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TRACKED LEVITATED RESEARCH VEHICLE

PERIODIC TEST SUMMARY REPORT

INDEPENDENT CUSHION SUSPENSION IN

PERTURBED GUIDEWAY - AEROPROPELLED

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16. Abstract

The results of the first tests of the Tracked Levitated Research Vehicle (TLRV) in the Independent Cushion Suspension mode over the perturbed guideway at the Transportation Test Center (TTC) are presented. Vehicle dynamic response behavior is discussed for the speed range from 0 to 90 mph, including comparisons of test data with the responses computed using the TLRV Dynamics Simulation Program.

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SYMBOLS

B/C	Body/Chassis
C/C_c	Viscous Damping Ratio
F	Force
Fo	Air Spring Load
k	Spring Rate
N	Acceleration
P_D	Aft Duct Pressure
P_o	Air Spring Pressure
PT1	Forward Vertical Body Acceleration (Sta. 183)
PT2	Aft Vertical Body Acceleration (Sta. 610
t	Time
V	Velocity
Y	Lateral
Z	Vertical
$\dot{\delta}$	Actuator Stroke Rate
Sta	Station, vehicle (inches, nose of vehicle is sta. 100) guideway (100 feet, north end is 1642 and increases from north to south)
WL	Vehicle Waterline height (levitation surface is 95.5 in.)
BL	Vehicle Butt line (centerline is 0 in.)

1.0 SUMMARY

This is the fifth of the series of technical reports documenting the analysis of 1973 test results from the aero-propelled TLRV. The dynamic responses of the independent cushion configured vehicle traversing ramp-step and parabolic pulse perturbations installed on the guideway levitation surface are covered herein. The maximum test speed during these runs was 90 mph.

The vehicle responses to the installed guideway perturbations (up to 3 inches high) are well within the stroking and load capabilities of the cushion suspension system, as shown by the relatively small measured values as compared to the design limits.

Except for the smaller ramp-step heights the perturbations excited identifiable dynamic responses in the vehicle.

There is a trend of increasing vehicle responses with increasing traverse speed, and the acceleration responses are relatively insensitive to moderate changes in the secondary suspension parameters. Asymmetric excitation (perturbation on one side only of the levitation surface of the guideway) produces less vertical vehicle response than symmetric. The lateral responses to asymmetric excitation are recognizable, but not much greater in amplitude than the ambient smooth guideway lateral responses.

The predicted responses from the Digital Simulation Program are close to those measured on the vehicle with a strong indication that the vehicle damping forces are considerably less than the design values.

2.0 INTRODUCTION

The TLRV and its guideway have been developed to provide a full scale test bed for the evaluation of system design parameters of advanced, high speed ground transportation systems.

Supported and guided by peripheral jet type air cushions within a 12 foot wide channel guideway, the 51 foot long research vehicle is powered by three JT15D turbofan engines (see Figure 2-1). As the next stage in the development program, a Linear Induction Motor Propulsion System (LIMPS) will be added to the vehicle, and a LIM Reaction Rail and Wayside Power System (WPS) added to the guideway to provide the thrust for extension of the test speed range.

The TLRV, shown in Figure 2-2, consists of two major assemblies, body and chassis. The chassis provides the supporting framework and air duct system for the air cushions, the primary suspension of the vehicle in the guideway. The body (containing the cabin, power conditioning equipment compartment and engines) is mounted on fore and aft pivots to provide banking capability for coordinated turns at all speeds (up to 300 mph) in the 13° superelevated $2\frac{1}{2}$ mile radius curved sections of the guideway. There are secondary suspension systems between body and chassis and between the chassis and the air cushions.

Three basic suspension modes were to be evaluated:

- Primary Suspension - all secondary suspension "locked out" with rigid links between cushions and chassis and chassis and body
- Body/Chassis - suspension free between chassis and body and between guidance cushions and chassis; chassis to levitation cushion suspension "locked out"
- Independent Cushion - cushion suspensions free; body to chassis "locked out"

The full evaluation of the TLRV at high speeds depends upon subsequent steps in the program with the incorporation of electric propulsion (LIMPS and WSP) and significant increase in the length of the guideway. These events will occur over a considerable period of time. Thus, the test potential for each area of interest is gradually expanded as the capability of the whole system becomes available. However, at each stage the test objectives are similar:

- o Familiarization - development of safe and efficient operating techniques
- o Performance - evaluation of ride quality, system efficiency, braking capability, acceleration and speed range, acoustics and component wearing
- o Cushion dynamics - determination of the effects of speed, guideway disturbances and cushion pitch on the air cushion characteristics
- o Secondary suspension dynamics - investigation of the effects on dynamic responses of varying spring rates, damping rates, banking and roll in both passive and active modes

The complete Aeropropelled Mode test sequence is shown in Figure 2-3. The first section of the guideway, $1\frac{1}{2}$ miles straight, was completed at the beginning of tests May 1973; and the second section, transition and curve, $1\frac{1}{2}$ miles, was available in November 1973. For the Independent Cushion Suspension mode tests all slots between guideway guidance panels were filled.

For previous tests, the measured weight of the vehicle was 34,100 pounds with the cg at Station 450. (The front of the vehicle starts, nominally, at Station 100.) With full fuel and crew this weight increased to 38,450 pounds with the cg at Station 452. The relatively far aft center of gravity was the result of the temporary installation of 4,000 pounds of lead ballast in the aft section of the body. This ballast counterbalanced the unloading of the rear body/chassis suspension from the air duct forces at the body/chassis flexible duct seal. Before conducting the tests over perturbations, the 4,000 pounds of ballast was removed. The weight of the vehicle without the 4,000 pound ballast, with full fuel and a 3-man crew, is 34,450 pounds with the cg at Station 435. Correspondence of levitation cushion loading to the weight and cg is shown in Figure 2-4. A more further breakdown of the vehicle geometry and mass properties is given in Appendix A, Figure A-2.

The long term test program objectives for the TLRV are discussed in the Test Plan-Aeropropelled Mode, Reference 1, and the priority tree of objectives from that plan is shown in Figure 2-5. This report is the fifth of a series of technical reports on the results from TLRV tests in the Aeropropelled Mode. The first, second and fourth tests reports (Reference 2, 3 and 5) covered Primary, Body/Chassis and Independent Cushion Suspension mode tests, respectively, conducted in the as-built smooth guideway. The third report (Reference 4) covered tests of the vehicle, in the Body/Chassis Suspension mode, traversing discrete perturbations installed on the guideway levitation surface. This, the fifth report, covers the tests of the vehicle, in the Independent Suspension mode, traversing discrete perturbations installed on the guideway levitation surface. The evaluation of the results from the three suspension mode series will be revised as necessary in a Final Technical Report of the TLRV Aeropropelled mode testing.

The test objectives for the TLRV, shown in Figure 2-5, include the complete coverage for the Aeropropelled Mode, Those specifically related to the tests in the Independent Cushion Suspension mode in the perturbed guideway are:

- Guideway
- Air Cushion Characteristics
- Secondary Suspension Dynamics

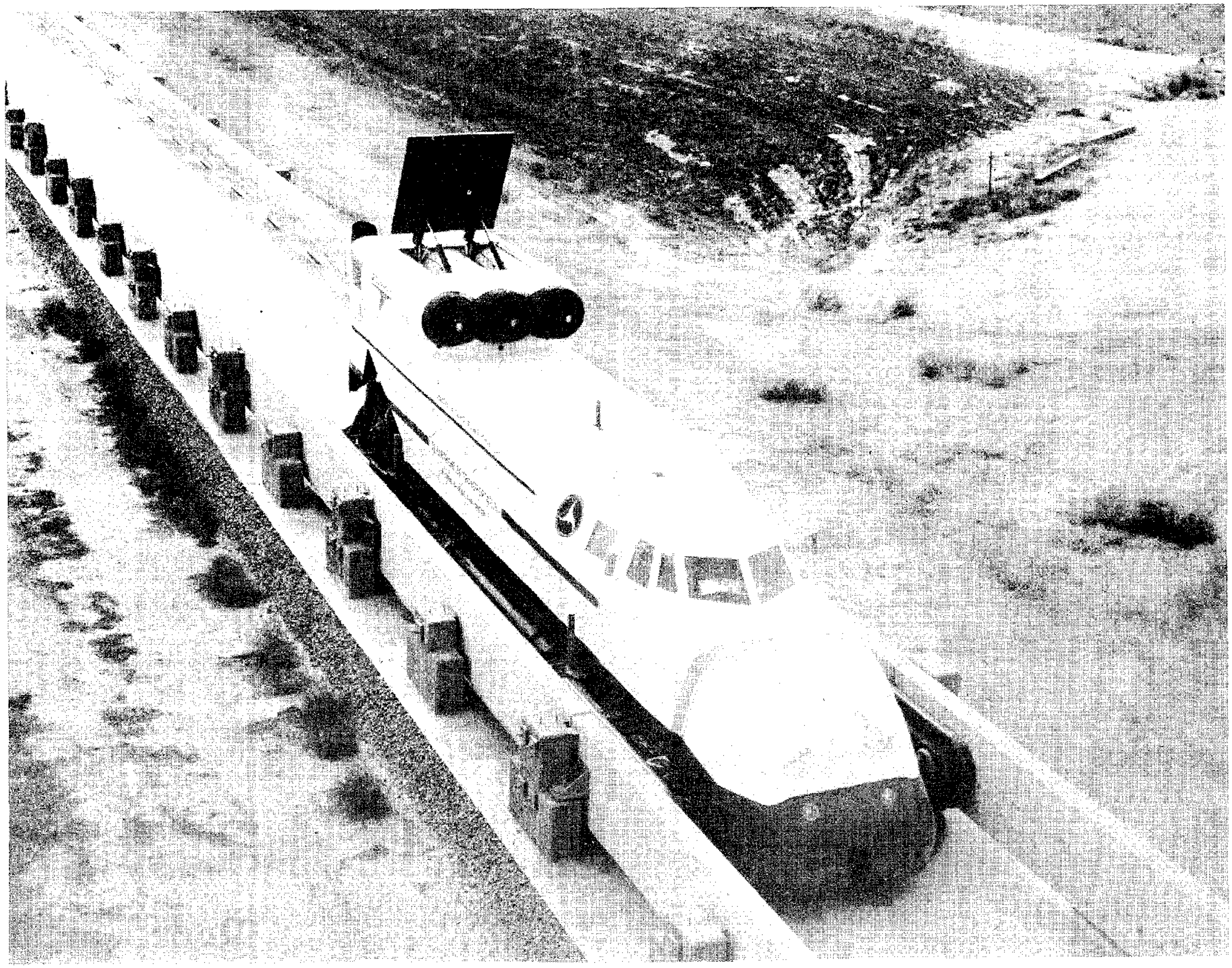


Figure 2-1 TLRV in Guideway at TTC

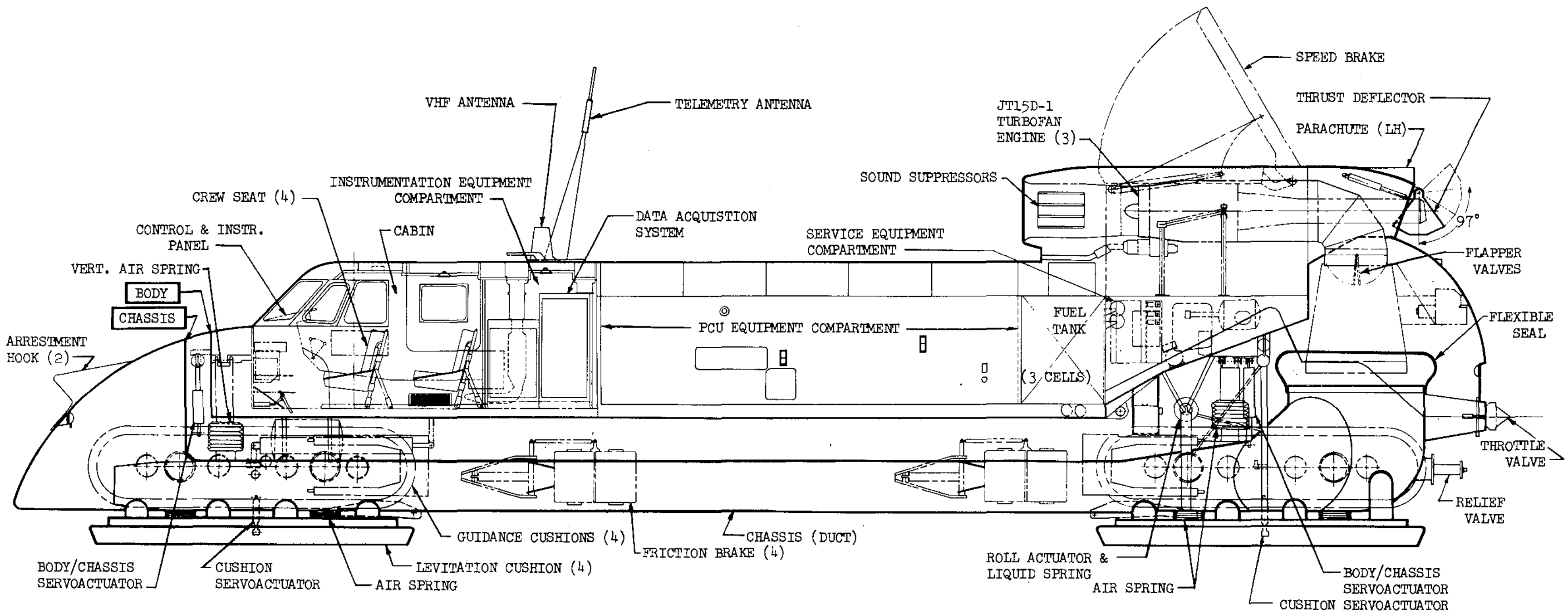
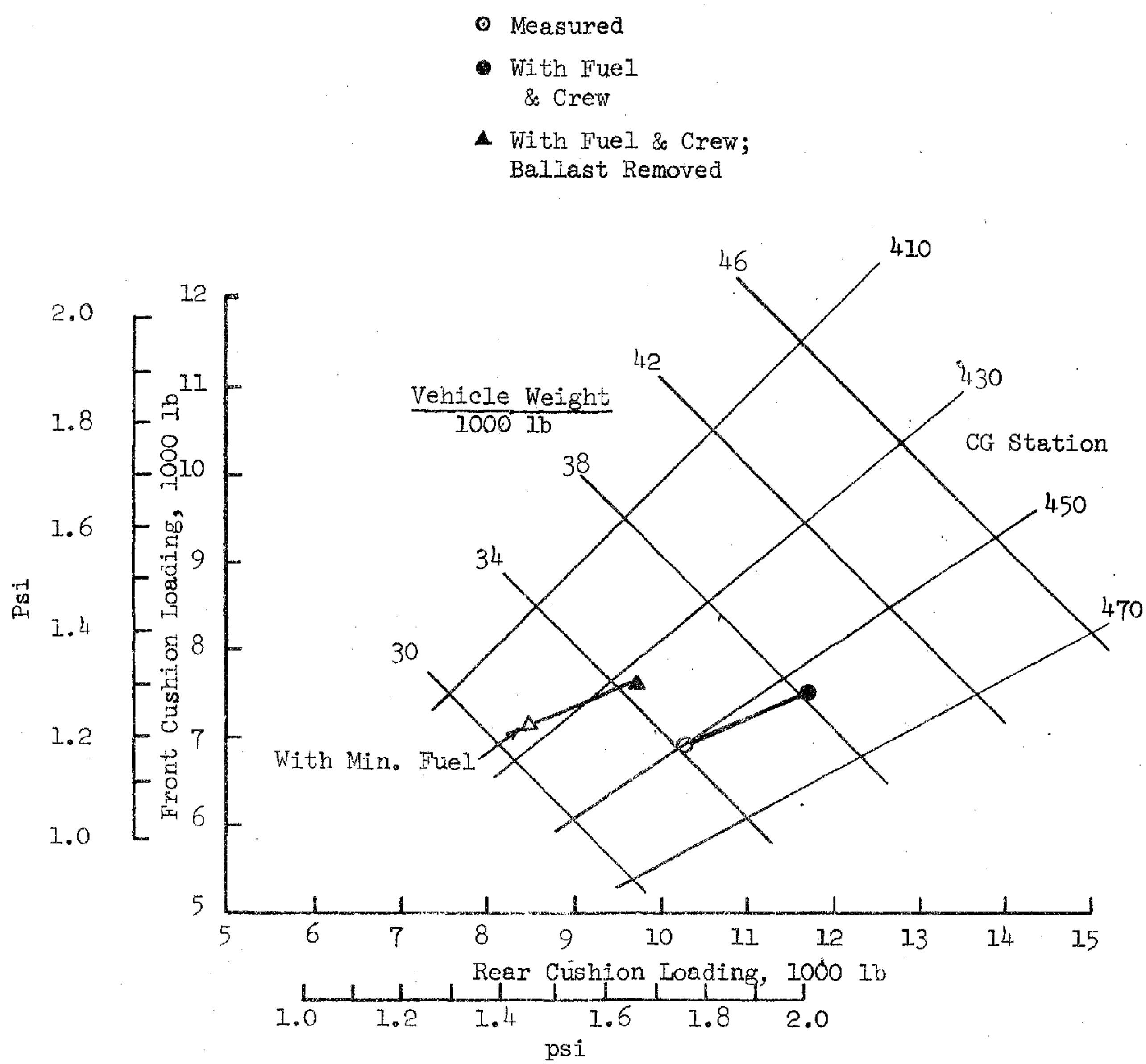


