REPORT NO. FRA/ORD–78–31 PB

TEST RESULTS REPORT
METROLINER TRUCK IMPROVEMENT PROGRAM
IN SUPPORT OF TEST REQUEST RR–254
VOLUME I

ENGINEERING TEST AND ANALYSIS DIVISION
ENSCO, INC.
ALEXANDRIA, VIRGINIA 22303

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

MAY 1978

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Office of Passenger Systems
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FRA/ORD -78-31		

4. Title and Subtitle	5. Report Date
Test Results Report Metroliner Truck Improvement Program In Support of Test Request RR-254 Volume 1 of 3	May 1978
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No. DOT-FR-78-25
9. Performing Organization Name and Address ENGINEERING TEST AND ANALYSIS DIVISION ENSCO, INC. 2560 Huntington Avenue Alexandria, Virginia 22303	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-FR-64113
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Passenger Systems Washington, DC 20590	13. Type of Report and Period Covered Test Results Report 1977 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract This report is divided into three volumes. Vol. I summarizes the testing procedures, describes the data reduction techniques and gives the results and conclusions. Vol. II describes Metroliner characteristics, modifications to Metroliner trucks, instrumentation, ride quality software and includes samples of software and stripped out data. Vol. III contains power spectral densities for the 3 test phases.

This report summarizes the results of the ride quality analysis associated with the Metroliner Truck Improvement Program. The overall objectives of this program were to provide ride improvement at a more modest cost by modifying existing trucks rather than replacing existing trucks with completely new trucks, to provide a design that would reduce truck maintenance, and to reduce noise. The Metroliner program was conducted by General Steel Industries under contract to FRA, Office of Passenger Systems. The ride quality testing covered in this report was performed by ENSCO, INC. under separate contract supporting the Office of Passenger Systems.

The first two series of tests were conducted using Metroliners 850 and 855. Metroliner 855 had standard trucks while Metroliner 850 had improved trucks. In the first series (using a Sumiride air spring) the ride quality results indicate that Metroliner 850 rode better. A Firestone air bag was used in the second series.

The third series of tests was conducted using two standard Metroliners. Metroliner 855 had recently been upgraded to specification while Metroliner 822 was in need of maintenance. The ride quality results indicated that the maintained Metroliner rode much better.

17. Key Words	18. Distribution Statement
Improved Metroliner Truck, Ride Quality Testing, Air Bag	Document available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	93	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

EXECUTIVE SUMMARY

This report summarizes the results of the ride quality analysis associated with the Metroliner Truck Improvement Program. The overall objectives of this program were to provide ride improvement at a more modest cost by modifying existing trucks rather than replacing existing trucks with completely new trucks, to provide a design that would reduce truck maintenance, and to reduce noise. The Metroliner Truck Improvement Program was conducted by General Steel Industries under contract to FRA, Office of Passenger Systems. The ride quality testing covered in this report was performed by ENSCO, Inc., under a separate contract supporting the Office of Passenger Systems.

This report is divided into three volumes. Volume I summarizes the testing procedures, describes the data reduction techniques and gives the results and conclusions. Volume II contains Appendices A through G. These appendices describe in detail Metroliner characteristics, modifications to Metroliner trucks and instrumentation and ride quality software. Volume II also includes a sample of the software and samples of the stripped-out data. Volume III contains power spectral densities for the three test phases.

The first two series of tests were conducted using Metroliners 850 and 855. Metroliner 855 had standard trucks while Metroliner 850 had improved trucks. In the first series (using a Sumiride air spring) the ride quality results indicate that Metroliner 850 rode better. A Firestone air bag was used in the second series.

The third series of tests was conducted using two standard Metroliners. Metroliner 855 had recently been upgraded to specification while Metroliner 822 was in need of maintenance. The ride quality results indicated that the Metroliner that had been maintained to specification rode much better.

TABLE OF CONTENTS

SECTION	TITLE	PAGE
	EXECUTIVE SUMMARY	i
	TABLE OF CONTENTS	ii
	LIST OF ILLUSTRATIONS	iii
	LIST OF TABLES	iv
1.0	INTRODUCTION	1
2.0	TEST DESCRIPTION	3
2.1	SUMMARY	3
2.2	INSTRUMENTATION	8
2.3	TEST PROCEDURE	11
2.4	COMPARISON TEST	22
3.0	DATA REDUCTION	26
3.1	STRIP CHART ANALYSIS	26
3.2	SOFTWARE ANALYSIS	26
3.3	RIDE QUALITY CRITERIA	27
4.0	RESULTS	34
4.1	SUMIRIDE VERTICAL DAMPING TESTS	34
4.2	SUMIRIDE ORIFICE VARIATION	35
4.3	SUMIRIDE PLATE/SANDWICH	39
4.4	SUMIRIDE LATERAL DAMPING	39
4.5	SUMIRIDE OPTIMUM COMPONENTS TEST	40
4.6	FIRESTONE VERTICAL DAMPING	52
4.7	FIRESTONE LATERAL DAMPING	53
4.8	FIRESTONE OPTIMUM COMPONENTS TEST	54
4.9	SUMIRIDE DEFLATED AIR SPRING TEST	64
4.10	855/822 METROLINER COMPARISON TEST	67
5.0	DATA DISCUSSION	82
6.0	CONCLUSION	86
7.0	REFERENCES	87

LIST OF ILLUSTRATIONS

FIGURE NO.	TITLE	PAGE
2-1	Test Consist	3
2-2	FRA/ENSCO Portable Ride Quality Package	6
2-3	Transducer Signal Flow	7
2-4	Location of Portable Ride Quality Accelerometers	10
2-5	Placement of PRQ Packages for Deflated Airspring Test	22
3-1	Ride Quality Specification	30
3-2	Ride Quality Variables and Possible Outcomes	31
3-3	Sample Level One Comparison Chart	32
3-4	Sample Level Two Comparison Chart	33
4-1	Sumiride Air Spring	36
4-2	Vertical Accelerometer Data Using 3/4 Inch Orifice	37
4-3	Vertical Accelerometer Data Using 7/8 Inch Orifice	38
4-4	Transverse Acceleration as a Function of Frequency and Exposure Time	45
4-5	Longitudinal Acceleration Limits as a Function of Frequency and Exposure Time	45A
4-6	W_z Plots GSI/Sumiride Trucks (Car Center)	46
4-7	W_z Plots GSI/Sumiride Trucks (over A-End Truck)	47
4-8	Roll Ratio for Tests F-1 and F-3	55
4-9	W_z Plots GSI/Firestone Trucks (Rear of Car)	58
4-10	W_z Plots GSI/Firestone Trucks (Car Center)	59
4-11	Static Tilt of Metroliner 850 - Deflated Air Spring)	65
4-12	Location of PRQ Packages - Deflated Air Spring Test	66
4-13	Ride Quality Accelerations - Best-of-All-Components Test	68
4-14	Ride Quality Accelerations - Deflated Air Spring Test	69
4-15	Summary - Deflated Air Spring Test	70

LIST OF TABLES

Table No.	Title	Page
2-1	Metroliner Improvement Program Test Zones	4
2-2	Summary of Tests Conducted	9
2-3	Accelerometer Characteristics	11
2-4	Signals Recorded During Test	12
2-5	Detailed Test Zones	15
2-6	Test Zones - Comparison Tests	25
4-1	Lateral Mode/Sumiride Air Spring	43
4-2	Vertical Mode/Sumiride Air Spring	44
4-3	Phase 1 - Ride Quality Specification - 850 Leading	48
4-4	Phase 2 - Ride Quality Specification - 850 Leading	49
4-5	Phase 1 - Ride Quality Specification - 855 Leading	50
4-6	Phase 2 - Ride Quality Specification - 855 Leading	51
4-7	Metroliner 850/855 Roll Angle Comparison	54
4-8	Vertical Mode/Firestone Air Spring	56
4-9	Lateral Mode/Firestone Air Spring	57
4-10	Phase 1 - Ride Quality Specification - 850 Leading	60
4-11	Phase 2 - Ride Quality Specification - 850 Leading	61
4-12	Phase 1 - Ride Quality Specification - 855 Leading	62
4-13	Phase 2 - Ride Quality Specification - 855 Leading	63
4-14	Deflated Air Bag Software Results	71
4-15	Phase 1 - Ride Quality Evaluation - 822 Leading	76
4-16	Phase 1 - Ride Quality Evaluation - 855 Leading	77
4-17	Phase 2 - Ride Quality Evaluation - 855 Leading	78
4-18	Phase 2 - Ride Quality Evaluation - 822 Leading	79
4-19	Lateral Mode	80

LIST OF TABLES (CONT)

Table No.	Title	Page
4-20	Vertical Mode	81
4-21	Overall Results - Ride Quality Specification	83

1.0 INTRODUCTION

Metroliner service on the Northeast Corridor has been well received by the rail-passenger public. There has, at the same time, been a need to upgrade ride quality to provide better standards of comfort. It is also generally recognized that track conditions on the Northeast Corridor have fallen short of what was originally envisioned. Two alternatives existed, i.e., replacement or modification of the existing hardware.

In the early 1970's, the Vought Systems Division of LTV Aerospace Corporation [2] in association with the Swiss Industrial Company designed, manufactured and tested a new type of Metroliner truck under contract to the Department of Transportation. This new design was intended to improve the ride qualities of the Metroliner at speeds up to 160 mph. However, due to the high costs involved in replacing the trucks, a program was proposed to modify and upgrade the present trucks.

In 1976, General Steel Industries was selected to design and build such a replacement truck and to test its performance. The GSI Metroliner Truck Improvement Program was intended to make use of major elements of the existing Metroliner trucks that had performed well in the past while at the same time improving the ride by changing the suspension elements that had the greatest influence on ride quality. The goals were to improve both the vertical and lateral ride, reduce the noise level and reduce maintenance costs.

Modifications to improve ride quality were made to the truck suspension and to the interface between the carbody and the improved truck. Acceptance testing was then conducted to determine if the quality of the ride of the improved Metroliner was better than the ride of the existing Metroliner with its suspension system maintained to specification.

The major change to the truck suspension was the addition of an air spring. An air spring is essentially a rubber tube filled with air and having piping arrangements to insure proper spring rates. The proper air spring on a rail vehicle will increase ride comfort and eliminate spring surge.

Both Sumiride and Firestone air springs were tested during the ride improvement program. A description of these air bags is included in Appendix G to this report.

General Steel Industries (GSI) coordinated the modifications and the changes to the carbody and the truck. During the testing phase, both ENSCO and GSI collected test data. GSI monitored truck and carbody parameters while ENSCO collected carbody accelerations and recorded the GSI signals. The data were analyzed using software programs and ride quality criteria.

Appendix A presents some general characteristics of Metroliners. Appendix B includes a detailed description of the modifications to the trucks.

2.0 TEST DESCRIPTION

2.1 SUMMARY

The purpose of the ride-quality testing on the Metroliner Truck Improvement Program was to collect vehicle vibration data on two Metroliners. One Metroliner (No. 855) had standard trucks that had been newly overhauled while the other Metroliner (No. 850) had improved trucks. The two vehicles were run together and a comparison of the ride quality was made. The primary test zone was Northeast Corridor Trackage between Wilmington, Delaware and Baltimore, Maryland. Table 2-1 gives a specific description of the various test zones, speeds and tracks which were used when collecting test data. Figure 2-1 is a photograph of the consist.

Figure 2-1. Test Consist

TABLE 2-1

METROLINER IMPROVEMENT PROGRAM TEST ZONES

Milepost	Speed (mph)	Track No.	Bolted Rail	Welded Rail
Southbound				
29-6-31	20	4	X	
33.0-34.5	40	4	X	
35.0-36.5	50	4	X	
37.0-38.0	20	4	X	
41.0-43.0	60	3		X
44.0-45.0	70	3		X
46.0-48.0	90	3	X	
49.0-51.0	90	3	X	
52.0-54.0	90	3		X
60.5-62.0	40	3		X
62.5-64.0	50	3		X
65.0-69.0	80	3		X
69.0-70.0	80	3	X	
73.0-75.0	90	3		X
Northbound				
71.0-70.0	40	3		X
69.5-68.0	50	3	X	
67.5-65.0	60	3		X
63.0-62.0	40	1		X
61.5-60.5	50	1	X	
56.5-54.0	70	2		X
53.5-51.0	70	2		X
48.0-45.0	90	2		X
38.0-45.0	90	2		X
34.0-33.0	50	2		X
32.5-31.5	40	2		X

Two Amtrak Metroliners (snack-bar coaches, car numbers 850 and 855) were removed from revenue service to serve as test vehicles for the Metroliner Truck Improvement Testing. Car 855 was used as a control or comparison car, and prior to the test, Metroliner 855 was overhauled. The overhaul included replacement of any defective or worn suspension parts and the installation of new wheelsets.

Metroliner 850 was the test vehicle and rode on the improved trucks. The improved trucks were designed and modified by General Steel Industries and incorporated modifications which allowed the testing of different air springs, and various shock absorbers and dampers.

The two vehicles were coupled with their B - ends together and Metroliner 850 was the leading end of the consist on southbound runs. These vehicles were the same as those used during the LTV/SIG Testing.

The FRA/ENSCO Portable Ride Quality Package (Figure 2-2) was used to collect ride quality data in both the 850 and 855 Metroliners. General Steel Industries test personnel installed various transducers to measure vehicle motions in both cars. In addition to the Visicorder data, the GSI signals were recorded by ENSCO test personnel using a 14-channel Bell and Howell recorder (Figure 2-3).

On the basis of on-board strip chart displays, accelerometer signals were compared to determine the better riding vehicle. The suspension system of the vehicle was then adjusted to obtain the best ride over the test track. The tapes were returned to Alexandria for processing using the standard ride quality data reduction package. This processing is described in Section 3.2. The results were then submitted to a two-phase ride quality criteria to determine the better riding vehicle.

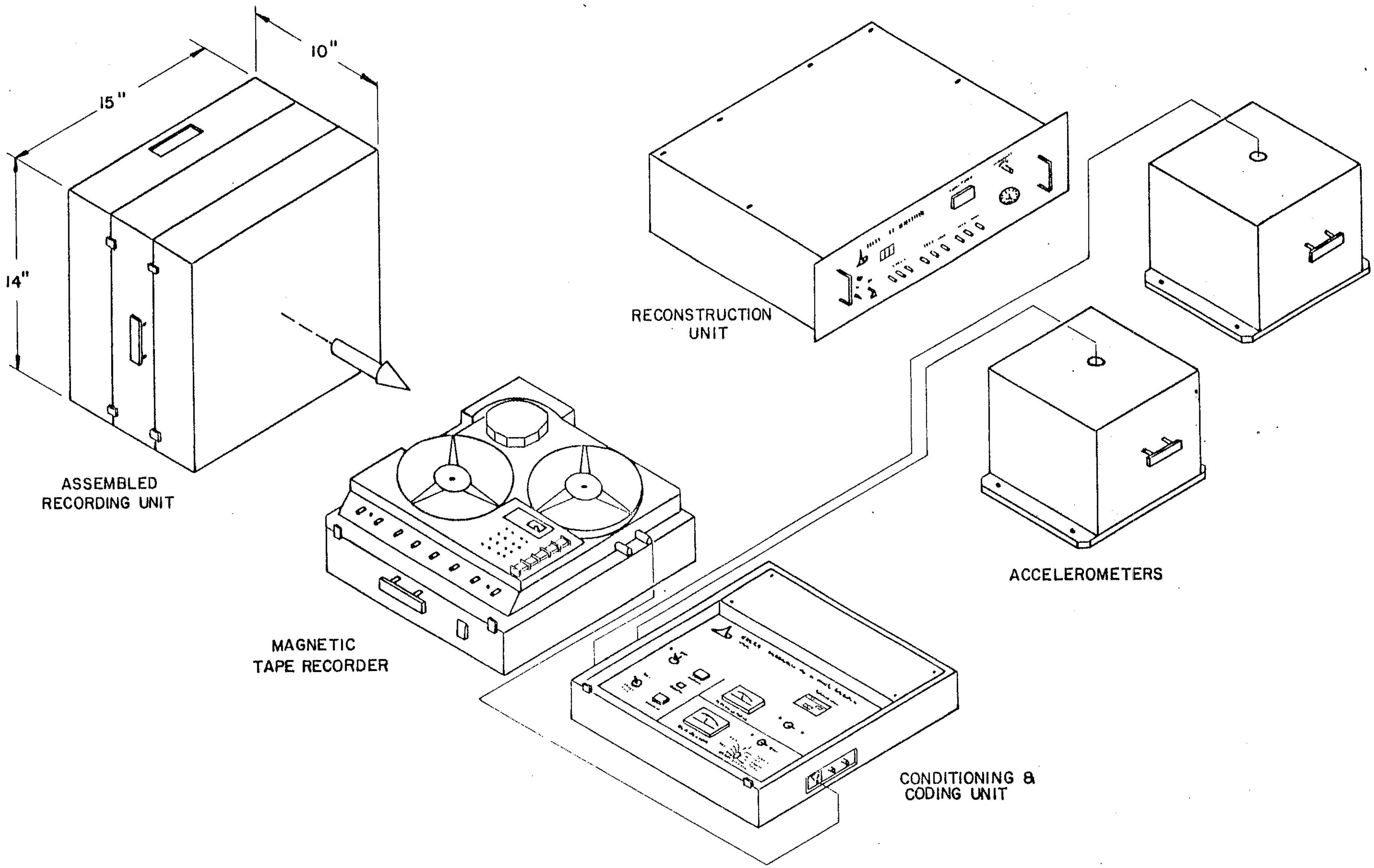


Figure 2-2. FRA/ENSCO Portable Ride Quality Package

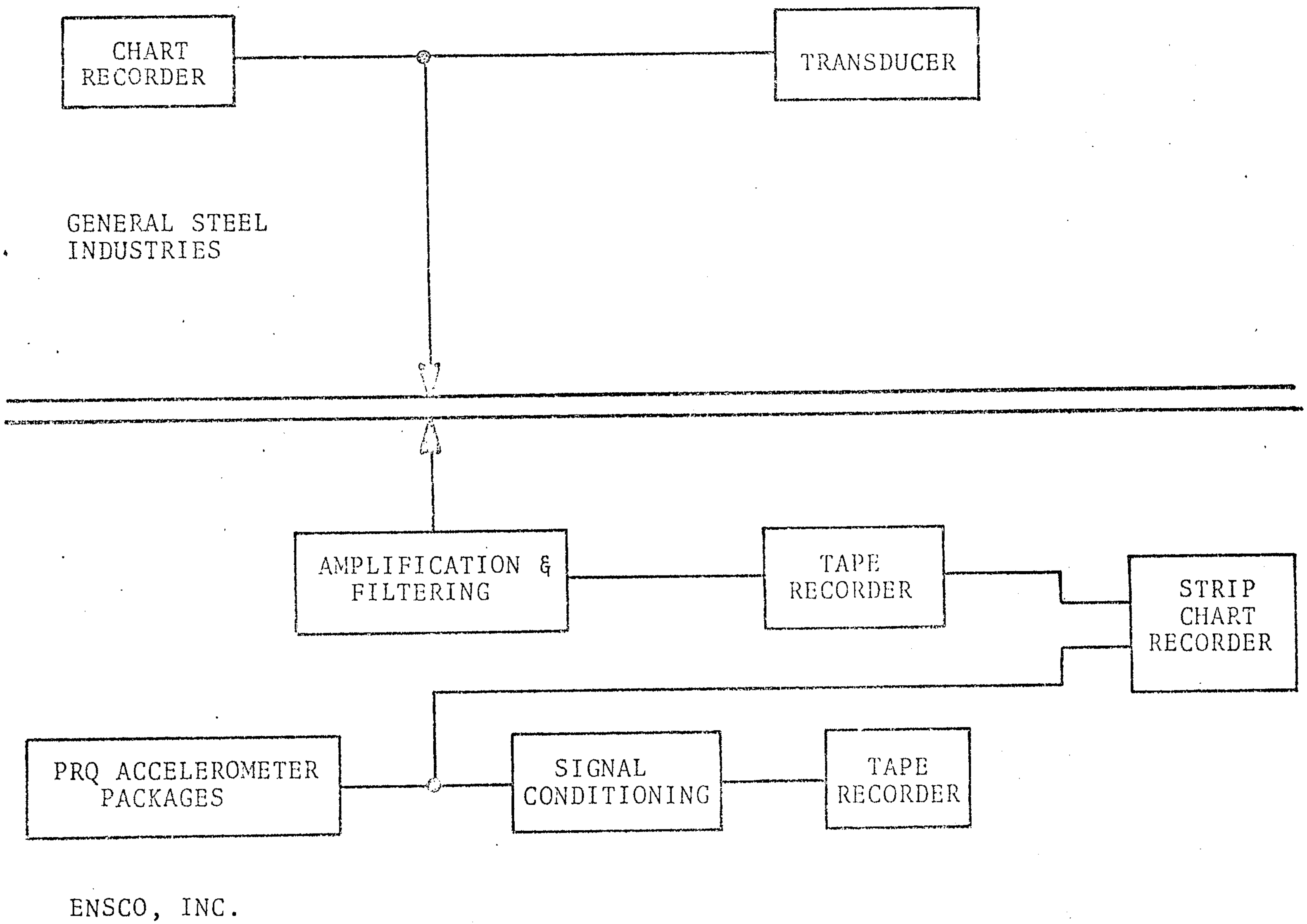


Figure 2-3. Transducer Signal Flow

The results were tabulated and submitted to FRA. Table 2-2 is a summary of the tests conducted. Figure 2-4 shows the locations of the ride-quality accelerometers.

