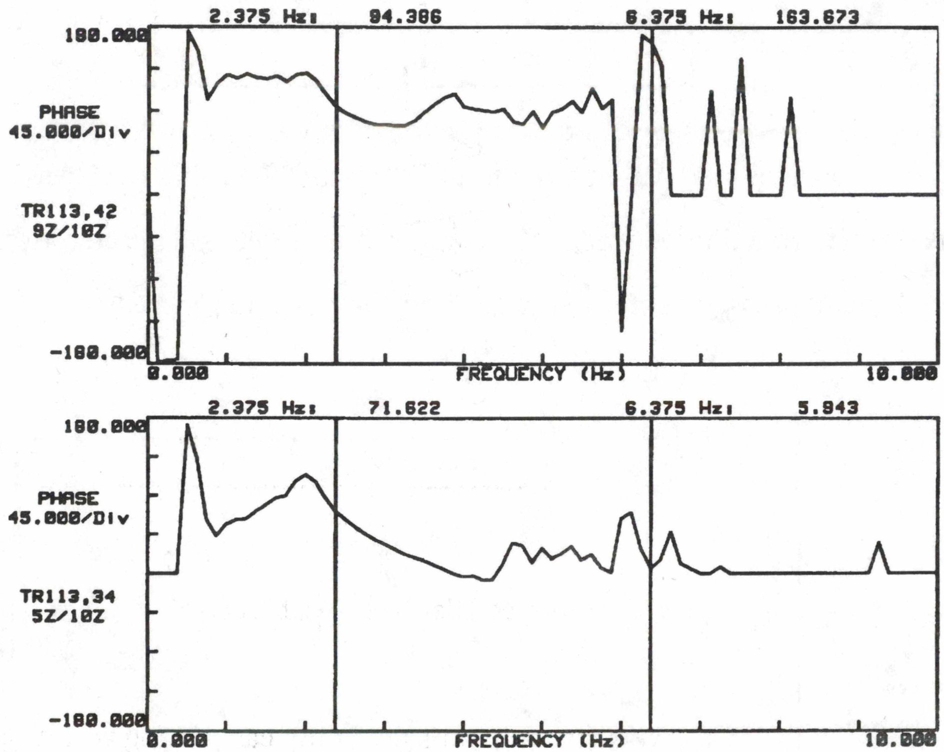


Figure 4.40 A- and B-end Vertical Phase Relationship

At 2.4 Hz point 9 was at 94 degrees and point 5 was at 72 degrees, essentially in phase. At 6.4 Hz point 9 was at 164 degrees and point 5 was at 6 degrees. The difference between the two was 158 degrees, essentially 180 degrees out of phase, which indicates a pitching motion.

Figure 4.41 shows the bounce mode as displayed with vectors by SMS. The base of the car is shown. Other points were removed for clarity. The small lines are the vectors indicating relative amplitude and direction of motion for each point.

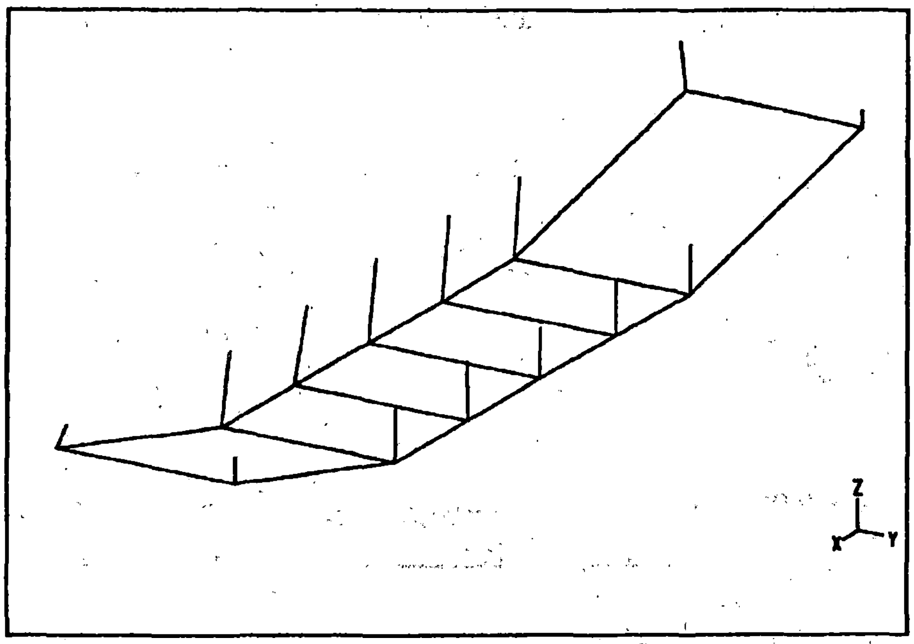


Figure 4.41 Bounce Displayed with Vectors

A pure bounce mode would show all points along the car moving vertically in the same direction with the same amplitude. The case shown here is typical of that excited by the MSU.

Figure 4.42 shows the same type vector plot for pitch. The relative magnitude of motion decreased toward the center of the car then increased again toward each end. At the A-end the direction of motion is in the negative z direction, while the B-end is moving in the positive z direction. The center is hardly moving as shown by the very small vectors. This indicates vertical pitch about the center of the car.

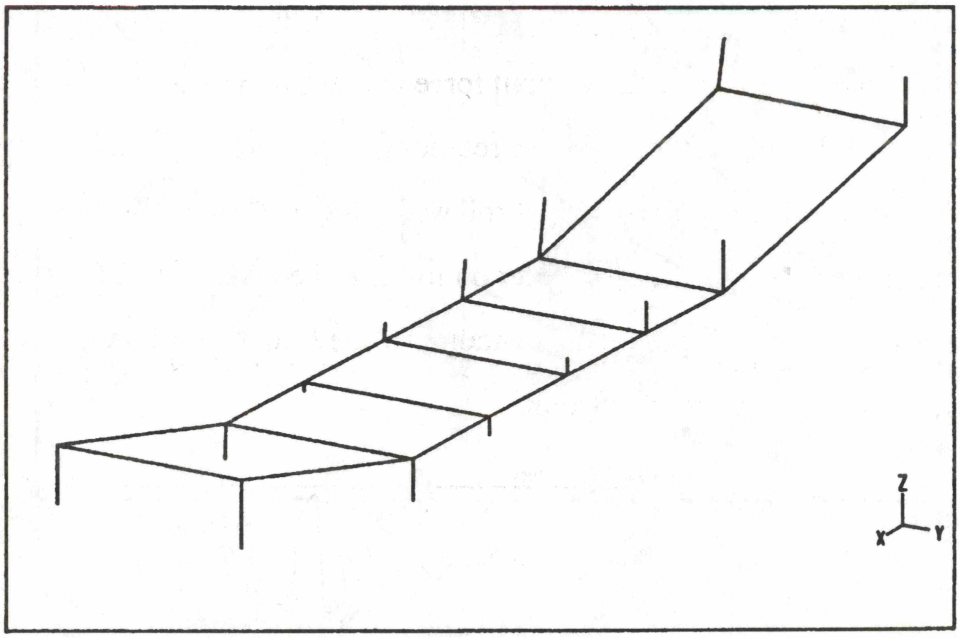


Figure 4.42 Pitch Displayed with Vectors

4.5.2 Rigid Body Roll

Data from runs such as TRIP_RN113 were also analyzed to obtain the roll resonant frequency.

MODE	FREQUENCY
Lower Center Roll	0.8 Hz

A 30 kip sinusoidal load was applied to the car. The sine wave was swept from .2-10 Hz. A transfer function of the actuator input force and an A-end vertical accelerometer is previously shown in Figure 4.39. The phase relationship between right and left side vertical accelerations was examined to determine if roll was present. Figure 4.43 shows the phase of the A-end (9) right vertical accelerometer on top and the A-end left (16) vertical accelerometer on bottom. The vertical line indicates the frequency at which the peak was observed on the previous transfer function.

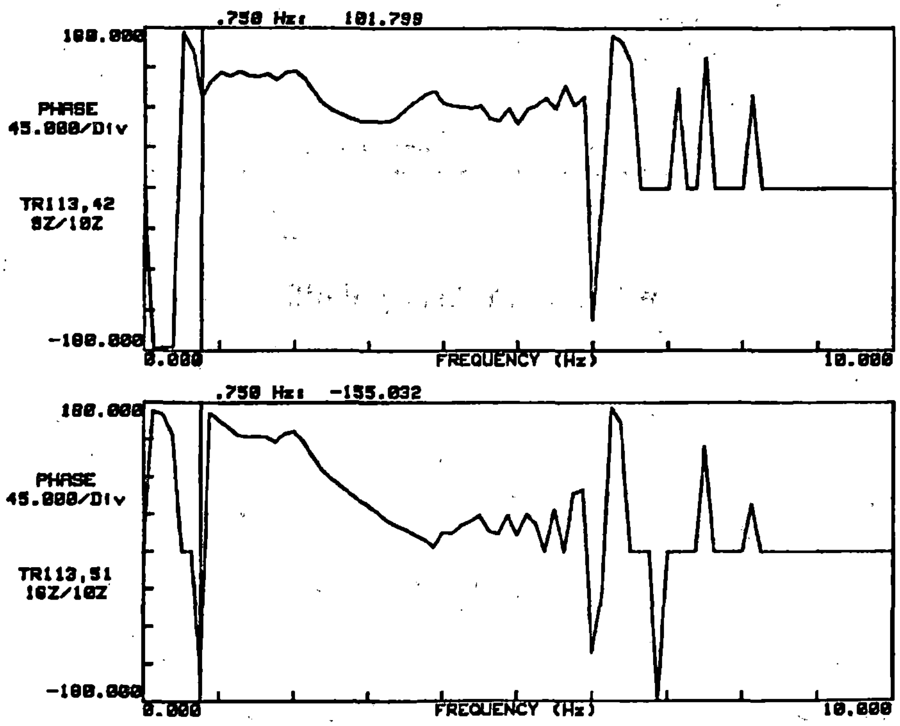


Figure 4.43 Right and Left side Vertical Phase Showing Roll

At 0.8 Hz, the right side phase was 101 degrees and the left was -155 degrees. The difference was 256 degrees. This shows that while the left side was moving down the right side was moving up, indicating roll or twist. The B-end phases were also examined to ensure that the phase relationship was similar to the A-end. If the car was twisting, the A- and B-end right side accelerometers would have been out of phase. The A-end would have been rolling right while the B-end was rolling left. This was not the case. Figure 4.44 shows the A-end of the car with vectors indicating the relative magnitude and direction of motion at 0.8 Hz. The small angle in the vectors indicates that the car was rolling about some point beneath the car body. The left side vector (9) is larger than the right side vector (16) which indicates the car was not rolling about the x-axis. Mass loading of the car is the likely cause of the non symmetrical roll about the x-axis.

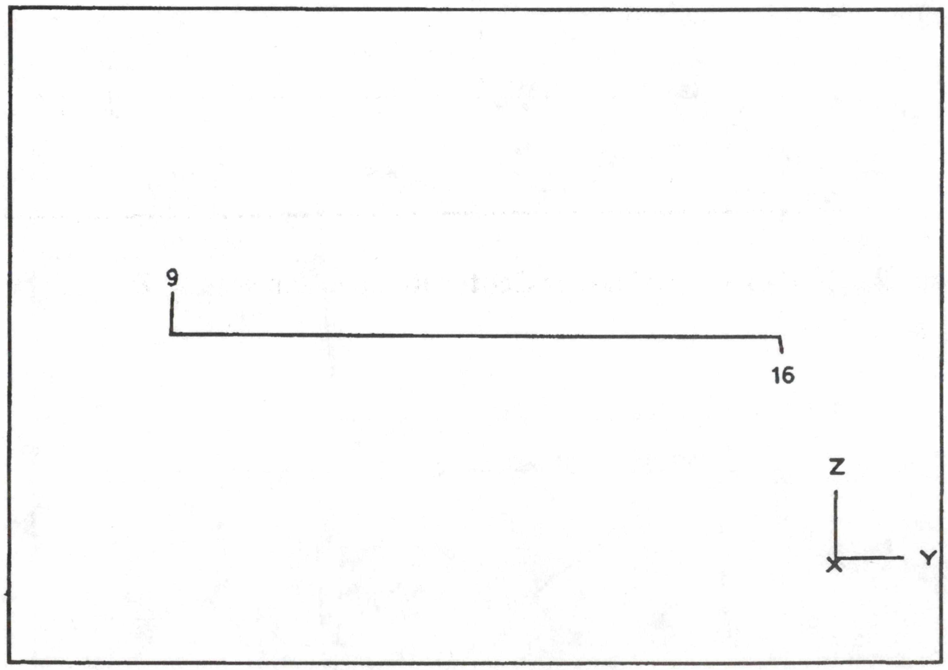


Figure 4.44 Lower Center Roll at A-End Displayed with Vectors

A line was drawn is SMS, connecting points 9 on the A-end left side and point 16 on the A-end right side. This line represents the car width. Figure 4.45 shows the connected A-end points at 0.8 Hz. Point 9 has rolled to the down position while point 16 is in the up position. To emphasise the non symmetric roll, y and z coordinates were added.

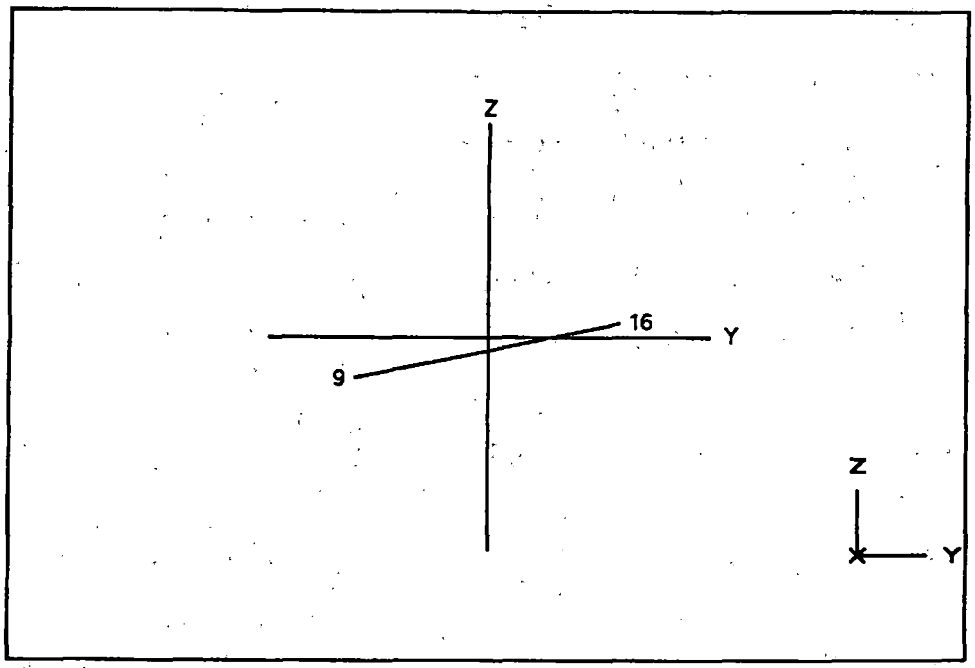


Figure 4.45 A-End View of Lower Center Roll Motion with Y, Z Coordinates

4.5.3 Flexible Body Torsion

Flexible body torsion was not found. Analysis of runs such as TRIP_RN113 showed a mode at 4.25 Hz. This mode displayed a combination of rolling and yaw motion. Figure 4.46 shows the mode at 4.25 Hz as displayed with vectors by SMS.

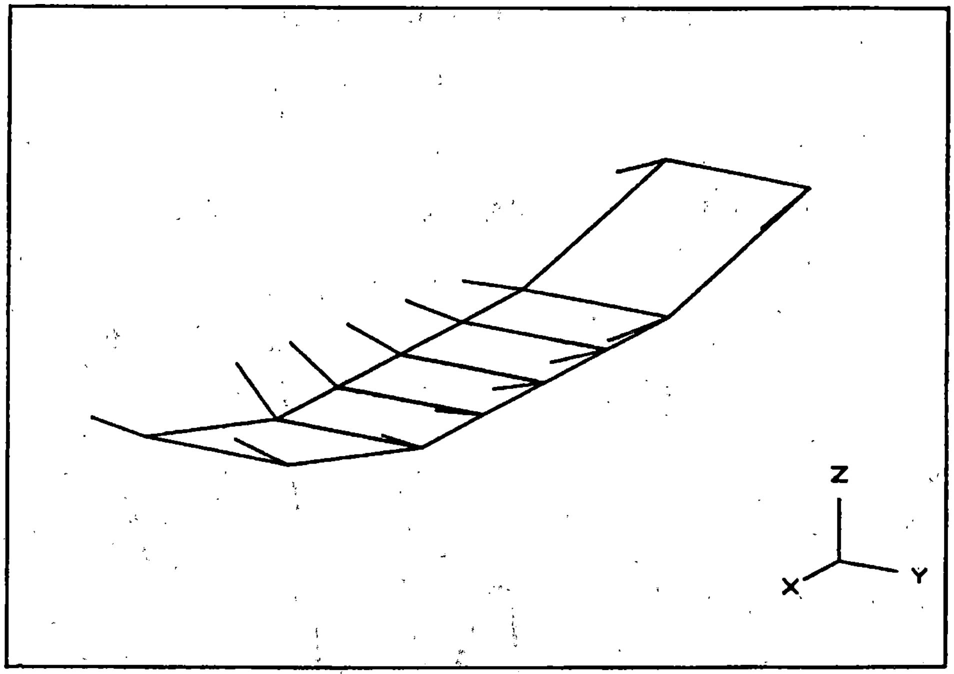


Figure 4.46 Undefined Mode at 4.25 Hz Displayed with Vectors

The A- and B-ends of the car are out of phase, while the acceleration measurements in the middle of the car indicate an in-phase rolling motion.

4.5.4 Flexible Body Vertical

A pure vertical bending mode was not found during testing. Figure 4.47 shows a transfer function between actuator force and a center line vertical accelerometer on the same side, and Figure 4.48 shows a transfer function between actuator force and a vertical accelerometer on the opposite side at the center line. When the data was "curve fit" with SMS modal software, it became apparent that neither mode was a pure vertical bending. Mass loading of the car could be causing the non-uniform bending.

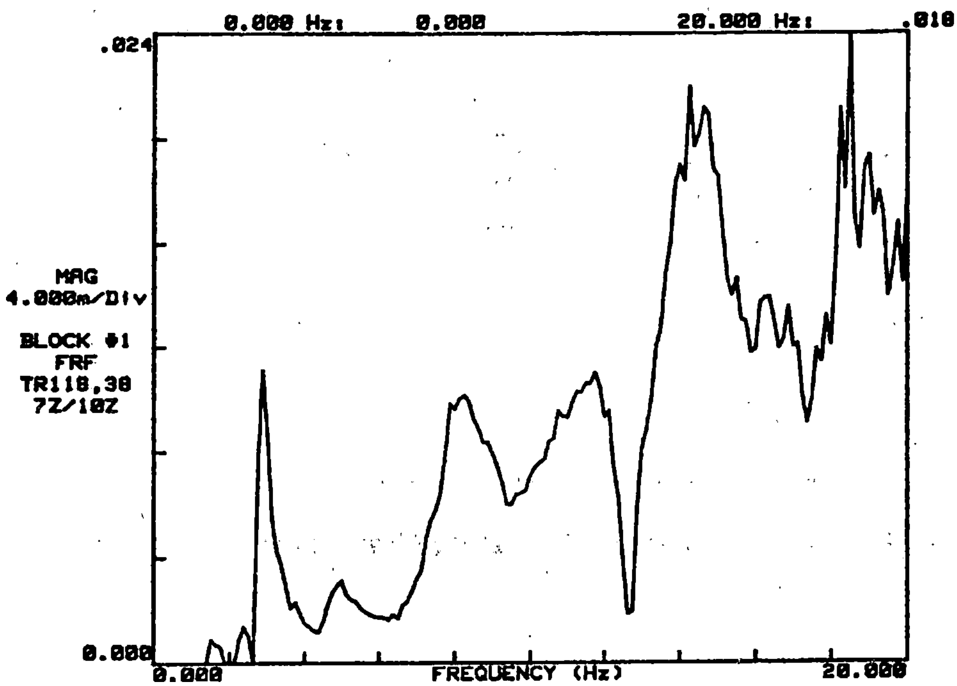


Figure 4.47 Non-Uniform Vertical Bending Transfer Function Actuator Side

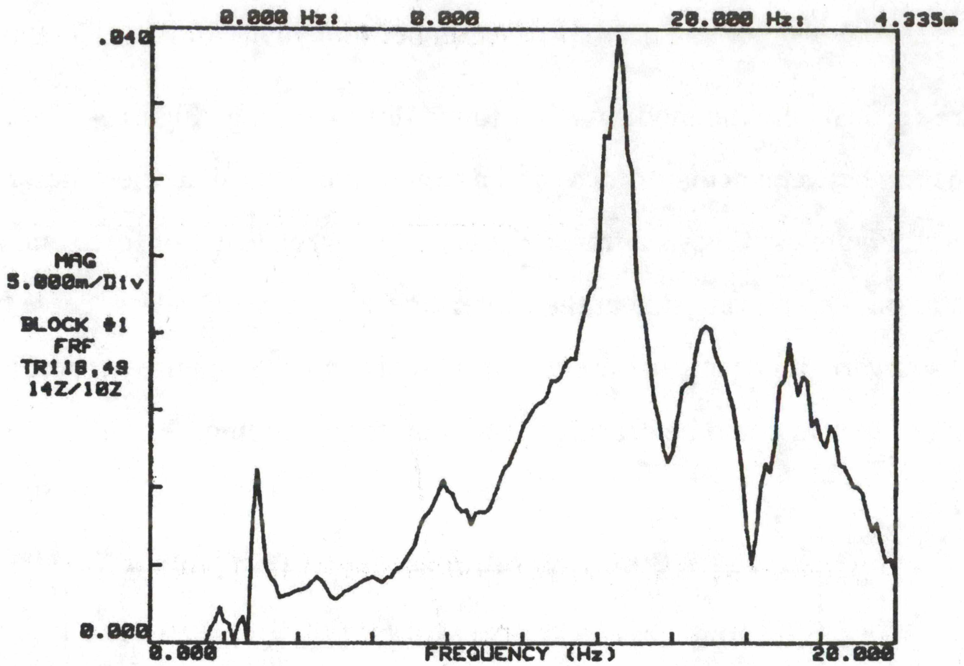


Figure 4.48 Non-Uniform Vertical Bending Transfer Function Opposite Actuator Side

4.5.5 <u>Rigid Body Lateral</u>

Rigid body modes of yaw and sway are best defined with large force inputs; therefore, run TRIP_RN131, with a 30 kip lateral input force, was analyzed for yaw and sway resonant frequencies. The matrix below shows the yaw resonant frequency. Sway was not found.

MODE	FREQUENCY
Yaw	9.8 Hz

Figure 4.49 shows yaw in a transfer function between input force and A-end lateral acceleration.

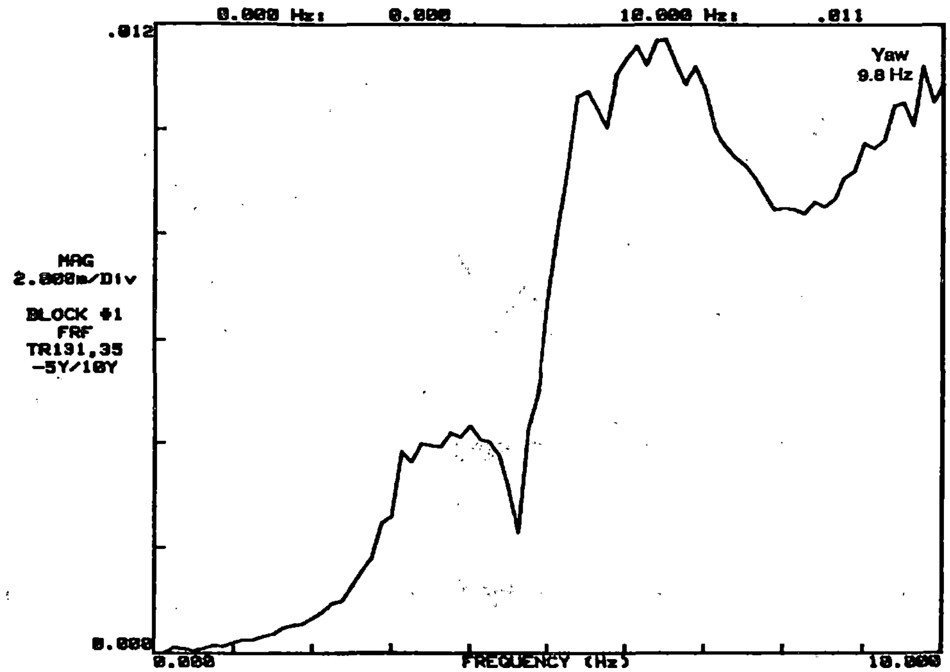


Figure 4.49 Yaw and Sway Transfer Function

The mode at 6.5 Hz was upper center roll. Because upper center roll is largely controlled by the lateral truck spring rate, it can be excited during lateral runs. The mode at 4 Hz is a testing phenomenon and should not be considered as a valid natural mode.

The yaw mode was verified at 9.8 Hz by comparing the A- and B-end lateral accelerations as in Figure 4.50.

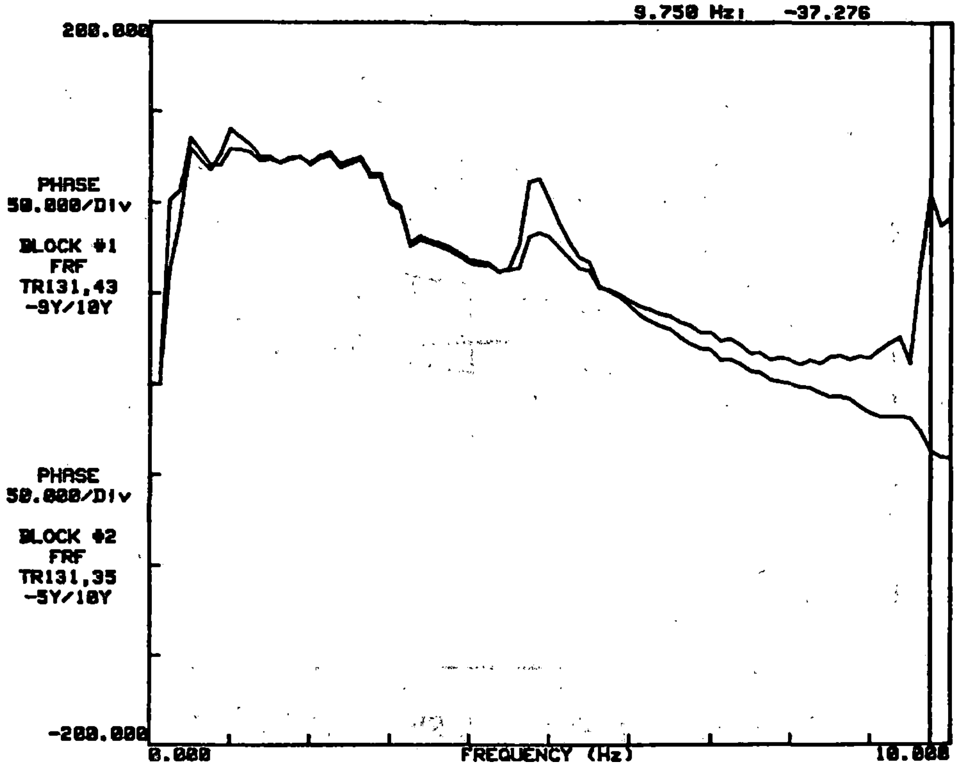


Figure 4.50 A- and B-End Phase Comparison Showing Yaw

The top line of the graph represents the phase at the A-end and the bottom line represents the phase at the B-end. The vertical line indicates the frequency at which the peak was observed on the previous transfer function. The difference between 104 and -37 degrees is 141 degrees, indicating yaw.

Figure 4.51 is a top view of the car floor showing yaw in a relative displacement format. The single horizontal line shows the normal orientation of the car.

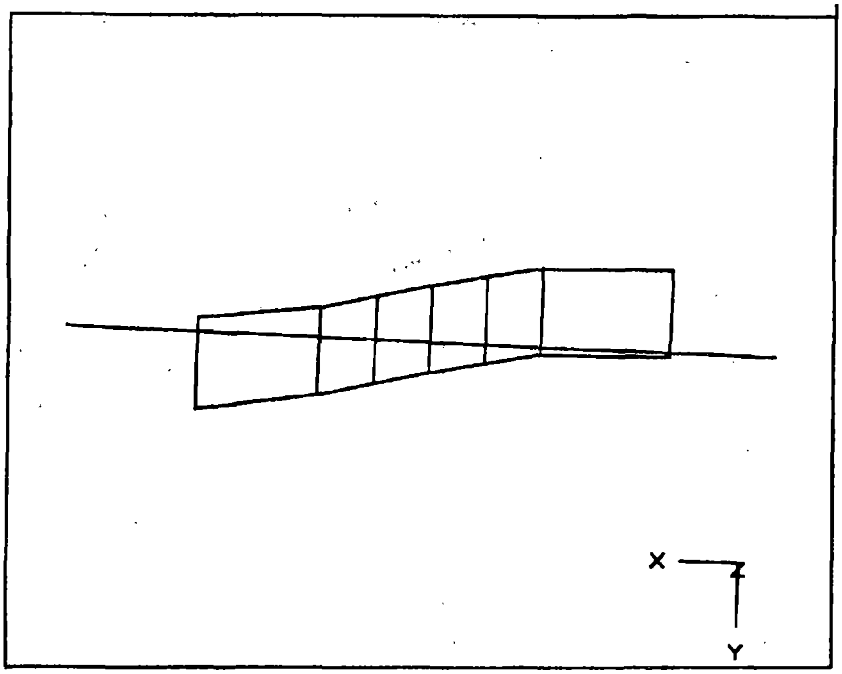


Figure 4.51 Yaw Mode Shape in Top View

During examination of the lateral modes, upper center roll was noted at 6.5 Hz. Figure 4.52 shows the A-end of the car with vectors indicating the relative magnitude and direction of motion at 6.5 Hz.