Figure 2-2 TLRV Inboard Profile

Test Block		Test Definition	April 1973	May	June	July	August	Sept	Oct	Nov
I Stationary Calibration	3.1.1	Subsystem Checkout								
	2	Engine Preparation								
	3	Single Engine Checkout								
	4	Data System Checkout								
	5	Throttle Valve								
	6	Exhaust Thrust Deflection								
	7	Exhaust Area Temperature Survey								
	8	Secondary Suspension Static								
	9	Guidance Cushion								
	10	Levitation Cushion								
	11	Levitation Suspension Damping								
	12	B/C Suspension Damping								
	13	Active Suspension Functional Checkout								
II Operational Shakedown	3.2.1	Emergency Egress Drills								
	2	Backing								
	3	Forward								
III Primary Suspension	3.3.1	Cushion Loading Equalization								
	2	Performance at Speed								
	3	Guidance Cushion Pitch								
IV B/C Suspension	3.4.1	Cushion Loading Equalization								
	2	Smooth G/W Speed Runs								
	3	Bank Actuation								
	4	Acoustic Survey								
	5	Active Control								
	6	Symmetrical G/W Peturbations								
	7	Asymmetrical G/W Perturbations								
	8	Transition, Curve to Tangent G/W								
I/C Suspension	3.5.1	Smooth G/W Speed Runs/Curve Transition								
	2	Initial Cushion Pitch Angle								
	3	Active Control								
	4	Ramp-Step G/W Perturbations								
	5	Long Wave Pulse G/W Perturbations								
	6	Asymmetrical G/W Perturbations								

Figure 2-3 Test Schedule - Aeropropelled Mode



Figue 2-4 TLRV Weight and Levitation Cushion Loading

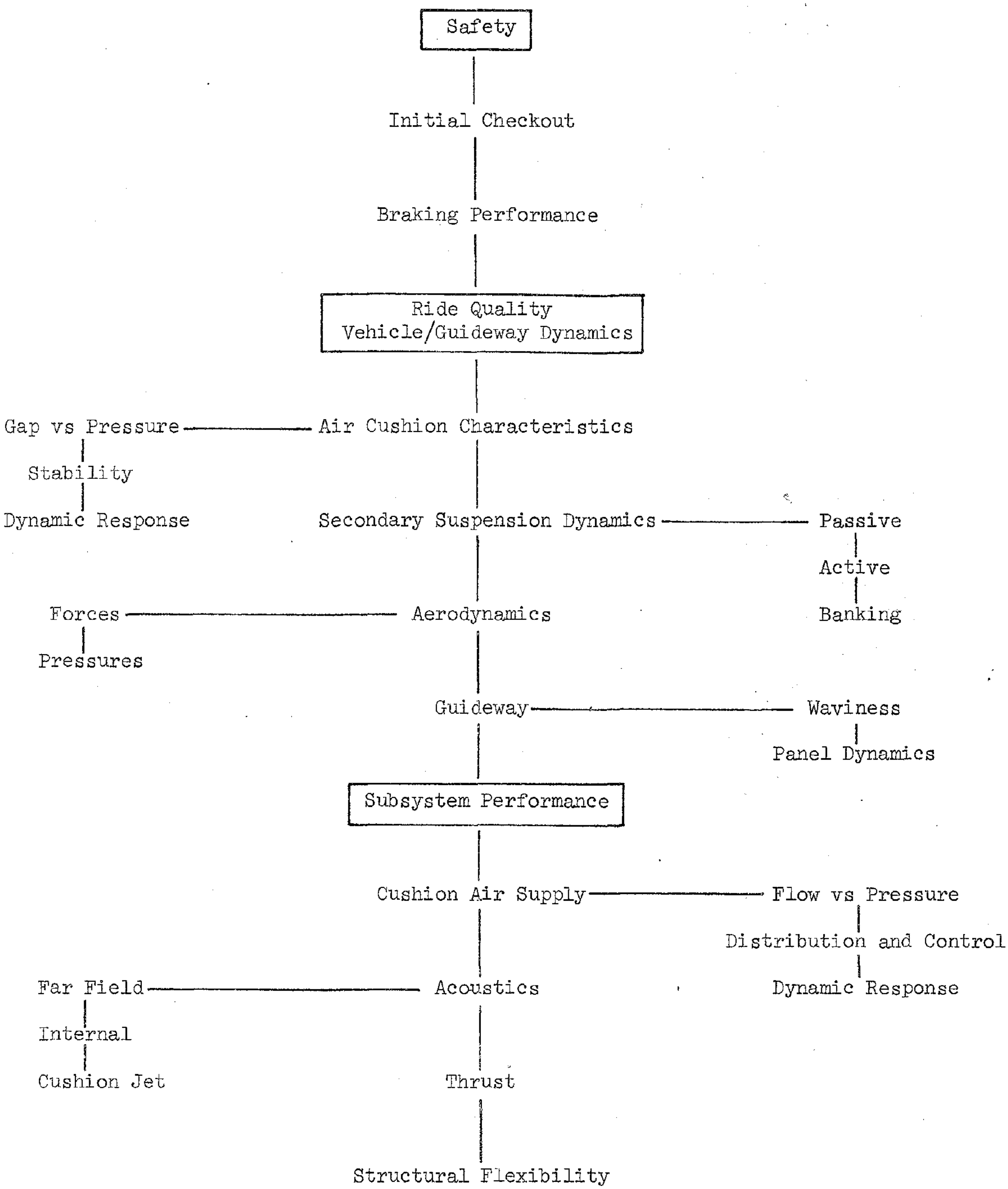


Figure 2-5 Test Categories

3.0 TEST CONDITIONS, MEASUREMENTS AND RECORDS

The summary tabulation of vehicle and guideway configurations, test speeds and suspension settings for each test run of the vehicle in the Independent Cushion Suspension mode is presented in Figure 3-1. The run sequence and test conditions follow the pattern established in the Test Plan-Aeropropelled Mode, Reference 1, modified as necessary in the day-to-day run schedule. The data in the tabulation are from the actual test conditions as recorded in the test logs.

The various measurements available from the vehicle data system and the several methods of recording the data for immediate and long term use in the data analysis are presented below.

3.1 Measurement List

Data on-board the vehicle are gathered from the various sensors (acceleration, pressure, position, temperature, speed, etc.) into a central processing area, the Data Acquisition System (DAS), where the raw signals are assigned to particular channels, scaled and filtered, converted to a PCM format and telemetered to the Data Van. The locations of the sensors on the vehicle are shown in Figure 3-2. A typical listing of the measurements with their calibrations, assigned channels, filters and other pertinent data is given in Figure 3-3. The explanation of the codes used as column headings is given below:

MEAS. NO.	-	the reference number of measurement (location in Figure 3-2
REV	-	a letter indicates a revised calibration
MEAS.	-	the abbreviated measurement name
PATCH NO.	-	the location of connection to DAS patch panel: "P" for an analog signal and "D" for digital
FUSE NO.	-	the fuse position in instrumentation power supply: CAU if powered through the suspension system control unit
FILT.	-	the nominal filter frequency for input to the PCM data stream, blank = unfiltered
MF/SF	-	the assigned main frame and subframe location in the PCM format

RPT	-	a "1" indicates measurement appears in each subframe at MF location; an "8" that it appears only at subframe indicated
LEV	-	the level refers to transducer output, "H" is either 0 to 5 or ±2.5 volts
POL	-	the polarity is "U" for 0 to 5 volts; "B" for ±2.5 volts where the zero is at 128 counts in PCM format
ZERO OFFSET	-	the engineering units value at 0 volts signal
EU PER COUNT	-	the engineering units per single count in PCM format
SERIAL NUMBER	-	the transducer identification serial number
VAL DATE	-	the month (1-9, 0, N, D) and day of validation of measureme
EU	-	the engineering units code

A - Amperes
B - BCD Word
D - Angular Degrees
E - Volts
F - Degrees Fahrenheit
G - "g"s
H - Hertz
I - Inches
K - Miles Per Hour
L - Pounds
M - Milliamps
N - Revolutions Per Minute
P - Pounds Per Square Inch

STA	-	the status-of-measurement code

0 - Not Installed
1 - Installation Incomplete
2 - Installation Complete, No Validation
3 - Analog Measurement (No PCM)
4 - Validated PCM Measurement
5 - Visual Measurements
9 - Questionable Measurement

The particular list of measurements given as an example in Figure 3-3 is from Measurement List 6. Written notations are made on the list to document changes in filters, patch panel locations, etc. which are required from time to time, and revised listings are made as changes accumulate. The list of measurements and related data to be used in the data analysis are subsequently prepared as an input card deck for the computer programs and the applicable measurement characteristics are recorded as a part of the Engineering Units Tape for long term retention.

3.2 Records

Three types of documentation were used to record TLRV test results; manual records, real time and playback oscillograph records and digital tape records of the measurements telemetered to the Data Van.

3.2.1 Manual Records

The vehicle test logs document:

- External test conditions
  - Temperature
  - Pressure
  - Wind Conditions
  - Condition of guideway (test length to be used)
- Vehicle Configuration
  - Weight
  - Suspension configuration
  - Throttle valve opening
- Run data
  - Time
  - Power conditions (duct pressure)
  - Guideway position (start, brake and stop)
  - Estimated speed
  - Measurement recorded on o'graphs
  - Observer comments

These logs are generally in a rough form and too voluminous for inclusion in total. The essential data are summarized in Figure 3-1 for all the tests in the Independent Cushion Suspension mode.

3.2.2 Oscillograph Records and On-Board Tape

Real time records of selected measurements are made on-board the vehicle and in the Data Van. During a test run, eight variables and the time code are recorded on the 7" o'graph in the vehicle directly from the sensors' analog signals or after the input conditioning (attenuation and filtering) in the DAS. Twelve variables and the time code are recorded on the 12" o'graph in the Data Van during the run. These measurements have been converted to digital form for transmission to the Data Van and reconverted to analog for recording purposes.

The primary purpose for the o'graphs is to provide immediate access to those selected measurements that are expected to reveal significant aspects of the vehicle responses. On the basis of these records, the run-to-run and day-to-day decisions are made to continue with or modify the planned test sequence and/or conditions. Examination of these records also permits the identification of events of interest for subsequent analysis and their time of occurrence. The results of such a review of the records are given in Figure 3-4. To the extent possible from the o'graphs the times for start, guideway transition (curve to tangent), perturbation encounter, braking and stop are included in the tabulation for every run.

The o'graphs may also be used as the basis for a limited analysis of vehicle dynamic characteristics. Particularly, long time spans of the available measurement records may be examined quickly to provide a broad data base for revealing data trends. However, in addition to the limited number of variables recorded, the detailed use of the traces is difficult due to poor line contrast and the small scale required to provide room for multiple traces. Reproduction from the o'graphs is generally unsatisfactory.

In addition to the real time o'graphs there is an on-board 14 channel magnetic tape recorder. One channel records the digital PCM data stream (all of the data going through the DAS to the Data Van), one the time code, and the rest may be used for analog records of selected measurements. The analog records may be played back after a run for recording on the on-board o'graph. In general, this on-board tape record is used as a backup for the data transmission system, and the tapes are re-used after a satisfactory Data Van tape generation is confirmed and there is no further need for its analog measurements.

3.2.3 Digital Tape Records

The primary data record is based upon the digitized measurement values gathered in the vehicle's DAS and transmitted in PCM format to the Data Van. There the serialized data are reformatted and recorded in parallel PCM format on the Raw Data Tape. The Raw Data Tape is later copied at Bethpage as an Edited Raw Data Tape (the editing consists primarily of skipping over data groups with parity errors or incorrect format). From this Edited Raw Data Tape and the pertinent Measurement Listing, an Engineering Units Tape is prepared for those times which are of interest for analysis, as indicated in the time-event summary listing shown in Figure 3-4.

The exact extent of the various data records on the tapes is necessary for correct access to the desired time intervals for analysis. The beginning and end times for each run, the times selected for the Engineering Units Tape conversions and the corresponding record numbers are tabulated in Figure 3-5

3.4 Indirect Measurements

Only a limited length of the guideway was marked with the white stripes which trigger the speed sensor and none was marked with the position-indicating stripes. Also, the sensitivity of the circuitry was such that unsteady readings of vehicle speed were obtained. Thus, other means of determining the speed and position on the guideway were employed as described in the following subsections.

3.4.1 Vehicle Speed

The most commonly used method of speed determination for various portions of a run is based on the time increment to traverse the distances between the slots at adjacent ends of the guideway guidance panels. Although the general level of speed was usually entered in the on-board test log records, that value, obtained from a pace car or hand-held timing of guideway station passage, applies only to the general area of maximum speed towards the end of a run. The measurements of guidance cushion base pressure, actuator pressure, deflection or acceleration show well defined pattern as the cushion passes a slot as described in Reference 2. The elapsed time for one or more traverses between slots provides the data for the speed determination near the point of interest.

3.4.2 Position in Guideway

Date	TL	Run	Guideway Configuration	Start Sta.	Brake Sta.	Stop Sta.	Run Dist. Ft.	Max. Vel. MPH	Duct Press. PSI	Lev. Act. Damp. D.B. Deg	Lev. Act. Damp. D.B. Turns	Lev. A/S in 3	Guid. Act. Damp. D.B. Deg.	Guid. Act. Damp. D.B. Turns	Guid. A/S Press. PSI	Susp. Mode	Nominal Cush. Pitch, in.	Remarks
11-8-73	92	static		1642.50						35	0	470	0	0	20	Passive	0	Static
11-9-73	93	38-1	Smooth	1642.50						35	0	470	0	0	20	Passive	0	
		39-2		1710	1670	1667.25	4275	25	3.7									
		39-4		1710	—	1642.50	6750	30	3.9									
11-12-73	94	39-6	Smooth	1720	1670	1665	5500	42	3.6	35	0	470	0	0	20	Passive	0	
		-8		1720	1670	1660.50	5950	52	3.6									
		-14		1710	1670	1667.75	4225	30.5	3.1									
		-16		1720	1670	1664.50	5550	42.5	3.1									
		-18		1720	1665	1642.50	7750	49	3.1									
11-13-73	95	40-2	Smooth	1710	1670	1666	4400	32	3.7	35	0	470	0	0	20	Passive	+.5	
		-4		1720	1668	1658	6200	57	3.7								+.5	
		39-10		1719.50	1670	1659.25	6025	57	3.8								0	45 MPH SE Wind
		39-20		1718	—	1642.50	7550	52.5	3.2								0	45 MPH SE Wind
11-14-73	96	39-12	Smooth	1765	1670	1657.25	10775	65	3.8	35	0	470	0	0	20	Passive	0	
11-15-73	97	42-2	1/2" X 25' ramp step	1710	—	1676.50	3350	36	4.0	35	0	470	0	0	20	Passive	0	4000 lb ballast removed before 42-2
		-4		1720	—	1673.75	4625	51	4.0									
		-8		1716.50	—	1642.50	7400	42.5	2.6									
		-6		1765	—	1665.75	9925	73	3.7			470						
		-12		1765	—	1654	11100	78	4.2			1130						
11-16-73	98	42-16	3/4" X 25' ramp step	1710	1680	1675.50	3450	30	4.0	35	0	470	0	0	20	Passive	0	
		-18		1720	—	1672.25	4775	53	4.0									
		-22		1720	—	1642.50	7750	44	2.6									
11-19-73	99	42-20	3/4" X 25' ramp step	1765	1670	1655	11000	73	4.1	35	0	470	0	0	20	Passive	0	
		-26		1765	—	1757	800		—	35		1130						Overspeed shutdown on L & C engines
		-26A		1765	1680	1667.25	9775	68	3.8	35		1130						40 MPH NE Wind
		-28		1765	1680	1670.25	9475	59	3.7	0		1130						
		-44		1765	—	1642.50	12250	58	4.0	0		470				Passive		Fwd & Aft guid and fwd Levitation actuators active
		41-4		1765	1670	1660.75	10425	55	2.9	0		470				Active		
11-20-73	100	44-2	Assymetric 1" X25'	1710	1680	1675.25	3475	28	—	0	0	470	0	0	40	Passive	0	
		-4		1765	1670	1665	10000	53	—	0		470	0					
		-6		1765	1680	1665.25	9975	72	—	35			0					
		-8		1765	1680	1664.50	10050	72	3.8	35			30					
		-10		1765	1668	1653.25	11175	72	—	35			30			Active		Guid. Active
11-21-73	101	42-30	1" X 25' ramp step	1710	1680	1672.50	3750	44	3.8	35	0	470	30	0	60	Passive	0	
		-34		1765	1680	1667	9800	68	3.8	35							0	
		-36		1765	1680	1654.25	11075	62.5	3.0	35							0	12 MPH E Wind
		-42		1765	1680	1666.75	9825	68	3.6	42							0	
		-38		1765	1680	1654.75	10025	—	3.6	42							.5	

Figure 3-1a Summary Log of Test Runs

Date	TL	Run	Guideway Configuration	Start Sta.	Brake Sta.	Stop Sta.	Run Dist. Ft.	Max. Vel. MPH	Duct Press. PSI	Lev. Act. Damp. D.B. Deg	Lev. Act. Damp. D.B. Turns	Lev. A/S in 3	Guid. Act. Damp. D.B. Deg.	Guid. Act. Damp. D.B. Turns	Guid. A/S Press. PSI	Susp. Mode	Nominal Cush. Pitch, in.	Remarks
11-26-73	102	43-2	1 1/2" X 106' Parabola	1710	—	1672.75	3725	36	3.9	42	0	470	30	0	60	Passive	0	
		-4		1730	1680	1669	6100	49	3.8	42		470						
		-6		1798	1680	1664	13400	76	4.0	42		470						
		-8		1765	1670	1659	10600	58	2.85	35		470						
		-12		1798	1670	1653	14500	82.5	4.1	35		470						
		-14		1798	1670	1653	14500	82.5	4.1	35		1130						
		-16		1798	1670	1651.25	14675	81	4.1	0		470						
		-10		1798	1670	1652	14600	79	4.0	0		1130				Passive		
		41-14		1798	1670	1653.50	14350	78	4.0	0		470				Active		Guid. Active
11-27-73	103	44-10	Asymmetric 1 1/2" X 106' Parabola	1710.75	1670	1661.75	4900	51	3.8	0	0	470	30	0	60	Passive	0	
		-16		1798	1668	1656	14200	70	3.9	0			30					Parachute deployed at 1680
		-12		1798	1680	1653	14500	76	—	35			30					
		-14		1798	1670	1642.50	15550	75	3.7	35			0			Passive		
		41-16		1798	1670	1655	14300	74	3.8	35			0			Active		Fwd Lev. active
		41-18		1798	1670	1655	14300	72	3.8	35			0			Active		Fwd Lev and all guid active RRL Cushion nosed into guidwy
11-29-73	104	38-3	3" X 150' Parabola							35	0	470	0	0	40	Passive	0	Tethered gap/airflow test
		43-18		1710	1680	1673.5	3650	43	3.7	35		470						
		-20		1730	1680	1668.25	6175	63	3.7	35		470						
		-22		1799.25	1670	1652.25	14700	80	3.6	35		470						
		-24		1730.25	1680	1675	5525	56	3.0	35		470						
		-26		1798	1670	1653.50	14450	80	3.6	35		1130						
		-30		1798	1670	1653.75	14425	79	3.6	0		1130						
		-28		1798	1670	1654.50	14350	77	3.6	0		470						
11-30-73	105	43-22A	3" X 150' Parabola	1728.25	1670	1658	7025	62	4.0	35	0	470	0	0	40	Passive	0	
		-28A		1799.75	1670	1651	14875	86	4.0	0								
		-28B		1799.50	1670	1649.25	15025	90	4.0	0								Relief valve removed, inlet screens off, weight removed
		38-4								0								Static Thrust Measurements