2.2 INSTRUMENTATION

The portable data collection system, known as the Portable Ride Quality Package (Figure 2-2) was used to collect vehicle acceleration data. This data collection system consists of a magnetic tape recorder, a signal conditioning and coding unit, and two accelerometer packages. Each accelerometer package contains three linear accelerometers and three angular accelerometers. For this test, only the linear accelerometers of each package were used. Table 2-3 lists the accelerometer characteristics.

The signal conditioning and coding unit converts the current output of each accelerometer to a proportional signal voltage suitable for recording. The unit provides metering for signal monitoring and calibration. The unit also contains batteries, and associated charging and regulator circuits which provide power to the system if a-c power is not available. The magnetic tape recorder accommodates eight channels of data. Six channels are used for recording accelerometer signals. The seventh channel is used for a multiplex recording of two external data signals, an internally generated digital annotation and a reference signal. A channel is also provided for voice annotation. Appendix C contains a more detailed description of the hardware.

A Brush chart recorder was used to display the data during the test. This allowed onboard analysis of the data and provided a means for validation of same. Appendix F provides a sample of the stripped-out data.

TABLE 2-2
SUMMARY OF TESTS CONDUCTED

Test	Date	Sumiride Air Spring	Firestone Air Spring	Rubber Sandwich on Air Spring	Steel Plate on Air Spring	7/8" Orifice	3/4" Orifice	Primary Vertical Damping	Secondary Vertical Damping	Secondary Lateral Damping	Comments	Test Series
1	5/11/77	X		X		X		Inter-Mediate	None	None		Primary Damping Series
2	5/12/77	X		X		X		None				
3	5/12/77	X		X		X		Max.				
4	5/16/77	X		X		X		4 Snubbers Per Truck				
5	5/16/77	X		X		X		2 Snubbers Per Truck				
6	5/17/77	X		X		X		Light				
7	5/25/77	X		X			X	None		Normal		Secondary Vertical Damping Series
8	5/25/77	X		X			X		Medium	Normal		
9	5/26/77	X		X			X		Light	Normal		
10	5/26/77	X		X			X	2 Snubbers Per Truck	None	2 Heavy		Secondary Lateral Damping Series
11	5/26/77	X		X			X	4 Snubbers Per Truck		Normal		
12	6/2/77	X		X			X	None		1 Light		
13	6/2/77	X		X			X			3 Light		
14	6/7/77	X			X		X			Normal		Steel Plate Series
15	6/7/77	X			X		X			1 Light		
16	6/8/77	X			X		X			Normal		
17	6/8/77	X			X		X			3 Light		
18	6/23/77	X		X			X			1 Light	(Best of All Components)	Sumiride
19	7/27/77	X		X			X			1 Light	(Deflated Air Spring Test)	Sumiride
20 (F-1)	7/12/77		X		X		X			1 Light		Firestone Damping/ Steel Plate Series
21 (F-2)	7/12/77		X		X		X			2 Light		
22 (F-3)	7/15/77		X	X			X					
23 (F-4)	7/15/77		X	X			X			1 Light		
24 (F-5)	7/26/77		X	X			X			1 Light	(Best of All Components)	Firestone
	8/29/77	822 Versus 855 Comparison										

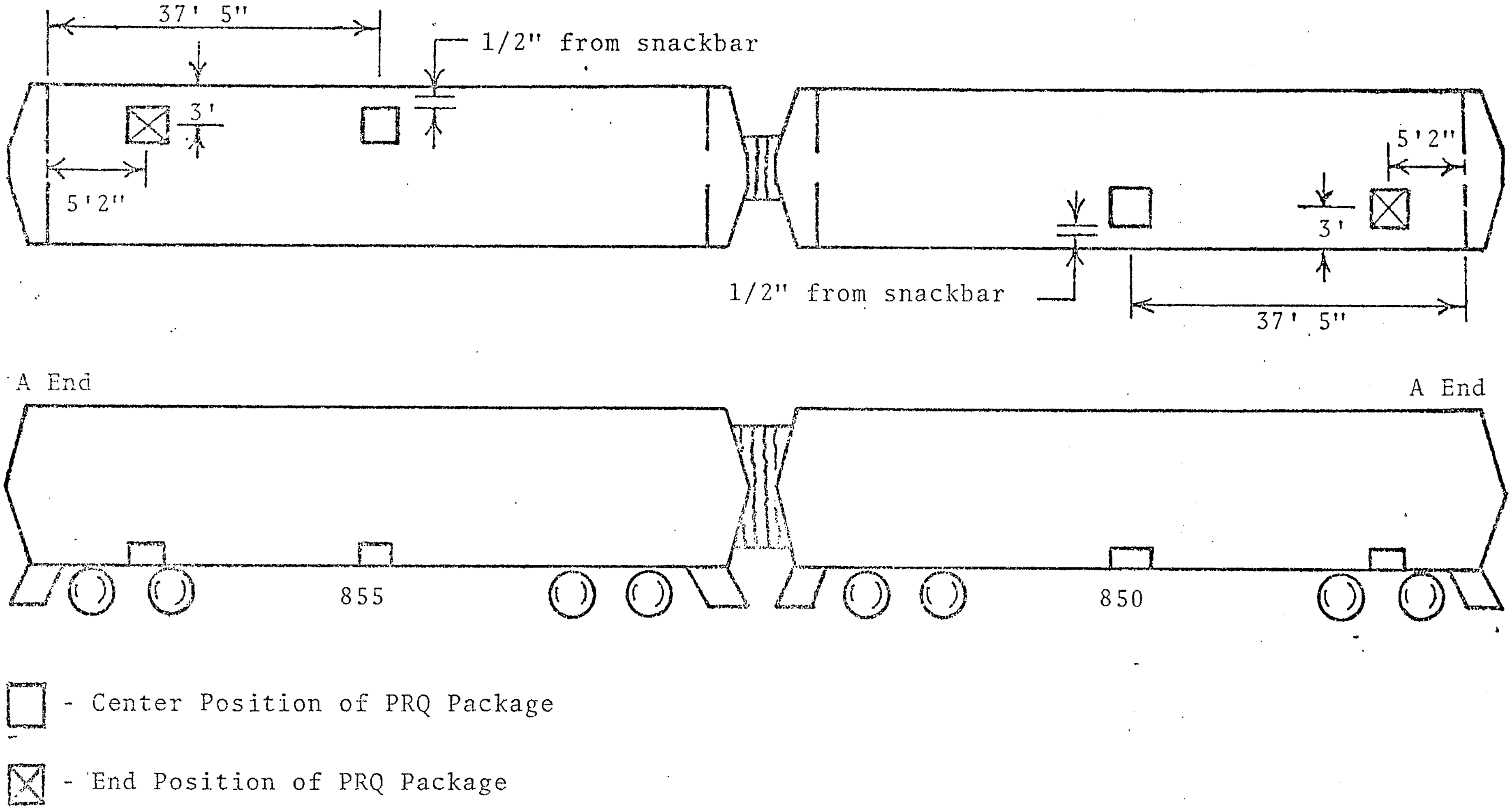


Figure 2-4. Locations of Portable Ride-Quality Accelerometers

TABLE 2-3
ACCELEROMETER CHARACTERISTICS

Accelerometer	Measurement Axis	Full-Scale Reading
Package No. E	Vertical Longitudinal Lateral	1 g 1 g 1 g
Package No. F	Vertical Longitudinal Lateral	1 g 1 g 1 g

In addition GSI installed displacement transducers on the trucks and strain gages on the bolster; GSI also placed carbody accelerometers in both cars. Table 2-4 is a list of signals that were recorded during the test.

GSI also placed accelerometers in the carbodies to measure accelerations related to vehicle ride quality. The GSI ride quality accelerometers were located (at different times) in both the center and the leading ends of the Metroliners.

2.3 TEST PROCEDURE

The Metroliner truck improvement test series was conducted on Northeast Corridor trackage between Wilmington, DE and Baltimore, MD. A siding adjacent to the Wilmington shops commonly referred to as the "Naught" track was used to conduct rock and roll tests and to perform system checkouts prior to daily testing.

Two Amtrak Metroliners made up the test consist. Both were snack-bar coaches of the type typically found in daily service between New York and Washington. One Metroliner (the 850) had been used in previous test programs and was chosen to ride on the improved trucks. The other Metroliner (the 855), also used in previous test programs, had its trucks

TABLE 2-4

SIGNALS RECORDED DURING TEST

Signal	Collected By		Recorded At Various Times by ENSCO
	ENSCO	GSI	
1. Vertical Carbody Acceleration (850)	X	X	X
2. Lateral Carbody Acceleration (850)	X	X	X
3. Longitudinal Carbody Acceleration (850)	X	X	X
4. Vertical Carbody Acceleration (855)	X	X	X
5. Lateral Carbody Acceleration (855)	X	X	X
6. Longitudinal Carbody Acceleration (855)	X	X	X
7. Car Yaw		X	X
8. Car Lateral - A end (850)		X	X
9. Car Bounce		X	X
10. Car Pitch		X	X
11. Car Roll		X	X
12. Truck Bounce		X	X
13. Truck Pitch		X	X
14. Truck Roll		X	X
15. Truck Swivel		X	X
16. Carbody Roll Angle (850)		X	X
17. Carbody Roll Angle (855)		X	X
18. Car Lateral Motion B end (850)		X	X
19. Car Lateral Motion B end (855)		X	X
20. Car Lateral Motion A end (855)		X	X
21. Bolster Strain Gage		X	X

and suspension components overhauled and brought to an improved condition. This coach was used to provide a comparison between the new and existing trucks. All work was performed at the Amtrak facility by shop personnel and directed by engineering personnel from General Steel Industries (GSI).

Test personnel from GSI installed displacement transducers, strain gages, and accelerometers on the two cars to obtain data for their analysis. ENSCO test personnel installed the FRA/ENSCO portable ride quality package to record vehicle acceleration information and a 14-channel recorder to record selected GSI signals.

Prior to testing, each Metroliner was ballasted to simulate a seated passenger-load. A safety inspection was performed to insure that instruments were properly anchored.

After the consist had been instrumented, GSI and ENSCO personnel calibrated their instruments. Calibration was performed every test day prior to leaving the yard and at appropriate intervals during the test. Rock and roll tests were performed on the "Naught" track for each suspension configuration. At the conclusion of each day's test the ride quality instrumentation was post-test calibrated.

During each test, data was recorded and displayed by GSI on their oscillographs. Data was collected on tape for specific test zones (Table 2-1); however it would have been impractical to display all data. Therefore, ENSCO personnel displayed data from Metroliner 850 and 855 vertical and lateral accelerometers between Mileposts 33-36 and 49-54. At the end of each test series, GSI sections of the data were reproduced from the ENSCO 14-channel recorder to ensure that the recording system was operating properly.

Table 2-5 is a listing of the test number, date and suspension configuration used during each test. The Sumiride air spring suspension was the first configuration tested. All tests between 11 May and 23 June 1977 were made to select the best configuration to be used on the suspension system.

GSI chose what they considered to be the best suspension combination using the Sumiride air spring and supervised the modifications to implement the changes. On 23 and 24 June 1977, the best-of-all-components test (Sumiride) was run and data was collected as previously outlined.

For the first southbound run, Metroliner 850 led the two-car consist and the ride quality packages were located in the A-ends of each car (leading end of 850, trailing end of 855). The northbound run was made with the ride quality packages in the center of each car. During the southbound runs speeds of 130 mph were attained.

The train was wyed (turned end-for-end) at Wilmington and the test repeated with 855 (equipped with standard trucks) leading southbound. Ride quality packages were in the same locations as when 850 was leading. This second series of runs was designed to obtain data related to car position.

After all of the "best-of-all-components tests" had been run, a deflated air bag test was performed and then the Firestone air spring suspension testing was started.

In order to observe the effects of a sudden air spring failure and to measure ride quality acceleration data after such a failure, two tests were performed on 27 June 1977. All components used during the "best-of-all components" test were used for the deflated air spring test.

TABLE 2-5

DETAILED TEST ZONES

Test No.	Date	Configuration
1	11 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 7/8-inch orifice. - Intermediate shocks on primary suspension. - No vertical secondary dampers. - No lateral secondary dampers.
2	12 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 7/8-inch orifice. - No primary vertical dampers. - No secondary vertical damping. - No secondary lateral damping.
3	12 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 7/8-inch orifice. - Maximum shock absorbers on primary vertical suspension. - No secondary vertical damping. - No secondary lateral damping.
4	16 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 7/8-inch orifice. - Four friction snubbers per truck for vertical primary damping. - No vertical secondary damping. - No lateral secondary damping.

TABLE 2-5 (CONT.)
DETAILED TEST ZONES

Test No.	Date	Configuration
5	16 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 7/8-inch orifice. - Two friction snubbers per truck for vertical primary damping. - No vertical secondary damping. - No lateral secondary damping.
6	17 May 1977	- Sumiride air spring. - Rubber sandwich over air spring. - 7/8-inch orifice. - Light shock absorbers on primary vertical suspension. - No vertical secondary damping. - No lateral secondary damping.
7	25 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - No primary damping. - No vertical secondary damping. - Normal secondary lateral damping.
8	25 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - No primary damping. - Medium vertical secondary damping. - Normal secondary lateral damping.

TABLE 2-5 (CONT.)

DETAILED TEST ZONES

Test No.	Date	Configuration
9	26 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - No primary damping. - Light vertical secondary damping. - Normal lateral damping.
10	26 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - Primary damping (two friction snubbers per truck). - No vertical secondary damping. - Two notch heavy secondary lateral damping.
11	26 May 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - Primary damping (four friction snubbers per truck). - No vertical secondary damping. - Normal lateral damping.
12	2 June 1977	- Sumiride air spring. - Rubber sandwich on air spring. - 3/4-inch orifice. - No primary damping. - No vertical secondary damping. - One notch light lateral secondary damping.

TABLE 2-5 (CONT.)
DETAILED TEST ZONES

Test No.	Date	Configuration
13	2 June 1977	- Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - No primary damping. - No vertical secondary damping. - Three notch light lateral secondary damping.
14	7 June 1977	- Sumiride air spring. - Steel plate on air spring. - 3/4-inch orifice. - No primary damping. - No secondary vertical damping. - Normal lateral secondary damping.
15	7 June 1977	- Sumiride air spring. - Steel plate on top of air spring. - 3/4-inch orifice. - No primary damping. - No secondary vertical damping. - One notch light lateral secondary damping.
16	8 June 1977	- Sumiride air spring. - Steel plate over air spring. - 3/4-inch orifice. - No primary damping. - No secondary vertical damping. - Normal lateral secondary damping.

TABLE 2-5 (CONT.)
DETAILED TEST ZONES

Test No.	Date	Configuration
17	8 June 1977	- Sumiride air spring. - Steel plate over air spring. - 3/4-inch orifice. - No primary damping. - No secondary vertical damping. - Three notch light lateral damping.
18	23 June 1977 & 24 June 1977	- Best of all components tests. - Sumiride air spring. - Rubber sandwich on top of air spring. - 3/4-inch orifice. - No primary vertical damping. - No secondary vertical damping. - One notch light lateral damping.
19	27 June 1977	- Deflated air spring test (same components as Test 18).
20 (F-1)	12 July 1977	- Firestone air spring. - Steel plate on top of air spring. - No primary damping. - No external vertical secondary damping. - One notch light lateral damping. - 3/4-inch orifice.
21 (F-2)	12 July 1977	- Firestone air spring. - Steel plate on top of air spring. - No primary damping. - No external secondary vertical damping. - Two notches heavy lateral. - 3/4-inch orifice.

TABLE 2-5 (CONT.)
DETAILED TEST ZONES

Test No.	Date	Configuration
22 (F-3)	15 July 1977	- Firestone air spring. - Rubber sandwich over air spring. - 3/4-inch orifice. - No vertical primary damping. - No vertical secondary damping. - Normal lateral damping.
23 (F-4)	15 July 1977	- Firestone air spring. - Rubber sandwich over air spring. - 3/4-inch orifice. - No vertical primary damping. - No vertical secondary damping. - One notch light lateral damping.
24 (F-5)	26 July 1977 & 27 July 1977	- "Best of all components tests". - Firestone air spring. - Rubber sandwich over air spring. - 3/4-inch orifice. - No primary vertical damping. - No vertical secondary damping. - One notch light lateral damping.

The first test was a static test performed at the Wilmington shops, and involved observing the 850 Metroliner tilt as the air was exhausted from the air bag to simulate an air spring failure. The second test was a dynamic test which consisted of running the 850/855 Metroliner consist over revenue track at various speeds up to 105 mph with one set of air springs deflated.

The static test was performed as follows:

- Plumb bobs were hung from the ceiling at both the A- and B-ends of the 850 Metroliner.
- All air springs were inflated to normal operating pressures.
- Zero marks were placed on the car floor beneath the plumb bobs.
- The B-end air spring set had its left side gage removed (leaving an open 3/4-inch pipe hole) and the air inside was allowed to escape.
- The time required to exhaust the air spring set was recorded.
- The maximum excursion of each plumb bob was recorded.

With the B-end air spring set deflated, ride quality acceleration signals and GSI displacement transducer signals were recorded. The ride quality acceleration packages were located on the A-and B-ends of the 850 Metroliner (Figure 2-5). The 850 Metroliner was equipped with the same "best-of-all-components" as in the "best-of-all-components" test. Test zones for this test consisted of trackage between Wilmington and Baltimore, Milepost 29.6 to Milepost 38. Additional data was collected northbound from Milepost 30 to Wilmington Station in order to record ride quality acceleration data through several interlockings.

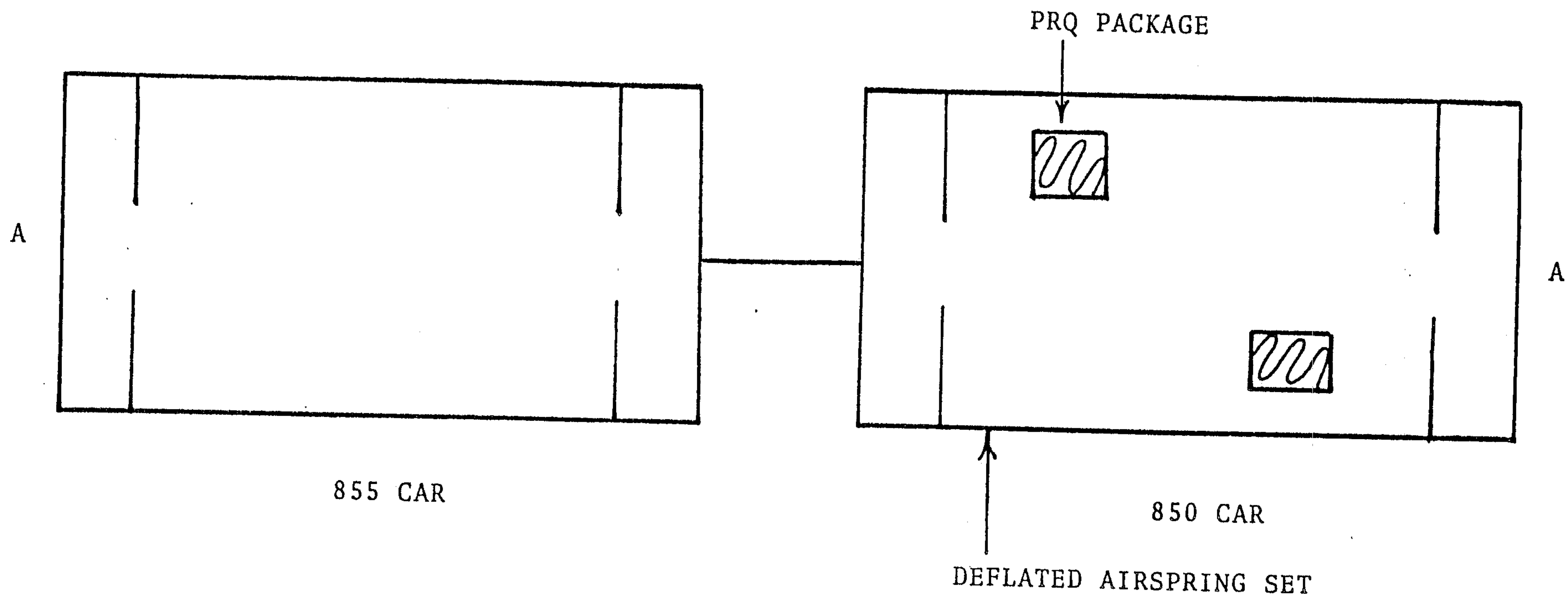


Figure 2-5. Placement of PRQ Packages for Deflated Air Apring Test

The Firestone tests were similar to the Sumiride tests as the general test procedures, ballasting, changeovers, etc., were all the same. However, based on the results from the Sumiride tests it was found that fewer actual tests were necessary. On 26 July 1977, the "best-of-all-components" test for the Firestone air spring was performed. The testing extended through 27 July 1977 and was done the same way as the Sumiride "best-of-all-components" tests.

On 11 July 1977, a bolster strain gage circuit which GSI installed on the A-end truck of the 850 Metroliner was connected to an amplifier and signal conditioning electronics by ENSCO test personnel. Data was collected and recorded on the 14-channel recorder for post-test analysis of bolster fatigue. The strain gage bridge was calibrated by ENSCO and GSI personnel at the end of the entire test series.

At the onset of testing, some questions concerning the repeatability and uniformity of the ride quality accelerometer signals were brought up by GSI test personnel. During random intervals throughout the test both GSI and ENSCO accelerometer packages were placed side by side, calibrated, and their output data were recorded. Both strip chart analysis and PSD plots show precisely the same acceleration levels and frequency response for both packages.