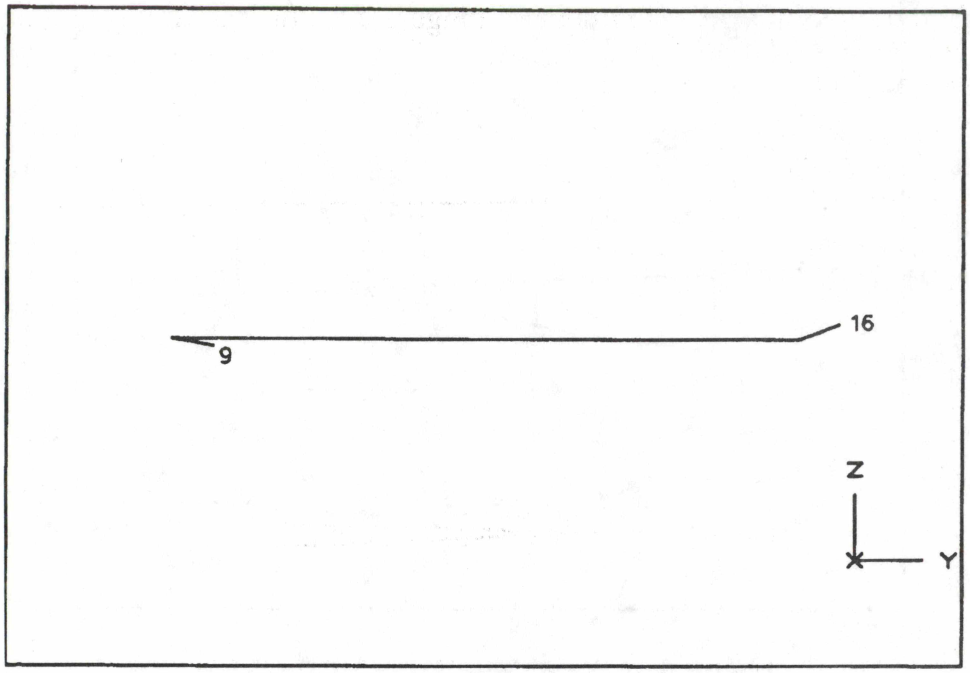


Figure 4.52 A-End Upper Center Roll Mode Shape

A line was drawn in SMS, connecting point 9 on the A-end left side and point 16 on the A-end right side. This line represents the car width. Acceleration measurements are depicted as vectors, showing relative magnitude and direction of motion. Vector 9 is moving downward and inward while vector 16 is moving upward and outward. This demonstrates roll about a point above the horizontal center line of the car.

The primary difference between lower and upper center roll is the point which the car rolls about. Figure 4.53 is a two frame depiction of upper center roll. The first frame shows the car rolling to the left with point 9 moving up and point 16 moving down. The second frame is the car body rolling right with point 9 moving down and point 16 moving up. When both frames are superimposed as in Figure 4.53, the full rolling motion of the car becomes apparent.

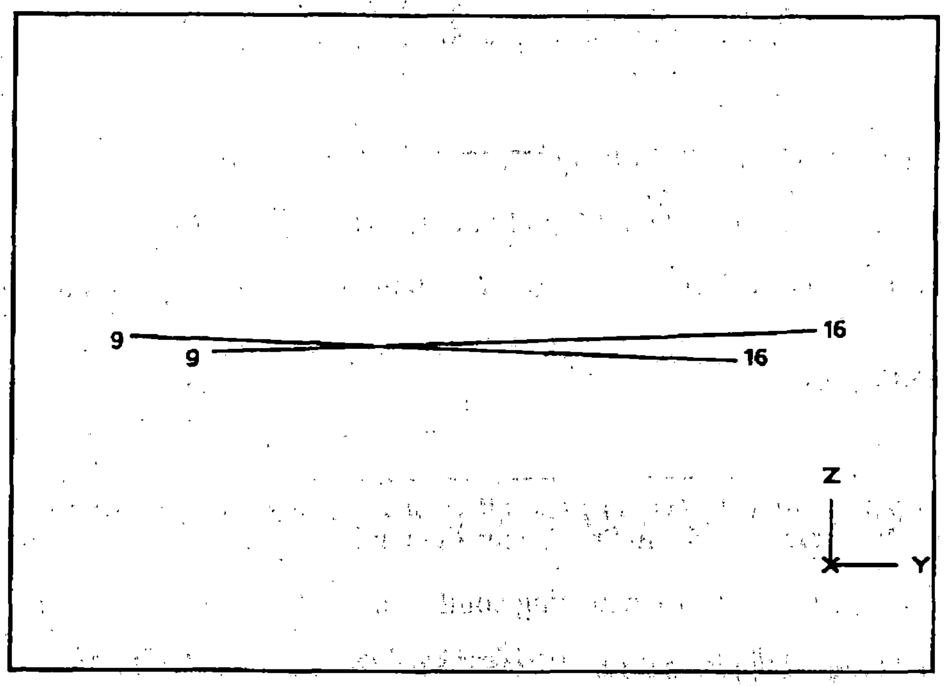


Figure 4.53 A-End View of Upper Center Roll Motion

4.5.6 Flexible Body Lateral

During runs TRIP_RN132 to TRIP_RN135, displacement control was used to maintain a constant g level while the frequency was swept from 3-30 Hz. These runs were analyzed for the first lateral bending mode. The matrix below shows the first lateral bending resonant frequency.

MODE	FREQUENCY
First Lateral Bending	23.4 Hz

Figure 4.54 is a transfer function between the actuator input force and the edge of the car on the same side at the center line.

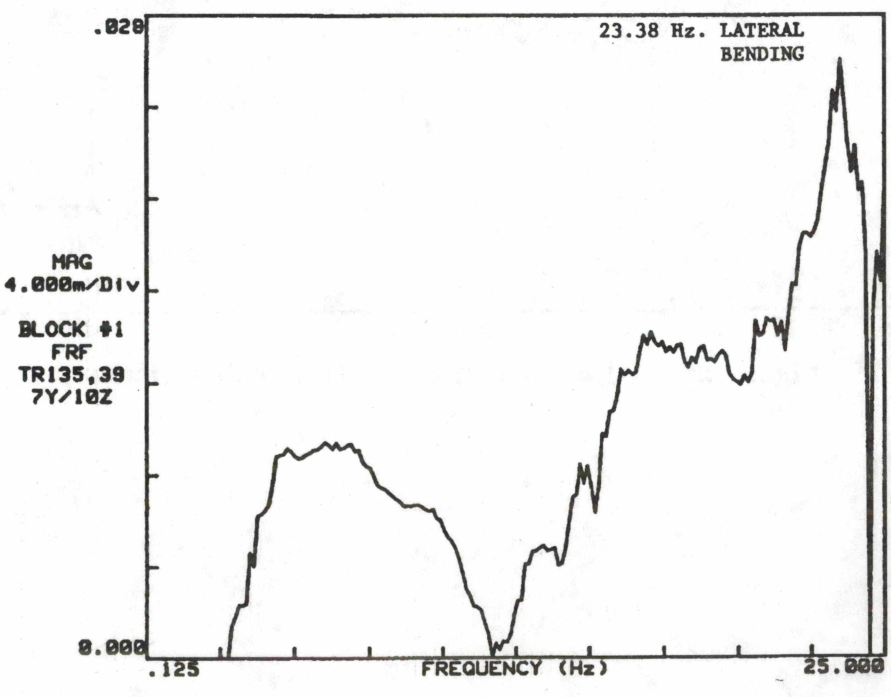


Figure 4.54 Mid Car Lateral Acceleration Transfer Function

The highest peak in the transfer function at the center of the car usually indicates first bending. Several other frequencies were examined, but none yielded the shape shown in Figure 4.55.

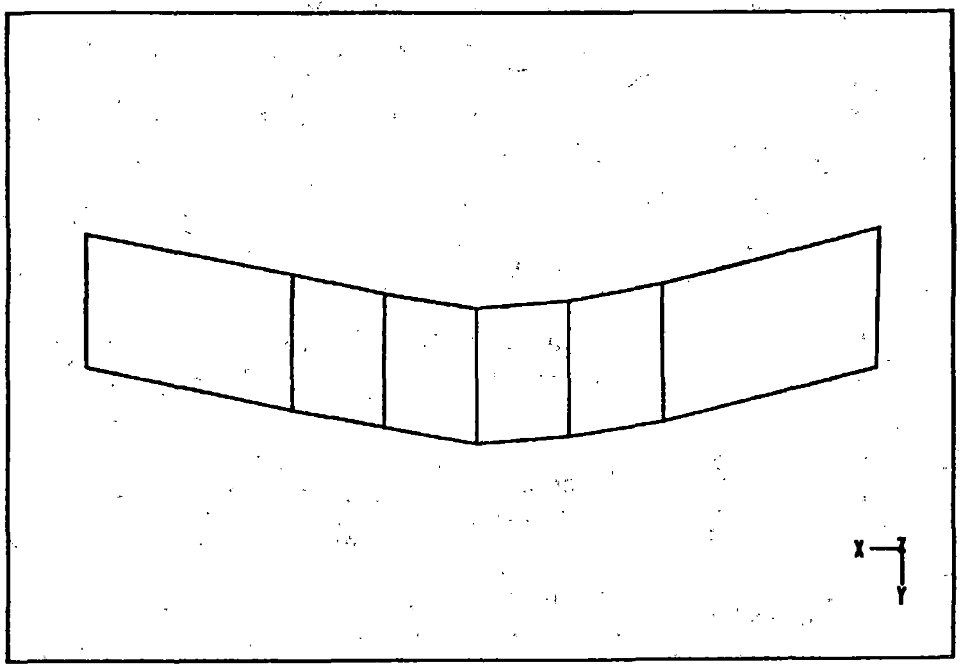


Figure 4.55 Exaggerated Lateral Bending Mode Shape

4.6 AIR BEARING AND MODAL TEST RESULTS SUMMARY

4.6.1 Air Bearing and Modal Results Summary for ATSF 90006

Table 4.18 is a summary of characterization data which was provided for the TDM.

Table 4.18 Air Bearing and Modal Results Summary for ATSF 90006

PARAMETER	VALUE
Span Bolster Yaw Moment	629,640 in-lbs
Single Truck Yaw Moment	181,475 in-lbs
Longitudinal Stiffness	43 kips/inch
Axle Yaw and Inter-Axle Bending Stiffness	223 in-kips/mrad
Bounce Frequency	2.3 Hz
Pitch Frequency	5.8 Hz
Lower Center Roll Frequency	.9 Hz
Upper Center Roll Frequency	6.1 Hz
Sway Frequency	1.1 Hz
Yaw Frequency	9.8 Hz
First Vertical Bending Frequency	10.6 Hz
First Torsional Frequency	Not Found
First Lateral Bending Frequency	13.6 Hz

4.6.2 Air Bearing and Modal Results Summary for ATSF 90004

Table 4.19 is a summary of characterization data which was provided for the TDM.

Table 4.19 Air Bearing and Modal Results Summary for ATSF 90004

PARAMETER	VALUE
Span Bolster Yaw Moment	125,100 in-lbs
Single Truck Yaw Moment	89,290 in-lbs
Longitudinal Stiffness	93 kips/inch
Axle Yaw and Inter Axle Bending Stiffness	510 in-kips/mrad
Bounce Frequency	2.4 Hz
Pitch Frequency	6.0 Hz
Lower Center Roll Frequency	.8 Hz
Upper Center Roll Frequency	6.5 Hz
Sway Frequency	Not Found
Yaw Frequency	9.8 Hz
First Vertical Bending Frequency	Not Found
First Torsional Frequency	Not Found
First Lateral Bending Frequency	23.4 Hz

4.6.3 Quasi-static 125-Ton Design Truck Characterization Results Summary

Table 4.20 is a summary of truck characterization data which was provided for the TDM.

Table 4.20 Quasi-static 125-Ton Design Test Results Summary

PARAMETER	VALUE
Vertical Stiffness	50.1 kips/inch
Vertical Damping Force	10.7 kips
Lateral Stiffness	42.4 kips/inch
Lateral Damping Force	22.8 kips
Roll Rate	67,775 kip-inches/radian

4.6.4 Quasi-Static 100-Ton Design Truck Characterization Results Summary

Table 4.21 is a summary of truck characterization data which was provided for the TDM.

Table 4.21 Quasi-Static 100-Ton Design Test Results Summary

PARAMETER	VALUE
Vertical Stiffness	44.8 kip/inch
Vertical Damping Force	10.7 kips
Lateral Stiffness	40.6 kips/inch
Lateral Damping Force	26.5 kips
Roll Rate	75,368 kip-inches/radian

5.0 CONCLUSIONS

5.1 AIR BEARING TABLE TEST ATSF 90006 and 90004

1. In general, enough data were measured to accurately assess the static suspension characteristics of both span bolster cars.
2. Longitudinal stiffness results from both cars were found to be usable values for TDM development.
3. Axle yaw stiffness results from both cars were found to be usable values for TDM development.
4. The span bolster yaw moment was over three times higher than the truck yaw moment. The values recorded for the truck yaw moment appear to be more realistic than the span bolster yaw moment.

5.2 QUASI-STATIC 125-TON DESIGN TRUCK CHARACTERIZATION TEST

1. The vertical spring nest stiffness was 4 percent higher than the calculated value. This was a familiar pattern among PKRG cars.
2. Vertical and lateral damping forces were found to be usable values for TDM development.
3. The Lateral spring nest stiffness was found to be a usable value for TDM development.
4. Truck roll rate was found to be a usable value for TDM development.

5.3 QUASI-STATIC 100-TON DESIGN TRUCK CHARACTERIZATION TEST

1. The vertical spring nest stiffness was 16 percent higher than the calculated value. This was a familiar pattern among PKRG cars.

2. Vertical and lateral damping forces were found to be usable values for TDM development.
3. The Lateral spring nest stiffness was found to be a usable value for TDM development.
4. Truck roll rate was found to be a usable value for TDM development.

5.4 MODAL RESPONSE TEST ATSF 90006

A frequency of 2.26 Hz equates to 60 mph on 39-foot perturbed track; therefore, any mode above 2.26 Hz was not cause for concern, and no track speed was calculated for that frequency.

1. Pitch and bounce resonant frequencies were found at 5.8 and 2.3 Hz, respectively.
2. Lower center roll resonance was found at 0.9 Hz. This would equate to a resonance speed of 35.1 ft/sec or 23.9 mph for the twist and roll test track.
3. Upper center roll resonance occurred at 6.1 Hz.
4. Sway and yaw resonances were found at 1.1 and 9.8 Hz, respectively. 1.1 Hz would equate to a resonance speed of 42.9 ft/sec or 29.2 mph for the yaw and sway track.
5. The first vertical bending mode was found at 10.6 Hz.
6. Twist was not found.
7. Lateral bending was found at 13.6 Hz.
8. This car is being used to simulate the LCC in weight only, due to its design and loading, these mode frequencies may differ greatly from the LCC. These tests were performed to assess any modal parameters that may be encountered during track testing.

5.5 MODAL RESPONSE TEST ATSF 90004

A frequency of 2.26 Hz equates to 60 mph on 39-foot perturbed track; therefore, any mode above 2.26 Hz was not cause for concern, and no track speed was calculated for that frequency.

1. Pitch and bounce resonant frequencies were found at 6.0 and 2.4 Hz, respectively. These resonant frequencies did not cause concern because they equate to a speed outside that of the planned track testing regime.
2. Lower center roll resonance was found at 0.8 Hz. This would equate to a resonance speed of 29.25 ft/sec or 20 mph for the twist and roll test track.
3. Upper center roll resonance was found at 6.5 Hz.
4. Yaw resonances was found at 9.8 Hz.
4. Sway was not found.
5. A pure vertical bending mode was not found. This can be attributed largely to mass loading and partly to car design.
6. Twist was not found.
7. Lateral bending was found at 23.4 Hz.
8. This car is being used to simulate the MLC in weight only, due to its design and loading, these mode frequencies may differ greatly from the MLC. These tests were performed to assess any modal parameters that may be encountered during track testing.

APPENDIX A

CHAPTER XI AAR'S M-1001
MANUAL OF STANDARDS AND RECOMMENDED PRACTICES

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).

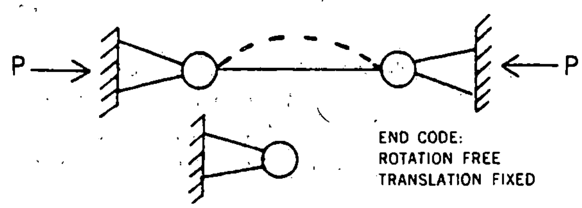


Figure 11.2.3.1

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 lb 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.

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

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.

11.5.1.3. 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.

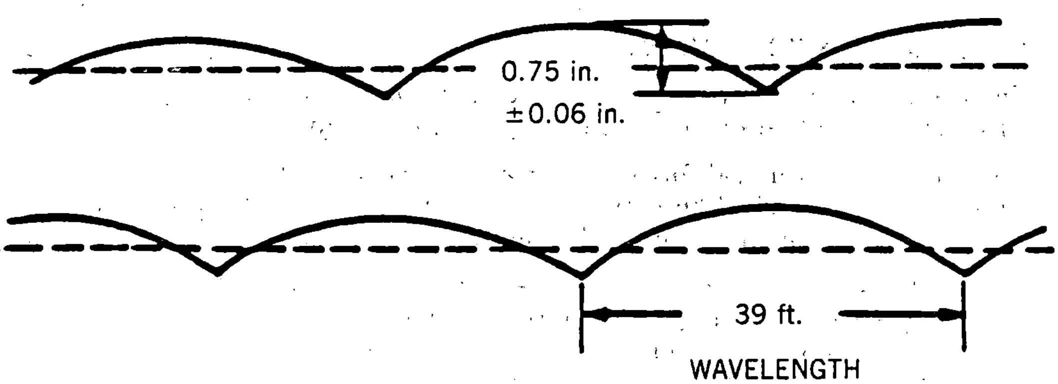


Figure 11.1.

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.

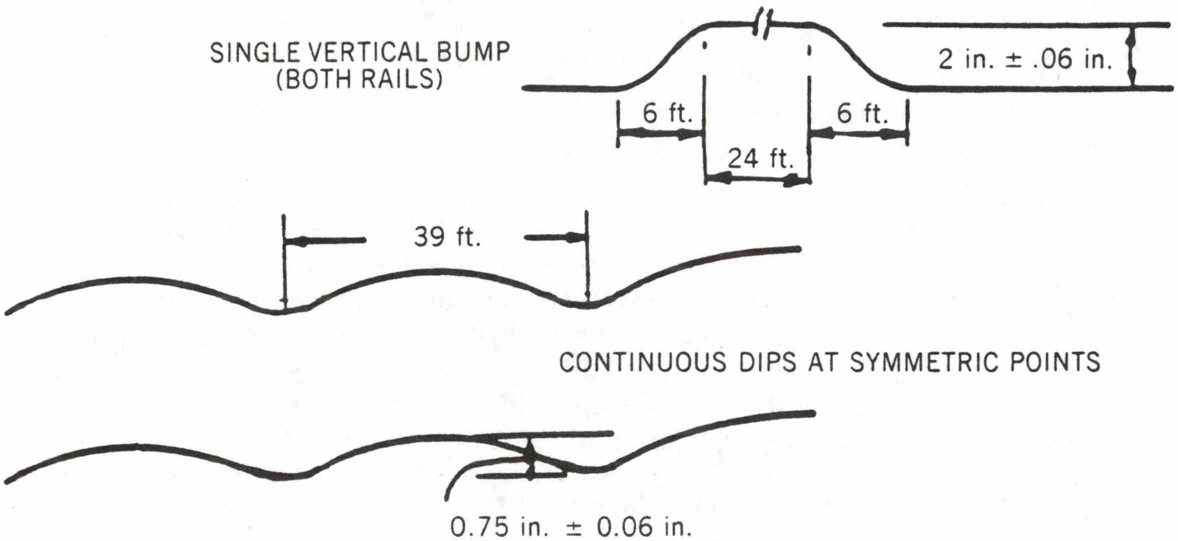


Figure 11.2.

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.

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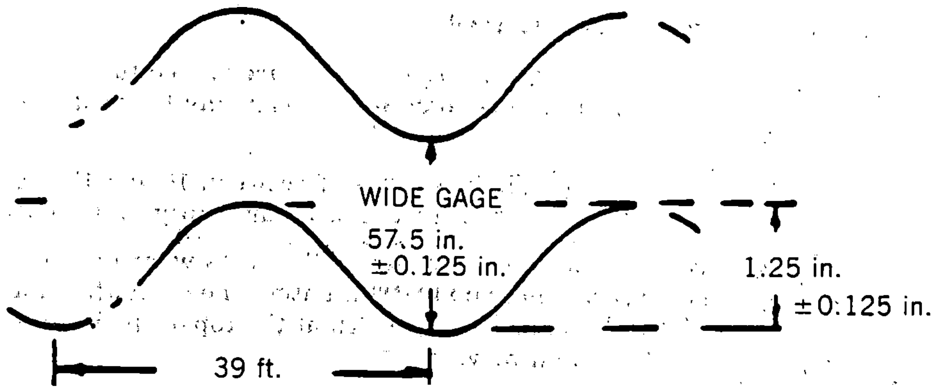


Figure 11.3.

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.*

*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.

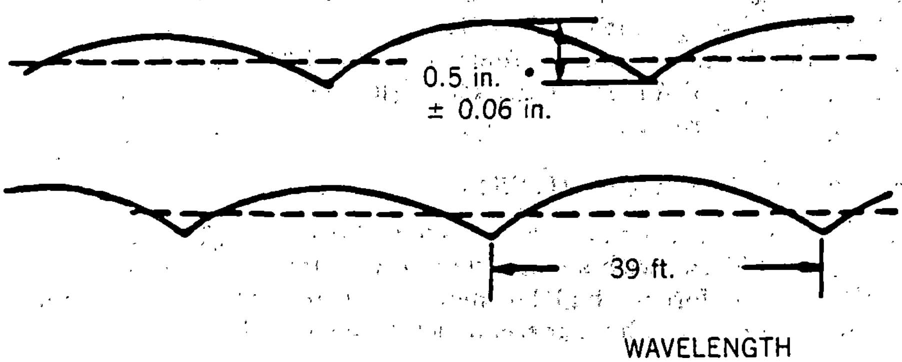


Figure 11.4.

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.

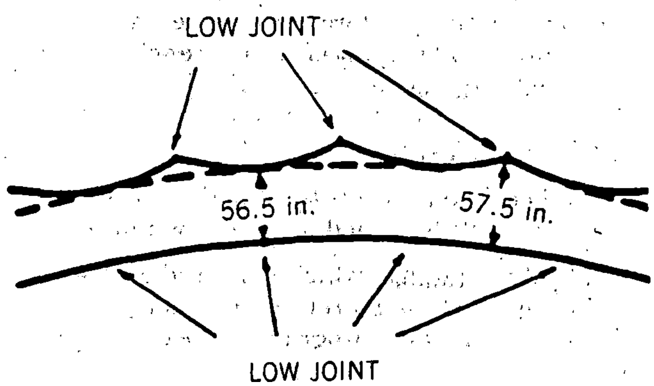


Figure 11.5.

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

AT&SF 90006 AND AT&SF 90004
TRUCK CHARACTERIZATION - AIR BEARING TABLE TEST PROCEDURE

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-4200-38" Triplet Car
TRUCK CHARACTERIZATION - AIR BEARING TABLE TEST

1.0 DESCRIPTION

The purpose of this procedure is to outline the sequence of steps to conduct truck characterization tests on air bearing tables located in the Urban Rail Building.

The truck characterization test consists of five sub-tests:

(1) Yaw Moment Test Between Span Bolster And Car Body
(2) Yaw Moment Test Between Truck And Span Bolster
(3) Axle Alignment Test
(4) Longitudinal Stiffness Test
(5) Axle Yaw Stiffness Test

1.1 INDEX

1.2 EQUIPMENT LIST

a.	4ea	Machinists Scale (0-48")
b.	2ea	Load Cell (10 KIP) with Accessories
c.	2ea	Celesco String Pot (+/− 1-inch)
d.	2ea	Ener Pac Hydraulic Cylinder (6" throw) with Accessories
e.	1ea	Axle Spud Kit
f.	2ea	String Pot Magnetic Bases
g.	1ea	Transit Square, Brunson Optical
h.	4ea	Machine Scale Support Stand
i.	2ea	Air Bearing Tables (120"x82"x7.5")
j.	2ea	Air Compressor with Accessories (750 cfm)
k.	4ea	100-Ton Jack (15-inch base)

l.	1ea	Chains and Clevis Kit
m.	1ea	6-foot Tape Measure
n.	10ea	Aluminium Sheets (12' X 4')
o.	8ea	Keepers, Axle
p.	2ea	Reaction Fixture
q.	1ea	X-Y-Y Plotter
r.	1ea	IBM PC with Metrabyte DAS 16F Card
s.	1ea	Actuator (10 KIP)
t.	4ea	Signal Conditioners
a.a.	1ea	Caliper, Vernier, 80-inch
b.b.	1ea	Torque Wrench (200 - 500 ft/lb Range)
c.c.	8ea	Rail Panels

1.3 FIGURE LIST

1.4 ATTACHMENT LIST

1 Test Configuration Data Sheet

1.5 REFERENCE LIST

PKRG 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

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 (e.g., Triplet Car).

1.6.2 Test Run Matrix

As test runs are completed, the Test Engineer will record the time of completion of each run, type of test, direction, and comments about the 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 Sheets

The Test Configuration Data Sheet is produced by performance of Procedure PKRG-3100, Instrument 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.

1.6.5 Run Statistics Print-Out X-Y-Y Plots

X-Y Plots will be made in Lotus format during testing. Lotus graphs of each test will also be made.

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 Procedure

NOTE

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	Inspect trucks in accordance with procedure PKRG-2100.	_____
2.1.3	Record side bearing and bolster clearance. Side bearing must have 3/16-inch minimum to 5/16-inch maximum clearance. Ensure car is level during inspection.	_____
	Clearance Right Side _______	
	Clearance Left Side _______	

2.1.4 Position test car so that A-end lead axle is centered on the center of the first reaction fixture, see Figure 2-1.

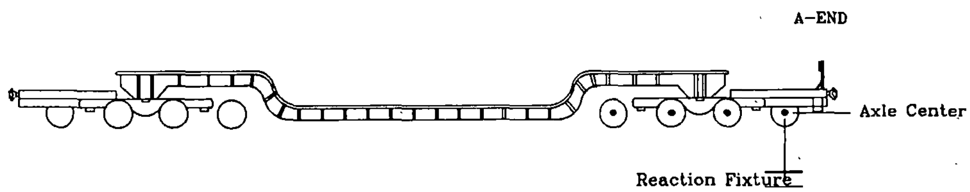


Figure 2-1 Triplet Car Located at Reaction Fixture

2.1.5 Disconnect hand brake chain and air brake line. Chock all B-end wheels.

2.1.6 Using two 100-ton jacks (with 12-inch extensions) at jacking pad, jack test car up approximately 12-inch to remove A-end running gear assembly.

NOTE

Ensure that there is 6-inch of travel left in the jacks when span bolster is clear.

2.1.7 Roll span bolster and trucks away from car.

2.1.8 Insert aluminum sheets beneath and around the test car, see Figure 2-2. Tape all seams and edges down to ensure a proper seal.

2.1.9 Chain truck #4 to the A-end span bolster.

2.1.10 Lift span bolster and truck #4 with a crane.

2.1.11 Lower span bolster and truck #4 onto air table.

2.1.12 Disconnect chains and crane.

2.1.13 Chain truck #3 to A-end span bolster.

2.1.14 Lift span bolster and truck #3 with the crane.

2.1.15 Lower span bolster and truck #3 onto air table #2.

2.1.16 Disconnect chain and crane.

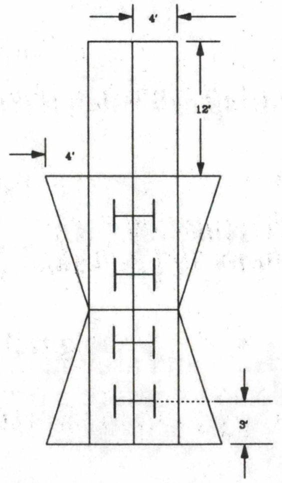


Figure 2-2 Aluminum Sheet Placement

2.1.17 Using connector plates, bolt both air bearing tables together as indicated in Figure 2-3.

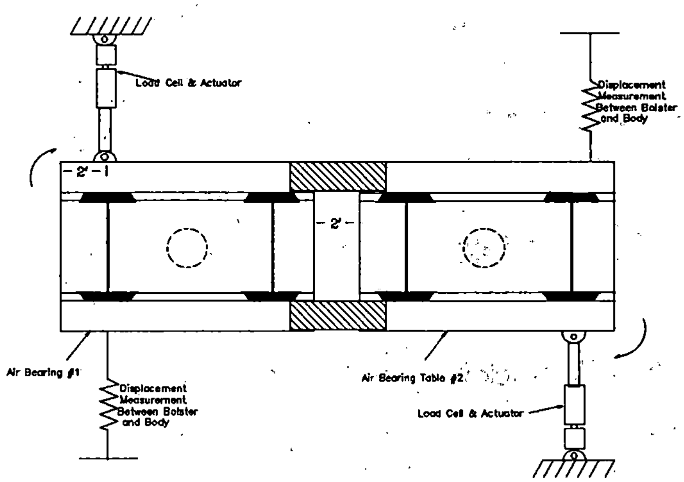


Figure 2-3 Span Bolster Yaw Moment

2.1.18 Float air bearing tables, trucks and span bolster under the car.

2.1.19 Ensure the spring group is in its correct position.

2.1.20 Lower the test car onto the span bolster and remove jacks from A-end of test car.

2.1.21 Level test car by jacking B-end and placing rail panels under B-end wheels.

NOTE

A-end height must equal B-end height + / − 1/2-inch.

2.1.22 Connect reaction fixtures to facility floor.

2.1.23 Connect actuator load cell and string pots to air bearing tables as illustrated in Figure 2-3.

NOTE

Actuators must be in line with lead and trail axle of A-end span bolster.

