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DEMONSTRATION OF
THE BUDD COMPANY AMCOACH
TILT BODY SYSTEM

23 - Passenger Operations

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THE Budd COMPANY
TECHNICAL CENTER
FORT WASHINGTON, PA. 19034

DEMONSTRATION OF
THE BUDD COMPANY AMCOACH
TILT BODY SYSTEM

Performed For

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OFFICE OF PASSENGER AND FREIGHT SERVICE

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16. Abstract

The objective of this program was to demonstrate the Tilt System developed by The Budd Company. This system is applicable to any corridor and it will provide the most cost effective method of reducing trip times on the Northeast Corridor by allowing higher travel speeds on existing curves while maintaining the same level of passenger comfort. The Tilt System can be retrofit on the existing Amfleet cars with minimum modifications.

The system is powered pneumatically. The controller is an on-off type. It is fail safe - in the event of a power failure, the system will return to the neutral position. This system allows increases in curving speeds of between 20% and 35% depending on superelevation as compared to conventional cars.

The demonstration was successful. The system performed well under the design conditions and safely under extreme over-speed conditions.

The subsequent analysis indicates that modified two-convolute air springs could also be used with the tilt body system. This would provide that the roll stiffness on the tilt body cars would always be equal to or greater than the conventional Amfleet cars.

Key Words
Amfleet Tilt Body Coach
Tilt Body System
Curving Performance

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PREFACE

The work reported herein was performed by The Budd Company Technical Center for the Federal Railroad Administration using AMTRAK properties and equipment. The Budd Company wishes to acknowledge the continuing assistance of the FRA; our contract monitor, Dick Scharr; AMTRAK engineering and operating groups; the Wilmington Car Shops; the New Haven Car Shop; and for the F40PH testing phase, ENSCO, Inc.

1.0 INTRODUCTION

The Federal Railroad Administration has been engaged in several programs aimed at the improvement of passenger train service in the Northeast Corridor (NEC). The trip times of 2 hours and 40 minutes between Washington/New York and 3 hours and 40 minutes between Boston/New York required under the 4-R Act (Public Law 94-210) is now being approached in regular service with Amfleet trains.

The Amtrak Improvement Act of 1978 (Public Law 95-421) amended the 4-R Act to require that the Secretary develop vehicles capable of providing 2:30 and 3:00 hour trip times between the respective city pairs.

To achieve these travel times, it is necessary to either increase the train speeds on curves or eliminate the curves. Cost estimates to straighten the track are in the 870 million dollar range and cost estimates to develop and deliver a new train which can traverse the curves at increased speeds is in the 87 million dollar range. As a result, the most cost effective method of achieving the reduced trip times is to add a tilt system to the existing Amfleet cars. For any specified lateral acceleration limit (established for passenger comfort) a tilt-body passenger train can traverse a given curve at a higher speed than a corresponding non-tilting train. For this reason, tilt-body technology has the potential to significantly affect a reduction in passenger train trip times, not only on the NEC, but on any passenger route in the country which possesses a significant number of curves.

The Budd Company has independently conducted analyses of carbody tilting systems developed by other manufacturers throughout the world, to determine if an existing tilt system could be adapted to an Amcoach to increase its curving performance. In every case, extensive modifications to the Amcoach body including loss of seats would be required to accommodate these systems.

As a result of this research, design, and analysis, The Budd Company has developed a simple tilt system that provides the required passenger comfort level at higher curving speeds. This simple tilt system can be installed on an Amcoach with minimum modifications to the truck and carbody, and will provide the most cost effective means of reducing trip times.

2.0 OBJECTIVE

The objective of this joint FRA/Amtrak/Budd project is to demonstrate by test the existing Budd Company design for an Amfleet tilt body system. The objectives of these tests is to demonstrate the ability of the Budd Tilt Body System to increase the curving speed of a retrofitted Amfleet coach without increasing the lateral accelerations experienced by the passengers and to verify the compliance of the car with the clearance constraints of the Northeast Corridor.

The tasks performed in the March, 1982 tests were mechanical equipment function test, response time evaluation, clearance testing, and a demonstration road test. The tasks performed in the July, 1982 tests were to evaluate adjustments to the system for performance improvements and to explore extreme operating conditions to assure system safety in both tilting and non-tilting service. An additional objective of this project is to provide a detail evaluation of system performance and to report conclusions to FRA, Amtrak, and others in the form of a final report.

3.0 CONCLUSIONS

The major conclusion that can be drawn from the evaluation program is that the Budd Tilt Body System provides an effective means of reducing trip times by increasing the speeds on existing curves while maintaining passenger comfort.

The Budd Tilt Body System incorporates on/off control, accelerometer sensing, pneumatic power, and torsion bar actuation into an integrated effective system. The concept implementation has been demonstrated to be a simple retrofit with minimum modification to carbody and truck, no loss of revenue seating capacity, and no hydraulics. Compatible air and electrical power consumption requires no change to present equipment capabilities.

Operational testing of the system during the March road test revealed some areas where adjustments could be made to improve the dynamic response of the tilt system. The July road test activity demonstrated the following adjustments were effective:

- The accelerometer output signal filtration was adjusted for minimum delay and maximum spike exclusion resulting in virtual elimination of multiple system actuations due to variations in a curve.
- The air supply to the solenoid pilot valve was modified to remove flow restrictions resulting in improved response.

Analysis of the collected test data indicates that an increase in roll stiffness of the tilt car is desirable to reduce the tendency of the tilt car to roll outboard on a curve prior to actuation of the tilt system. A change from the three-convolute air spring used on the tilt car to a modification of the two-convolute air spring used on the standard Amcoach is being studied. The area change rate characteristics of the modified air spring will supply the necessary increase in roll stiffness and the extended stroke range requirements of the tilt system. The change to the modified double-convolute air spring is recommended for the final design.

The ability of the system to operate reliably has been demonstrated throughout the test program. The only problem requiring equipment repair was associated with the train line dual air supply feed to the leveling valve on board all Amcoaches and was not related to the tilt system. The problem was resolved by replacing the contaminated valves for the continuation of the test. A permanent resolution is proposed wherein a single line from the car air reservoir, which is supplied with air from both air supply lines, would replace separate lines and check valves presently in use.

An inspection of the tilt hardware removed from the car after testing and revenue service with the tilt system disabled showed the equipment to be in good condition. There were no signs of wear or fatigue to indicate that the equipment would not have a service life comparable to other under-car equipment. One collar retention pin on a mechanical down-stop sheared off during testing without interrupting normal operation of the system. The final equipment design will incorporate a more secure collar retention. Better sealing is required to retain lubricant in ball joint located at the end of the tilt arm. Replacement with a rubber bushing is being considered.

During the road test, a gap appeared between the diaphrams of the tilt car and a non-tilt car. This situation will be corrected with a wider diaphram face plate.

Observations of the general ride quality of the car and associated Amcoaches indicate that the lateral suspension shock absorbers should be retuned for transient track disturbances.

4.0 DESCRIPTION OF TILT SYSTEM

4.1 General

The Budd Tilt System is designed to be retrofitted to the existing Amfleet coach with a minimum of carbody and truck modifications. The system utilizes a simple on-off control and is powered by a pneumatic actuator which requires the addition of an auxiliary air reservoir to insure an adequate supply of pressurized air.

The tilting of the carbody is accomplished by applying an external moment to the secondary suspension to tilt the carbody with respect to the truck. This moment is generated by a split torsion bar with an air cylinder and piston rod connecting the two halves of the bar. When the air cylinder is actuated, the arms of the torsion bar (one on each side of the carbody) rotate in opposite directions. This opposed rotating lowers the carbody on one side with respect to the truck and raises it on the other, thus producing the carbody tilt.

The control system uses two lateral accelerometers mounted on the lead truck. When both of these accelerometers register an acceleration level exceeding a pre-established lateral acceleration, the carbody is tilted to its maximum position at a pre-determined rate. When either of these accelerometers register an acceleration slightly below the pre-established level for tilt, the carbody is returned to its neutral position by exhausting the cylinder air. Two accelerometers are used to insure that one failed accelerometer will not cause the system to tilt or prevent it from returning to normal. Additionally, the tilt command is nullified unless the car is traveling over 60 mph.

The operating criteria for this system is to utilize the maximum available tilt at all times and limit the quasi-static lateral acceleration experienced by the passenger to the present value of .05 g's.

The tilt angle of the existing Amfleet coach and truck is limited to 4° between the carbody and truck but, unlike other tilt systems which must compensate for the roll of the secondary suspension, the complete 4° is realized. The additional curving speed that can be achieved with an Amfleet coach equipped with the tilt body system, over the standard Amfleet coaches, is an inverse function of the superelevation of the curve being traversed. As the superelevation of the curve increases, the percent additional speed in curving decreases. On a 2" superelevated curve, the additional speed during curving is approximately 33% more than the standard coach; on a 4" superelevated curve, the additional speed is 25%; and on a 6" superelevated curve, the additional speed is 20%.

In order to obtain maximum benefit from this tilt system, the speed profile of the train should maintain a cant deficiency in all curves of 7". At this cant deficiency, the tilt system will function so that the passengers experience a quasistatic lateral acceleration of .05 g's. On the standard Amfleet coach, the maximum speed on curves is equivalent to 3" cant deficiency.

The Budd Tilt Body System was fabricated and installed on a standard Amfleet coach for the evaluation of the design. The system consists of a modified Amfleet II truck, air actuated torsion bar assembly, air control valves, accumulators, truck lateral accelerometers, and an electronic controller. The Amfleet coach used for the tilt suspension testing was Car #21183. The elements added to the car for the demonstration include:

1) a triple-convolute air spring to provide more displacement and accommodate the extra motion that accompanies carbody tilt action;
2) a spring plank similar to that used on the SPV-2000 to stabilize the air-coil spring suspension;
3) Knorr leveling valves moved to the exact car centerline to attain symmetrical tilt characteristics;
4) air-operated mechanical down stops to limit the motion between the carbody and truck bolster in non-tilt situations while allowing travel beyond the stop position during tilt operations;
5) the removal of the bolster-mounted roll orifice connecting the two air spring reservoirs to improve return to center operation;
6) magnetic speed pickup to supply speed and direction information for the controller;
7) attachment points for carbody mounted torsion bar assembly for tilt actuation;

8) two accelerometers mounted to the truck bolster to provide the required signals for both actuation of tilt and return to normal;

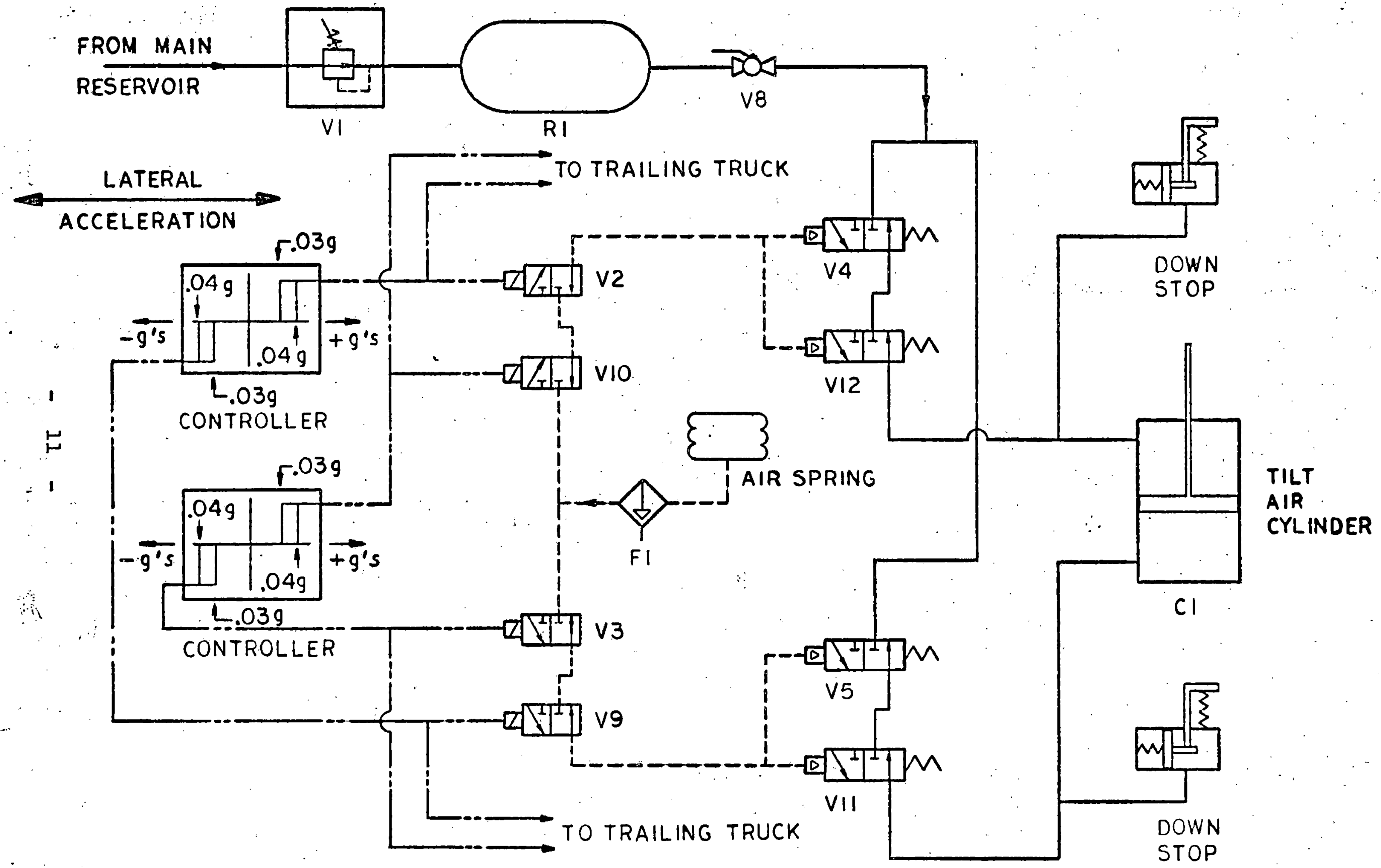
9) a soft primary suspension as used on standard Amfleet II trucks;

10) tread brakes mounted low on the side frames for clearance considerations that act to supplement the disc brakes.

In operation, the Budd Tilt Body System will trigger only at a predetermined lateral "g" level on the truck. When the tilt system is actuated, it tilts the car to a maximum angle and holds it there until the signal drops below a lower "g" level causing the mechanism to return the carbody to its normal position. An acceleration level of 0.04g's was selected as the tilt actuation level and an acceleration level of 0.03g's was selected as the return to normal level.

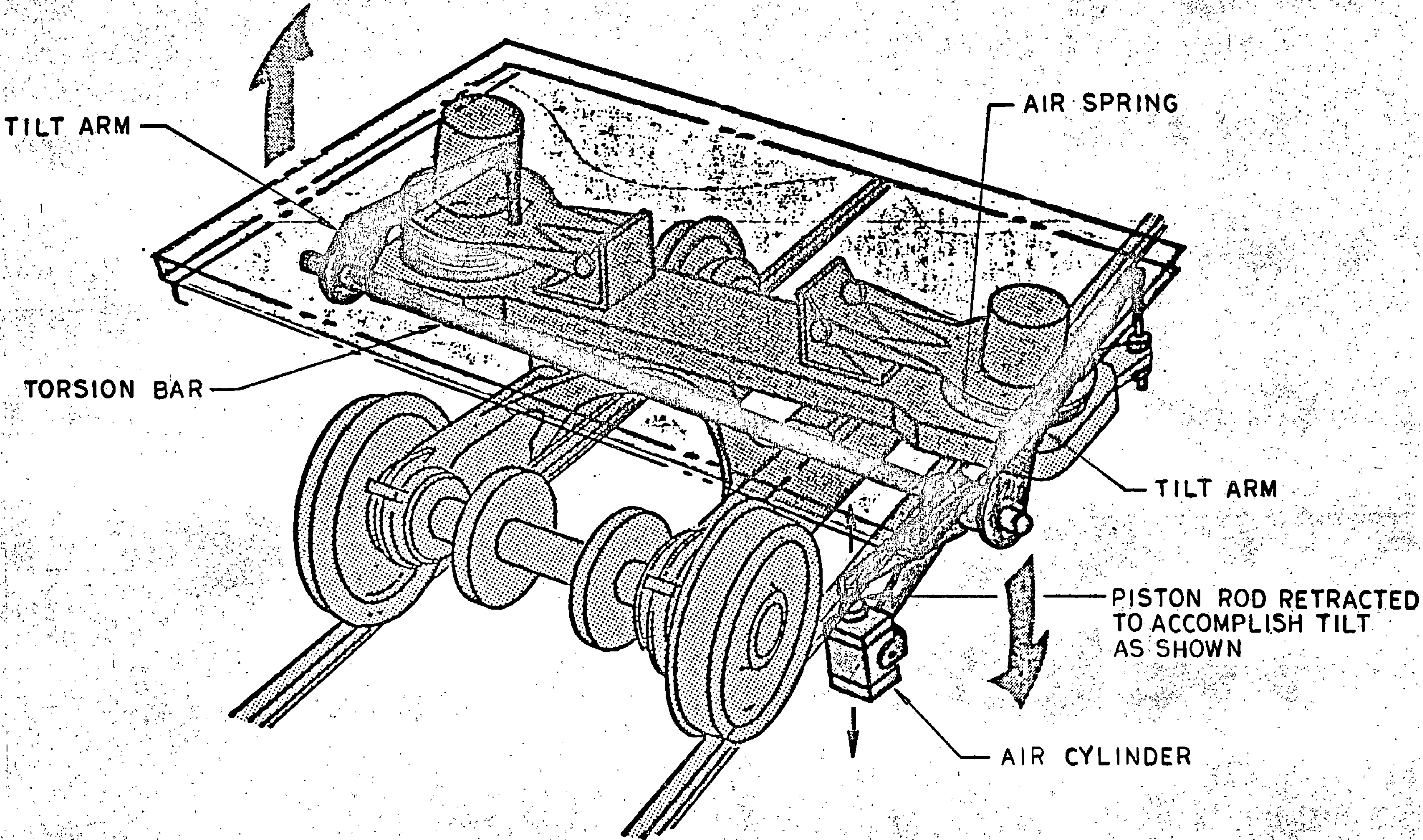
Figure 4-1 shows a mechanical schematic of the system.

Figure 4-2 is a picture drawing of the Tilt Arm and Torsion Bar Arrangement. The system is shown with the carbody tilted to the right. The operation is as follows: to tilt to the right, the air cylinder and piston rod assembly is retracted. This causes the tilt arm on the left to rotate clockwise lifting the carbody with respect to the truck and the tilt arm on the right is rotated counter clockwise lowering the carbody with respect to the truck. This action causes the carbody to tilt to the right.



MECHANICAL SCHEMATIC

FIGURE 4-1



TILT ARM & TORSION BAR ARRANGEMENT

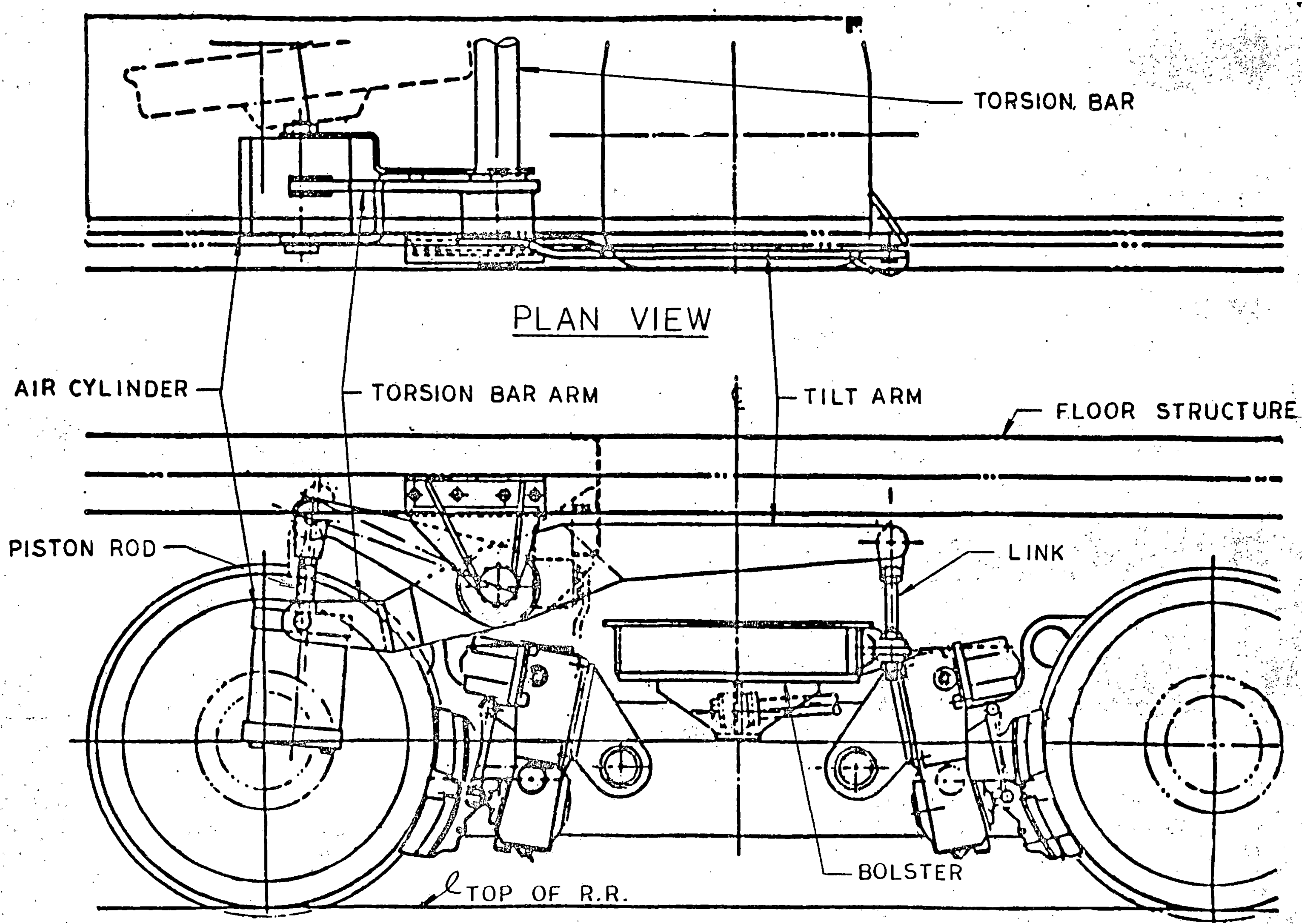
FIGURE 4-2

Figure 4-3 shows the tilt truck mechanism including air cylinder, piston rod, torsion bar arm, tilt arms, truck attachment link, truck bolster, and carbody attachment for torsion bar assembly.

Figure 4-4 is a cross-section through the bolster showing the location of coil springs, the spring planks, three-convolute air springs, and the down stops.

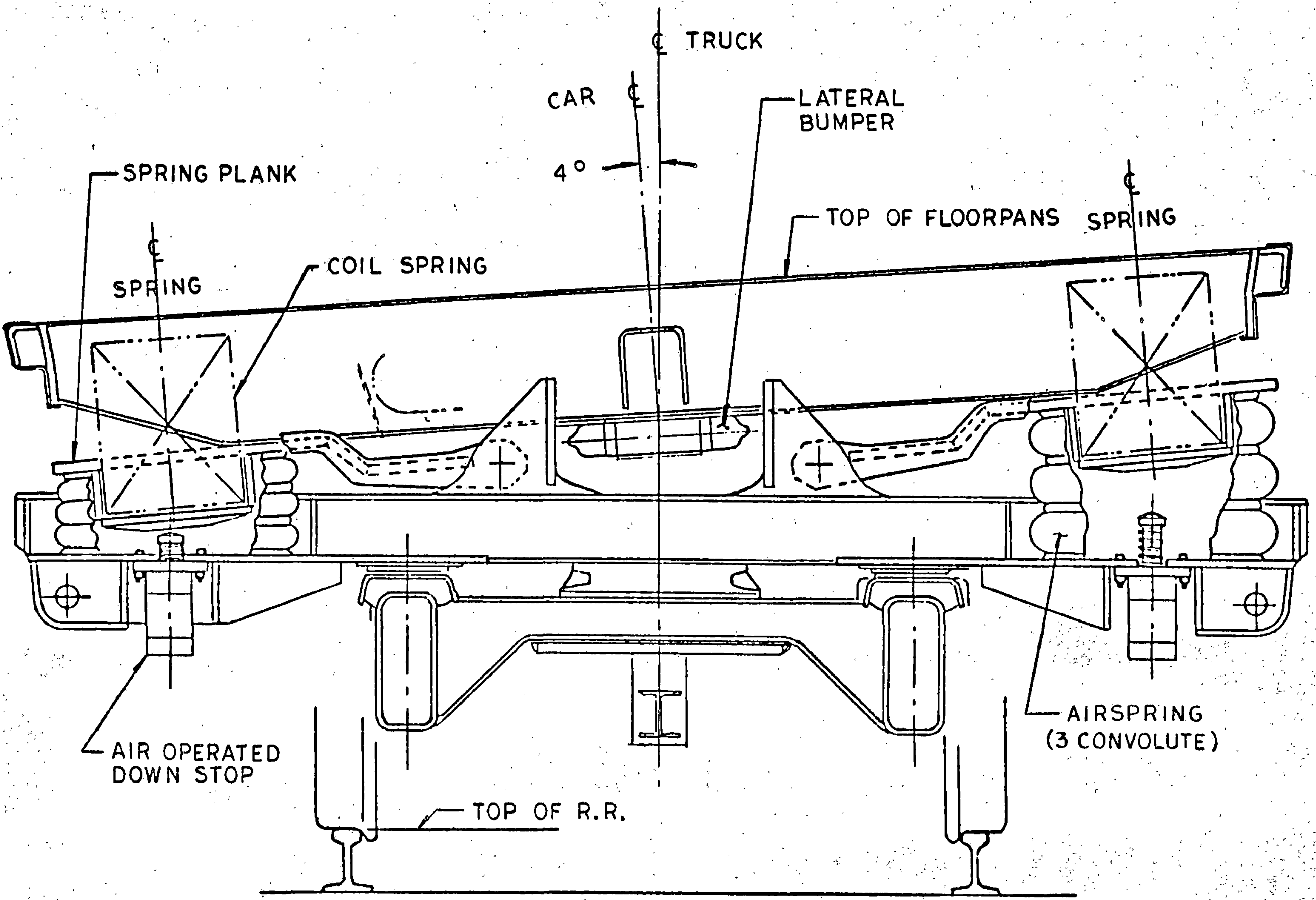
Figure 4-5 is a view of the under floor area showing the location of the valve module, accumulator, tilt mechanism and truck. Each end of the car is similarly equipped and is fed from the main air reservoir.