2.4 COMPARISON TEST

In testing the 855/850 Metroliner consist, the general consensus was that the reference vehicle (855 with standard trucks) was an exceptionally good riding car. A separate test was proposed to evaluate the ride of two Metroliners with standard trucks. The trucks under Metroliner 855 had recently been overhauled and were in very good condition. Metroliner 822 was scheduled for overhaul and rode very badly.

Cars scheduled for maintenance were identified and members of Amtrak and ENSCO rode the cars to determine a "seat of the pants" ride description. Metroliner 822 was selected by examining the maintenance records of Metroliners.

The test zone and the test procedures were identical to that of the previous testing. The test zone was Northeast Corridor Trackage between Wilmington and Baltimore. Detailed locations of each test zone are shown in Table 2-6. Ride quality data was collected on both cars during the test.

On the southbound run, Metroliner 855 was in the lead and the instrumentation was located in the A-end (unattached end) of the consist (B-ends are coupled). The consist returned northbound with 822 in the lead and the instrumentation located in the center of the car.

At Wilmington, the train wyed (turned end-to-end) and returned southbound with 822 in the lead. The instrumenation was relocated in the A-end of the vehicle. On the northbound run, the packages were again relocated to the center of the car.

Vertical, lateral and longitudinal accelerations were recorded while travelling each test zone. Speeds of 50, 90 and 105 mph were attained over a particular test zone. However, two of the 105-mph zones were missed due to heavy traffic.

TABLE 2-6

TEST ZONES - COMPARISON TESTS

Direction of Travel	Milepost	Leading Car	Package Location	Speed (mph)	Track Class	Track No.	Rail Type
Southbound	35.0 - 36.5	855	Rear	50	4	4	Bolted
	44.0 - 45.0			90	6	3	Welded
	49.0 - 51.0			90	6	3	Bolted
	51.0 - 52.0			Track	6	3	Interlocking
	52.0 - 54.0			90	6	3	Welded
	62.5 - 64.0			50	6	3	Welded
	73.0 - 75.0			105	6	3	Welded
Northbound	69.5 - 68.0	822	Center	50	4	3	Bolted
	61.5 - 60.5			50	6	1	Bolted
	56.5 - 54.0			90	6	2	Welded
	48.0 - 45.0			105	6	2	Welded
	38.0 - 35.0			105	6	2	Welded
	34.0 - 33.0			50	6	2	Welded
Southbound	35.0 - 36.5	822*	Rear	50	4	4	Bolted
	44.0 - 45.0			90	6	3	Welded
	49.0 - 51.0			90	6	3	Bolted
	51.0 - 52.0			Track	6	3	Interlocking
	52.0 - 54.0			90	6	3	Welded
	62.5 - 64.0			50	6	3	Welded
	73.0 - 75.0			105	6	3	Welded
Northbound	69.5 - 68.0	855	Center	50	4	3	Bolted
	61.5 - 60.5			50	6	1	Bolted
	56.5 - 54.0			90	6	2	Welded
	48.0 - 45.0			105	6	2	Welded
	38.0 - 35.0			105	6	2	Welded
	34.0 - 33.0			50	6	2	Welded

*Turn cars at Wilmington.

3.0 DATA REDUCTION

3.1 STRIP CHART ANALYSIS

As part of the instrumentation, a 6-channel Brush chart recorder was onboard for all the 850/855 testing. It was used to monitor the recording of the available GSI signals. The accelerations were displayed so that the response of the vehicles as they passed through the test zone could be visually monitored. The Brush Chart recorder was used to compare the responses of the modified suspension to that of the standard truck. Particular emphasis was placed on peak-to-peak amplitudes observed as the Metroliners crossed switches, road crossings, and sections of track which tended to force the truck suspension at the resonant frequency of the truck or carbody. From these data comparisons, preliminary conclusions were drawn as to the ride quality of the vehicles.

During the suspension system changes, the strip charts were analyzed to determine the effect of changing a certain component. This information was provided to GSI to support their selection of the optimum suspension configuration.

3.2 SOFTWARE ANALYSIS

The analog data tapes from the ride quality system were returned to Alexandria, VA for processing. The analog data was digitized at 128 Hz using the ENSCO RDS-500 computer system. The signals were low-pass filtered using a four-pole, Bessel, programmable filter prior to being digitized. The corner frequency was set at 20 Hz. The characteristics of the filters are:

- The signal is two db down at 20 Hz.
- The signal falls off at approximately 12 db/octave between 20 and 40 Hz.
- The signal falls off at 24 db/octave above 40 Hz.

Plots of the data were generated by the computer from the digitized data. From this data and the test log, the segments for data reduction were selected.

The data was reduced using a digital computer program. The output of the program includes:

- Standard deviations
- Probability density estimates
- distribution function estimates
- RMS acceleration plots
- ISO ride evaluation formats
- Power spectral density plots
- Wz ratings

A more detailed description of this program is given in Appendix D. In addition, Appendix E gives a sample of the software output. Copies of the PSD plots are included in Appendices H, I, and J.

3.3 RIDE QUALITY CRITERIA

In order to allow a direct comparative analysis between the improved Metroliner (850) and the standard Metroliner (855), a Ride Quality Acceptance Criteria was established. This criteria was divided into two discrete classifications:

- Determining whether the ride quality of one vehicle was better than the ride quality of the other.

- Determining how much better the ride quality of one vehicle was relative to the other.

By definition, Vehicle A will be the 855 (standard) Metroliner, and Vehicle B will be the 850 (improved) Metroliner.

Phase 1

Three tests at three different speeds were chosen from the entire "best of all components" test series. There were two different locations for the instrumentation packages and two consist positions. One was the A-end of each vehicle, and the other was the center of each vehicle. This yields a maximum of 12 data points which can be used for comparison. For each test chosen, the analysis produced four means of comparison:

- Exposure time as determined by the International Standards Organization (ISO).
- The standard deviation of the data from the mean.
- The peak value associated with the RMS data plotted.
- 99.5-percent levels.

In order to provide for a comparison between the two vehicles using the four methods mentioned in the preceding paragraph, a point system was developed. Points are scored as follows:

If ISO Reduced Comfort Exposure Time (A)	-	ISO Reduced Comfort Exposure Time (B)	< 0
If Standard Deviation (a)	-	Standard Deviation (B)	> 0
If RMS Peak Value (A)	-	RMS Peak Value (B)	> 0
If Value of 99 percent-Level (A)	-	Value of 99 percent Level (B)	> 0

This gives a maximum total of 48 comparison points. After comparison, the points are tallied, and the quality of the ride is determined as follows:

Percentage that Car B Scores a Point	Quality of Ride, Car B With Respect to Car A	Next Step
< 50	Not better than	--
> 50	Possibly better than	Phase 2

Conclusions can then be drawn that the ride of Car B is not better than, possibly better than, or better than the ride of Car A.

Phase 2

Assuming Phase 1 of the ride quality comparison has been completed and one vehicle rides better than the other, it is necessary to determine how much better the vehicle rode relative to the other. An analysis similar to the one used in Phase 1 may also be used for Phase 2. Since the Phase 2 analysis is an attempt to determine how much better the ride of one vehicle is as compared to another, the idea of using a ratio (B vehicle/A vehicle) is particularly simple to visualize.

For the same tests chosen in Phase 1, the following criteria may be used to establish another point system for comparison:

IF:

$$\frac{\text{ISO Reduced Comfort Exp Time}_B}{\text{ISO Reduced Comfort Exp Time}_A} > \begin{cases} 2.0 & \text{(Vertical)} \\ 1.5 & \text{(Lateral)} \end{cases}$$

$$\frac{\text{Stand Dev}_B}{\text{Stand Dev}_A} < \begin{cases} 0.70 & \text{(Vertical)} \\ 0.75 & \text{(Lateral)} \end{cases}$$

$$\frac{\text{RMS Peak}_B}{\text{RMS Peak}_A} < \begin{cases} 0.85 & \text{(Vertical)} \\ 0.85 & \text{(Lateral)} \end{cases}$$

$$\frac{\text{99-Percent Level}_B}{\text{99-Percent Level}_A} < \begin{cases} 0.70 & \text{(Vertical)} \\ 0.75 & \text{(Lateral)} \end{cases}$$

Each time the criteria is met, a point is scored. No points are scored for ratios less than or equal to the number chosen. This point system again involves 48 comparison points as in Phase 1. Similarly a chart may be set up which describes how much better one vehicle rides than the other.

Percentage that Car B Scores a Point	Quality of Ride Car B With Respect to Car A
< 25	Slightly better than
25 - 75	Better than
> 75	Significantly better than

Based on the point totals for the better riding vehicle and referring to the chart above, one may determine how much better one vehicle rides than the other.

Figure 3-1 summarizes the ride quality specification. Figure 3-2 lists the variables used and possible outcomes. Finally, Figure 3-3 and 3-4 give a sample of the tables to be filled out when investigating the criteria.

LEVEL 1

POINTS ARE SCORED IF:

ISO	: 850 ≥ 855
ST. DEV.	: 850 ≤ 855
RMS PEAK	: 850 ≤ 855
99%	: 850 ≤ 855

RATING:

< 50% - NOT BETTER THAN

> 50% - POSSIBLY BETTER THAN

LEVEL 2

ISO	: 850/855	≥ 2.0 Vertical 1.5 Lateral
ST. DEV.	: 850/855	≤ 0.70 Vertical 0.75 Lateral
RMS PEAK	: 850/855	≤ 0.85
99%	: 850/855	≤ 0.70 Vertical 0.75 Lateral

RATING:

< 25% - SLIGHTLY BETTER THAN

25-75% - BETTER THAN

> 75% - SIGNIFICANTLY BETTER THAN

Figure 3-1. Ride Quality Specification

LEVEL 1: DETERMINE IF ONE VEHICLE RIDES BETTER

LEVEL 2: DETERMINE IF THE DIFFERENCE IS SIGNIFICANT

<u>VARIABLES</u>

CONSIST POSITION	2
SPEED	3
LATERAL AND VERTICAL	2
INSTRUMENTATION LOCATION	2
RIDE QUALITY CRITERIA	4
(ISO,ST.DEV., RMS PEAK, 99%)	
	96 POSSIBLE OUTCOMES

Figure 3-2. Ride Quality Variables and Possible Outcomes

Test: ______________________

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO 850	ISO 855	STANDARD DEVIATION 850	STANDARD DEVIATION 855	RMS PEAK VALUE 850	RMS PEAK VALUE 855	99% LEVEL 850	99% LEVEL 855
"A" TRUCK	LATERAL									
	VERTICAL									
CAR CENTER	LATERAL									
	VERTICAL									

POINTS: 855 ________ 850 ________ TOTAL ________

________ ________ RATING ____________

Figure 3-3. Sample Level One Comparison Chart

Test: ____________________

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO			STANDARD DEVIATION			RMS PEAK VALUE			99% LEVEL		
			850/855	NO	YES	850/855	NO	YES	850/855	NO	YES	850/855	NO	YES
"A"	LATERAL													
TRUCK	VERTICAL													
	LATERAL													
CAR														
CENTER	VERTICAL													

POINTS: NO _____ YES _____ TOTAL _____

RATING ____________

Figure 3-4. Sample Level Two Comparison Chart

4.0 RESULTS

4.1 SUMIRIDE VERTICAL DAMPING TESTS

The first series of tests during the Metroliner Improvement Program involved changes to the primary suspension system in the vertical mode. Over a period of seven days, the following conditions were set on the vertical dampers of the suspension system:

- Intermediate setting on the shock absorbers
- Zero damping (no shock absorbers)
- Maximum setting on the shock absorbers
- Maximum setting on the friction snubbers (four friction snubbers)
- Half setting on friction snubbers (two friction snubbers)
- Light setting on shock absorbers

For this series the zones were selected at operating speeds of 40 and 90 mph and examined for various types of rail (bolted, welded, interlocking). Lateral and vertical carbody accelerations were examined for each zone. At 40 mph, carbody vertical acceleration, truck bounce, truck roll, and truck pitch were also examined to determine whether there were any differences between tests. Based on these strip chart displays of recorded GSI suspension data and ENSCO ride quality data, several conclusions were drawn.

The use of shock absorbers in conjunction with primary springs does not cause appreciable differences in truck bounce, roll, or pitch. The use of shock absorbers does not appear to influence vertical accelerations felt within the carbody.

The use of friction snubbers produced little or no change in the displayed motions. When the number of friction snubbers was reduced by half, no detectable difference was recorded.

Lateral accelerations in the 850 Metroliner were just slightly greater than those on the 855 Metroliner. This percentage is nearly consistant for all vertical-damping-variation tests. The vertical accelerations in the 850 Metroliner were slightly less (21 percent) than those in the 855 Metroliner.

A comparison was also made between Northbound and Southbound runs. The ride quality on these runs was comparable, indicating that there was little difference when the 850 or the 855 Metroliner was leading the consist.

4.2 SUMIRIDE ORIFICE VARIATION

Within the Sumiride air spring (Figure 4-1) there is an orifice or choke, which allows air to exhaust from the air spring into the bolster reservoir. Two orifice diameters (7/8 and 3/4 inch) were used by GSI to determine how much the ride changed by varying the size of the orifice.

To assist in making the determination as to which type of orifice produced the best ride, ENSCO personnel generated PSD plots. The data were collected by using the Portable Ride Quality Package located in the center of each car and PSD plots were developed by using a Ubiquitious Spectrum Analyzer and a Nicolet Print Plotter.

Sections of data (from Test 2 (5/12/77) and Test 8 (5/25/77)) which were analyzed and plotted were all taken from a 20-mph, southbound, test run on Track 4 (bolted rail) from about Milepost 30 to Milepost 31.

Test 2 (5/12/77) had no external dampers attached. However, for Test 8 (5/25/77) the lateral dampers were attached. This should not have significantly affected the data.

Copies of the PSD plots are shown in Figures 4-2 and 4-3. Notice that the curves are very similar in the regions above 11 Hz. The only real difference appears between zero Hz and 11 Hz and is primarily at four Hz. GSI decided to continue using the 3/4 inch orifice in spite of the results which showed the PSD plots to be similar. These plots showed that it was difficult to determine the relative merits of one orifice as compared to another.

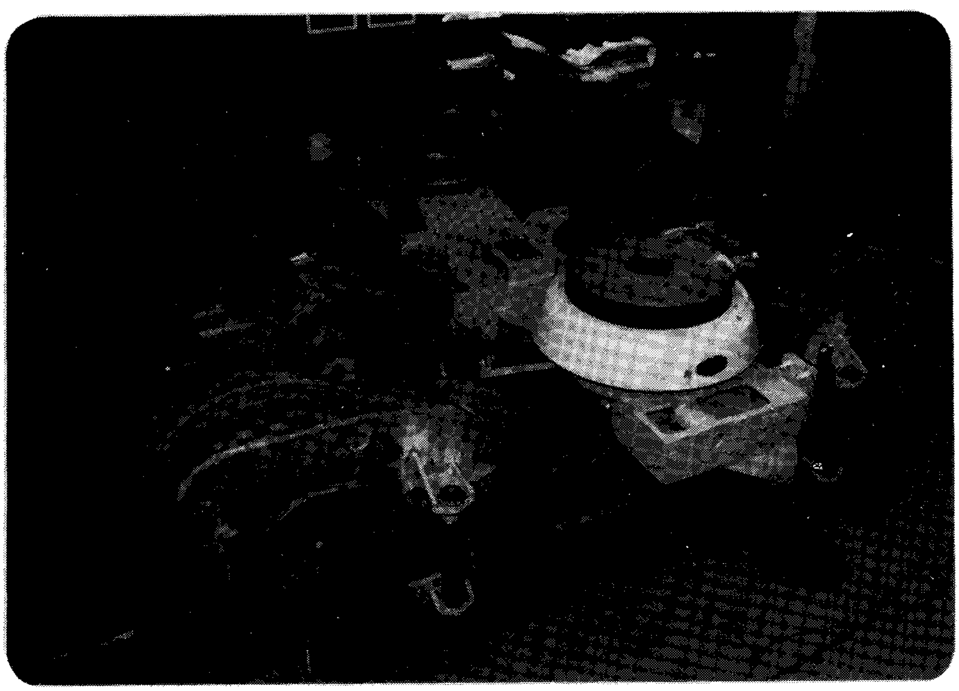


Figure 4-1. Sumiride Air Spring

TEST 8 25 MAY 1977
NO VERTICAL DAMPING
NORMAL LATERAL DAMPING
≈MP 30 20 MPH TRACK 4
850 CAR
VERTICAL ACCELERATION DATA FROM
PRQ DATA 3/4 INCH ORIFICE

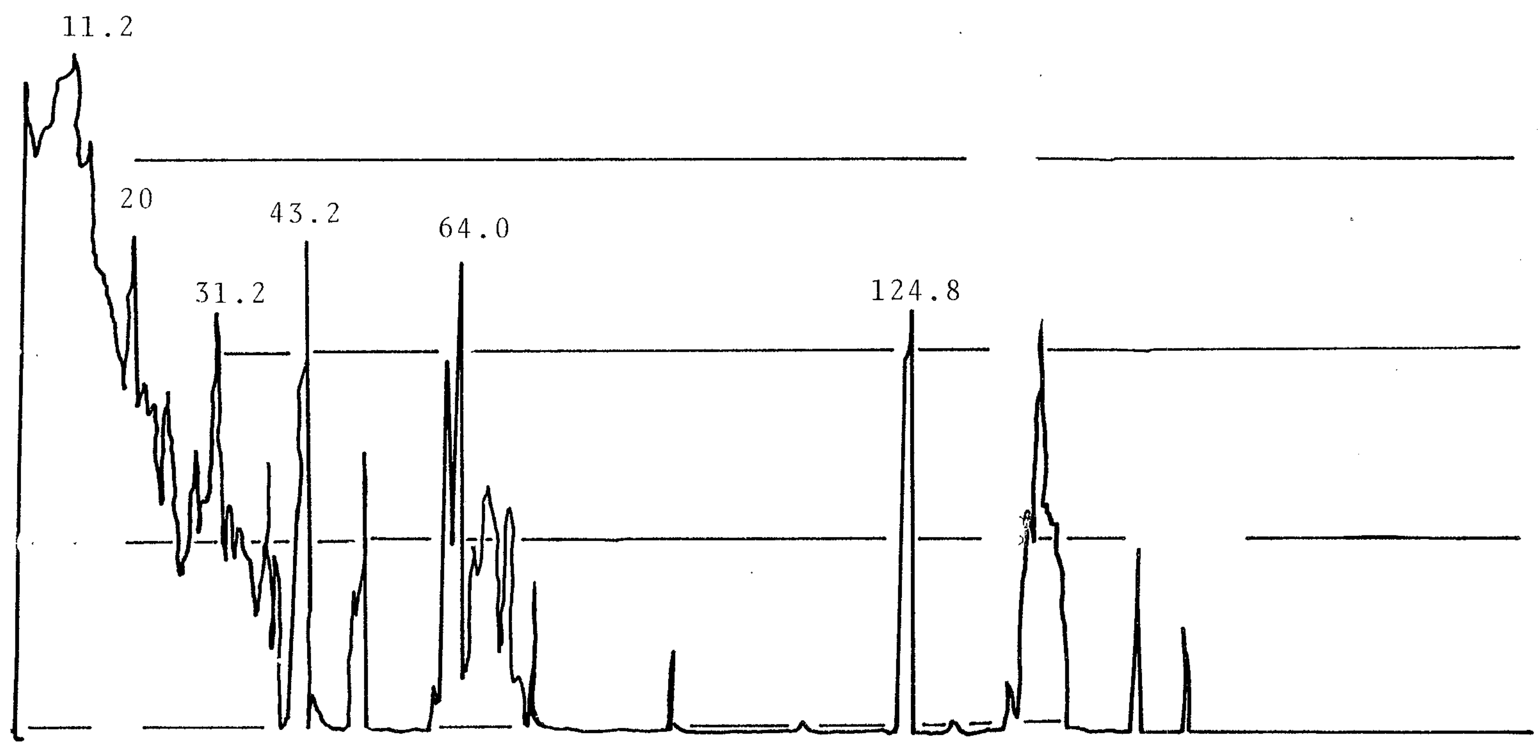


FIGURE 4-2. VERITICAL ACCELEROMETER DATA USING 3/4 INCH-ORIFICE

TEST 2--12 MAY 1977

NO DAMPING

MP 30 SOUTHBOUND
20 MPH TRACK 4
850 CAR FROM PRQ DATA (VERTICAL ACCEL.)
7/8 ORIFICE

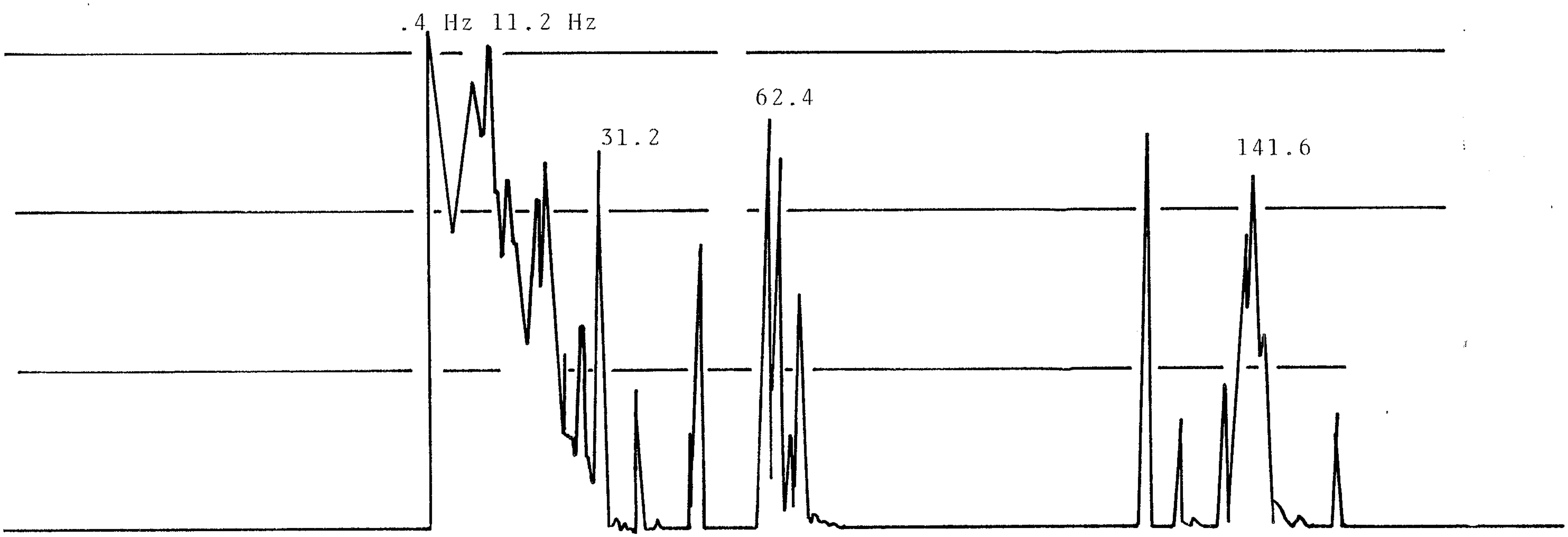


FIGURE 4-3. VERTICAL ACCELEROMETER DATA USING 7/8-INCH ORIFICE

4.3 SUMIRIDE PLATE/SANDWICH

On the modified truck, GSI made provision for the installation of a rubber or steel pad between the Sumiride or Firestone air spring and the carbody. Tests were conducted using both a steel plate and a rubber sandwich.