2.1.24 Connect string pots between air bearing table and reaction fixtures.

2.1.25 Connect car stabilizing fixtures to facility floor. Chain car body to stabilizing fixtures, as shown on Figure 2-4. ______

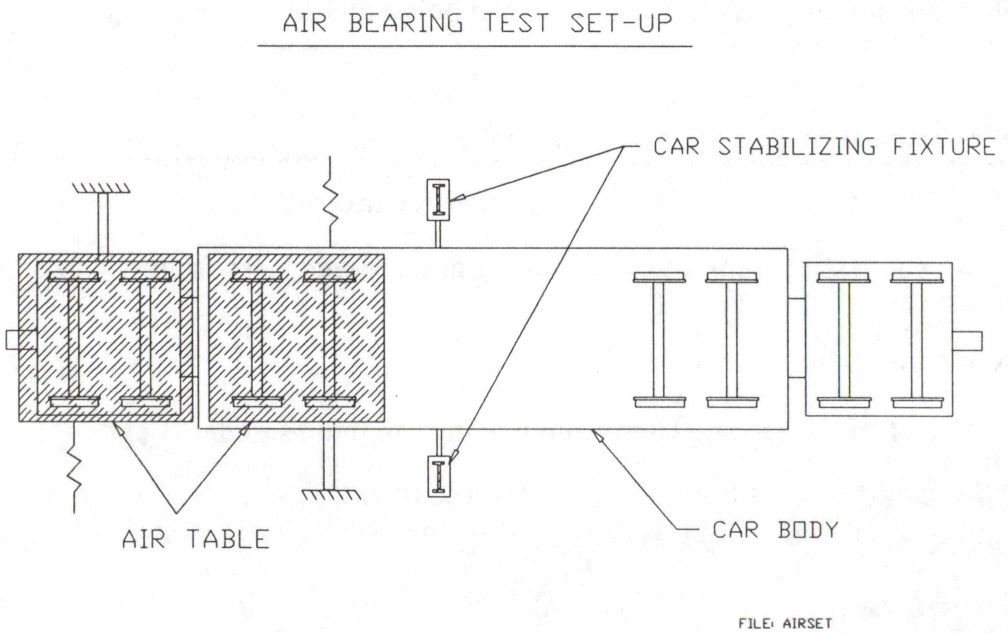


Figure 2-4 Car Stabilizing Fixture

2.1.26 Connect transducer cables (string pots and load cells) through signal conditioners to the PC and plotter.

2.1.27 Measure initial force at each actuator for both tables. Ensure that actuators measure less than 500 lbs. ________

NOTE

Do not re-zero Load Cells at this time.

2.2 Yaw Moment Measurement Test, Span Bolster to Car Body

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Ensure pre-load on tables is less than 500 lbs. Ensure that tables remain in a floating attitude throughout the test. Mark position of tables on the aluminum to ensure air bearing table has not moved. Start the data acquisition program and sample at 10 Hz.	
2.2.2	Slowly apply force to both actuators while observing load cell output to ensure the force values rise together. The force will drop suddenly as the span bolster begins to rotate. When force drops, stop force application.	
2.2.3	Realign truck using two come-a-longs.	
2.2.4	Repeat Steps 2.2.1 through 2.2.3 two times, record load cell output readings at point of truck rotation and cross check with data acquired with PC.	________
2.2.5	Following Steps 2.1.20 through 2.1.24, remove and reinstall actuators, load cells and string pots, to rotate span bolster in the opposite direction.	

2.2.6 Repeat Steps 2.2.1 through 2.2.4. ________

2.3 Yaw Moment Test, Truck To Span Bolster

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	Remove air bearing table connector plates.	
2.3.2	Connect actuator to front table as illustrated in Figure 2-5.	________

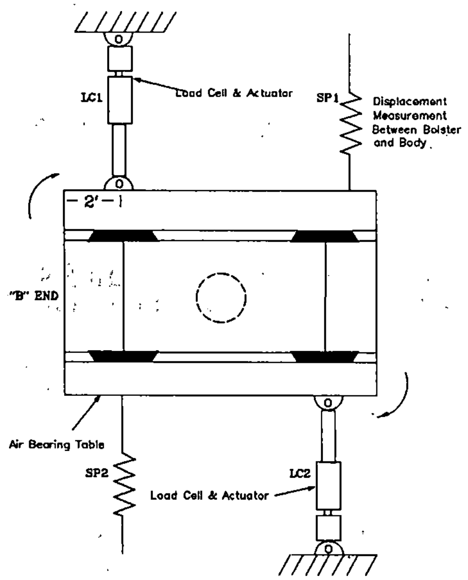


Figure 2-5 Truck Yaw Moment Test Set-up

2.3.3.	Ensure initial pre-load on actuators is less than 500 lbs. and that both tables remain in a floating attitude throughout the test. Mark table location if different than previous test.	________

2.3.4 Start acquisition program, slowly apply force to actuators while observing X-Y-Y plotter to ensure the force values rise together. The force will drop 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.

2.3.5 Realign truck using two come-a-longs.

2.3.6 Repeat Steps 2.3.3 through 2.3.5 two times, record load cell readings in Test Events Log. ________

2.3.7 Reconfigure load cell actuators and brackets. Then perform test in opposite direction Steps 2.3.2 through 2.3.6. ________

2.3.8 Disconnect actuators from front table and reconfigure on rear table as illustrated in Figure 2-4.

2.3.9 Ensure initial pre-load on actuators is less than 500 lbs. Ensure that tables remain in a floating attitude throughout the test. Mark table location. ________

NOTE

Do not re-zero Load Cells at this time.

2.3.10 Start acquisition program, slowly apply force to actuators while observing X-Y-Y plotter to ensure the force values rise together. The force will drop suddenly as the truck begins to rotate. Record break-away force and cross check with measurement acquired on PC.

2.3.11 Realign truck using two come-a-longs.

2.3.12	Repeat Steps 2.3.9 through 2.3.11 two times, record load cell readings in the Test Events Log.	________
2.3.13	Reconfigure load cells, actuators and brackets. Then perform test in opposite direction Step 2.3.9 through 2.3.12.	________

2.4 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
2.4.1	Remove string pots, load cells and actuators.	
2.4.2	Jack A-end off of air bearing tables and running gear.	
2.4.5	Apply air and float tables and running gear away from car.	
2.4.6	Reverse Steps 2.1.5 through 2.1.14.	
2.4.7	Lower all jacks evenly from side to side. Attach cut lever and place Bad Order Tag on car for non-functioning brakes.	
2.4.8	Quality assurance will verify test tear down is complete.	________

3.0 AXLE ALIGNMENT TEST PROCEDURE

3.1 Test Setup Procedure

NOTE

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
3.1.1	Ensure test area is clean and secure from outside interference; furthermore, ensure that the trucks are ready for testing.	________
3.1.2	Install Truck S/N T.C. # 4 under the B-end of a gondola that is loaded to simulate Triplet Test Car axle weight.	________
3.1.3	Measure load on A-end trucks span bolster and record below. Wt. ______	________

NOTE

Leave brake rigging detached.

3.1.4 Using chain, secure A-end axles and trucks to the car body.

3.1.5 Using two 100-ton jacks, jack the A-end of the test car up approximately 6-inch and place trucks on rail panels.

3.1.5.1 Lower jacks.

NOTE

Ensure that there is no compression on the A-end side bearings.

3.1.6 Insert aluminum sheets beneath and around test car, see Figure 3-1. Tape all seams and edges down to ensure proper seal.

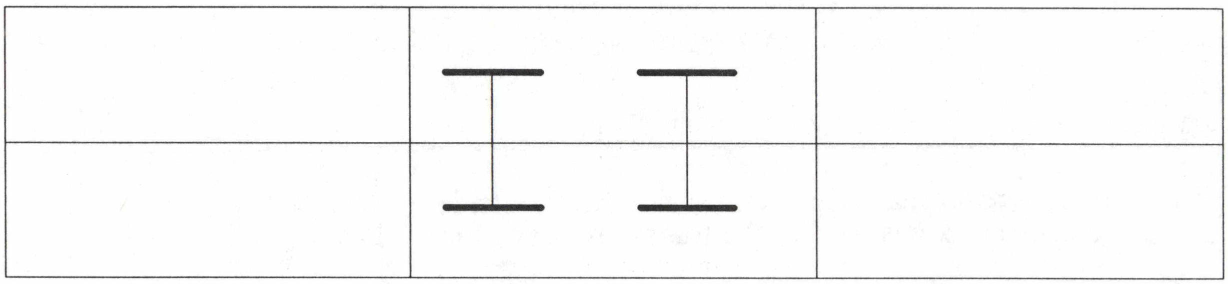


Figure 3-1 Aluminum Sheet Placement for Single Truck Tests

3.1.7 Position air bearing tables under B-end truck (one table per axle), leaving 2 inches between tables.

3.1.8 Lower test car onto the air bearing tables, ensure spring group is in the correct location and remove jacks from the B-end of the test car.

3.1.9 Level test car by jacking A-end and placing rail panels under A-end wheels.

NOTE

A-end height must equal B-end height +/−+/- 1/2-inch.

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 tables for 15 seconds then release air.	

NOTE

Test may be preformed on the right or left side of the truck.

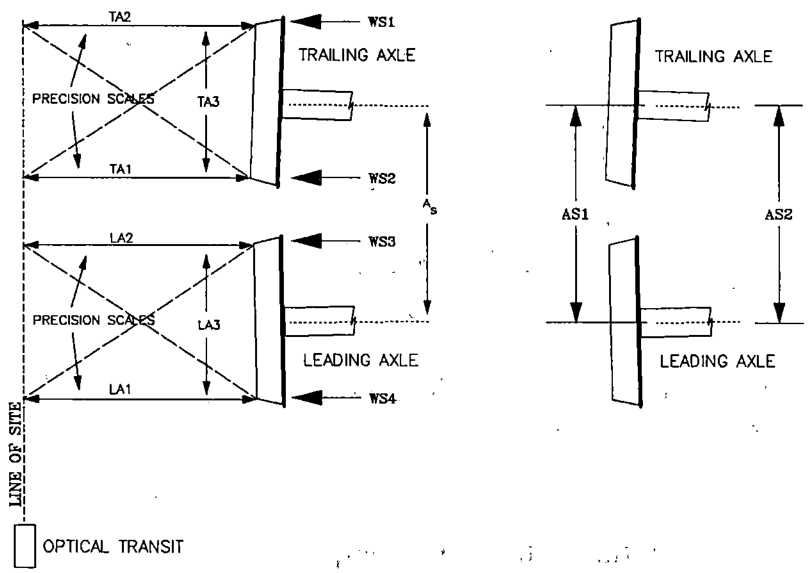


Figure 3-2 Axle Alignment Test Configuration

3.2.2	Mark a level with 4 lines, one pair will be 10 inches on each side from the center point, the other will be 11 inches on each side from the center point.	______
3.2.3	Trace the top of the level at the points on the wheel where the 20-inch marks line 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 measuring 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 430 - 460 ft.-lbs.
DO NOT permit wheels to rotate while caps are off.

3.2.9 Float tables and release air.

3.2.10 Remove end caps on all four bearings.

3.2.11 Measure axle spacing on the south sides of the truck using vernier calipers, record the measurements on the Data Sheet.

3.2.12 Measure wheel spacing for each axle. Measure distance from inside of rim to inside of rim at two locations (120 degrees apart).

3.2.13 Align transit (rotationally) until front most and rear most rulers read within 1/100-inch of each other.

3.2.14 Read all scales to thousandth, and record data on the Data Sheet. ______

3.2.15 Perform Axle Alignment Test Steps 3.2.2 through 3.2.15 three times. ______

3.2.16 Reinstall end caps and torque to 430 - 460 ft. lbs. ______

3.2.17 Remove S/N T.C. #4 and replace with truck S/N T.C. #3.

3.2.18 Repeat Steps 3.1.4 through 3.2.16.

3.3 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Remove scales and transit.	______

4.0 LONGITUDINAL STIFFNESS TEST PROCEDURE

4.1 Test Setup Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
4.1.1	This procedure requires trucks to be situated on the air bearing tables. Ensure procedural Steps 3.1.4 through 3.1.9 have been accomplished.	_____
4.1.2	Install Axle Spud Kit as illustrated in Figure 4-1 and in accordance with AAR Wheel Axle Manual, torque bolts to 430 - 460 ft.-lbs.	_____

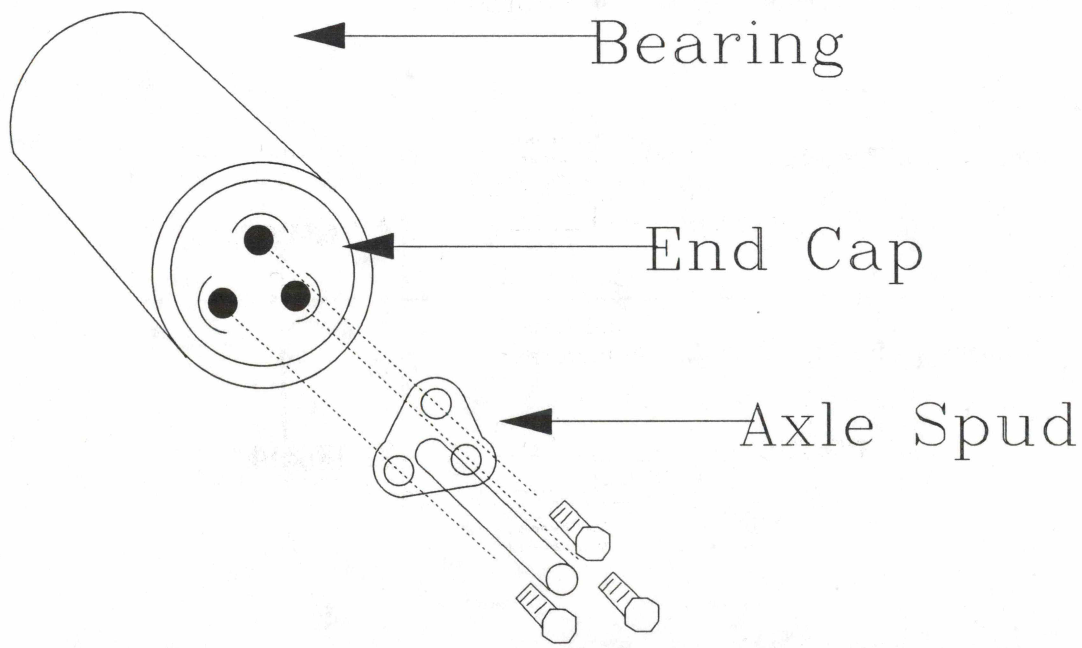


Figure 4-1 Axle Spud Kit Installation

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. Measure A and B dimensions.

4.1.2.2 C-clamp the load cells to the truck and shim to prevent any motion other than linear.

4.1.2.3 Connect load cell and string pot cables through conditioners and to plotter and computer.

4.1.2.4 Check zero and R-cal on each transducer.

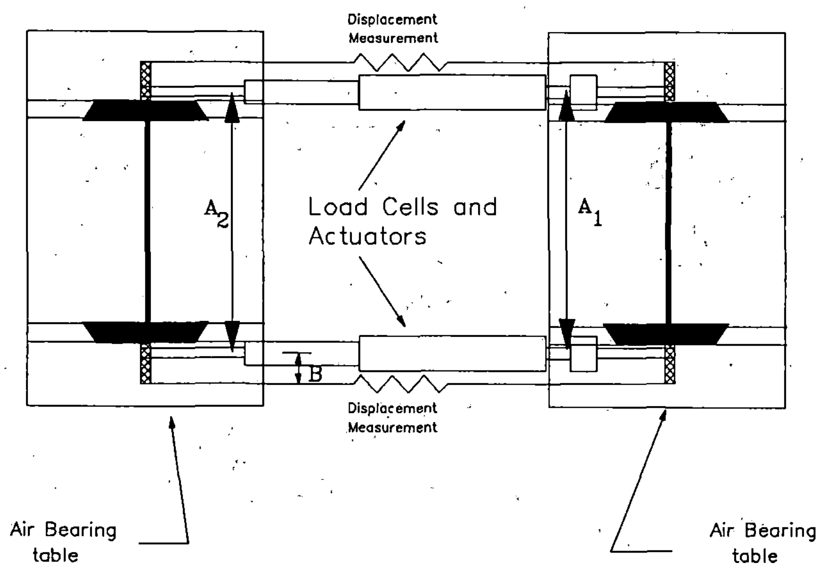


Figure 4-2 Longitudinal Stiffness, Axle Yaw and Inter-axle Bending Test Setup

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 vs displacement is no longer linear, refer to Figure 4-3.	______

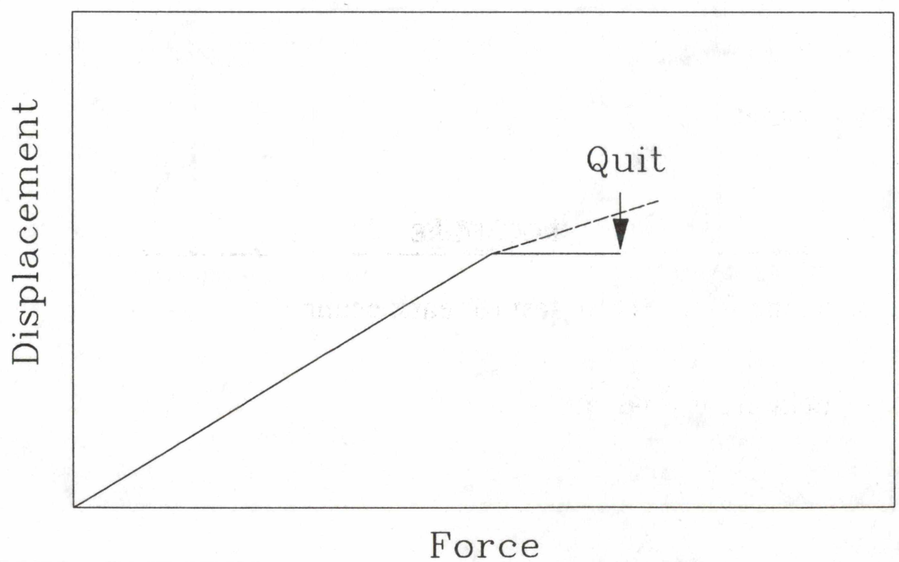


Figure 4-3 Force versus Displacement Sample

4.2.4 Ensure axle is centered in pedestal before proceeding with testing by allowing axles to come to rest in their normal position. ______

4.2.5 Repeat test Steps 4.2.1 through 4.2.4 two additional times.

4.2.6 Reverse actuators and repeat Steps 4.2.1 through 4.2.3 three times. ______

4.3 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
4.3.1	Test tear down is not required at this point in order to continue the Truck Characterization Test.	

5.0 AXLE YAW AND INTER-AXLE BENDING STIFFNESS TEST PROCEDURE

5.1 Test Setup Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
5.1.1	Check zero and R-cal before test for each channel.	______
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 tension 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 vs displacement is no longer linear as illustrated in Figure 4-3	_____
5.2.4	Repeat test Steps 5.2.1 through 5.2.3 two times and record data.	
5.2.5	Reverse actuator force and repeat Steps 5.2.1 through 5.2.4.	_____

5.3 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL

CAUTION

Torque end cap bolts to 430 - 460 ft.-lbs.

TASK NUMBER	PROCEDURE	QA INITIAL
5.3.1	Remove actuators, string pots and spud kit.	_____
5.3.2	Replace end caps and torque bolts to 430 - 460 ft.-lbs.	_____

5.3.3 Ensure that the proper information has been transferred from the old locking plates to the new ones and the locking plate tabs have been bent.

5.3.4 Apply end cap per rule 1K11, 1K12 and 1K15.

6.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
6.0.1	Quality verified that PKRG-4200-38" Triplet Cars is complete and closed.	
6.0.2	Authorized QA signature_______________________________.	

ATTACHMENT 1

TEST CONFIGURATION DATA SHEET

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 1 OF 2

TEST NAME AIR BEARING SPAN BLST ROTATION DATE JUNE 90 W.O. 87593 LOC. URB AIR TABLES

INSTR. ENGR./TECH. MARTIN. TEST ENGR. BIER 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	.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:

ACAD FILE: TRIPAIR1.DWG

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 2 OF ___

TEST NAME AIR BEARING LONG. STIFFNESS DATE JUNE 90 W.O. 87593 LOC. URB AIR TABLES

INSTR. ENGR./TECH. MARTIN TEST ENGR. BIER 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	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:

ACAD FILE: TRIPAIR2.DWG

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-4200-36" Triplet Car
TRUCK CHARACTERIZATION - AIR BEARING TABLE TEST

1.0 DESCRIPTION

The purpose of this procedure is to outline the sequence of steps to conduct truck characterization tests on air bearing tables located in the Urban Rail Building.

The truck characterization test consists of five sub-tests:

(1) Yaw Moment Test Between Span Bolster And Car Body
(2) Yaw Moment Test Between Truck And Span Bolster
(3) Axle Alignment Test
(4) Longitudinal Stiffness Test
(5) Axle Yaw Stiffness Test

1.1 INDEX

1.2 EQUIPMENT LIST

a.	4ea	Machinists Scale (0-48")
b.	2ea	Load Cell (10 KIP) with Accessories
c.	2ea	Celesco String Pot (+/− 1-inch)
d.	2ea	Ener Pac Hydraulic Cylinder (6" throw) with Accessories
e.	1ea	Axle Spud Kit
f.	2ea	String Pot Magnetic Bases
g.	1ea	Transit Square, Brunson Optical
h.	4ea	Machine Scale Support Stand
i.	2ea	Air Bearing Tables (120"x82"x7.5")
j.	2ea	Air Compressor with Accessories (750 cfm)
k.	4ea	100-Ton Jack (15-inch base)

l.	1ea	Chains and Clevis Kit
m.	1ea	6-foot Tape Measure
n.	10ea	Aluminium Sheets (12' X 4')
o.	8ea	Keepers, Axle
p.	2ea	Reaction Fixture
q.	1ea	X-Y-Y Plotter
r.	1ea	IBM PC with Metrabyte DAS 16F Card
s.	1ea	Actuator (10 KIP)
t.	4ea	Signal Conditioners
a.a.	1ea	Caliper, Vernier, 80-inch
b.b.	1ea	Torque Wrench (200 - 500 ft/lb Range)
c.c.	8ea	Rail Panels

1.3 FIGURE LIST

1.4 ATTACHMENT LIST

1. Test Configuration Data Sheet

1.5 REFERENCE LIST

PKRG 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

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 (e.g., Triplet Car).

1.6.2 Test Run Matrix

As test runs are completed, the Test Engineer will record the time of completion of each run, type of test, direction, and comments about the 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 Sheets

The Test Configuration Data Sheet is produced by performance of Procedure PKRG-3100, Instrument 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.

1.6.5 Run Statistics Print-Out X-Y-Y Plots

X-Y Plots will be made in Lotus format during testing. Lotus graphs of each test will also be made.

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 Procedure

NOTE

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	Inspect trucks in accordance with procedure PKRG-2100.	______
2.1.3	Record side bearing and bolster clearance. Side bearing must have 3/16-inch minimum to 5/16-inch maximum clearance. Ensure car is level during inspection. Clearance Right Side ______ Clearance Left Side ______	______

2.1.4 Position test car so that A-end lead axle is centered on the center of the first reaction fixture, see Figure 2-1.

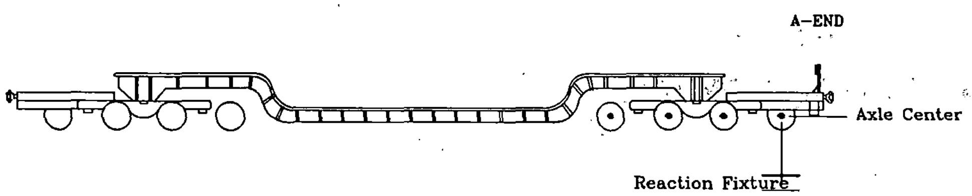


Figure 2-1 Triplet Car Located at Reaction Fixture

2.1.5 Disconnect hand brake chain and air brake line. Chock all B-end wheels.

2.1.6 Using two 100-ton jacks (with 12-inch extensions) at jacking pad, jack test car up approximately 12-inch to remove A-end running gear assembly.

NOTE

Ensure that there is 6-inch of travel left in the jacks when span bolster is clear.

2.1.7 Roll span bolster and trucks away from car.

2.1.8 Insert aluminum sheets beneath and around the test car, see Figure 2-2. Tape all seams and edges down to ensure a proper seal.

2.1.9 Chain truck #4 to the A-end span bolster.

2.1.10 Lift span bolster and truck #4 with a crane.

2.1.11 Lower span bolster and truck #4 onto air table.

2.1.12 Disconnect chains and crane.

2.1.13 Chain truck #3 to A-end span bolster.

2.1.14 Lift span bolster and truck #3 with the crane.

2.1.15 Lower span bolster and truck #3 onto air table #2.

2.1.16 Disconnect chain and crane.

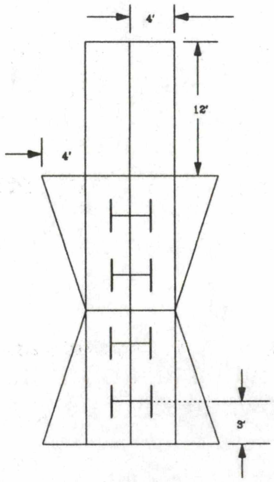


Figure 2-2 Aluminum Sheet Placement

2.1.17 Using connector plates, bolt both air bearing tables together as indicated in Figure 2-3.

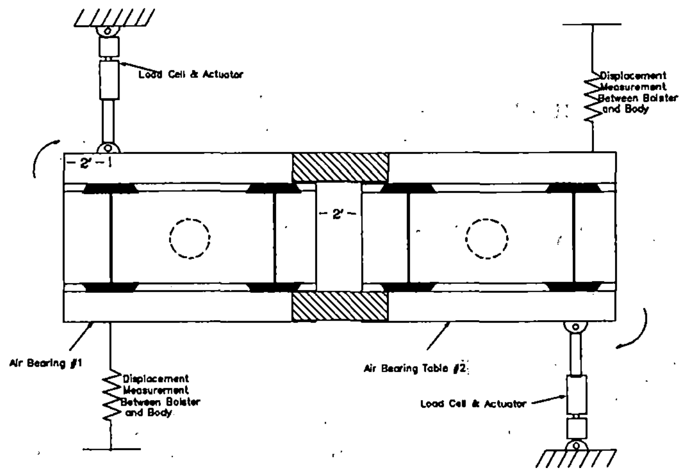


Figure 2-3 Span Bolster Yaw Moment

2.1.18 Float air bearing tables, trucks and span bolster under the car.

2.1.19 Ensure the spring group is in its correct position.

2.1.20 Lower the test car onto the span bolster and remove jacks from A-end of test car.

2.1.21 Level test car by jacking B-end and placing rail panels under B-end wheels.

NOTE

A-end height must equal B-end height +/− 1/2-inch.

2.1.22 Connect reaction fixtures to facility floor.

2.1.23 Connect actuator load cell and string pots to air bearing tables as illustrated in Figure 2-3.

NOTE

Actuators must be in line with lead and trail axle of A-end span bolster.

2.1.24 Connect string pots between air bearing table and reaction fixtures.

2.1.25 Connect car stabilizing fixtures to facility floor. Chain car body to stabilizing fixtures, as shown on Figure 2-4. ______

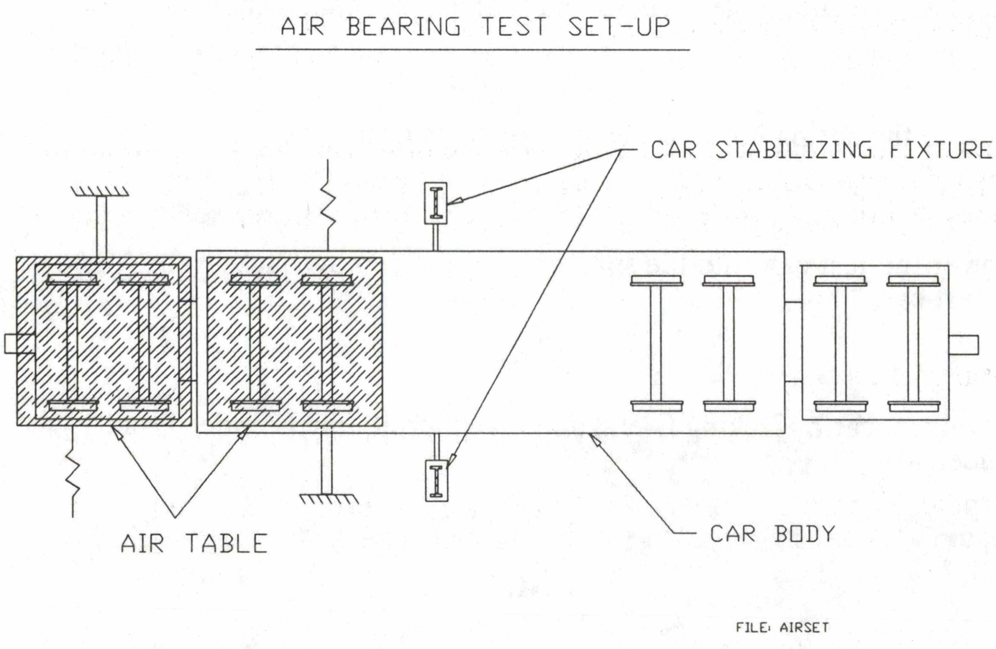


Figure 2-4 Car Stabilizing Fixture

2.1.26 Connect transducer cables (string pots and load cells) through signal conditioners to the PC and plotter.

2.1.27 Measure initial force at each actuator for both tables. Ensure that actuators measure less than 500 lbs. ________

NOTE

Do not re-zero Load Cells at this time.

2.2 Yaw Moment Measurement Test, Span Bolster to Car Body

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Ensure pre-load on tables is less than 500 lbs. Ensure that tables remain in a floating attitude throughout the test. Mark position of tables on the aluminum to ensure air bearing table has not moved. Start the data acquisition program and sample at 10 Hz.	
2.2.2	Slowly apply force to both actuators while observing load cell output to ensure the force values rise together. The force will drop suddenly as the span bolster begins to rotate. When force drops, stop force application.	
2.2.3	Realign truck using two come-a-longs.	
2.2.4	Repeat Steps 2.2.1 through 2.2.3 two times, record load cell output readings at point of truck rotation and cross check with data acquired with PC.	________
2.2.5	Following Steps 2.1.20 through 2.1.24, remove and reinstall actuators, load cells and string pots, to rotate span bolster in the opposite direction.	