Figure 3-1b Summary Log of Test Runs

Date	T.L.	Run No.	OB o'graph Real Time Rolls	OB o'graph Play Back Rolls	DV o'graph Real Time Rolls	DV o'graph Play Back Rolls	OB Tape Reel No.	DV Tape Reel No.	On-Board O'graph Measurement No.	Data Van O'graph Meas. No.	Remarks
11-8-73	92	Static	2		3		26				
11-9-73	93	39-2, -4	2		2		27	24	111,113,92,114, 115,93,94,95	1,532,10,3,27,542,28,29,30,543, 166,groundspeed photocell output	DV O'graph sensitivities were setup incorrectly
11-12-73	94	39-6,-8,-16, -18	1		2		28	25,26	same as TL 93	same as TL 93 (except 4 replaced 29 after 39-6)	DV O'graph sensitivities were setup incorrectly
11-13-73	95	40-2,-4, 39-10,-20	2		2	1	28	27	same as TL 93	Same as TL 93. Playback for 39-20: 2,4,9,5,21,22,23,24,166, photocell.	DV O'graph sensitivities were setup incorrectly
11-14-73	96	39-12	1		1		28	28	same as TL 93	same as TL 93	DV O'graph sensitivities were setup incorrectly
11-15-73	97	42-2,-4,-8, -6,-12	2		4		28	29	same as TL 93	same as TL 93	DV O'graph sensitivities were setup incorrectly
11-16-73	98	42-16,-18,-22	1		3		29	30	same as TL 93	same as TL 93	Except for Meas. 1, sensitivities are within 10% of nominal
11-19-73	99	42-20,-26,-26A -28,-44,41-4	2		5		29	31,32	same as TL 93	1,532,10,3,27,542,28,29*,30,543, 166, photocell (5,4 replace 532, 10 for 41-4)	29 bad on 42-26A
11-20-73	100	44-2,-4,-6,-8, 41-10	2		5		29	33,34	111*,113,92*,114* 115*,93,94*,95	1,532,10,3,27,542*,28,29,30,543, 166, photocell* (9 replaced 542 after 44-4)	Mud covering guideway plugged press ports and obscured photocell during backup 44-1.
11-21-73	101	42-30,-34,-36, -42,-38	2		2		30	35,36 (42-30)	same as TL 100	1,532,10,3,27,542,28,29,30,543, 166, photocell (4,5 replace 532, 10)	
11-26-73	102	43-2,-4,-6,-8, -12,-14,-16,-10, 41-14	2		7		30	37,38,39	same as TL 100	1.5,4,3,27,542,28,29,30,543,166, photocell	
11-27-73	103	44-10,-16,-12, -14,41-16,-18	1		2		30	40,41,42	same as TL 100	same as TL 102	
11-29-73	104	38-3,43-18,-20, -22,-24,-26, -30,-28	2		5		31	43,44	111*,544,92,545, 115,93*,94*,95	same as TL 102	544,545 temporarily added as RFL,LRL mid base press measurements. Good base press data for all four cushions
11-30-73	105	43-22A,-28A, -28B,38-4	4		4		31	45	same as TL 104	same as TL 102	

* Questionable Data

Figure 3-1c Summary Log of Test Runs

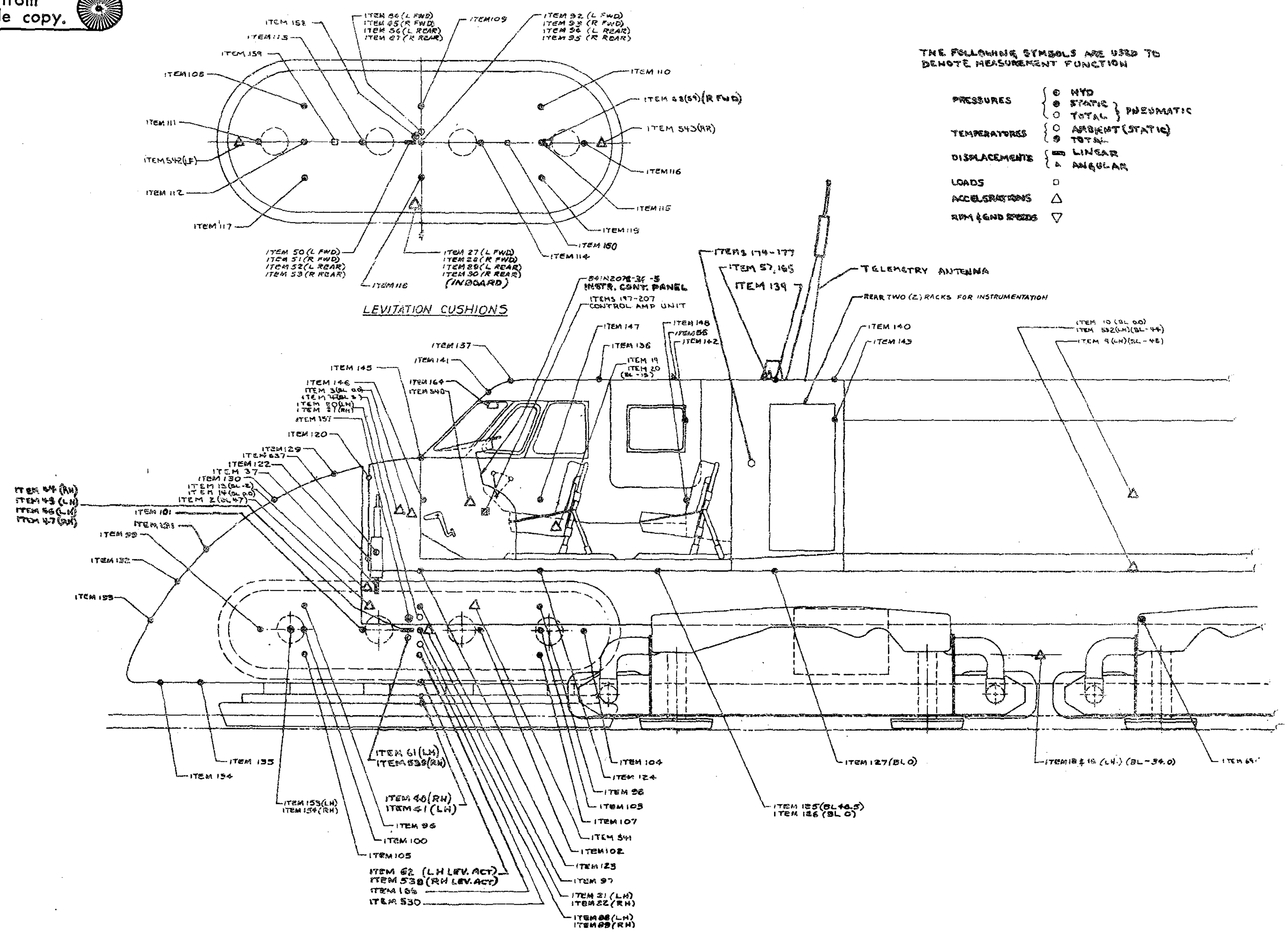


Figure 3-2a Sensor Location on Vehicle

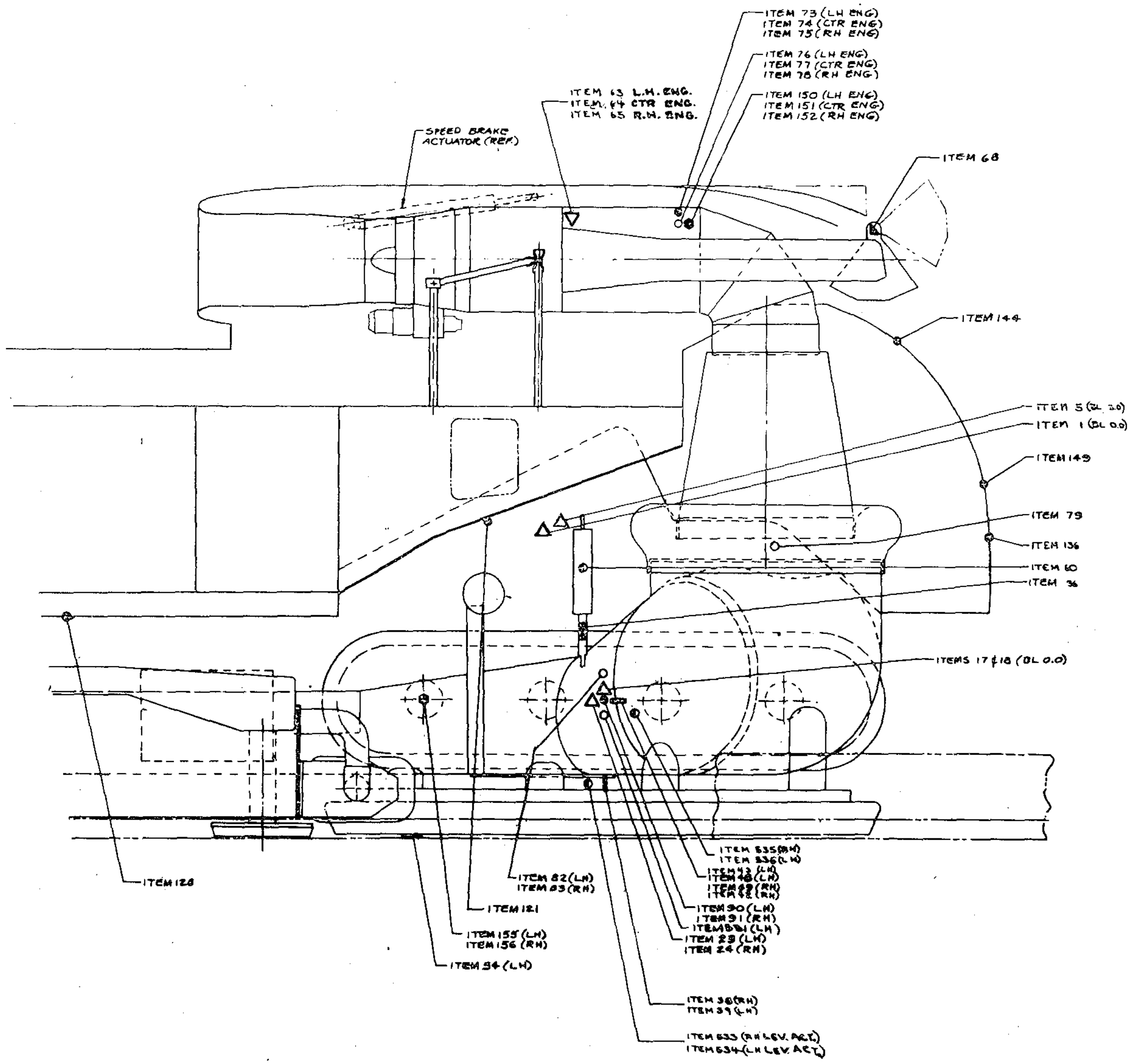


Figure 3-2b Sensor Location on Vehicle

Meas. No.	Name	Location W. L.	B. L.	Sta.
1	* NZ Body Aft	168	0	602
2	NZ Chassis R. H. Forward	138	47R	174
3	* NZ Body Forward	168	0	192
4	* NY Body Forward	172	3R	189
5	* NY Body Aft	172	3R	606
9	NY Body Mid	169	48L	422
10	NZ Body Mid	150	3R	422
13	NY Chassis Forward	145	2L	174
14	NZ Chassis Forward	145	0	174
15	NY Chassis Mid L. H.	121	33L	409
16	NZ Chassis Mid L. H.	121	34L	407
17	NY Chassis Aft	130	2L	623
18	NZ Chassis Aft	132	0	623
19	NY Operator's Seat	165	15L	250
20	NZ Operator's Seat	165	15L	250
21	NY LF Guidance Cushion Mid	129	60L	194
22	NY RF Guidance Cushion Mid	129	60R	194
23	NY LR Guidance Cushion Mid	129	60L	625
24	NY RR Guidance Cushion Mid	129	60R	625
27	NZ LF Levitation Cushion Mid	107	26L	193
28	NZ RF Levitation Cushion Mid	107	26R	193
29	NZ LR Levitation Cushion Mid	107	26L	626
30	NZ RR Levitation Cushion Mid	107	26R	626
532	NZ Body L. H. Mid	150	44L	422
540	NY Body Axis Forward	174	0	214
542	NZ LF Levitation Cushion Edge	104	40.5L	134
543	NZ RR Levitation Cushion Edge	104	42.5R	684.5