GSI selected and installed the rubber sandwich for the "best-of-all-components" tests for both the Sumiride and the Firestone air springs. At slow speeds (0-60 mph), vertical ride was not noticeably affected by using the steel plate on top of the air springs instead of the rubber sandwich. The 850 Metroliner (with improved trucks) experienced vertical accelerations which were approximately 25 percent less than those experienced by the 855 Metroliner (with standard trucks). At high speeds (60-99 mph), no significant difference was observed in the vertical accelerations measured in the two Metroliners.

Lateral accelerations in the 850 Metroliner were not significantly changed by using the steel plate over the air spring. The ride quality measurement equipment was located in the center of both vehicles where it is particularly insensitive to yawing motion. Therefore, no conclusions can be drawn as to the effect of the steel plate on yawing motion.

4.4 SUMIRIDE LATERAL DAMPING

Lateral damping tests were conducted on Metroliner 850 (with improved trucks) to determine how the damping would affect lateral ride quality. The air spring can affect lateral damping to some extent but has little effect when compared to external dampers.

The lateral damping tests indicated that the lateral accelerations within Metroliner 850 were equivalent to those within Metroliner 855. No significant differences were found in lateral damping with the dampers adjusted to normal, one-notch light or three-notches light.

However, strip-chart displays indicated that the sharpness of the acceleration traces decreased when the lateral dumping was decreased. The vehicle appeared to oscillate more before coming to rest with one-notch light damping and this tendency was more pronounced with the three-notch light damping setting.

The lateral accelerations of both cars (850 and 855) were similar for all test runs. The only change between test runs was in the response decay after an initial acceleration. With heavy damping, the decay period was shorter than with normal or light damping, and the displays on the strip chart appeared as a more distinct series of lateral peaks. With normal or light damping, the accelerations on the strip chart appeared smoother (with less distinct peaks) than with heavy damping. When the damping on the 850 was decreased to three-notches light, the lateral accelerations in both 850 and 855 were similar. When both cars received similar lateral inputs, the 850 tended to oscillate (laterally) for a longer period of time than the 855.

4.5 SUMIRIDE OPTIMUM COMPONENTS TEST

4.5.1 Strip Chart Analysis

During the optimum components test, ride quality accelerations were displayed on a 6-channel Brush chart recorder. During each test, the chart records were visually examined to determine how the cars were riding and to check the data as it was being recorded.

4.5.2 Software Results

After the test, the data was processed using standard software reduction programs. The data is presented in Tables 4-1 and 4-2. For both the vertical and lateral modes, the following information is presented:

- Speed (mph)
- Leading vehicle
- Location of instrumentation
- RMS level (g's)
- ISO exposure time for reduced comfort (hrs)
- Alternate ISO exposure time (hrs)
- 99-percent level (g's)

To interpret these results, it is necessary to define what is meant by ISO reduced comfort exposure time, standard deviation (RMS level), RMS peak value rating (99-percent level), alternate ISO exposure time, and Wz. These parameters are defined in the following paragraphs.

ISO reduced comfort exposure time is a ride evaluation index established by the International Standards Organization. The exposure time system was established by subjecting human subjects to shaker experiments and then tabulating the results. From the tabulated results, curves were established (Figures 4-4 and 4-5) which relate frequency of vibration to human exposure time. To interpret these figures, choose some particular frequency (i.e., 0.2 M/sec^2 = 0.02 g's). By moving vertically from the 16 Hz mark and laterally from the 0.2 M/sec^2 mark, it can be seen that the ISO exposure time for an 8 Hz, 0.2 M/sec^2 acceleration is≃24 hours. Note that the general trend of the ISO reduced comfort curve is to give smaller exposure times to low frequency signals. More detail is presented in Appendix D.

Standard deviation (RMS level) is a statistical approach to evaluating ride quality and relates the mean deviation of all acceleration levels from the average acceleration during the processing time.

RMS peak value is another statistical approach to ride quality level and is simply the root mean square value of the highest acceleration experienced during a given time interval. The RMS peak value is particularly useful in ride quality evaluation since it allows a comparison between peak accelerations experienced within either vehicle. The values for the RMS peak value are given in the next section.

The 99-percent level indicates a range in which 99 percent of the data falls. This provides a means of determining how closely spaced the data is and statistically allows the determination of the limits of the data. The 99 percent level is measured in g.

A discussion of ISO exposure time is presented in Appendix D. W_z rating (a similar criteria) is also discussed in that Appendix. The W_z rating scheme can be used to obtain a better look at the results. Figures 4-6 and 4-7 are plots of W_z as measured at the center of the car and over the A-end truck. ISO exposure time is measured in hours.

4.5.3 Ride Quality Criteria

The previously described point systems were used in conjunction with ride quality data from the "best-of-all-components" test and the results are tabulated in Tables 4-3 through 4-6. Table 4-3 lists the results for Phase 1 with 850 leading and Table 4-4 lists the results for Phase 2. Table 4-5 lists the results for Phase 1 with 855 leading and Table 4-6 lists the results for Phase 2.

One point of emphasis should be made when interpreting the data in Tables 4-3 through 4-6, each category is a discrete presentation of ride quality acceleration data. Although each

TABLE 4-1

LATERAL MODE/SUMIRIDE AIR SPRING

SPEED	VEHICLE IN LEAD	INSTRU. LOCATION	RMS LEVEL (g)		ISO (hrs)		ALT ISO (hrs)		99 % LEVEL (g)		W_Z	
			850	855	850	855	850	855	850	855	850	855
50	850	Rear*	0.020	0.015	5.6	11.1	2.5	4.2	0.059	0.048	2.1	2.0
90			0.033	0.027	2.0	2.9	0.8	1.5	0.098	0.075	2.5	2.4
130			0.041	0.037	1.4	2.1	0.5	0.7	0.120	0.115	2.7	2.6
50		Center	0.011	0.011	22.6	23.8	10.7	10.3	0.030	0.032	1.8	1.8
90			0.017	0.016	10.6	10.0	4.4	4.4	0.048	0.047	2.1	2.1
105			0.020	0.017	6.5	9.0	3.0	4.0	0.057	0.051	2.2	2.1
50	855	Rear	0.019	0.024	6.8	4.0	2.8	2.1	0.058	0.069	2.1	2.3
90			0.038	0.033	1.3	2.3	0.6	0.9	0.110	0.109	2.6	2.5
130			0.047	0.033	0.8	2.8	0.3	0.9	0.137	0.097	2.8	2.5
50		Center	0.011	0.010	24.0	24.0	12.1	14.8	0.028	0.027	1.8	1.7
90			0.018	0.015	9.3	18.2	4.0	6.6	0.049	0.044	2.1	2.0
105			0.020	0.017	7.0	12.2	3.0	4.8	0.055	0.049	2.2	2.1

*Unattached ends of vehicle

TABLE 4-2

VERTICAL MODE/SUMIRIDE AIR SPRING

SPEED	VEHICLE IN LEAD	INSTRU. LOCATION	RMS LEVEL (g)		ISO (hrs)		ALT ISO (hrs)		99% LEVEL (g)		W_Z	
			850	855	850	855	850	855	850	855	850	855
50	850	Rear*	0.033	0.040	7.2	5.5	2.8	2.2	0.096	0.116	2.4	2.5
90			0.030	0.029	7.7	7.4	2.7	2.9	0.098	0.082	2.4	2.3
130			0.045	0.080	4.6	1.1	1.3	0.4	0.131	0.231	2.7	3.2
50		Center	0.024	0.028	7.9	6.9	4.1	3.7	0.076	0.080	2.1	2.2
90			0.026	0.030	6.0	4.4	2.6	2.2	0.075	0.080	2.3	2.4
105			0.033	0.036	3.5	3.1	1.7	1.5	0.094	0.100	2.5	2.6
50	855	Rear	0.039	0.043	5.5	4.8	2.2	2.1	0.116	0.126	2.5	2.6
90			0.029	0.037	6.3	7.3	2.4	2.3	0.085	0.110	2.4	2.5
130			0.066	0.055	2.9	1.6	0.7	0.9	0.195	0.173	3.0	2.9
50		Center	0.022	0.025	11.1	9.3	5.0	4.2	0.064	0.072	2.1	2.2
90			0.032	0.026	3.6	5.0	1.9	2.6	0.092	0.072	2.5	2.3
105			0.035	0.030	3.8	4.5	1.6	2.1	0.102	0.086	2.6	2.4

*Unattached ends of vehicle

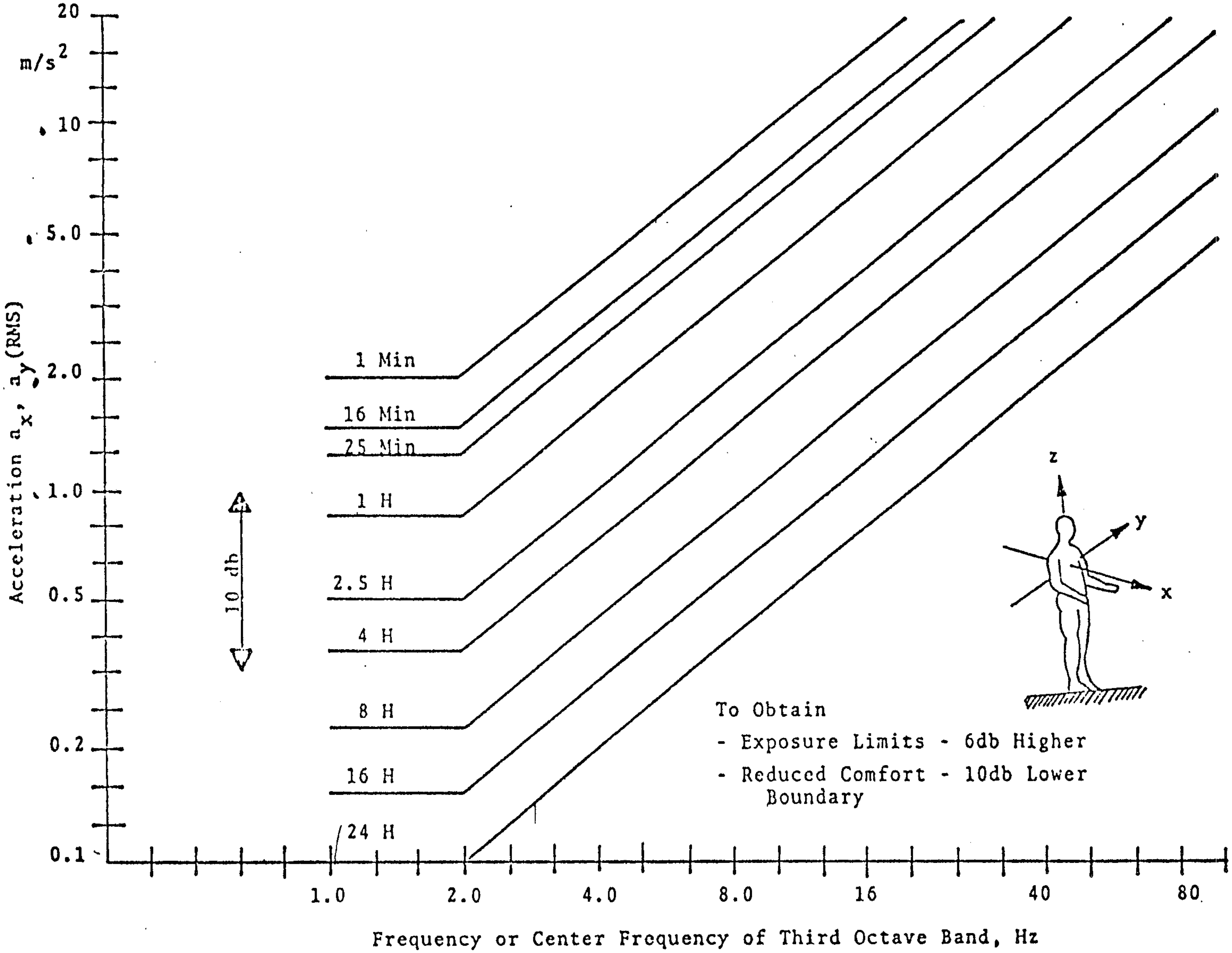


Figure 4-4. Transverse Acceleration as a Function of Frequency and Exposure Time (Fatigue-Decreased Proficiency Boundary).

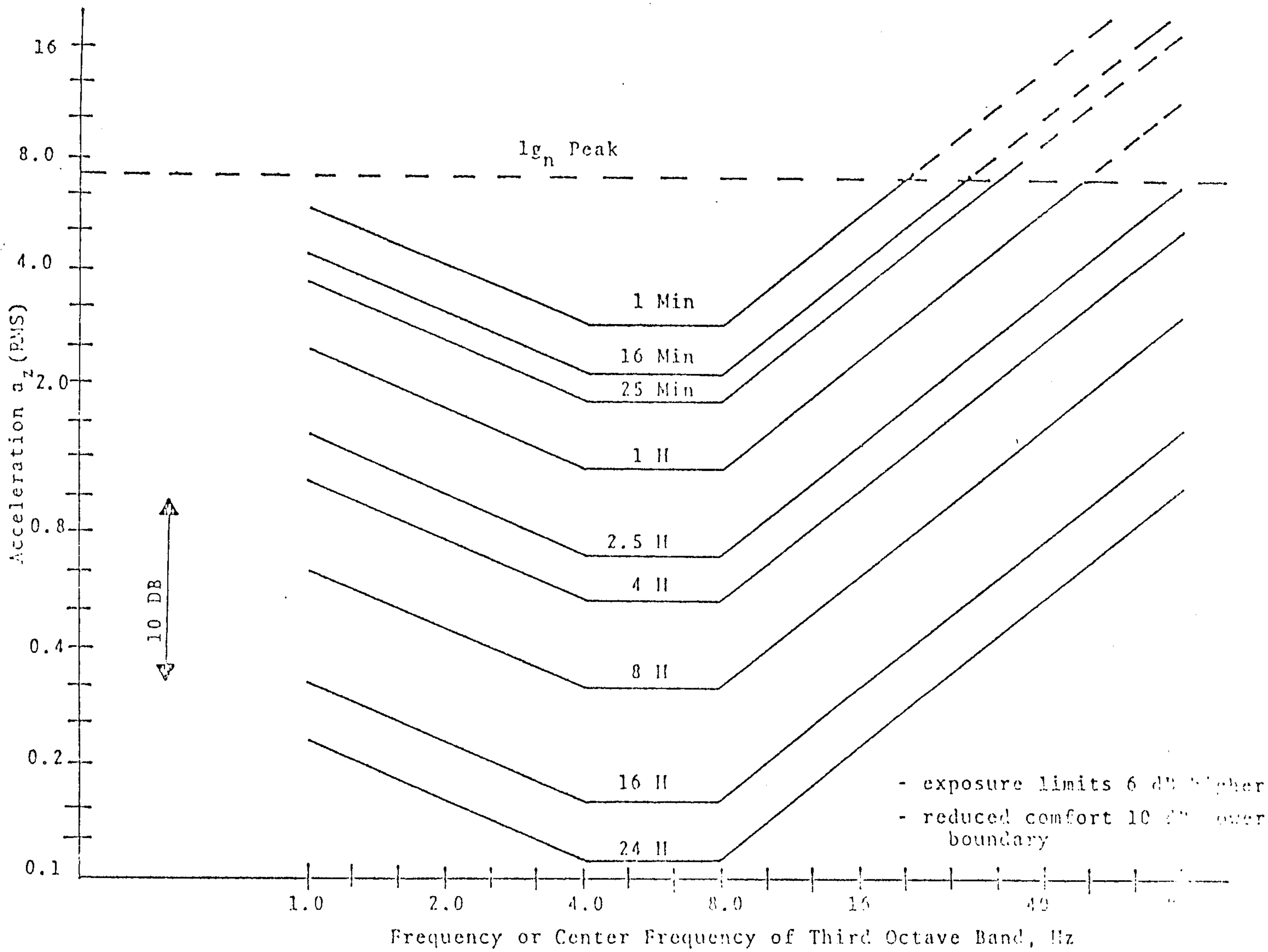


Figure 4-5. Longitudinal Acceleration Limits as a Function of Frequency and Exposure Time (Fatigue-Decreased Proficiency Boundary)

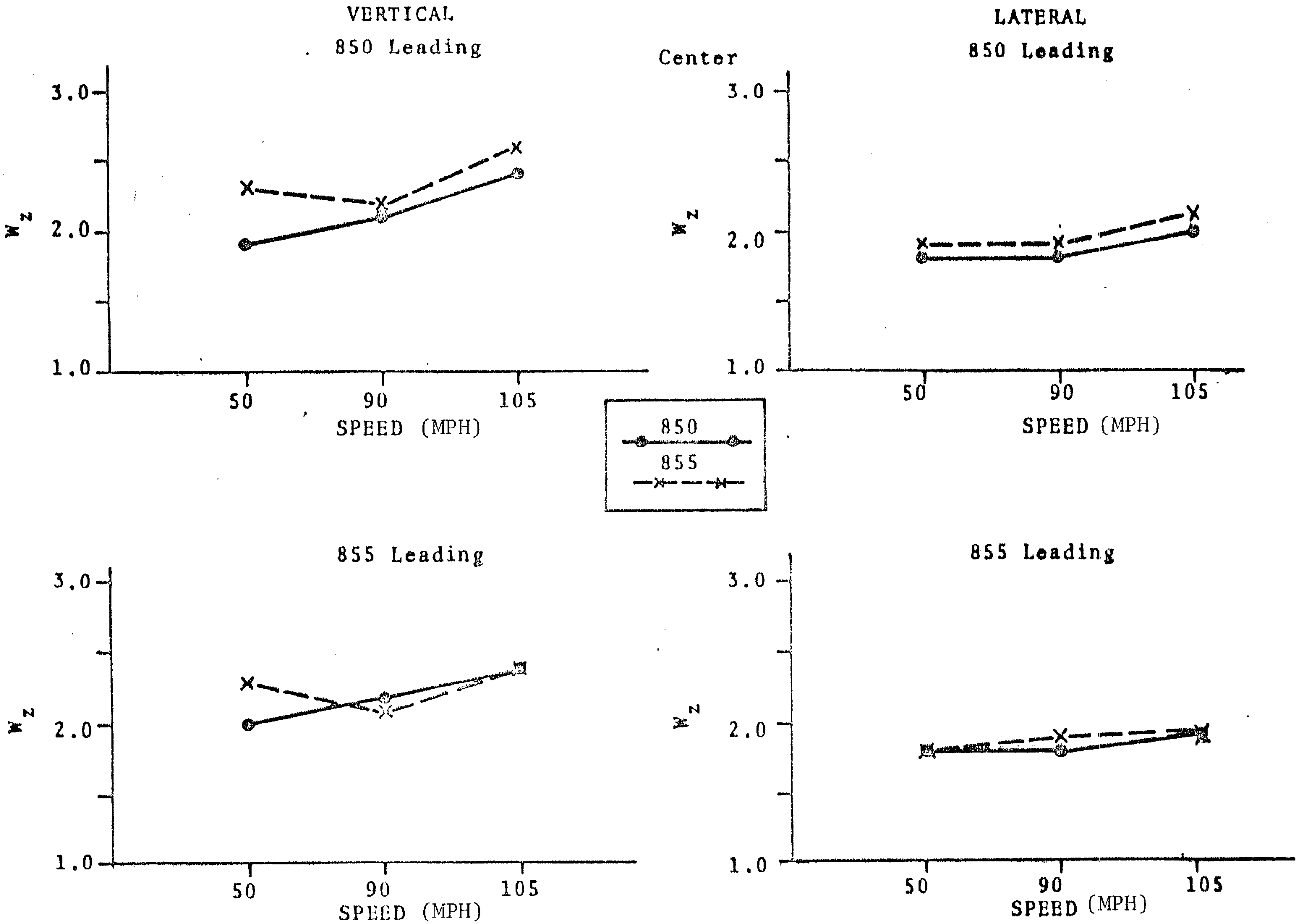


Figure 4-6. W_Z Plots GSI/Sumiride Trucks (Car Center)