2.2.6 Repeat Steps 2.2.1 through 2.2.4. ________

2.3 Yaw Moment Test, Truck To Span Bolster

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	Remove air bearing table connector plates.	
2.3.2	Connect actuator to front table as illustrated in Figure 2-5.	________

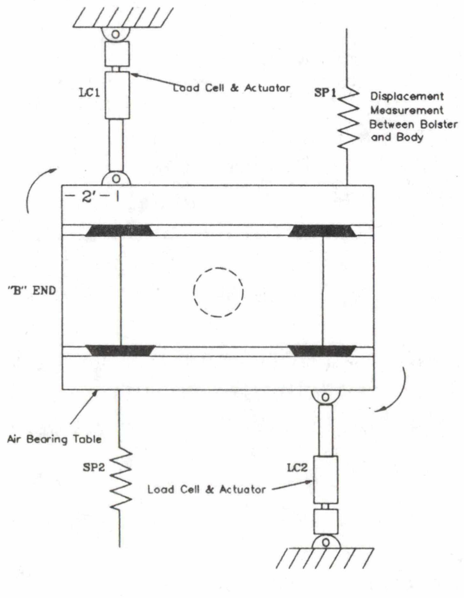


Figure 2-5 Truck Yaw Moment Test Set-up

2.3.3.	Ensure initial pre-load on actuators is less than 500 lbs. and that both tables remain in a floating attitude throughout the test. Mark table location if different than previous test.	________

2.3.4 Start acquisition program, slowly apply force to actuators while observing X-Y-Y plotter to ensure the force values rise together. The force will drop 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.

2.3.5 Realign truck using two come-a-longs.

2.3.6 Repeat Steps 2.3.3 through 2.3.5 two times, record load cell readings in Test Events Log. ________

2.3.7 Reconfigure load cell actuators and brackets. Then perform test in opposite direction Steps 2.3.2 through 2.3.6. ________

2.3.8 Disconnect actuators from front table and reconfigure on rear table as illustrated in Figure 2-4.

2.3.9 Ensure initial pre-load on actuators is less than 500 lbs. Ensure that tables remain in a floating attitude throughout the test. Mark table location. ________

NOTE

Do not re-zero Load Cells at this time.

2.3.10 Start acquisition program, slowly apply force to actuators while observing X-Y-Y plotter to ensure the force values rise together. The force will drop suddenly as the truck begins to rotate. Record break-away force and cross check with measurement acquired on PC.

2.3.11 Realign truck using two come-a-longs.

2.3.12	Repeat Steps 2.3.9 through 2.3.11 two times, record load cell readings in the Test Events Log.	________
2.3.13	Reconfigure load cells, actuators and brackets. Then perform test in opposite direction Step 2.3.9 through 2.3.12.	________

2.4 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
2.4.1	Remove string pots, load cells and actuators.	
2.4.2	Jack A-end off of air bearing tables and running gear.	
2.4.5	Apply air and float tables and running gear away from car.	
2.4.6	Reverse Steps 2.1.5 through 2.1.14.	
2.4.7	Lower all jacks evenly from side to side. Attach cut lever and place Bad Order Tag on car for non-functioning brakes.	
2.4.8	Quality assurance will verify test tear down is complete.	________

3.0 AXLE ALIGNMENT TEST PROCEDURE

3.1 Test Setup Procedure

NOTE

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
3.1.1	Ensure test area is clean and secure from outside interference; furthermore, ensure that the trucks are ready for testing.	______
3.1.2	Install Truck S/N T.C. # 4 under the B-end of a gondola that is loaded to simulate Triplet Test Car axle weight.	______
3.1.3	Measure load on A-end trucks span bolster and record below. Wt. ______	______

NOTE

Leave brake rigging detached.

3.1.4	Using chain, secure A-end axles and trucks to the car body.	
3.1.5	Using two 100-ton jacks, jack the A-end of the test car up approximately 6-inch and place trucks on rail panels.	

3.1.5.1 Lower jacks.

NOTE

Ensure that there is no compression on the A-end side bearings.

3.1.6 Insert aluminum sheets beneath and around test car, see Figure 3-1. Tape all seams and edges down to ensure proper seal.

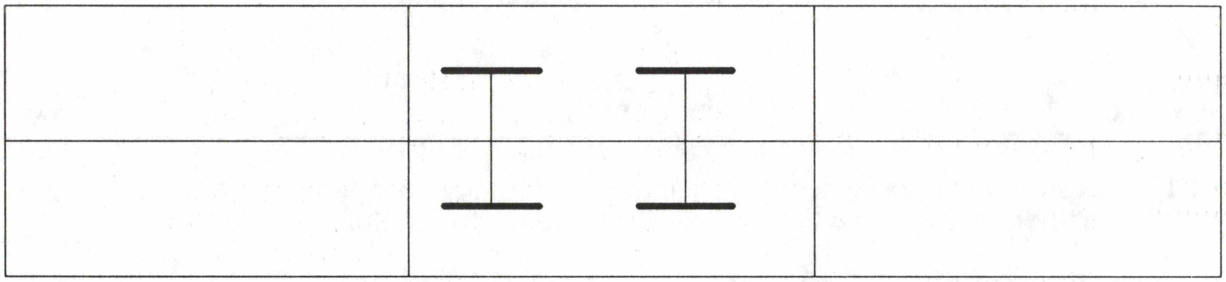


Figure 3-1 Aluminum Sheet Placement for Single Truck Tests

3.1.7 Position air bearing tables under B-end truck (one table per axle), leaving 2 inches between tables.

3.1.8 Lower test car onto the air bearing tables, ensure spring group is in the correct location and remove jacks from the B-end of the test car.

3.1.9 Level test car by jacking A-end and placing rail panels under A-end wheels.

NOTE

A-end height must equal B-end height + / − + /- 1/2-inch.

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 tables for 15 seconds then release air.	

NOTE

Test may be preformed on the right or left side of the truck.

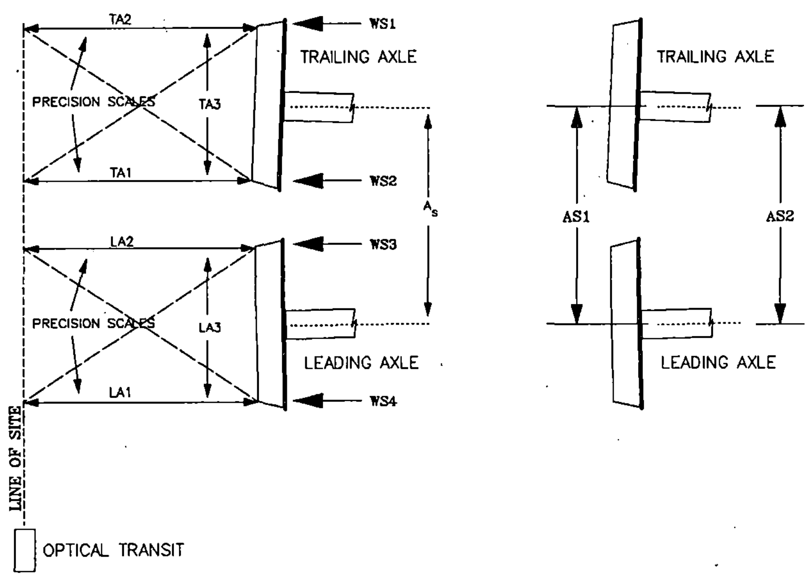


Figure 3-2 Axle Alignment Test Configuration

3.2.2	Mark a level with 4 lines, one pair will be 10 inches on each side from the center point, the other will be 11 inches on each side from the center point.	______
3.2.3	Trace the top of the level at the points on the wheel where the 20-inch marks line 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 measuring 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 430 - 460 ft.-lbs.
DO NOT permit wheels to rotate while caps are off.

3.2.9 Float tables and release air.

3.2.10 Remove end caps on all four bearings.

3.2.11 Measure axle spacing on the south sides of the truck using vernier calipers, record the measurements on the Data Sheet.

3.2.12 Measure wheel spacing for each axle. Measure distance from inside of rim to inside of rim at two locations (120 degrees apart).

3.2.13 Align transit (rotationally) until front most and rear most rulers read within 1/100-inch of each other.

3.2.14 Read all scales to thousandth, and record data on the Data Sheet. ______

3.2.15 Perform Axle Alignment Test Steps 3.2.2 through 3.2.15 three times. ______

3.2.16 Reinstall end caps and torque to 430 - 460 ft. lbs. ______

3.2.17 Remove S/N T.C. #4 and replace with truck S/N T.C. #3.

3.2.18 Repeat Steps 3.1.4 through 3.2.16.

3.3 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Remove scales and transit.	______

4.0 LONGITUDINAL STIFFNESS TEST PROCEDURE

4.1 Test Setup Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
4.1.1	This procedure requires trucks to be situated on the air bearing tables. Ensure procedural Steps 3.1.4 through 3.1.9 have been accomplished.	______
4.1.2	Install Axle Spud Kit as illustrated in Figure 4-1 and in accordance with AAR Wheel Axle Manual, torque bolts to 430 - 460 ft.-lbs.	______

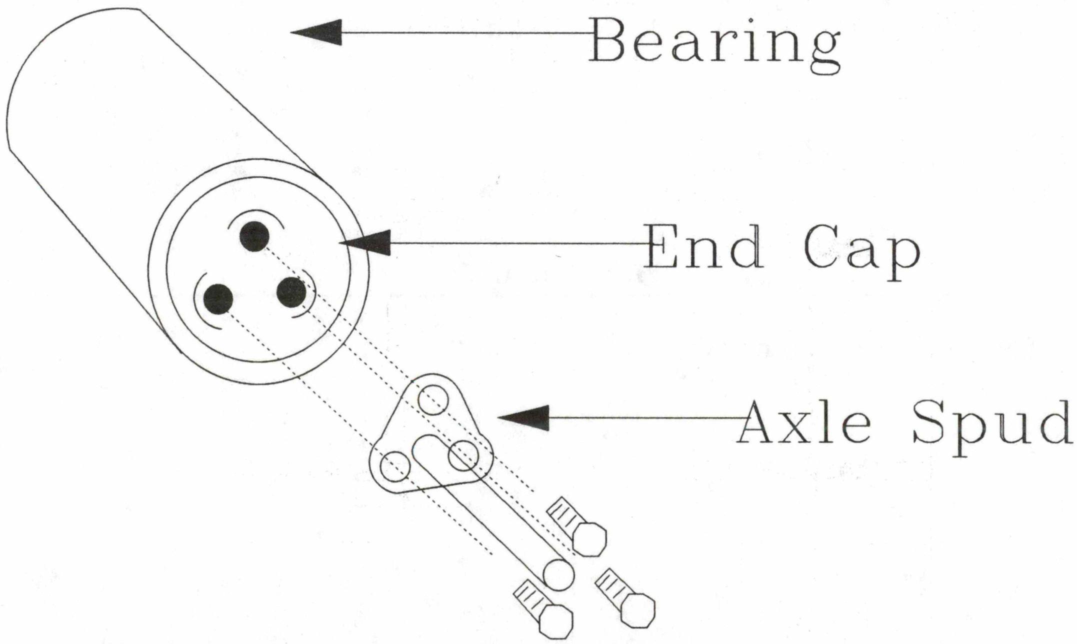


Figure 4-1 Axle Spud Kit Installation

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. Measure A and B dimensions.

4.1.2.2 C-clamp the load cells to the truck and shim to prevent any motion other than linear.

4.1.2.3 Connect load cell and string pot cables through conditioners and to plotter and computer.

4.1.2.4 Check zero and R-cal on each transducer.

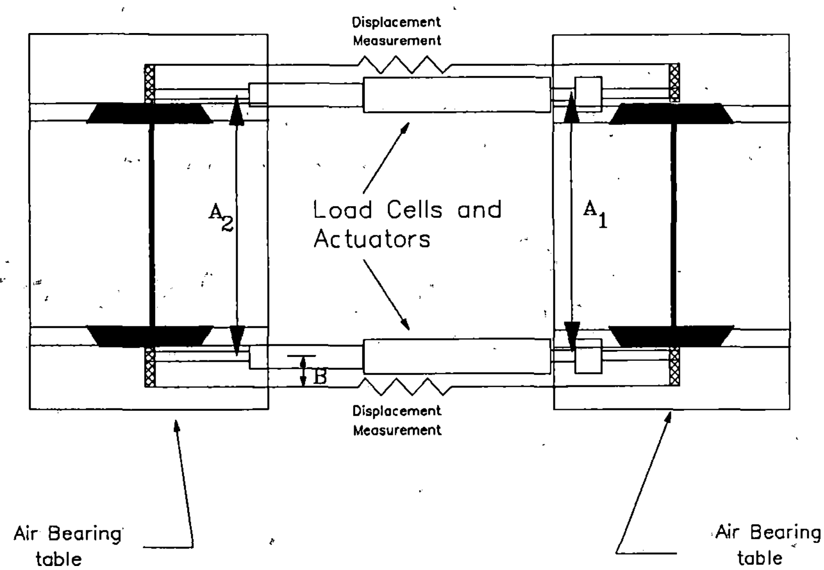


Figure 4-2 Longitudinal Stiffness, Axle Yaw and Inter-axle Bending Test Setup

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 vs displacement is no longer linear, refer to Figure 4-3.	______

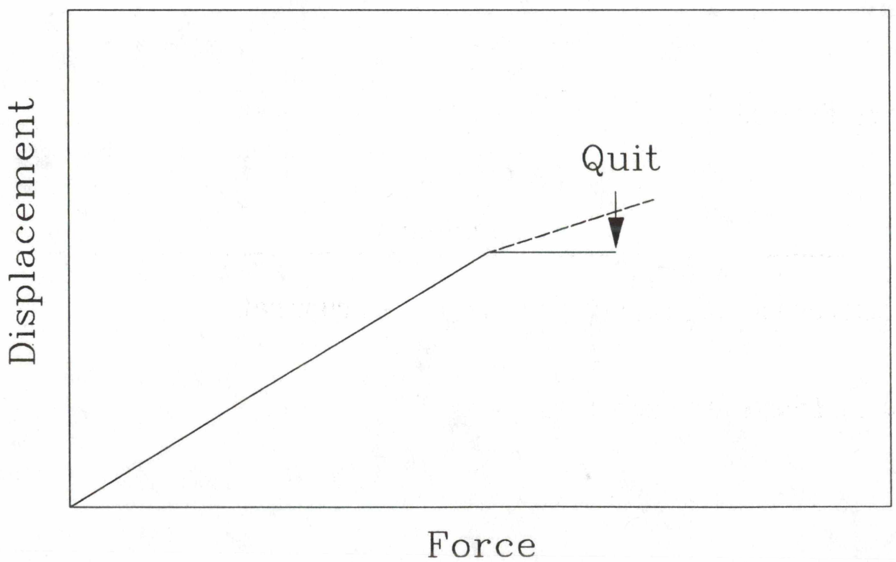


Figure 4-3 Force versus Displacement Sample

4.2.4	Ensure axle is centered in pedestal before proceeding with testing by allowing axles to come to rest in their normal position.	______
4.2.5	Repeat test Steps 4.2.1 through 4.2.4 two additional times.	
4.2.6	Reverse actuators and repeat Steps 4.2.1 through 4.2.3 three times.	______

4.3 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
4.3.1	Test tear down is not required at this point in order to continue the Truck Characterization Test.	

5.0 AXLE YAW AND INTER-AXLE BENDING STIFFNESS TEST PROCEDURE

5.1 Test Setup Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
5.1.1	Check zero and R-cal before test for each channel.	______
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 tension 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 vs displacement is no longer linear as illustrated in Figure 4-3	_____
5.2.4	Repeat test Steps 5.2.1 through 5.2.3 two times and record data.	
5.2.5	Reverse actuator force and repeat Steps 5.2.1 through 5.2.4.	_____

5.3 Test Tear Down Procedure

TASK NUMBER	PROCEDURE	QA INITIAL

CAUTION

Torque end cap bolts to 430 - 460 ft.-lbs.

5.3.1	Remove actuators, string pots and spud kit.	_____
5.3.2	Replace end caps and torque bolts to 430 - 460 ft.-lbs.	_____

5.3.3 Ensure that the proper information has been transferred from the old locking plates to the new ones and the locking plate tabs have been bent.

5.3.4 Apply end cap per rule 1K11, 1K12 and 1K15.

6.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
6.0.1	Quality verified that PKRG-4200-38" Triplet Cars is complete and closed.	
6.0.2	Authorized QA signature ______________________.	

ATTACHMENT 1

TEST CONFIGURATION DATA SHEET

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 1 OF 2

TEST NAME AIR BEARING SPAN BLST ROTATION DATE JUNE 90 W.O. 87593 LOC. URB AIR TABLES

INSTR. ENGR./TECH. MARTIN. TEST ENGR. BIER 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.	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 AO (E.U.)	A1 (E.U./VOLT)	ENGR. UNITS	RECORDER CH. NO.	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:

ACAD FILE: TRIPAIR1.DWG

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 2 OF ____

TEST NAME AIR BEARING LONG. STIFFNESS DATE JUNE 90 W.O. 87593 LOC. URB AIR TABLES

INSTR. ENGR./TECH. MARTIN TEST ENGR. BIER 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:

ACAD FILE: TRIPAIR2.DWG

APPENDIX C

QUASI-STATIC TEST PROCEDURE
AND
QUALITY CONTROL CHECKLIST PROCEDURE

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG4100
TRUCK CHARACTERIZATION-MINI-SHAKER UNIT (MSU) TEST

1.0 DESCRIPTION

This is the procedure for conducting truck characterization tests on the Mini-Shaker Unit (MSU) in the Rail Dynamics Laboratory. Tests included are Vertical, Roll, and Lateral Suspension Characterization.

2.0 PREREQUISITES

a. Trucks to be tested have been inspected in accordance with Procedure PKRG-2100 and found to be acceptable for testing.

b. MSU is properly configured for vertical excitation (Figure A).

3.0 DOCUMENTATION

Performance of this procedure will be documented by:

a. Test Events Log
b. Test Run Matrix
c. Test Configuration Data Sheet
d. Data Disk
e. Run statistics printout
f. Quality Control Checklist

3.1 Test Events Log

The Test Engineer will maintain a Test Events Log throughout the testing process. The log will be used to record:

a. the time of completion of each major phase of the test procedure,
b. the occurrence of any unexpected or unusual events, anomalies, or delays, and
c. any other events that potentially impact the evaluation or validity of test results.

Upon completion of this procedure, the Test Events Log will be permanently filed in the appropriate case file (e.g., Triplet Cars).

3.2 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.

3.3 Test Configuration Data Sheet

The Test Configuration Data Sheet is produced by performance of Procedure PKRG-3100, Instrument Installation (see Step 5.1.5). It will be permanently filed in the appropriate case file upon completion of this test procedure.

3.4 Data Disk

Test data will be recorded on a data disk, which will be permanently filed in the appropriate case file upon completion of this procedure.

3.5 Run Statistics Printout

A printout of all run statistics will be produced and permanently filed in the appropriate case file upon completion of this procedure.

3.6 Quality Control Checklist

The Quality Control Checklist will be completed and permanently filed in the appropriate case file upon completion of this procedure.

4.0 SAFETY CONSIDERATIONS

All personnel involved in the performance of this procedure or observing the test(s) will comply with the TTC Safety Rule Book. Test Conductor will review potential safety hazards with team members and insure all particpants sign the Safety Briefing Log. Test area will be encompassed with a safety barrier and only essential personnel will be allowed within the barrier.

5.0 VERTICAL AND ROLL TESTING

5.1 Preparations

5.1.1 Verify truck has been inspected and accepted for testing in accordance with Procedure PKRG-2100. (Quality Control Point)

NOTE: STEPS IDENTIFIED AS QUALITY CONTROL POINTS MUST BE VERIFIED BY QUALITY ASSURANCE AND SIGNED OFF ON THE QUALITY CONTROL CHECKLIST BEFORE SUCCEEDING STEPS ARE PERFORMED.

5.1.2 Remove snubbers (if present) and replace with standard springs. (Quality Control Point)

5.1.3 Install truck on MSU in accordance with Procedure PKRG-4110. (Quality Control Point)

5.1.4 Ensure side bearing to car body clearance is between 3/16" and 5/16". (Quality Control Point)

5.1.5 Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet. (Quality Control Point)

5.1.6 Exercise truck in vertical mode for approximately 30 minutes.

5.1.7 Photograph instrument configuration, transducer locations and string pot attachment points. This step is necessary only for the first truck in a set of trucks. (Quality Control Point)

5.1.8 Disconnect string pots and LVDTs. (Quality Control Point)

5.1.9 Remove center springs and reinstall snubbers, if applicable.

5.1.10 Reconnect string pots and LVDTs. (Quality Control Point)

5.1.11 Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200. (Quality Control Point)

5.2 Vertical and Roll Test Operations

5.2.1 Select vertical run parameters from the Test Run Matrix.

5.2.2 Start DAS in collection mode.

5.2.3 Begin truck excitation in vertical mode.

5.2.4 Start data collection.

NOTE: FOR EACH VERTICAL TEST, START DATA COLLECTION AT THE SAME POINT IN THE EXCITATION CYCLE (E.G., AT PEAK HIGH OR LOW POINT)

5.2.5 Record data for four (4) complete cycles.

5.2.6 Print statistics.

5.2.7 Verify run parameters. (Quality Control Point)

5.2.8 Repeat steps 5.2.3 through 5.2.7 for all vertical run parameters.

5.2.9 Stop truck excitation.

5.2.10 Select roll run parameters from the Test Run Matrix.

5.2.11 Begin truck excitation in roll mode.

5.2.12 Record data for four (4) cycles.

NOTE: FOR EACH ROLL TEST, START DATA COLLECTION AT THE SAME POINT IN THE ROLL CYCLE.

5.2.13 Print statistics.

5.2.14 Verify run parameters. (Quality Control Point)

5.2.15 Repeat steps 5.2.11 through 5.2.14 for all roll run parameters.

5.2.16 Stop truck excitation.

5.2.17 Perform post-test instrumentation verification procedure in accordance with Procedure PKRG-3200. (Quality Control Point)

5.2.18 Shut down MSU

5.2.19 Disconnect cables from transducers.

5.2.20 Remove transducers.

5.2.21 Remove truck 2 (A-end) from MSU and replace with truck 1 (B-end) truck in accordance with Procedure PKRG-4110. (Quality Control Point)

5.2.22 Repeat steps 5.1.1 through 5.2.21 until all trucks have been tested against all vertical and roll parameters.

5.2.23 Instruct RDL personnel to reconfigure MSU to lateral mode (Figure B).

6.0 LATERAL TESTING

6.1 Preparations

6.1.1 Install truck on MSU in accordance with Procedure PKRG-4110. (Quality Control Point)

6.1.2 Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet. (Quality Control Point)

6.1.3 Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200. (Quality Control Point)

6.2 Lateral Test Operations

6.2.1 Move truck to position wheel flanges against North rails. (Quality Control Point)

6.2.2 Select lateral run parameters from Test Run Matrix.

6.2.3 Start DAS in collection mode.

6.2.4 Begin truck excitation in lateral mode.

6.2.5 Start data collection.

NOTE: FOR EACH LATERAL TEST RUN, START DATA COLLECTION AT THE SAME POINT IN THE EXCITATION CYCLE (E.G., EXTREME LEFT OR RIGHT)

6.2.6 Record data for four (4) complete cycles.

6.2.7 Print statistics.

6.2.8 Verify run parameters. (Quality Control Point)

6.2.9 Repeat steps 6.2.4 through 6.2.8 for all lateral run parameters.

6.2.10 Stop truck excitation.

6.2.11 Move truck to position wheel flanges against South rail. (Quality Control Point)

6.2.12 Repeat steps 6.2.2 through 6.2.10.

6.2.13 Perform post-test instrumentation verification in accordance with Procedure PKRG-3200. (Quality Control Point)

6.2.14 Shut down MSU.

6.2.15 Disconnect cables from transducers.

6.2.16 Remove transducers and all mounting hardware from truck.

6.2.17 Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110. (Quality Control Point)

6.2.18 Visually inspect truck in accordance with Procedure PKRG-2100. (Quality Control Point)

6.2.19 Repeat steps 6.1.1 through 6.2.18 until all trucks have been tested against all lateral parameters.

6.2.20 Make back-up copy of data disk.

6.2.21 Switch trucks back to orginal position in accordance with Procedure

6.2.21 Switch truck back to orginal position in accordance with Procedure PKRG-4110. (Quality Control Point)

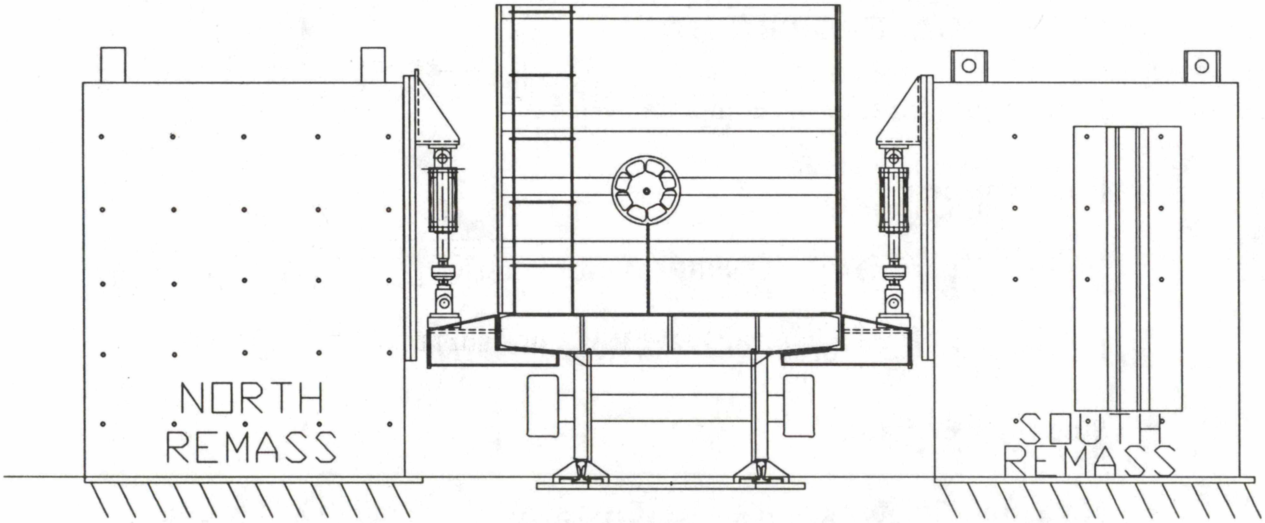


Figure A Vertical Test MSU Configuration

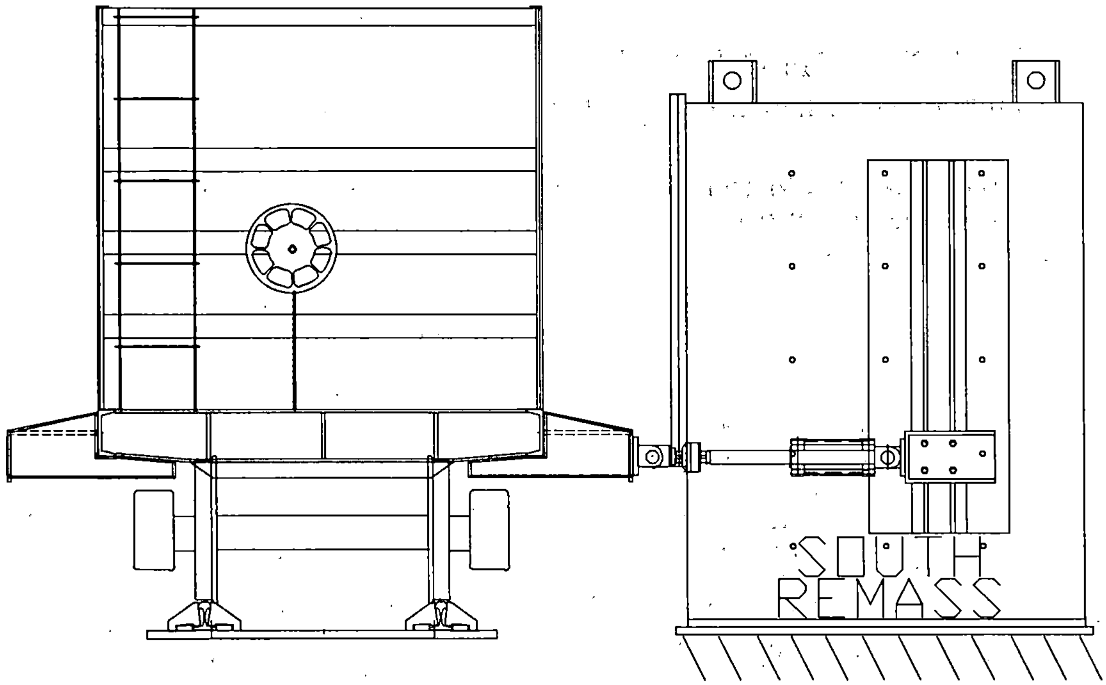


Figure B Lateral Test MSU Configuration

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-4100
TRUCK CHARACTERIZATION - MINI-SHAKER UNIT (MSU) TESTS

QUALITY CONTROL CHECKLIST

This checklist is to be used by the Quality Control Inspector to document adherence to Procedure PKRG-4100. Each procedure step designated as a Quality Control Point must be verified by the Quality Control Inspector before succeeding steps may be performed.

		Initials
5.1	Review safety briefing for validity.	______
5.1.1	Verify truck has been inspected and accepted for testing in accordance with Procedure PKRG-2100.	______
5.1.2	Remove snubbers (if present) and replace with standard springs.	______
5.1.3	Install truck on MSU in accordance with Procedure PKRG-4110.	______
5.1.4	Ensure side bearing to car body clearance is between 3/16" and 5/16".	______
5.1.5	Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet.	______
5.1.6	Photograph instrument configuration, transducer locations and string pot attachment points. This step is necessary only for the first truck of a set of trucks.	______
5.1.7	Disconnect stringpots and LVDTs.	______
5.1.10	Reconnect stringpots and LVDTs.	______
5.1.11	Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200.	______
5.2.7	Verify (vertical) run parameters (+/- 5% of vertical actuator displacement).	______
5.2.14	Verify (roll) run parameters (+/- 5% of vertical actuator displacement).	______

5.2.17	Perform post-test instrumentation verification in accordance with Procedure PKRG-3200.	_______
5.2.21	Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110.	_______
6.1.1	Install truck on MSU in accordance with Procedure PKRG-4110.	_______
6.1.2	Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet.	_______
6.1.3	Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200.	_______
6.2.1	Move truck to position wheel flanges against North rails.	_______
6.2.8	Verify run parameters (+/- 5% of lateral actuator load cells).	_______
6.2.11	Move truck to position wheel flanges against South rails.	_______
6.2.13	Perform post-test instrumentation verification in accordance with Procedure PKRG-3200.	_______
6.2.17	Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110.	_______
6.2.18	Visually inspect truck in accordance with Procedure PKRG-2100.	_______

Truck Identification____________ Bolster Serial No.________ Date________

Testing was performed in compliance with Procedure PKRG-4100 and all required documentation has been completed.