Figure 4-6 is a cross-section of the down stop showing all operational elements. The unit is bolted to the bottom of the tilt truck bolster at the center of the air spring and extends up through the air spring to make contact with the bottom of the spring plank. In the normal, non-tilt position (no pressure in the tilt cylinder), the stop is configured, as shown in Figure 4-6, such that the spring plank will contact a cap (7) threaded to the end of a shaft (3) which is guided by a seal (10) and sleeve (2) in the main housing (1) such that the shaft cannot move beyond the block (8) which is also supported by the housing (1). When the car is to be tilted, air is applied at the inlet port forcing a piston (5) to retract the block (8) against the force of spring (9) to a position that will allow the shaft (3) to move to the bottom of the central hole in the housing (1). When air



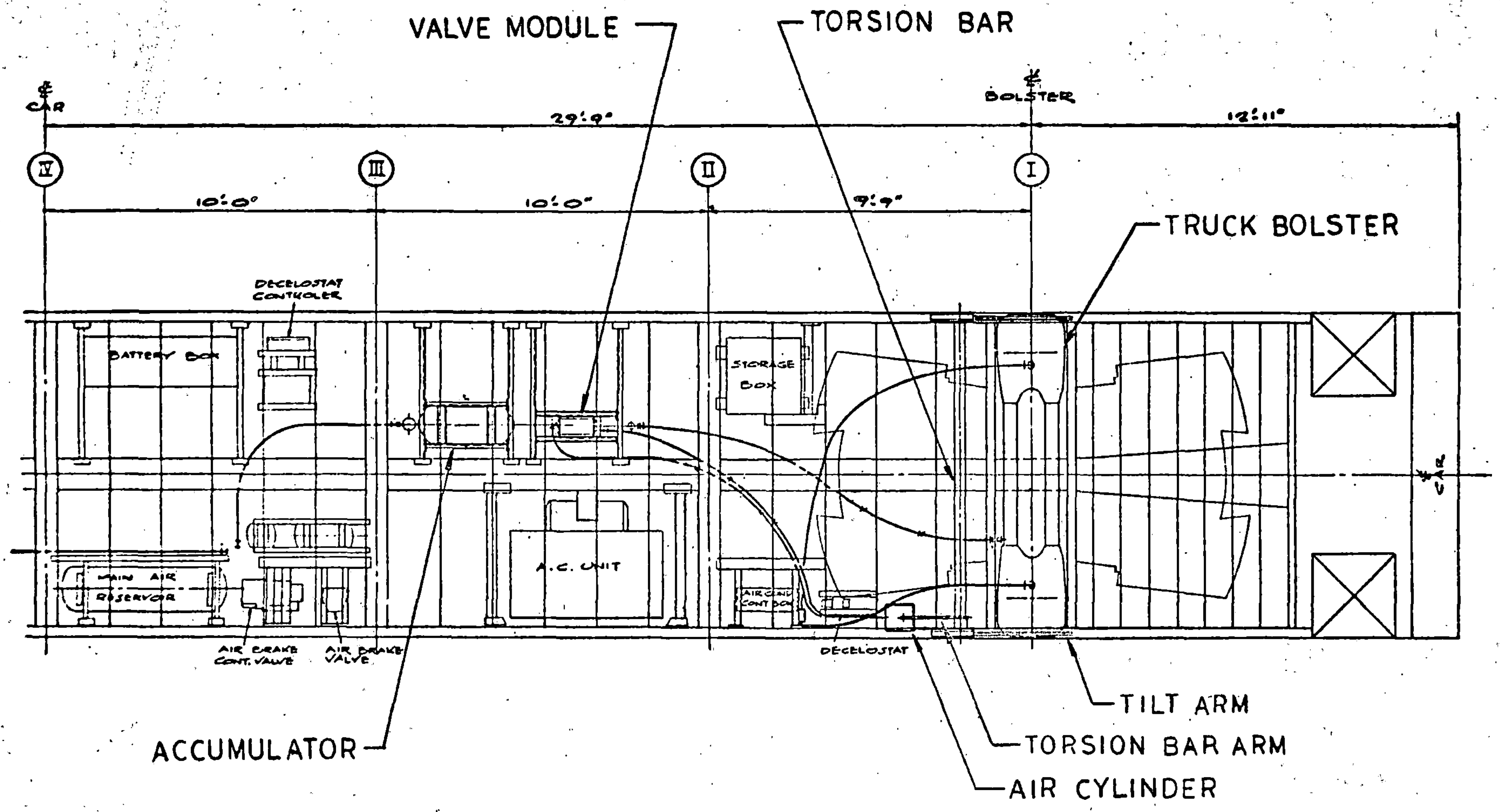
TILT TRUCK MECHANISM

FIGURE 4-3



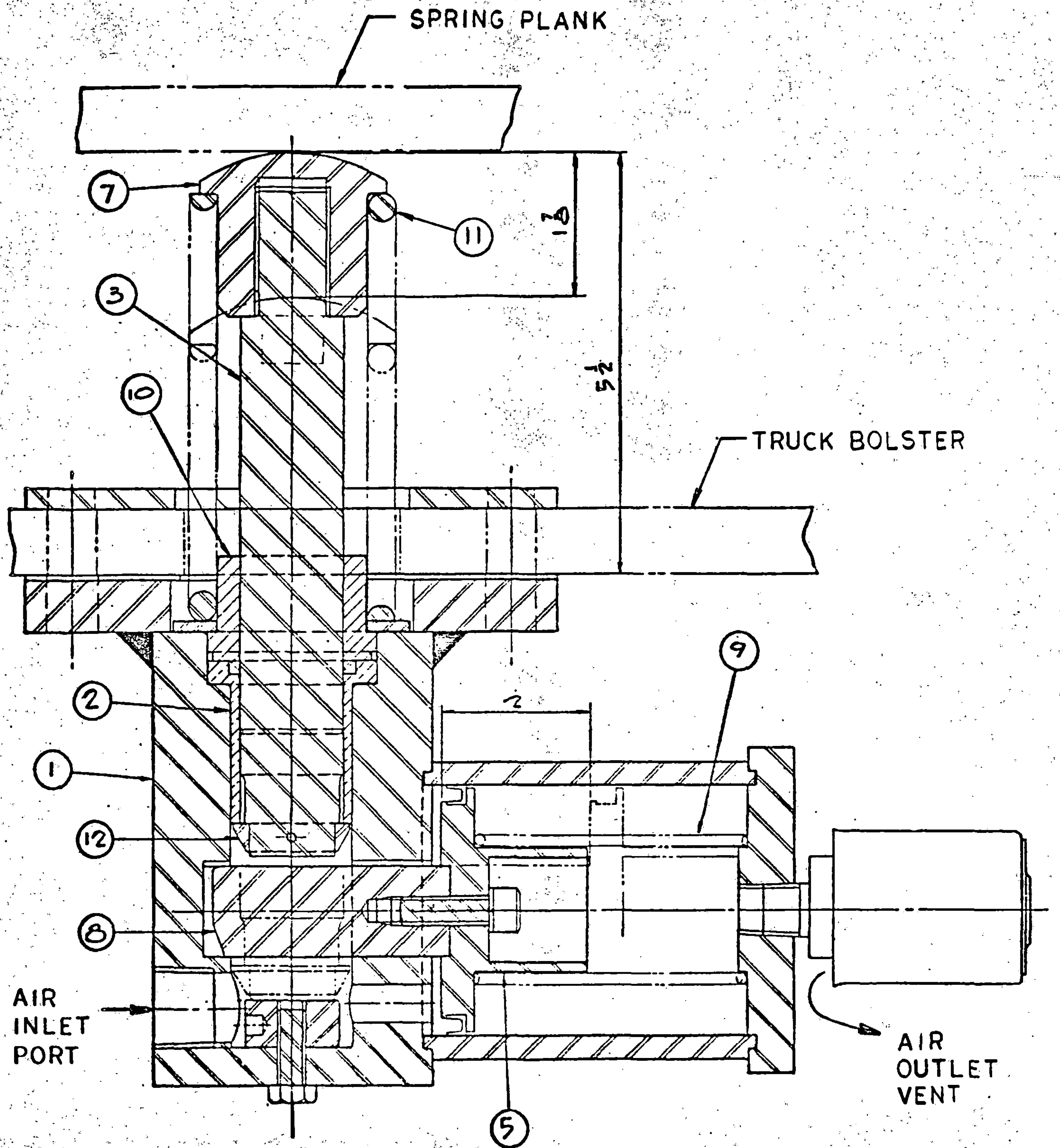
TRANSVERSE SECTION THRU TRUCK BOLSTER

FIGURE 4-4



PLAN VIEW UNDERFLOOR "A"-END

FIGURE 4-5



DOWN STOP ARRANGEMENT

FIGURE 4-6

is released, the spring (11) returns the shaft (3) to the full "up" position limited by a stop (12) as the spring plank returns to normal position. Spring (9) returns the piston (5) and block (8) to the normal stop position as the shaft (3) extends to the full "up" position.

Figures 4-7 A&B show the down stop in the "up" and "down" positions, respectively.

The truck bolster roll orifice, located between the left and right air spring chambers, was completely removed for the March test, thus offering no resistance to the air flow between the chambers under a roll condition. In order to compensate for the reduced roll stiffness of the three-convolution air spring design, a method of restricting the roll orifice,except during tilting, was fabricated for the July testing. The bolster orifice hole was plugged completely and the air springs were externally interconnected, as shown in Figure 4-8, to provide a high restriction of air flow between the two air spring chambers through metering valve #1 prior to tilt actuation and a low restriction of air flow between the two air spring chambers through an open air-operated ball valve during tilt operation. The extra plumbing draws air from either side of the tilt cylinder through a double check valve and a single check valve to open the large diameter ball valve with an air operator. When the ball valve is open, there is a negligible restriction between the two air spring chambers. When the tilt air pressure is removed from the cylinder, the air operator must bleed down through metering valve #2 delaying the ball

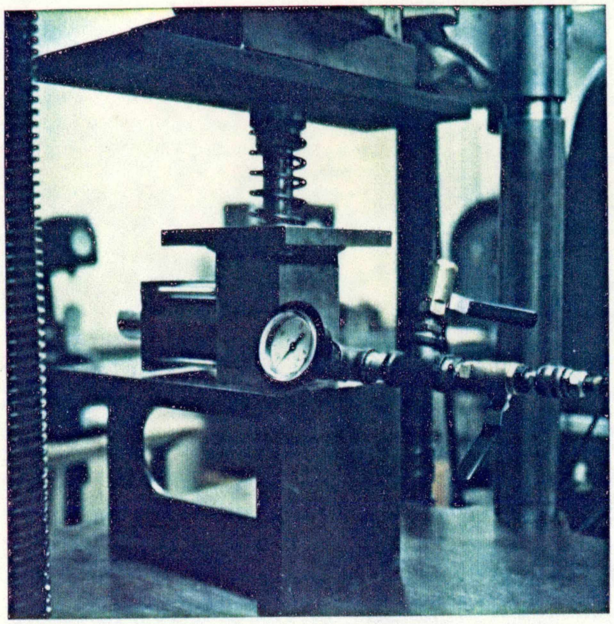


FIGURE 4-7a: DOWN STOP, TESTING - UP

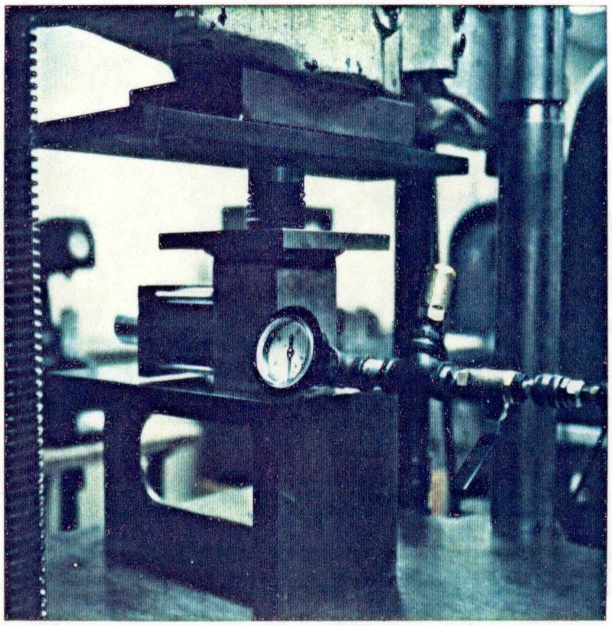
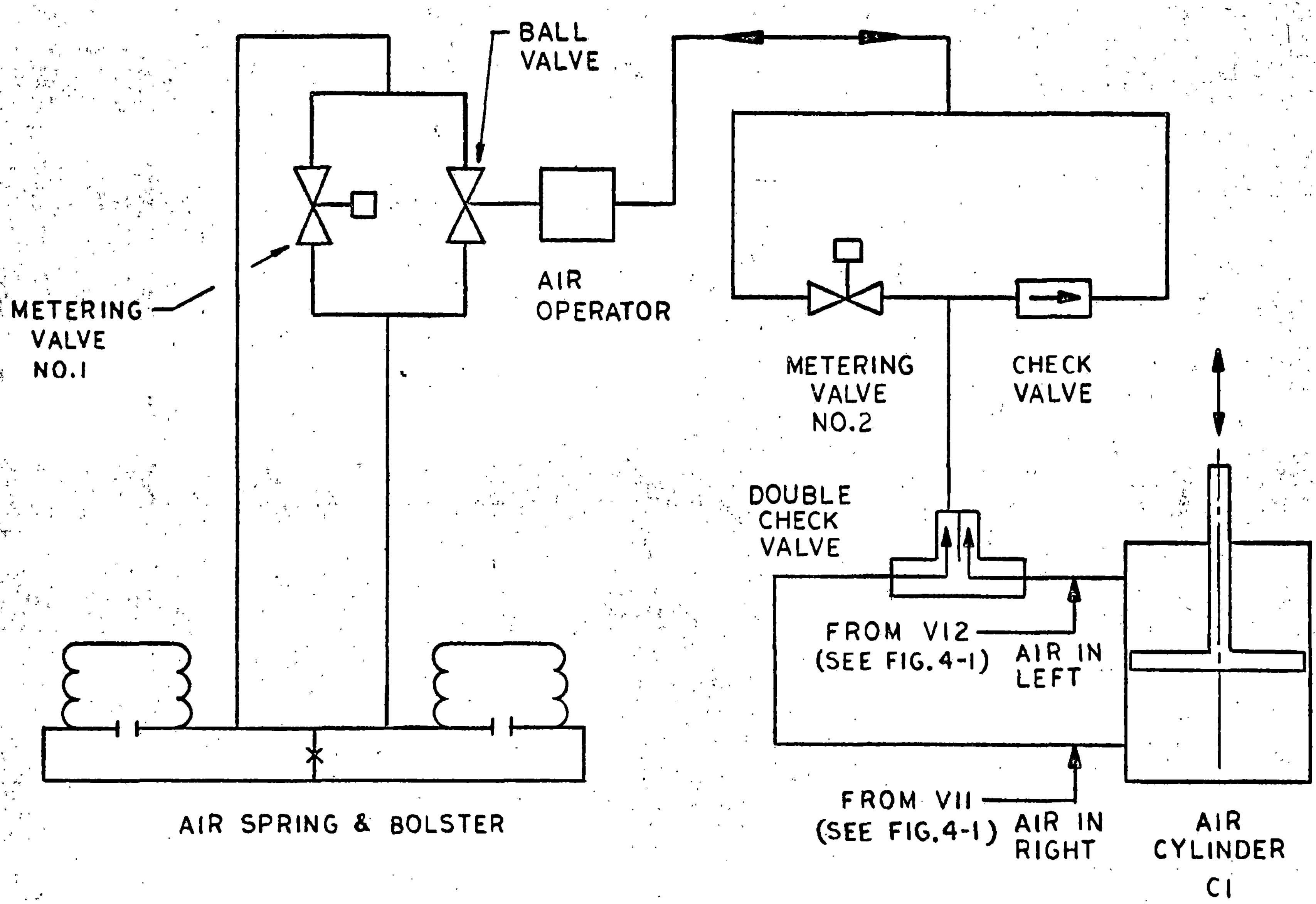


FIGURE 4-7b: DOWN STOP, TESTING - DOWN



INTER SPRING ORIFICE SCHEMATIC
FOR JULY TESTING

FIGURE 4-8

valve closing until the tilt car has returned to center. This system was eliminated since it added too much complexity for the marginal improvements experienced.

The pictures that follow in Figure 4-9 through 4-16 show the principle elements of the tilt system as they are installed on the test car.

4.2 Tilt Control System Signal

A simplified block diagram of the Budd Tilt Body Control System is shown in Figure 4-17. This diagram represents the functions performed from receiving the accelerometer signals from the two accelerometers on the lead truck to the air solenoid valves which pilot the main tilt air cylinder solenoid valves.

When the filtered signals from both the accelerometers exceed the tilt command level, as established by the left tilt or right tilt level detectors, a signal is sent to the appropriate logic combiners. If the speed of the car is greater than the tilt threshold level (approximately 60 mph), the logic combiners will activate both appropriate solenoid valves, pressurizing the tilt air cylinder. When the filtered signal from either accelerometer is less than a fixed level below the tilt command level, either solenoid valve will be de-energized exhausting the tilt air cylinder returning the car to neutral.

4.2.1 Accelerometers

The signal used for control of carbody tilt, is generated by two accelerometers mounted on the truck bolster to detect the