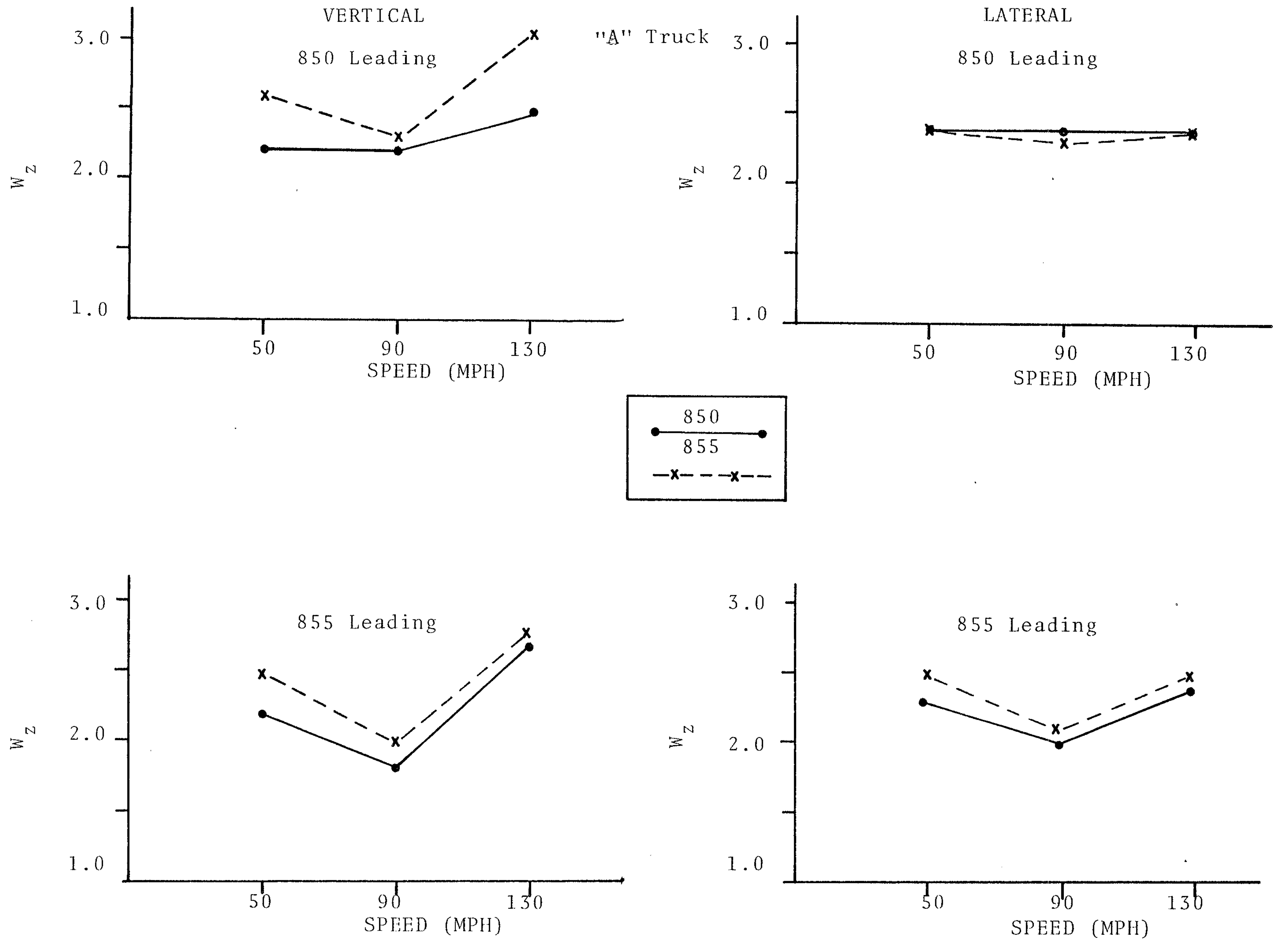


FIGURE 4-7. W_z PLOTS GSI/SUMIRIDE TRUCKS (OVER A-END TRUCK)

TABLE 4-3

PHASE 1 - RIDE QUALITY SPECIFICATION

Test: SUMIRIDE: 850 Leading

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO		STANDARD DEVIA-TION		RMS PEAK VALUE		99% LEVEL	
			855	850	855	850	855	850	855	850
"A" TRUCK	LATERAL	50	2.2	2.6	0.027	0.025	0.017	0.013	0.059	0.058
		90	4.6	2.7	0.025	0.027	0.027	0.080	0.080	0.096
		130	3.5	2.7	0.029	0.028	0.069	0.068	0.089	0.082
	VERTICAL	50	5.0	10.2	0.043	0.024	0.050	0.030	0.119	0.069
		90	5.6	9.1	0.026	0.023	0.062	0.052	0.079	0.075
		130	1.5	5.7	0.072	0.034	0.170	0.085	0.215	0.107
CAR CENTER	LATERAL	50	9.1	10.6	0.013	0.012	0.026	0.021	0.039	0.036
		90	13.9	20.8	0.014	0.012	0.036	0.024	0.043	0.032
		105	9.4	13.1	0.017	0.015	0.041	0.031	0.050	0.040
	VERTICAL	50	6.5	17.9	0.029	0.017	0.055	0.039	0.079	0.048
		90	7.4	8.9	0.024	0.019	0.044	0.028	0.069	0.052
		105	3.2	4.0	0.036	0.029	0.070	0.060	0.100	0.083

POINTS: 855 5 (10%) 850 43 (90%) **TOTAL** 48

RATING Possibly better

TABLE 4-4

PHASE 2 - RIDE QUALITY SPECIFICATION

Test: SUMIRIDE: 850 Leading

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO 850/855	ISO NO	ISO YES	STANDARD DEVIATION 850/855	STANDARD DEVIATION NO	STANDARD DEVIATION YES	RMS PEAK VALUE 850/855	RMS PEAK VALUE NO	RMS PEAK VALUE YES	99% LEVEL 850/855	99% LEVEL NO	99% LEVEL YES
"A" TRUCK	LATERAL	50	1.18	x		0.93	x		0.76		x	0.98	x	
		90	0.59	x		1.08	x		1.07	x		1.20	x	
		130	0.77	x		0.97	x		0.99	x		0.92	x	
	VERTICAL	50	2.04		x	0.56		x	0.60		x	0.58		x
		90	1.63	x		0.88	x		0.84		x	0.95	x	
		130	3.8		x	0.47		x	0.50		x	0.50		x
CAR CENTER	LATERAL	50	1.16	x		0.92	x		0.81		x	0.92	x	
		90	1.50		x	0.86	x		0.67		x	0.74		x
		105	1.39	x		0.88	x		0.76		x	0.80	x	
	VERTICAL	50	2.75		x	0.59		x	0.71		x	0.61		x
		90	1.20	x		0.79	x		0.64		x	0.75	x	
		105	1.25	x		0.81	x		0.86	x		0.83	x	

POINTS: NO 28 YES 20 TOTAL 48 42%

RATING Better Than

TABLE 4-5

PHASE 1 - RIDE QUALITY SPECIFICATION

Test: SUMIRIDE: 855 Leading

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO 855	ISO 850	STANDARD DEVIATION 855	STANDARD DEVIATION 850	RMS PEAK VALUE 855	RMS PEAK VALUE 850	99% LEVEL 855	99% LEVEL 850
"A" TRUCK	LATERAL	50	2.2	2.8	0.030	0.023	0.024	0.030	0.077	0.050
		90	10.8	6.1	0.017	0.016	0.031	0.031	0.050	0.043
		130	3.7	2.9	0.029	0.030	0.062	0.062	0.086	0.088
	VERTICAL	50	5.8	8.3	0.040	0.025	0.048	0.040	0.101	0.077
		90	17.6	12.8	0.021	0.013	0.034	0.026	0.056	0.038
		130	1.8	4.0	0.050	0.047	0.085	0.100	0.149	0.152
CAR CENTER	LATERAL	50	17.1	11.7	0.012	0.011	0.032	0.026	0.035	0.031
		90	21.1	16.1	0.014	0.012	0.041	0.030	0.041	0.037
		105	13.9	16.2	0.016	0.015	0.028	0.031	0.045	0.040
	VERTICAL	50	7.0	15.3	0.029	0.018	0.070	0.044	0.080	0.053
		90	9.8	7.2	0.020	0.021	0.045	0.043	0.059	0.062
		105	4.8	5.0	0.029	0.029	0.068	0.068	0.085	0.086

POINTS: 855 15 850 33 TOTAL 48

21% 69% RATING Possibly better

TABLE 4-6

PHASE 2 - RIDE QUALITY SPECIFICATION

Test: SUMIRIDE AIRPSRING: 855 Leading

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO			STANDARD DEVIATION			RMS PEAK VALUE			99% LEVEL		
			850/855	NO	YES	850/855	NO	YES	850/855	NO	YES	850/855	NO	YES
"A" TRUCK	LATERAL	50	1.27	x		0.77	x		1.25	x		0.65		x
		90	0.56	x		0.94	x		1.0	x		0.86	x	
		130	0.78	x		1.03	x		1.0	x		1.02	x	
	VERTICAL	50	1.43	x		0.63		x	0.83		x	0.76	x	
		90	0.73	x		0.62		x	0.76		x	0.68		x
		130	2.22		x	0.94	x		1.18	x		1.02	x	
CAR CENTER	LATERAL	50	0.68	x		0.92	x		0.81		x	0.89	x	
		90	0.77	x		0.86	x		0.73		x	0.90	x	
		105	1.17	x		0.94	x		0.90	x		0.89	x	
	VERTICAL	50	2.19		x	0.62		x	0.63		x	0.66		x
		90	0.73	x		1.05	x		0.96	x		1.05	x	
		105	1.04	x		1.0	x		1.00	x		1.01	x	

POINTS: NO 35 YES 13 TOTAL 48

RATING Slightly better

category is related to every other by virtue of being measured on a similar track section, vehicle, etc., comparing RMS peak value to ISO exposure time would be of little value. Use of the point system described previously was proposed early in the program and accepted as a reasonable method for comparing data collected on both cars by Amtrak and GSI. The results of the ride quality test indicate that the 850 Metroliner ride (with the improved truck) was better in the vertical direction. The lateral ride was not drastically improved.

In general, the 850 Metroliner rode better than the 855. With the 850 leading, the 850 rode better than the 855 and scored 90 percent. With the 855 leading, the 850 rode better and scored 60 percent more points on the selected test runs.

By averaging the total percentages, the 850 Metroliner was rated 79 percent as compared to the 855. This averaging technique tends to compensate for the car's position in the consist, and indicates the improvement in ride quality of the 850 Metroliner.

Since the point system was made up using four different results, it is not readily apparent that the 850 car rode better than the 855 car 79 percent of the time. However, since each method was used on the same segment of data for each vehicle, and since the data points used in the point system represent random points in time during the test, it can be stated that the 850 Metroliner rode better than the 855 Metroliner 79 percent of the time due to its improved suspension.

4.6 FIRESTONE VERTICAL DAMPING

For the Firestone air-spring test on the Metroliner 850 test, no primary damping, no external vertical damping, and a 3/4-inch orifice were used. Two tests were made with a steel plate on top of the air spring and two tests were made with the steel plate replaced by a rubber sandwich.

The results of the four tests were monitored, using a Brush chart recorder in the same manner as in other tests. The following observations were made from the analysis of the Brush charts. Some segments of test data indicate that the vertical accelerations of the 850 Metroliner were 10 percent lower than those measured on the 855. This reduction is not consistent throughout all test zones, and there are some cases (northbound runs with 855 leading) where the vertical accelerations in the 850 exceed those of the 855.

Therefore, the vertical ride of Metroliner 850 was not found to be significantly better than that of 855.

4.7 FIRESTONE LATERAL DAMPING

When the lateral shock absorber was set to one-notch light or factory setting (mid-range) the lateral accelerations of the 850 Metroliner were not significantly different from those of the 855 Metroliner. This result was observed with both the steel plate and the rubber sandwich over the air spring. With the shock absorbers set two notches above mid-range, the lateral acceleration of the 850 Metroliner was approximately 25 percent greater than that of the 855. This ratio did not remain constant throughout all test zones. It was clear, however, that the two-notch heavy setting did not improve lateral ride but tended to degrade it.

During the Firestone air spring series, carbody roll angle was measured. Roll data collected from the GSI roll transducers indicate that the roll characteristics of the 850 Metroliner are worse than those of the 855 between 8 and 16 mph. Table 4-7 is a summary of the results of a general peak-to-peak comparison of strip chart data.

If the ratio 850/855 (Table 4-7) is greater than one then 855 rolled less than 850. If the ratio 850/855 is less than one

TABLE 4-7
METROLINER 850/855 ROLL ANGLE COMPARISON

Test	Speed (mph)	Car				850/855
		850		855		
		Radians	Degrees	Radians	Degrees	
F-3	8	.069	3.9	.048	2.8	1.4
	10	.081	4.6	.039	2.2	2.0
	12	.073	4.2	.042	2.9	1.4
	14	.085	4.9	.059	3.4	1.4
	16	.069	3.9	.055	3.2	1.2
F-1	10	.084	4.8	.043	2.5	1.9
	12	.081	4.6	.065	3.7	1.2
	14	.069	5.9	.048	2.0	1.4
	16	.087	4.9	.067	3.8	1.2

then the 850 rolled less than the 855. By plotting the results of the ratio 850/855 versus speed, it can be seen that the 850 does indeed roll more than the 855. Figure 4-8 shows this plot.

4.8 FIRESTONE OPTIMUM COMPONENTS TEST

4.8.1 Strip Chart Analysis

The data was displayed on a six-channel strip chart in a similar manner to the methods used during the Sumiride testing. Lateral and vertical carbody accelerations were visually compared to determine the relative amplitudes of the two cars. These results were used to form a preliminary opinion of the relative riding qualities of the two metroliners.

4.8.2 Software Results

The data from the Firestone testing was software processed using methods similar to those used in processing the Sumiride data. Tables 4-8 and 4-9 summarize the results of the software programs.

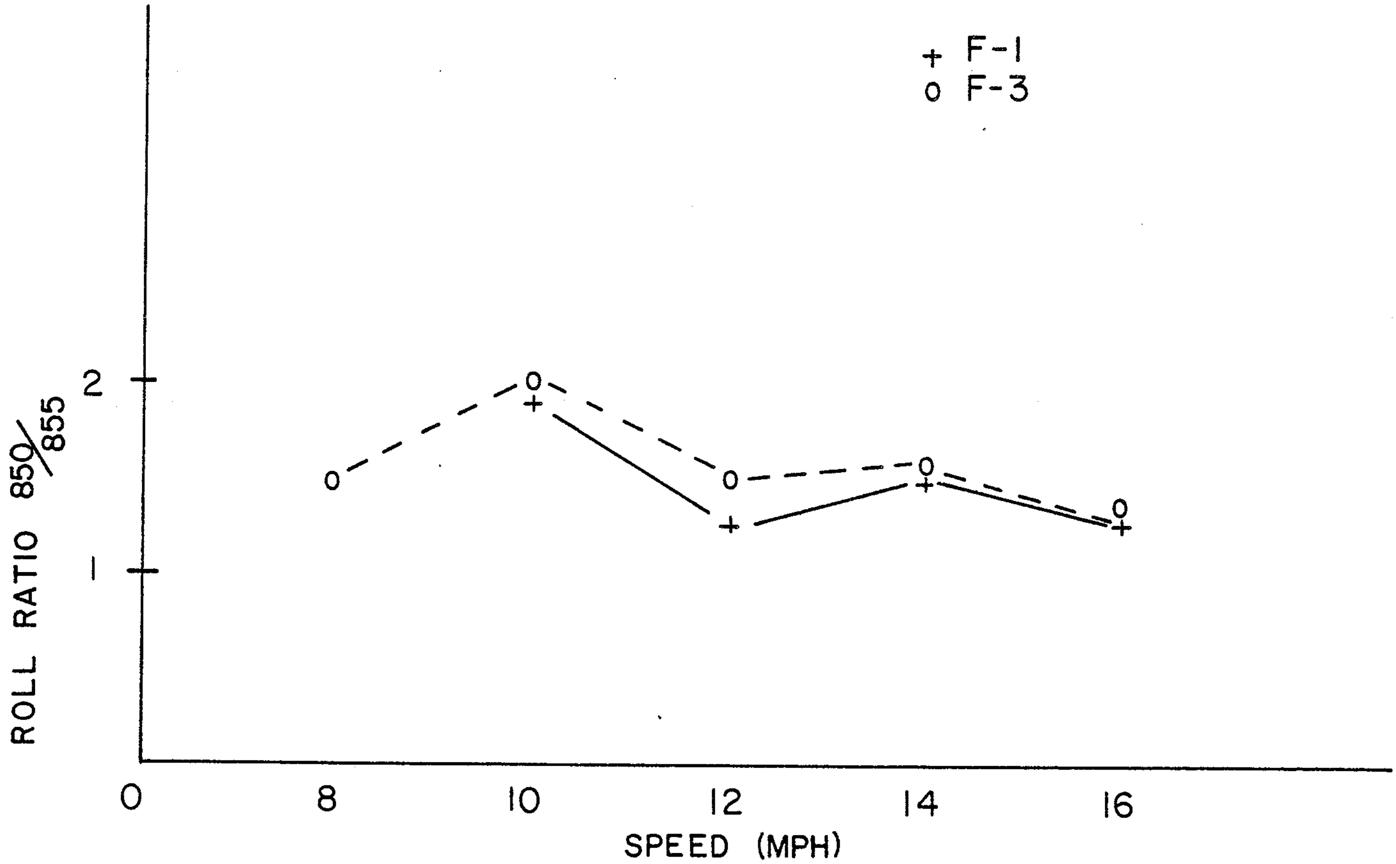


FIGURE 4-8. ROLL RATIO FOR TESTS F-1 AND F-3

The method for examining the results is to investigate the plots of W_z versus speed. These plots are shown in Figures 4-9 and 4-10.

4.8.3 Ride Quality Criteria

The ride quality criteria was applied to the results of the Firestone data. This ride quality criteria was discussed in detail in Section 4.5.3. The results of the criteria are shown in Tables 4-10 through 4-13.

Utilizing the point system which was established, the 850 car rode better than the 855 car with the 850 leading with a score of 52 percent. With 855 leading, the 855 scored higher than Metroliner 850. Phase 2 of the evaluation is not important in this particular test and was not done since Metroliner 850 was not better as shown by the Phase 1 evaluation. Overall, the ride of the two vehicles was basically the same.