____
Quality Control Inspector

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-4100
TRUCK CHARACTERIZATION-MINI-SHAKER UNIT (MSU) TEST
AND
PROCEDURE PKRG-4100-A
QUALITY CONTROL CHECKLIST

1.0 DESCRIPTION

This procedure outlines the steps for conducting Truck Characterization Tests on the Mini-Shaker Unit (MSU) in the Rail Dynamics Laboratory. Tests included are Vertical, Roll, and Lateral Suspension Characterization.

1.1 INDEX

1.2 PREREQUISITES

A. Trucks to be tested have been inspected in accordance with Procedure PKRG-2100 and found to be acceptable for testing.

B. MSU is properly configured for vertical excitation (Figure A on Page 10).

1.3 REFERENCE DOCUMENTATION

Performance of this procedure will be documented by:

1.3.1 Test Event Log

The Test Engineer will maintain a Test Events Log throughout the testing process. The log will be used to record:

a. The time of completion of each major phase of the test
b. procedure.
c. The occurrence of any unexpected or unusual events, anomalies, or delays.
Any other events that potentially impact the evaluation or validity of test results.

1.3.2 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.

1.3.3 Test Configuration Data Sheet

The Test Configuration Data Sheet is produced by performance of Procedure PKRG-3100, Instrument Installation (see Step 5.15). It will be permanently filed in the appropriate case file upon completion of this test procedure.

1.3.4 Data Disk

Test data will be recorded on a data disk, which will be permanently filed in the appropriate case file upon completion of this procedure.

1.3.5 Run Statistics Printout

A printout of all run statistics will be produced and permanently filed in the appropriate case file upon completion of this procedure.

1.3.6 Quality Control Checklist (PKRG-4100-A)

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. Test conductor will review potential safety hazards with team members and ensure all participants sign the Safety Briefing Log. Test area will be encompassed with a safety barrier and only essential personnel will be allowed within the barrier.

2.0 VERTICAL AND ROLL TESTING

2.1 Preparations

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Verify truck has been inspected and accepted for testing in accordance with Procedure PKRG-2100 (Quality Control Point).	

NOTE

Steps identified as Quality Control Points must be verified by Quality Assurance and signed off on the Quality Control Checklist (PKRG-4100-A) before succeeding steps are performed.

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.2	Remove hydraulic snubbers (if present) and replace with standard springs (Quality Control Point).	
2.1.3	Install truck on MSU in accordance with Procedure PKRG-4110 (Quality Control Point).	
2.1.4	Ensure side bearing to car body clearance is between 3/16-inch and 5/16-inch (Quality Control Point).	

2.1.5	Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet (Quality Control Point).	
2.1.6	Photograph instrument configuration, transducer locations and string pot attachment points. This step is necessary only for the first truck in a set of trucks (Quality Control Point).	
2.1.7	Disconnect string pots and LVDT's (Quality Control Point).	
2.1.8	Exercise truck in vertical mode for 4 hours.	
2.1.9	Remove center springs and reinstall snubbers, if applicable.	
2.1.10	Reconnect string pots and LVDT's (Quality Control Point).	
2.1.11	Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200 (Quality Control Point).	

2.2 Vertical and Roll Test Operations

TASK NUMBER	PROCEDURE	QA INITIAL
2.2.1	Select vertical run parameters from the Test Run Matrix.	
2.2.2	Start DAS in collection mode.	
2.2.3	Begin truck excitation in vertical mode.	

2.2.4 Start data collection.

NOTE

For each vertical test, start data collection at the same point in the excitation cycle (e.g., at peak high or low point)

2.2.5 Record data for 4 complete cycles.

2.2.6 Print statistics.

2.2.7 Verify run parameters (Quality Control Point).

2.2.8 Repeat Steps 2.2.3 through 2.2.7 for all vertical run parameters.

2.2.9 Stop truck excitation.

2.2.10 Select roll run parameters from the Test Run Matrix.

2.2.11 Begin truck excitation in roll mode.

2.2.12 Record data for 4 cycles.

NOTE

For each roll test, start data collection at the same point in the roll cycle.

2.2.13 Print statistics.

2.2.14 Verify run parameters (Quality Control Point).

2.2.15 Repeat Steps 2.2.11 through 2.2.14 for all roll run parameters.

2.2.16 Stop truck excitation.

2.2.17 Perform post test instrumentation verification procedure in accordance with Procedure PKRG-3200 (Quality Control Point).

2.2.18 Shut down MSU.

2.2.19 Disconnect cable from transducers.

2.2.20 Remove transducers.

2.2.21 Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110 (Quality Control Point).

2.2.22 Repeat Steps 2.1.1 through 2.2.21 until all trucks have been tested against all vertical and roll parameters.

2.2.23 Instruct RDL personnel to reconfigure MSU to lateral mode (Figure B on Page 10).

3.0 LATERAL TESTING

3.1 Preparations

TASK NUMBER	PROCEDURE	QA INITIAL
3.1.1	Install truck on MSU in accordance with Procedure PKRG-4110 (Quality Control Point).	
3.1.2	Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet (Quality Control Point).	
3.1.3	Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200 (Quality Control Point).	

3.2 Lateral Test Operations

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Move truck to position wheel flanges against north rails (Quality Control Point).	
3.2.2	Select lateral run parameters from Test Run Matrix.	
3.2.3	Start DAS in collection mode.	
3.2.4	Begin truck excitation in lateral mode.	
3.2.5	Start data collection.	

NOTE

For each lateral test run, start data collection at the same point in the excitation cycle (e.g., extreme left or right).

3.2.6 Record data for 4 complete cycles.

3.2.7 Print statistics.

3.2.8 Verify run parameters (Quality Control Point).

3.2.9 Repeat Steps 3.2.4 through 3.2.8 for all lateral run parameters.

3.2.10 Stop truck excitation.

3.2.11 Move truck to position wheel flanges against south rail (Quality Control Point).

3.2.12 Repeat Steps 3.2.2 through 3.2.8.

3.2.13 Perform post-test instrumentation verification in accordance with Procedure PKRG-3200 (Quality Control Point).

3.2.14 Shut down MSU.

3.2.15 Disconnect cables from transducers.

3.2.16 Remove transducers and all mounting hardware from truck.

3.2.17 Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110 (Quality Control Point).

3.2.18 Visually inspect truck in accordance with Procedure PKRG-2100 (Quality Control Point).

3.2.19 Repeat Steps 3.1.1 through 3.2.18 until all trucks have been tested against all lateral parameters.

3.2.20 Make back-up copy of data disk.

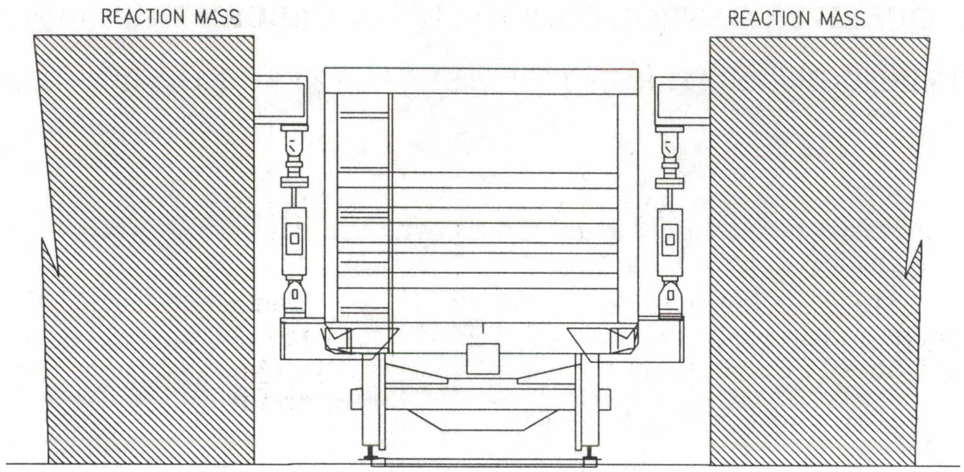


Figure A MSU Vertical Configuration

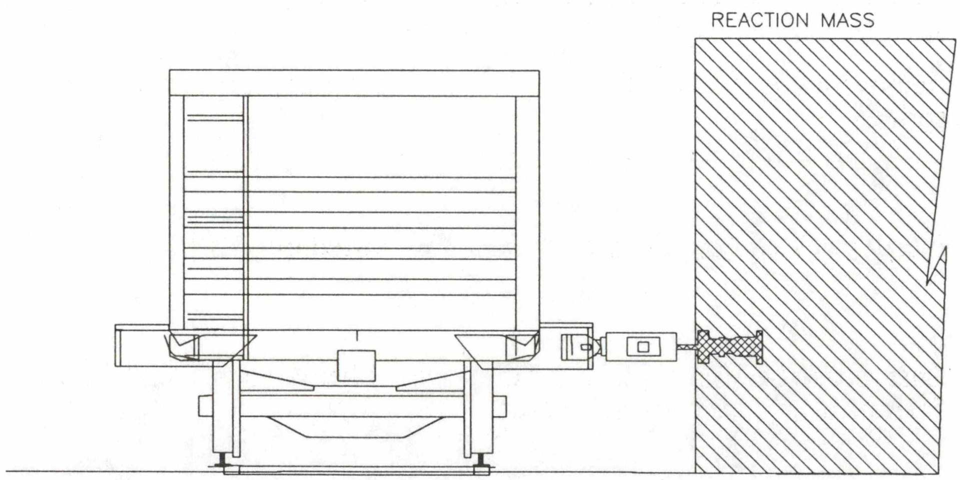


Figure B MSU Lateral Configuration

PEACEKEEPER RAIL GARRISON
QUALITY CONTROL CHECKLIST PROCEDURE PKRG-4100-A
FOR
TRUCK CHARACTERIZATION-MINI-SHAKER UNIT (MSU) TESTS

QUALITY CONTROL CHECKLIST

This checklist is to be used by the Quality Control Inspector to document adherence to Procedure PKRG-4100. Each procedure step designated as a Quality Control Point must be verified by the Quality Control Inspector before succeeding steps may be performed.

TASK NUMBER	PROCEDURE	QA INITIAL
2.1	Review safety briefing for validity.	______
2.1.1	Verify truck has been inspected and accepted for testing in accordance with Procedure PKRG-2100.	______
2.1.2	Remove hydraulic snubbers (if present) and replace with standard springs.	______
2.1.3	Install truck on MSU in accordance with Procedure PKRG-4110.	______
2.1.4	Ensure side bearing to car body clearance is between 3/16-inch and 5/16-inch.	______
2.1.5	Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet.	______

2.1.6 Photograph instrument configuration, transducer locations and string pot attachment points. This step is necessary only for the first truck of a set of trucks. ______

2.1.7 Disconnect string pots and LVDT's. ______

2.1.10 Reconnect string pots and LVDT's. ______

2.1.11 Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200. ______

3.0.7 Verify (vertical) run parameters (± 5 percent of vertical actuator displacement). ______

3.0.14 Verify (roll) run parameters (± 5 percent of vertical actuator displacement). ______

3.0.17 Perform post-test instrumentation verification in accordance with Procedure PKRG-3200. ______

3.0.21 Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110. ______

4.1.1 Install truck on MSU in accordance with Procedure PKRG-4110. ______

4.1.2 Install instrumentation in accordance with Procedure PKRG-3100 and the Test Configuration Data Sheet. ______

4.1.3 Perform pre-test instrumentation verification in accordance with Procedure PKRG-3200. ______

4.2 Move truck to position wheel flanges against north rails. ______

4.2.8 Verify run parameters (± 5 percent of lateral actuator load cells). ______

4.2.11 Move truck to position wheel flanges against south rails. ______

4.2.13 Perform post-test instrumentation verification in accordance with Procedure PKRG-3200. ______

4.2.17 Remove truck from MSU and replace with next truck in accordance with Procedure PKRG-4110. ______

4.2.18 Visually inspect truck in accordance with Procedure PKRG-2100. ______

Truck Identification ______________ Bolster Serial No. ________ Date ________

Testing was performed in compliance with Procedure PKRG-4100 and all required documentation has been completed.

____

Quality Control Inspector

APPENDIX D

QUASI-STATIC DETAILED TEST LOG

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN001	4-36"	Stroke Control± 5"	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN002	4-36"	Stroke Control± 5"	0.25Hz	Vertical	16S	A,B,C,D
TRIP_RN003	4-36"	Stroke Control± 1.0"	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN004	4-36"	Stroke Control± 1.0"	0.25Hz	Vertical	16S	A,B,C,D
TRIP_RN005	4-36"	Stroke Control± C.P.	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN006	4-36"	Stroke Control± C.P.	0.25Hz	Vertical	16S	A,B,C,D
TRIP_RN007	4-36"	Stroke Control± 5"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN008	4-36"	Stroke Control± 5"	0.25Hz	Roll	16S	E,F,G,H
TRIP_RN009	4-36"	Stroke Control± 1.0"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN010	4-36"	Stroke Control± 1.0"	0.25Hz	Roll	16S	E,F,G,H
TRIP_RN011	4-36"	Stroke Control± 1.5"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN012	4-36"	Stroke Control± 1.5"	0.25Hz	Roll	16S	E,F,G,H
TRIP_RN013	4-36"	Stroke Control± 2.0"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN014	4-36"	Stroke Control± 2.0"	0.25Hz	Roll	40S	E,F,G,H
TRIP_RN015	4-36"	Stroke Control± 2.0"	0.25Hz	Roll	40s	E,F,G,H
TRIP_RN016	4-36"	Force Control± 10 Kips	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN017	4-36"	Force Control± 10 Kips	0.25Hz	Lat. North	16S	I,J,K,L

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION CONTINUED

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN018	4-36"	Force Control±H.L.	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN019	4-36"	Force Control±H.L.	0.25Hz	Lat. North	16S	I,J,K,L
TRIP_RN020	4-36"	Force Control±S.L.	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN021	4-36"	Force Control±S.L.	0.25Hz	Lat. North	16S	I,J,K,L
TRIP_RN022	4-36"	Force Control±10 Kips	0.1Hz	Lat. South	40s	I,J,K,L
TRIP_RN023	4-36"	Force Control±10 Kips	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN024	4-36"	Force Control±H.L.	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN025	4-36"	Force Control±H.L.	0.25Hz	Lat. South	416	I,J,K,L
TRIP_RN026	4-36"	Force Control±S.L.	0.1Hz	Lat. South	40s	I,J,K,L
TRIP_RN027	4-36"	Force Control±S.L.	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN028	4-36"	Force Control±10 Kips	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN029	4-36"	Force Control±10 Kips	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN030	4-36"	Force Control±H.L.	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN031	4-36"	Force Control±H.L.	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN032	4-36"	Force Control±S.L.	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN033	4-36"	Force Control±S.L.	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN034	4-36"	Force Control±10 Kips	0.1Hz	Lat. South	40S	I,J,K,L

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION CONTINUED

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN035	4-36"	Force Control- 10 Kips	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN036	4-36"	Force Control- H.L.	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN037	4-36"	Force Control- H.L.	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN038	4-36"	Force Control- S.L.	0.1Hz	Lat. South	40s	I,J,K,L
TRIP_RN039	4-36"	Force Control- S.L.	0.25Hz	Lat. South	16S	I,J,K,L
TRIP_RN040	3-36"	Stroke Control- 0.5"	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN041	3-36"	Stroke Control- 0.5"	0.25Hz	Vertical	16S	A,B,C,D
TRIP_RN042	3-36"	Stroke Control- 2.0"	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN043	3-36"	Stroke Control- 2.0"	0.25Hz	Vertical	16S	A,B,C,D
TRIP_RN044	3-36"	Stroke Control- 1.0"	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN045	4-36"	Stroke Control- 1.0"	0.25Hz	Vertical	16s	A,B,C,D
TRIP_RN046	4-36"	Stroke Control- C.P.	0.1Hz	Vertical	40S	A,B,C,D
TRIP_RN047	4-36"	Stroke Control- C.P.	0.25Hz	Vertical	416	A,B,C,D
TRIP_RN048	4-36"	Stroke Control- 0.5"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN049	4-36"	Stroke Control- 0.5"	0.25Hz	Roll	16s	E,F,G,H
TRIP_RN050	4-36"	Stroke Control- 1.0"	0.1Hz	Roll	40S	E,F,G,H
TRIP_RN051	4-36"	Stroke Control- 1.0"	0.25Hz	Roll	16s	E,F,G,H

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION CONTINUED

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN052	4-36"	Stroke Control± 1.5"	0.1Hz	Roll	40S	E,F,G,H
TRIP_RN053	4-36"	Stroke Control± 1.5"	0.25Hz	Roll	16s	E,F,G,H
TRIP_RN054	4-36"	Stroke Control± 2.0"	0.1Hz	Roll	40S	E,F,G,H
TRIP_RN055	4-36"	Stroke Control± 2.0"	0.25Hz	Roll	16s	E,F,G,H
TRIP_RN056	4-38"	Stroke Control± 0.5"	0.1Hz	Vertical	40S	A,B,C,D
TRIP_RN057	4-38"	Stroke Control± 0.5"	0.25Hz	Vertical	16s	A,B,C,D
TRIP_RN058	4-38"	Stroke Control± 1.0"	0.1Hz	Vertical	40S	A,B,C,D
TRIP_RN059	4-38"	Stroke Control± 1.0"	0.25Hz	Vertical	16s	A,B,C,D
TRIP_RN060	4-38"	Stroke Control± C.P.	0.1Hz	Vertical	40s	A,B,C,D
TRIP_RN061	4-38"	Stroke Control± C.P.	0.25Hz	Vertical	16S	A,B,C,D
TRIP_RN062	3-38"	Stroke Control± 0.5"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN063	3-38"	Stroke Control± 0.5"	0.25Hz	Roll	16S	E,F,G,H
TRIP_RN064	3-38"	Stroke Control± 1.0"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN065	3-38"	Stroke Control± 1.0"	0.25Hz	Roll	16S	E,F,G,H
TRIP_RN066	3-38"	Stroke Control± 1.5"	0.1Hz	Roll	40s	E,F,G,H
TRIP_RN067	3-38"	Stroke Control± 1.5"	0.25Hz	Roll	16s	E,F,G,H
TRIP_RN068	3-38"	Stroke Control± 2.0"	0.1Hz	Roll	40S	E,F,G,H

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION CONTINUED

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN069	3-38"	Stroke Control- 2.0"	0.25Hz	Roll	416	E,F,G,H
TRIP_RN070	3-38"	Force Control- 10 Kips	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN071	3-38"	Force Control- 10 Kips	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN072	3-38"	Force Control- H.L.	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN073	3-38"	Force Control- H.L.	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN074	3-38"	Force Control- S.L.	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN075	3-38"	Force Control- S.L.	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN076	3-38"	Force Control- 10 Kips	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN077	3-38"	Force Control- 10 Kips	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN078	3-38"	Force Control- H.L.	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN079	3-38"	Force Control- H.L.	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN080	3-38"	Force Control- S.L.	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN081	3-38"	Force Control- S.L.	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN082	4-38"	Force Control- 10 Kips	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN083	4-38"	Force Control- 10 Kips	0.25Hz	Lat. North	16S	I,J,K,L
TRIP_RN084	4-38"	Force Control- H.L.	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN085	4-38"	Force Control- H.L.	0.25Hz	Lat. North	16S	I,J,K,L

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION CONTINUED

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN086	4-38"	Force Control± S.L.	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN087	4-38"	Force Control± S.L.	0.25Hz	Lat. North	16S	I,J,K,L
TRIP_RN088	4-38"	Force Control± 10 Kips	0.1Hz	Lat. South	40s	I,J,K,L
TRIP_RN089	4-38"	Force Control± 10 Kips	0.25Hz	Roll	16s	E,F,G,H
TRIP_RN090	4-38"	Force Control± H.L.	0.1Hz	Roll	40S	E,F,G,H
TRIP_RN091	4-38"	Force Control± H.L.	0.25Hz	Roll	416	E,F,G,H
TRIP_RN092	4-38"	Force Control± S.L.	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN093	4-38"	Force Control± S.L.	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN094	4-38"	Stroke Control± 0.5"	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN095	4-38"	Stroke Control± 0.5"	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN096	4-38"	Stroke Control± 1.0"	0.1Hz	Lat. North	40S	I,J,K,L
TRIP_RN097	4-38"	Stroke Control± 1.0"	0.25Hz	Lat. North	16s	I,J,K,L
TRIP_RN098	4-38"	Stroke Control± C.P.	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN099	4-38	Stroke Control± C.P.	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN100	4-38"	Stroke Control± 0.5"	0.1Hz	Lat. South	40S	I,J,K,L
TRIP_RN101	4-38"	Stroke Control± 0.5"	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN102	4-38"	Stroke Control± 1.0"	0.1Hz	Lat. South	40S	I,J,K,L

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

TRIPLET CARS

QUASI-STATIC TRUCK CHARACTERIZATION CONTINUED

Run No.	Truck No.	Description	Freq	Test	Burst	Data Reduction Option
TRIP_RN103	4-38"	Stroke Control= 1.0"	0.25Hz	Lat. South	16s	I,J,K,L
TRIP_RN104	4-38"	Stroke Control= 1.5"	0.1Hz	Lat. North	40s	I,J,K,L
TRIP_RN105	4-38"	Stroke Control= 1.5"	0.25Hz	Roll	16s	I,J,K,L
TRIP_RN106	4-38"	Stroke Control= 2.0"	0.1Hz	Roll	40s	I,J,K,L
TRIP_RN107	4-38"	Stroke Control= 2.0"	0.25Hz	Roll	16s	I,J,K,L

C.P. = FULL SPRING COMPRESSION
S.L. = 1/5 VERTICAL STATIC LOAD
H.L. = (S.L. - 10 KIPS / 2) + 10 KIPS

APPENDIX E

36" TRIPLET CAR (AT&SF 90006) MODAL RESPONSE TEST PROCEDURE
AND
38" TRIPLET CAR (AT&SF 90004) MODAL RESPONSE TEST PROCEDURE

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-5100-TRIPLET CARS-36"
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 three commercial span bolster (Triplet) Cars.

1.1 INDEX

1.2 EQUIPMENT LIST

a.	2 ea.	77 KIP Actuators
b.	2 ea.	Load Cell, 0 - 100 kips Range
c.	8 ea.	Instrumented Rails, 0 - 100 kips Vertical Range 0 - 60 kips Lateral Range
d.	2 ea.	Displacement Transducer (LVDT), +/- 5" Range
e.	2 ea.	String Pot, +/- 4" Range
f.	1 ea.	Strong Pot, +/- 1" Range
g.	6 ea.	String Pot, +/- 5" Range
h.	32 ea.	Accelerometer, +/- 5G Range
i.	1 ea.	HP 9000, Model 360 Computer System
j.	1 ea.	HP 6944a Multi-Programmer
k.	As needed	Safety Equipment as required by Rail Dynamics Lab (RDL)
l.	1 ea.	Attachment Fixture
m.	1 ea.	HP 3325B Function Generator

n.	1 ea.	MTS Control System
o.	61 ea.	Signal Conditioners
p.	61 ea.	Filters (0 - 50 Hz)

1.3 FIGURE LIST

Figure 2-1 Test Car Overview

Figure 2-2 Vertical Test Configuration

Figure 3-2 Lateral Test Configuration

1.4 ATTACHMENT LIST

(1) Instrumented Rail Placement

(2) Bolster Instrumentation Placement

(3) Car Body Accelerometer Placement

(4) Car Body To Ground Displacement Measurement Placement

(5) Test Configuration Data Sheets (6 Sheets)

(6) Applicable PSD's

1.6 REFERENCE LIST

PKRG-2100 Truck Inspection Procedure

PKRG-2200 Car Inspection Procedure

PKRG-3100 Instrumentation Installation Procedure

PKRG-3200 Instrumentation Verification Procedure

M1001 Manual of Standards and Recommend Practices, C, Part II, Volume 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, Triplet Cars Testing

PKRG-5110 Triplet Cars Modal Test Car Attachment Fixture Installation Procedure

PKRG-5120-Triplet Cars, Modal Response Test Fixture Removal

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 PROCEDURE

2.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Install car attachment fixtures per PKRG-5110-Triplet Cars, Attachment Fixture Installation Procedure.	________

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.

2.1.2	Move test car onto the RDL Mini-shaker as illustrated in Figure 2-1. Comply with TTC Operating Rules.	________

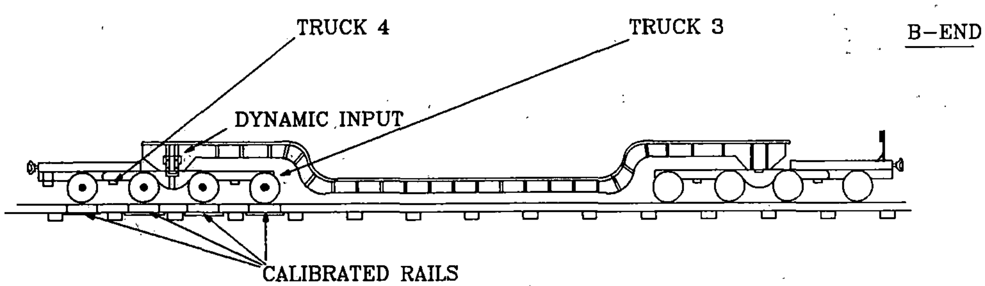


Figure 2-1 Test Car Overview

2.2 Load 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 Test Configuration Data Sheets (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	
2.2.3	Refer to Instrumented Rail Placement (Attachment 1) for instrumentation location.	
2.2.4	Zero the load cells by adjusting the zero knob on the north and south MTS 443 DC conditioners, (+/- 10 mV).	
2.2.5	Print checkout values and label Pre-test Load Cell Zeros.	
2.2.6	RCAL the load cells by pressing the CAL button on the DC conditioners and compare the values with the Test Configuration Data Sheets (Attachment 5), tolerance should be +/- 5 percent.	
2.2.7	Print checkout values and label Pre-test Load Cell RCAL.	
2.2.8	Quality verify load cell calibration completed.	________

2.3 LVDT Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	This calibration procedure is for all LVDT Channels.	
2.3.2	Refer to procedure PKRG-3100 for completing the Test Configuration Data Sheets (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	
2.3.3	Zero all LVDT's using the knob labeled ZERO on the AC conditioner located inside the MTS443 hydraulic control system +/- 10 mV.	
2.3.4	Print calibration values and label Pre-test LVDT Zeros.	
2.3.5	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 Sheets (Attachment 5).	

NOTE

If output does not match, adjust gage factor knob on the AC conditioner and repeat Step 2.3.4.

2.3.6 Quality verify LVDT'S calibration completed.

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 Test Configuration Data Sheets (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	
2.4.5	Refer to the Test Configuration for Data Sheets (Attachment 5) for instrumentation 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 Sheets (Attachment 5). Ensure CAL knob is positioned to + 100.

2.4.11 Place CAL knob to OPR position.

2.4.12 Place B & F calibration controller into Mode O record data for 60 seconds. Label Pre-test Instrumented Rail Zero.

2.4.13 Place B & F Calibration Controller into Mode I, record data for 60 seconds. Label Pre-test Instrumented Rail CALS.

2.4.14 Place B & 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 2-4.

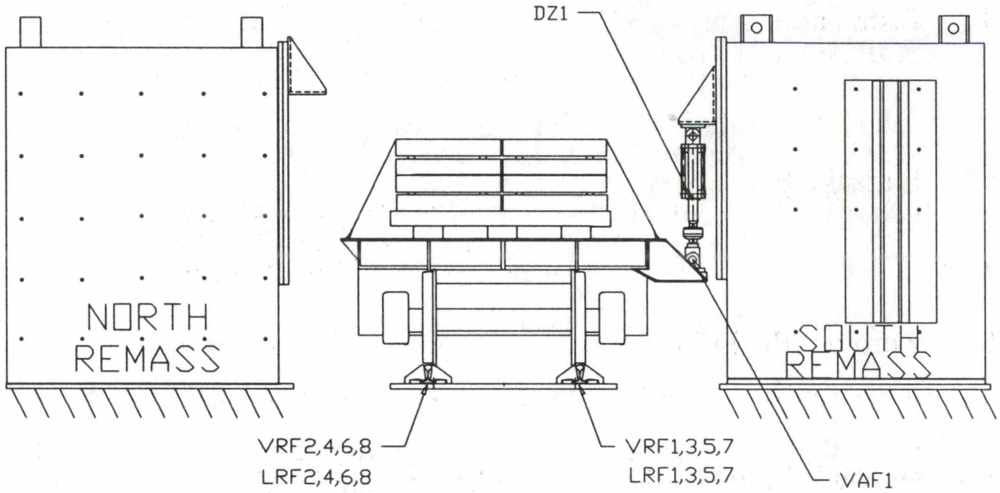


Figure 2-4 Vertical Test Configuration

2.4.17 Quality Verify instrumented rail calibration completed. ______

2.5 Accelerometer Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.5.1	This calibration procedure for all PKRG accelerometer channels.	
2.5.2	Refer to procedure PKRG-3100 for completing the Test Configuration Data Sheets (Attachment 5), PKRG-3100 Section 5.1 through 5.8 (Page 1-2).	

2.5.3 Refer to Car Body Accelerometer Placement (Attachment 3) for instrumentation location.

2.5.4 Install accelerometer 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 Sheets (Attachment 5). 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 position and adjust the amplifier course and fine gain, adjust for the output to correspond to the system EU/VOLT section and the Test Configuration Data Sheets (Attachment 5).