* Located on body end of suspension (A frame), but does not bank with body

Y - Lateral

Z - Vertical

ACCELEROMETER LOCATIONS

Figure 3-2c Sensor Location on Vehicle

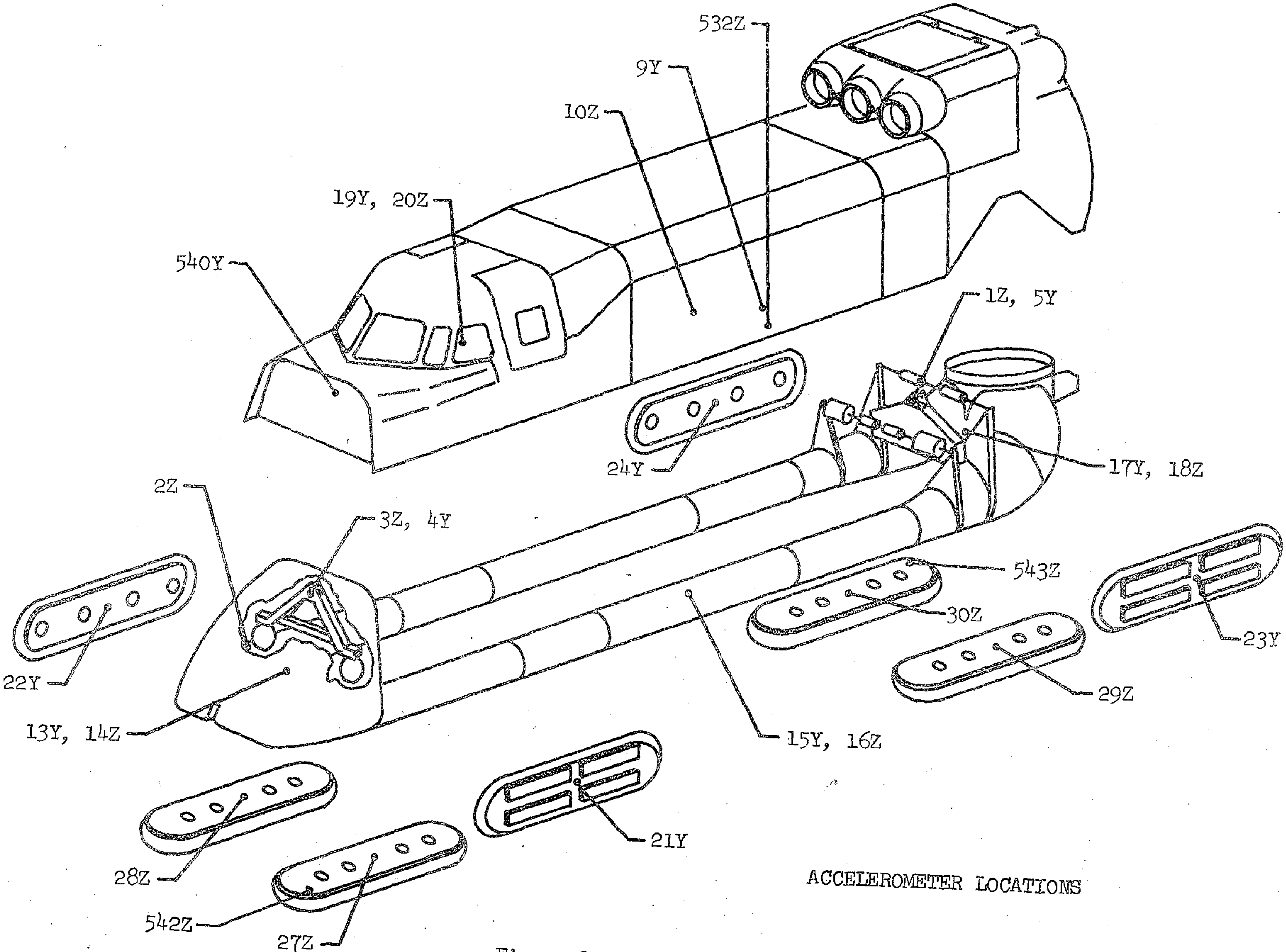


Figure 3-2d Sensor Location on Vehicle

(2) MEAS. NO.	(3) REV	(4) MEAS.	(5) PATCH NO.	(6) FUSE NO.	(7) FILT	(8) MF/SF	(9)(10) RLP PEO TVL	(11)(12) ZERO OFFSET	(13) EU PER COUNT	(14) SERIAL NUMBER	(15) VAL DATE	(16)(17) E U / S T A	(18) NOTES
062A		DP LFL ACT	P046	CAU	50	89-1	1HB	5.5711	38.706	18031		P2	
063A		RPM LEFT FAN	P047	068		30-1	6HU	0.0	69.716	36099	522	N4	
064A		RPM CNTR FAN	P048	069		30-2	8HU	0.0	69.716	36097	522	N4	
065A		RPM RGHT FAN	P049	070		30-3	8HU	0.0	69.716	36098	522	N4	
068		PDS THR DEFL	P050		5	126-8	8HU	.42	3.44			E1	
069A		DP BRAKE ACT	P051	054	5	127-2	8HU	-139.0	15.55	136372		P2	
073		PT-PS L FAN	P052	071	5	125-1	8HU	0.0	.00392	601-1004	516	P4	
074A		PT-PS C FAN	P053	072	5	125-2	8HU	.00055	.00394	601-1002	516	P4	
075		PT-PS R FAN	P054	073	5	125-3	8HU	0.0	.00395		516	P4	
076A		PT L FAN	P055	074	5	125-4	8HU	.0117	.03963	701-1013	516	P4	
077A		PT C FAN	P056	076	5	125-5	8HU	0.0	.0392	701-1015	516	P4	
078A		PT R FAN	P057	077	5	125-6	SHU	0.0	.0392	701-1016	516	P4	
079A		PT AFT DUCT	P058	52	5	125-7	8HB	-.1376	.04567	701-1007	516	P4	
080A		PT LFG PLEN	P059	1	5	125-8	8HU	.0602	.0391	701-1004	522	P4	
081A		PT RFG PLEN	P060	030	5	126-1	8HU	-.0112	.03916	701-1001	522	P4	
082A		PT LRG PLEN	P061	039	50	126-2	6HU	.0373	.0388	701-1003	522	P4	
083A		PT RRG PLEN	P062	36	50	126-3	8HU	.0453	.0413	701-1002		P1	
084A		PT LFL PLEN	P063	13	5	126-4	8HU	.0402	.0398	701-1011	518	P4	
085A		PT RFL PLEN	P064	27	5	126-5	8HU	.0039	.0393	701-1014	518	P4	
086A		PT LRL PLEN	P065	42	50	126-6	8HU	-.0098	.03918	701-1009	522	P4	
087A		PT RRL PLEN	P066	33	50	126-7	8HU	-.0043	.03918	701-1008	522	P4	
088A		PS LFG BASE	P067	2	50	102-1	1HU	-.0345	.01955	801-1016	518	P4	
089A		PS RFG BASE	P068	31	50	103-1	1HU	-.0172	.01953	801-1009	522	P4	
090A		PS LRG BASE	P069	40	50	104-1	1HU	-.0043	.0196	801-1018	522	P4	

Figure 3-3 Instrumentation Configuration Measurement Status List

Test Log	Run No.	Times of Significant Events (Hr:Min:Sec)					Comment
		Transition		Straight			
		Begin Sta 1742	End Sta 1716	Pre-Cruise Sta 1692	Perturbation Sta 1690	Cruise Sta 1675	
93	39-02						
	39-04			15:46:23		15:47:03	
94	39-06		11:15	11:17:11		11:17:38.78	
	39-08		11:28	11:29:21		11:29:44.27	
	39-14			14:08:38		14:09:16.71	
	39-16		14:16	14:18:04		14:18:30.84	
	39-18		14:23	14:25:04		14:25:28.18	
95	40-02			10:41:29		10:42:02.57	
	40-04		10:50	10:50:42		10:51:03.92	
	39-10			15:13:27		15:13:48.66	
	39-20			15:30:39		15:31:03.12	
96	39-12					12:36:49.8	
97	42-02			09:58:03	09:58:07.50		
	42-04		10:14:32	10:15:12	10:15:15.20	10:15:37	
	42-08			10:37:09	10:37:13		
	42-06	11:45:11	11:45:43		11:46:08.5	11:46:22	
	42-12	12:05:25	12:05:55		12:06:20	12:06:33	
98	42-16				08:51:58		
	42-18		09:07.05		09:07:48		
	42-22		09:20:27		09:21:23.5		
99	42-20	09:35:09	09:35:40		09:36:05.2		a
	42-26A	10:16:38	10:17:25		10:17:51.8		
	42-28	12:13:23	12:14:00		12:14:30.7		
	42-44	12:26:18	12:26:55		12:27:27		
	41-04	15:04:53	15:05:31		15:06:04		
100	44-02				14:31:33		
	44-04				14:53:11.5		
	44-06	16:18:09	16:18:36		16:19:04.4		
	44-08	16:42:56	16:43:19		16:48:47.8		
	41-10	16:56:43	16:57:07		16:57:37.5		
101	42-30				10:05:19.5		
	42-34				10:19:56.2		
	42-36				10:38:46		
	42-42		16:18:04		16:18:35.8		a,b,c
	42-38		16:54:14		16:54:41		

Figure 3-4a Times of Significant Events

Test Log	Run No.	Times of Significant Events (Hr:Min:Sec)					Comment
		Transition		Straight			
		Begin Sta 1742	End Sta 1716	Pre-Cruise Sta 1692	Perturbation Sta 1690	Cruise Sta 1675	
102	43-02				09:28:57		
	43-04	09:43:38	09:44:15		09:44:57		c
	43-06	10:16:40	10:17:10		10:17:29.7		
	43-08				11:39:33		
	43-12	11:51:29	11:51:54		11:52:18		c
	43-14	12:09:58	12:10:23		12:10:46		
	43-16	13:50:34	13:50:54		13:51:19		
	43-10	14:08:04	14:08:20		14:08:46		b
	41-14	14:56:28	14:56:52		14:57:17		c
103	44-10				09:41:28		
	44-16	09:57:30	09:58:00		09:58:25		b
	44-12	11:14:07	11:14:30		11:14:55		a,b
	44-14	11:50:27	11:50:50		11:51:15		a
	41-16	14:03:32	14:04:19		14:04:45		a,c
	41-18	14:22:35	14:23:01		14:23:27		a,b,c
104	43-18				10:40:53		
	43-20	13:06:08	13:06:42		13:07:20		
	43-22	13:21:17	13:21:42		13:22:05		
	43-24	13:33:18	13:33:55		13:34:33		
	43-26	14:26:10	14:26:45		14:27:08		a,b,c
	43-30	15:01:25	15:01:50		15:02:14		
	43-28	16:01:16	16:01:41		16:02:05		c,d
105	43-22A	13:03:31	13:04:07		13:04:46		
	43-28A	14:38:22	14:38:46		14:39:08		
	43-28B	15:56:52	15:57:15		15:57:35		a,c

a Large body vertical accelerations

b Large body lateral accelerations

c Large levitation cushion vertical accelerations

d Left front levitation cushion damaged at perturbation: 3 ft of fwd section ripped off

Figure 3-4b Times of Significant Events

TL	ERDT	EUT	Run	EU Data Block		
				Block	Record Number / Start Time	Record Number / Stop Time
93	052315	042525	39-2		2 /15:35:17.108	
				1	376 /15:36:05.108	805 /15:37:00.020
						1207 /15:37:51.476
			39-4		1209 /15:45:12.820	
				2	2047 /15:47:00.084	2397 /15:47:45.012
						3043 /15:49:08.468
94	052316	037329	39-6		2 /11:15:46.688	
				1	858 /11:17:37.152	1043 /11:18:01.088
						1152 /11:18:15.168
			39-8		1154 /11:28:09.344	
				2	1700 /11:29:19.232	1902 /11:29:45.088
						2902 /11:30:09.536
			39-14		2094 /14:07:31.940	
		016254		3	2900 /14:09:15.108	3087 /14:09:39.044
						3105 /14:09:41.348
			39-16		3107 /14:16:49.252	
				4	3879 /14:18:28.068	3926 /14:18:34.084
						4103 /14:18:56.836
			39-18		4105 /14:23:41.484	
				5	4914 /14:25:25.036	4954 /14:25:30.156
						5058 /14:25:43.468
95	052318	042496	40-2		2 /10:40:29.688	
				1	583 /10:41:44.056	911 /10:42:26:040
						930 /10:42:28.472
			40-4		932 /10:49:32.408	
				2	1476 /10:50:42.040	1876 /10:51:32.984
						1876 /10:51:32.984
	052319	031464	39-10		2 /15:11:40.076	
				1	822 /15:13:25.036	1143 /15:14:06.124
						1220 /15:14:15.980
			39-20		1222 /15:29:31.340	
				2	1696 /15:30:32.012	1712 /15:30:34.060
				3	1743 /15:30:38.028	2173 /15:31:33.068
						2332 /15:31:53.676
96	052320	027559	39-12		2 /12:34:18.680	
				1	7 /12:34:19.448	43 /12:34:24.056
				2	388 /12:35:08.084	559 /12:35:30.104
				3	753 /12:35:55.064	910 /12:36:15.032
				4	1027 /12:36:30.008	1382 /12:37:15.704
						1392 /12:37:16.984
97	052321	030345	42-2		3 /09:56:54.228	
				1	494 /09:57:57.076	623 /09:58:13.588
						840 /09:58:41.364
			42-4		842 /10:14:06.292	
				2	1028 /10:14:30.100	1055 /10:14:33.556
				3	1301 /10:15:05.044	1426 /10:15:21.044
						1610 /10:15:44.724
			42-8		1612 /10:35:56:628	
				4	2131 /10:37:03.060	2256 /10:37:19.060
						2702 /10:38:16.148
			42-6		2704 /11:44:15.492	
				5	3520 /11:46:00.068	3622 /11:46:13.124
						3834 /11:46:40.260
			42-12		3836 /12:04:30.980	
				6	4438 /12:05:48.036	4532 /12:06:00.068
				7	4665 /12:06:17.092	4805 /12:06:35.012
						5023 /12:07:02.916
98	052322	053077	42-16		3 /08:50:57.262	
				1	400 /08:51:48.212	524 /08:52:04.084
						711 /08:52:28.020
			42-18		714 /09:06:46.388	
				2	961 /09:07:18.004	1415 /09:08:16.116
						1424 /09:08:17.268
			42-22		1426 /09:19:58.836	
				3	2006 /09:21:13.076	2162 /09:21:33.044
						2357 /09:21:58.004
99	052323	030853	42-20		2 /09:34:15.728	
				1	67 /09:34:24.048	114 /09:34:30.064
				2	348 /09:35:00.016	505 /09:35:20.112
				3	583 /09:35:30.112	911 /09:36:12.080
						1250 /09:36:55.472
			42-26		1252 /09:50:19.952	
				4	1394 /09:50:38.128	1472 /09:50:48.112
						1513 /09:50:53.360
			42-26A		1515 /10:15:58.704	
				5	2315 /10:17:41.104	2448 /10:17:58.128
						2648 /10:18:23.728

Figure 3-5a Summary of Digital Data Tape Records

TL	ERDT	EUT	Run	EU Data Block		
				Block	Record Number / Start Time	Record Number / Stop Time
99	052323	029557	42-28		2651 /12:12:22.324	
				1	3328 /12:13:49.108	3695 /12:14:36.084
						3896 /12:15:01.812
			42-44		3899 /12:25:17.268	
				2	4577 /12:26:44.052	4952 /12:27:32.052
						5078 /12:27:48.180
	052324	054994	42-44		2 /12:27:48.308	
				1	2 /12:27:48.308	234 /12:28:18.004
						366 /12:28:34.900
			41-4		368 /15:03:51.216	
				2	788 /15:04:45.104	944 /15:05:05.072
		048999		1	1061 /15:05:20.048	1444 /15:06:09.072
						1780 /15:06:52.208
100	050502	027749	44-2		1 /14:30:30.188	
				1	446 /14:31:28.044	522 /14:31:38.028
						884 /14:32:24.492
			44-4		886 /14:50:48.268	
				2	1968 /14:53:07.020	2030 /14:53:15.084
						2671 /14:54:37.772
			44-6		2674 /16:17:06:676	
				3	3127 /16:18:05.044	3205 /16:18:15.028
				4	3344 /16:18:33.076	3422 /16:18:43.060
				5	3555 /16:19:00.084	3633 /16:19:10.068
						3861 /16:19:39.252
			44-8		3863 /16:41:57.236	
				6	4284 /16:42:51.124	4362 /16:43:01.108
				1	4463 /16:43:14.036	4541 /16:43:24.020
		055000		2	4705 /16:43:45.012	4784 /16:43:55.124
						5000 /16:44:22.772
	052326	045194	41-10		2 /16:55:52.436	
				1	358 /16:56:38.004	437 /16:56:48.116
				2	569 /16:57:05.012	647 /16:57:15.124
				3	779 /16:57:32.020	920 /16:57:50.068
				4	1037 /16:58:05.044	1170 /16:58:22.068
						1482 /16:59:02.004
101	052327	030309	42-34		19 /10:17:52.980	
				1	929 /10:19:50.100	1022 /10:20:02.004
						1345 /10:20:43.348
			42-36		1347 /10:36:02.772	
				2	2575 /10:38:40.084	2669 /10:38:52.116
						3154 /10:39:54.196
			42-42		3160 /16:16:32.656	
				3	3843 /16:18:00.080	3904 /16:18:08.016
				4	4092 /16:18:32.080	4344 /16:19:04.432
						4442 /16:19:16.880
	052328	029004	42-38		2 /16:54:00.336	
				1	78 /16:54:10.064	156 /16:54:20.048
				2	289 /16:54:37.072	539 /16:55:09.072
						582 /16:55:14.576
102	052329	026592	43-2		49 /09:28:03.008	
				1	440 /09:28:53.056	534 /09:29:05.088
						832 /09:29:43.744
			42-34		834 /09:43:29.600	
				2	877 /09:43:35.104	939 /09:43:43.040
				3	1166 /09:44:12.096	1226 /09:44:20.032
				4	1491 /09:44:54.208	1583 /09:45:06.016
						1850 /09:45:40.192
			43-6		1852 /10:14:17.824	
				5	2939 /10:16:37.088	3001 /10:16:45.024
				6	3173 /10:17:07.040	3236 /10:17:15.104
				7	3322 /10:17:26.112	3415 /10:17:38.016
						3656 /10:18:08.088
			43-8		3659 /11:36:58.236	
						4701 /11:39:11.612
	052330	026516	43-12		145 /11:49:59.036	
				1	825 /11:51:26.076	887 /11:51:34.012
				2	1020 /11:51:51.036	1083 /11:51:59.100
				3	1208 /11:52:15.100	1301 /11:52:27.004
						1563 /11:53:00.540
			43-14		1565 /12:08:14.748	
				4	2349 /12:09:55.100	2411 /12:10:03.036
				5	2544 /12:10:20.060	2607 /12:10:28.124
				6	2716 /12:10:42.076	2810 /12:10:54.108
						3092 /12:11:30.204

Figure 3-5b Summary of Digital Data Tape Records

TL	ERDT	EUT	Run	Block	Record Number / Start Time	Record Number / Stop Time
				EU Data Block		
102	052330	026516	43-16		3094 /13:49:04.932	
				7	3768 /13:50:31.204	3829 /13:50:39.012
				8	3923 /13:50:51.044	3986 /13:50:59.108
		019970		1	3986 /13:50:59.108	4204 /13:51:27.012
						5421 /13:52:07.588
	052331	041179	43-10		2 /14:07:36.132	
				1	197 /14:08:01.092	259 /14:09:09.028
				2	330 /14:08:18.116	392 /14:08:26.052
				3	517 /14:08:42.052	611 /14:08:54.084
						897 /14:09:30.692
			41-14		900 /14:54:46.016	
				4	1674 /14:56:25.088	1736 /14:56:33.024
				5	1861 /14:56:49.024	1924 /14:56:57.088
				6	2049 /14:57:13.088	2143 /14:57:25.120
						2449 /14:58:04.304
103	052332	035910	44-10		2 /09:40:21.936	
				1	494 /09:41:25.040	557 /09:41:33.104
						907 /09:42:17.904
			44-16		909 /09:55:53.424	
				2	1197 /09:56:30.432	1233 /09:56:35.024
				3	1647 /09:57:28.016	1680 /09:57:33.008
				4	1882 /09:57:58.112	1921 /09:58:03.088
				5	2077 /09:58:23.056	2171 /09:58:35.088
				6	2172 /09:58:35.216	2288 /09:58:50.064
						2416 /09:59:06.448
			44-12		2419 /11:12:27.424	
				7	3171 /11:14:04.064	3234 /11:14:12.128
				8	3357 /11:14:28.128	3417 /11:14:36.064
		043973		1	3534 /11:14:51.040	3628 /11:15:03.072
						3925 /11:15:41.216
			44-14		3928 /11:48:16.984	
				2	4483 /11:49:28.024	4530 /11:49:34.040
				3	4921 /11:50:24.088	4983 /11:50:32.024
				4	5108 /11:50:48.024	5171 /11:50:56.088
						5176 /11:50:56.728
	052333	031052	44-14		2/11:50:56.856	
				1	4/11:50:57.112	207/11:51:23.096
						472/11:51:57.016
	052334	031271	41-16		6/14:02:11.144	
				1	469/14:03:09.128	515/14:03:15.016
				2	631/14:03:30.120	693/14:03:38.056
				3	998/14:04:17.112	1060/14:04:25.048
				4	1185/14:04:41.048	1279/14:04:53.064
						1552/14:05:28.008
			41-18		1554/14:20:50.664	
				5	1792/14:21:21.128	1987/14:21:46.088
				6	2354/14:22:33.064	2471/14:22:48.040
		039424		1	2471/14:22:48.040	2596/14:23:04.040
				2	2721/14:23:20.040	2994/14:23:55.112
						3403/14:24:40.296
104	052335	043646	43-18		19/10:39:52.028	
				1	439/10:40:46.044	556/10:41:01.020
						766/10:41:27.900
			43-20		769/13:05:54.000	
				2	863/13:06:06.048	910/13:06:12.048
				3	1121/13:06:39.056	1168/13:06:45.072
				4	1387/13:07:13.104	1488/13:07:26.048
						1699/13:07:53.168
			43-22		1701/13:19:24.880	
				5	2562/13:21:15.088	2609/13:21:21.104
				6	2749/13:21:39.024	2796/13:21:45.040
				7	2898/13:21:58.112	3000/13:22:11.152
						3246/13:22:42.640
		018568	43-24		3249/13:33:05.744	
				1	3330/13:33:16.112	3447/13:33:31.088
				2	3611/13:33:52.080	3658/13:33:58.112
				3	3884/13:34:27.024	3986/13:34:40.080
						4263/13:35:15.536
			43-26		4265/14:24:42.720	
				4	4283/14:24:45.024	4330/14:24:51.040
				5	4932/14:26:08.112	4979/14:26:14.112
						5126/14:26:32.944