TABLE 4-8

VERTICAL MODE/FIRESTONE AIR SPRING

SPEED	VEHICLE IN LEAD	INSTRU. LOCATION	RMS LEVEL (g)		ISO (hrs)		ALT ISO (hrs)		99% LEVEL (g)		W_Z	
			850	855	850	855	850	855	850	855	850	855
50	850	Rear*	0.033	0.040	7.2	5.5	2.8	2.2	0.096	0.116	2.4	2.5
90			0.030	0.029	7.7	7.4	2.7	2.9	0.098	0.082	2.4	2.3
130			0.045	0.080	4.6	1.1	1.3	0.4	0.131	0.231	2.7	3.2
50		Center	0.024	0.028	7.9	6.9	4.1	3.7	0.076	0.080	2.1	2.2
90			0.026	0.030	6.0	4.4	2.6	2.2	0.075	0.080	2.3	2.4
105			0.033	0.036	3.5	3.1	1.7	1.5	0.094	0.100	2.5	2.6
50	855	Rear	0.039	0.043	5.5	4.8	2.2	2.1	0.116	0.126	2.5	2.6
90			0.029	0.037	6.3	7.3	2.4	2.3	0.085	0.110	2.4	2.5
130			0.066	0.055	2.9	1.6	0.7	0.9	0.195	0.173	3.0	2.9
50		Center	0.022	0.025	11.1	9.3	5.0	4.2	0.064	0.072	2.1	2.2
90			0.032	0.026	3.6	5.0	1.9	2.6	0.092	0.072	2.5	2.3
105			0.035	0.030	3.8	4.5	1.6	2.1	0.102	0.086	2.6	2.4

*Unattached ends of vehicle

TABLE 4-9

VERTICAL MODE/SUMIRIDE AIR SPRING

SPEED	VEHICLE IN LEAD	INSTRU. LOCATION	RMS LEVEL (g) 850	RMS LEVEL (g) 855	ISO (hrs) 850	ISO (hrs) 855	ALT ISO (hrs) 850	ALT ISO (hrs) 855	99% LEVEL (g) 850	99% LEVEL (g) 855	W_Z 850	W_Z 855
50	850	Rear*	0.024	0.043	10.2	5.0	3.8	1.8	0.069	0.119	2.2	2.6
90			0.023	0.026	9.1	5.6	3.7	3.0	0.075	0.079	2.2	2.3
130			0.034	0.072	5.7	1.5	1.9	0.6	0.107	0.215	2.5	3.1
50		Center	0.016	0.029	17.9	6.5	6.3	3.6	0.048	0.079	1.9	2.3
90			0.019	0.024	8.9	7.4	4.3	3.4	0.052	0.069	2.1	2.2
105			0.029	0.036	4.0	3.2	2.1	1.5	0.083	0.100	2.4	2.6
50	855	Rear	0.025	0.039	8.3	5.8	3.7	2.0	0.077	0.101	2.2	2.5
90			0.013	0.021	12.8	17.6	7.2	5.4	0.038	0.056	1.8	2.0
130			0.047	0.050	4.0	1.8	1.3	1.0	0.152	0.149	2.7	2.8
50		Center	0.018	0.029	15.3	7.0	6.1	3.5	0.053	0.080	2.0	2.3
90			0.021	0.020	7.2	9.8	3.7	4.2	0.062	0.059	2.2	2.1
105			0.029	0.029	5.0	4.8	2.1	2.2	0.086	0.085	2.4	2.4

*Unattached ends of vehicle

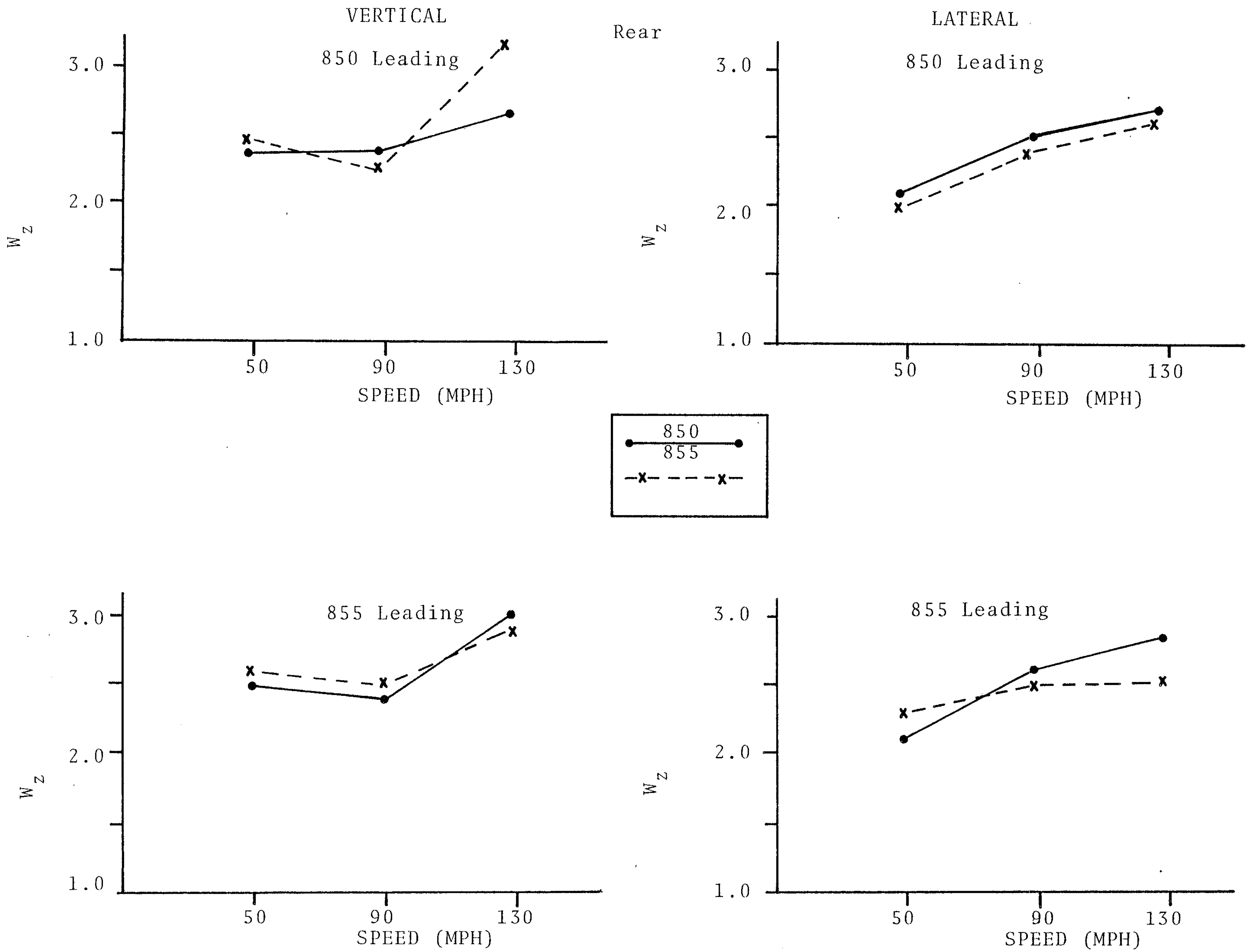


FIGURE 4-9. W_z PLOTS GSI/FIRESTONE TRUCKS (REAR OF CAR)

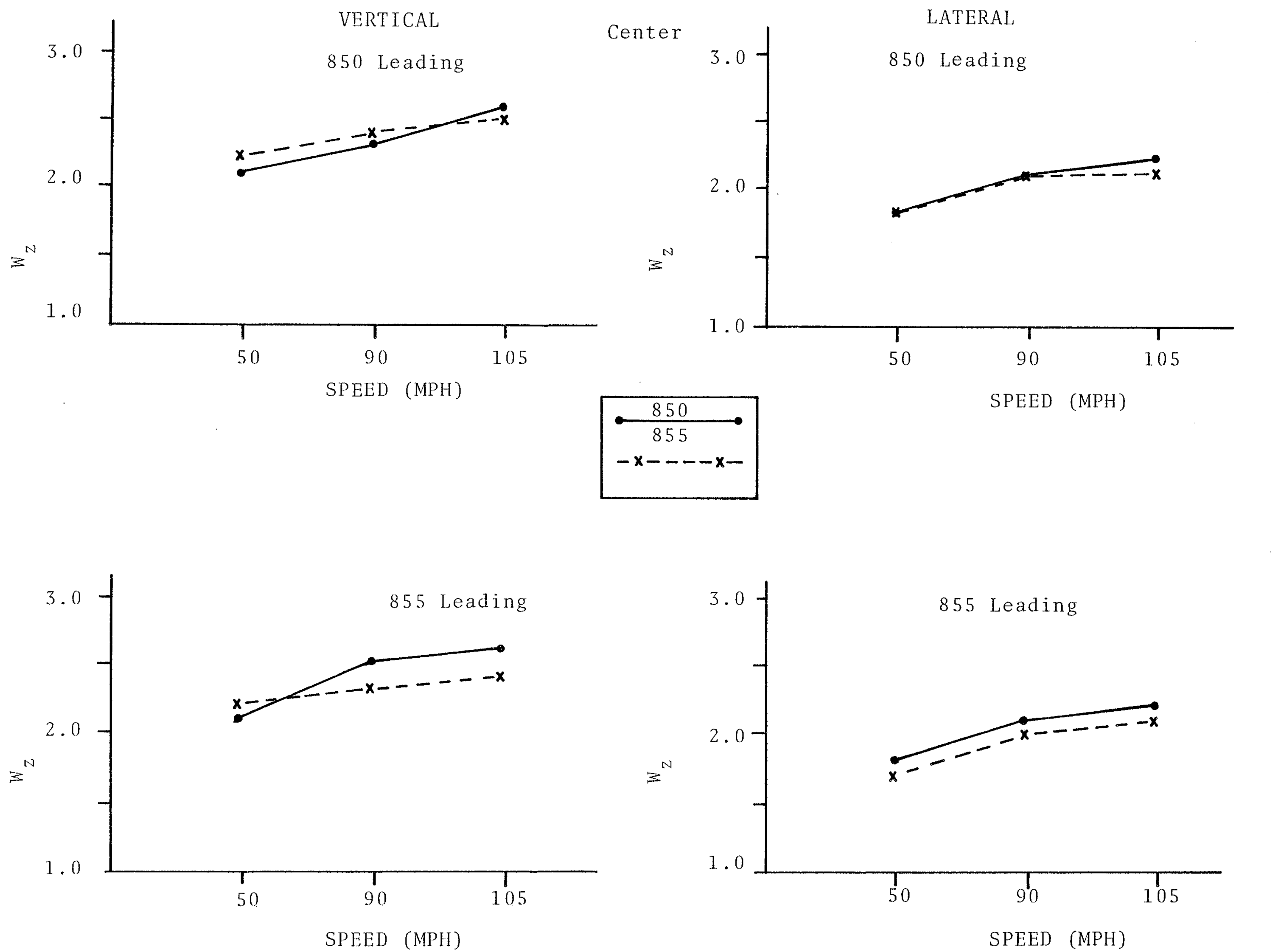


FIGURE 4-10. W_z PLOTS GSI FIRESTONE TRUCKS (CAR CENTER)

TABLE 4-10

PHASE 1 - RIDE QUALITY SPECIFICATION

Test: FIRESTONE - 850 Leading

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO		STANDARD DEVIATION		RMS PEAK VALUE		99% LEVEL	
			855	850	855	850	855	850	855	850
"A" TRUCK	LATERAL	50	11.1	5.6	0.015	0.020	0.038	0.042	0.048	0.059
		90	2.9	2.0	0.027	0.033	0.050	0.065	0.075	0.098
		130	2.1	1.4	0.037	0.041	0.095	0.103	0.115	0.120
	VERTICAL	50	5.5	7.2	0.040	0.033	0.115	0.072	0.116	0.096
		90	7.4	7.7	0.029	0.030	0.050	0.055	0.082	0.083
		130	1.1	4.6	0.080	0.045	0.200	0.100	0.231	0.131
CAR CENTER	LATERAL	50	23.8	17.2	0.011	0.011	0.025	0.022	0.032	0.030
		90	10.0	10.6	0.016	0.017	0.036	0.028	0.047	0.048
		105	9.0	6.5	0.017	0.020	0.038	0.035	0.051	0.057
	VERTICAL	50	6.9	11.2	0.028	0.024	0.042	0.050	0.080	0.076
		90	4.4	6.0	0.030	0.026	0.058	0.058	0.080	0.075
		105	3.1	3.5	0.036	0.033	0.060	0.075	0.100	0.094

POINTS: 855 23 850 25 TOTAL 48

48% 52% RATING Not better

TABLE 4-11

PHASE 2 - RIDE QUALITY SPECIFICATION

Test: FIRESTONE: 850 Leading

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO			STANDARD DEVIATION			RMS PEAK VALUE			99% LEVEL		
			850/855	NO	YES	850/855	NO	YES	850/855	NO	YES	850/855	NO	YES
"A" TRUCK	LATERAL	50	0.50	x		1.33	x		1.11	x		1.23	x	
		90	0.69	x		1.22	x		1.30	x		1.31	x	
		130	0.67	x		1.11	x		1.08	x		1.04	x	
	VERTICAL	50	1.31	x		0.83	x		0.63	x		0.83	x	
		90	1.04	x		1.03	x		1.10	x		1.01	x	
		130	4.78		x	0.56		x	0.50		x	0.57		x
CAR CENTER	LATERAL	50	0.72	x		1.00	x		0.88	x		0.94	x	
		90	1.06	x		1.06	x		0.78	x		1.02	x	
		105	0.72	x		1.18	x		0.92	x		1.12	x	
	VERTICAL	50	1.62	x		0.86	x		1.19	x		0.95	x	
		90	1.36	x		0.87	x		1.00	x		0.94	x	
		105	1.13	x		0.92	x		1.25	x		0.94	x	

POINTS: NO 44 YES 4 TOTAL 48

RATING Slightly better

TABLE 4-12

PHASE 2 - RIDE QUALITY SPECIFICATION

Test: FIRESTONE: 855 Leading

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO		STANDARD DEVIATION		RMS PEAK VALUE		99% LEVEL	
			850	855	850	855	850	855	850	855
"A" TRUCK	LATERAL	50	4.0	6.8	0.024	0.019	0.056	0.057	0.069	0.058
		90	2.3	1.3	0.033	0.038	0.104	0.106	0.109	0.110
		130	2.8	0.8	0.033	0.047	0.040	0.075	0.097	0.137
	VERTICAL	50	4.8	5.5	0.043	0.039	0.115	0.115	0.126	0.116
		90	7.3	6.3	0.037	0.029	0.058	0.048	0.110	0.085
		130	1.6	2.9	0.055	0.066	0.130	0.120	0.173	0.195
CAR CENTER	LATERAL	50	24.0	24.0	0.010	0.011	0.015	0.019	0.027	0.049
		90	18.2	9.3	0.015	0.018	0.026	0.025	0.044	0.049
		105	12.2	7.0	0.017	0.020	0.045	0.040	0.049	0.055
	VERTICAL	50	9.3	11.1	0.025	0.022	0.053	0.051	0.072	0.064
		90	3.0	3.6	0.026	0.032	0.055	0.068	0.072	0.092
		105	4.5	3.8	0.030	0.035	0.070	0.092	0.086	0.102

POINTS: 855 30 850 18 TOTAL 48

52% 38% RATING Not better than

TABLE 4-13

PHASE 2 - RIDE QUALITY SPECIFICATION

Test: FIRESTONE: 855 Leading

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO			STANDARD DEVIATION			RMS PEAK VALUE			99% LEVEL		
			850/855	NO	YES	850/855	NO	YES	850/855	NO	YES	850/855	NO	YES
"A" TRUCK	LATERAL	50	1.7	x		0.79	x		1.02	x		0.84	x	
		90	0.57	x		1.15	x		1.02	x		1.01	x	
		130	0.29	x		1.42	x		1.88	x		1.41	x	
	VERTICAL	50	1.15	x		0.91	x		1.0	x		0.92	x	
		90	0.86	x		0.78	x		0.83		x	0.77	x	
		130	1.81	x		1.2	x		0.92	x		1.13	x	
CAR CENTER	LATERAL	50	1.0	x		1.1	x		1.27	x		1.04	x	
		90	0.51	x		1.2	x		0.96	x		1.11	x	
		105	0.57	x		1.18	x		0.89	x		1.12	x	
	VERTICAL	50	1.19	x		0.88	x		0.96	x		0.89	x	
		90	0.72	x		1.23	x		1.24	x		1.28	x	
		105	0.84	x		1.17	x		1.31	x		1.19	x	

POINTS: NO 47 YES 1 TOTAL 48

RATING Slightly better

4.9 SUMIRIDE DEFLATED AIR SPRING TEST

4.9.1 Strip Chart Analysis

In order to observe the effects of a sudden air spring failure and to measure ride quality acceleration data after such a failure, two tests were performed on 27 June 1977. All components used during the "best-of-all components" test of the Sumiride air spring were used for the deflated air spring test.

The first test was a static test performed at the Wilmington shops, and involved observing the tilt of the 850 Metroliner as the air was exhausted from one air bag to simulate an air spring failure. The second test was a dynamic test which consisted of running the 850/855 Metroliner consist over revenue track at various speeds with one set of air springs deflated.

The static test was performed as follows:

- Plumb bobs were hung from the ceiling at both the A-end and B-end of the 850 Metroliner.
- All air springs were inflated to normal operating pressures.
- Zero marks were placed on the car floor beneath the plumb bobs.
- The B-end air spring set had its left side gage removed (leaving an open 3/4-inch pipe hole) and the air inside was allowed to escape.
- The time required to exhaust the air spring was recorded.
- The maximum excursion of each plumb bob was recorded.

The results of the static test were:

- It took three minutes for the B-end air spring to exhaust its air through a 3/4-inch pipe hole.

- Shortly after removing the gage on the left side, both the A-end plumb bobs moved to the left. After a maximum travel of 1/2 inch, both plumb bobs returned to the zero or original position as shown in Figure 4-11.

With both air springs on the B-end of Metroliner 850 deflated, ride quality acceleration signals and GSI transducer displacement signals were recorded. The ride quality acceleration packages were located on the A-end and B-end of the 850 Metroliner (Figure 4-12). The 850 Metroliner was equipped with the same "best-of-all-components" as in the "best-of-all-components test. Test zones for this test consisted of Amtrak trackage between Wilmington and Baltimore, Milepost 29.6 to Milepost 38. Additional data was collected northbound from Milepost 30 to Wilmington Station in order to record ride quality acceleration data through several interlockings.

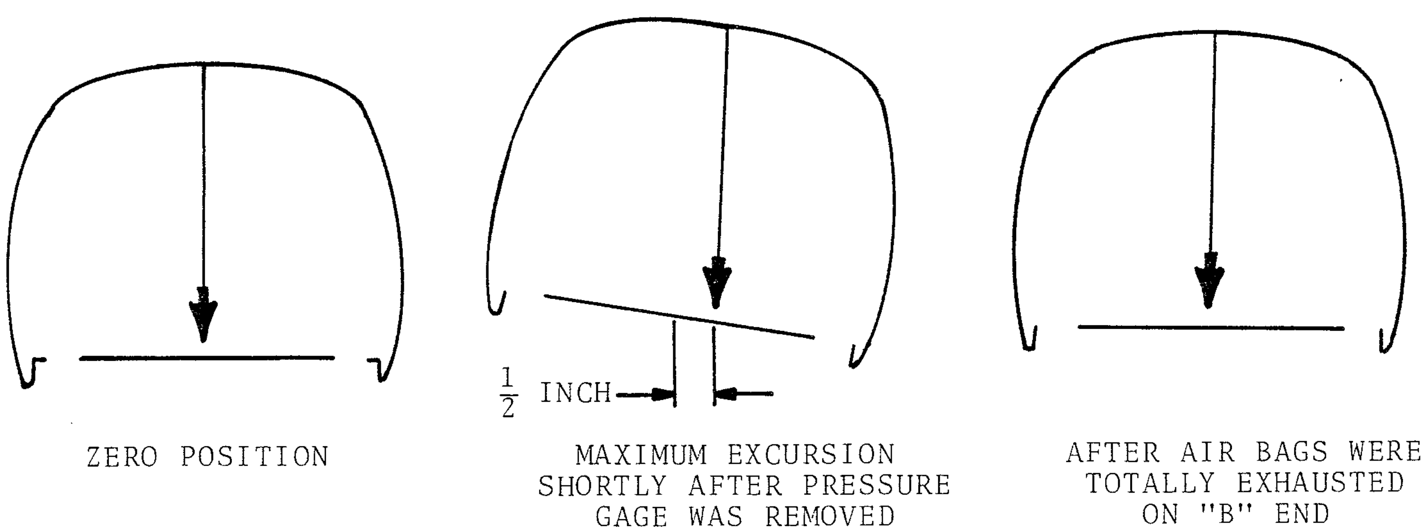


FIGURE 4-11

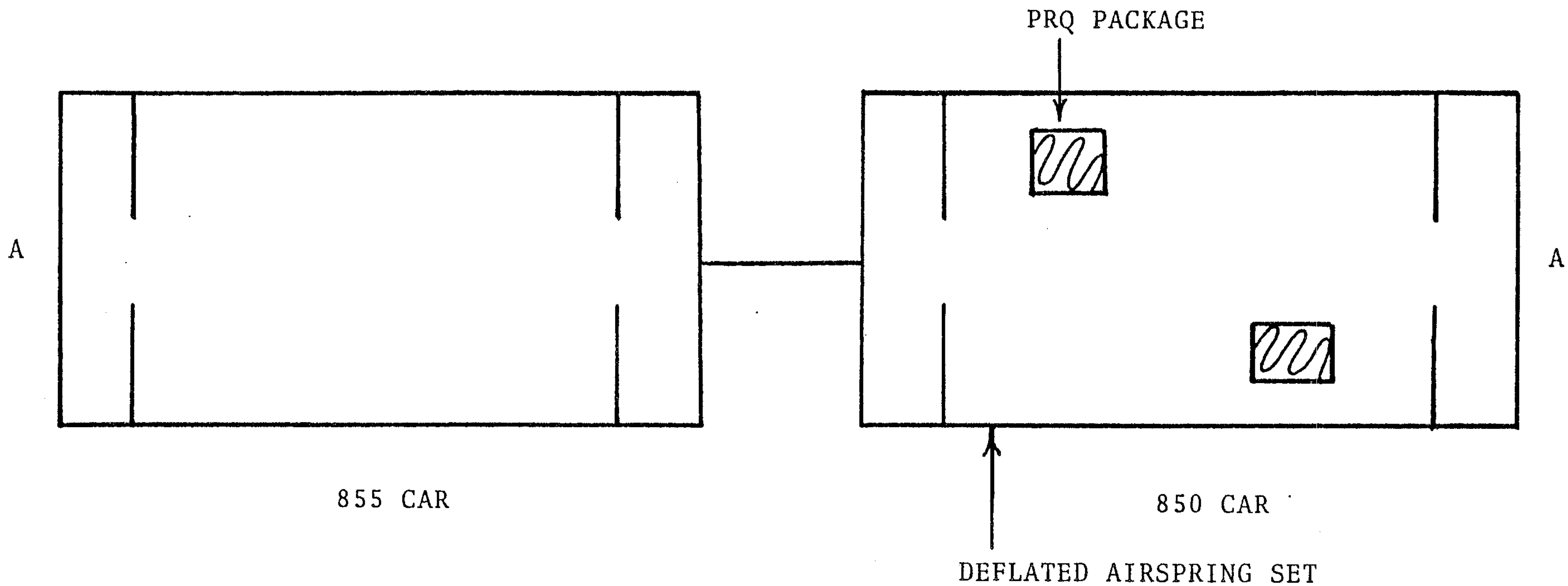


Figure 4-12. Location of PRQ Packages - Deflated Air Spring Test

At slow speeds (20-40 mph) the vertical acceleration levels were approximately 20 percent larger on the B-end than on the A-end. As speeds increased (50-105 mph), the vertical accelerations on the B-end became as much as four times greater than those on the A-end. Lateral accelerations were not significantly different on either end of the car, nor were longitudinal accelerations significantly different.