2.5.14 Quality verify accelerometer calibration completed. ________

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 Test Configuration Data Sheets (Attachment 5), PKRG-3100 Section 5.1 through 5.8 (Page 1-2).	
2.6.3	Refer to Car Body to Ground Displacement Measurement Placement (Attachment 4) 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 Test Configuration Data Sheets (Attachment 5). 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 Pre-test Instrumented Rail Zero.

2.6.12 Place B & F Calibration Controller into Mode I, record data for 60 seconds. Label Pre-test Instrumented Rail CALS.

2.6.13 Place B & 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. ________

3.0 MODAL TEST

3.1 Vertical Twist and Roll 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.

B. At the Data Acquisition System load the function generator with the D_Sweep_A Program and set the following parameters:

1. Load (kip)	15 kip
2. Displacement (stroke)	N/A
3. Freq. Range (Hz)	.5-10 Hz
a. Dwell Points (cycles/step)	10
b. Frequency Steps (Hz)	.1
c. Constant G	N/A
4. Sweep Duration (sec)	320

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's) Attachment 6 for test data. Examine for pitch and bounce resonant frequencies.

3.1.5 Repeat Steps 3.1.1 through 3.1.4 with force control settings 20 kip and 25 kip, if it is determined safe after previous test.

3.1.5.1 Quality verify test parameter are satisfied for:

15 kip	______
20 kip	______
25 kip	______

3.2 Flexible Body Vertical Twist Modal Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Disconnect all string pots.	
3.2.2	Setup computer and control system for Flexible Body Vertical Modal Test.	

A. At the 443 Control System Panel, set MODE switch to the positive position.
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" max
3. Freq. Range (Hz)	3-30 Hz
a. Dwell Points (cycles/step)	N/A
b. Frequency Steps (Hz)	N/A
c. Constant G	.10
4. Sweep Duration (sec)	300

3.2.3 Start data acquisition and control program to begin test.

3.2.4 Save file when test stops.

3.2.5 Calculate a PSD's (see Attachment 6) for test data. Examine for vertical bending (first, second and third if possible) frequencies.

3.2.6 Quality verify acceptable constant G level at .10. ______

3.2.7 Repeat Steps 3.2.3 through 3.2.6 for constant G levels of .20 and .30 at 5 - 30 Hz, .50 g at 10 - 30 Hz and .50g at 10 - 30 Hz, if it is determined safe after previous test.

3.2.7.1 Quality verify acceptable constant G level at:

20	______
.30	______
.40 at 05-39 Hz	______
.50 at 8-30 Hz	______

3.3 Rigid Body Lateral Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL

3.3.1 Setup hydraulic actuators for rigid and flexible body lateral test configuration as shown in Figure 3-2. Reconnect string pots.

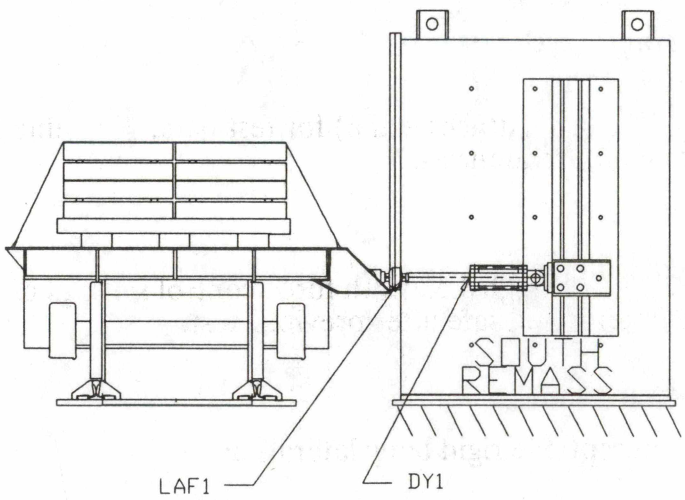


Figure 3-2 Lateral Test Configuration

3.3.2 Ensure all instrumentation is connected for lateral modal testing. ______

3.3.3 At the 443 Control System Panel, Ensure the top MODE switch is in the positive position.

3.3.4 At the HP 360 data acquisition and control computer set the following parameters:

1. Load (kip)	15 kip
2. Displacement (stroke)	N/A
3. Freq. Range (Hz)	.5-10 Hz
a. Dwell Points (cycles/step)	10
b. Frequency Steps (Hz)	.1
c. Constant G	N/A
4. Sweep Duration (sec)	320

3.3.5 Start data acquisition and control program to begin test.

3.3.6 Save file when test stops.

3.3.7 Calculate a PSD's (see Attacnment 6) for test data. Examine for lateral rigid body resonant frequencies.

3.3.8 Repeat Steps 3.5.4 through 3.5.7 with force control settings of 20 kip and 25 kip, if it is determined safe after previous test.

3.3.9 Quality verify acceptable rigid body laterals at:

15 kip ______
20 kip ______
25 kip ______
30 kip ______

3.4 Flexible Body Lateral Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.4.1	Disconnect all string pots.	_____
3.4.2	Setup the HP 360 Data Acquisition and Control Computer for Flexible Body Twist Modal Test. A. At the Control System Panel, keep MODE switch in positive position. B. At the HP 360 Data Acquisition and Control Panel Computer keep the same parameters as the previous test.	
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 6) for test data. Examine for Twist (first, second and third if possible) frequencies.	
3.4.6	Repeat Steps 3.2.3 through 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	Quality verify acceptable constant G levels at: .20 .30 .40 at 5-30hz	 _____ _____ _____

4.0 TEST TEAR-DOWN

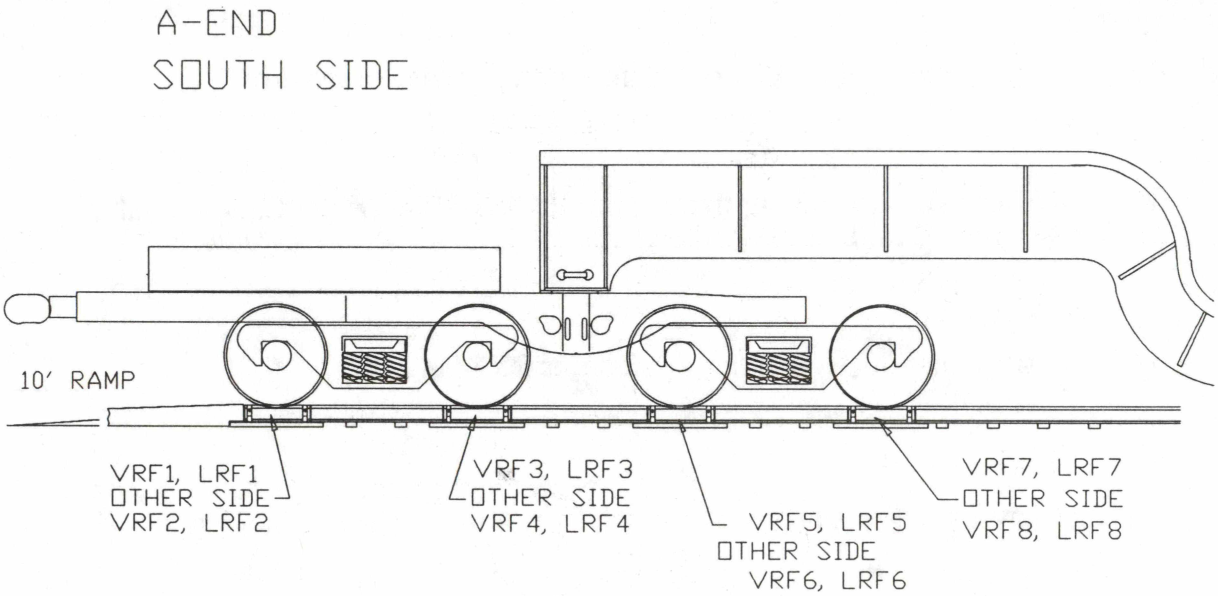
TASK NUMBER	PROCEDURE	QA INITIAL
4.0.1	Remove instrumentation from car.	
4.0.2	Remove car from MSU following TTC operating procedures.	
4.0.3	Remove car attachment fixtures per PKRG-5120-Triplet Cars, Modal Response Test Fixture Removal.	_______
4.0.4	Perform car inspection per Procedures PKRG-2200.	_______

5.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
5.0.1	Quality verification	_______
5.0.2	Quality verified that PKRG-5100 is complete and closed.	_______
5.0.3	Authorized QA signature.	_______________

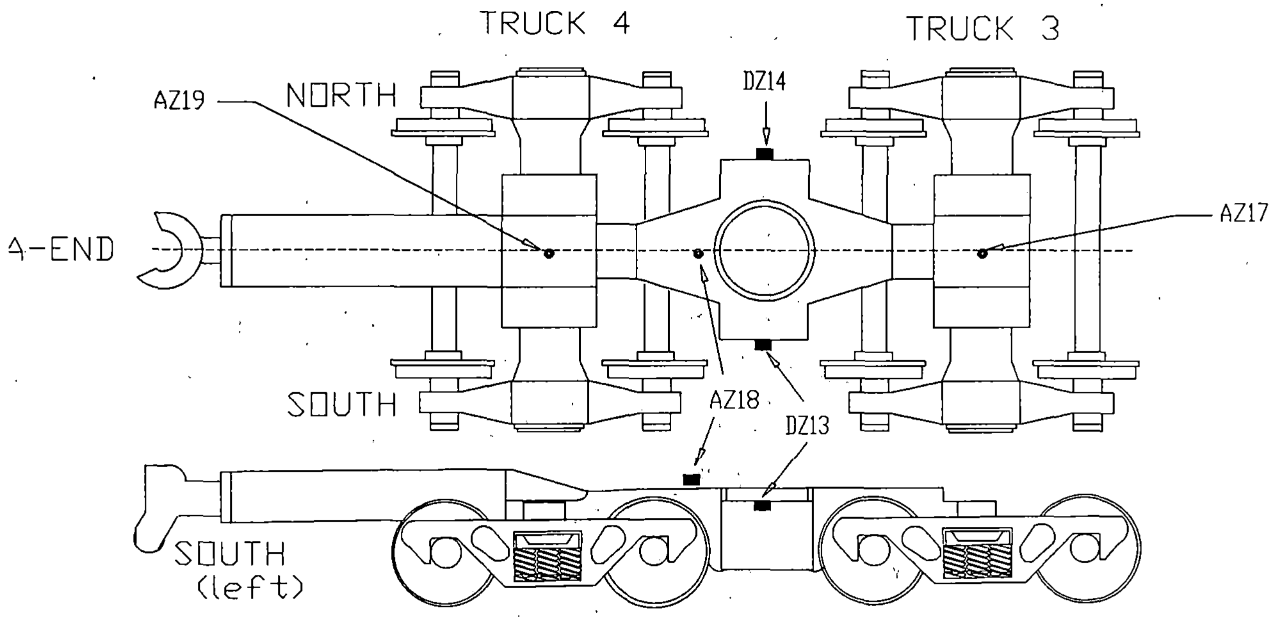
ATTACHMENT 1

INSTRUMENTED RAIL PLACEMENT



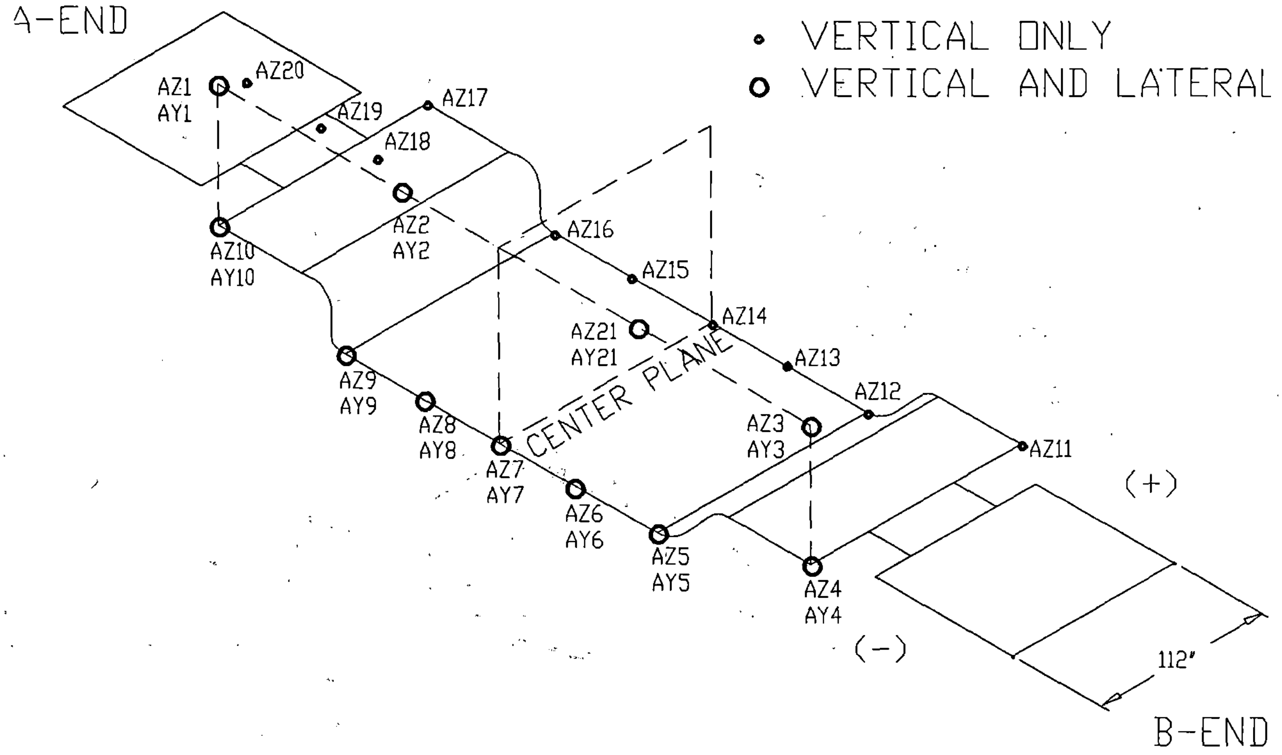
ATTACHMENT 2

BOLSTER INSTRUMENTATION PLACEMENT



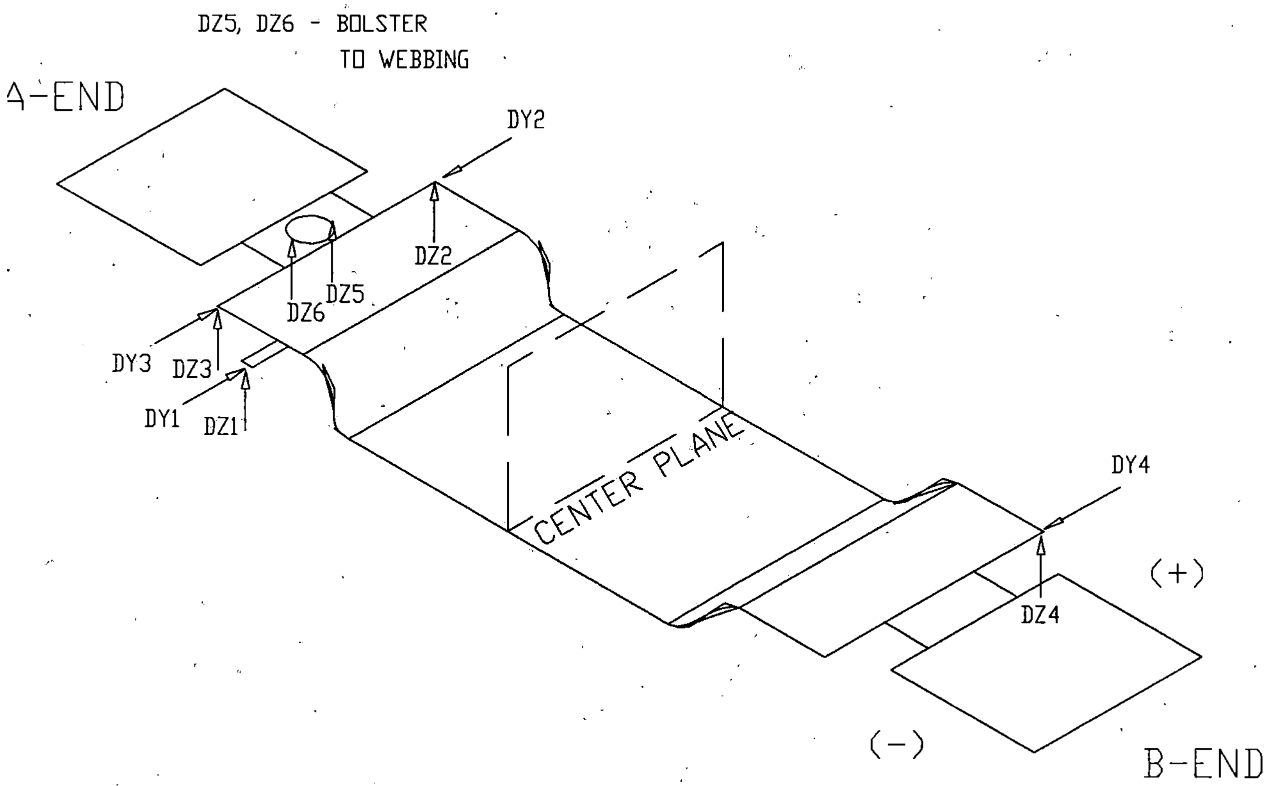
ATTACHMENT 3

CAR BODY ACCELEROMETER PLACEMENT



ATTACHMENT 4

CAR BODY TO GROUND DISPLACEMENT MEASUREMENT PLACEMENT



ATTACHMENT 5

TEST CONFIGURATION DATA SHEETS (6 Sheets)

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 1 OF 6

TEST NAME TRIPLET CAR MODAL 36" DATE 7-26-90 W.O. 87593 LOC. RDL-MSU
INSTR. ENGR./TECH. COOKSEY/JOHNS TEST ENGR. BIER QA
SOFTWARE/VERSION ~~xGNRL_AQ8A MIF TIPMD2~~ RECORDER I.D. NO. HP360 SET-UP FILE GNRL_MIF_D
SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP6944A

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
J 50	0	A 1	AL01	MTS load cell	14781	.1158614 v/kip	X= Y= Z=	23 JAN 91	57 X 25	0	1	174.66 K	43.5 K / 5.04 V	DEC 90		30	1	DEC 90		8.631 kip/v	KIP	1-1		ACTUATOR FORCE
J 52	1	A 3	AD01	MTS LVDT	14991	2 v/in	X= Y= Z=	23 JAN 91	58 X 26	0	1	N/A	1 IN / 2 V	DEC 90		30	1	DEC 90		.5 IN/V	INCH	1-2		ACTUATOR DISPLACEMENT
J 33	2	A 5	VRF1	AAR	1	73.774 mv/kip	X= Y= Z=	5 JAN 91	1 W 33	15	1K	499 K	73.942 / 5.455 V	DEC 90	1	30	1	DEC 90		13.555 kip/v	KIP			VERTICAL RAIL FORCE LD-LF-TRK-4-A-END-S-AX8
J 35	3	A 7	VRF2	AAR	2	71.681 mv/kip	X= Y= Z=	5 JAN 91	2 W 34	15	1K	499 K	73.310 / 5.470 V	DEC 90	2	30	1	DEC 90		13.951 kip/v	KIP			VERTICAL RAIL FORCE LD-RT-TRK-4-A-END-AX8
J 37	4	A 9	VRF3	AAR	3	71.559 mv/kip	X= Y= Z=	5 JAN 91	3 W 35	15	1K	499 K	76.580 / 5.475 V	DEC 90	3	30	1	DEC 90		13.974 kip/v	KIP			VERTICAL RAIL FORCE TR-LF-TRK-4-A-END-S-AX7
J 39	5	A 11	VRF4	AAR	4	68.413 mv/kip	X= Y= Z=	5 JAN 91	4 W 36	15	1K	499 K	79.956 / 5.470 V	DEC 90	4	30	1	DEC 90		14.617 kip/v	KIP			VERTICAL RAIL FORCE TR-RT-TRK-4-A-END-N-AX7
J 34	0	A 13	LRF1	AAR	1	171.257 mv/kip	X= Y= Z=	5 JAN 91	5 W 37	15	1K	499 K	31.94 / 5.475 V	DEC 90	5	30	1	DEC 90		5.839 kip/v	KIP			LATERAL RAIL FORCE LD-AX-TRK-4-A-END-S-AX8
J 36	7	A 15	LRF2	AAR	2	167.321 mv/kip	X= Y= Z=	5 JAN 91	6 W 38	15	1K	499 K	32.751 / 5.480 V	DEC 90	6	30	1	DEC 90		5.977 kip/v	KIP			LATERAL RAIL FORCE LD-RT-TRK-4-A-END-N-AX8
J 38	8	A 17	LRF3	AAR	3	183.637 mv/kip	X= Y= Z=	5 JAN 91	7 W 39	15	1K	499 K	29.841 / 5.480 V	DEC 90	7	30	1	DEC 90		5.446 kip/v	KIP			LATERAL RAIL FORCE TR-LF-TRK-4-A-END-S-AX7
J 40	9	A 19	LRF4	AAR	4	165.574 mv/kip	X= Y= Z=	5 JAN 91	8 W 40	15	1K	499 K	33.127 / 5.485 V	DEC 90	8	30	1	DEC 90		6.040 kip/v	KIP			LATERAL RAIL FORCE TR-RT-TRK-4-A-END-N-AX7

NOTES:

FILE: G:\CADDWG\TMOD201.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 2 OF ____

TEST NAME TRIPLET CAR MODAL 36" DATE ________ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. COOKSEY/JOHNS TEST ENGR. BIER QA ________

SOFTWARE/VERSION ~~xGNRL_AQ8A MIF_TIPMD2~~ RECORDER I.D. NO. HP360 SET-UP FILE GNRL_MIF_D

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP6944A

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
J 41	10	A 33	VRF5	AAR	5	76.576 mv/kip	X= Y= Z=	5 JAN 91	9 W 41	15	1K	499 K	71.367 5.465 V	DEC 90	9	30	1	DEC 90		13.059 kip/v	KIP			VERTICAL RAIL FORCE LD-LF-TRK3-AEND-N-AX6
J 43	11	A 35	VRF6	AAR	6	78.419 mv/kip	X= Y= Z=	5 JAN 91	10 W 42	15	1K	499	69.881 5.480 V	DEC 90	10	30	1	DEC 90		12.752 kip/v	KIP			VERTICAL RAIL FORCE LD-RT-TRK3-AEND-N-AX6
J 45	12	A 37	VRF7	AAR	7	79.014 mv/kip	X= Y= Z=	5 JAN 91	11 W 43	15	1K	499 K	68.912 5.450 V	DEC 90	11	30	1	DEC 90		12.656 kip/v	KIP			VERTICAL RAIL FORCE TR-LF-TRK3-AEND-S-AX5
J 47	13	A 39	VRF8	AAR	8	73.126 mv/kip	X= Y= Z=	5 JAN 91	12 W 44	15	1K	499 K	74.597 5.460 V	DEC 90	12	30	1	DEC 90		13.675 kip/v	KIP			VERTICAL RAIL FORCE TR-RT-TRK3-AEND-N-AX5
J 42	14	A 41	LRF5	AAR	5	173.43 mv/kip	X= Y= Z=	5 JAN 91	13 W 45	15	1K	499 K	31.511 5.465 V	DEC 90	13	30	1	DEC 90		5.766 kip/v	KIP			LATERAL RAIL FORCE LD-LF-TRK3-AEND-S-AX6
J 44	15	A 43	LRF6	AAR	6	145.77 mv/kip	X= Y= Z=	5 JAN 91	14 W 46	15	1K	499 K	37.456 5.460 V	DEC 90	14	30	1	DEC 90		6.86 kip/v	KIP			LATERAL RAIL FORCE LD-RT-TRK3-AEND-N-AX6
J 46	16	A 45	LRF7	AAR	7	156.99 mv/kip	X= Y= Z=	5 JAN 91	15 W 47	15	1K	499 K	34.65 5.445 V	DEC 90	15	30	1	DEC 90		6.37 kip/v	KIP			LATERAL RAIL FORCE TR-LF-TRK3-AEND-S-AX5
J 48	17	A 47	LRF8	AAR	8	173.43 mv/kip	X= Y= Z=	5 JAN 91	16 W 48	15	1K	499 K	31.281 5.430 V	DEC 90	16	30	1	DEC 90		5.766 kip/v	KIP			LATERAL RAIL FORCE TR-RT-TRK3-AEND-N-AX5
J 83	18	A 49	AZ01	END	KR88	12.9 mv/G	X= Y= Z=	25 JAN 91	17 W 49	10	100	59.88 K	3.244 G 4.185 V	DEC 90	17	30	1	DEC 90		.775 G/v	G	3-5		VERTICAL CARBODY LOAD AEND UPPER LF CORNER
J 84	19	A 51	AY01	END	MY28	11.67 mv/G	X= Y= Z=	25 JAN 91	18 W 50	10	100	59.88 K	3.565 G 4.155 V	DEC 90	18	30	1	DEC 90		.857 G/v	G	3-6		LATERAL CARBODY LOAD AEND UPPER LF CORNER

NOTES:

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PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 3 OF ____

TEST NAME TRIPLET CAR MODAL 36" DATE ______ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. COOKSEY/JOHNS TEST ENGR. BIER QA ______

SOFTWARE/VERSION ~~xGNRL_AQ8A_MIF_TIPMD2~~ RECORDER I.D. NO. HP360 SET-UP FILE GNRL_MIF_D

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP6944A

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
J 81	20	A 53	AZ02	END.	JQ 54	24.69 mV/G	X= 702 Y= 56 Z= 127	24 JAN 91	19 V 51	10	50	59.88 K	2.575 G 3.180 V	DEC 90	19	30	1	DEC 90		.810 G/v	G			VERTICAL CARBODY (LOAD) LF EDGE WEST OF CTR/LN
J 82	21	A 55	AY02	END.	RH 83	20.92 mV/G	X= 702 Y= 56 Z= 127	25 JAN 91	20 V 52	10	50	59.88	2.533 G 2.655 V	DEC 90	20	30	1	DEC 90		.956 G/v	G			LATERAL CARBODY (LOAD) LF EDGE WEST OF CTR/LN
J 79	22	A 57	AZ03	END.	GT 42	28.8 mV/G	X= 144 Y= 56 Z= 127	24 JAN 91	21 V 53	10	50	59.88 K	2.132 G 3.070 V	DEC 90	21	30	1	DEC 90		.694 G/v	G	3-7		VERTICAL CARBODY (LOAD) B-END UPPER CORNER
J 80	23	A 59	AY03	END.	HF 67	23.82 mV/G	X= 144 Y= 56 Z= 127	24 JAN 91	22 V 54	10	50	59.88 K	2.485 G 2.960 V	DEC 90	22	30	1	DEC 90		.840 G/v	G	3-8		LATERAL CARBODY (LOAD) B-END UPPER CORNER
J 65	24	A 61	AZ04	END.	JQ 78	24.17 mV/G	X= 144 Y= 56 Z= 127	24 JAN 91	23 V 55	10	50	59.88 K	2.703 G 3.26 V	DEC 90	23	30	1	DEC 90		.827 G/v	G	3-1		VERTICAL CARBODY B-END LEFT LOWER CORNER EDGE
J 66	25	A 63	AY04	END.	JQ 66	19.36 mV/G	X= 144 Y= 56 Z= 127	24 JAN 91	24 V 56	10	50	59.88 K	2.789 G 2.705 V	DEC 90	24	30	1	DEC 90		1.033 G/v	G	3-2		LATERAL CARBODY B-END LEFT LOWER CARBODY EDGE
J 67	26	A 35	AZ05	END.	ML 36	12.23 mV/G	X= 331 Y= 56 Z= 9	25 JAN 91	25 V 57	10	100	59.88 K	3.459 G 4.22 V	DEC 90	25	30	1	DEC 90		.818 G/v	G			VERTICAL CARBODY B-END LEFT LOWER EDGE (2)
J 68	27	A 37	AY05	END.	PA 16	11.14 mV/G	X= 331 Y= 56 Z= 9	25 JAN 91	26 V 58	10	100	59.88 K	3.793 G 4.225 V	DEC 90	26	30	1	DEC 90		.898 G/v	G			LATERAL CARBODY B-END LEFT LOWER EDGE (2)
J 97	28	A 39	AZ06	END	RH 68	20.06 mV/G	X= 424 Y= 56 Z= 9	25 JAN 91	27 V 59	10	50	59.88 K	2.637 G 2.635 V	DEC 90	27	30	1	DEC 90		.997 G/v	G	1-6		VERTICAL CARBODY B-END LEFT LOWER EDGE (3)
J 98	29	A 41	AY06	END	MY 22	11.92 mV/G	X= 424 Y= 56 Z= 9	24 JAN 91	28 V 60	10	100	59.88 K	3.536 G 4.22 V	DEC 90	28	30	1	DEC 90		.839 G/v	G	1-7		LATERAL CARBODY B-END LEFT LOWER EDGE (3)

NOTES:

FILE: G:\CADDWG\TMOD203.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME TRIPLET CAR MODAL 36" DATE ________ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. COOKSEY/JOHNS TEST ENGR. BIER QA ________