Figure 3-5c Summary of Digital Data Tape Records

TL	ERDT	EUT	Run	EU Data Block		
				Block	Record Number/ Start Time	Record Number/ Stop Time
104 (cont)	052336	051976			2/14:26:33.56	
				1	72/14:26:42.016	119/14:26:48.048
				2	221/14:27:01.088	338/14:27:16.064
						535/14:27:41.280
			43-30		537/14:59:50.656	
				3	1259/15:01:23.072	1306/15:01:29.088
				4	1446/15:01:47.008	1493/15:01:53.024
				5	1603/15:02:07.104	1720/15:02:22.080
						1981/15:02:55.488
			43-28		1983/15:59:24.684	
				6	2838/16:01:14.124	2884/16:01:20.012
				7	3033/16:01:39.084	3080/16:01:45.100
				8	3197/16:02:00.076	3291/16:02:12.108
						3573/16:02:48.204
105	052337	024761	43-22A		2/13:01:38.740	
				1	170/13:03:29.012	217/13:03:35.028
				2	452/13:04:05.108	499/13:04:11.124
				3	725/13:04:40.052	827/13:04:53.108
						1186/13:05:39.060
			43-28A		1188/14:36:39.284	
				4	1975/14:38:20.020	2022/14:38:26.036
				5	2155/14:38:43.060	2202/14:38:49.076
				6	2303/14:39:02.004	2405/14:39:15.060
						2662/14:39:47.956
			43-28B		2665/15:54:53.300	
				7	3288/15:56:13.044	3335/15:56:19.060
				8	3577/15:56:50.036	3624/15:56:56.052
				9	3757/15:57:13.076	3804/15:57:19.092
		024264		1	3890/15:57:30.100	4124/15:58:00.052
						4277/15:58:19.636

Figure 3-5d Summary of Digital Data Tape Records

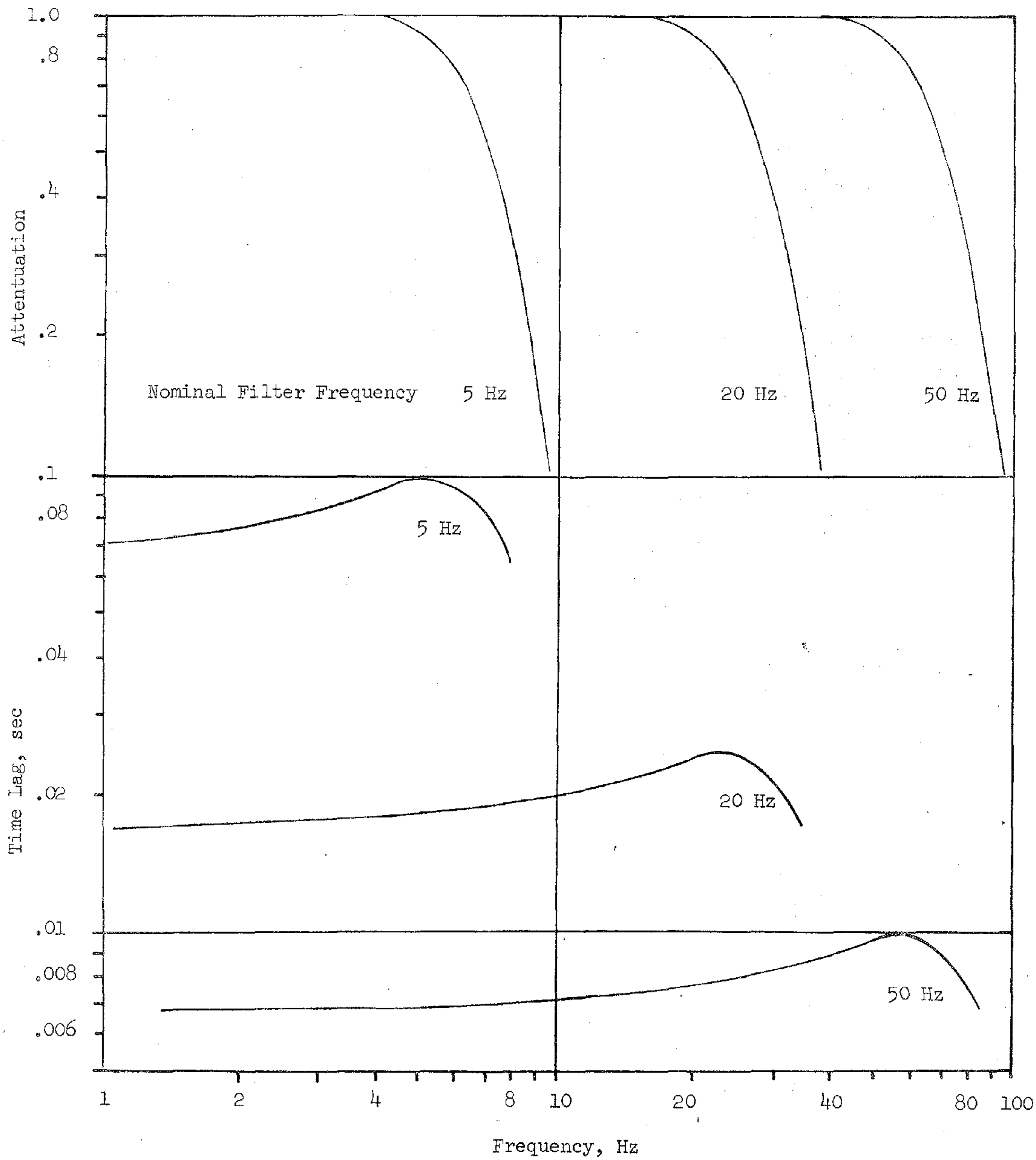


Figure 3-6 DAS Filter Characteristics

4.0 PERTURBATIONS

In view of the short lengths of guideway available for tests and the costs of construction, the originally planned adjustable test sections are not included. Instead, a different technique is employed to provide information for the first stages of the dynamic evaluation of the several suspensions. Discrete disturbances are applied to the vehicle by placing perturbations on the guideway levitation surfaces. Designed to be easily installed and removed, these perturbations have two basic shapes; short ramp-steps and longer pulses of inverted parabolic form. The short ramps extend 25 feet (longer than a single cushion but shorter than the longitudinal distance between cushions) and end in an abrupt step of from $\frac{1}{2}$ to 1 inch in height. The nominal length of the pulse type is 100 or 150 feet with a corresponding height of $1\frac{1}{2}$ or 3 inches. Symmetrical application of the perturbations (both sides of the levitation surface) is the primary technique for excitation of heave and pitch, while removing one side of the perturbations provides an asymmetrical excitation inducing roll (and indirectly lateral motions) as well as heave and pitch.

4.1 Design Basis for Perturbations

The range of frequencies representative of the anticipated response modes of the TLRV in the Independent Cushion Suspension mode have been discussed in a previous report, Reference 5. They range from 1 Hz to 35 Hz, representing many response modes - some of which were not readily identified. The purpose of the discrete guideway perturbations is to excite these various modes in such a fashion that the relationship between the forcing function and response can be identified and correlated with the Dynamics Simulation Model.

The ramp-step provides a dual action and is intended to excite the widest range of response frequencies. The abrupt loss of pressures as the cushion moves past the step edge should trigger the higher frequencies even at low traverse speeds. The impulse from the ramp to each cushion varies in both magnitude and time extent in proportion to the speed. The pitch excitation is also a function of the speed of traverse (distance between the centers of the front and rear cushions is 35 feet). The height range of the ramp-step perturbations was based upon the assumption that the vehicle should be able to traverse a step at least equal to the cushion air gap.

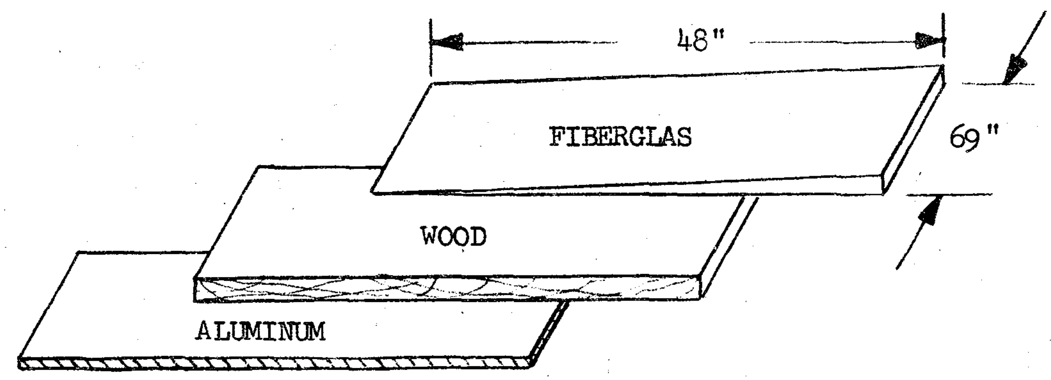
The longer pulses provide the stronger excitation in heave and roll since both front and rear cushions are on the perturbation for the major portion of the traverse time. The height-to-length ratio of the pulses was selected to provide a perturbation substantially greater than normal construction tolerances. For the speed range of the tests the 100 foot and 150 foot lengths provide excitation frequencies in the .3 to 1 Hz range. Additionally, the beginning and end of the long pulse traverse provides excitation similar to the ramp of the ramp-step perturbation.

4.2 Construction and Installation

Each ramp-step consists of a series of six 48 x 69 inch panels cemented to the levitation surface of the guideway to form a 24 foot long assembly tapering from 1/32 inch at the leading edge to the step height, as shown in Figure 4-1. Because of the finite thickness of the thinnest edge of the panel, the slopes of the ramps as constructed correspond to a greater length than the actual 24 feet. For the 3/4 inch step the theoretical length is 25 feet, and this nominal length has been used as a convenient constant reference without adjustment for step height.

The long wave pulse perturbations are approximations of parabolic pulses having 100 ft chord, $1\frac{1}{2}$ inches high at the center, or 50 ft chord, 3 inches high at the center. Each pulse consists of a .1 inch ramp at each end with a series of box sections extending from one ramp to the other as indicated in Figure 4-2. The total constructed length was 106 feet for the shorter parabola and 168 feet for the longer. Comparison of the constructed pulse versus theoretical parabolas are shown in Figures 4-3 and 4-4.

The general location of the perturbation installations in the guideway is shown in Figure 4-5. The various sections were cemented to the guideway, seams and edges sealed with tape; and the longitudinal edges were also retained by clamps secured to the levitation surface by bolts. Both installation and removal of sections of the perturbations proved to be a relatively easy task, and this permitted a reasonable number of symmetrical and asymmetric perturbation configurations to be tested within the limited schedule time.