Figure 4-13 and 4-14 show the ride quality acceleration data. Figure 4-13 is a reproduction from the "best-of-all-components" test, comparing the modified Metroliner with the standard 855 Metroliner. Figure 4-14 shows the deflated air spring test. Finally, Figure 4-15 summarizes the deflated air bag test.

4.9.2 Software Results

The data was processed using the standard ride quality software. The results were tabulated and are given in Table 4-14. The worst vertical ride with the deflated air bag was at 50 mph. Power Spectral Densities are given for this speed in Figures 4-16 and 4-17.

4.10 855/822 METROLINER COMPARISON TEST

A comparison was made between Metroliner 855 (good condition) and Metroliner 822 (in need of maintenance). This test was performed similar to tests conducted earlier on 850/855. The PRQ packages were located both at the center of the car and at the unattached ends of the consist. Both vehicles were at the leading end of the consist at different times. Speeds over the test zones of 50 and 90 mph were achieved with no problems. On the southbound runs, 105 mph was not achieved due to track maintenance. It was planned that 105 mph would be the maximum speed achieved.

Tha analog data was digitized and processed and the results placed into the ride quality specification. The overall results are as follows:

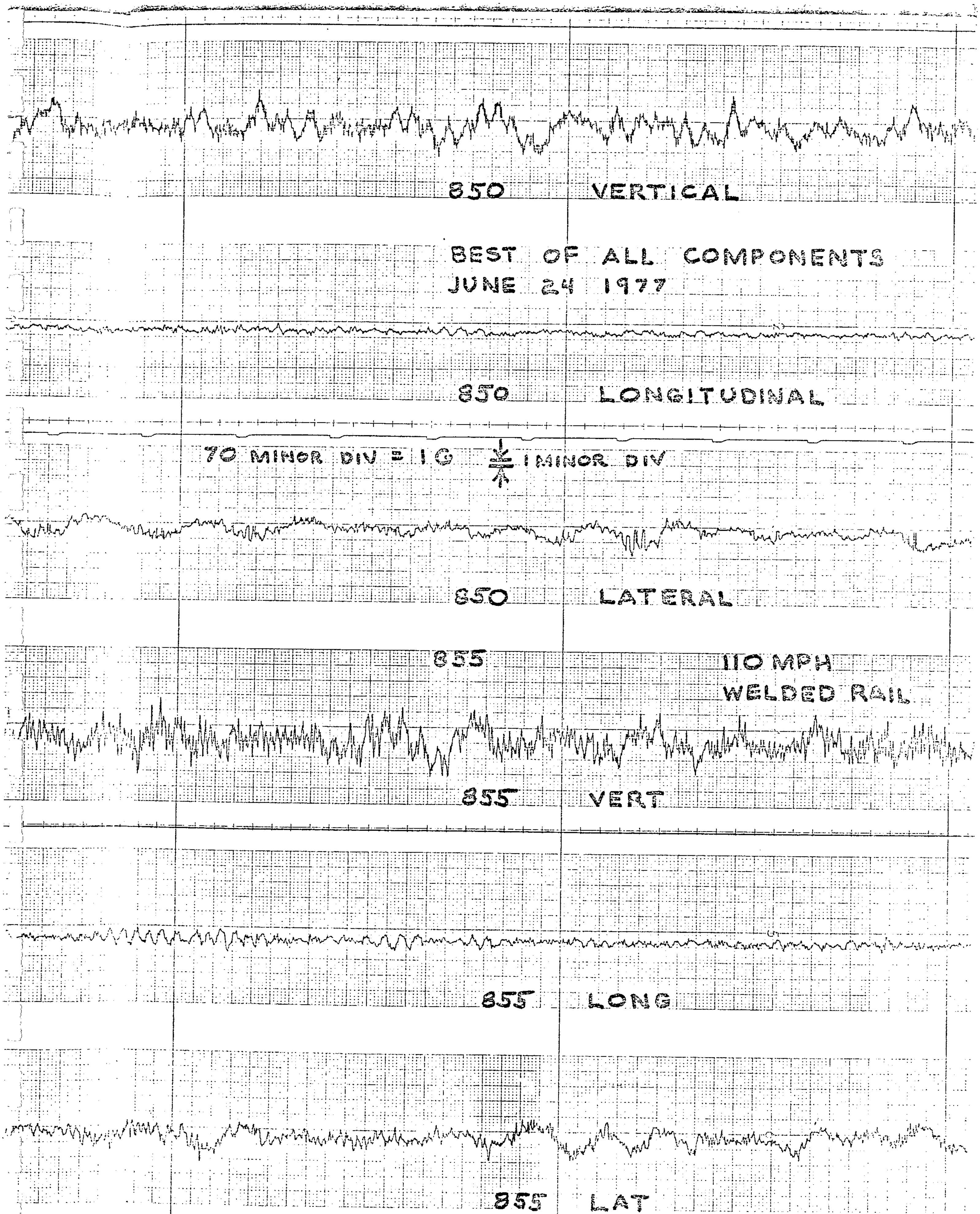


Figure 4-13. Ride Quality Accelerations - Best-of-All-Components Test

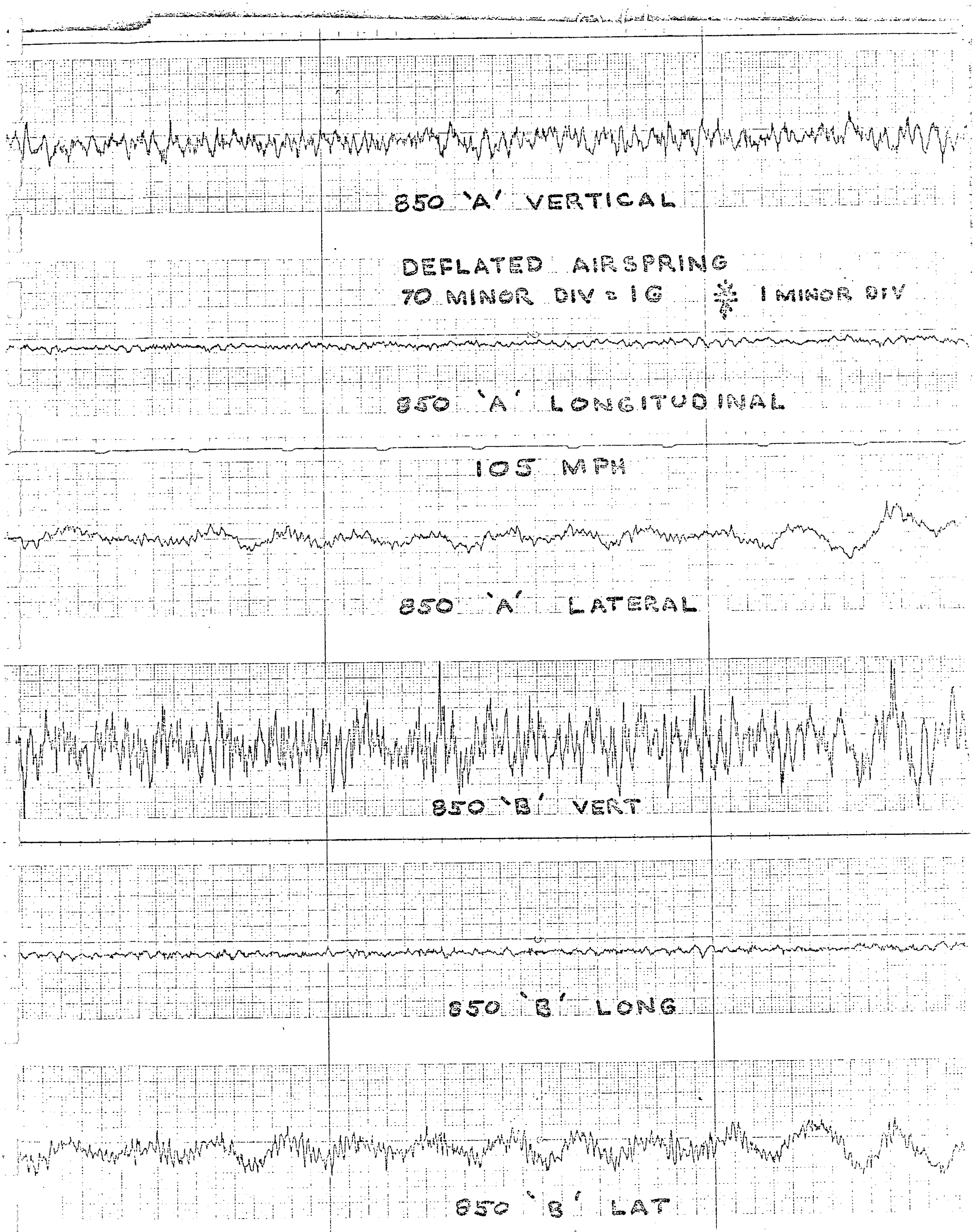


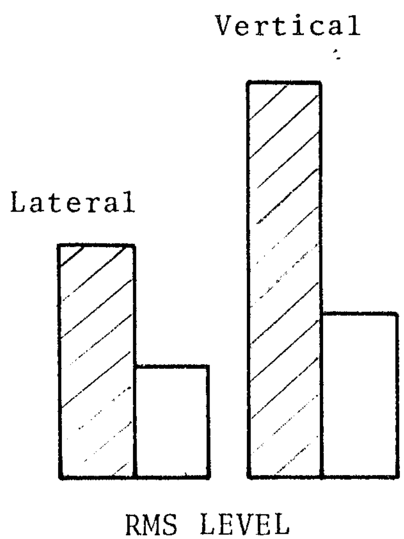
Figure 4-14. Ride Quality Acceleration - Deflated Air Spring Test 69

SPEEDS: UP TO 105 MPH

RESULTS: NOTHING DRAMATIC

REASONABLE ACCELERATIONS

			LATERAL	VERTICAL
			INFLATED	
VALUES:	105 MPH	99% LEVEL	0.061 G	0.085 G
		STD. DEV.	0.023 G	0.034 G
		ISO	8.0 HRS	4.6 HRS
			DEFLATED	
		99% LEVEL	.137 G	.217 G
		STD. DEV.	.047 G	.082 G
		ISO	1.3 HRS	1.3 HRS



[///] - Deflated

[ ] - Normal

Figure 4-15. Summary - Deflated Air Spring Test

TABLE 4-14

DEFLATED AIR BAG SOFTWARE RESULTS

VERTICAL MODE

Speed	Zone	Leading Vehicle	RMS Level		99% Level		ISO		Alt ISO		Wz	
			"A"	"B"	"A"	"B"	"A"	"B"	"A"	"B"	"A"	"B"
20	MP 30-31	850	0.015	0.023	0.043	0.047	18.9	11.5	8.9	3.9	1.8	2.1
50	MP 35-36.6	850	0.038	0.105	0.107	0.283	4.5	0.7	1.9	0.1	2.5	3.5
105	MP 34-32	855	0.031	0.082	0.080	0.217	4.3	1.3	2.1	0.3	2.4	3.2

LATERAL MODE

Speed	Zone	Leading Vehicle	RMS Level		99% Level		ISO		Alt ISO		Wz	
			"A"	"B"	"A"	"B"	"A"	"B"	"A"	"B"	"A"	"B"
20	MP 30-31	850	0.015	0.018	0.039	0.046	10.4	12.0	7.0	5.7	1.9	2.0
50	MP 35-36.6	850	0.029	0.038	0.071	0.093	2.0	1.3	1.2	0.7	2.4	2.6
105	MP 34-32	855	0.036	0.047	0.116	0.137	1.6	1.3	0.8	0.4	2.5	2.8

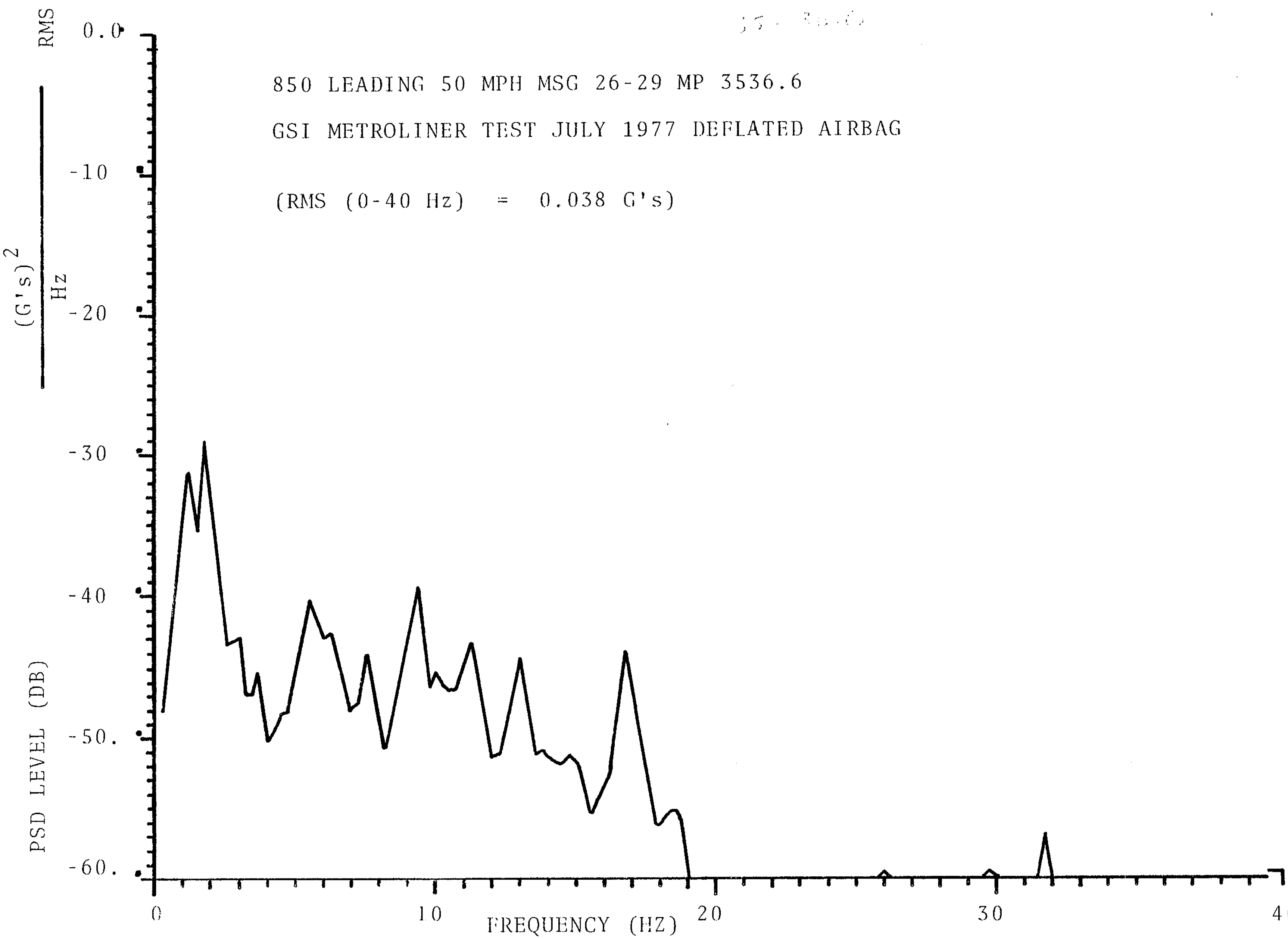


FIGURE 4-16. INFLATED AIR BAG - PSD PLOT (50 MPH)

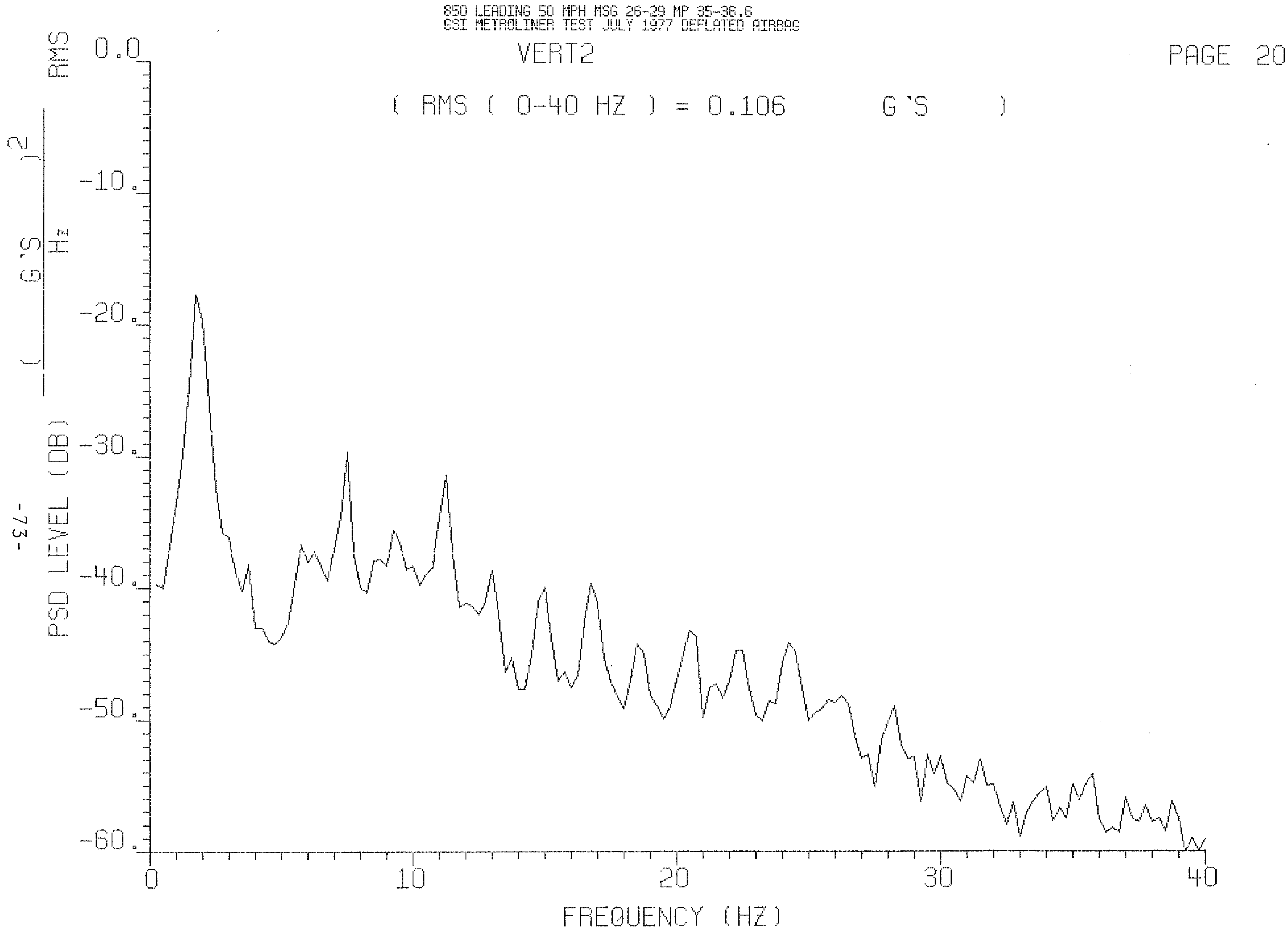


Figure 4-17. Deflated Air Bag - PSD Plot (50 mph)

Phase 1	855 leading - scored 90 percent	
	822 leading - scored 73 percent	
	Average - 81 percent	
Phase 2	855 leading - scored 28 percent	
	822 leading - scored 23 percent	
	Average - 25 percent	

In terms of lateral and vertical performance:

Phase 1	855 leading - scored 80 percent (vertical)	
	scored 100 percent (lateral)	
	822 leading - scored 60 percent (vertical)	
	scored 85 percent (lateral)	
	Average - 70 percent (vertical)	
	93 percent (lateral)	
Phase 2	855 leading - scored 15 percent (vertical)	
	scored 40 percent (lateral)	
	822 leading - scored 10 percent (vertical)	
	scored 35 percent (lateral)	
	Average - 12 percent (vertical)	
	37 percent (lateral)	

The following conclusions summarize the results:

1. Overall, 855 scored 81 percent in Phase 1 and 25 percent in Phase 2.
2. In the vertical mode, 855 achieved a higher score in Phase 1 70 percent of the time and 822 achieved a higher score 30 percent of the time.
3. In the vertical mode, 855 achieved a Phase 2 rating 12 percent of the time while 822 achieved a significant rating 8 percent of the time.

4. In the lateral mode, 855 achieved a higher score in Phase 1 93 percent of the time and 822 achieved a higher score 90 percent of the time.

5. In the lateral mode, 855 achieved a Phase 2 rating 37 percent of the time while 822 achieved a significant rating zero percent of the time.

Tables 4-15 through 4-18 summarize the results for this test. Additional results not included in the ride quality evaluation are listed in Tables 4-19 and 4-20.

In summary, the upgraded Metroliner 855 rode much better than Metroliner 822, which was at the end of its maintenance cycle.