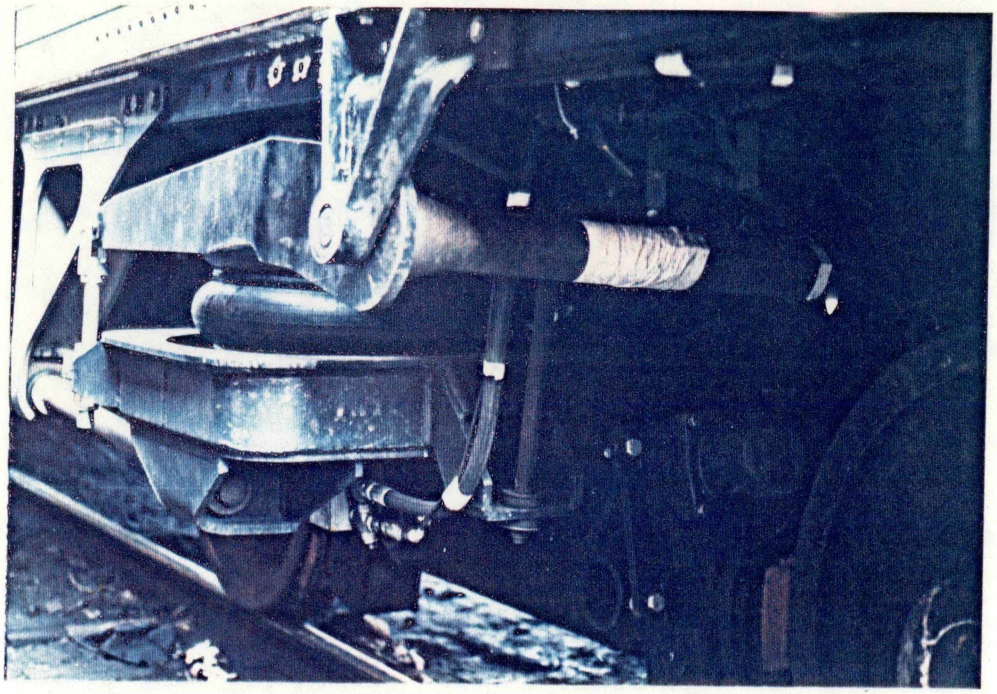


FIGURE 4-9: TORSION BAR & ARM - CARBODY TILTED UP ON LEFT SIDE TOWARD RIGHT

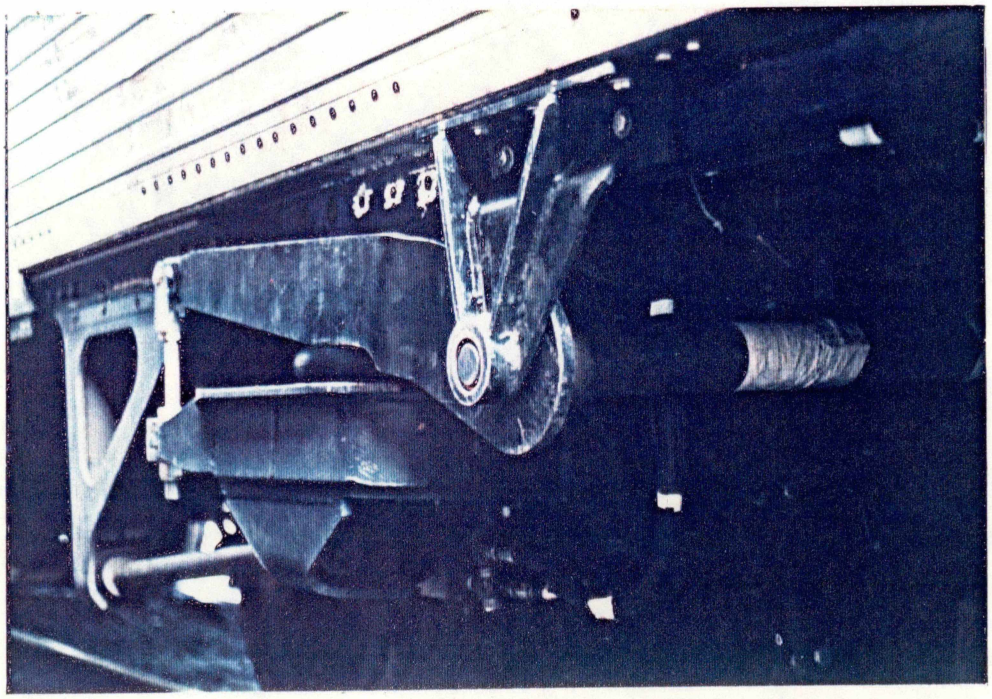


FIGURE 4-10: TORSION BAR & ARM - CARBODY TILTED DOWN ON LEFT SIDE

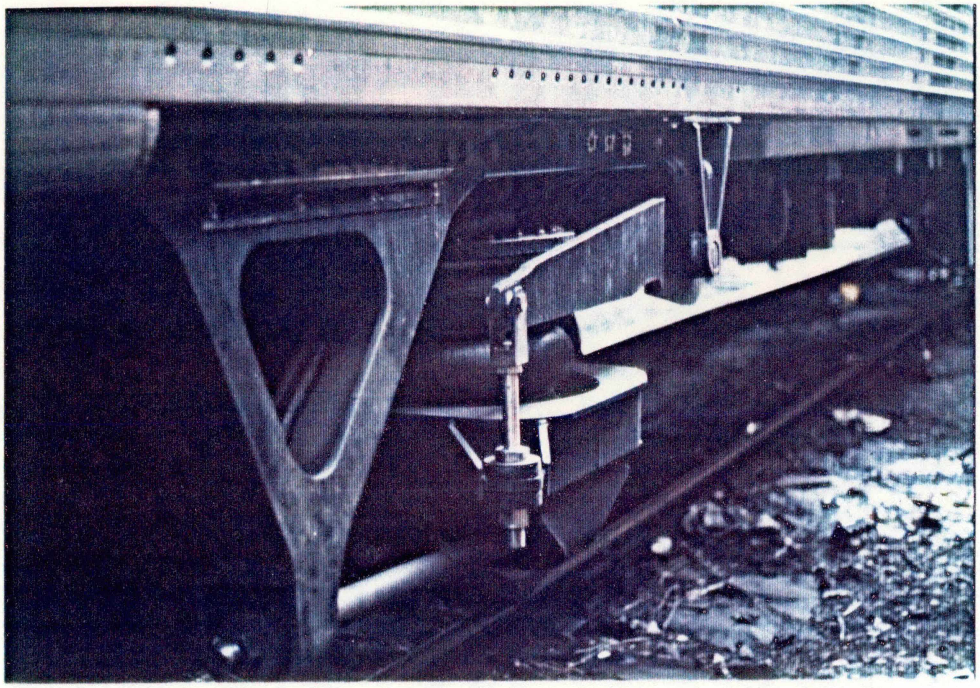


FIGURE 4-11: CARBODY TILTED UP ON SIDE SHOWN

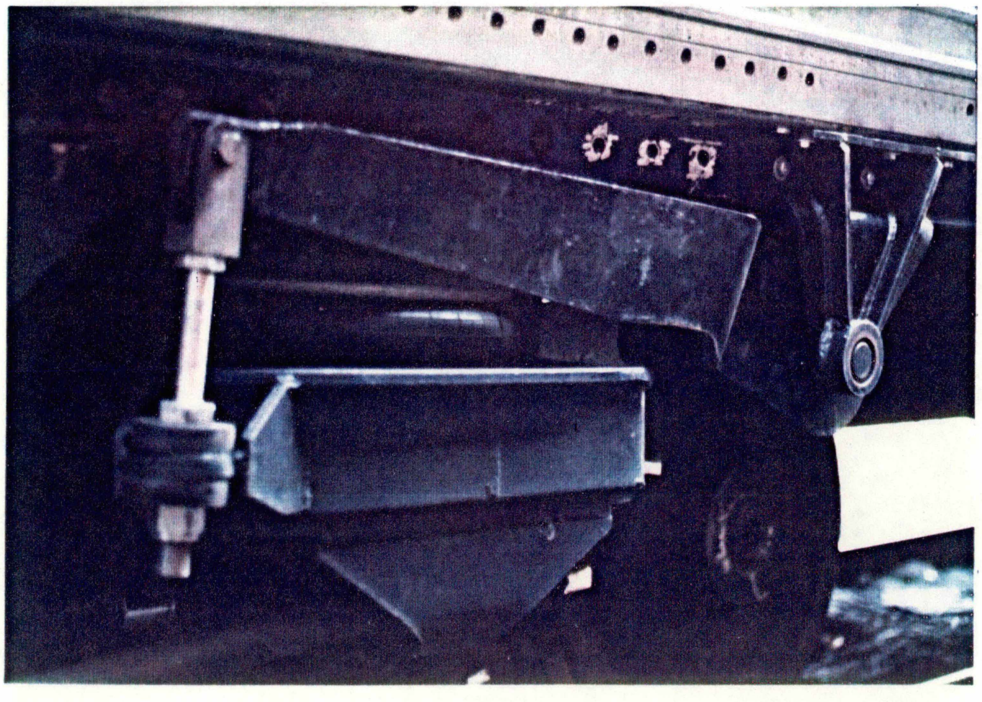


FIGURE 4-12: CARBODY TILTED DOWN ON SIDE SHOWN

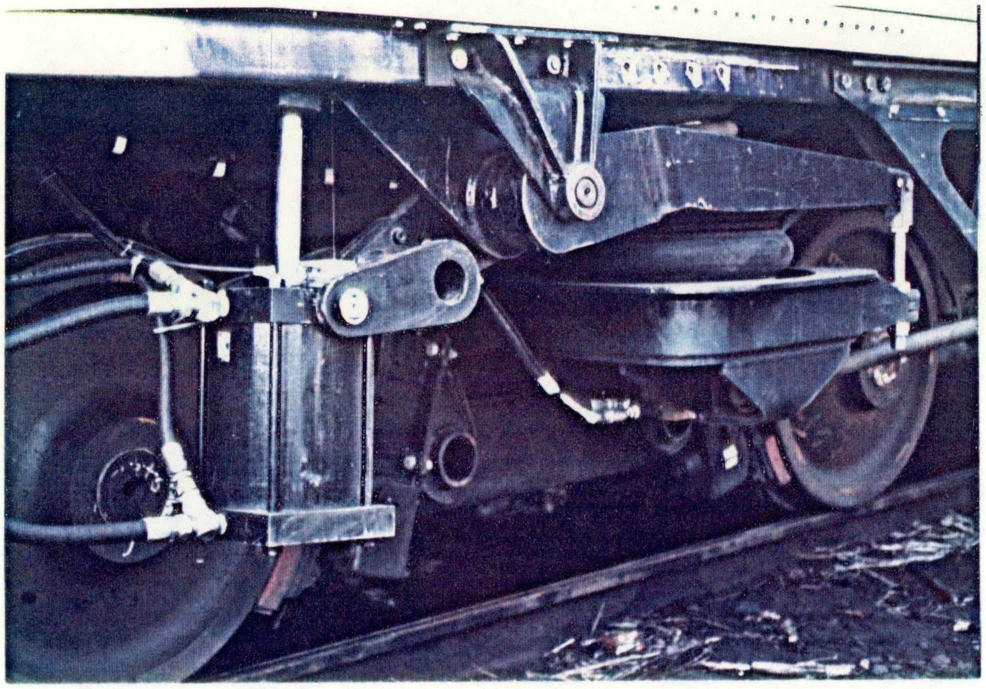


FIGURE 4-13: AIR CYLINDER & ARM - CARBODY TILTED UP ON SIDE SHOWN, AIR CYLINDER EXTENDED

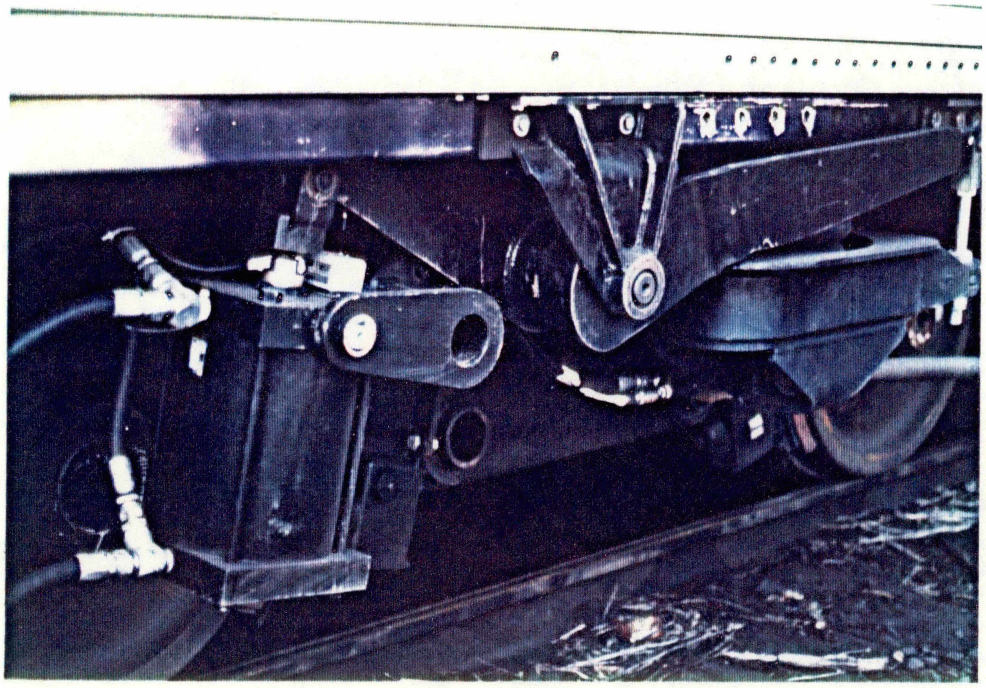


FIGURE 4-14: AIR CYLINDER & ARM - CARBODY TILTED DOWN ON SIDE SHOWN, AIR CYLINDER RETRACTED

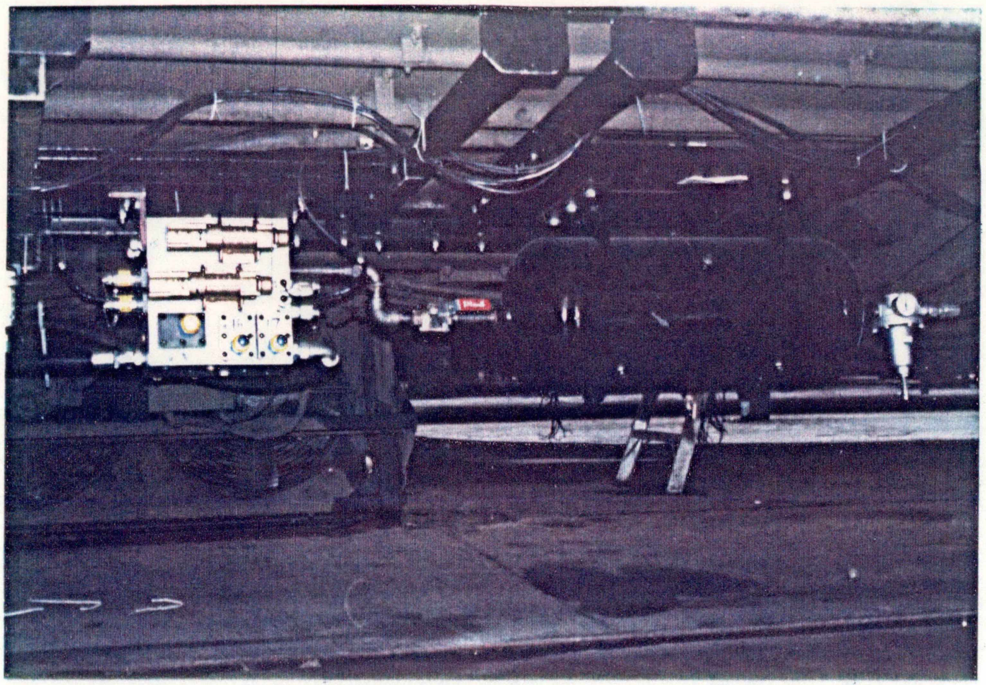


FIGURE 4-15: CONTROL VALVE MANIFOLD, AIR ACCUMULATOR AND REGULATOR

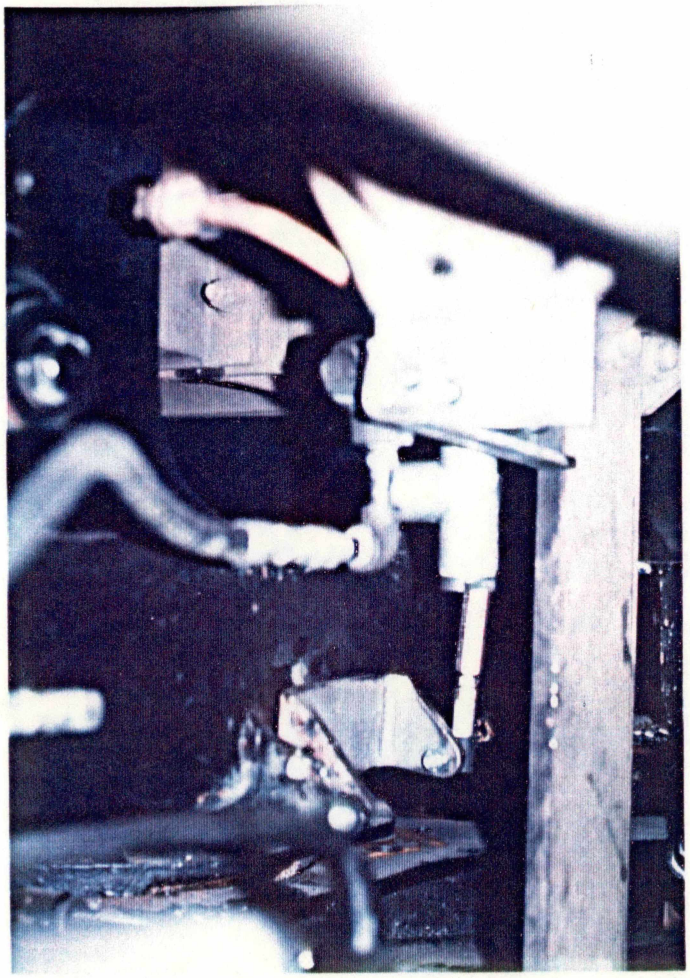
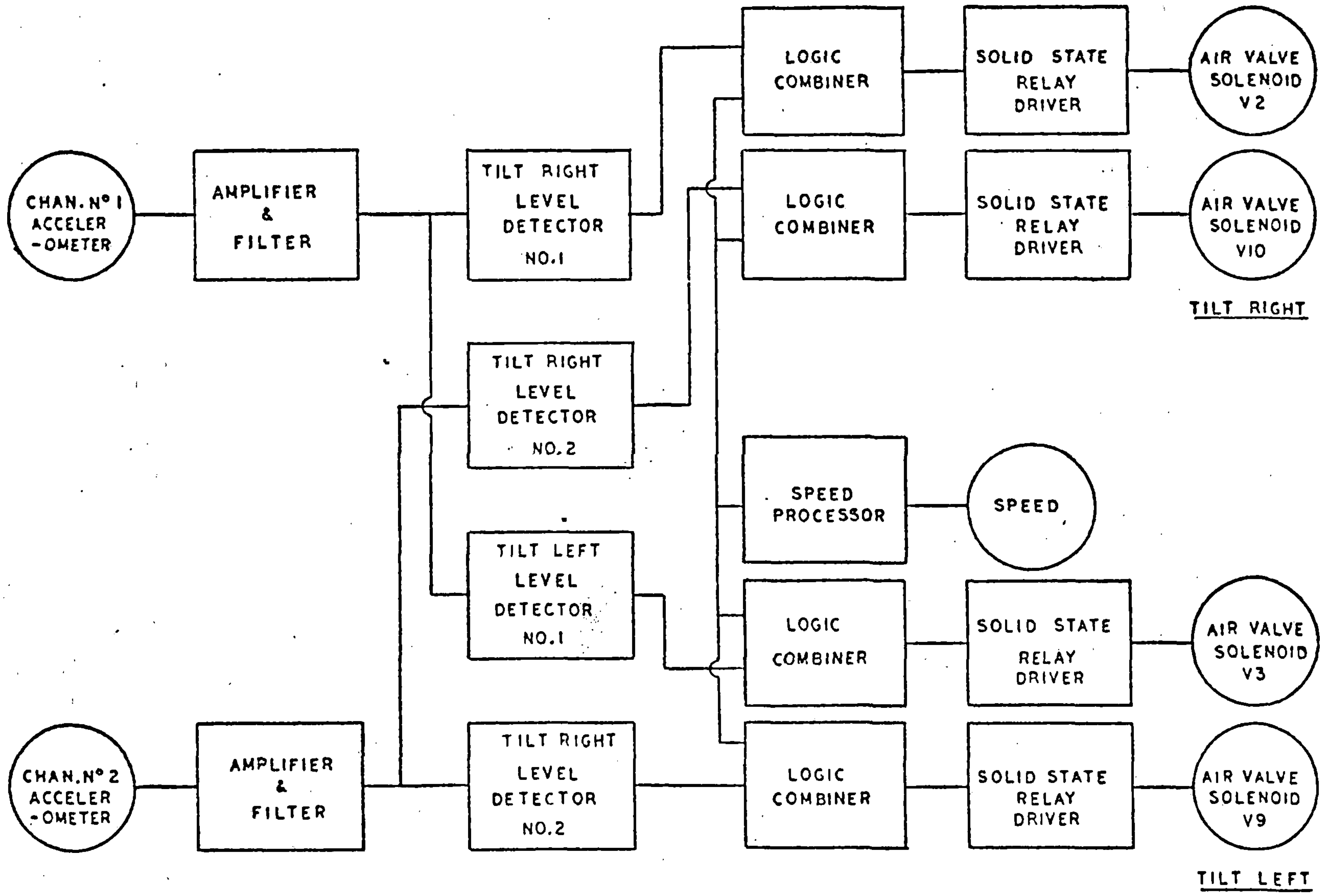


FIGURE 4-16: LEVELING VALVE MOVED TO TRUE CENTERLINE BOLSTER



SIMPLIFIED BLOCK DIAGRAM OF TILT SYSTEM

FIGURE 4-17

level of the lateral acceleration experienced by the truck. As mounted, the accelerometer measured the difference between the acceleration component due to the centrifugal force and that caused by track superelevation. The accelerometers used have the following specifications:

Sensitivity	± .25 g
Natural Frequency	50 Hz
Damping Factor	2.0

By selecting a unit with a high natural frequency and high damping constant, the accelerometer acted as a filter for high frequency noise without introducing excessive signal delay at frequencies of interest.

4.2.2 Signal Filter Systems

March, 1982 Road Test

The filter system used during the March, 1982 Road Test consisted of a 6-pole, resistance capacitance filter. This was a low pass filter set to pass frequencies up to about 0.8 Hz and to have 6 db attenuation at 1 Hz. The other two poles were located at .55 Hz and the two zeros at .25 Hz. The latter two poles and zeros were added to reduce the time delays at low frequencies, .1 to .4 Hz. This filter performed quite adequately but did introduce delay of .8 to 1 second in system response.

July, 1982 Road Test

Analyses of the unfiltered accelerometer data taken during the March demonstration test revealed that noise levels never exceeded approximately .05 g's and were in a frequency bank of .6 Hz to 1.5 Hz. Thus, to simplify the system, a simple notch or band pass filter was designed and incorporated. This notch filter attenuated frequencies from .5 Hz to 3 Hz with less time delay (.4 to .6 seconds) than the low pass filter used in the March, 1982 test.

The July test had the test vehicle coupled directly to the locomotive rather than isolated by intervening coaches. In this consist, the accelerometer output exhibited a 12 Hz signal with an amplitude greater than .1 g's that originated in the locomotive. The notch filter provided no attenuation at these frequencies. As a result, an additional filter, 4-pole 1 Hz low pass, available as part of the ENSCO instrumentation package, was connected in series with the notch filter. This added filter accomplished the desired results. The 12 Hz signal was attenuated to less than .01 g's.

4.2.3 Signal Threshold Detectors

The tilt command level detectors were of the same design for each of the two test programs. Each channel contained four detectors, two for positive signals (tilt right) and two for negative signals (tilt left). Each of these detectors compared the incoming signal to a reference signal (tilt command level signal) and generated a turn-on signal whenever the command signal level was equaled or exceeded. When the signal reduced below the command level by a pre-determined amount, the system turned off.

In the March road test, the tilt command level was set for .04 g's and the return to neutral level was .03 g's or .1 g's below the tilt command level. In the July test program, the same tilt command level was used but the return to neutral level was changed to .02 g's. This change basically decreased the system switching sensitivity to signal variation while maintaining original turn-on sensitivity.

4.2.4 Logic Combiner

The logic combiners were the same for both the March and July tests. The devices insured that the car was traveling above 60 mph before the tilt system is operated.

5.0 DISCUSSION OF TESTS

5.1 Wilmington Shop Tests

In the first quarter of 1982, the retrofit of the Budd Tilt Body System was completed by Amtrak at the Wilmington car shops.

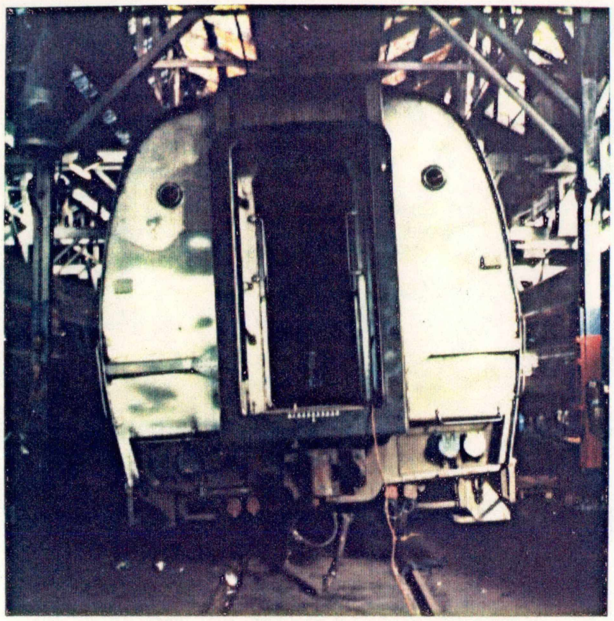
5.1.1 Tilt Body System Response

Figures 5-1 A,B, and C show the tilt car tilting left, centered, and tilting right respectively during initial equipment response and clearance testing in the Amtrak Wilmington car shop.

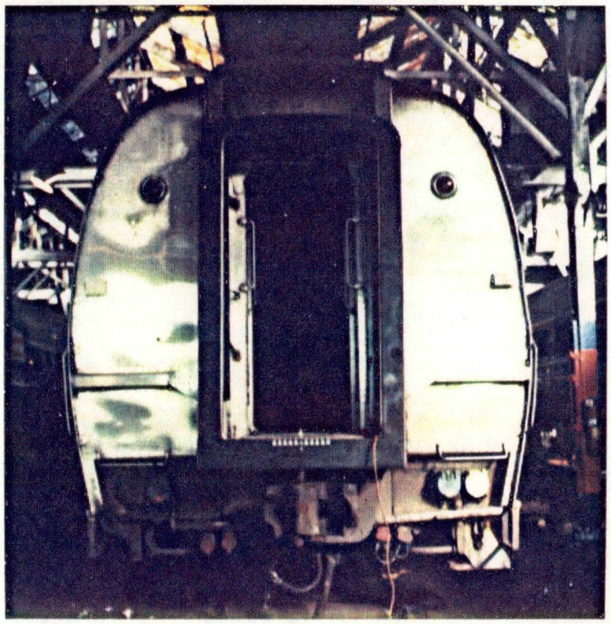
The initial response time measured from actuation of the system to complete movement of the car during yard testing at the Wilmington shops is shown in Figure 5-2. The .6 second delay before tilt, 4.0 seconds to complete tilt, and 9 seconds to complete return to center were all excessive. The primary cause of the start delay was determined to be the air mufflers on the air valve manifold. The cause of the excessive time for tilt and return to center was determined to be the bolster orifice limiting flow from one air spring to the other. Removing the air manifold mufflers and the bolster orifices reduced these times as shown in Figure 5-3 with .5 second delay before tilt, 1.8 seconds to complete tilt, and 3.2 seconds to complete return to center. These improved response times were acceptable for the start of road testing.

5.1.2 Clearance Testing

Clearance testing was conducted to assure the unrestricted operation of the tilt system at $\pm 4^{\circ}$ of tilt with truck swivel



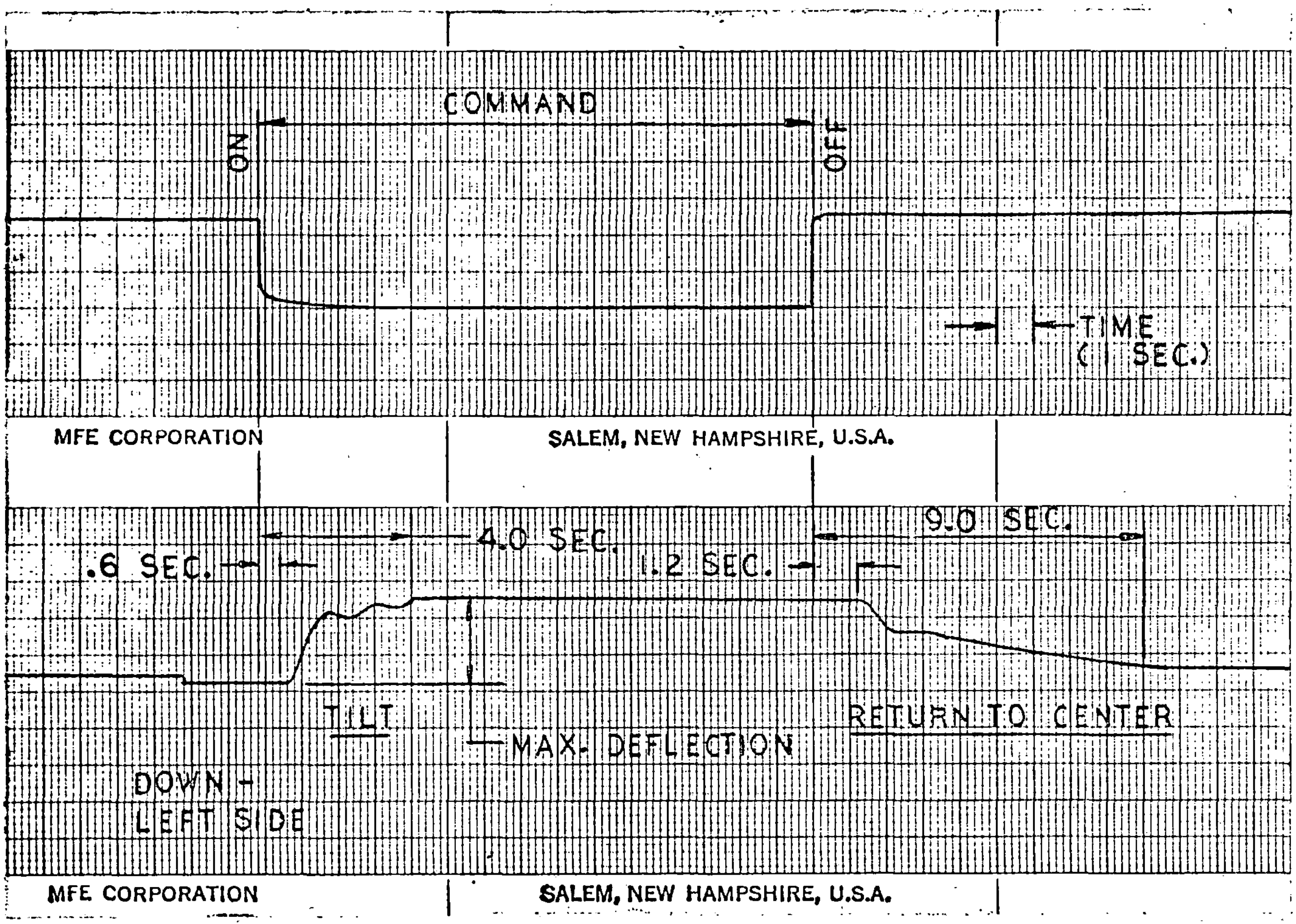
A. TILT LEFT



B. CENTERED

C. TILT RIGHT

FIGURE 5-1: TILT CHECKOUT



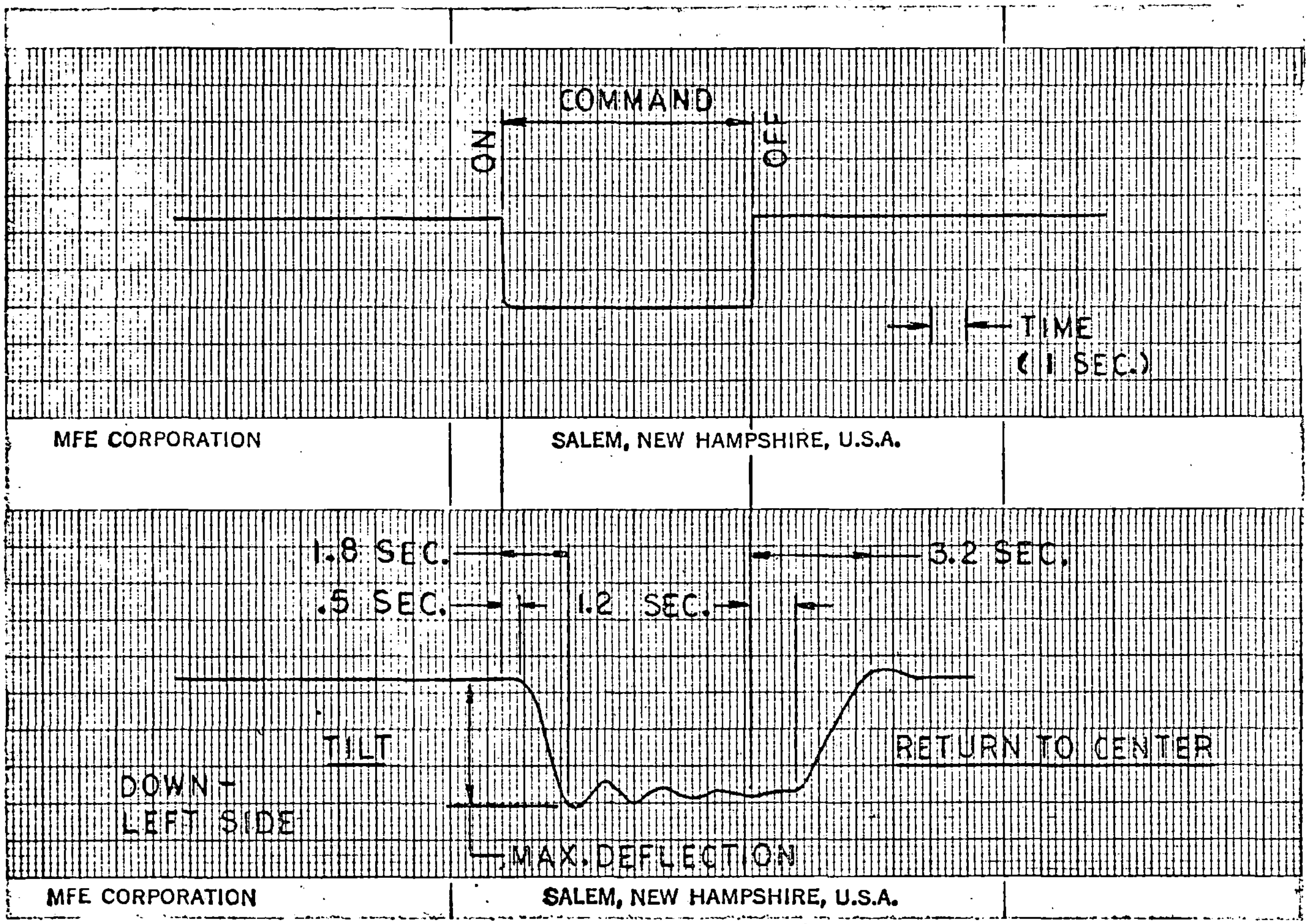
TILT AIR CYLINDER SOLENOID VALVE COMMAND

TILT AIR CYLINDER DISPLACEMENT

INITIAL YARD TEST TIME RESPONSE TO FULL TILT

FIGURE 5-2

TILT AIR CYLINDER SOLENOID VALVE COMMAND



TILT AIR CYLINDER DISPLACEMENT

INITIAL YARD TEST IMPROVED TIME RESPONSE TO FULL TILT

FIGURE 5-3

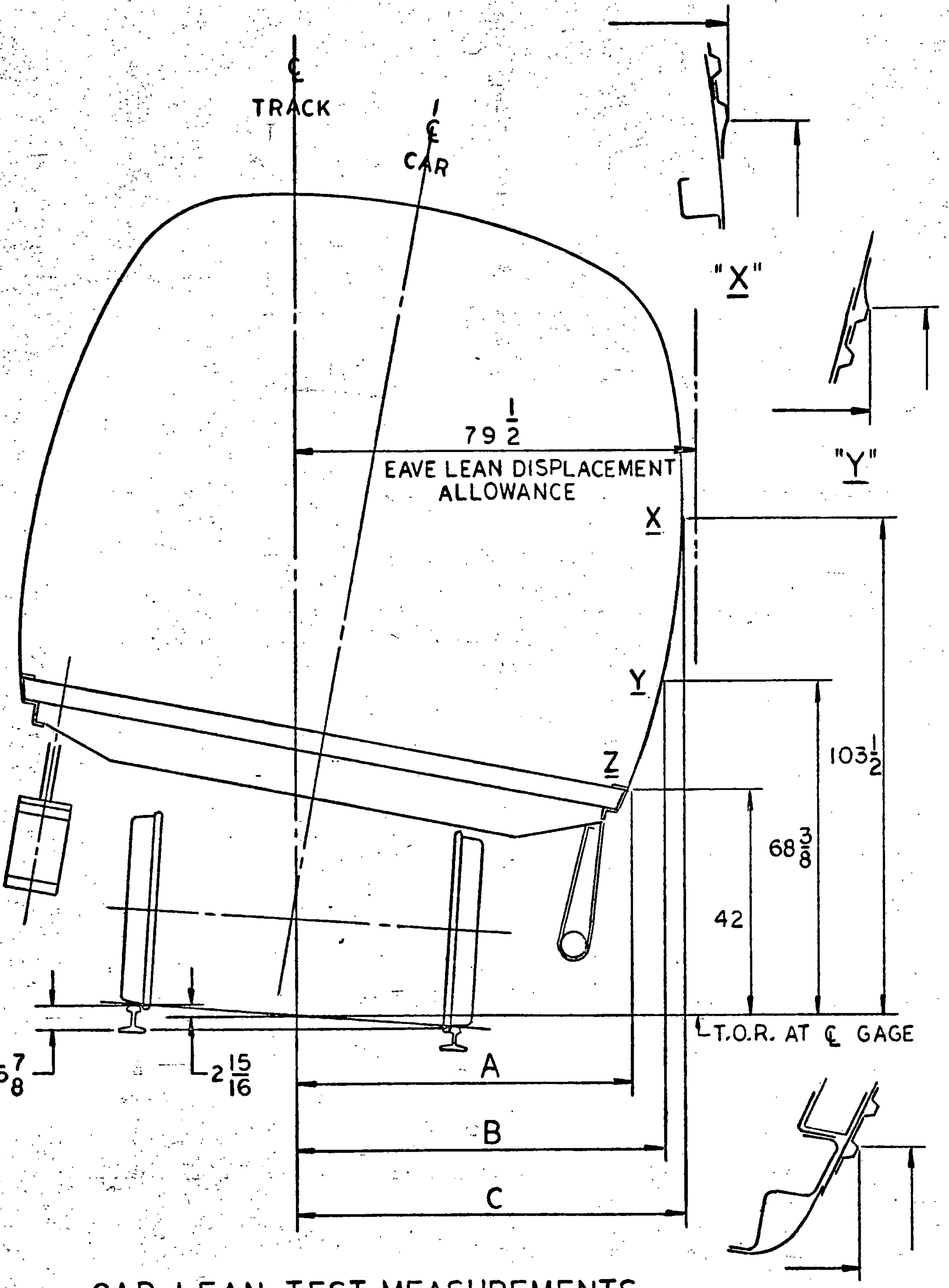
angles equivalent to a 5° curve, and to assure non-tilt operation on the equivalent of a 23° curve. These tests were conducted with the car positioned half on and half off the transfer table in the Wilmington yard. The displacement of the table with respect to the fixed track allowed selection of the required swivel angles.