TYPICAL BUILD-UP OF BONDED SECTION

ALL SEAMS AND EDGES TAPED, LONGITUDINAL EDGES CLAMPED TO GUIDEWAY SURFACE

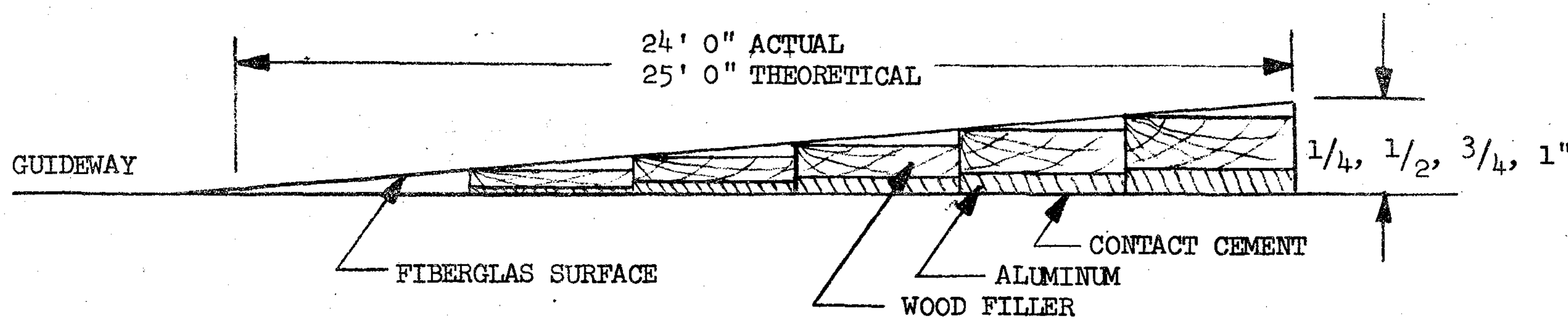


Figure 4-1 Ramp-Step Perturbation Construction

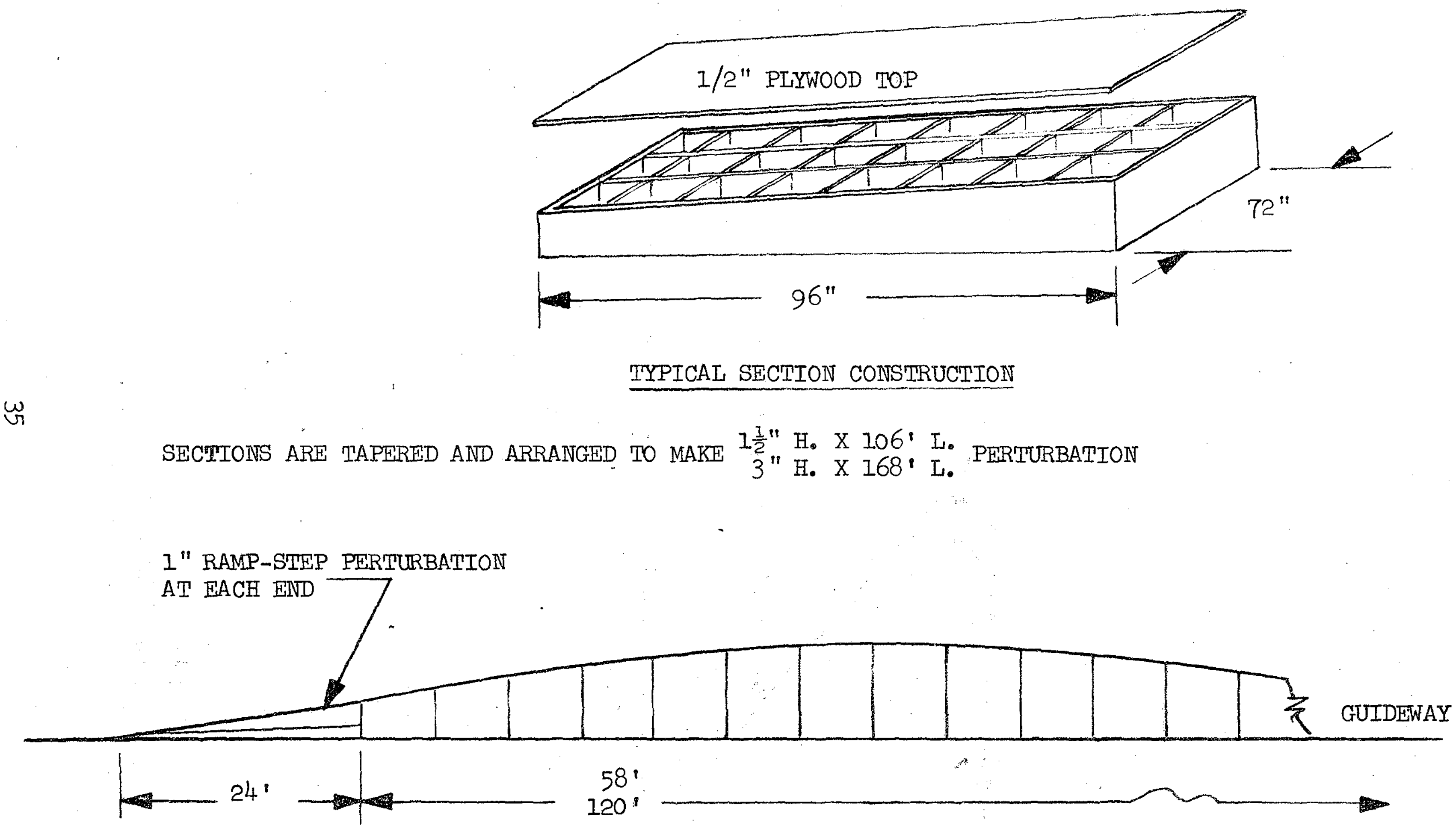


Figure 4-2 Pulse Type Perturbation Construction

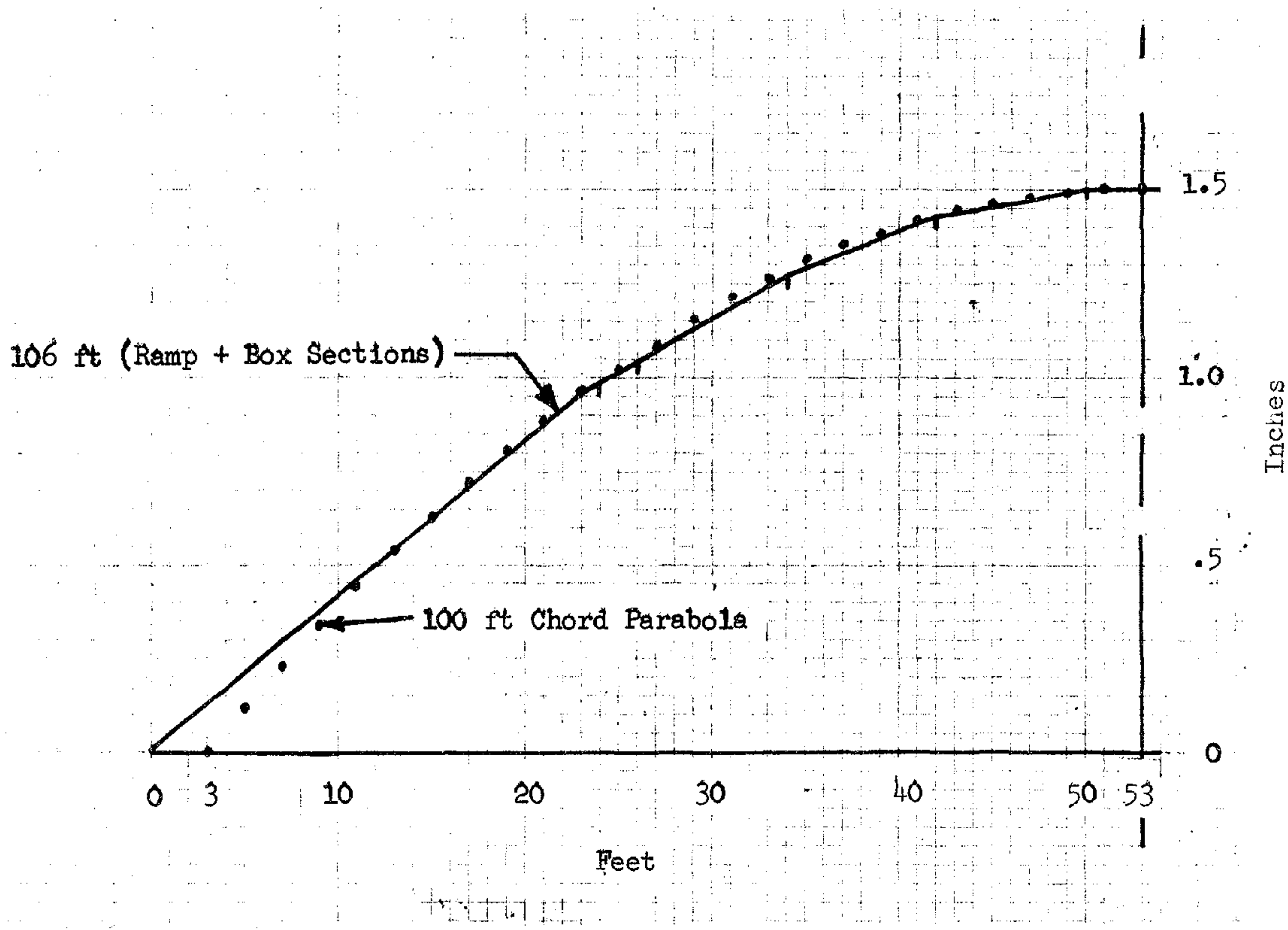


Figure 4-3 Comparison of Actual Long Wave Perturbation with Ideal $1\frac{1}{2}$ inch by 100 foot Parabola

Distance (ft)	Height (in)
0	1/32
24	1
32	1-1/2
40	1-59/64
48	2-17/64
56	2-35/64
64	2-49/64
72	2-29/32
80	3
84	3

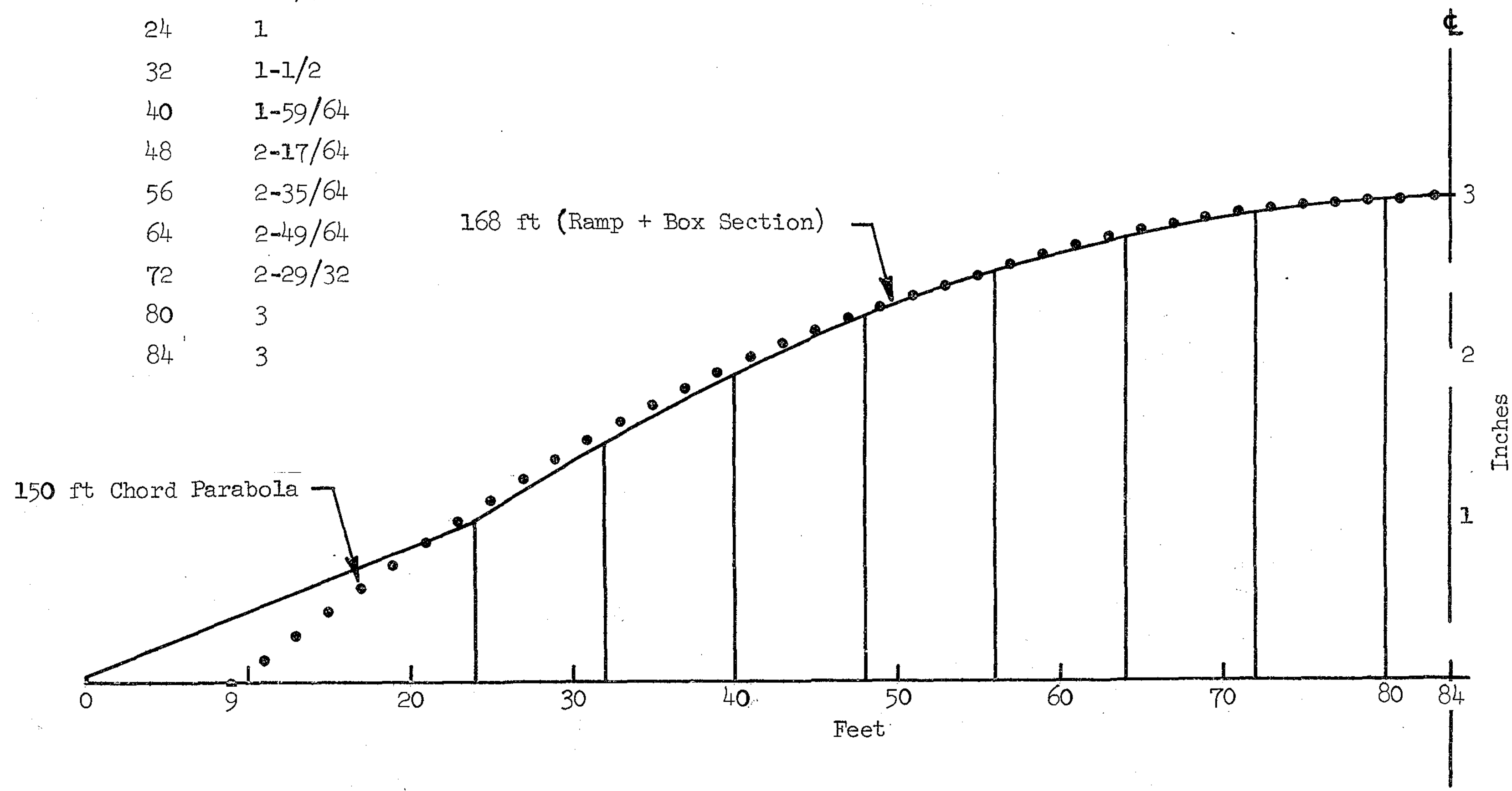


Figure 4-4 Comparison of Actual Long Wave Perturbation with Ideal 3 inch by 150 foot Parabola

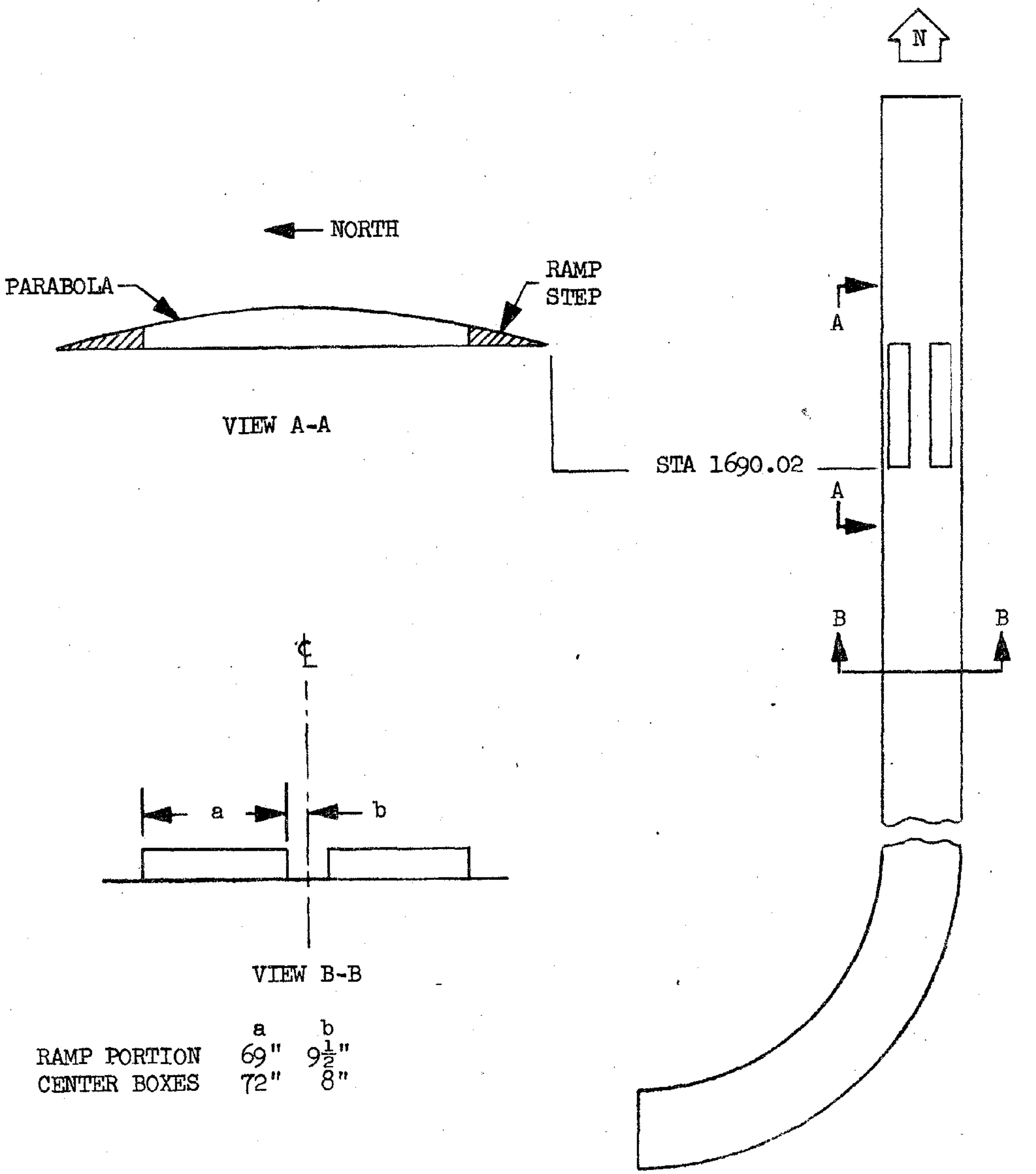


Figure 4-5 Location of Perturbations on TLRV Guideway

5.0 VEHICLE RESPONSES

Selected data for the TLRV response to perturbations on the guideway are presented in this section. Vehicle speeds vary from 0-90 mph and the vehicle is in the Independent Cushion Suspension configuration.

Various test parameters such as actuator damper settings, levitation cushion air spring volume, guidance cushion air spring pressure etc., are listed for each test run in Section 3, Figure 3-1. The relationship of these parameters to suspension characteristics such as spring rate and actuator force are given herein, and vehicle weight properties are outlined.

A limited amount of oscillograph data obtained during runs over ramp-step perturbations was analyzed and is summarized. Since response to the $\frac{1}{2}$ inch perturbations is barely perceptible above the measured noise level on the smooth guideway, the data presented centers on responses to the 3/4 and 1 inch ramp-steps. These data are used to illustrate trends in response with changes in vehicle speed, duct pressure, suspension stiffness, damping, active control and ramp-step height.

The Dynamics Simulation Program is used to generate Calcomp plots of measured data. This digital computer program has been recently updated (Reference 6) to provide automatic plotting of:

- Measured results
- Analytical results
- Combined Measured and Analytical Results

Data from these plots for peak responses are tabulated for 24 test runs. These data include responses to the 1 inch ramp-step and $1\frac{1}{2}$ and 3 inch parabolic wave pulses. Major response trends evident from examination of peak response data are examined in greater detail and illustrated by Calcomp plots of selected measurements.

A detailed comparison between predicted and measured responses is then performed. The Dynamics Simulation Program is used to generate plots of predicted and measured data on common axes for 19 test runs. These plots are presented and typical cases which show the correlation of measured and calculated responses are discussed in detail. Simulation changes which improve the correlations are also presented.

5.1 Test Parameters

The various test parameters such as suspension damper settings, air spring volume and duct pressure are listed in the summary table, Figure 5-1. In the Independent Cushion Suspension configuration vertical heave, pitch and roll isolation is provided by the levitation cushion suspension and lateral and yaw isolation is provided by the guidance cushion suspension. The suspension system consists of air springs and servoactuators. The servoactuators function in either of two modes. When in the passive mode, they function as hydraulic dampers; when in the active control mode, the servoactuators apply forces to the cushions under control system command. A detailed description of suspension characteristics as a function of the listed test parameters was presented in Reference 5 and is summarized here for convenience.

The spring rates for the levitation cushion air springs depend on the spring load and the air spring volume. The variation of dynamic air spring load with air spring height is given in Figure 5-2. Either one or two auxiliary air bottles (660 cubic inches each) may be added to the basic air spring volume (470 cubic inches) to produce lower suspension stiffnesses. In the tests, the basic (470 cubic inches) and the basic plus one bottle (1130 cubic inches) configurations were used. Near the nominal height (7.75 inches) the spring rates are approximately equal to:

$k = .22\ F_o$ lb/in. (470 cubic inches)

$k = .12\ F_o$ lb/in. (1130 cubic inches)

where

F_o = the total static load on the spring - lb.

The guidance cushion air spring rates were taken from the slopes of the spring-force characteristic curves of Reference 3. These spring rates are plotted versus air spring pressure in Figure 5-3.

The servoactuators in the passive mode provide the suspension damping between the levitation cushion and chassis and between the guidance cushion and chassis. The actuators were subject to vendor checkout to establish the variation of damping force with actuator stroke rate ($\dot{\delta}$) for several damping spring settings. The average data from these tests, for the levitation cushion actuators are presented in Figure 5-4 for the three spring settings; 0° (minimum), 50° (moderate) and 58° (maximum). Although there is moderate scatter among the data, a reference slope representing $V^{2/3}$ damping variation gives a reasonable average for the data. Interpolated lines have been estimated for 35° and 42° settings. Similar data are given in Figure 5-5 for the guidance cushion actuators for three damping spring settings; 0° (minimum), 30° (moderate) and 35° (maximum).

During the Independent Cushion Suspension mode tests, the air spring rates and damping were adjusted over the range of suspension parameters below:

- levitation cushion air spring volume - 470 and 1130 $in.^3$
- levitation cushion damper setting - 0°, 35° and 42°
- guidance cushion air spring pressure - 20, 40 and 60 psi
- guidance cushion damper setting - 0° and 30°.

The range of vehicle weight and center of gravity position is determined by the fuel consumed. With allowance for fuel consumed in preparation for a series of tests and a provision for some margin at the end of a test series, the on-board fuel during test runs ranges between 20 and 80% of available full fuel load (3150 lb). Thus, the nominal test weight is 33,450 lb ±1000 lb with the center of gravity at Station 431. The range of front and rear suspension (levitation cushion) loadings as a function of fuel weight may be estimated from Figure 2-4. Appendix A delineates the mass properties used in the Simulation Model.

5.2 Measured Responses - Oscillograph Data

As noted in the previous report for the Body/Chassis Suspension mode, Reference 4, traverse of the smaller perturbations is imperceptible. For the ½ inch ramp-step perturbation it is difficult to identify the unique vehicle responses amid the general level of responses to the "smooth" guideway in the vicinity of the installed perturbation. With 3/4 and 1 inch ramp-steps the excursions due to the sudden step are easily identified, but the ramp portion could not be identified were it not for the known guideway location and the step portion of the perturbation.

The characteristic responses due to the ramp are similar for the ramp-step and the two parabolic pulse type perturbations since the 1 inch ramp is common to all three. These measured and calculated responses (related to the ramps) are presented in the following section. This section is concerned with the responses to the step as obtained from the oscillograph records.

A tabulation of the vertical acceleration responses for body and levitation cushions is presented in Figure 5-6. The data for the three symmetrical perturbations are listed in the order of increasing response (for the forward body location). The response is defined as the difference between the total (double amplitude) response at the step and the ambient response (double amplitude) in the region prior to the ramp. The two values are presented in the tabulation to identify the substantial ambient level changes that occur.

5.2.1 Effect of Speed and Duct Pressure

Three typical traces of the forward and aft body accelerations for the TLRV are presented in Figure 5-7a. Runs 42-16 and -20 represent the test traverses of the 3/4 inch ramp-step at low and high speed respectively, and Run 42-22 has a low value for the test duct pressure. The moderate rise in the body acceleration with almost double the speed is typical of all the symmetrical ramp-step traverses; most of the increase may be attributed to the doubling of the ambient response level. The change in duct pressure (cushion operating gap) from 4 to 2.6 psi has practically no effect on either the ambient or step responses in the body.

The tabulated values for the cushion responses exhibit a much more erratic characteristic than those for the body. However, there is a definite trend of increasing cushion response with increase of traverse speed. For the particular comparison of 42-16 with -20 the net cushion response is doubled as the speed is doubled. The change in duct pressure yields conflicting data at the lower pressure, 2.6 psi; the forward cushion responses increase while the aft decrease.