TABLE 4-15
PHASE 1 - RIDE QUALITY EVALUATION

Test: 822 Leading

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO 822	ISO 855	STANDARD DEVIATION 822	STANDARD DEVIATION 855	RMS PEAK VALUE 822	RMS PEAK VALUE 855	99% LEVEL 822	99% LEVEL 855
"A" TRUCK	LATERAL	50	1.4	2.7	.032	.022	.050	.032	.082	.054
		90	5.5	5.3	.026	.024	.048	.036	.077	.069
		105	-	-	-	-	-	-	-	-
	VERTICAL	50	6.5	5.3	.036	.041	.075	.085	.100	.111
		90	8.6	6.5	.030	.025	.048	.040	.081	.067
		105	-	-	-	-	-	-	-	-
CAR CENTER	LATERAL	50	14.3	21.9	.013	.010	.021	.017	.035	.029
		90	11.5	11.9	.018	.016	.036	.034	.053	.049
		105	9.3	8.1	.019	.017	.036	.035	.055	.056
	VERTICAL	50	6.0	9.5	.027	.025	.043	.042	.070	.066
		90	5.1	5.1	.028	.028	.052	.042	.074	.076
		105	3.2	3.6	.034	.035	.068	.072	.092	.092

POINTS: 855 11 822 49 TOTAL 40

RATING 73%

TABLE 4-16
PHASE 1 - RIDE QUALITY EVALUATION

Test: 855 Leading

LOCATION OF INSTRUMENT	ACCELERATION MODE	SPEED (MPH)	ISO		STANDARD DEVIATION		RMS PEAK VALUE		99% LEVEL	
			822	855	822	855	822	855	822	855
"A" TRUCK	LATERAL	50	1.9	2.8	.028	.024	.052	.036	.071	.064
		90	2.9	5.0	.032	.025	.072	.054	.095	.078
		105	-	-	-	-	-	-	-	-
	VERTICAL	50	5.2	5.4	.042	.036	.092	.078	.119	.104
		90	9.3	3.7	.028	.037	.078	.112	.081	.116
		105	-	-	-	-	-	-	-	-
CAR CENTER	LATERAL	50	10.2	16.1	.013	.011	.078	.030	.039	.035
		90	8.0	12.9	.020	.016	.058	.041	.058	.046
		105	7.4	12.7	.019	.017	.038	.034	.060	.048
	VERTICAL	50	6.2	6.9	.032	.030	.076	.069	.088	.083
		90	3.8	3.4	.033	.029	.061	.060	.091	.078
		105	2.0	5.5	.039	.029	.078	.065	.103	.076

POINTS: 855 4 822 36 TOTAL 40

RATING 90%

TABLE 4-17

PHASE 2 - RIDE QUALITY EVALUATION

Test: 855 Leading

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO			STANDARD DEVIATION			RMS PEAK VALUE			99% LEVEL		
			855/822	NO	YES	855/822	NO	YES	855/822	NO	YES	855/822	NO	YES
"A" TRUCK	LATERAL	50	1.47	X		0.86	X		0.69		X	0.90	X	
		90	1.72		X	0.78	X		0.75		X	0.82	X	
		105	-			-			-			-		
	VERTICAL	50	1.04	X		0.86	X		0.85		X	0.87	X	
		90	0.40	X		1.32	X		1.44	X		1.43	X	
		105	-			-			-			-		
CAR CENTER	LATERAL	50	1.58		X	0.85	X		0.38		X	0.90	X	
		90	1.61		X	0.80	X		0.71		X	0.79	X	
		105	1.72		X	0.89	X		0.89	X		0.80	X	
	VERTICAL	50	1.11	X		0.94	X		0.91	X		0.94	X	
		90	0.89	X		0.88	X		0.98	X		0.86	X	
		105	2.75		X	0.74	X		0.83		X	0.74	X	

POINTS: NO 29 YES 11 TOTAL 40

RATING 28%

TABLE 4-18

PHASE 2 - RIDE QUALITY EVALUATION

Test: 822 Leading

LOCATION OF INSTRUMENTATION	ACCELERATION MODE	SPEED (MPH)	ISO			STANDARD DEVIATION			RMS PEAK VALUE			99% LEVEL		
			855/822	NO	YES	855/822	NO	YES	855/822	NO	YES	855/822	NO	YES
"A" TRUCK	LATERAL	50	1.93		X	0.69		X	0.64		X	0.66		X
		90	0.96	X		0.92	X		0.75		X	0.90	X	
		105	-			-			-			-		
	VERTICAL	50	0.82	X		1.14	X		1.13	X		1.11	X	
		90	0.76	X		0.83	X		0.83		X	0.83	X	
		105	-			-			-			-		
CAR CENTER	LATERAL	50	1.53		X	0.77	X		0.81		X	0.83	X	
		90	1.03	X		0.89	X		0.94	X		0.92	X	
		105	0.87	X		0.89	X		0.97	X		1.02	X	
	VERTICAL	50	1.58	X		0.93	X		0.98	X		0.94	X	
		90	1.00	X		1.00	X		0.81		X	1.03	X	
		105	1.13	X		1.03	X		1.06	X		1.00	X	

POINTS: NO 31 YES 9 TOTAL 40

RATING 23%

TABLE 4-19

LATERAL MODE

SPEED	VEHICLE IN LEAD	INSTRU. LOCATION	RMS LEVEL (g) 822	RMS LEVEL (g) 855	ISO (hrs) 822	ISO (hrs) 855	ALT ISO (hrs) 822	ALT ISO (hrs) 855	99% LEVEL (g) 822	99% LEVEL (g) 855	W_Z 822	W_Z 855
50	855	Rear*	0.027	0.024	1.9	2.8	1.2	1.8	0.071	0.064	2.4	2.3
90			0.032	0.025	2.9	5.0	1.2	2.0	0.095	0.078	2.6	2.4
---			-----	-----	---	---	----	---	-----	-----	---	---
50		Center	0.013	0.011	10.2	16.1	5.1	7.5	0.039	0.035	1.9	1.8
90			0.020	0.016	8.0	12.9	3.7	5.4	0.058	0.046	2.2	2.0
105			0.019	0.017	7.4	12.7	3.3	4.8	0.060	0.048	2.2	2.1
50	822	Rear	0.032	0.023	1.4	---	0.9	2.4	0.082	-----	2.5	2.3
90			0.026	0.024	5.5	5.3	2.1	3.0	0.077	0.069	2.4	2.4
---			-----	-----	---	---	----	---	-----	-----	---	---
50		Center	0.012	0.010	14.3	21.9	7.4	10.0	0.035	0.029	1.9	1.7
90			0.018	0.016	11.5	11.9	5.1	4.9	0.053	0.049	2.1	2.0
105			0.019	0.017	9.3	8.1	4.1	3.7	0.055	0.056	2.2	2.1

*Unattached ends of vehicle

TABLE 4-20

VERTICAL MODE

SPEED	VEHICLE IN LEAD	INSTRU. LOCATION	RMS LEVEL (g)		ISO (hrs)		ALT ISO (hrs)		99% LEVEL (g)		W_Z	
			822	855	822	855	822	855	822	855	822	855
50	855	Rear*	0.042	0.036	5.2	5.4	2.0	2.4	0.119	0.104	2.5	2.4
90			0.028	0.037	9.3	3.7	3.1	1.9	0.081	0.116	2.3	2.5
---			-----	-----	---	---	---	---	-----	-----	---	---
50		Center	0.032	0.030	6.2	6.9	2.8	3.3	0.088	0.083	2.4	2.3
90			0.033	0.029	3.8	3.4	1.8	2.1	0.091	0.078	2.5	2.4
105			0.039	0.029	2.0	5.5	1.3	2.2	0.103	0.076	2.6	2.4
50	822	Rear	0.036	0.040	6.5	---	2.4	2.5	0.100	-----	2.4	2.4
90			0.030	0.025	8.6	6.5	2.9	3.7	0.081	0.067	2.3	2.1
---			-----	-----	---	---	---	---	-----	------	---	---
50		Center	0.027	0.025	6.0	9.5	3.1	3.8	0.070	0.066	2.3	2.2
90			0.028	0.028	5.1	5.1	2.3	2.5	0.074	0.076	2.3	2.3
105			0.034	0.035	3.2	3.6	1.6	1.6	0.092	0.092	2.5	2.6

*Unattached ends of vehicle

5.0 DATA DISCUSSION

The initial intent of the Metroliner truck improvement program was to determine the effect of varying the suspension components of Metroliner 850. Metroliner 855 was chosen as the reference vehicle strictly for historical purposes, since it was also used as the reference car in the LTV/SIG Testing Program. After riding Metroliner 855, it was noted that this particular car rode better than the average Metroliner. A second test was scheduled to compare Metroliner 855 with Metroliner 822, a car that was near the end of its maintenance cycle. Table 4-21 lists the overall results of the program after the data was subjected to the ride quality criteria.

A better way of looking at the results is by way of bar chart comparisons. Figure 4-18 is a comparison of the three test phases for both vertical and lateral modes for each of the two levels.

As a by-product of the testing W_z was plotted against the ISO and Alternate ISO criteria. It should be noted that this is one of the first times that W_z has been reported. The approximate one-to-one correspondence indicates that the three criteria agree fairly well in examining the ride quality of Metroliners Figure 4-19 shows the plots of W_z.

TABLE 4-21

OVERALL RESULTS RIDE QUALITY SPECIFICATION

LEVEL	SUMIRIDE		FIRESTONE		IN-SERVICE	
	850	855	850	855	855	822
1	79%	21%	45%	55%	81%	19%
2	34%	1%	8%	7%	25%	4%

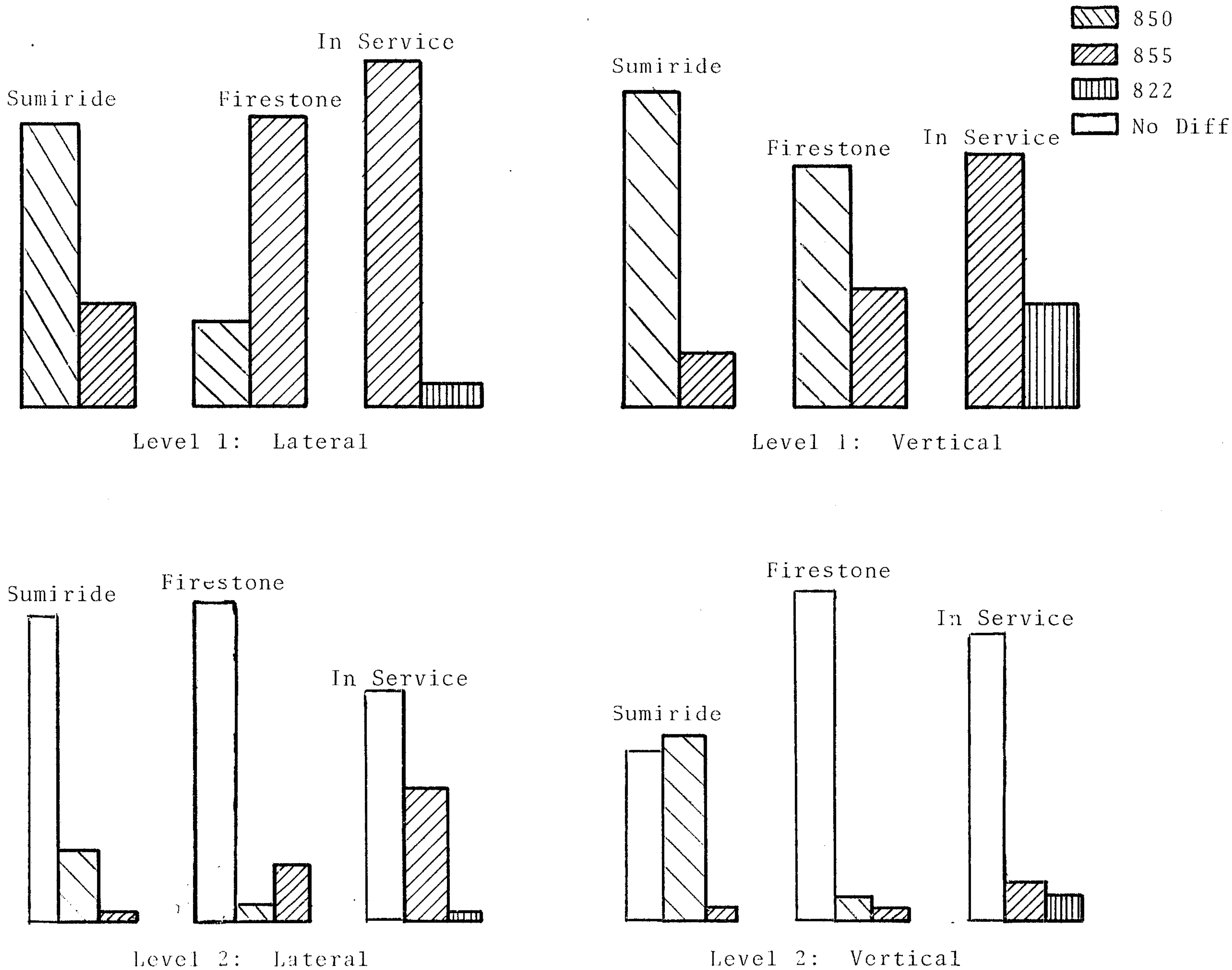
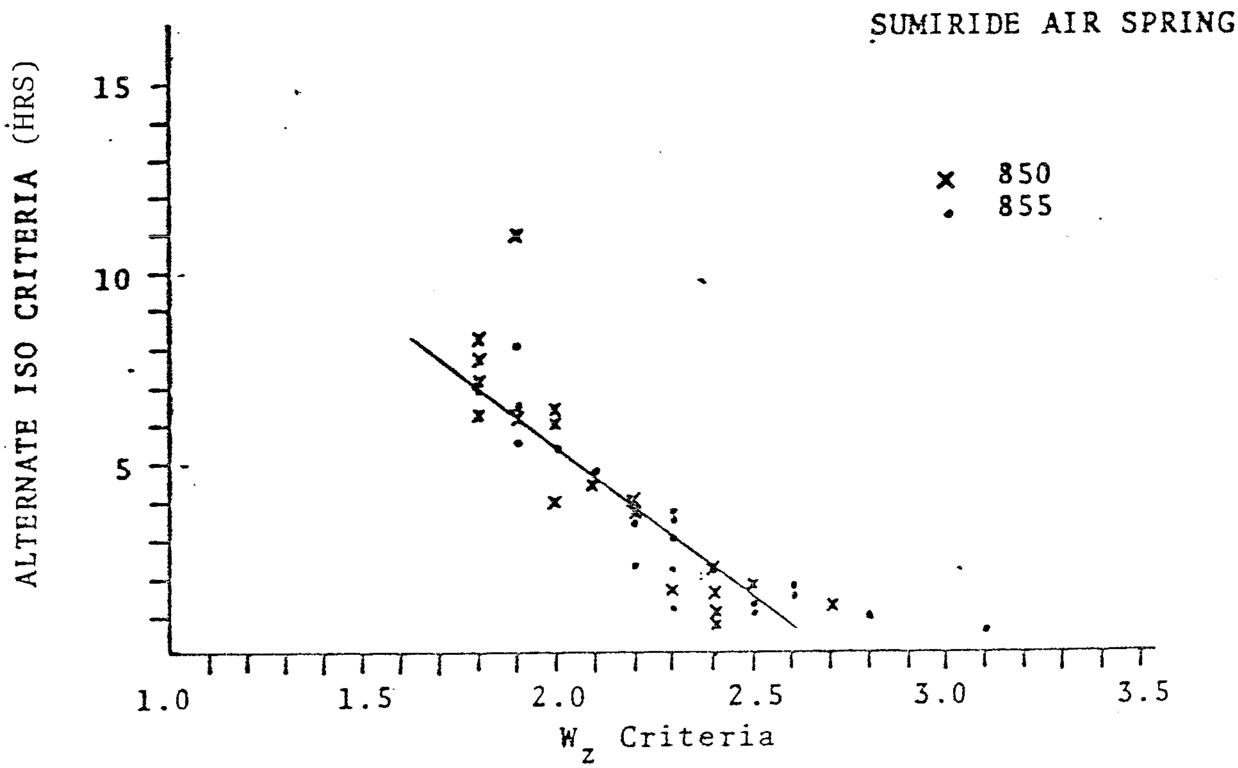


Figure 4-18. Lateral/Vertical Comparisons

ISO vs. W_z



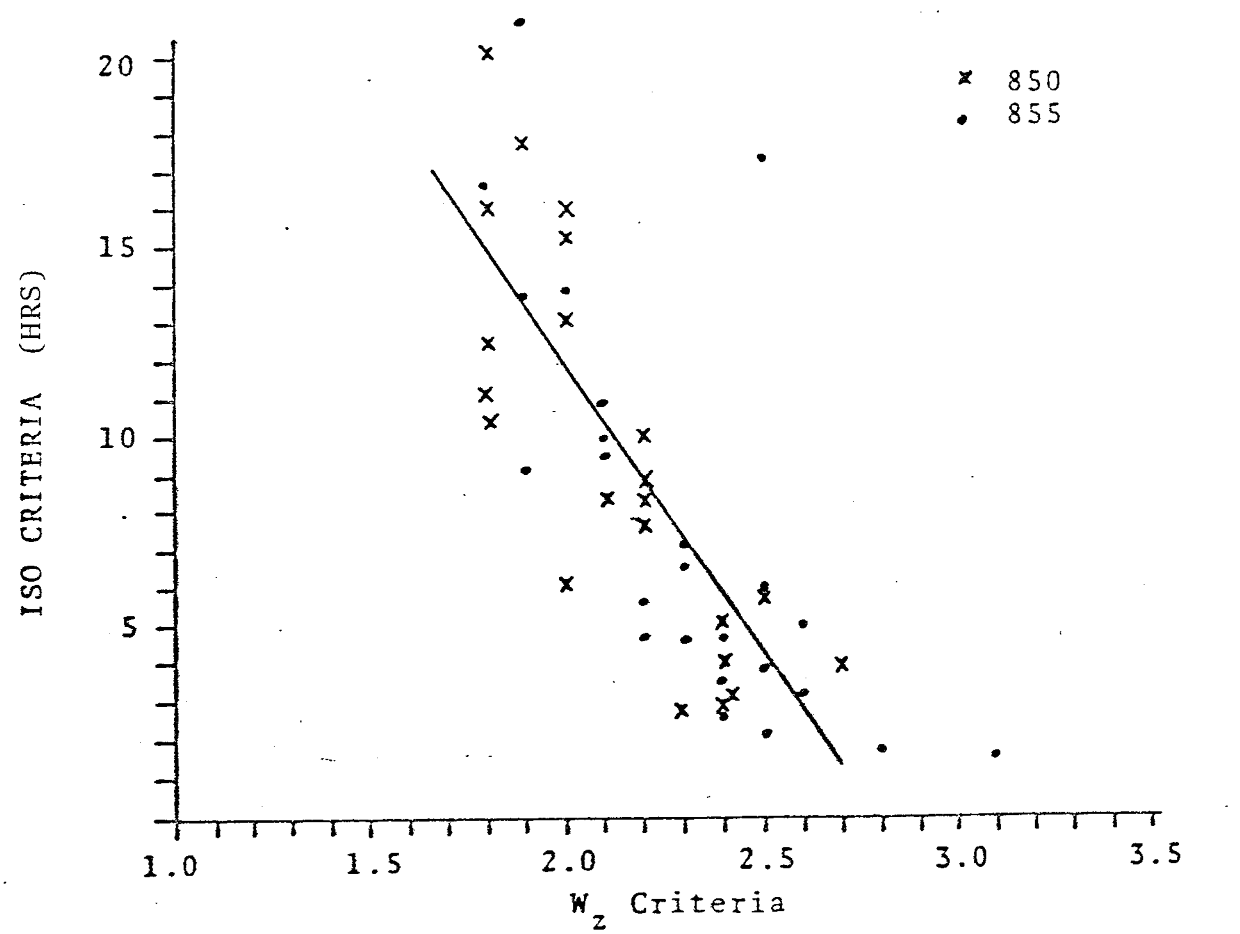


Figure 4-19. ISO Criteria Versus W_z Criteria

6.0 CONCLUSIONS

Sumiride and Firestone air bags can be adapted to the suspension system of a Metroliner.

In testing the Sumiride air bag, the Metroliner with the Sumiride secondary air bag rode much better than the standard Metroliner equipped with secondary air/steel coil springs which had been upgraded to specification.

In testing the particular Firestone air bag selected (that would fit into the standard Metroliner carbody bolster cavity), there appeared to be very little difference between the Metroliner with the Firestone secondary air spring and the standard Metroliner with the secondary air/steel coil spring.

In testing the two Metroliners in various stages of their maintenance cycle, it was apparent that the maintained Metroliner rode better than the Metroliner in need of maintenance.

In varying the components of the suspension system, it was found that the use of vertical primary shock absorbers, friction snubbers, etc., made little difference in the ride of the Metroliner. Adjustments to the lateral dampers in the secondary suspension seemed to be the only component change that affected the ride.

Results of the deflated air bag test indicated that accelerations remained within an acceptable level.

7.0 REFERENCES

[1] Herring, James M., "Metroliner Ride Improvement Program," Report No. FRA-RT-73-30, February 1973.

[2] "LTV/SIG Metroliner Truck - Final Design Report," Report No. FRA-OR&D 76-250, August 1975.

[3] Drawings and Specifications received from GSI, 1977.

[4] "Sumiride Air Spring," General Steel Industries , Castings Division.

[5] "Firestone Air Springs," brochure distributed by Firestone.

[6] ISO Specification 2631, First Edition, 1974-07-01.