A static lean test to simulate stationary operation on a 6" superelevated curve was conducted by jacking one side of the car to allow placement of 5-7/8" high rail segments under all four wheels on that side. Plumb bobs hung from the upper window sill, the belt line, and the floor level on the low side of the car allowed measurements of the maximum envelope of the car. Measurements were made at the truck bolster centerline at each end and at the center of the car. Three conditions were measured - one with the air springs deflated and the stops retracted, the second with the air springs inflated and the low side downstops retracted, and the third with the air springs inflated and all downstops in the extended position. Case #1 represents a failure of all downstops and all air springs. Condition #2 is an abnormal case representative of failed downstops. Condition #3 is the case of a normal train stopped on 6" superelevation. In all cases, the eave lean displacement was less than the Amtrak allowance.

Figure 5-4 shows the lean test set up.

Figure 5-5 shows the numerical results of the lean testing.

Figure 5-6 shows lean test wheel block application.



CAR LEAN TEST MEASUREMENTS

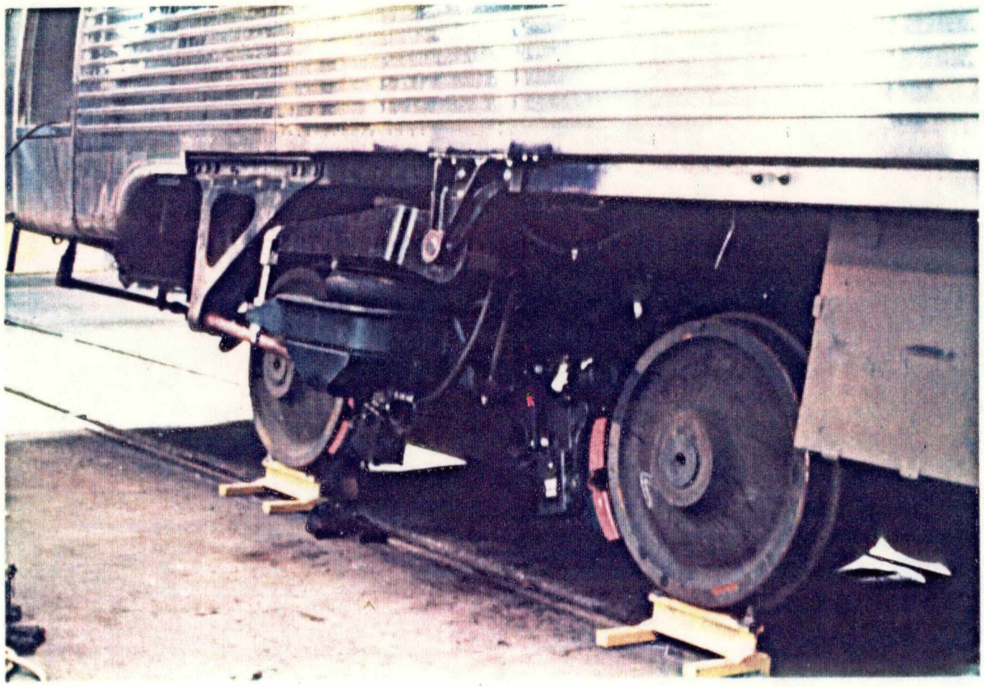
FIGURE 5-4

CAR POSITION	TRANSVERSE DIM. LOCATION	LONGITUDINAL DIM. LOCATION		
		B END ℄ BOLSTER	℄ CAR	A END ℄ BOLSTER
AIR SPRINGS DEFLATED STOPS RETRACTED	A	$66\frac{1}{2}$	$66\frac{1}{4}$	66
	B	$73\frac{1}{4}$	$73\frac{1}{4}$	$72\frac{3}{4}$
	C ✱	$74\frac{1}{4}$	$74\frac{1}{4}$	$72\frac{1}{4}$
AIR SPRINGS INFLATED LOW SIDE STOPS RETRACTED	A	$67\frac{1}{4}$	$67\frac{1}{2}$	67
	B	$75\frac{1}{4}$	$75\frac{1}{4}$	$75\frac{1}{4}$
	C ✱	$78\frac{1}{4}$	$78\frac{1}{4}$	$77\frac{3}{4}$
AIR SPRINGS INFLATED STOPS EXTENDED	A	$67\frac{1}{4}$	$66\frac{3}{4}$	$66\frac{5}{8}$
	B	74	$74\frac{1}{4}$	$73\frac{3}{4}$
	C ✱	$75\frac{3}{4}$	$75\frac{3}{4}$	$75\frac{1}{4}$

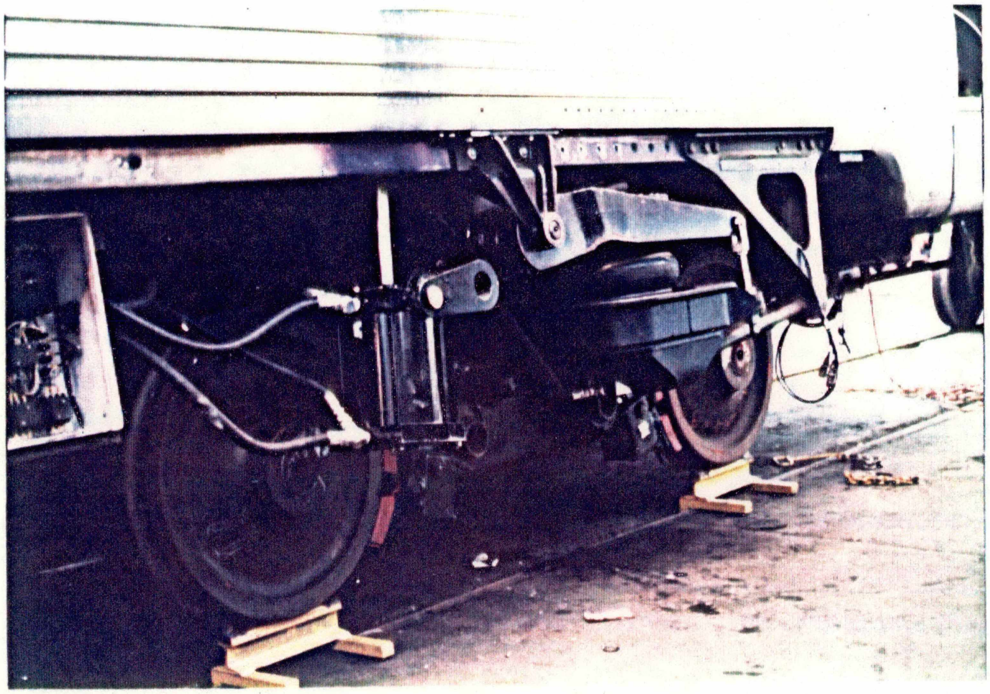
✱ AMTRAK EAVE LEAN DISPLACEMENT ALLOWANCE $C_{MAX} = 79\frac{1}{2}$

CAR LEAN TEST RESULTS

FIGURE 5-5



"B" END



"A" END

FIGURE 5-6: LEAN TEST - WHEEL BLOCK APPLICATION

Figure 5-7 and 5-8 show lean test measurement plump bobs.

5.2 March, 1982 Road Test

On March 10, 1982, a road test run was conducted by Amtrak on the Northeast Corridor to collect operational road data on the tilt body retrofitted Amcoach. The test consist was made up of * LRC #39 locomotive, Amcoach #21128 first car acting to isolate the test car from the locomotive, Amcoach with tilt body system #21183 as the test and instrumentation car, Amcoach #21873 as the control car with recently refurbished trucks, and Amcoach cafe car #20024 as the last car in the train.

A detail test plan and the track charts for the test run including a chart presenting the LRC speed profile, cant deficiencies, lateral acceleration balance speed, etc., are presented in Appendix A.

The Instrumentation Schematic, Figure 5-9, shows the plan used to collect the test data for the March, 1982 test. This plan provided for obtaining a permanent data record via magnetic tape and for continuous monitoring of all data being recorded on tape. Provision was made for spot check of actual tape data recorded by viewing the reproduced data on an oscilloscope, one channel at a time.

Figure 5-10 is a photograph of the instrumentation set up in the tilt equipped Amfleet coach.

* Light, Rapid, and Comfortable - Canadian, Bombardier

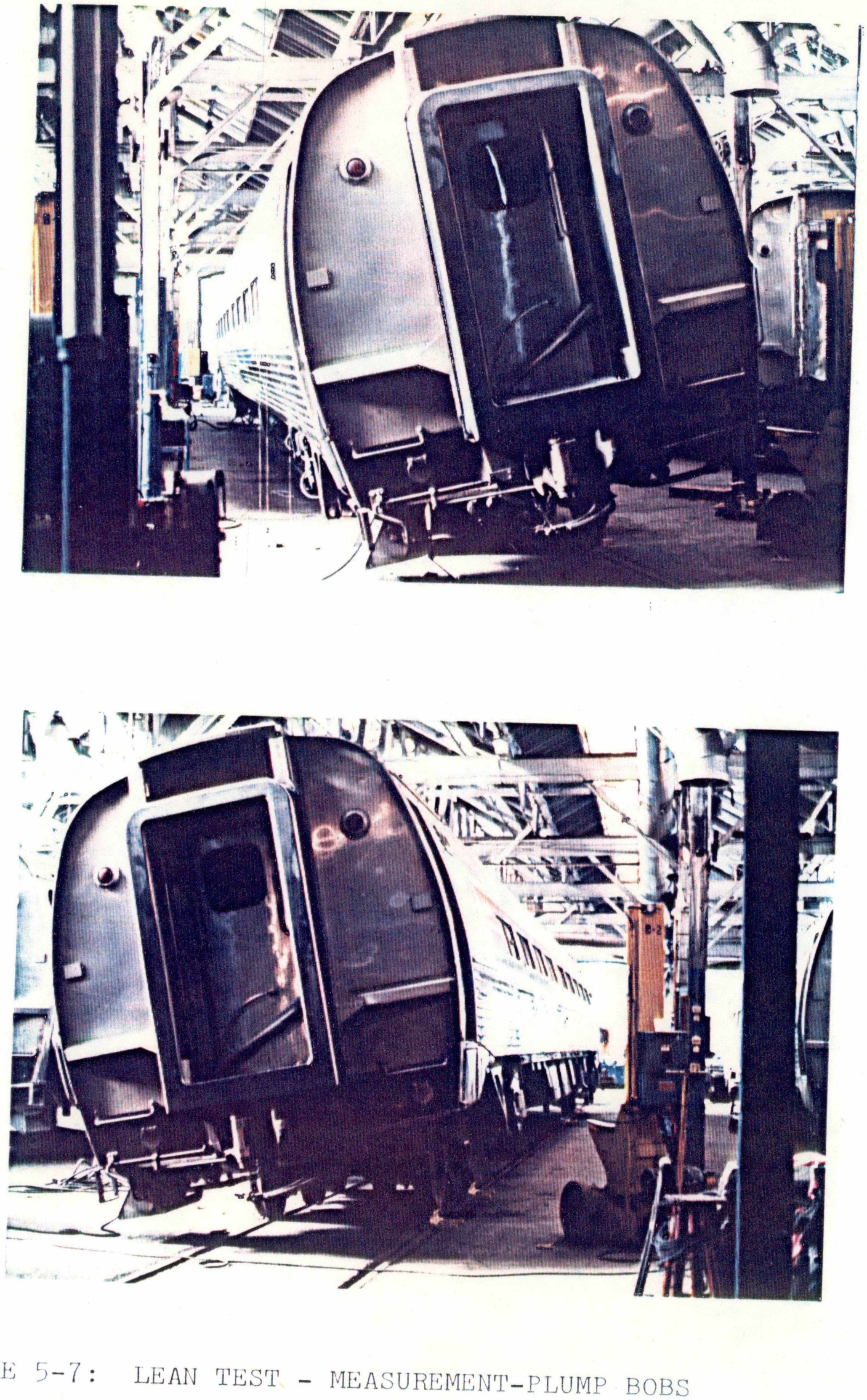
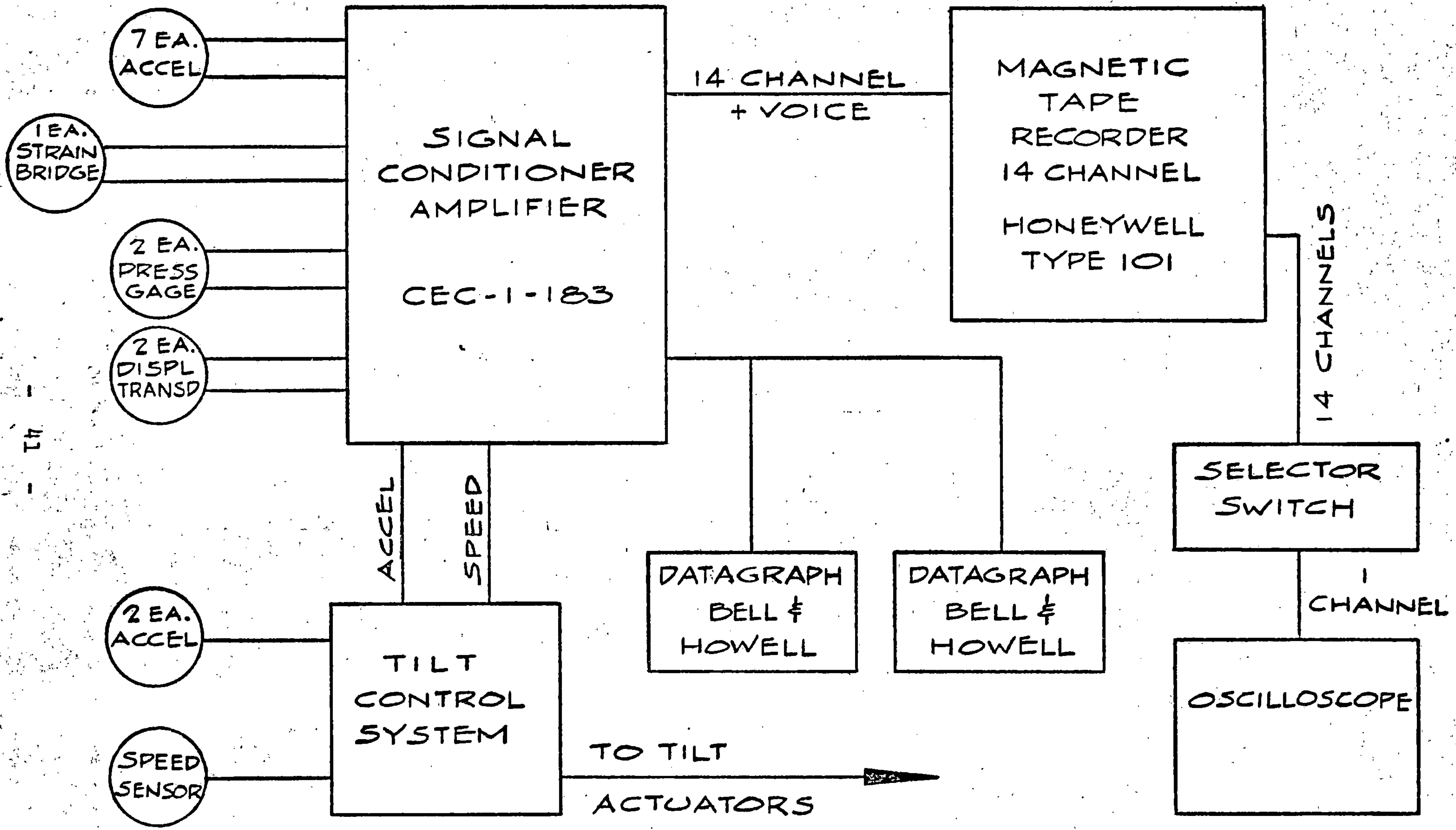


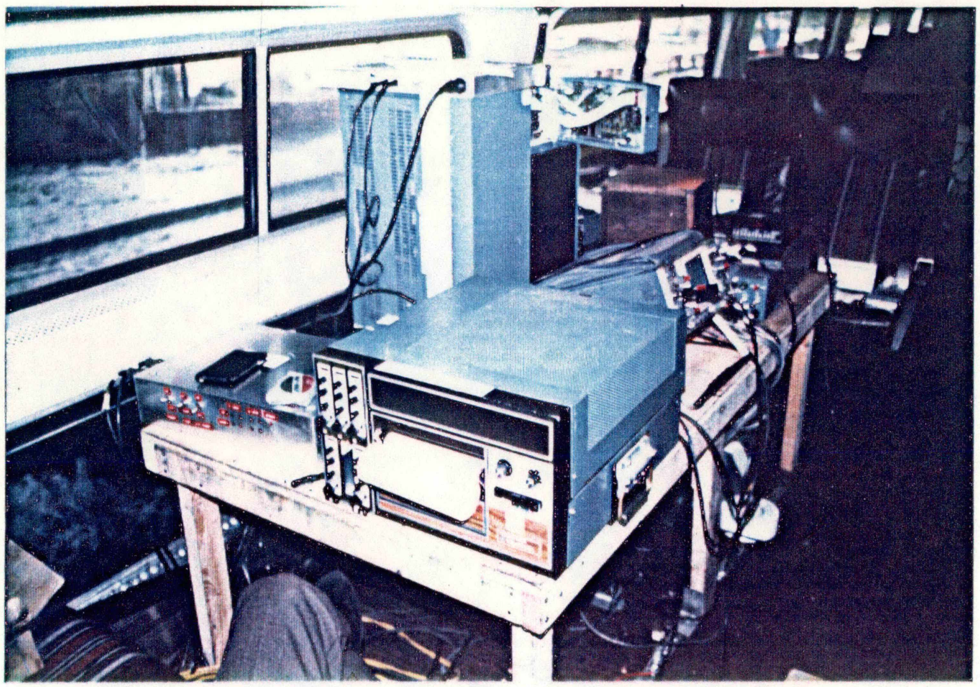
FIGURE 5-7: LEAN TEST - MEASUREMENT-PLUMP BOBS

FIGURE 5-8: LEAN TEST - MEASUREMENT-PLUMP BOBS



INSTRUMENTATION SCHEMATIC

FIGURE 5-9



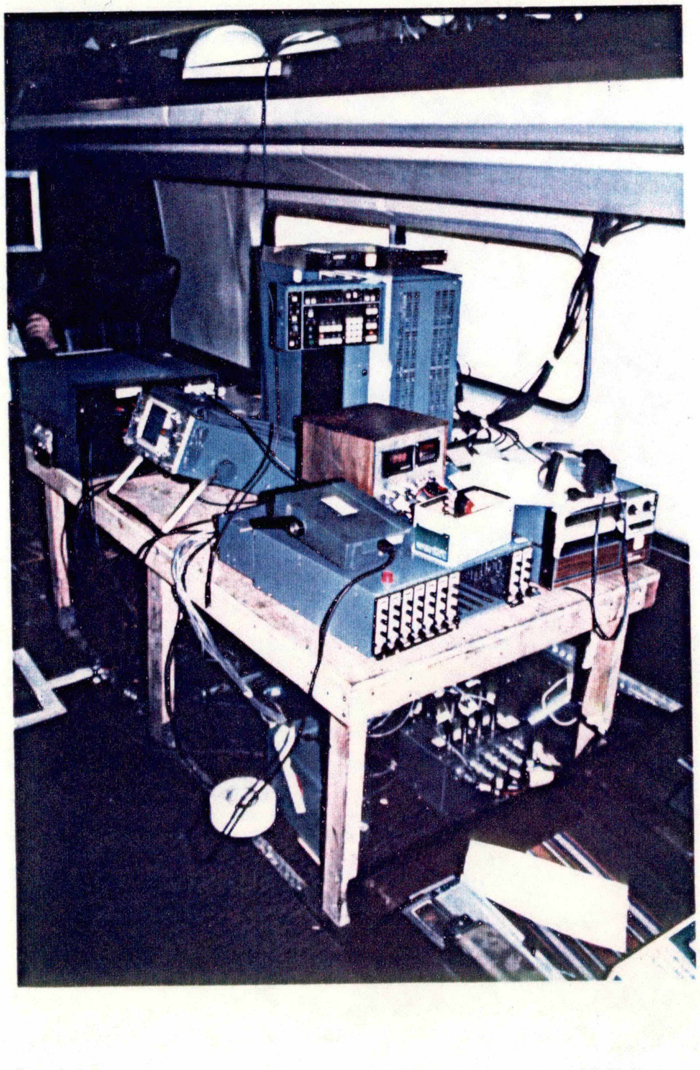


FIGURE 5-10: RECORDING EQUIPMENT - MARCH RUN

Figure 5-11 shows the location of the strain gage rossette measuring torsion bar strain.

Figure 5-12 shows the location of the displacement transducer measuring the tilt air cylinder displacement.

Figure 5-13 shows the location of the truck yaw displacement transducer.

Figure 5-14 shows the location of the journal housing vertical accelerometer.

Figure 5-15 shows the test train consist.

Figure 5-16 shows the tilt body car tilted in the New Haven yards.

Figure 5-17 shows the diaphram gap between the tilted Amcoach and a standard Amcoach

5.2.1 Test Equipment - March, 1982 Test

- Sensors
  1. Channel 1 - Accelerometer,Setra Systems Inc., Model 115 H.P. (tilt signal)
  2. Channels 2-8 - Accelerometers, Setra Systems Inc. Model 114
     - a) 4 ea., ± 1g on Channels 2,3,4, & 5 (carbody lateral)
     - b) 2 ea., 0 to 2g on Channels 6 & 7 (carbody vertical)
     - c) 1 ea., ± 100 g on Channel 8 (journal vertical)
  3. Channel 9 - Speed Pickup, Airpax Model 1-4002
  4. Channels 11 and 14 - Displacement Transducer, Celesco Transducer Products Inc., Type PT 101B (tilt cylinder & yaw displacement)

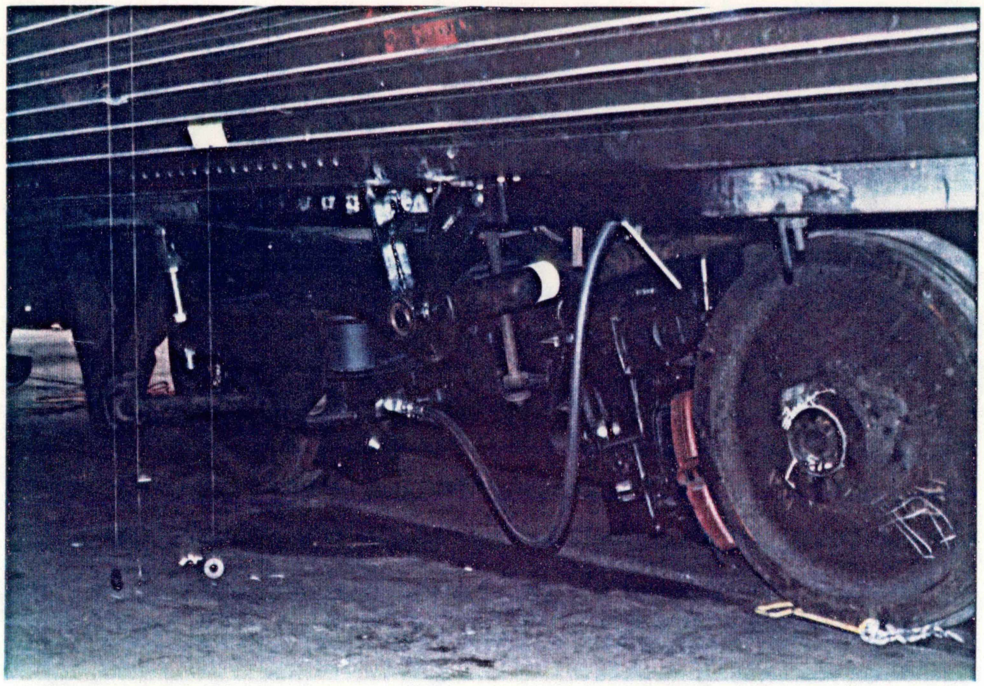


FIGURE 5-11 : TORSION BAR STRAIN GAGE

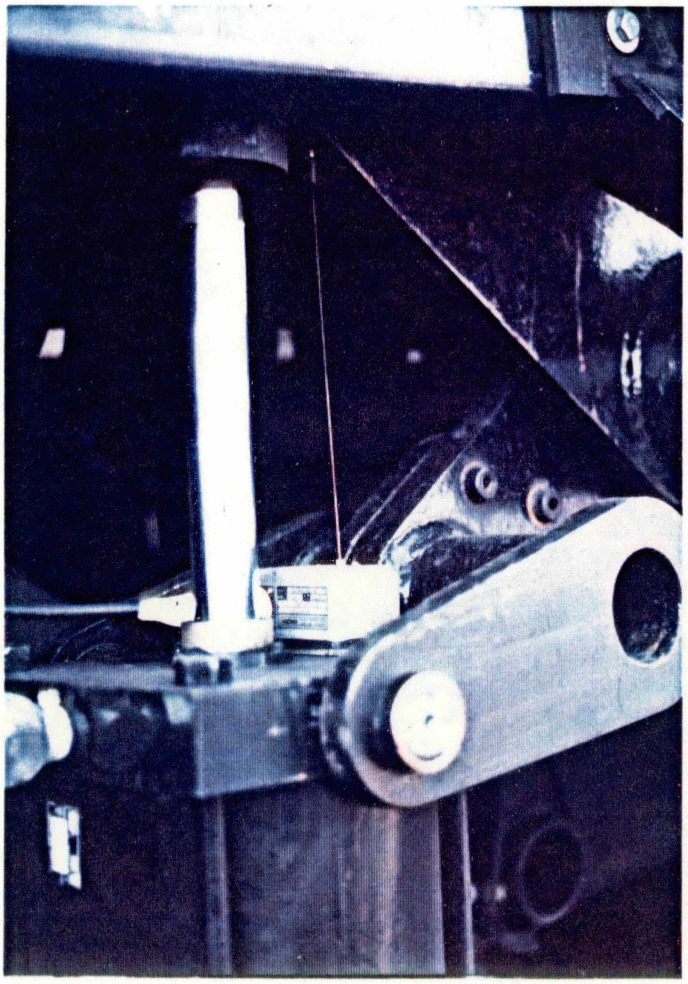


FIGURE 5-12 :