5.2.2 Effect of Suspension Stiffness and Damping

A review of the data tabulated in Figure 5-6 shows that neither stiffness nor damping parameter changes are critical to the vehicle responses. The increase in spring rate from the high volume air spring (1130 cu. in.) to the normal volume (470 cu. in.) is about 100%, but the body response increases only 20 to 30%. The change in damping from the 0° setting to 35° is an increase of damping force of approximately 30%, and this change is reflected in an equal increase in body acceleration response. However, an increase from 35° to 42° in damping setting does not produce increased responses in the body.

Comparative traces of the forward and aft body accelerations are presented in Figure 5-7b. Run 42-44 has the normal air spring volume and Run 42-28 has the added volume (lower spring rate). The trace for Run 42-44 may be compared with that for 42-20 in Figure 5-7a for the effect of damping change.

The effect of suspension stiffness on the cushion acceleration responses is opposite to the body. Increase in suspension stiffness yields a substantial reduction in cushion acceleration. However, increases in suspension damping increase the cushion acceleration responses.

5.2.3 Effect of Active Control of Suspension

The data (Figure 5-6) for the one run with active control on the forward levitation cushion suspensions show that a significant lowering of the body accelerations is possible. When the 3/4 inch ramp-step traverse with active control, Run 41-4, is compared with Runs 42-18 and 22, it is observed that the aft response hardly changes (since the aft suspension is passive) but that the forward body accelerations are reduced over 30% while the mid body response is reduced more than 50%.

The ambient response level for the forward cushions is increased by active suspension, but the increments in responses due to the step are approximately the same for active control or passive.

5.2.4 Effect of Ramp-Step Height

The net forward and aft body acceleration responses are plotted in Figure 5-8 as a function of step height for the most common suspension parameters;

air spring volume, 470 cu. in., and damping, 35°. It is interesting to note that the response for both forward and aft locations approach 0 at a $\frac{1}{4}$ inch step height, indicating that the ambient "smooth" guideway is equivalent to a $\frac{1}{4}$ inch ramp-step perturbation.

The data for the asymmetrical 1 inch ramp-step are plotted in Figure 5-8 at the $\frac{1}{2}$ inch height; on the assumption that the body response would be only half that of the symmetrical case. Actually, most of the data points lie below the trend curves, indicating an even lower body response than might have been expected.

5.3 Measured Responses - Digital Data Base

Selected test response data were reduced by the digital computer and Calcomp plots were formed. Peak-to-peak values of response were obtained and are summarized in Figure 5-9 for the following perturbations:

Test Log 101 - 1 inch by 25 foot Symmetric Ramp

102 - $1\frac{1}{2}$ inch by 100 foot Symmetric Parabola

103 - $1\frac{1}{2}$ inch by 100 foot Asymmetric Parabola

104 - 3 inch by 150 foot Symmetric Parabola

105 - 3 inch by 150 foot Symmetric Parabola

In general, data are listed for vertical response and response on the right side of the vehicle. In some cases, lateral and left side response is also included.

Comparison of responses to the different type symmetric perturbations shows that at the higher speeds the 1 inch high ramp-step generally produces the highest body vertical accelerations (.4-.5g peak-to-peak) while the $1\frac{1}{2}$ inch high parabola produces the next highest values (.2-.4g peak-to-peak) and the 3 inch high parabola produces the lowest values (.2-.3g peak-to-peak). It is of interest to note that the $1\frac{1}{2}$ inch by 100 foot parabola produces higher response than the 3 inch by 150 foot parabolic pulse although the latter pulse has generally higher slopes. Lateral body accelerations are relatively insensitive to pulse type and are in the range of .1-.3g peak-to-peak.

5.3.1 Effects of Perturbation Length

The responses to the $1\frac{1}{2}$ in. high by 100 foot long parabolic pulse are generally larger than for the 3 in. high by 150 foot long parabolic pulse. An examination of the accelerations measured shows that the difference occurs during the time the vehicle is leaving the pulse. The results appear reasonable from a consideration of the timing of the levitation cushion impulses and the chassis motions relative to the levitation surfaces; e.g. as in Runs 43-12 and 43-22, for which the vehicle is configured the same, and during which the perturbation traverse speed is about the same, nominally 80 mph, but with the former run over the $1\frac{1}{2}$ in. high by 100 foot long pulse and the latter over the 3 in. high by 150 foot long pulse.

The vertical chassis acceleration traces for the aforementioned runs are shown in Figure 5-10. The primary components are indicated in these figures by the dashed lines. These primary components are evidence of the idealized dynamic response motions depicted in Figure 5-11 which demonstrate the mechanism setting up the conditions for the vehicle motions and loads as it leaves the perturbation. As shown in Figure 5-11 for a mass spring point follower system with the natural response period equal to two thirds of pulse period, the mass oscillates about the static equilibrium positions, and is moving parallel to the unperturbed guideway at the instant of leaving the perturbation. As a result of this motion no load is subsequently induced in the suspension (spring or damper). For the same dynamic model, but with the pulse period equal to the response period, the mass is descending at the maximum perturbed velocity relative to the unperturbed guideway, at the instant of leaving the perturbation, as depicted in Figure 5-11. As a result of this condition a maximum load is subsequently induced in the suspension, as the vehicle leaves the perturbation; i.e. in this case the vehicle is "falling" onto the guideway as it leaves the pulse.

The particular runs noted above, Runs 43-12 and 43-22 do not correspond exactly to the ideal cases described, but appear to be sufficiently similar, in the major components, to the ideal so as to show the idealized characteristics. The pertinent natural frequency of the vehicle would appear to be near 1 Hz, but the higher frequency distortions present in the acceleration preclude an exact determination from these traces alone.

5.3.2 Effects of Vehicle Speed Over 3 in. by 150 ft Parabolic Pulse

A number of vehicle responses during a traverse of a 3 in. by 150 foot parabolic pulse are given in Figure 5-12 for vehicle speeds of 36, 56 and 80 mph (Test Log 104, Runs 43-18, -20, -22).

The forward (PT1) and aft (PT2) body vertical accelerations are shown in the upper portion of Figure 5-12a. The forward peak-to-peak vertical acceleration response increases from .14g at 36 mph to .20g at 56 mph and .26g at 80 mph. For each of the three speed runs the response shows a single peak when entering the perturbation but exhibits a double peak when leaving. The aft body peak-to-peak vertical acceleration response increases with speed (.14g, .17g and .20g) at approximately half the rate of the forward body response. A double response peak is exhibited by both the forward and aft body acceleration traces when the vehicle cushions leave the pulse.

The variations in forward and aft right chassis suspension deflections are shown in the lower portion of Figure 5-12a. The peak-to-peak deflection measured at the forward end, increases with speed from .11 to .39 to .53 in. The deflection at the aft end also increases with speed from .21, to .27, to .36 in. At the low speed (36 mph) the peak-to-peak forward response is less than that of the aft (response), but at the higher speeds (56 and 80 mph) the peak-to-peak forward deflection is greater than the aft.

Forward and aft right cushion forces, vertical accelerations for the aft cushion and actuator force for the forward cushion are plotted in Figure 5-12b. Forward cushion peak-to-peak forces increase from 1240 lb at 36 mph to 1580 lb at 56 mph to 1920 lb at 80 mph. Aft cushion forces increase similiarly from 1360 to 1480 to 1920 lb. The aft cushion shows a predominant response in the range of 16-20 Hz, approximately 2.g peak-to-peak for all cases. There is some indication of higher response entering and leaving the pulse but, in general, the response is near that for a smooth guideway, levels for which were reported in Reference 5. At 36, 56 and 80 mph the peak-to-peak measured actuator forces were 1200, 1160 and 1040 lb, respectively, a decrease with increasing speed.

Lateral responses for the three speeds are shown in Figure 5-12c. The peak-to-peak forward acceleration increases with speed from .087 to .12 to

.15g. The aft peak-to-peak acceleration increases from .065 to .072 to .106g. With increasing speed the response also changes in character. The response at the low speed is primarily in the 8-20 Hz range. At 56-mph a response component of approximately 1.7 Hz becomes evident. At 80 mph a response at approximately 2.2-2.5 Hz emerges. Note that the response frequencies in these latter cases approximately correspond to a disturbance length of 50 ft (twice the length of a guidance panel).

Peak-to-peak forward and aft right guidance suspension deflections are maximum at the lowest speed (.235 in. forward and .26 in. aft) and are minimum not at the higher speed but at 56 mph (.14 in. forward and .10 in. aft). Except for the aft cushion response at 56 mph, each of the appropriate traces shows a relatively large compressive deflection as the forward or aft cushion enters the perturbation.

5.3.3 Comparison of Symmetric and Asymmetric

The responses of the vehicle to symmetric and asymmetric 1.5 in. by 100 foot parabolic pulse perturbations are given in Figure 5-13. The vehicle suspension settings are the same, and the speed is practically the same for both cases (Run 43-12 Sym. and Run 44-12 Asym.). The parabolic pulse was located only on the right (east) side for the asymmetric case.

Vertical body accelerations are shown in Figure 5-13a. The peak-to-peak forward body acceleration is almost twice as great for the symmetric (.45g) than for the asymmetric (.245g) case. The aft peak-to-peak acceleration response is also greater for the symmetric (.315g) than for the asymmetric (.182g) case.

Lateral accelerations are also plotted in Figure 5-13a. For the symmetric case, both forward and aft acceleration traces are identical. It is probable that one measurement was being recorded for both channels. The peak response occurs at a time near that for forward cushion entry into the perturbation indicating that this trace is related to forward body motion ($T \approx 1.5$ sec). For the asymmetric case the forward and aft lateral acceleration responses to the pulse perturbation clearly rise above the smooth guideway ambient levels.

The effects of increasing speed can be seen by comparing the responses of Runs 43-18 (36 mph), 43-20 (56 mph), and 43-22 (80 mph) to the 3 inch symmetric parabolic pulse. Most of the peak-to-peak responses increase with the 122% increase in speed with the greatest percentage changes being in forward chassis suspension deflection (+280%) and forward body vertical acceleration (+86%). Aft cushion accelerations maintain a peak-to-peak value of approximately 2g throughout the speed range. Similar results are obtained when comparing the results of Runs 43-02 (39 mph), 43-04 (42 mph) and 43-06 (72 mph) which show the response to a $1\frac{1}{2}$ in. symmetric parabolic pulse. Aft cushion response in this series rises above the 2g level to 2.57g at the high speed.

A comparison of the results of Runs 43-12 and 44-12 shows the effect of symmetric versus asymmetric excitation by the $1\frac{1}{2}$ inch parabolic pulse. The vertical body accelerations, which are measured at the vehicle centerline, decrease by almost 50% when the symmetric excitation is changed to asymmetric. Forward chassis suspension deflection (1.25 in. peak-to-peak) increases to near the height of the pulse (1.5 in.) on the right side (perturbation side) under asymmetric excitation. It should be noted that even under symmetric excitation that peak-to-peak deflection of the aft left chassis suspension is well below the values of the other three corners indicating a greater suspension stiffness or damping for this corner.

The effects of varying chassis suspension damping are minor. For the 1 in. ramp-step, comparison of Runs 42-34 and 42-42 where actuator damping is changed from the medium setting (35°) to the maximum setting (42°) show minor changes in response. Similar results are obtained for the $1\frac{1}{2}$ inch parabola by comparing Runs 43-16 (0° damper setting), 43-12 (35° damper setting) and 43-06 (42° damper setting). For example, forward vertical body accelerations vary only from (.38 to .45g) and aft body vertical acceleration vary only from (.3 to .34g) for this series of runs. Damping changes for the 3 inch parabolic pulse, Run 42-26 at 35° setting and Run 43-30 at 0° setting, also produce minor response variation.

A significant change in lateral deflection response is produced when guidance actuator damping is varied from the medium setting (30°) to the minimum setting (0°) during asymmetric excitation. Comparison of Run 44-12 (30° damper setting) and 44-14 (0° setting) show that guidance suspension peak-to-peak deflections increase by a factor of 4 to 5 with decreased damping. Other peak-to-peak responses such as acceleration, and vertical deflection, however, change only slightly.

Increase in vertical suspension stiffness decreases peak-to-peak vertical deflection while producing minor changes in peak-to-peak accelerations. This is illustrated by comparing the results of Run 43-30 (maximum air spring volume = 1130 in.^{3}) and Run 43-28 (minimum air spring volume = 470 in.^{3}). Vertical peak-to-peak suspension deflections decrease by a factor of 1.4 to 2.5 while peak-to-peak accelerations remain virtually constant when spring rate is increased. Similar type results are obtained if the results of Runs 43-10 and 43-16 or 43-14 and 43-12 are compared.

The effects of active control of the front cushions (Run 41-16) and the front cushion and all guidance cushions (Run 41-18) can be determined by comparing these cases with Run 44-14 which was under passive control. No major change in peak-to-peak response is evident with the exception of lateral guidance cushion deflection which increased 5 to 6 times under active control.

The major response trends which are evident from examination of peak-to-peak response data are:

- o Decrease in response when $1\frac{1}{2}$ inch by 100 foot parabola perturbation is increased to 3 inch by 150 foot parabola
- o Increase in response with increasing speed
- o Decrease in vertical body response when symmetric excitation is changed to asymmetric
- o Increase in vertical suspension deflection with decreasing suspension spring stiffness.

These effects are examined in greater detail in the following subsections. The lack of response sensitivity to vertical suspension damping is also examined since this is contrary to the results obtained when the TLRV was in the Body/Chassis Suspension mode (Reference 4).

Forward and aft deflections for both the left and right side are shown in Figure 5-13b for the symmetric and the asymmetric cases. Response to symmetric pulse excitation is not symmetric. The right forward suspension compresses approximately .25 in. while the left compresses approximately .15 in. with forward cushion entry onto the perturbation. With cushion exit, the right suspension experiences a travel of .72 inches peak-to-peak while the left experiences a travel of .65 in. The rear right cushion suspension travels .69 in. peak-to-peak while the rear left travels .51 in. during cushion exit. Asymmetric deflections are generally greater than symmetric and the forward right suspension deflection (1.25 in.) approaches the step height (1.5 in.).

Aft right levitation cushion acceleration and force measurements are shown in Figure 5-13c. Accelerations differ only a little from the ambient smooth guideway results with some increase in levels locally when the aft cushion leaves the perturbation. The cushion force for the symmetric and asymmetric cases are similar with the peak asymmetric force slightly higher. This is in contrast with the results obtained in the Body/Chassis configuration of Reference 4. In the Independent Cushion configuration the soft suspension in each of the four corners allows each cushion to follow the perturbation in a more independent fashion thus reducing the cater-cornered loading effect.

Levitation cushion actuator forces are also given in Figure 5-13c for the forward left and right cushions. Left and right actuator forces due to symmetric force excitation are not identical. Actuator forces were predicted by using the slopes of the deflection curves of Figure 5-13b and the force and velocity relations of Figure 5-4. The results are shown in Figure 5-14. For the symmetric case where velocities are approximately 3-6 in./sec, the predicted values are approximately 90% of the measured values. For the asymmetric case, the predicted values are approximately 70% of the measured values.

Peak air spring forces can be obtained by multiplying the peak-to-peak suspension deflections presented in Figure 5-9 by the appropriate spring rate. The spring rate, in turn, is determined from the data in Figures 2-4 and 5-2. For example, the reaction at a forward air cushion is 7400 lb (vehicle weight = 33,450 lb, cg = 431) as shown in Figure 2-4. Subtracting the weight of the levitation cushion and support yoke ($\approx$ 750 lbs) yields an air spring load of 6650 lb. The spring rate for the forward air spring is approximately equal to .22 x 6650 = 1460 lb/in. (see Section 5-1). Forward symmetric peak-to-peak actuator forces of 1125 lb (left) and 1390 lb (right) compare with the spring forces of 950 lb (left) and 1050 lb (right). Asymmetric peak-to-peak actuator forces of 1110 lb (left) and 1525 lb (right) compare with spring forces of 1210 lb (left) and 1830 (right). Thus, air spring forces and actuator damping forces are equally important in contrast to the Body/Chassis configuration of Reference 4 where damping forces were predominent.

5.3.3.1 Indications of Vehicle Asymmetry

It has been previously noted that the vehicle has responded asymmetrically to a symmetric perturbation. Possible candidate mechanisms which contribute to this result are:

- o Air supply pressure pulsation
- o Different rate settings for the suspension elements
- o Non-symmetric guideway subsequent to the initial ramp perturbation.

A comparison plot of right and left levitation cushion suspension deflections for Run 42-34 is shown in Figure 5-15. The vehicle is responding to a 1 inch by 25 foot ramp-step at a velocity of 68 mph. Initially the forward suspension deflects almost symmetrically in response to the forward cushions leaving the ramp-step. When the aft cushions leave the ramp-step, the forward suspensions begin to respond asymmetrically. The aft suspensions also initially respond symmetrically but the response decays asymmetrically. The decay frequency is approximately constant for the four traces indicating a matched set of air springs. The rates of response decay, however, are slower on the right side indicating that the actuator damping is not symmetric.

5.3.4 Effects of Suspension Stiffness and Damping - Over 3 in. by 150 ft. Parabolic Pulse

The variations of vehicle response caused by changes in vehicle suspension stiffness and damping properties are shown in Figure 5-16. The comparison is made for traverses of a 3 in. by 150 ft parabolic pulse in the 70-80 mph speed range. The stiffness was varied by changing the levitation cushion air springs from their maximum volume (1130 cubic in.-Run 43-30) to their minimum

(470 cubic in. - Run 43-28). The levitation cushion actuator damping was varied using the minimum setting of 0^{o} (Run 43-30) and the medium setting of 35 degrees (Run 43-26).

The variation of forward vertical body acceleration with stiffness and damping is shown in Figure 5-16a. The peak-to-peak acceleration is approximately the same (.25-.27g) when the stiffness is varied and decreases slightly to .20g when the damping is increased. The aft body peak-to-peak acceleration is approximately the same (.2g) for all cases and is slightly less than the forward.