SOFTWARE/VERSION ~~xGNRL_AQ8A_MIF_TIPMD2~~ RECORDER I.D. NO. HP360 SET-UP FILE GNRL_MIF_D

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP6944A

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
J 99	30	B 43	AZ07	END.	TG 93	10.09 mv/G	X= 702 Y= 56 Z= 9	15 SEP 90	29 W 61	10	100	59.88 K	4.197 G 4.22 V	DEC 90	29	30	1	DEC 90		.991 G/v	G			VERTICAL CARBODY CTR/LN LEFT LOWER EDGE
J 100	31	B 45	AY07	END.	RW 62	9.714 mv/G	X= 516 Y= 56 Z= 9	23 JAN 91	30 W 62	10	100	59.88	4.344 G 4.22 V	DEC 90	30	30	1	DEC 90		1.029 G/v	G			LATERAL CARBODY B-END LEFT LOWER EDGE
J 101	32	B 47	AZ08	END.	FP 90	17.24 mv/G	X= 609 Y= 56 Z= 9	24 JAN 91	31 W 63	10	50	59.88 K	2.695 G 2.68 V	DEC 90	31	30	1	DEC 90		1.16 G/v	G	—		VERTICAL CARBODY B-END LEFT LOWER EDGE (4)
J 102	33	B 49	AY08	END.	FM 79	21.03 mv/G	X= 609 Y= 56 Z= 9	24 JAN 91	32 W 64	10	50	59.88 K	2.688 G 2.82 V	DEC 90	32	30	1	DEC 90		.951 G/v	G			LATERAL CARBODY B-END LEFT LOWER EDGE (4)
J 103	34	B 51	AZ09	END.	RW 99	9.27 mv/G	X= 702 Y= 56 Z= 9	20 JAN 91	33 X1	10	100	59.88 K	4.579 G 4.245 V	DEC 90	33	30	1	DEC 90		1.079 G/v	G			VERTICAL CARBODY B-END LEFT LOWER EDGE (5)
J 104	35	B 53	AY09	END.	EZ 49	18.63 mv/G	X= 702 Y= 56 Z= 9	24 JAN 91	34 X2	10	50	59.88 K	2.696 G 2.515 V	DEC 90	34	30	1	DEC 90		1.074 G/v	G			LATERAL CARBODY B-END LEFT LOWER EDGE (5)
J 105	36	B 55	AZ10	END.	MR 11	13.91 mv/G	X= 889 Y= 56 Z= 41	16 OCT 90	35 X3	10	100	59.88 K	3.775 G 5.250 V	DEC 90	35	30	1	DEC 90		.719 G/v	G	1-3		VERTICAL CARBODY A-END LEFT LOWER CORNER EDGE
J 106	37	B 57	AY10	END.	KR 29	12.82 mv/G	X= 889 Y= 56 Z= 41	19 JAN 91	36 X4	10	100	59.88 K	3.237 G 4.150	DEC 90	36	30	1	DEC 90		.780 G/v	G	1-4		LATERAL CARBODY A-END LEFT LOWER CORNER EDGE
J 69	38	B 59	AZ11	END	RW 21	9.314 mv/G	X= 144 Y= -56 Z= 41	20 JAN 91	37 X5	10	100	59.88 K	4.883 G 4.547 V	DEC 90	37	30	1	DEC 90		1.074 G/v	G	1-8		VERTICAL CARBODY B-END LOWER RIGHT CORNER EDGE
J 70	39	B 61	AZ12	END	RW 85	9.568 mv/G	X= 331 Y= -56 Z= 9	20 JAN 91	38 X6	10	100	59.88 K	4.581 G 4.384 V	DEC 90	38	30	1	DEC 90		1.045 G/v	G			VERTICAL CARBODY B-END LOWER RIGHT (2)

NOTES:

FILE: G:\CADDWG\TMOD204.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME TRIPLET CAR MODAL 36" DATE ________ W.O. 87593 LOC. RDL-MSU
INSTR. ENGR./TECH. COOKSEY/JOHNS TEST ENGR. BIER QA ________
SOFTWARE/VERSION ~~xGNRL_AQ8A MIF TIPMD2~~ RECORDER I.D. NO. HP360 SET-UP FILE GNRL_MIF_D
SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP6944A

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
J 71	40	C 33	AZ13	END.	NN 23	11.97 mv/G	X= 424 Y= -56 Z= 9	20 JAN 91	39 X7	10	100	59.88 K	3.520 G / 4.215 V	DEC 90	39	30	1	DEC 90		.835 G/v	G			VERTICAL CARBODY B-END LOWER RIGHT (3)
J 72	41	C 35	AZ14	END.	RW 19	9.47 mv/G	X= 516 Y= -56 Z= 9	24 JAN 91	40 X8	10	100	59.88	4.451 G / 4.215 V	DEC 90	40	30	1	DEC 90		1.056 G/v	G			VERTICAL CARBODY CTR/LN MIDDLE LOWER RIGHT
J 73	42	C 37	AZ15	END.	MR 84	9.318 mv/G	X= 604 Y= -56 Z= 9	20 JAN 91	41 X9	10	100	59.88 K	4.748 G / 4.245 V	DEC 90	41	30	1	DEC 90		1.073 G/v	G			VERTICAL CARBODY A-END LOWER EDGE RT (4)
J 74	43	C 39	AZ16	END.	NZ 07	8.633 mv/G	X= 702 Y= -56 Z= 9	20 JAN 91	42 X10	10	100	59.88 K	4.927 G / 4.255 V	DEC 90	42	30	1	DEC 90		1.158 G/v	G	3-3		VERTICAL CARBODY A-END LOWER EDGE RT (5)
J 75	44	C 41	AZ17	END.	MR 29	8.945 mv/G	X= 889 Y= -56 Z= 41	20 JAN 91	43 X11	10	100	59.88 K	4.729 G / 4.230 V	DEC 90	43	30	1	DEC 90		1.118 G/v	G	1-5		VERTICAL CARBODY A-END RIGHT CORNER
J 76	45	C 43	AZ18	END.	NF 15	12.87 mv/G	X= 795 Y= -12 Z= 41	20 JAN 91	44 X12	10	100	59.88 K	3.279 G / 4.220 V	DEC. 90	44	30	1	DEC 90		.777 G/v	G			VERT SPAN BLST TRAIL TRK-3 CTR PLATE
J 77	46	C 45	AZ19	END.	KY 10	12.23 mv/G	X= 901 Y= -12 Z= 31	19 JAN 91	45 X13	10	100	59.88 K	3.472 G / 4.245 V	DEC 90	45	30	1	DEC 90		.818 G/v	G			VERT SPAN BLST CTR PLATE CTR CARBODY
J 78	47	C 47	AZ20	END.	MG 10	9.346 mv/G	X= 961 Y= 0 Z= 41	20 JAN 91	46 X14	10	100	59.88 K	4.526 G / 4.230 V	DEC 90	46	30	1	DEC 90		1.070 G/v	G	3-4		VERT SPAN BLST CTR/PLATE LEAD TRK-4
J 79	48	C 49	AZ21	END	TG 91	12.34 mv/G	X= 500 Y= 56 Z= 127	21 JUN 91	47 X15	10	100	59.88 K	3.404 G / 4.20 V	DEC 90	47	30	1	DEC 90		.810 G/v	G			VERT CARBODY (LOAD) LF EDGE EAST OF CTR/LN
J 86	49	C 51	AY21	END	KE 52	12.46 mv/G	X= 500 Y= 56 Z= 127	19 JUN 91	48 X16	10	100	59.88 K	3.387 G / 4.22 V	DEC 90	48	30	1	DEC 90		.803 G/v	G			LATERAL CARBODY (LOAD) LF EDGE EAST OF CTR/LN

NOTES:

FILE: G:\CADDWG\TMOD205.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME TRIPLET CAR MODAL 36" DATE ________ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. COOKSEY/JOHNS TEST ENGR. BIER QA ________

SOFTWARE/VERSION ~~xGNRL_AQ8A MIF_TIPMD2~~ RECORDER I.D. NO. HP360 SET-UP FILE GNRL_MIF_D

SAMPLE RATE 256 ENCODER/DIGITIZER I.D. NO. HP6944A

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
J 53	50	C 53	DZ01	CELESCO	142.32	2 v/in	X= 889 Y= -56 Z= 41	24 JAN 91	49 X17	10	VAR	29.88 K	3.783 / 7.565 V	DEC 90	49	30	1	DEC 90		.500 IN/V	G	2-1		VERTICAL CARBODY A-END LOWER RT CORNER TO GND
J 62	51	C 55	DY01	CELESCO	144.45	2 v/in	X= 889 Y= -56 Z= 41	23 JAN 91	50 X18	10	VAR	29.88 K	3.85 IN / 7.700 V	DEC 90	50	30	1	DEC 90		.500 IN/V	G	2-2		LATERAL CARBODY A-END LOWER RT CORNER TO GND
J 55	52	C 57	DZ02	CELESCO	14233	2 v/in	X= 889 Y= 56 Z= 41	20 DEC 90	51 X19	10	VAR	29.88 K	3.85 IN / 7.705 V	DEC 90	51	30	1	DEC 90		.500 IN/V	G	2-3		VERTICAL CARBODY A-END LOWER LF CORNER TO GND
J 63	53	C 59	DY02	CELESCO		2 v/in	X= 889 Y= 56 Z= 41		52 X20	10	VAR	29.88 K		DEC 90	52	30	1	DEC 90		.500 IN/V	G	2-4		LATERAL CARBODY A-END GND LEFT CORNER
J 90	54	C 61	DZ03	CELESCO	14230	2 v/in	X= 144 Y= -56 Z= 41	23 JAN 91	53 X21	10	VAR	29.88 K	3.745 IN / 7.490 V	DEC 90	53	30	1	DEC 90		.500 IN/V	G	2-5		VERTICAL CARBODY B-END LOWER RT CORNER TO GND
J 91	55	C 33	DY03	CELESCO	14231	2 v/in	X= 144 Y= -56 Z= 41	23 JAN 91	54 X22	10	VAR	29.88 K	3.800 IN / 7.600 V	DEC 90	54	30	1	DEC 90		.500 IN/V	G	2-6		LATERAL CARBODY B-END LOWER RT CORNER TO GND
J 56	56	C 35	DZ04	CELESCO	10379	10 v/in	X= 889 Y= -12 Z= 31	31 NOV 90	55 X23	10	VAR	29.88 K	2.17 IN / 4.340 V	DEC 90	55	30	1	DEC 90		.500 IN/V	G	2-7		VERTICAL CARBODY A-END TO SPAN BLST RT
J 92	57	C 37	DY04	CELESCO	14239	10 v/in	X= 889 Y= 12 Z= 31	24 JAN 91	56 X24	10	VAR	29.88 K	.6725 IN / 6.725 V	DEC 90	56	30	1	DEC 90		.100 IN/V	G	2-8		VERTICAL CARBODY A-END TO SPAN BLST LEFT
							X= Y= Z=																	
							X= Y= Z=																	

NOTES:

FILE: G:\CADDWG\TMOD206.DWG /KFLORES

ATTACHMENT 6

APPLICABLE PSD'S TRANSFER FUNCTIONS TO BE REVIEWED BEFORE CONTINUING TEST

TEST	PERTINENT PSD CHANNEL	TRANSFER FUNCTION REF CHANNEL
VERTICAL TWIST AND ROLL	DZ2, DZ3, DZ4	VAF1
FLEXIBLE BODY VERTICAL AND TWIST	AZ4, AZ7, AZ10, AZ14, AZ17, AZ11	VAF1
RIGID BODY LATERAL	DY2, DY3, DY4	LAF1
FLEXIBLE BODY LATERAL	AY4, AY7, AY10	LAF1

PEACEKEEPER RAIL GARRISON
PROCEDURE PKRG-5100-TRIPLET CARS-38"
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 three commercial span bolster (Triplet) Cars.

1.1 INDEX

3.1 Vertical Twist and Roll Modal Test Procedure

3.2 Flexible Body Vertical Twist Modal Test

3.3 Rigid Body Lateral Modal Test Procedure

3.4 Flexible Body Lateral Modal Test Procedure

4.0 Test Tear Down

5.0 Quality Verification

1.2 EQUIPMENT LIST

a.	2 ea.	77 KIP Actuators
b.	2 ea.	Load Cell, 0 - 100 kips Range
c.	8 ea.	Instrumented Rails, 0 - 100 kips Vertical Range 0 - 60 kips Lateral Range
d.	2 ea.	Displacement Transducer (LVDT), +/- 5" Range
e.	2 ea.	String Pot, +/- 4" Range
f.	1 ea.	Strong Pot, +/- 1" Range
g.	6 ea.	String Pot, +/- 5" Range
h.	32 ea.	Accelerometer, +/- 5G Range
i.	1 ea.	HP 9000, Model 360 Computer System
j.	1 ea.	HP 6944a Multi-Programmer
k.	As needed	Safety Equipment as required by Rail Dynamics Lab (RDL)
l.	1 ea.	Attachment Fixture
m.	1 ea.	HP 3325B Function Generator

n. 1 ea. MTS Control System

o. 61 ea. Signal Conditioners

p. 61 ea. Filters (0 - 50 Hz)

1.3 FIGURE LIST

1.4 ATTACHMENT LIST

(1) Instrumented Rail Placement

(2) Bolster Instrumentation Placement

(3) Car Body Accelerometer Placement

(4) Car Body To Ground Displacement Measurement Placement

(5) Test Configuration Data Sheets (6 Sheets)

(6) Applicable PSD's

1.6 REFERENCE LIST

PKRG-2100 Truck Inspection Procedure

PKRG-2200 Car Inspection Procedure

PKRG-3100 Instrumentation Installation Procedure

PKRG-3200 Instrumentation Verification Procedure

M1001 Manual of Standards and Recommend Practices, C, Part II, Volume 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, Triplet Cars Testing

PKRG-5110 Triplet Cars Modal Test Car Attachment Fixture Installation Procedure

PKRG-5120-Triplet Cars, Modal Response Test Fixture Removal

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 PROCEDURE

2.1 Test Setup

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.1	Install car attachment fixtures per PKRG-5110-Triplet Cars, Attachment Fixture Installation Procedure.	______

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.

TASK NUMBER	PROCEDURE	QA INITIAL
2.1.2	Move test car onto the RDL Mini-shaker as illustrated in Figure 2-1. Comply with TTC Operating Rules.	______

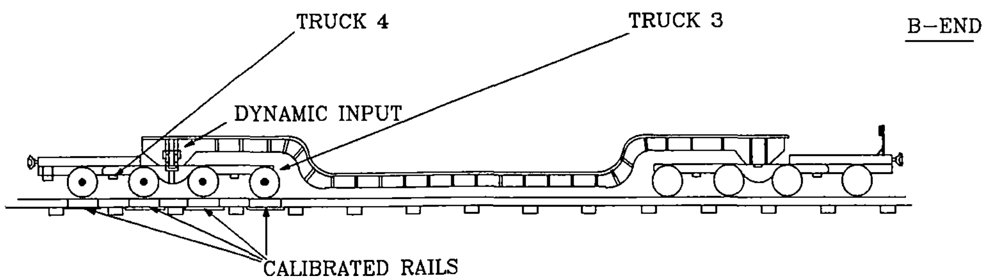


Figure 2-1 Test Car Overview

2.2 Load 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 Test Configuration Data Sheet, PKRG-3100 Section 5.1 through 5.8.	
2.2.3	Refer to Instrumented Rail Placement (Attachment 1) for instrumentation location.	
2.2.4	Zero the load cells by adjusting the zero knob on the north and south MTS 443 DC conditioners, (+/- 10 mV).	
2.2.5	Print checkout values and label Pre-test Load Cell Zeros.	
2.2.6	RCAL the load cells by pressing the CAL button on the DC conditioners and compare the values with the Test Configuration Data Sheet (Attachment 5), tolerance should be +/- 5 percent.	
2.2.7	Print checkout values and label Pre-test Load Cell RCAL.	
2.2.8	Quality verify load cell calibration completed.	______

2.3 LVDT Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.3.1	This calibration procedure is for all LVDT Channels.	
2.3.2	Refer to procedure PKRG-3100 for completing the Test Configuration Data Sheet (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	
2.3.3	Zero all LVDT's using the knob labeled ZERO on the AC conditioner located inside the MTS443 hydraulic control system +/- 10 mV.	
2.3.4	Print calibration values and label Pre-test LVDT Zeros.	
2.3.5	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 (Attachment 5).	

NOTE

If output does not match, adjust gage factor knob on the AC conditioner and repeat Step 2.3.4.

2.3.6 Quality verify LVDT'S calibration completed.

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 Test Configuration Data Sheet (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	
2.4.5	Refer to the Test Configuration for Data Sheet (Attachment 5) for instrumentation 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 (Attachment 5). Ensure CAL knob is positioned to + 100.

2.4.11 Place CAL knob to OPR position.

2.4.12 Place B & F calibration controller into Mode O record data for 60 seconds. Label Pre-test Instrumented Rail Zero.

2.4.13 Place B & F Calibration Controller into Mode I, record data for 60 seconds. Label Pre-test Instrumented Rail CALS.

2.4.14 Place B & 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 2-4.

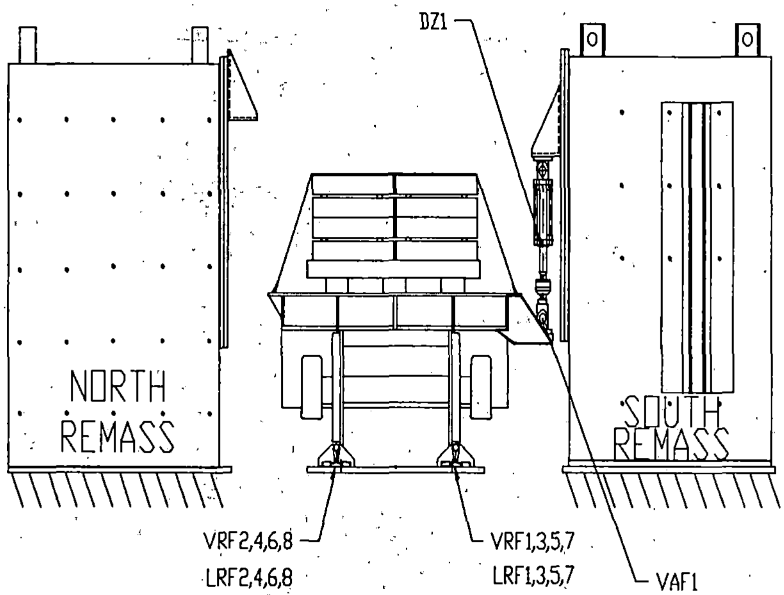


Figure 2-4 Vertical Test Configuration

2.4.17 Quality Verify instrumented rail calibration completed. ________

2.5 Accelerometer Calibration

TASK NUMBER	PROCEDURE	QA INITIAL
2.5.1	This calibration procedure for all PKRG accelerometer channels.	
2.5.2	Refer to procedure PKRG-3100 for completing the Test Configuration Data Sheet (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	

2.5.3 Refer to Car Body Accelerometer Placement (Attachment 3) for instrumentation location.

2.5.4 Install accelerometer 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 (Attachment 5). 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 position and adjust the amplifier course and fine gain, adjust for the output to correspond to the system EU/VOLT section and the Test Configuration Data Sheets (Attachment 5).

2.5.14 Quality verify accelerometer calibration completed. _______

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 Test Configuration Data Sheets (Attachment 5), PKRG-3100 Section 5.1 through 5.8.	
2.6.3	Refer to Car Body to Ground Displacement Measurement Placement (Attachment 4) 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 Test Configuration Data Sheets (Attachment 5). 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 Pre-test Instrumented Rail Zero.

2.6.12 Place B & F Calibration Controller into Mode I, record data for 60 seconds. Label Pre-test Instrumented Rail CALS.

2.6.13 Place B & 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. ________

3.0 MODAL TEST

3.1 Vertical Twist and Roll 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.
B. At the Data Acquisition System load the function generator with the D_Sweep_A Program and set the following parameters:

1. Load (kip)	15 kip
2. Displacement (stroke)	N/A
3. Freq. Range (Hz)	.2-5 Hz
a. Dwell Points (cycles/step)	10
b. Frequency Steps (Hz)	.1
c. Constant G	N/A
4. Sweep Duration (sec)	350
5. Filter	30 Hz

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's) Attachment 6 for test data. Examine for pitch and bounce resonant frequencies.

3.1.5 Repeat Steps 3.1.1 through 3.1.4 with force control settings 20 kip and 25 kip if it is determined safe after previous test.

3.1.5.1 Quality verify test parameter are satisfied for:

15 kip	________
20 kip	________
25 kip	________

3.2 Flexible Body Vertical Twist Modal Test

TASK NUMBER	PROCEDURE	QA INITIAL
3.2.1	Disconnect all string pots.	
3.2.2	Setup computer and control system for Flexible Body Vertical Modal Test.	

A. At the 443 Control System Panel, set MODE switch to the positive position.
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" max
3. Freq. Range (Hz)	3-30 Hz
a. Dwell Points (cycles/step)	N/A
b. Frequency Steps (Hz)	N/A
c. Constant G	.10
4. Sweep Duration (sec)	300

3.2.3 Start data acquisition and control program to begin test.

3.2.4 Save file when test stops.

3.2.5 Calculate a PSD's (see Attachment 6) for test data. Examine for vertical bending (first, second and third if possible) frequencies.

3.2.6 Quality verify acceptable constant G level at .10. ______

3.2.7 Repeat Steps 3.2.3 through 3.2.6 for constant G levels of .20 and .30 at 3 - 30 Hz, .40g at 5 - 30 Hz and .50g at 10 - 30 Hz, if it is determined safe after previous test.

3.2.7.1 Quality verify acceptable constant G level at:

15 kip	______
.20	______
.30	______
.40 at 05-39 Hz	______
.50 at 10-30 Hz	______

3.3 Rigid Body Lateral Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.3.1	Setup hydraulic actuators for rigid and flexible body lateral test configuration as shown in Figure 3-2. Reconnect string pots.	

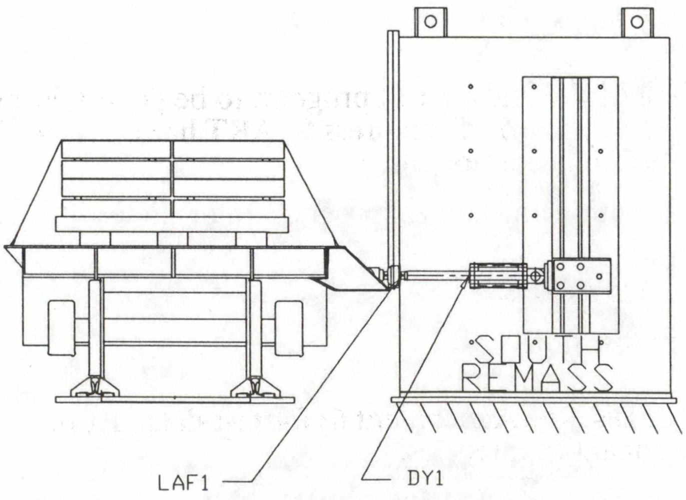


Figure 3-2 Lateral Test Configuration

3.3.2 Ensure all instrumentation is connected for lateral modal testing. ______

3.3.3 At the HP 360 data acquisition and control computer load the HP3325B function generator with the D_Sweep_A Program and set the following parameters:

1. Load (kip)	15 kip
2. Displacement (stroke)	N/A
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

3.3.4 Determine amplitude by using the following formula:

$$\left(\frac{kips}{8.63}\right)x2$$

Where kips equals desired kips

3.3.5 Input calculated amplitude into HP3325B function generator.

3.3.6 Start data acquisition and control program to begin test, by pressing F1 (RUN) on the Keyboard. Then press START button twice on the HP3325B function generator.

3.3.7 Save file when test stops.

3.3.8 Calculate a PSD's (see Attachment 6) for test data. Examine for lateral rigid body resonant frequencies.

3.3.9 Repeat Steps 3.5.4 through 3.5.7 with force control settings of 20 kip and 25 kip, if it is determined safe after previous test.

3.3.10. Quality verify acceptable rigid body laterals at:

15 kip	______
20 kip	______
25 kip	______

3.4 Flexible Body Lateral Modal Test Procedure

TASK NUMBER	PROCEDURE	QA INITIAL
3.4.1	Disconnect all string pots.	______
3.4.2	Setup the HP 360 Data Acquisition and Control Computer for Flexible Body Twist Modal Test.	

NOTE

At the HP 360 Data Acquisition and Control Computer keep the same parameters as the previous test.

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 6) for test data. Examine for Twist (first, second and third if possible) frequencies.

3.4.6 Repeat Steps 3.2.3 through 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 Quality verify acceptable constant G levels at:

.15	______
.20	______
.30	______
.40 at 10-30hz	______

4.0 TEST TEAR-DOWN

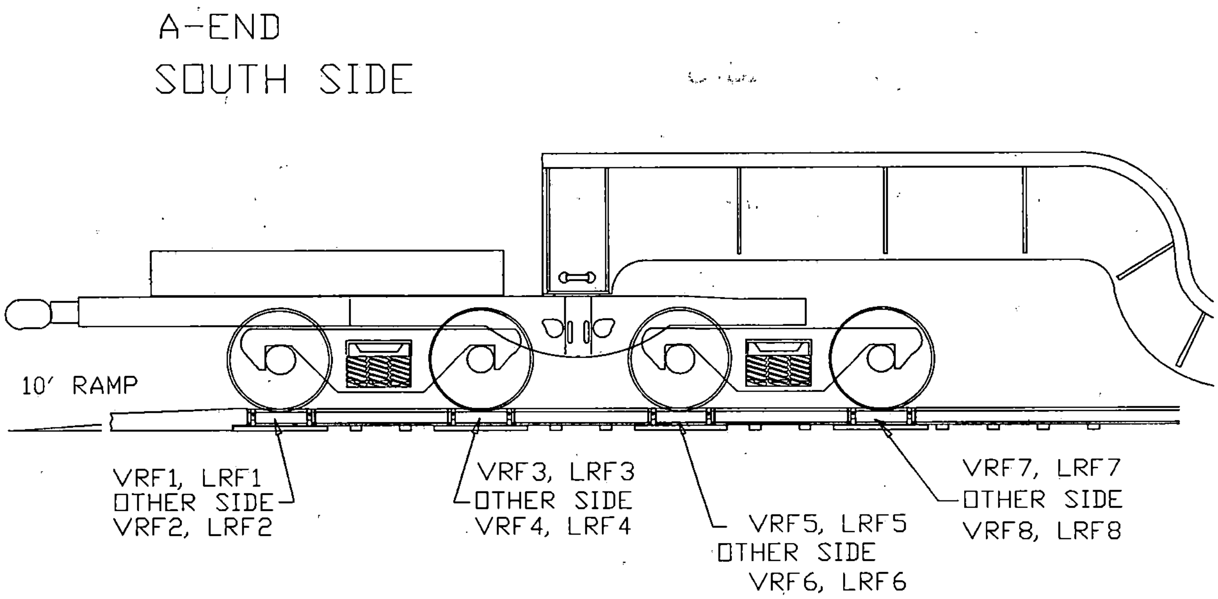
TASK NUMBER	PROCEDURE	QA INITIAL
4.0.1	Remove instrumentation from car.	
4.0.2	Remove car from MSU following TTC operating procedures.	
4.0.3	Remove car attachment fixtures per PKRG-5120-Triplet Cars, Modal Response Test Fixture Removal.	______
4.0.4	Perform car inspection per Procedures PKRG-2200.	______

5.0 QUALITY VERIFICATION

TASK NUMBER	PROCEDURE	QA INITIAL
5.0.1	Quality verification	_______
5.0.2	Quality verified that PKRG-5100 is complete and closed.	_______
5.0.3	Authorized QA signature.	_______________