TILT AIR CYLINDER DISPLACEMENT TRANSDUCER

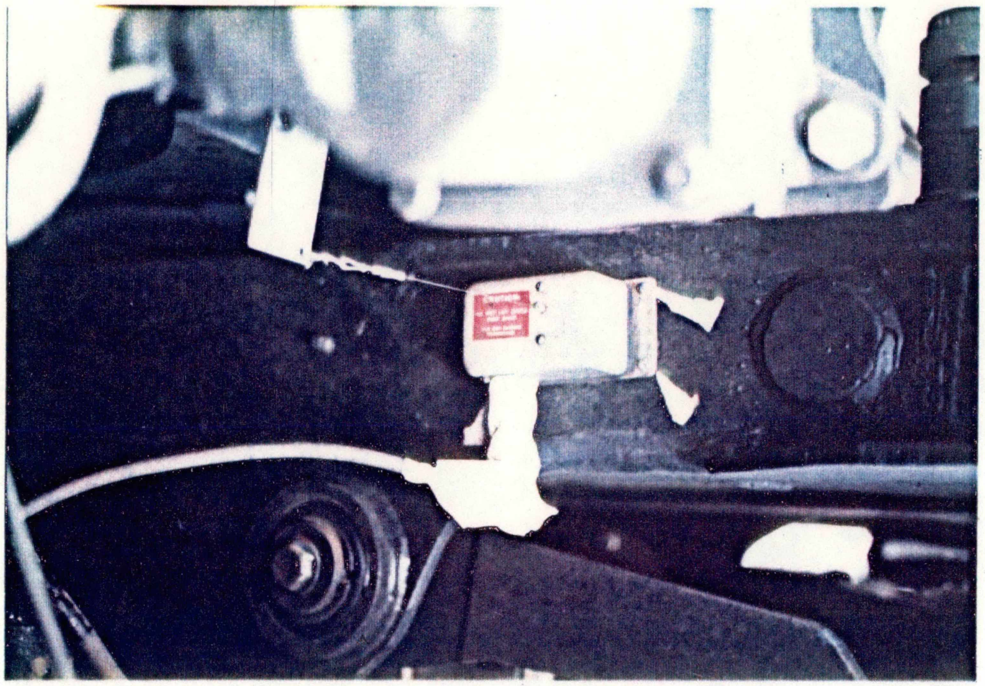


FIGURE 5-13: TRUCK YAW DISPLACEMENT TRANSDUCER

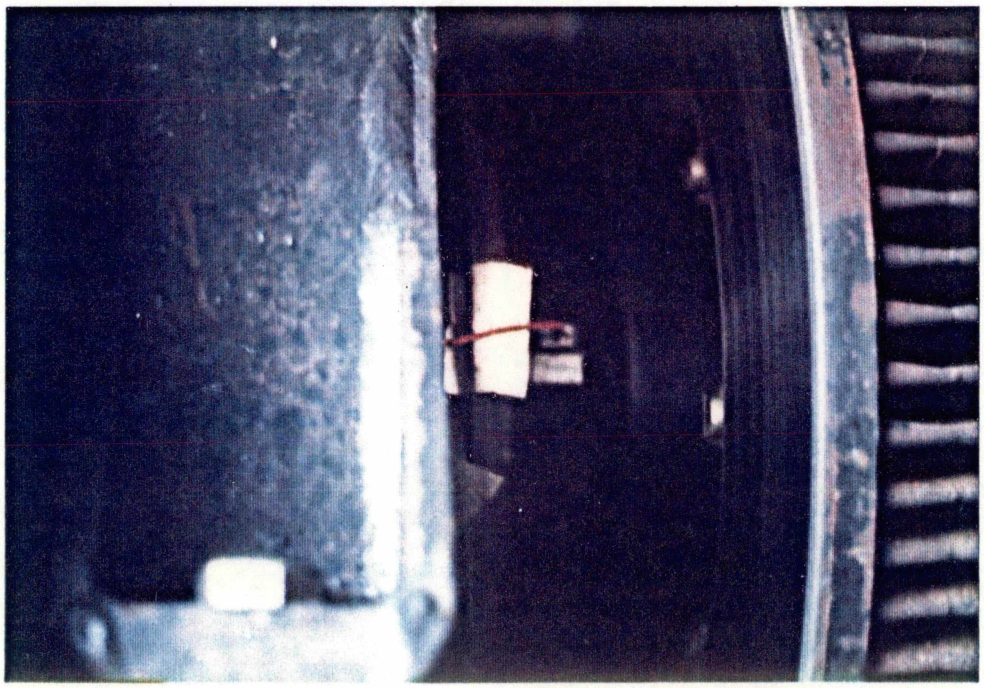


FIGURE 5-14: JOURNAL HOUSING VERTICAL ACCELEROMETER

FIGURE 5-15: MARCH, 1982 TEST TRAIN CONSIST IN BOSTON

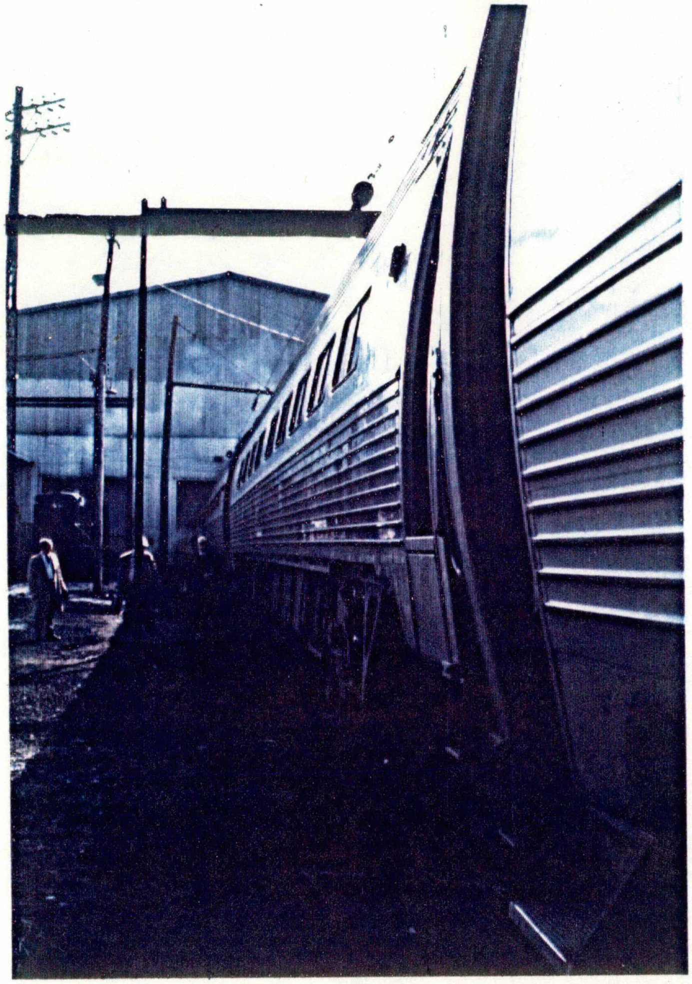


FIGURE 5-16: TILT CAR TILTED IN NEW HAVEN YARD

FIGURE 5-17: DIAPHRAM GAP BETWEEN TILTED AND STANDARD AMFLEET COACH

5. Channel 13 - Pressure Transducer, Allegheny Instruments Co., Model 152, 300 psig (tilt cylinder pressure)

- Signal Processors
  1. Bell and Howell Type 1-183
  2. Custom designed frequency to voltage converter and frequency to distances processor for speed and distance data

- Recorders
  1. 16-channel magnetic tape recorder. Honeywell type 101
  2. Paper tape recorder - Bell & Howell data grapher

5.2.2 System Calibration

Accelerometers, Channels 2 thru 8,have a specific input terminal for application of a calibration voltage. The calibration voltage provides an offset or output of about 10% of full scale span when applied. The calibration input was applied and the individual accelerometer output was measured and cross checked by rotating the units prior to installation. During actual test program, the calibration input signal was applied to Channels 2 thru 8 and the outputs recorded on appropriate recorder channels.

Pressure gauge, displacement transducers and strain gage rossette are all resistance bridge type instruments. The shunt method of calibration was employed where a known fixed resistor was selected and installed in the signal processor. A simple switch operation placed this resistor in the bridge circuit thus simulating an actual sensor signal.

The tilt command accelerometer channels were calibrated by inclining the accelerometers on an inclined plane and measuring the angle of incline at the point where the system actuated to tilt the carbody.

To calibrate the speed distance transducer, the circumference of the lead axle wheels was measured. This measurement and the number of teeth on the axle gear, permitted the calculation of the calibration frequency. An external signal of a frequency equivalent to 60 mph was inserted for calibration.

5.2.3 Results of March, 1982 Road Test

From the March, 1982 test, the performance of the Amcoach tilt body system under three curve conditions will be discussed in detail. These conditions include typical performance on a single curve, Curve #62 (Figure 5-18); performance on a reverse curve, Curves #112 and #113 (Figure 5-19); and performance on a curve composed only of an inlet and exit spiral, Curve #67 (Figure 5-20).

At Curve #62, the car is traveling at 89 mph as opposed to the normal limit of 74 mph. In Figure 5-18, the top trace is the truck bolster command accelerometer output showing a 0.09g's measured lateral acceleration in the truck bolster. The inlet spiral is about 540' long as measured by the 100' blips at the bottom of the chart. The exit spiral is about 480' long. The tilt command acceleration level of .04g's occurs on a steep slope part of the command acceleration turning the system on to tilt

[redacted]

MARCH TEST - CURVE #62

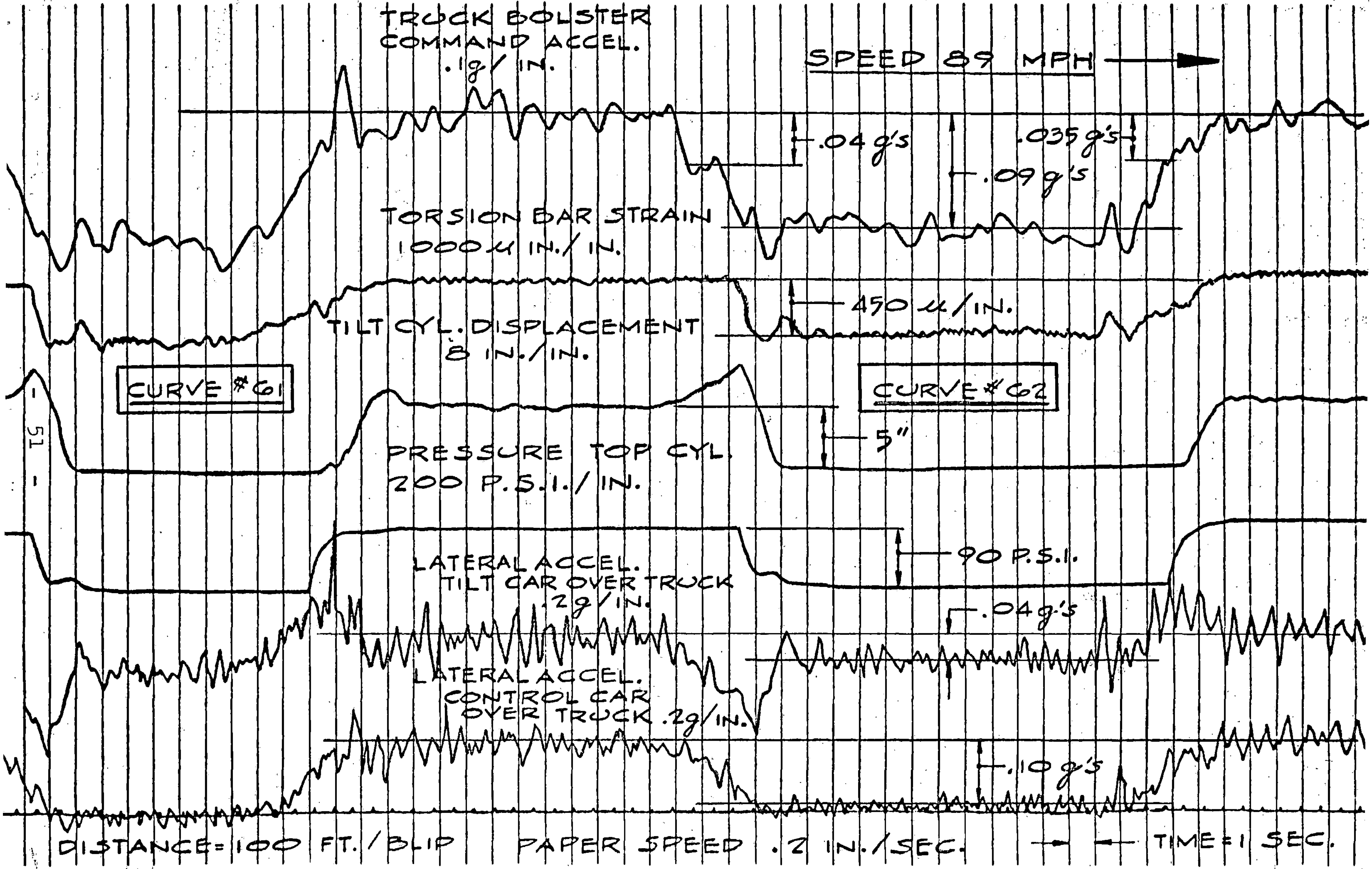


FIGURE 5-18

MARCH TEST - CURVE #112 AND #113

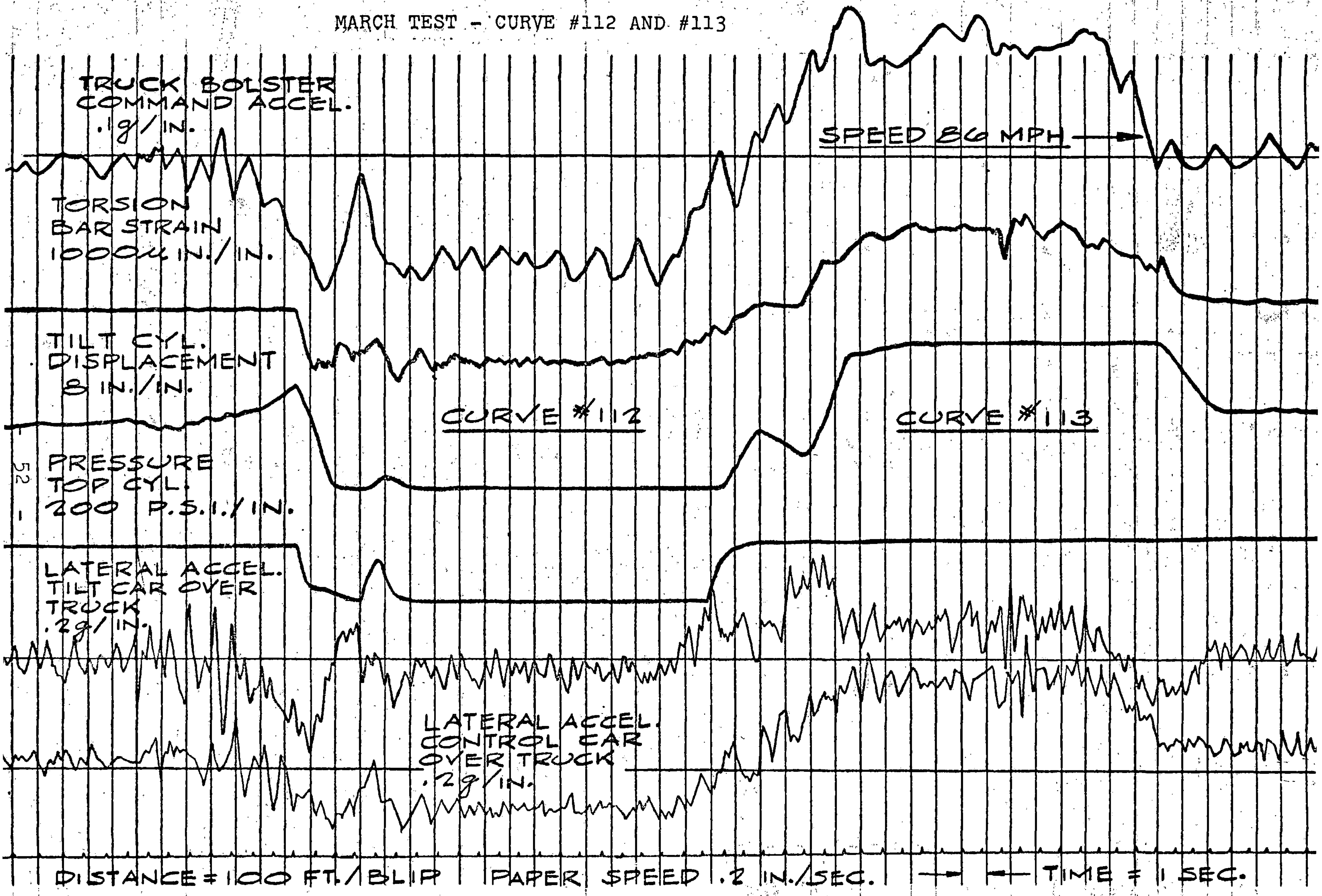


FIGURE 5-19

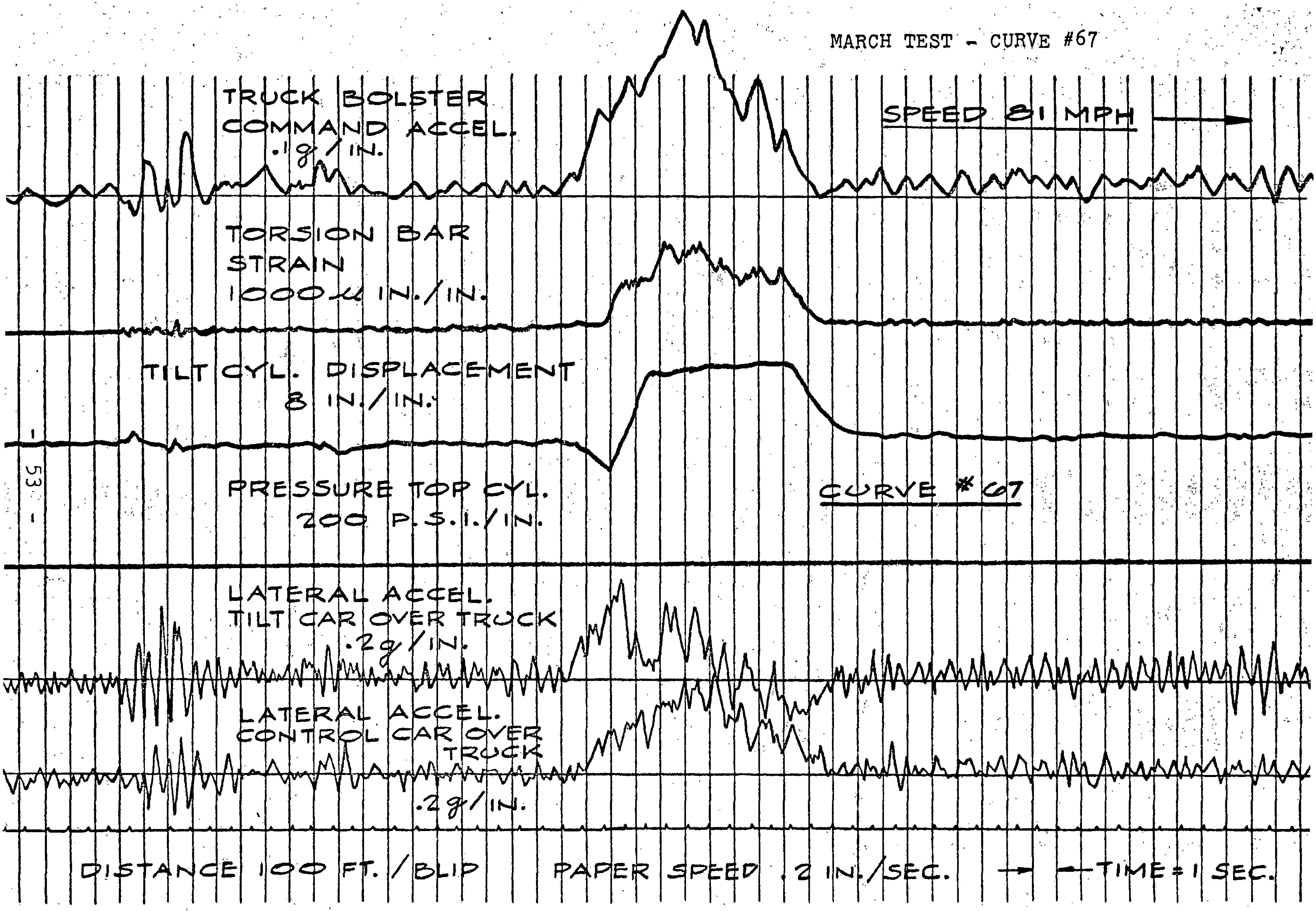

MARCH TEST - CURVE #67
TRUCK BOLSTER
COMMAND ACCEL.
.1g/IN.
SPEED 81 MPH
TORSION BAR
STRAIN
1000μ IN./IN.
TILT CYL. DISPLACEMENT
8 IN./IN.
PRESSURE TOP CYL.
200 P.S.I./IN.
CURVE #67
LATERAL ACCEL.
TILT CAR OVER TRUCK
.2g/IN.
LATERAL ACCEL.
CONTROL CAR OVER
TRUCK
.2g/IN.
DISTANCE 100 FT./BLIP
PAPER SPEED .2 IN./SEC.
TIME = 1 SEC.

FIGURE 5-20

after a 0.2 second delay.

The second trace shows the torsion bar strain increasing from zero at .3 second after actuation to 450 u in/in at about 0.9 second after actuation. This strain level is held until 1.7 seconds after actuation when a drop in strain occurs for 1 second.

The third trace measures air cylinder stroke and is proportional to carbody roll, 4° equals 5" of cylinder stroke. This trace shows the carbody roll starting just as the car enters the spiral and building to 2.7° outboard at the start of tilt motion. At .3 second after actuation, the tilt system rolls the car from -2.7° to +4° inboard completing the full tilt at 1.7 seconds after actuation.

The fourth trace shows the air pressure in the tilt cylinder building from zero psi at .3 second after actuation to 70 psi at .9 second after actuation and holding at that level until 1.7 seconds after actuation at which point the pressure continues to build reaching supply pressure of 90 psi at 2.8 seconds after actuation.

The fifth trace is the lateral acceleration measured in the tilt body car and the sixth trace is the lateral acceleration in the control car. Both traces show the lateral acceleration building as the cars enter the curve. The control car is delayed in its start since it enters the curve one car length after the tilt body car. The levels build to .12g's in the tilt car at the point where the tilt system is actuated. While the car is tilting, the lateral spike in the track (Trace 1) causes the lateral in the tilt car to reach .15g's before being reduced to .04g's for the duration of the curve. By comparison, the control car reaches a maximum spike of .11g's before averaging .10g's for the duration of the curve. The tilt system can be seen to reduce the steady state lateral acceleration felt by the passengers from 0.10 to .04 - a drop of .06g's to a level well within the comfort criteria. The low roll stiffness of the tilt car is the cause of the increased initial lateral acceleration in the tilt car. The change to a modified double-convolute air spring on the tilt system,as is recommended in this report for a final design, will reduce the initial lateral level to that experienced by the control car at the corresponding point on the curve, or for this curve, .08g's before the tilt system activates and reduces the level to .04g's.

As the car exits the curve, the truck lateral acceleration decreases as shown in the first trace. At .035g's, the controller turns the tilt system off. The pressure shown in the fourth trace starts to drop after a .2 second delay for valve opening. After .8 second from turn-off, the car roll begins its return directly to center and by 2 seconds from turn-off, it has completely returned. The strain gage in trace #2 shows the decrease in force necessary to hold the car in the tilt position beginning as the truck lateral acceleration starts to drop. The carbody lateral acceleration in the tilt car, as shown in the fifth trace, begins to decrease as the car exits the curve, returning to normal as the car roll reaches center and showing a slight overshoot of .03g's. The perceived return to center is very smooth in the tilt body car.

Figure 5-19 shows the performance of the consist on a set of reverse curves, #112 and #113, where the truck experiences a lateral acceleration of approximately .09g's and .1g's respectively. (5.4" cant deficiency and 6" cant deficiency). As the car enters the spiral of Curve #112, the performance is typical of that experienced in Curve #62, except that there is a large deviation in the spiral which momentarily deactivates the tilt system. In the transition between the two curves, the system recovers and again behaves similar to Curve #62 as it enters Curve #113. The steady lateral accelerations experienced by the passengers are reduced from .09g's to .04g's on Curve #112 and from .12g's to .06g's on Curve #113.

Figure 5-20 shows the performance of the consist on a curve composed of two spirals with no fixed radius portion. Even in this case, the tilt body system provides a significant level of reduction of the lateral acceleration experienced by the passengers with the exception of the initial roll prior to tilting.

The general results of the March tests indicate that the system performs as anticipated providing the same level of passenger comfort operating with cant deficiencies of 7" as the non-tilt body car provides with 3" cant deficiency.

Additionally, the lower roll rate of the three-convolution air spring suspension produces excessive lateral accelerations during curve entry, prior to the activation of the tilt body system. To overcome the deficiency, the three-convolution air spring will be replaced with a modified two-convolution spring. These modifications will increase the roll rate of the suspension to that of the standard Amcoach and provide the increased stroke required by the tilt body suspension.

5.2.4 Results of July, 1982 Road Test

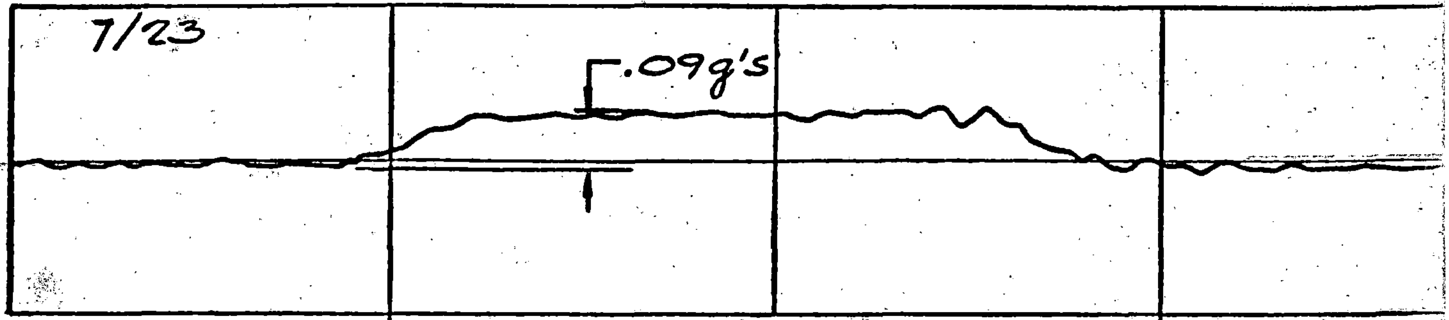
During the month of July, additional testing was conducted as part of the "F40PH/Banking Amcoach Cant Deficiency Tests" for FRA by ENSCO, Inc. under Contract #DTFR53-80-C-00002. The consist for this phase of testing was the F40/PH locomotive, the tilt body Amcoach and a trailing Amcoach. Instrumentation supplied by ENSCO provided data used in the system evaluation.

In this section, the results on three curves will be discussed. A complete summary of all July testing is described in the Final Report, "High Cant Deficiency Test of The F40PH Locomotive and The Prototype Banking Amcoach ", DTFR53-80-C-00002.

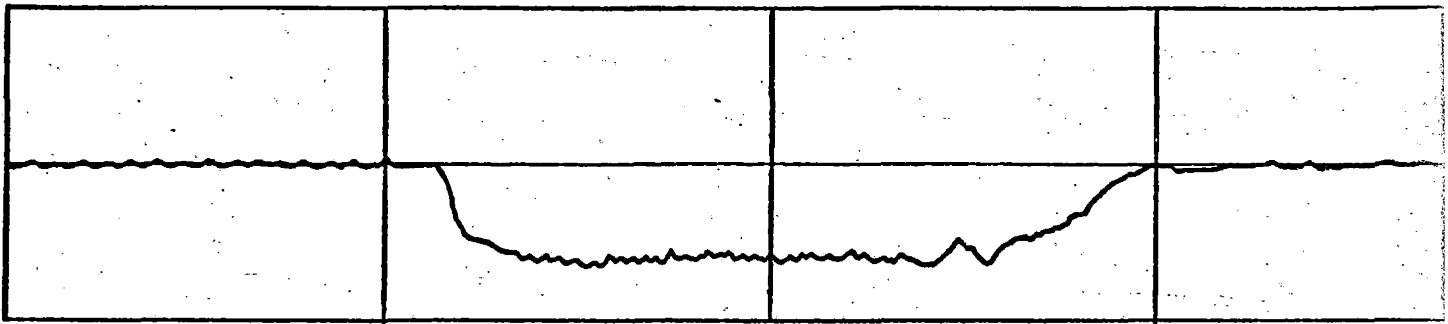
Figure 5-21 shows the performance on Curve #62 for comparison to the March tests.

The truck lateral command acceleration in the first trace shows .9g's sustained through the curve which is the same as on the March test. The carbody lateral acceleration, as shown in the fourth trace for the tilt car, and the fifth trace for the control

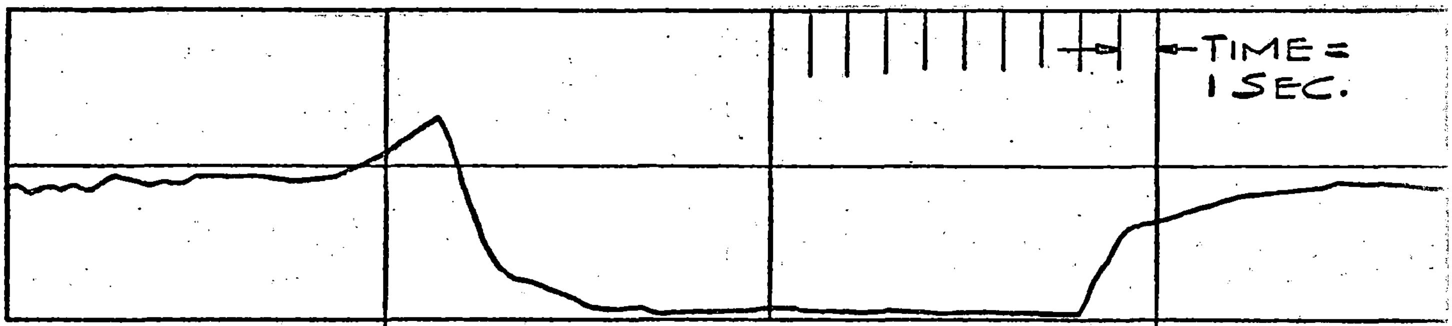
JULY TEST - CURVE #62 89 M.P.H.



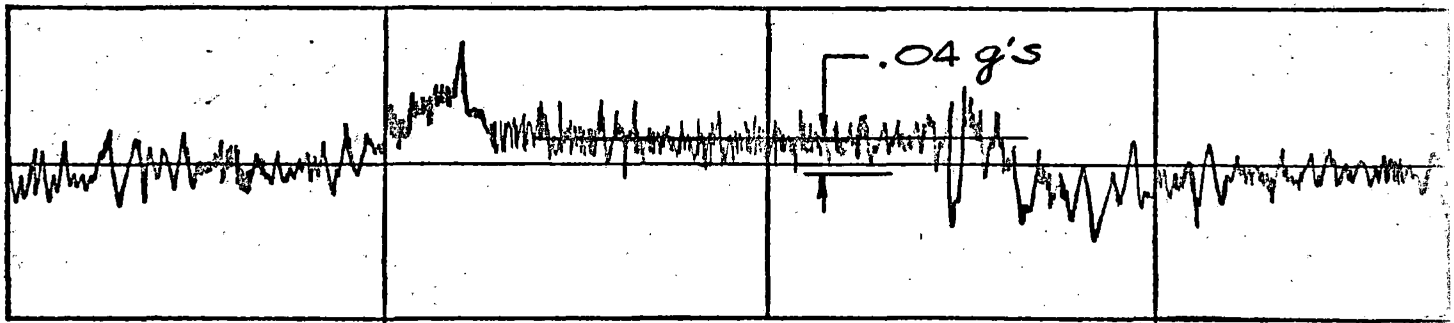
TRUCK BOLSTER COMMAND ACCEL. .31g/IN.



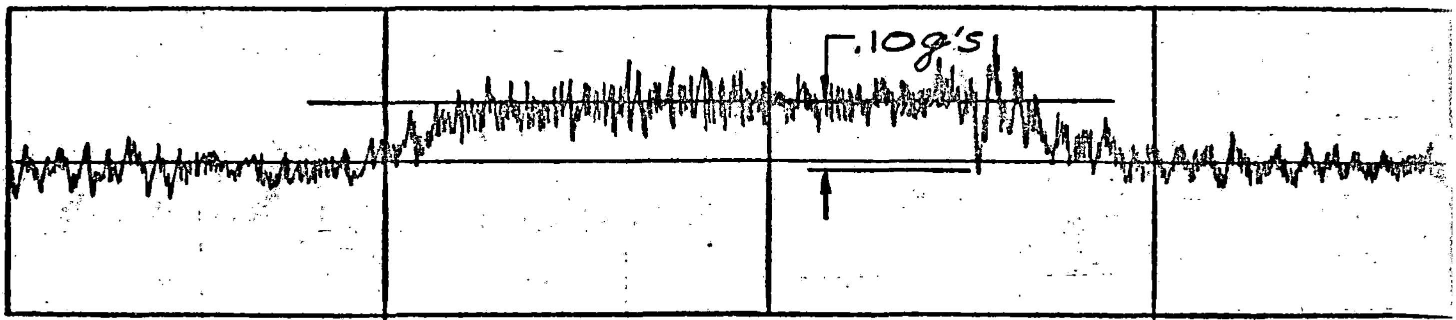
TORSION BAR STRAIN 1220 μ IN./IN.



TILT CYL. DISPLACEMENT 6.3 IN./IN.



LATERAL ACCEL. TILT CAR OVER TRUCK .31g/IN.



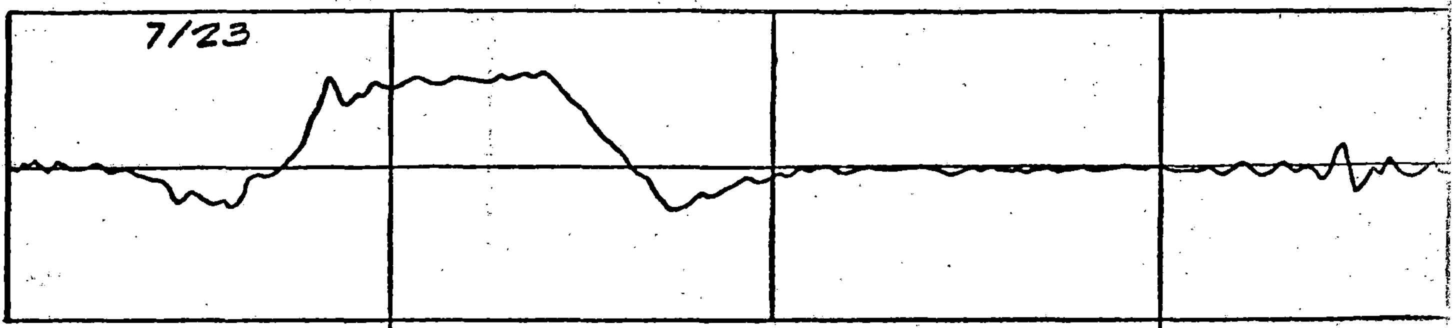
LATERAL ACCEL. CONTROL CAR OVER TRUCK .31g/IN

FIGURE 5-21

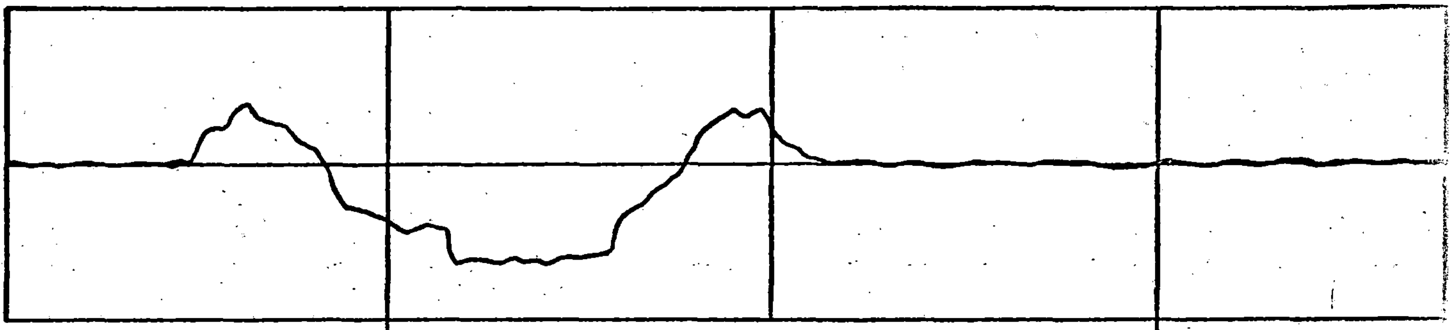
car, shows the same decrease from .10g's in the control car to .04g's in the tilt car as was experienced in the March test. The tilt cylinder displacement trace shows a 2.0° outboard roll before the tilt action starts. This is 0.7° less than the March run due to the air spring orifice valving. 80% of full tilt is reached in 1.8 seconds, but full tilt of 4° is not reached until 5 seconds after actuation due to the additional restriction of the air spring orifice bypass valve. A similar delay occurs on return to center after the tilt signal is removed with 1.1 second delay to start, and 7 seconds to complete return to center. The improved roll stiffness of the modified double convolute air bags,recommended for the final design, will eliminate the necessity of additional inter-air spring orificing and will allow response times as shown on the March test rnn.

Figure 5-22 shows the performance of the tilt body system on a curve where the superelevation starts on the straight portion of track prior to the curve and ends on the straight portion of track after the curve. This practice is often used in curves where sufficient space is not available for entry and exit spirals. As the tilt body car approaches the curve, the lateral truck command acceleration builds up due to the superelevation and the carbody is tilted to bring it level. Once it enters the curve, the centrifugal acceleration exceeds that generated by the superelevation and the car first untilts then tilts into the curve. The system does not tilt the car to the full 4° since the car is

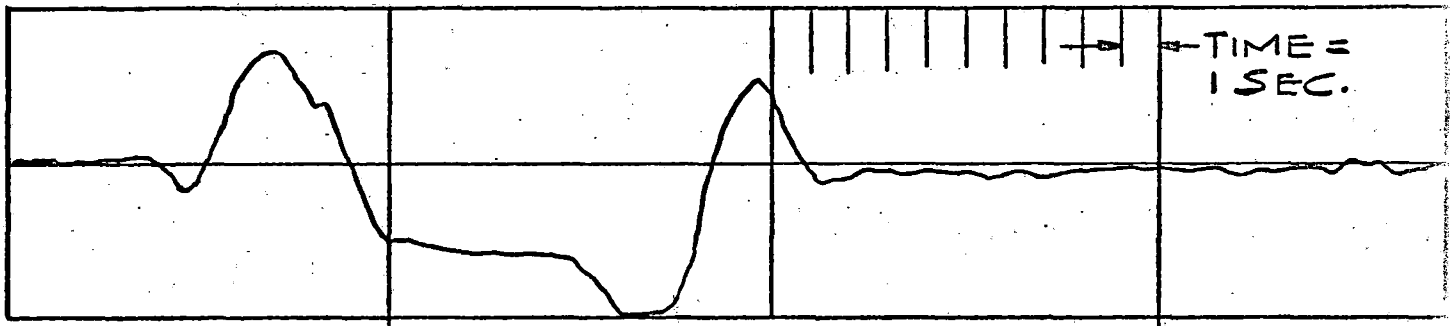
JULY TEST - CURVE #46 66 M.P.H.



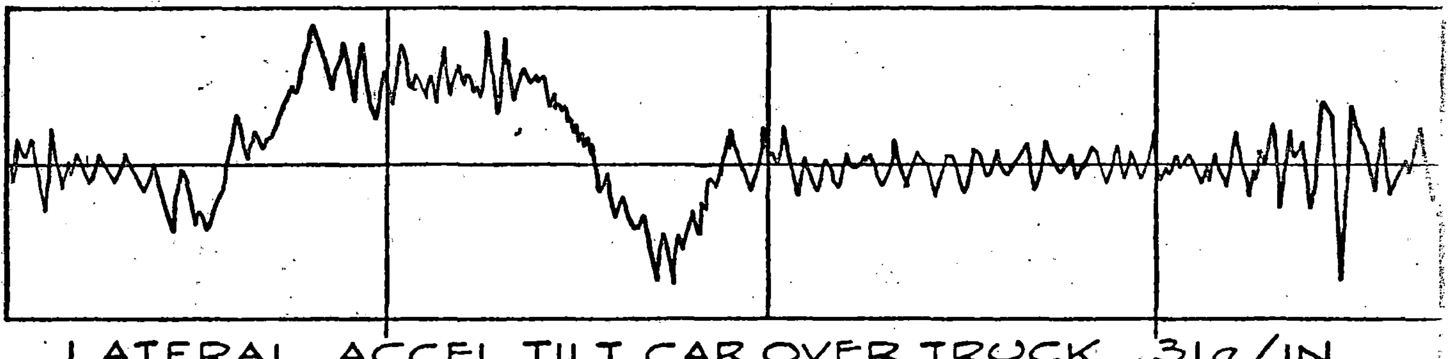
TRUCK BOLSTER COMMAND ACCEL. .31g/IN.



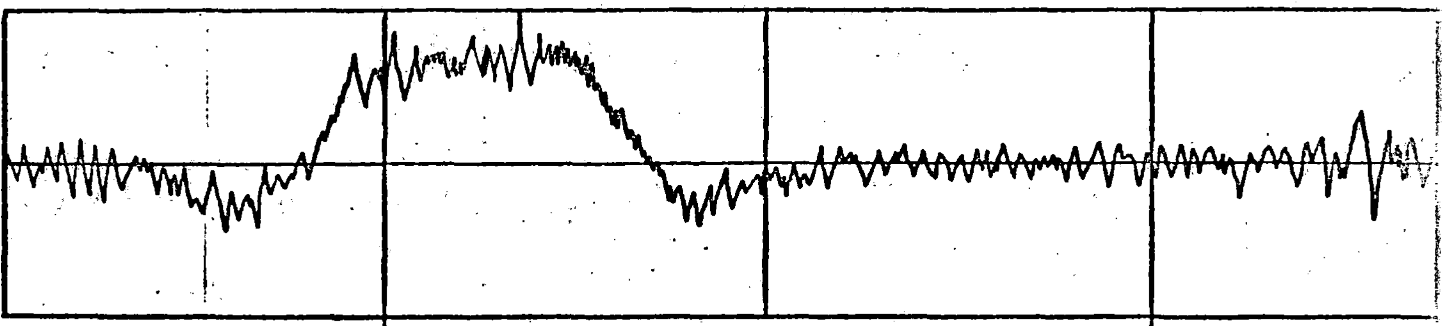
TORSION BAR STRAIN 1220 μ IN./IN.



TILT CYL. DISPLACEMENT 6.3 IN./IN.



LATERAL ACCEL. TILT CAR OVER TRUCK .31g/IN.



LATERAL ACCEL. CONTROL CAR OVER TRUCK .31g/IN

FIGURE 5-22

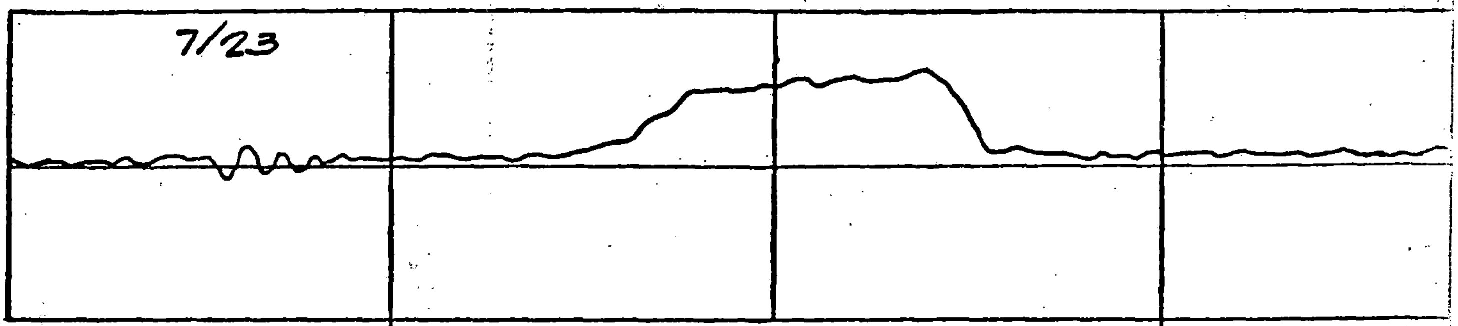
traveling with a cant deficiency of 9" versus the 7" for which the system was designed. At the end of the curve, the cant deficiency is reduced to the 7" level and the system rotates the carbody to the full 4° as can be seen in the trace of the tilt cylinder displacement. In the curved section, the acceleration level is reduced by .03g's even though we are operating the system at a cant deficiency higher than the design point.

The tilt body system operates effectively on curves with superelevation on the straight portion of track leading into and out of curves.

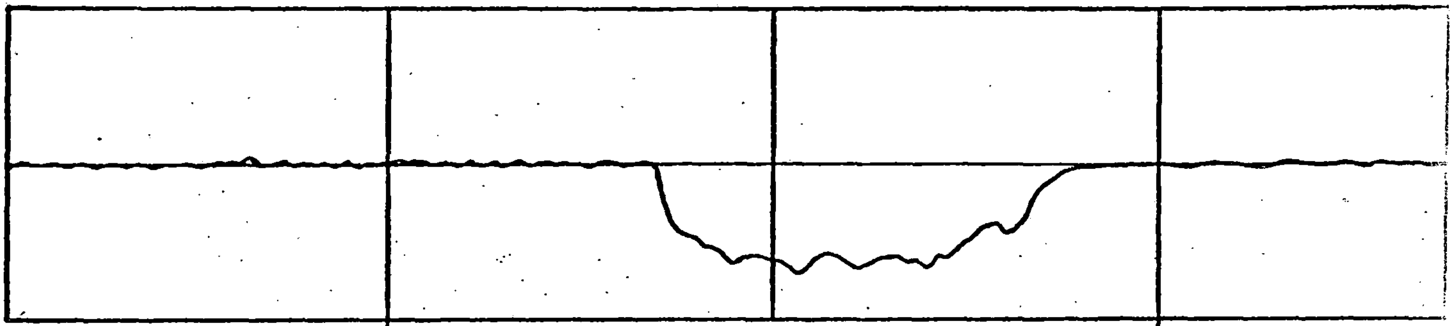
In order to minimize the effect of the pre-superelevation, the amount should be limited to about 2" prior to the curve.

Figure 5-23 shows the performance of the system in the area of Curve #127. Of major interest on this data is the magnitude of the transient accelerations on the straight portions of track compared to the accelerations experienced in the curve. From the data, it appears that in addition to a tilt body system, the lateral suspension shock absorbers should be tuned for the transient inputs, not the steady state irregularities as they presently are. This retuning,along with the higher roll stiffness air bags, will have the greatest impact on further improving ride quality.

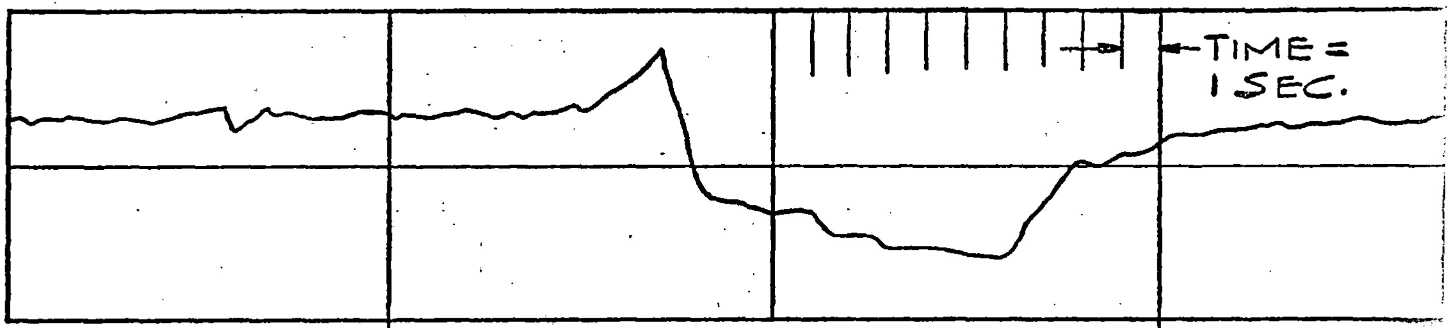
JULY TEST - CURVE #127 102 M.P.H.



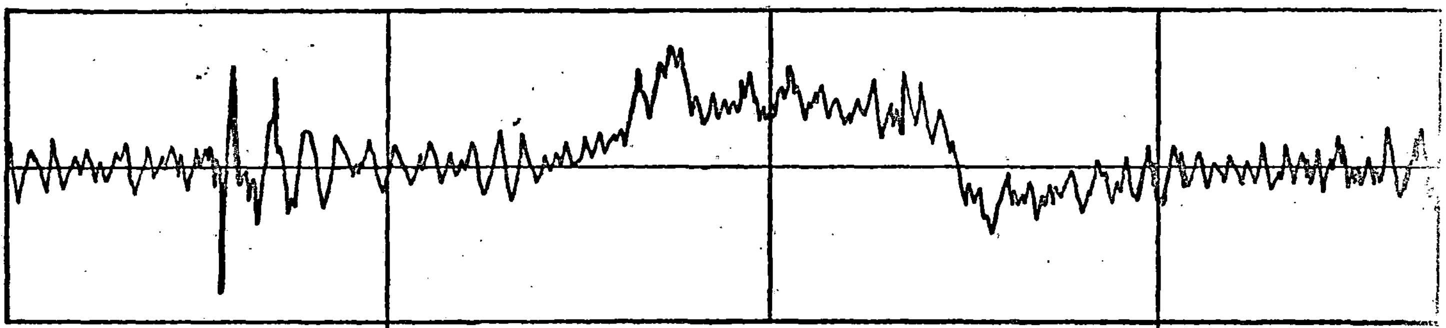
TRUCK BOLSTER COMMAND ACCEL. .31g/IN.



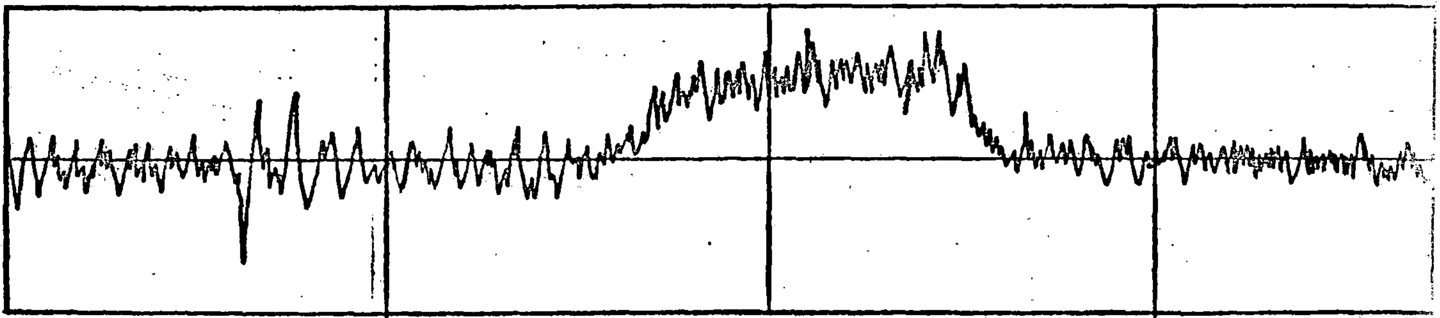
TORSION BAR STRAIN 1220 μ IN./IN.



TILT CYL. DISPLACEMENT 6.3 IN./IN.



LATERAL ACCEL. TILT CAR OVER TRUCK .31g/IN.



LATERAL ACCEL. CONTROL CAR OVER TRUCK .31g/IN

FIGURE 5-23

6.0 AIR CONSUMPTION ESTIMATES

The total number of tilt system actuations on the March run westbound between Providence and New Haven was 108 cycles. On a typical July test run, the number was 80. The projected normal run over this section of track with all system improvements incorporated, no slowdowns for track work, and maintaining a 6" maximum superelevation speed with a speed profile similar to that approved for the LRC locomotive should result in 86 actuations of the system. Based on this number of actuations and an average speed of 79 mph, the rate of tilt cycles is 1 per minute, resulting in a level consumption of 3.2 standard cubic feet per minute (SCFM) per car. In areas where curves are closely spaced with a maximum of three tilts per minute, the system can be expected to consume air at a maximum rate of 10 SCFM per car, well within the capacity of the two (2) 3.4 cubic feet air accumulator and train line supply rate.

7.0 MAINTENANCE IMPLICATIONS

The Budd Tilt Body System uses air and electrical power and sturdy mechanical components to produce a system that is compatible with the under-car environment and that will be familiar to car maintenance personnel. The electronic controller is configured on wire wrap boards in a metal container and will be mounted in the electrical locker. The accelerometers are mounted on the truck bolster in a weather-tight box and is connected to the controller through weather-proof cables similar to those used on the existing wheel speed sensors.

Upon removal of the tilt system for the return of the test car to a standard Amfleet I configuration and revenue service, all of the removed equipment was closely inspected for signs of wear, fatigue, weathering, or other degradation. All electrical equipment was in excellent shape. The air cylinders showed no signs of wear or rust. The torsion bar bushings were in good shape, three of the four downstops were in good condition. The fourth had a loose retaining collar and, as a result, showed signs of wear where the stop was held in contact with the spring plank. All brackets, manifolds, torsion bars, arms, regulators, valves, and accumulators were in excellent condition. The tilt arm end bushings were not sealed during testing resulting in corrosion at the retaining bolt. In the final design, the bushings will be sealed or they will be replaced with a rubber bushing.

During testing in July, the air valves feeding the leveling valve on the test car were all replaced to solve a persistent loss of air pressure problem. Contamination of the double check valve with its close fitting sliding spool is suspected as the cause of the problem. These air valves are present on all Amfleet I and II cars to assure a supply of air to the air springs from either the brake pipe or the main air line. The same assured supply could be made available by running a single line with a single filter, check valve, orifice, and leveling valve to each truck from the main air reservoir since this reservoir is supplied with air at all times from the main air line or from the brake line through the brake valves. The resulting simplicity should greatly reduce air spring related maintenance on all Amfleet cars.

8.0 FINAL CONFIGURATION

The final configuration of the Budd Tilt Body System will incorporate -

- The filtering of accelerometer signals used in the July test.
- The selected tilt set points will be .04g's to tilt and .02g's to return to normal to reduce extraneous actuations of the tilt system and to achieve minimum air consumption.
- The mechanical downstops will have a more durable collar retainer.
- The tilt arm end bushings will be sealed or replaced with a rubber bushing to prevent corrosion.
- The size of the air line feeding the air pilot valves will be increased for improved response.
- The triple-convolute air spring will be replaced with a modified double convolute air spring for increased roll stiffness during non-tilting operations.
- The inter-car door diaphragm face seal width will be increased to accommodate relative roll between cars without opening an air gap.
- The air supply to the leveling valves will be modified to a single line to each truck from the main air reservoir.
- The lateral shock absorbers will be tuned to minimize the response to transient track inputs.

9.0 SUMMARY

The Budd Tilt Body System Evaluation Program enjoyed the cooperation of FRA, Amtrak, and ENSCO, Inc. while demonstrating that tilt train operation in the Northeast Corridor will reduce trip times and maintain passenger comfort. Increased curving speeds are possible using a simple, affordable Amfleet retrofit tilt system. The Budd Company stands ready to provide the manufacturing and installation necessary to add this system to Amfleet coaches to provide entire tilt trains for any location in the country where numerous curves are limiting schedule improvements.

APPENDIX "A"

ROAD TEST PLAN

MARCH TEST

TEST PLAN

BUDD TILT SUSPENSION

REVISION B 2/25/82

The objective of these tests is to demonstrate the ability of the new Budd Tilt System to increase the curving speed of a retrofitted Amcoach without increasing the lateral accelerations experienced by the passengers and to verify the compliance of this car with the clearance constraints of the Northeast Corridor.

The initial tests will be conducted within the confines of the Wilmington yard. The controls will be artificially excited to show how the system reacts and to measure the time, displacement, velocity and acceleration of this reaction. Initial tuning of the pneumatic system will be performed at this time to obtain tilt performance near the anticipated optimum. Under car truck clearances will be checked at maximum curving angles. A static lean test will be conducted to measure the lateral displacement and lean angle of the car on a 6" superelevated track.