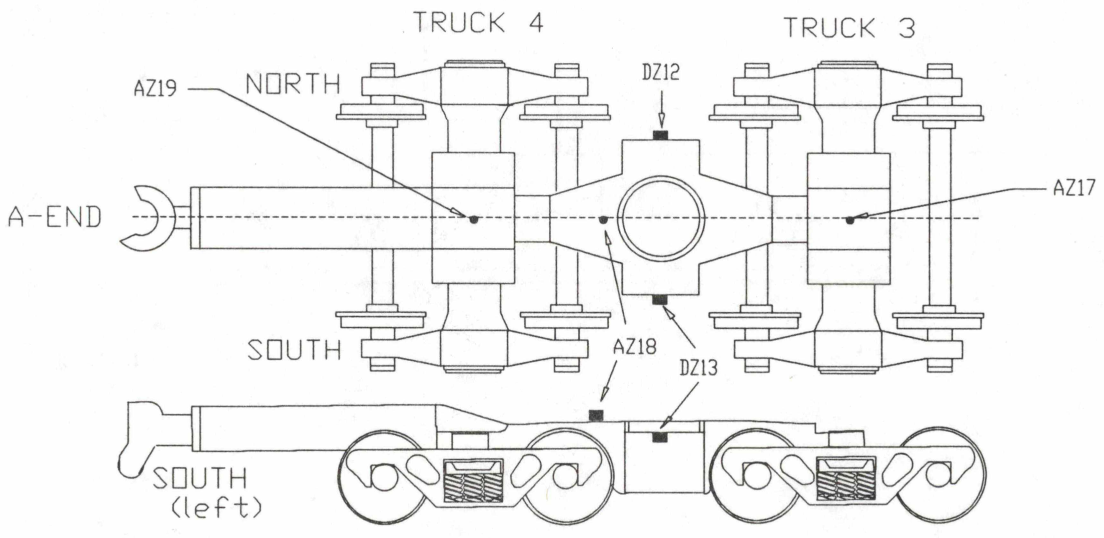
ATTACHMENT 1

INSTRUMENTED RAIL PLACEMENT



ATTACHMENT 2

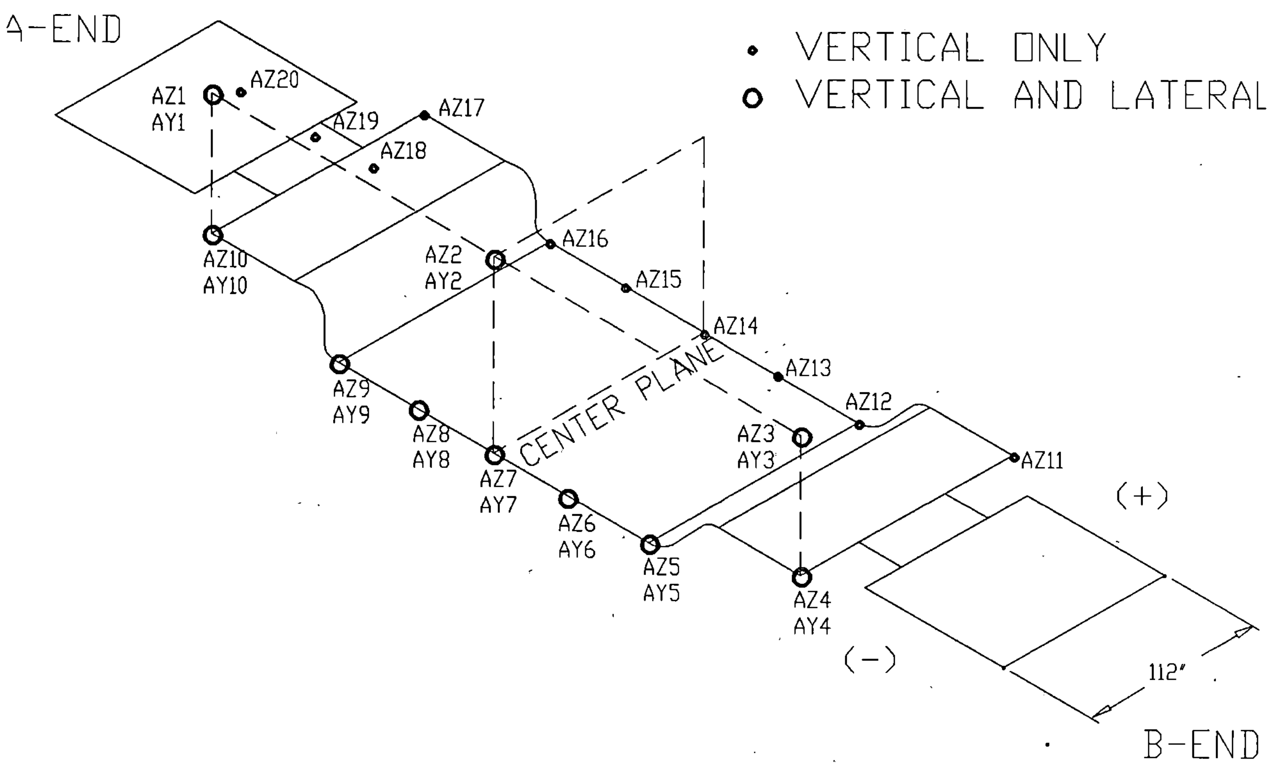
BOLSTER INSTRUMENTATION PLACEMENT



BOLSTER INSTRUMENTATION PLACEMENT

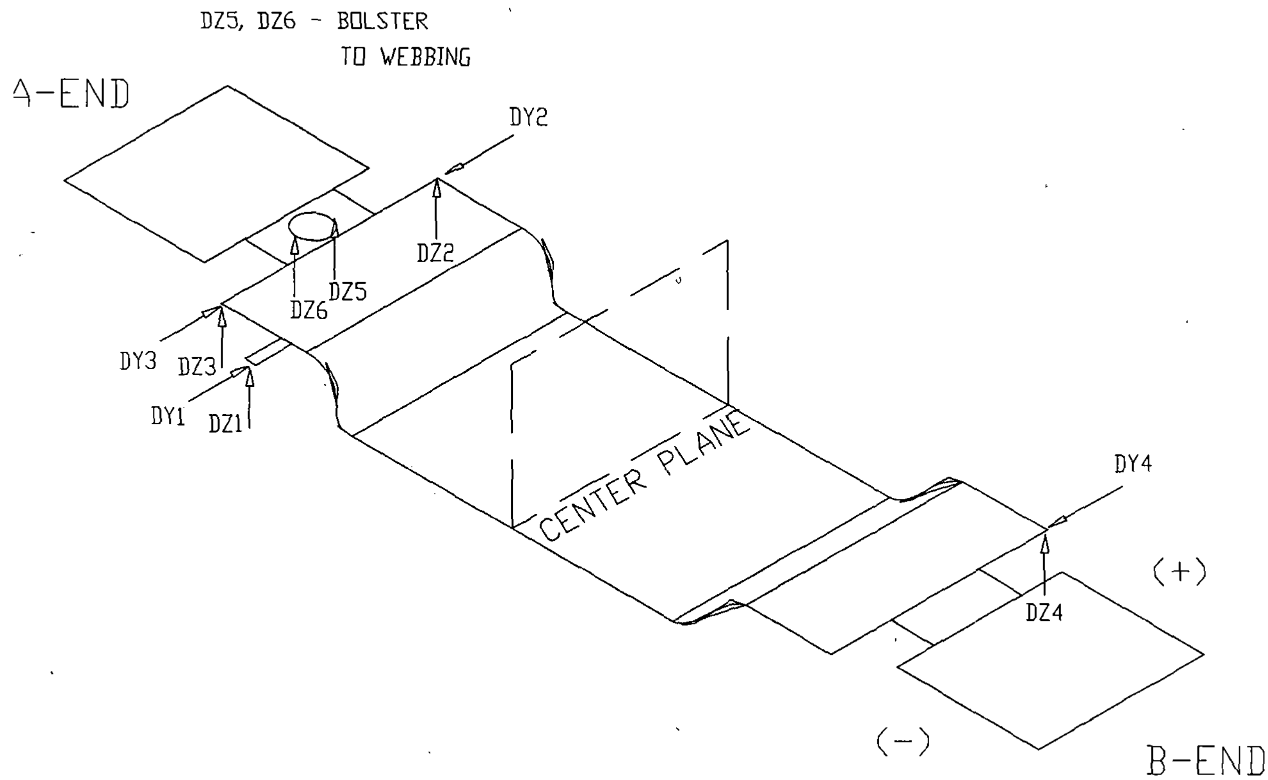
ATTACHMENT 3

CAR BODY ACCELEROMETER PLACEMENT



ATTACHMENT 4

CAR BODY TO GROUND DISPLACEMENT MEASUREMENT PLACEMENT



ATTACHMENT 5

TEST CONFIGURATION DATA SHEETS (6 Sheets)

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME TRIPLET CAR MODAL 38" DATE AUG 90 W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. BIER X775 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.)	
0			VAF1				X= Y= Z=								0	50				10 KLBS/V	KLBS			VERT ACTUATOR FORCE LEFT SOUTH A-END
1			LAF1				X= Y= Z=								1	50								LAT ACTUATOR FORCE LEFT SOUTH A-END
2			VRF1				X= Y= Z=								2	50								VERT RAIL FORCE LEAD LF TRK-4 A-END S-AX-8
3			VRF2				X= Y= Z=								3	50								VERT RAIL FORCE RT LEAD-AX-8 TRK-4 A-END
4			VRF3				X= Y= Z=								4	50								VERT RAIL FORCE TRAIL LF TRK-4 A-END S-AX-7
5			VRF4				X= Y= Z=								5	50								VERT RAIL FORCE TRAIL RT TRK-4 A-END N-AX-7
6			LRF1				X= Y= Z=								6	50								LAT RAIL FORCE LEAD LF TRK-4 A-END S-AX-8
7			LRF2				X= Y= Z=								7	50								LAT RAIL FORCE LEAD RT TRK-4 A-END N-AX-8
8			LRF3				X= Y= Z=								8	50								LAT RAIL FORCE TRAIL LF TRK-4 A-END S-AX-7
9			LRF4				X= Y= Z=								9	50								LAT RAIL FORCE TRAIL RT TRK-4 A-END N-AX-7

NOTES:

ACAD11 FILE: G:\CADDWG\TMODAL01.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME TRIPLET CAR MODAL 38" DATE ________ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. ____________ TEST ENGR. BIER X775 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.)	
10			VRF5				X= Y= Z=																	VERT RAIL FORCE LEAD LF TRK-3 A-END N-AX-6
11			VRF6				X= Y= Z=																	VERT RAIL FORCE LEAD RT TRK-3 A-END N-AX-6
12			VRF7				X= Y= Z=																	VERT RAIL FORCE TRAIL LF TRK-3 A-END S-AX-5
13			VRF8				X= Y= Z=																	VERT RAIL FORCE TRAIL RT TRK-3 A-END N-AX-5
14			LRF5				X= Y= Z=																	VERT RAIL FORCE LEAD LF TRK-4 A-END S-AX-7
15			LRF6				X= Y= Z=																	LAT RAIL FORCE LEAD RT TRK-3 A-END N-AX-6
16			LRF7				X= Y= Z=																	LAT RAIL FORCE TRAIL LF TRK-3 A-END S-AX-5
17			LRF8				X= Y= Z=		K															LAT RAIL FORCE TRAIL RT TRK-3 A-END N-AX-5
18			DZ1	LVDT			X= Y= Z=																	VERT ACTUATOR DISP LF SOUTH A-END
19			DZ2	LVDT			X= Y= Z=																	LAT ACTUATOR DISP LF SOUTH A-END

NOTES:

ACAD11 FILE: G:\CADDWG\TMODAL02.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 4 OF ____

TEST NAME TRIPLET CAR MODAL 38" DATE ______ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. ______ TEST ENGR. BIER X775 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
	30	J 81	AZ2	ENDEVCO	JQ54		X= 488 Y= -40 Z= 177	24 JAN 91																VERT CAR BODY ACCEL UPPER EDGE LF OG CTR LINE
	31	J 82	AY2	ENDEVCO	RH83		X= 488 Y= -40 Z= 177	25 JAN 91																LAT CAR BODY ACCEL UPPER EDGE LF OF CTR LINE
	32	J 79	AZ3	ENDEVCO	GT42		X= 172 Y= 40 Z= 153	24 JAN 91																VERT CAR BODY ACC B-END LF UPPER EDGE CORNER
	33	J 80	AY3	ENDEVCO	HF67		X= 172 Y= -40 Z= 153	24 JAN 91																LAT CARBODY ACC B-END LF UPPER EDGE CORNER
	34	J 65	AZ4	ENDEVCO	JQ78		X= 148 Y= -44 Z= 39	24 JAN 91																VERT CARBODY ACC A-END LF LOWER EDGE CORNER
	35	J 66	AY4	ENDEVCO	JQ66		X= 48 Y= -44 Z= 39	24 JAN 91																LAT CAR BODY ACCEL A-END LF EDGE CORNER
	36	J 67	AZ5	ENDEVCO	ML36		X= 330 Y= -44 Z= 8	25 JAN 91																VERT CARBODY ACCEL A-END LF LOWER EDGE (2)
	37	J 68	AY5	ENDEVCO	PA16		X= 330 Y= -44 Z= 8	25 JAN 91																LAT CARBODY ACCEL A-END LF LOWER EDGE (2)
	38	J 97	AZ6	ENDEVCO	RH68		X= 409 Y= -44 Z= 8	25 JAN 91																VERT CARBODY ACCEL A-END LF LOWER EDGE (3)
	39	J 98	AY6	ENDEVCO	EY98		X= 409 Y= -44 Z= 8	24 JAN 91																LAT. CARBODY ACCEL A-END LF LOWER EDGE (3)

NOTES:

ACAD11 FILE: G:\CADDWG\TMODAL04.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

TEST NAME TRIPLET CAR MODAL 38" DATE ________ W.O. 87593 LOC. RDL-MSU

INSTR. ENGR./TECH. ________ TEST ENGR. BIER X775 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.)	
	40	J 99	AZ7	ENDEVCO	TG93		X= 488 Y= -44 Z= 8	15 SEP 90																VERT CARBODY ACCEL CTR/LN CTR/LN LF LOWER EDGED
	41	J 100	AY7	ENDEVCO	EY97		X= 488 Y= -44 Z= 8	23 JAN 91																LAT CARBODY ACCEL CTR/LN LF LOWER EDGE
	42	J 101	AZ8	ENDEVCO	FP50		X= 567 Y= -44 Z= 8	24 JAN 91																VERT CARBODY ACCEL B-END LF LOWER EDGE (4)
	43	J 102	AY8	ENDEVCO	FM79		X= 567 Y= -44 Z= 8	24 JAN 91																LAT CARBODY ACCEL B-END LF LOWER EDGE (4)
	44	J 103	AZ9	ENDEVCO	RW99		X= 646 Y= -44 Z= 8	20 JAN 91																VERT CARBODY ACCEL B-END LF LOWER EDGE (5)
	45	J 104	AY9	ENDEVCO	EZ49		X= 646 Y= -44 Z= 8	24 JAN 91																LAT CARBODY ACCEL B-END LF LOWER EDGE (5)
	46	J 105	AZ10	ENDEVCO	MR11		X= 829 Y= -44 Z= 39	16 OCT 91																VERT CARBODY ACCEL CORNER EDGE LOWER LF B-END
	47	J 106	AY10	ENDEVCO	KR29		X= 829 Y= -44 Z= 39	19 JAN 91																LAT CARBODY ACCEL CORNER EDGE LOWER LF B-END
	48	J 69	AZ11	ENDEVCO	RW21		X= 148 Y= 44 Z= 39	20 JAN 91																VERT CARBODY ACCEL CORNER EDGE LOWER RT EDGE B-END
	49	J 70	AY11	ENDEVCO	RW85		X= 330 Y= 44 Z= 8	20 JAN 91																VERT CARBODY ACCEL LOWER RT (2) B-END

NOTES:

ACAD11 FILE: G:\CADDWG\TMODAL05.DWG /KFLORES

PEACEKEEPER RAIL GARRISON
TEST CONFIGURATION DATA SHEET

PAGE 6 OF ____

TEST NAME TRIPLET CAR MODAL 38" DATE ____ W.O. 87593 LOC. RDL-MSU
INSTR. ENGR./TECH. ____ TEST ENGR. BIER X775 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
	50	J 71	AZ13	ENDEVCO	NN23		X= 409 Y= 44 Z= 8	20 JAN 91																VERT CARBODY ACCEL LOWER RT (3) B-END
	51	J 72	AZ14	ENDEVCO	FA95		X= 488 Y= 44 Z= 8	24 JAN 91																VERT CARBODY ACCEL MIDDLE CTR/LN LOWER RT
	52	J 73	AZ15	ENDEVCO	MR84		X= 567 Y= 44 Z= 8	20 JUN 91																VERT CARBODY ACCEL LOWER EDGE RT A-END (4)
	53	J 74	AZ16	ENDEVCO	NZ07		X= 646 Y= 44 Z= 8	20 JUN 91																VERT CARBODY ACCEL LOWER EDGE RT A-END (5)
	54	J 75	AZ17	ENDEVCO	MR29		X= 829 Y= 44 Z= 39	20 JUN 91																VERT CARBODY ACCEL A-END RT CORNER TO GND
	55	J 76	AZ18	ENDEVCO	NF15		X= 743 Y= 0 Z= 36	20 JUN 91																VERT SPAN BLST TRAIL TRK-3 CTR PLATE
	56	J 77	AZ19	ENDEVCO	KY10		X= 855 Y= 0 Z= 36	19 JUN 91																VERT SPAN BLST CTR CARBODY CTR PLATE
	57	J 78	AZ20	ENDEVCO	MG10		X= 890 Y= -4 Z= 41	20 JUN 91																VERT SPAN BLST LEAD TRK-4 CTR PLATE
							X= Y= Z=																	
							X= Y= Z=																	

NOTES:

ACADII FILE: G:\CADDWG\TMODAL06.DWG /KFLORES

ATTACHMENT 6

APPLICABLE PSD'S TRANSFER FUNCTIONS TO BE REVIEWED BEFORE CONTINUING TEST

TEST	PERTINENT PSD CHANNEL	TRANSFER FUNCTION REF CHANNEL
VERTICAL TWIST AND ROLL	DZ2, DZ3, DZ4	VAF1
FLEXIBLE BODY VERTICAL AND TWIST	AZ4, AZ7, AZ10, AZ14, AZ17, AZ11	VAF1
RIGID BODY LATERAL	DY2, DY3, DY4	LAF1
FLEXIBLE BODY LATERAL	AY4, AY7, AY10	LAF1

APPENDIX F

QUASI-STATIC DATA REDUCTION PLOTS

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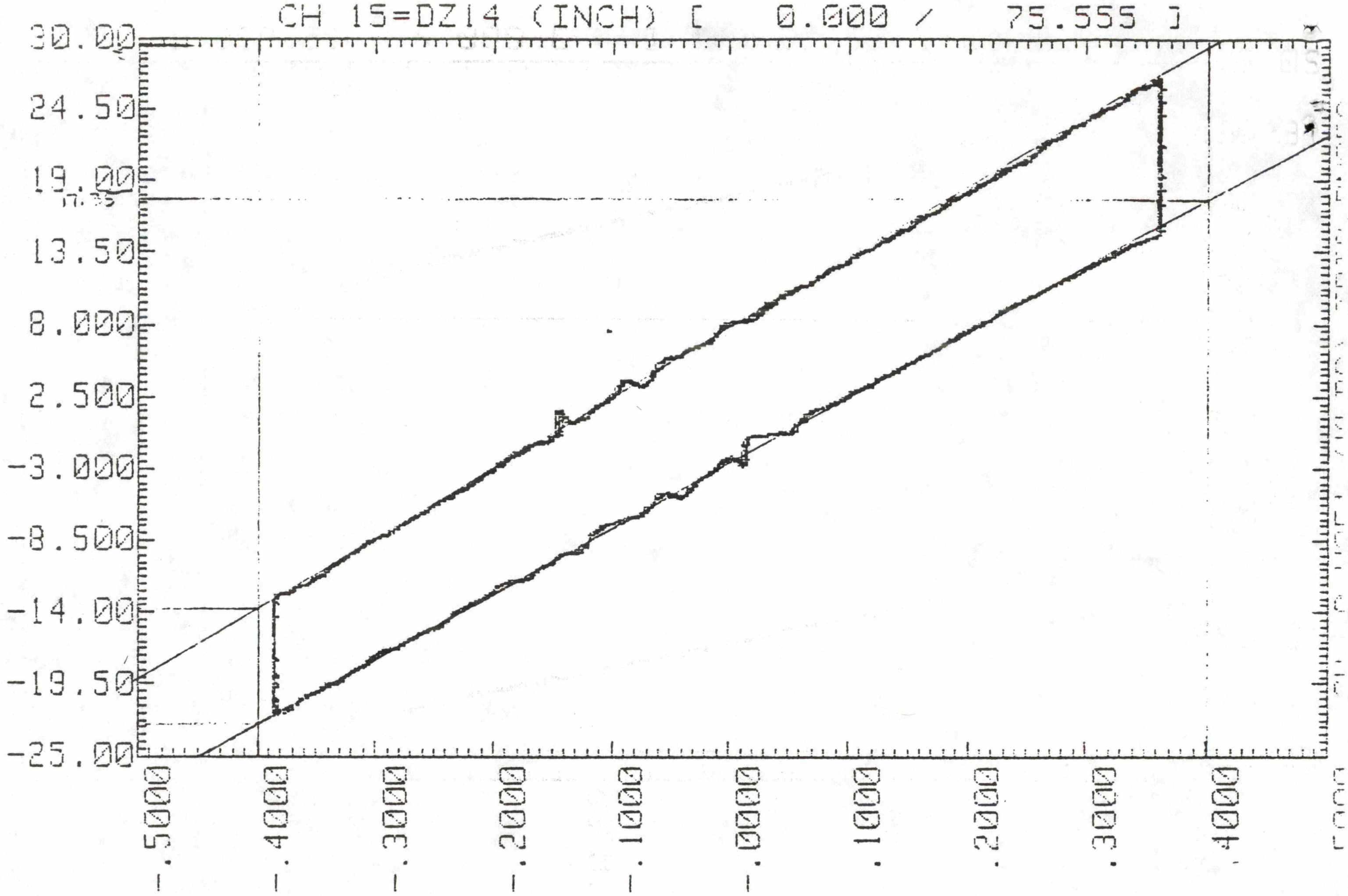

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52.25 Kips/Inch

DAMPING FORCE:

10.45 Kips

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TRIP_RN085 22 Oct 1990 20:02:33
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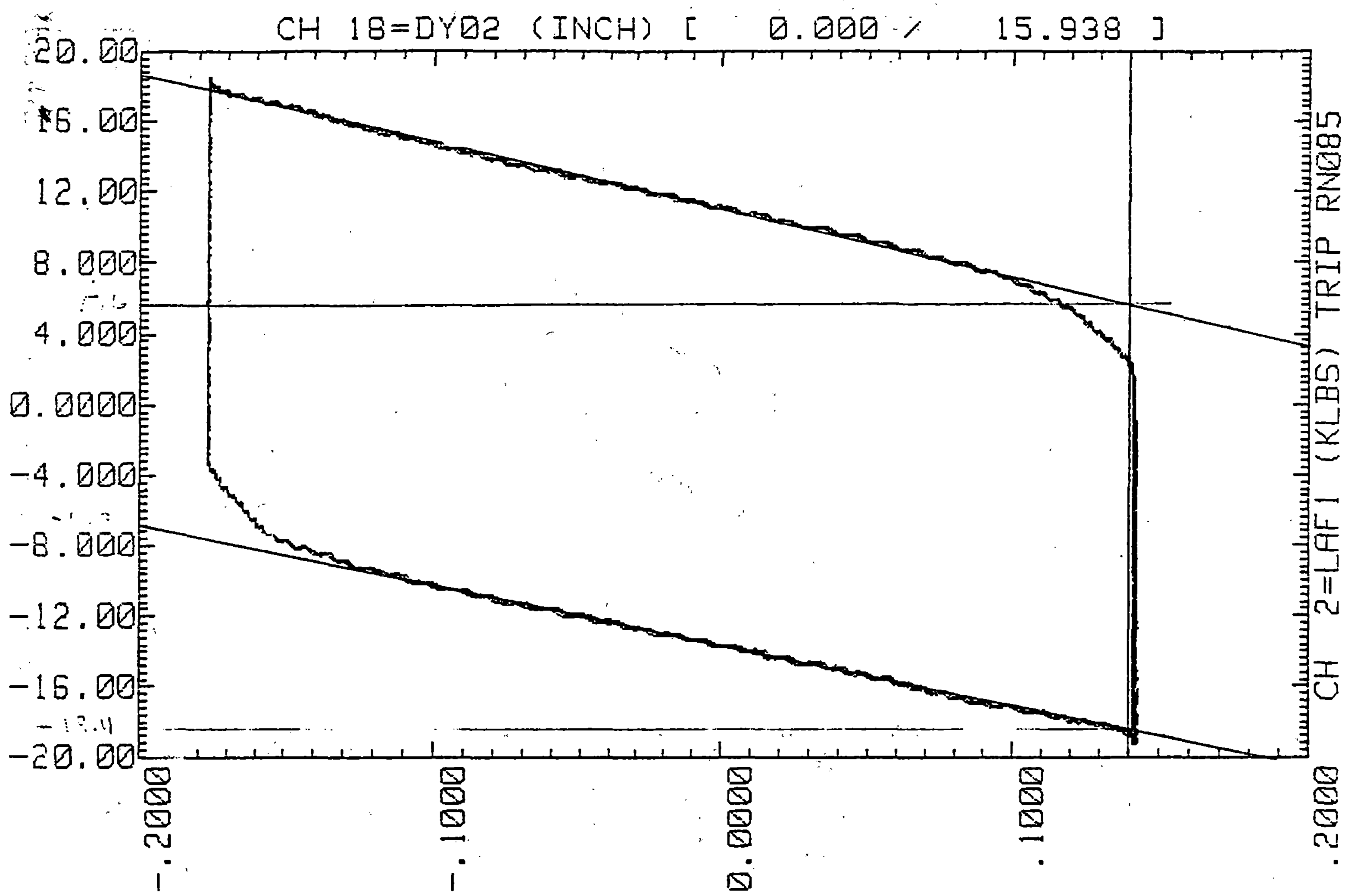

LATERAL SPRING RATE:

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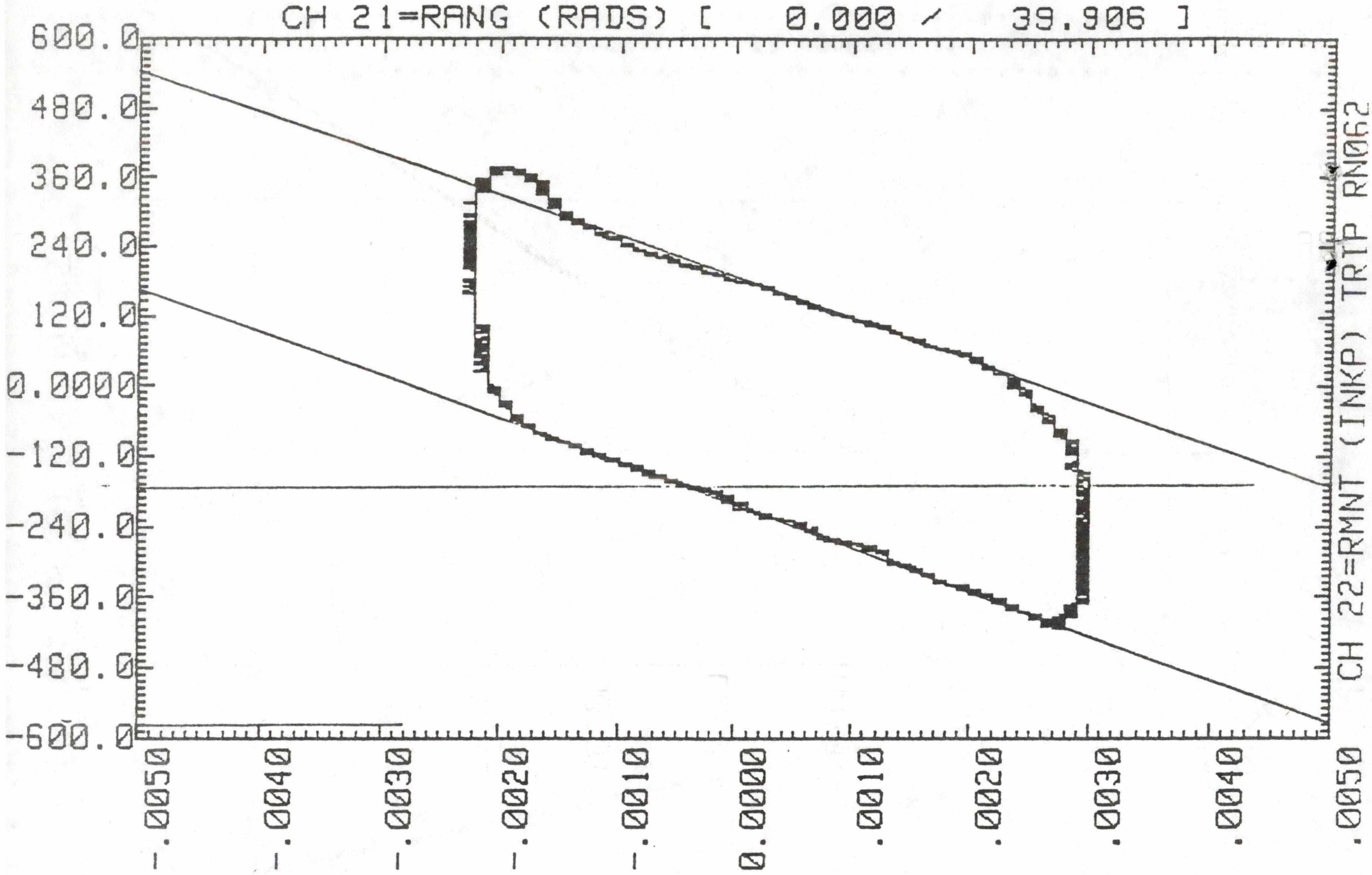
LATERAL DAMPING FORCE:

24.7 Kips



ROLL RATE:

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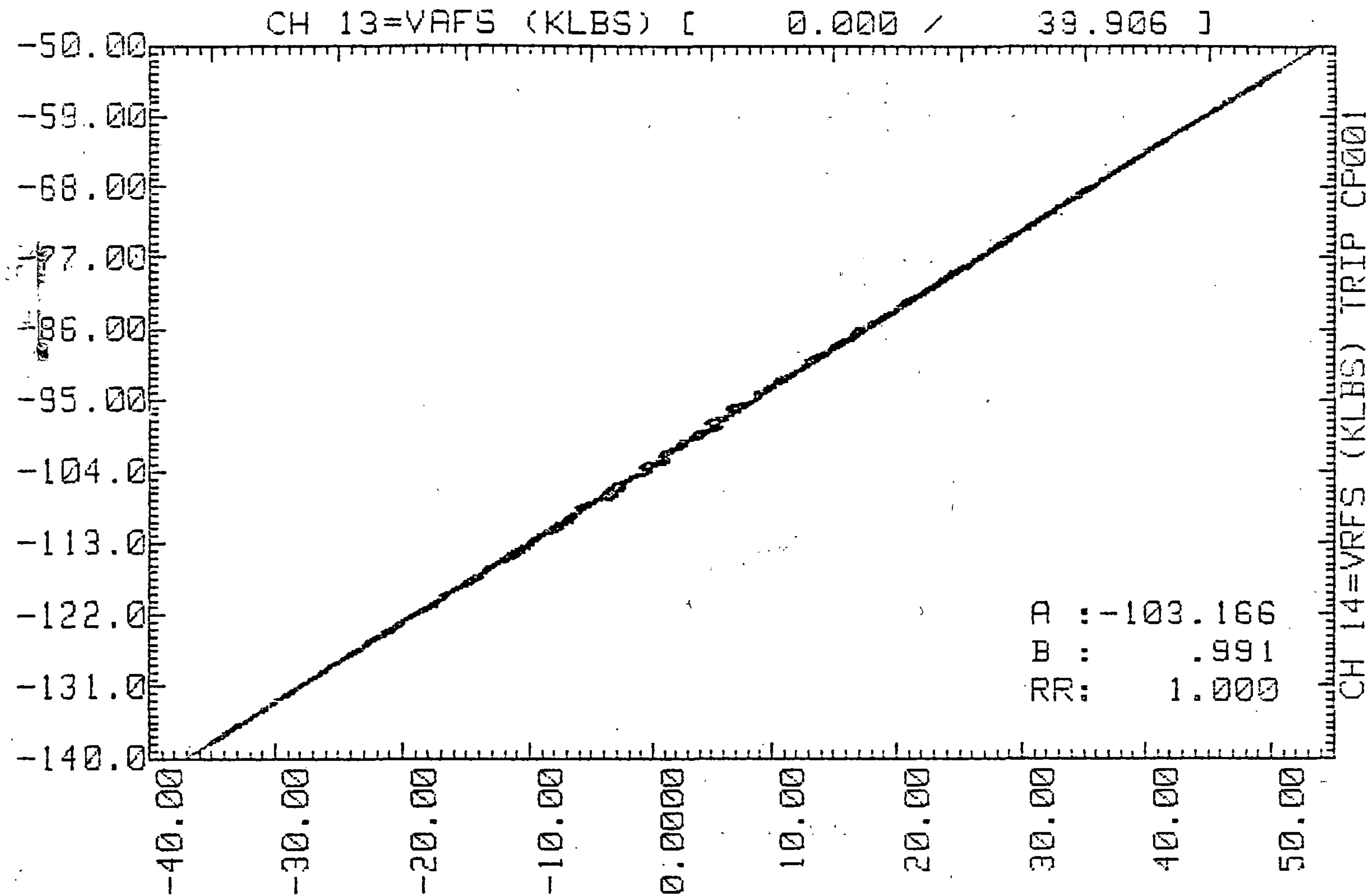
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B : .991
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