After completion of yard tests, the test car will be coupled into a test consist. The preferred test consist will be four cars and a locomotive. A standard Amcoach will be coupled to the locomotive followed by the test car, then the control car, which is also a standard Amcoach, and then a final Amcoach. This configuration is the most desirable, since it isolates the test car and the control car from undesirable side effects caused by the locomotive on the lead car, and from excessive sway experienced in the last car of a train. An alternate three car and one locomotive consist is less desirable but acceptable if the additional Amcoach is not available. This alternate configuration will be coupled as follows: locomotive, control car, test car, and standard Amcoach. The control Amcoach will have recently refurbished trucks. The cars will be instrumented for road tests and all wheels will be taped. The locomotive need not be added to the consists until the instrumentation has been added. The train intercom will be used for communication between the locomotive and the test car. A rider in the locomotive, along with the engineer, will be used to call out mileposts and curve numbers to the test personnel.

The test consist will be operated under conditions and procedures approved by the clearance group of Amtrak.

Upon satisfactory completion of the clearance tests and approval of this test plan, a high speed run will be made over the portion of the Northeast corridor from New Haven to Providence.

After turning the train around in Providence or Boston, a return run over the second track from Providence to New Haven will be made.

The speed profile presented in the track chart will be followed, developing cant deficiencies and excess lateral accelerations as shown. The speeds selected are within the maximum speeds set down in paragraph (P), NEC Bulletin Order No. 3-16. After activating the system while stopped in New Haven, speeds will be gradually increased to obtain sequential increases in cant deficiency and real time evaluation of performance.

The following measurements will be made and recorded on magnetic tape during the test run. The tape track number is shown in parentheses.

Lateral Acceleration - accelerometers will be set up to measure the lateral accelerations at floor height. The difference between these lateral accelerations is the improvement due to the tilt body system. A second set of accelerometers will be set up at the forward end of the test car (#4) and control car (#5) over the truck at floor height to measure the lateral acceleration. The difference between this lateral acceleration and the lateral acceleration at the middle of the car is a measure of the yaw of the carbody.

Vertical Acceleration - accelerometers will be installed in the middle of the test car at the sides (right #6, left #7) to measure the vertical acceleration. These measurements are a means of gauging the vertical comfort and the difference a gauge of roll comfort.

Truck Acceleration - one of the system control accelerometers mounted on the bolster of the lead truck of the test car will be used to measure lateral accelerations (#1). The difference between this acceleration and that of the carbody is an indicator of the effect of the tilted body. An accelerometer will be mounted on the journal housing (#8) to measure vertical acceleration.

Distance and Speed - the speed of the car will be recorded (#9). The speed signal will be the same signal which is used to limit the tilt operation. This signal is obtained by counting pulses from a gear mounted on the axle - it is the same gear used in the slip-slide system. Multiples of axle rotation will be recorded as blips on this record. These blips are distance indicators.

Torsion Bar Stress - a strain gauge will be mounted on the surface of the torsion bar to measure the shear stress in the bar (#10). This stress is a measure of the torque and an angle of twist of the torsion bar. The torsion bar will be calibrated prior to installation on the car.

Tilt Signal - the electric signals which cause the car to tilt left or tilt right will be recorded on one channel (#11).

Cylinder Displacement - the displacement of the tilt actuating cylinder will be measured (#12).

Cylinder Pressure - the pressure in both ends of one tilt actuating cylinder will be measured. The difference in pressure between the two chambers is a measure of the force required to tilt the car.

Only one pressure is recorded at a time at the option of test personnel (#13).

Truck Yaw - the lead truck yaw angle will be recorded to indicate surve angle (#14).

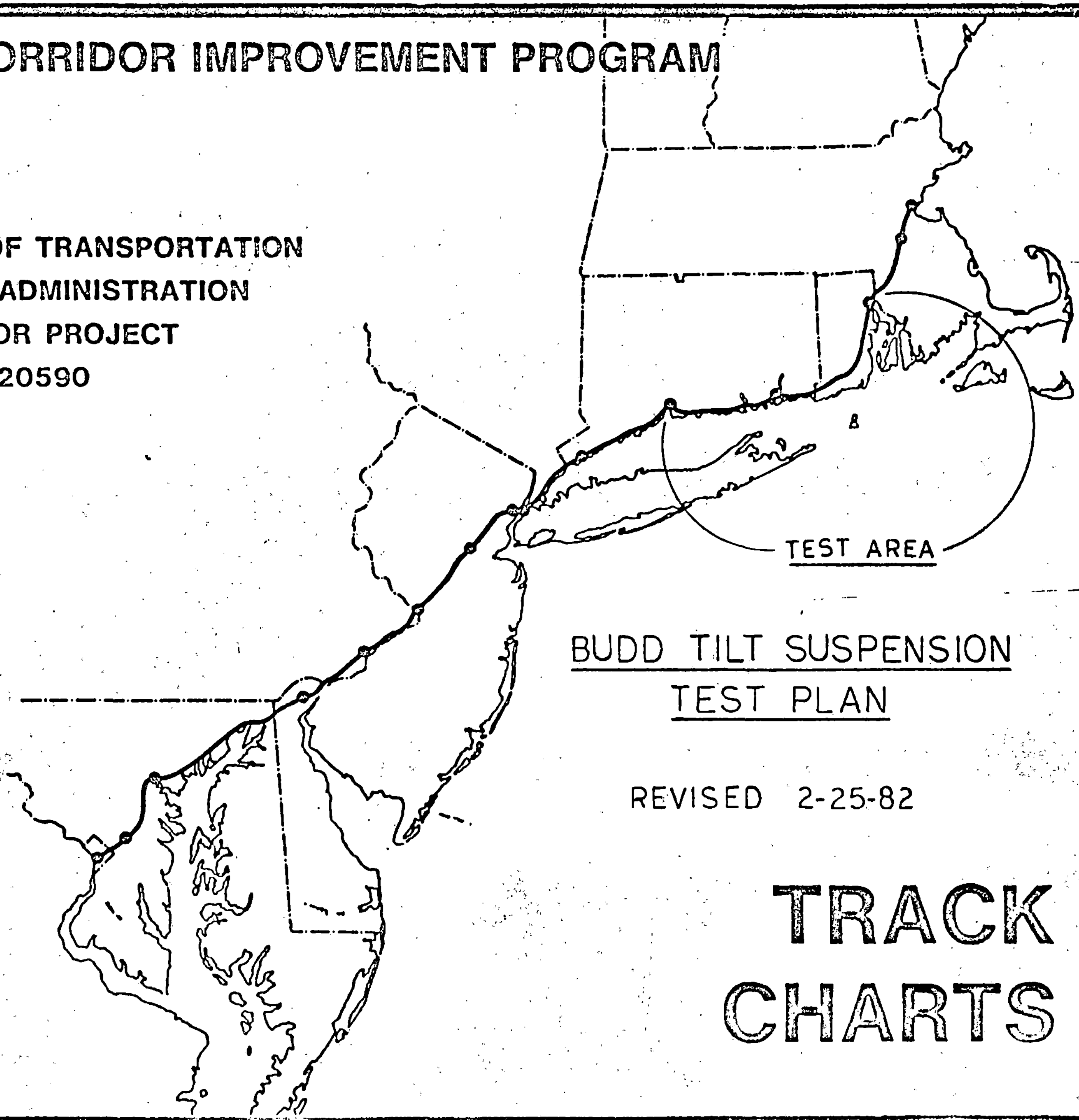
In addition to the magnetic tape recorder, a paper tape recorder will be used to monitor and compare the data being recorded on the magnetic tape. A voice channel is provided on the magnetic tape to record locations and other interesting events during the test.

The entire train will be turned around in Providence or Boston so as to maintain the same relative positions of all the instruments for the return trip.

Following these tests, the data will be reviewed, evaluated, and presented in the final report.

NORTHEAST CORRIDOR IMPROVEMENT PROGRAM

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
NORTHEAST CORRIDOR PROJECT
WASHINGTON, D. C. 20590

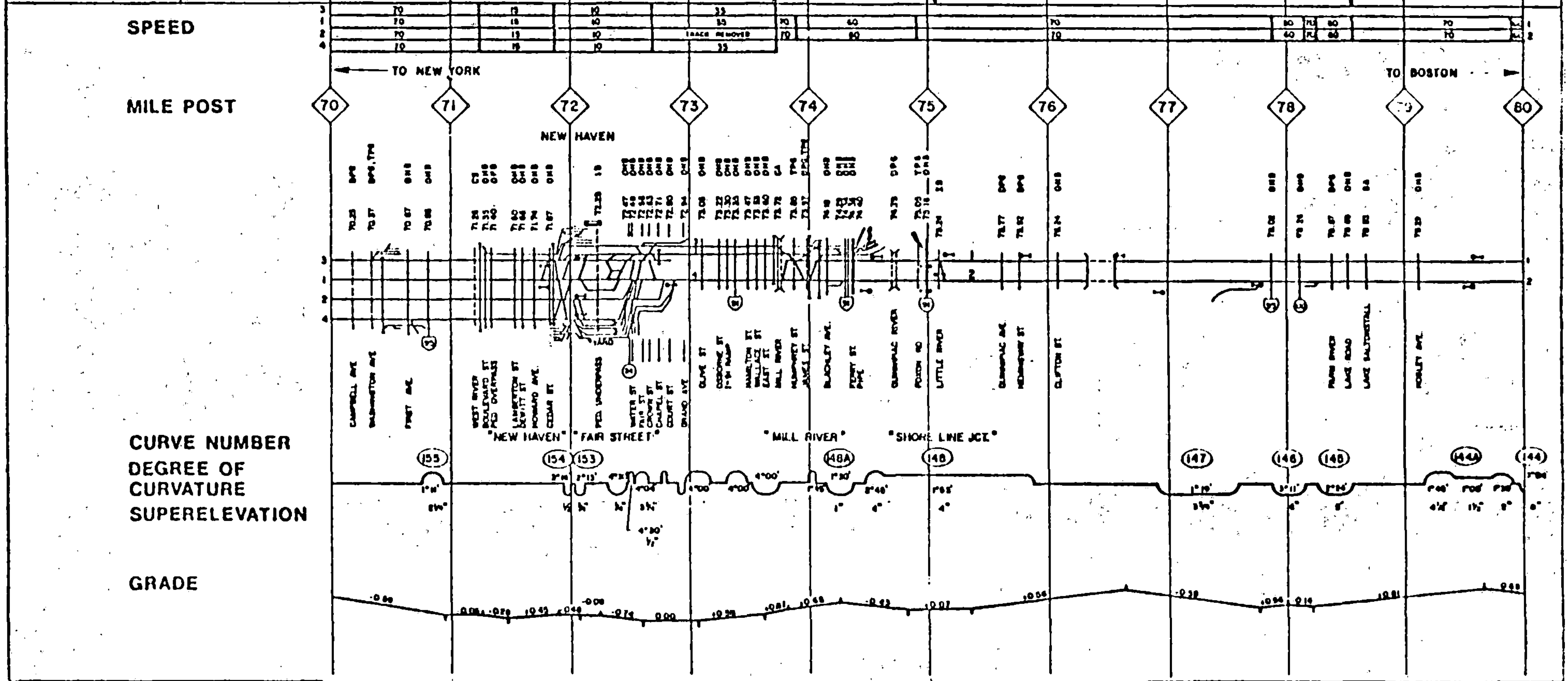


BUDD TILT SUSPENSION TEST PLAN

REVISED 2-25-82

TRACK CHARTS

CANT DEFICIENCY IN INCHES AT TEST SPEED					3.10 1.40	2.50		1.25 4.90	3.40	1.75 1.93 3.14
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED					.07 .09	.041		.013 .082	.053	.029 .032 .052
BALANCE SPEED M.P.H.					31 45	55		64 52	47	59 40 44
MAX. TEST SPEED M.P.H. WEST TRACK-1			35		70		70			70
MAX. TEST SPEED M.P.H. EAST TRACK-2			35		35		50			60



TRACK CHART

NEW YORK TO BOSTON

MILE POST 70 TO MILE POST 80

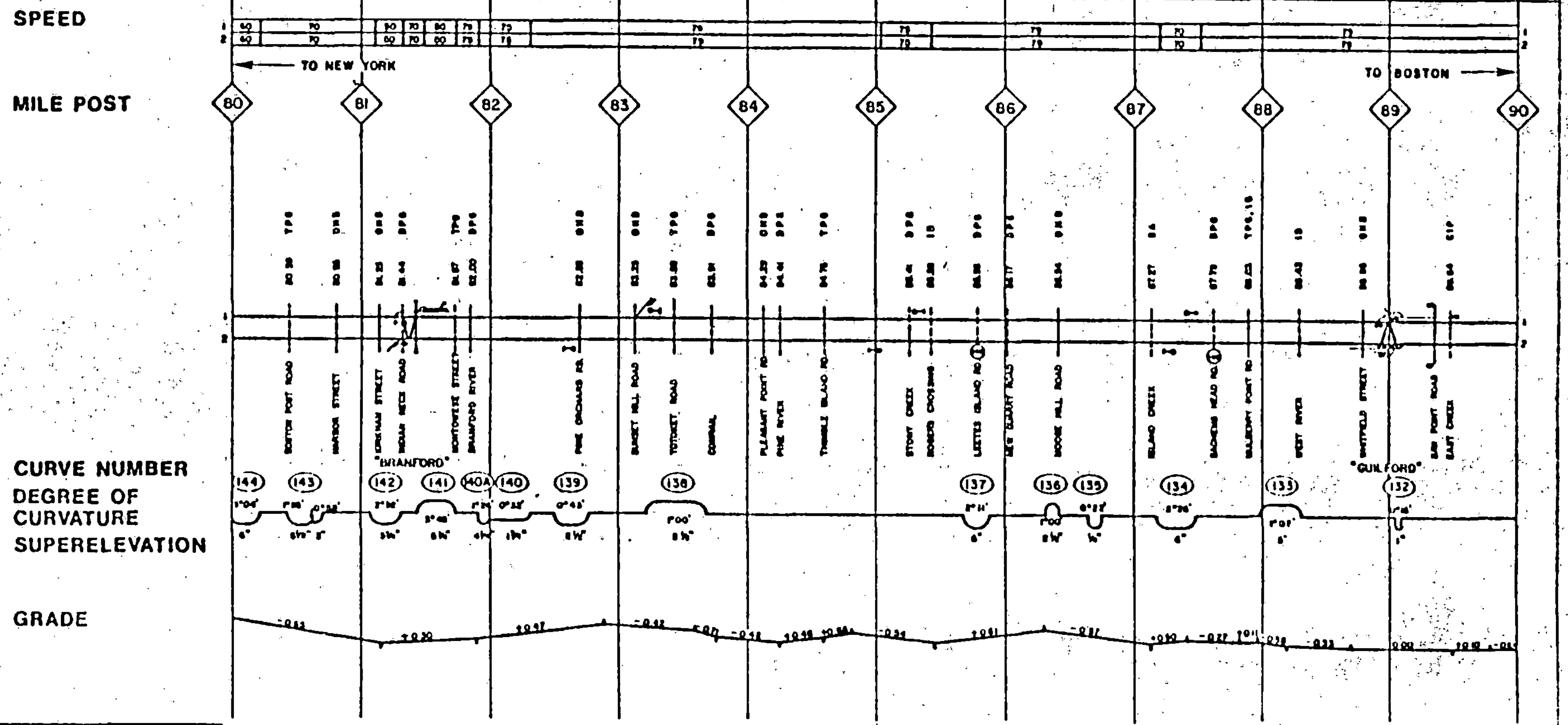
(32)

DESCRIPTION

REVISIONS

CAN. DEFICIENCY IN INCHES AT TEST SPEED	3.60	1.88	3.47	3.84	—	2.02	3.8	5.04	2.55 1.60	4.89	4.01	.56
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED	.075	.031	.058	.064	—	.034	.064	.084	.043 .027	.082	.067	.01
BALANCE SPEED M.P.H.	53	74 60	43	46	65	71	60	63	60 31	59	62	70

MAX. TEST SPEED M.P.H.							
	WEST TRACK-1	60	65	95	85	80	95
	EAST TRACK-2	60	65	95	85	80	95

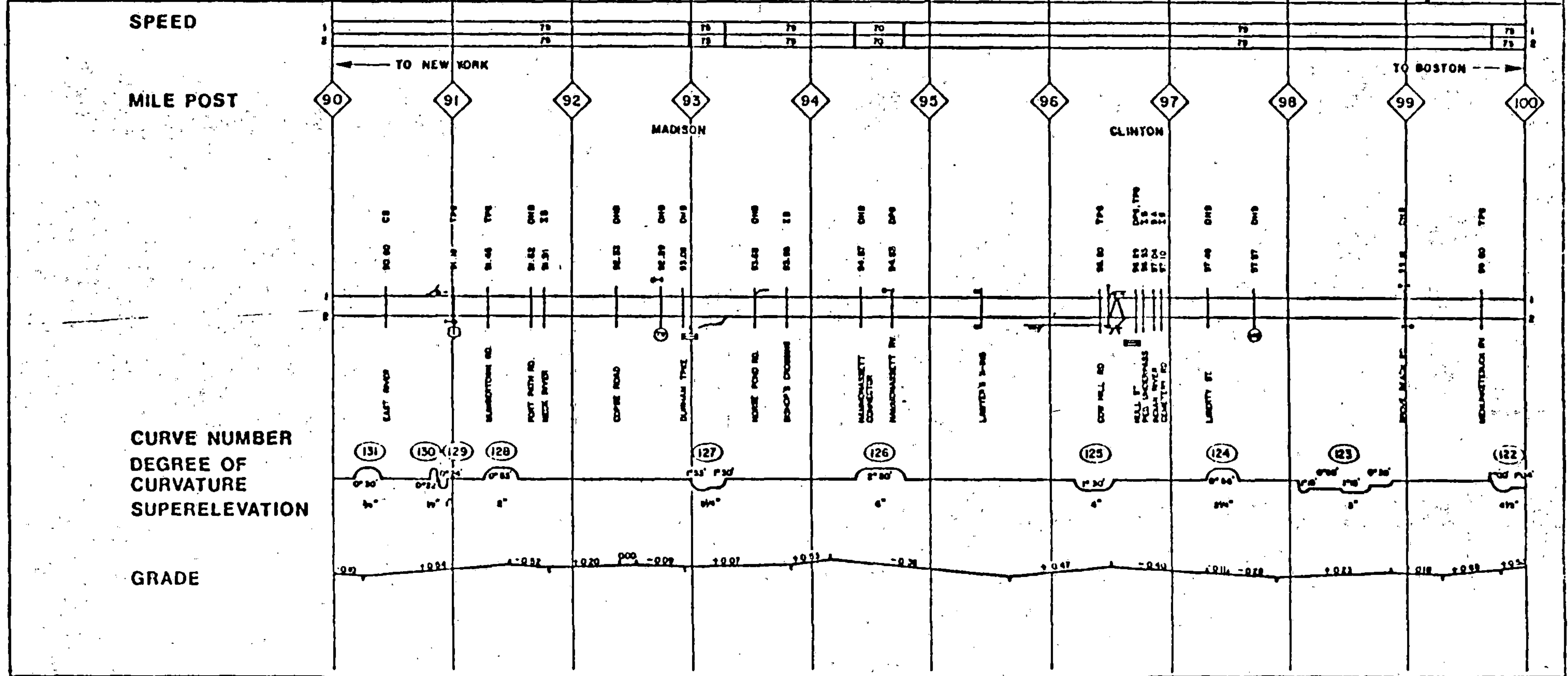


TRACK CHART

NEW YORK TO BOSTON

MILE POST 80 TO MILE POST 90

CANT DEFICIENCY IN INCHES AT TEST SPEED		2.40 1.80 1.50	3.79		5.41 3.24	5.79		5.47	3.64	4.89 2.89 4.36 .15	4.36
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.040 .030 .025	.063		.090 .087	.097		.091	.061	.082 .048 .073 .002	.093
BALANCE SPEED M.P.H.		46 44 60	56		63	61		62	59	59	57
MAX. TEST SPEED M.P.H.	WEST TRACK-1		95		90	85		95			85
	EAST TRACK-2		95		90	85		95			85



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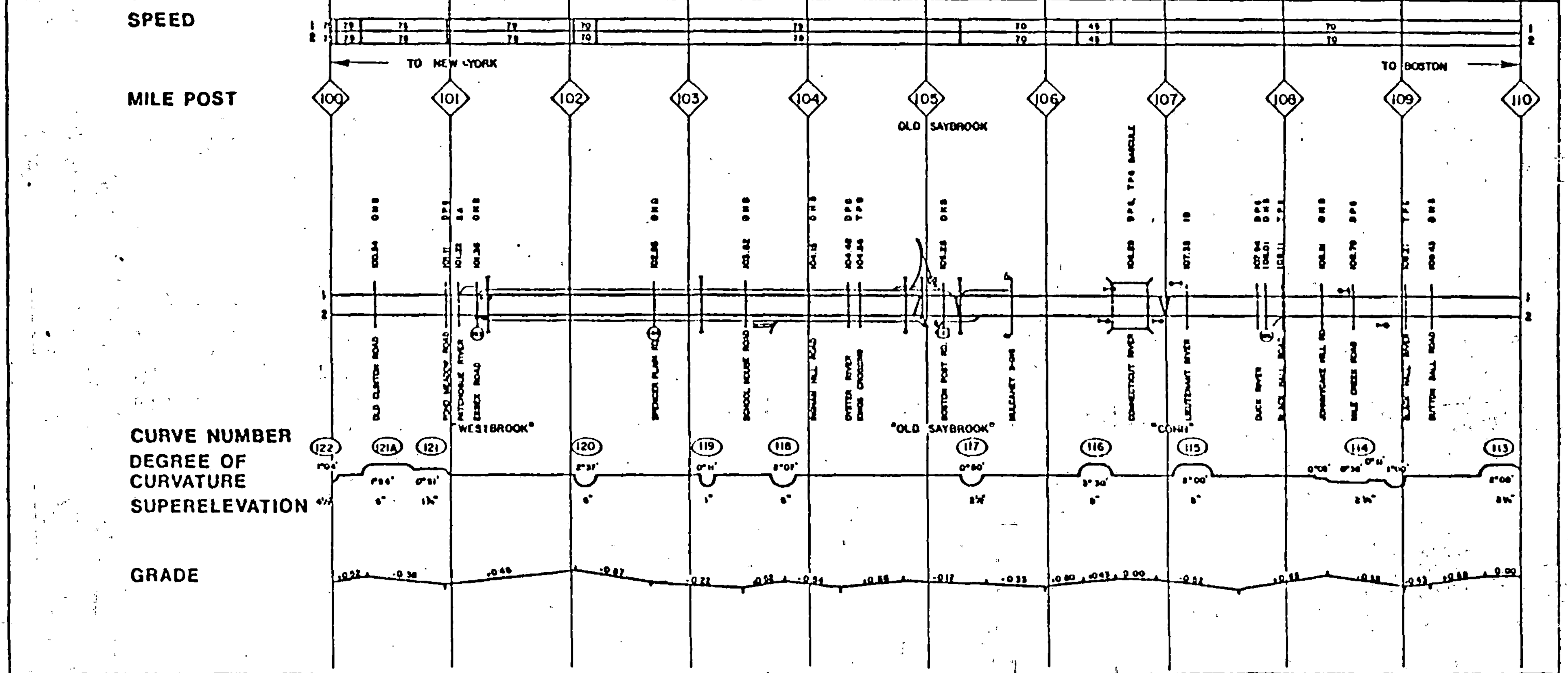
FIRST ISSUE - 1977 [illegible]
DESCRIPTION
REVISIONS

NEW YORK TO BOSTON
MILE POST 90 TO MILE POST 100

(34)

CANT DEFICIENCY IN INCHES AT TEST SPEED		3.60 2.54		2.97	.07 4.70		1.71	3.81	5.10	2.80	5.53
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.060 .042		.049	.001 .078		.028	.064	.085	.047	.092
BALANCE SPEED M.P.H.		67 54		57	88 64		66	45	60	57	59
MAX TEST SPEED M.P.H.	WEST TRACK-1	85		70		85		60 55		85	
	EAST TRACK-2	85		70		85		60 55		85	



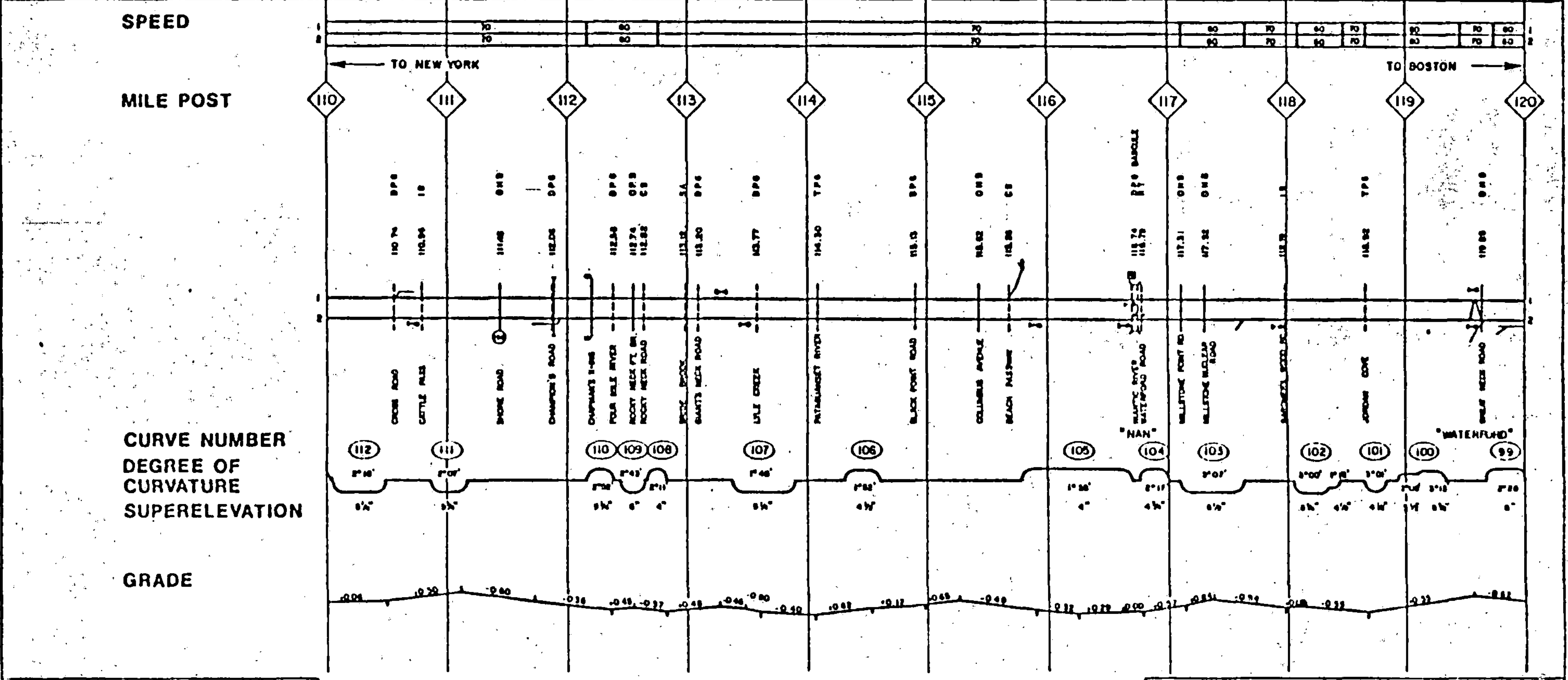
DATE BY REV DESCRIPTION REVISIONS

TRACK CHART

NEW YORK TO BOSTON

MILE POST 100 TO MILE POST 110

CANT DEFICIENCY IN INCHES AT TEST SPEED		6.37	4.95	2.72 2.02 2.45	3.85	4.94		3.31 1.00	2.33	1.80 3.10	2.35 .21
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.106	.082	.045 .034 .041	.064	.082		.055 .017	.039	.030 .052	.039 .003
BALANCE SPEED M.P.H.		57	62	54 56 51	65	59		59 54	50	52 40	51 59
MAX. TEST SPEED M.P.H.	WEST TRACK-1	85		65		85		80		60	
	EAST TRACK-2	85		65		85		80		60	



REVISIONS

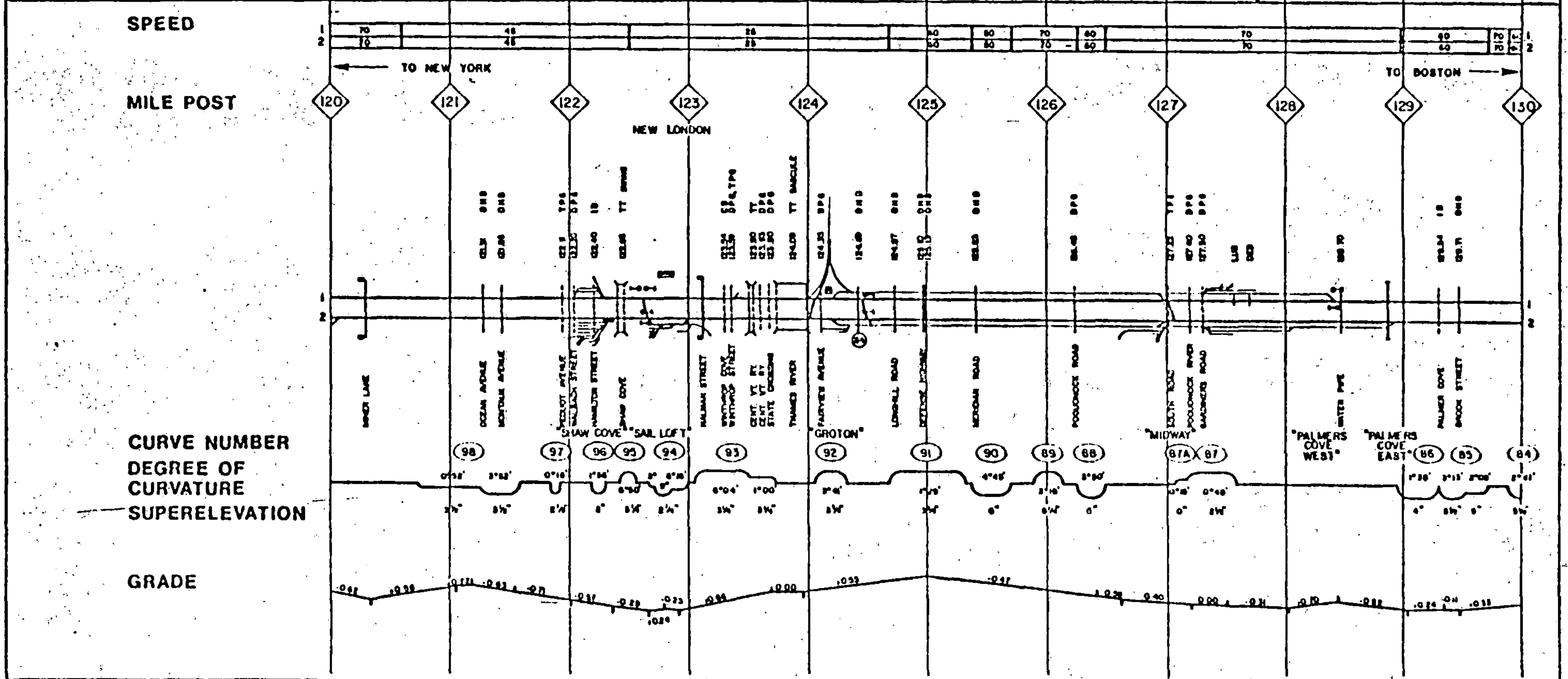
TRACK CHART

NEW YORK TO BOSTON

MILE POST 110 TO MILE POST 120

(36)

	120–121	121–122	122–123	123–124	124–125	125–126	126–127	127–128	128–129	129–130
CANT DEFICIENCY IN INCHES AT TEST SPEED		5.97 1.71			—	5.96 .54	3.65	.50		.82 4.00 2.68
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.104 .029			—	.099 .009	.061	.008		.014 .007 .045
BALANCE SPEED M.P.H.		36 109	38 26 33	28	38 82	43 57	47	67		59 49 53
MAX. TEST SPEED M.P.H. WEST TRACK-1		60		25		60			65	
MAX. TEST SPEED M.P.H. EAST TRACK-2		60		25		60			65	



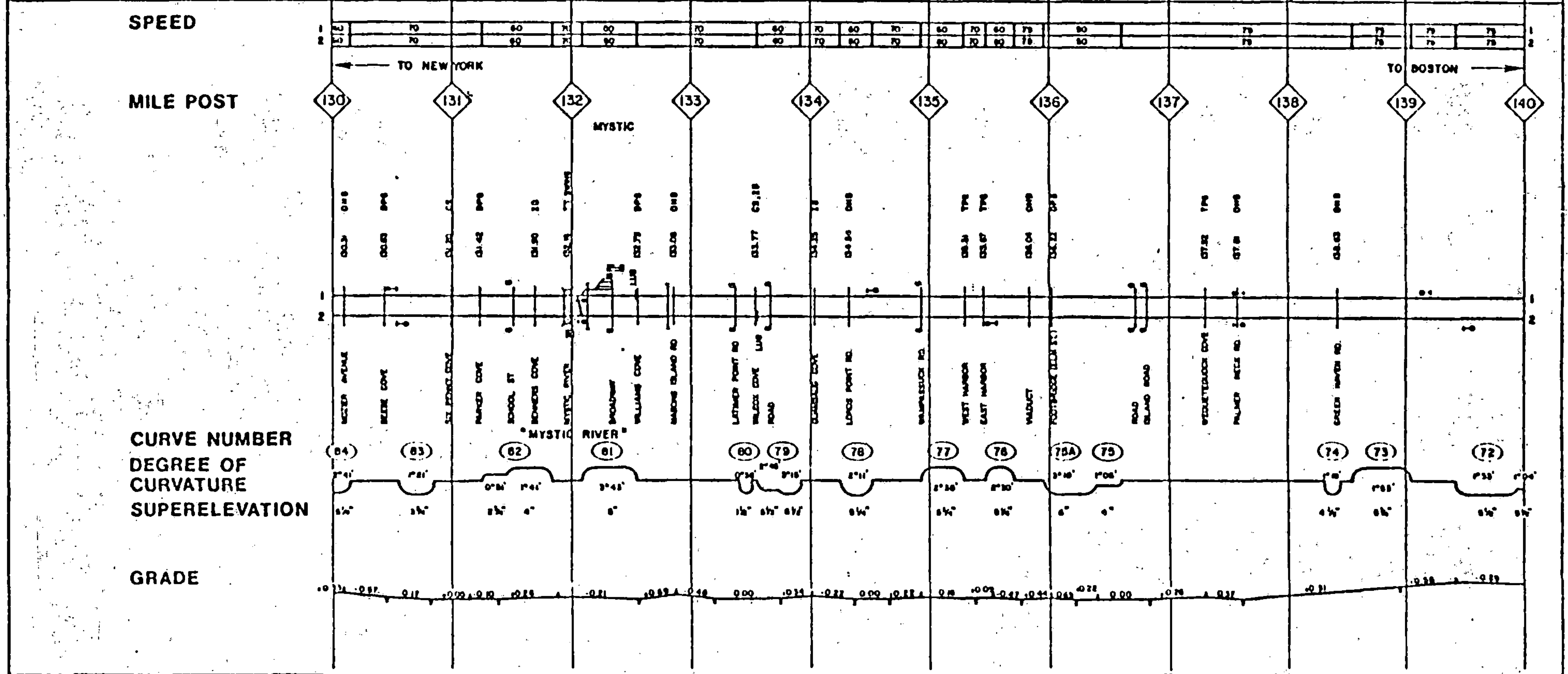
TRACK CHART

NEW YORK TO BOSTON

MILE POST 120 TO MILE POST 130

(37)

		130–131	131–132	132–133	133–134	134–135	135–136	136–137	137–138	138–139	139–140
CANT DEFICIENCY IN INCHES AT TEST SPEED		2.68 .24	.24	4.36	2.6 4.10	6.13	2.03 2.14	3.80		4.50 3.07	4.02
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.045 .004	.004	.072	.044 .068	.102	.034 .030	.063		.075 .061	.067
BALANCE SPEED M.P.H.		53 63	58	44	52 49	44	56 55	51		70 66	65
MAX. TEST SPEED M.P.H.	WEST TRACK-1	65	60 50	60			65				85
	EAST TRACK-2	65	60 50	60			65				85



REVISIONS
DESCRIPTION

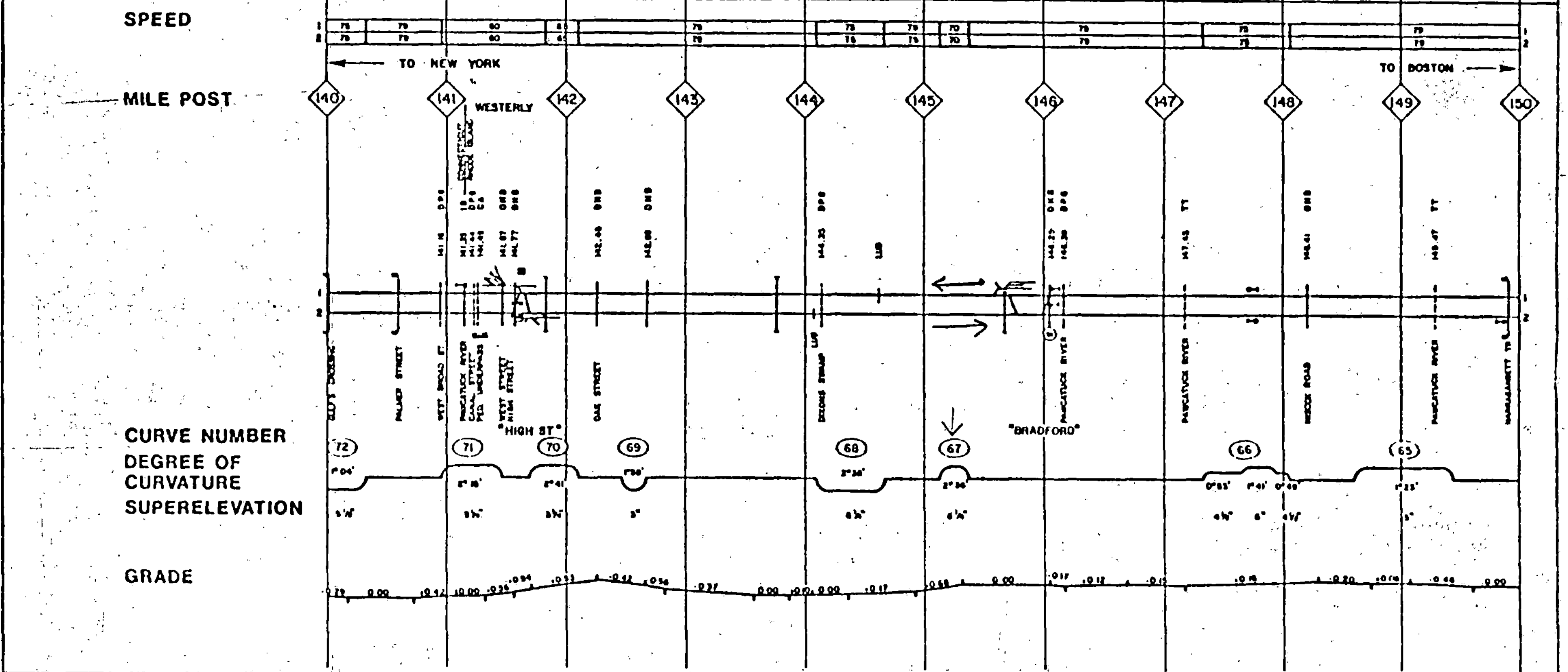
TRACK CHART

NEW YORK TO BOSTON

MILE POST 130 TO MILE POST 140

(38)

CANT DEFICIENCY IN INCHES AT TEST SPEED		.100	6.12/ 3.60 6.26	5.80		5.54	5.34		2.51	1.98	
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.001	.102/ .060 .104	.097		.092	.090		.042	.033	
BALANCE SPEED M.P.H.		80	59 55	47		58	59		71	72	
MAX. TEST SPEED M.P.H.	WEST TRACK-1	85	85		80					85	
	EAST TRACK-2	85	75		80					85	



	DESCRIPTION
	REVISIONS

TRACK CHART

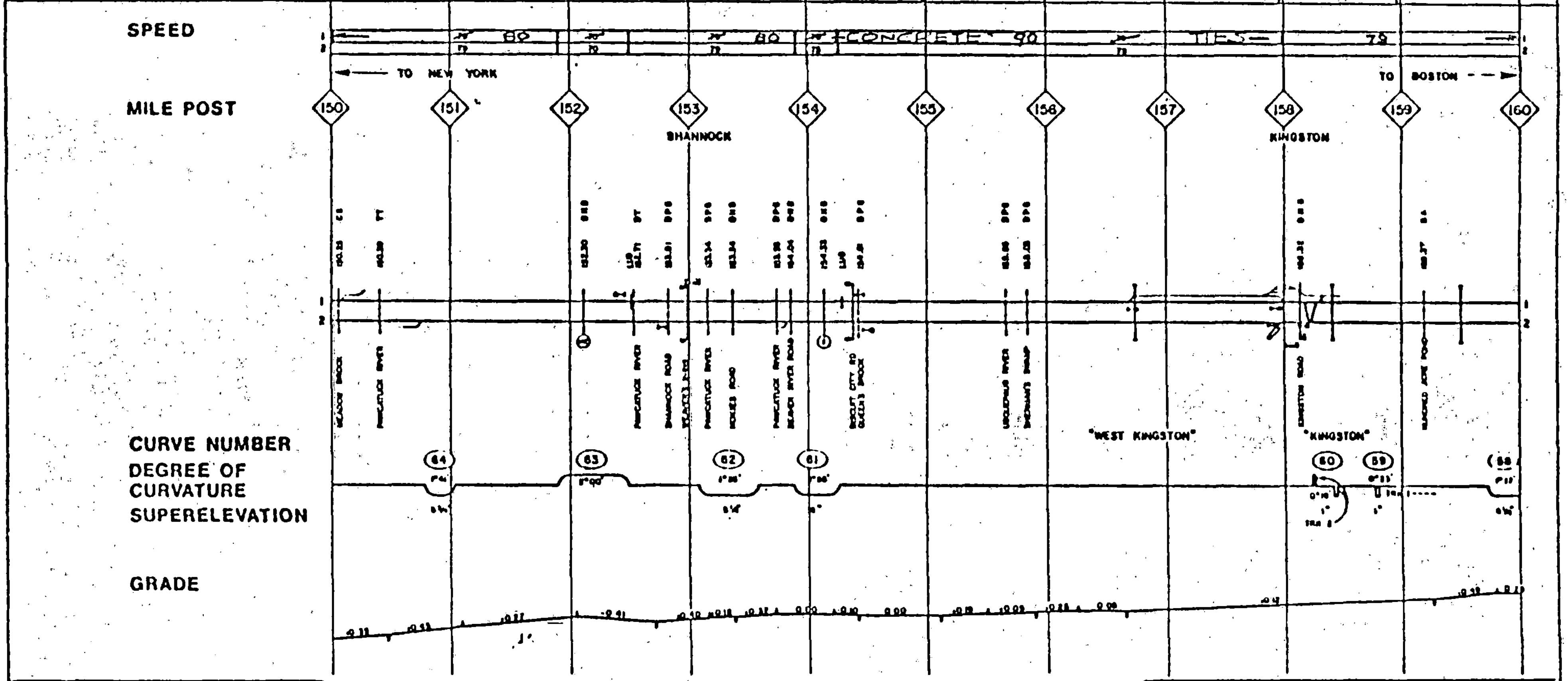
NEW YORK TO BOSTON

MILE POST 140 TO MILE POST 150

59

CANT DEFICIENCY IN INCHES AT TEST SPEED	2.76	4.00	2.86	4.87	—	4.72
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED	.046	.067	.048	.088	—	.079
BALANCE SPEED M.P.H.	70	65	72	67	61	69

MAX. TEST SPEED M.P.H.						
	WEST TRACK-1	85	90	100	90	100
	EAST TRACK-2	85	90	90	85	100



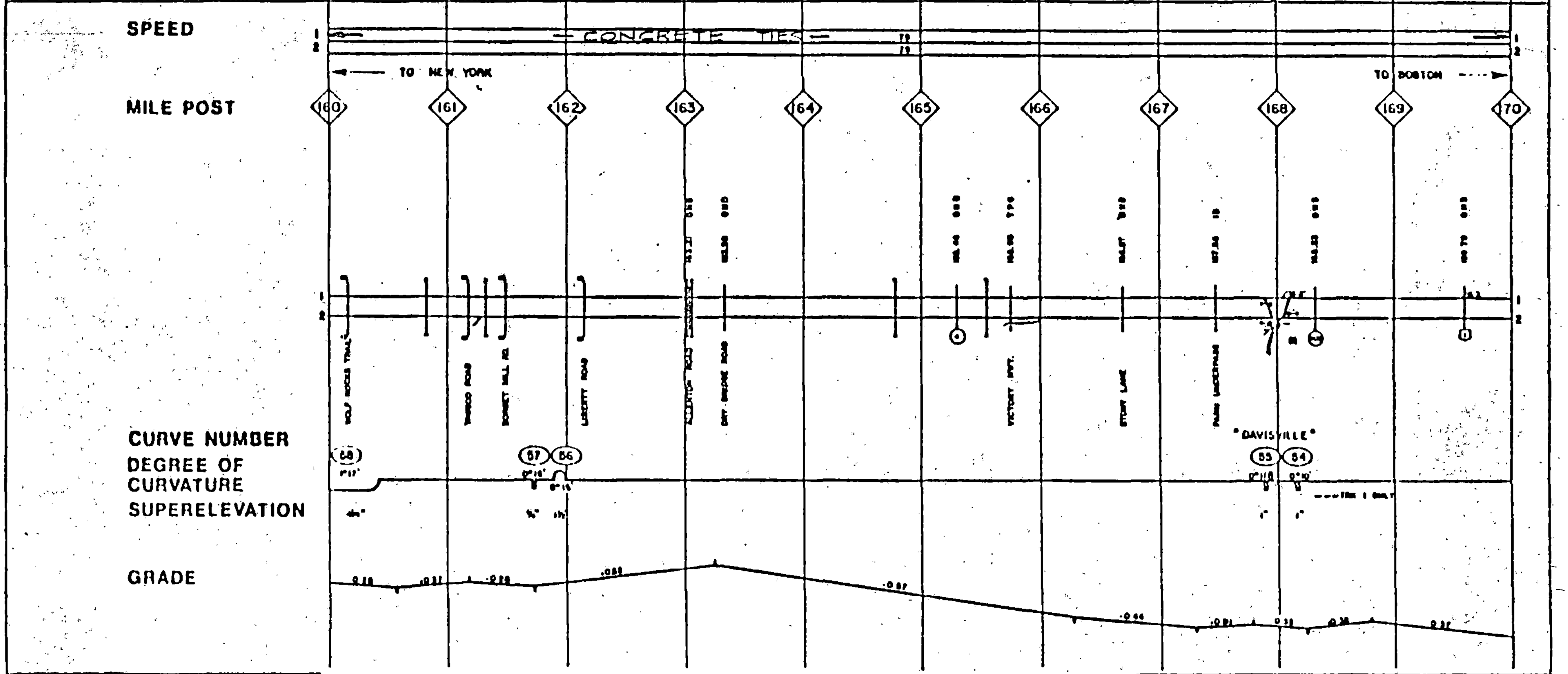
TRACK CHART

NEW YORK TO BOSTON

MILE POST 150 TO MILE POST 160

140

CANT DEFICIENCY IN INCHES AT TEST SPEED		4.72	1.49 .24						—	.05	
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED		.079	.025 .004						—	.001	
BALANCE SPEED M.P.H.		69	38 93						88	93	
MAX. TEST SPEED M.P.H.	WEST TRACK-1					100					95
	EAST TRACK-2					100					95



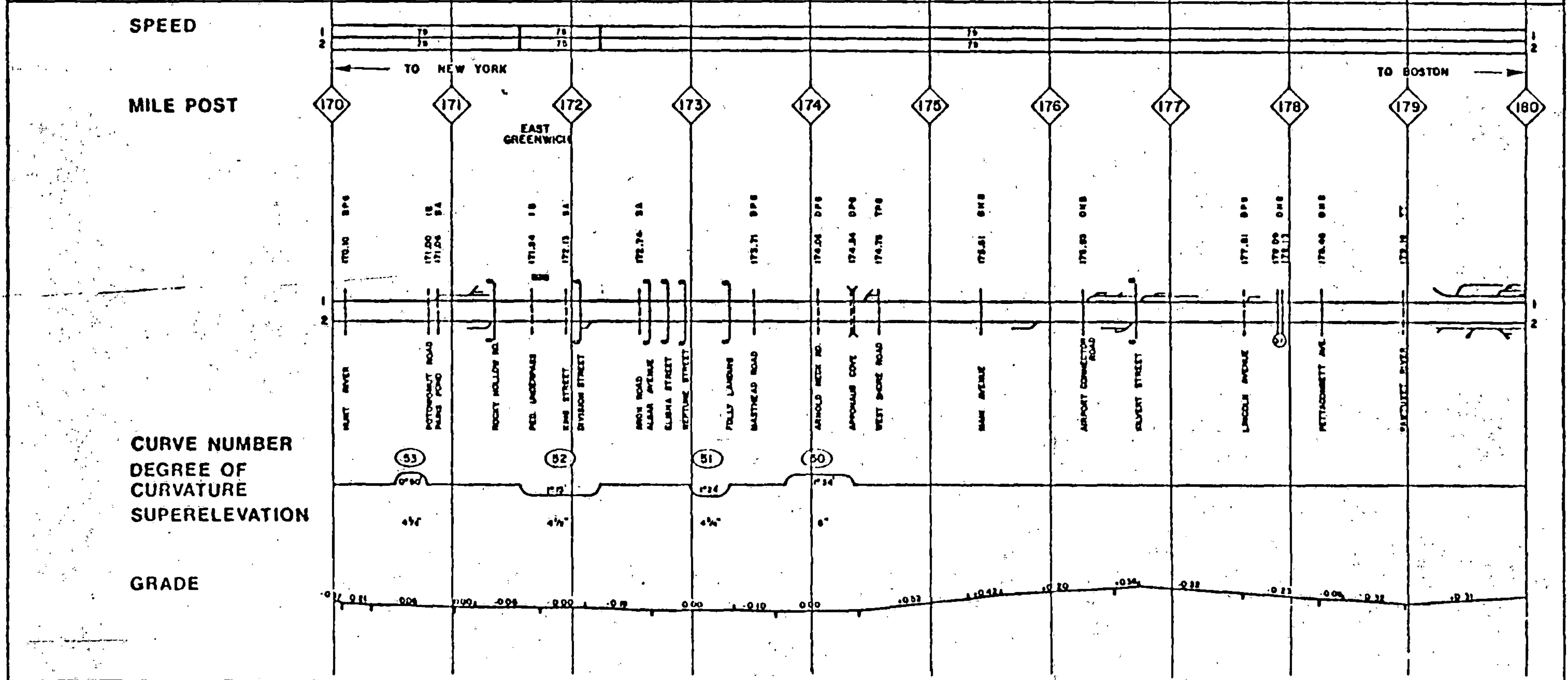
TRACK CHART

NEW YORK TO BOSTON

MILE POST 160 TO MILE POST 170

(41)

CANT DEFICIENCY IN INCHES AT TEST SPEED	1.59	3.39	4.09	4.8	
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED	.008	.057	.068	.082	
BALANCE SPEED M.P.H.	90	72	70	68	
MAX TEST SPEED M.P.H. — WEST TRACK-1					95
MAX TEST SPEED M.P.H. — EAST TRACK-2					95



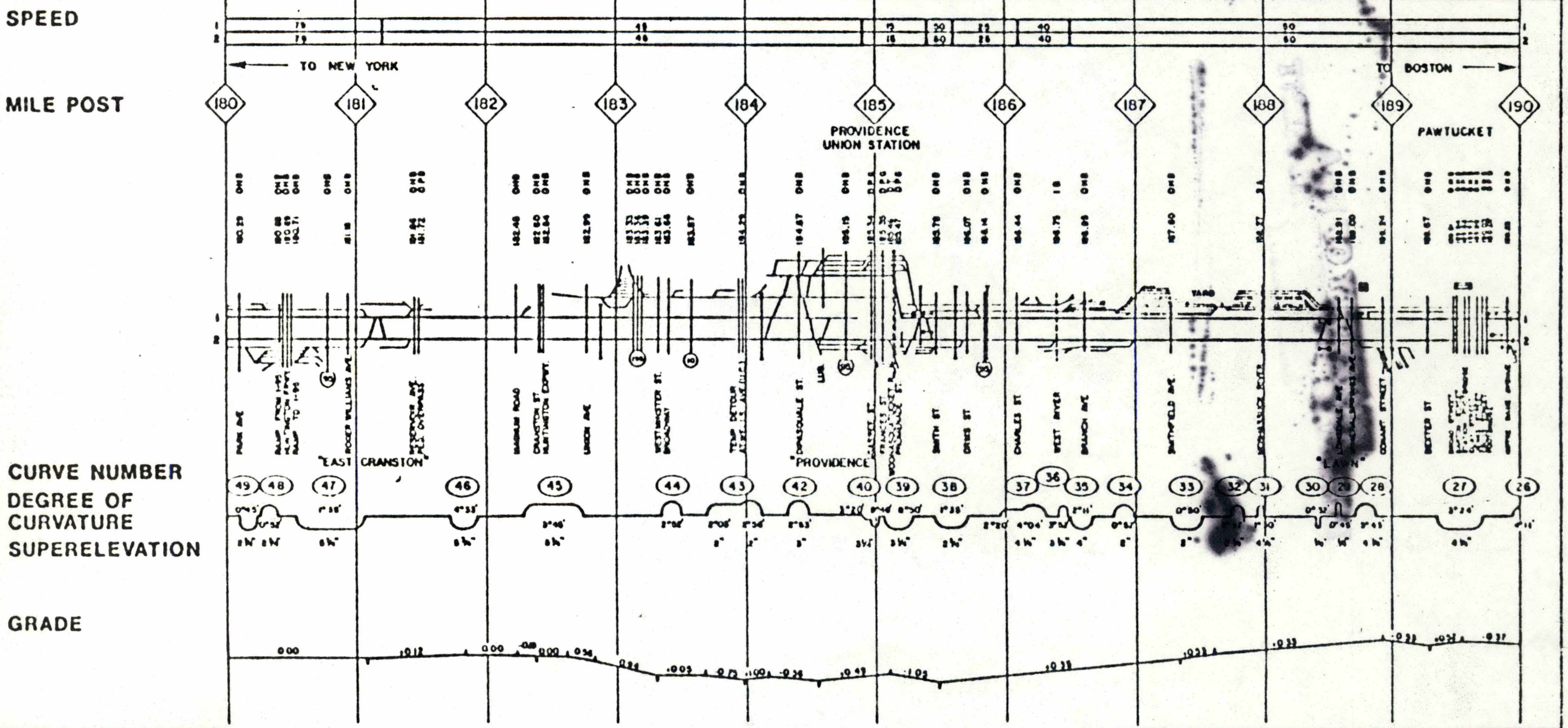
TRACK CHART

NEW YORK TO BOSTON

MILE POST 170 TO MILE POST 180

(42)

CANT DEFICIENCY IN INCHES AT TEST SPEED	1.99 2.72 4.24									
NOMINAL LATERAL G ACCELERATIONS WITHOUT TILT AT MAX. TEST SPEED	.033 .045 .078									
BALANCE SPEED M.P.H.	72 67 72	42	47	31	39 21	23 50	38 37 51 57	59 45 63	25 21 40	35
MAX. TEST SPEED M.P.H. — WEST TRACK-1	95					50				
MAX. TEST SPEED M.P.H. — EAST TRACK-2	95					50				



DATE	BY	REV	DESCRIPTION
		0	FIRST ISSUE - 1977 EXISTING CONFIGURATION

REVISIONS

TRACK CHART

NEW YORK TO BOSTON

MILE POST 180 TO MILE POST 190

(43)

Demonstration of the Budd Company Amcoach Tilt
Body System, W Clark Dean, James M Herring, Jr,
1983 -23-Passenger Operations

RE [illegible] NT