The largest response change with suspension stiffness variation is seen in chassis suspension deflection and is also shown in Figure 5-16a. With increased stiffness the forward peak-to-peak travel decreased from .89 inches to .64 inches while the aft suspension travel decreases from .81 inches to .33 inches. Increased damping also reduces suspension deflection but to a lesser extent. The forward suspension deflection decreases from .89 inches to .75 inches with increased damping while the aft travel decreases from .81 to .66 inches.

The variation of levitation cushion forces is shown in Figure 5-16b. The forward peak-to-peak cushion force increases from 1250 lb to 1570 lb with increasing stiffness while the aft peak-to-peak force decreases from 2150 to 1690. With increased damping the forward cushion peak-to-peak force decreases from 1250 to 1050 lb while the aft cushion force decreases slightly from 2150 lbs to 2060 lbs.

Levitation cushion vertical acceleration is also shown on Figure 5-16b. The aft cushion acceleration data show a peak-to-peak response of 2g at 16-20 Hz. The wave form is complicated, and does not appear related to the perturbation.

The peak-to-peak forward cushion actuator force shown in Figure 5-16b decreases from 1300 lb to 1190 lb with increasing stiffness. With increased damping, the traces of response are similar with a peak-to-peak value of 1300 lb.

5.4 Correlation of Vehicle Test and Calculated Responses

Initial correlation studies were performed by manual preparation of comparative traces for the analytical responses and the test data presented on the (Data Van) oscillographs. Since the analytical results are plotted to amplitude and time scales different from those for the test data, any overlay plotting work for comparative studies required rescaling and plotting, a time consuming chore. Even when automated data retrieval and plotting means are employed (Reference 7) the desired uniformity of scale is not always achieved. Thus, a modification to the Dynamic Simulation Program has been made (Reference 6) which greatly simplifies this task. This program now has the additional capabilities to:

(1) Acquire the test data from test data tapes

(2) Plot these data on the same graph with the analytical data (to the same scales).

All the plots contained in this section on correlation are of this type i.e. dual plotting of test and analytical data.

To form the broadest possible base for this study, correlative plots were made of many successful test runs even if the test conditions appeared to be nearly identical. These plots are presented in Appendix A. This provides:

(1) a check on whether the data are truly repetitive, and

(2) a check on the sensitivity to a given variable if small differences did exist.

Each computer run requires input data to the analytical program identical to the test conditions. Although the test conditions were properly recorded in the test log, a higher degree of accuracy is required for two items. These are vehicle speed and time of perturbation encounter; for proper correlation these must be accurate. Vehicle speed was not always as indicated in the log. Time of perturbation encounter was at best approximate and produced errors of ± 50 feet. A manually operated on-board button or switch which amplified the time code signal on the oscillograph serves to mark the vicinity of the event but not the instant of encounter. The initial topic of this section is addressed to a detailed discussion of how correlation start time is established.

Subsequent subsections discuss the correlation of various response parameters considered of prime importance or most interest. The initial studies included the following:

- Body vertical acceleration, forward and aft
- Levitation cushion vertical acceleration, forward and aft, right side
- Levitation cushion suspension deflection, forward and aft, right side
- Levitation force, forward and aft, right side.

The comparative runs presented for symmetric cases are limited to these parameters. However, for asymmetric perturbation cases more parameters are included to cover lateral responses.

In all, 23 separate cases are presented, covering the following perturbations:

- 3 inch x 150 foot parabola (symmetric)
- $1\frac{1}{2}$ inch x 100 foot parabola (symmetric)
- $1\frac{1}{2}$ inch x 100 foot parabola (asymmetric)
- 1 inch x 25 foot ramp (symmetric).

A summary of the input data for the analytical portion of each of these (23) cases is presented along with the plots in Appendix A. This constitutes a permanent record of the data actually used in each case and hence provides a means of making data comparisons, such as, speed, air spring volume, actuator damping, etc. In order to identify the various numerical values used for each analytical input variable and accompanying perturbation shapes, a sample printout with descriptive titles is included.

Toward the end of this correlation study a few distinct correlation discrepancies began to stand out: i.e. high damping (analytical) in the levitation suspension system and somewhat lower frequencies in the suspension and cushion responses. Although these are evident in all the cases, they become most obvious in the 25 foot ramp cases. There the sharp edged end of ramp provides a sharp and distinct pulse followed by a system decay signal strong enough to stand out above the ambient disturbances. Accordingly, a few cases were performed with input data changes which would improve this correlation. All of these changes were made to the same case, Run 42-34, over the symmetric 1 inch by 25 foot ramp-step.

5.4.1 Vehicle Position Over a Perturbation

The discussion of vehicle location on the perturbation will be limited to the parabolic pulse since it presented the greater challenge in locating vehicle position. The ramp-step perturbation produced a sharp edged response such that the vehicle position was never in question whereas vehicle response to the parabola was more subtle.

The method of determining vehicle position relative to the parabola depends upon whether a photocell signal has been recorded. As shown in Figure 5-17, a unique signature is generated as the vehicle passes over the parabola. The characteristics of the parabola (drawn here on the same time scale) are immediately recognizable: the six, four-foot panels that made up the 24 foot end ramps and the fifteen eight-foot panels that made up the parabolic shape. These sections are apparent since the photocell is sensitive to changes in lighting due to surface material, paint, and the tape joints between panels.

As shown in Figure 5-17 the photocell is 9.4 feet aft of the cushion leading edge. By using the timing signals on the oscillograph in conjunction with the photocell signature (known distances) the velocity can be determined quite accurately. With this information the correlative start time would be at point A on the body acceleration curve. However, this seems too early based on its position on the acceleration traces and comparison with subsequent correlative runs. Point A precedes the time at which the acceleration trace makes an abrupt change in direction, point C. If one assumes (somewhat arbitrarily) that the initial input force is felt by the body when the cushion c.g. encounters the ramp, then the start time would be at point B. This is very close to the point when the forward body acceleration trace crosses the zero g line. Since the analytical traces show an immediate, steep and essentially uniform slope starting at time = 0, (see Figures 5-18 and 5-19) it is reasonable to select the crossover point as the correlation time point. In most of the runs, the slopes at this point (analysis and test) are quite similar and rise to a local peak at the same time.

In the absence of the photocell signal, the vehicle location process is one of finding the particular zero crossover point of the forward body vertical acceleration trace due to the perturbation from among the many occurring during the traverse of the smooth guideway. The general procedure is described in Section 3.4.2 but several particular clues are described below. A typical response signature of body vertical acceleration for the parabolic pulse is shown in Figure 5-18. These traces, forward and aft, reflect two fixed distances: length of parabola and distance between levitation cushions. The distance between the two positive acceleration pulses reflects the parabola length. The time lag between forward and aft acceleration pulse reflects the difference between forward and aft levitation cushions. The location of this typical pattern in the oscillograph traces (both the entrance and exit peaks and the lag between the forward and aft traces) is confirmed by relating these distances, speed and time.

5.4.2 Correlation of Vehicle Response - 3 inch by 150 foot Parabolic Pulse

The correlation of predicted and measured response to a 3 inch by 150 foot parabolic pulse is examined by comparing the results of two typical test runs (TL 104 Run 43-28 and -30). These two runs also serve to illustrate the effects of changes in air spring volume (suspension stiffness) as discussed in Section 5.3.4. Prior to this discussion, an examination of the effects of the actual profile of the perturbation versus a theoretical parabola is made.

5.4.2.1 Effects of the Actual Pulse versus Theoretical Parabola

As discussed in Section 4 (Figure 4-4) the 150 foot parabolic perturbation is neither a perfect parabola nor 150 feet in length. Initially, the theoretical parabola was used for analytical predictions; however, when the exact perturbation shape is defined in the analysis, a major improvement in the correlation with experimental data is attained. Vertical body acceleration response to a theoretical 3 inch by 150 foot parabola is shown in Figure 5-18. This response contrasts with the response to the as-built perturbation given in Figure 5-19. To assist in the understanding of these phenomena, the actual parabola shape has been drawn to scale (vertical scale exaggerated) on Figure 5-19. The most obvious change is the reduction in the predicted amplitudes of response pulses during perturbation entrance and exit when the actual profile is used. These responses were cut approximately in half, a direct consequence of the reduction in the local slope of the parabola due to the 24 foot ramps. This reduction places the calculated levels in excellent agreement with the measured data.

The next change to be noted is the appearance of a double response peak during ramp entrance and exit. This characteristic was previously noted as occurring during ramp exit at various speeds (Section 5.3.2). This is caused by the discontinuity in slope that exists at the end of the 24 foot ramp and the start of the (segmented) parabola. The improvement in correlation due to this discontinuity is more subtle but definitely there (Figure 5-19), although it is obscured in one case, by the sharp spike at exit in the forward (PT 1) experimental response.

5.4.2.2 Effects of Suspension Stiffness

The effects of levitation suspension stiffness are determined by comparing the results of Test Log 104 - Run 43-30 (airspring volume = 1130 in.^{3}) to Test Log 104 - Run 43-28 (air spring volume = 470 in.^{3}). The velocity for both runs is nearly the same, 76 versus 78 mph. The predicted response for both cases was obtained using the actual pulse shape for the 3 inch by 150 foot parabola.

Although the overall correlation is good, there are some additional responses in the test data that either do not appear or are barely discernable in the calculated data. These fall into two frequency categories, 2.5 to 3.8 Hz and 15 to 18 Hz. During traverse of the parabola (between the predominant on-off pulses) some extra low frequency pulses appear, the sharper just prior to the off ramp. The other occurrence is post perturbation on the forward (PT 1) trace. Here the analysis shows the response having fairly good frequency correlation but apparently more highly damped. The high frequency response riding on top the low frequency test data is barely discernible in the analytical data trace during parabola traverse. This frequency is 17 Hz. The measured cushion acceleration traces in Figure 5-20 show this same high frequency response.

Body response acceleration for the stiffer suspension is shown in Figure 5-23. Again correlation is quite good for the on-off response pulses. The low frequency pulses during parabola traverse also appear but in this case they are sharper and more pronounced. In addition, another pulse now appears at the off ramp in the forward body trace. The large negative spike in the same trace for the softer suspension case (Figure 5-19) apparently now has an identity that cannot be ignored. At present no explanation exists for either the measured phenomena or the discrepancy in correlation.

The deflection characteristics of the forward and aft levitation cushions relative to the chassis are shown in Figure 5-21 for the softer suspension. Correlation of response amplitude and shape is, in general, good. If the curves were time shifted for best fit, two discrepancies between test and analytical data would still remain. For the forward cushion a positive pulse (extension) would exist above the analytical curve at approximately .8 sec and for the aft cushion a negative pulse (compression) would exist at between 1.1 sec and 1.7 seconds. The half-period of this response (approximately .5 seconds) is equivalent to a much lower frequency (1.0 Hz) than any previously seen in the body acceleration data. Similar observations about these pulses can be made about the deflection response of the stiffer suspension as shown in Figure 5-24. However, for the stiffer suspension the correlation of response amplitude is poor. Forward deflection test data now exceed the analytical by 85% versus 55% previously and aft deflection test data now fall below the analytical, -25% versus +5% previously. The stiffer suspension, in general, reduces the deflection response by approximately 50%.

Excluding the high frequency content, levitation cushion force data for both the softer (Figure 5-22) and stiffer suspensions (Figure 5-25) show good correlation in both amplitude and shape. (The softer suspension experimental data should be shifted to eliminate bias.) For the stiffer suspension, the correlation displays the same general characteristics as the forward body acceleration including the deviations between the entrance and exit peaks (at approximately 2.-2.5 Hz). Aft cushion force, however, shows a major deviation at approximately 1.4 seconds. This may bear some relation to the area between the two negative pulses in the aft body acceleration.

In summary, the correlation between predicted and experimental data is good when the actual parabolic pulse shape is used. Pulses exist while the vehicle is on the parabola (2.5Hz) which are not predicted.

5.4.3 Correlation of Vehicle Responses - 1-1/2 inch by 100 foot Parabola

The correlation of responses to the 1-1/2 inch by 100 foot parabola is investigated by comparing the results of Test Log 102-Run 43-12 (Symmetric) and Test Log 103-Run 44-12 (Asymmetric). The vehicle suspension settings are the same and speed is practically the same for both cases. A comparison of the experimental results is given in Section 5.3.3.

5.4.3.1 Symmetric Response

Whereas the correlation of both amplitude and shape is good for the responses 150 foot parabola (Sect. 5.4.2) the correlation of responses due to the 1-1/2 inch by 100 foot parabola is found to be less favorable.

The actual installed perturbation closely approximates the theoretical parabola except for the flattening at each end due to the 24 foot ramp (see Figure 4-3), and the exact description of the 106 foot perturbation shape using 11 flat segments has been used in the analyses.

Forward (PT1) and aft (PT2) vertical body acceleration responses, shown in Figure 5-26, reveal:

- o Unconservative prediction of response amplitude at the perturbation exit pulse (predicted = 50% experimental).
- o Lack of prediction of local responses at 2.5 Hz while on exit ramp (forward - PT1 response) and during exit from entrance ramp (aft - PT2 response)
- o Higher damping in simulation during post perturbation decay.

Excessive analytical damping may explain all three of these discrepancies although the presence of the experimental 2.5 Hz response is not clearly evident in the predicted response.

Traces of levitation suspension deflections left and right as well as fore and aft are given in Figures 5-27 and 5-28. The test data show little left-right asymmetry. For both the forward and aft deflections, the on-ramp and parabola traverse correlation is fairly good. The discrepancies occur on the off-ramp and post perturbation. For the forward case a distinct extension and the subsequent compression overshoot exceed the analytical response data. These pulses have a frequency of 2.5 Hz and closely follow the characteristics of the forward body acceleration trace in Figure 5-26. For the aft case, the off ramp response is a stronger than predicted compression and the extension overshoot far exceeds the analytical values. These aft response characteristics closely follow those of the aft body acceleration.

Due to data measurement problems, correlation of levitation cushion force is limited to one cushion-aft right (see Figure 5-29). Taking the zero bias shift into account, the traverse and off-ramp correlation is good. The post perturbation response exhibits the same characteristics as the deflection and acceleration response. The absence of an on-ramp pulse as predicted by analysis is similarly noted in the large parabola data (see Figure 5-22).

The right and left side correlation plots for the levitation cushion actuator force are shown in Figures 5-30 and 5-31. The on-ramp and parabola traverse shows good correlation for the forward actuator force with the same off-ramp pulse and overshoot as noted in the cushion deflection and body acceleration data. The aft actuator force correlation is fair for the left side except for some extra pulses on the parabola traverse. (The right side test data appear to be in error.) These response characteristics tend to follow those of the aft body acceleration. A decay pattern is beginning to emerge in the post perturbation of the forward trace at approximately 2.5 Hz.

5.4.3.2 Asymmetric Response

Asymmetric responses are excited by placing the perturbation on the right side of the levitation guideway only, the left side being undisturbed. Such a disturbance induces roll and lateral forces to the vehicle as well as different forces on the left and right levitation cushions.

Correlation plots of vertical body accelerations are presented in Figure 5-32. The reduction in peak responses from the symmetric case is approximately 50% since only one side of the vehicle is being accelerated upward creating nominally half the lifting force on the vehicle. The discrepancies in the correlation are similar to but much larger than those noted for the symmetric case.

The body lateral acceleration data are shown in Figure 5-33. In characteristic shape, the correlation is good; in amplitude, poor. The analytical data is low, approximately half the test data. This is more easily recognized at PT2 than at PT1. The forward (PT1) trace has a large amplitude, secondary frequency response riding on top of the basic long period undulation. Although this frequency varies, the predominant value is 3.1 Hz.

Traces of predicted and experimental suspension deflection are given for the right (Figure 5-34) and left (Figure 5-35) levitation suspension. The correlation for the forward suspension is good. Aft suspension correlation is poor with right side predictions generally lower in magnitude than experimental and the left side predictions generally higher except for a large post perturbation test response.

The correlation plots for the right levitation cushion force are shown in Figure 5-36. The correlation is poor for the aft cushion and the amplitude of the test data for the forward cushion may be in error.

The correlation for the levitation cushion actuator force is shown in Figures 5-37 and 5-38. The correlation is fair for the general trend but just as in the symmetric case, the sharp off-ramp pulses are not duplicated.

Left and right guidance cushion deflection correlation data are shown in Figures 5-39 and 5-40. Despite large bias errors for the left side data, the correlation is considered good. In both sets of data, left and right, both the amplitude and general characteristics have been duplicated.

5.4.4 <u>Correlation of Vehicle Response - 1 inch by 25 foot Ramp-Step</u>

The correlation between experimental and theoretical results when traversing the 1 inch by 25 foot ramp step is demonstrated with the results from two runs (Test Log 101 Runs 42-36 and 42-38). These data serve to demonstrate typical response to the ramp step perturbation and the effects of varying levitation actuator damping. The damper setting for Run 42-36 is 35° (medium) and for run 42-38 it is 42° (higher). This corresponds to an increase in damping value of 15%.

Vertical body acceleration traces are shown in Figure 5-41 (medium damping) and Figure 5-45 (higher damping). The correlation between theory and test is particularly good just after the vehicle cushions leave the ramp. Later, the response decay characteristics are quite different with the measured data more lightly damped than the analytical. Approximate values of equivalent viscous damping (C/Cc) were calculated from the traces to be tetween .1 and .2, measured, versus .3 to .4, theoretical.

Leviation suspension deflections for the medium damping case are given in Figure 5-42 and for the higher damping case, in Figure 5-46. Corresponding cushion forces are given in Figures 5-43 and 5-47; actuator forces are given in Figures 5-44 and 5-48. With the exception of the forward cushion force and aft cushion actuator force, where experimental data appear to be questionable, the results are similar to those noted for the body acceleration, i.e. good correlation immediately after leaving the ramp step and poor correlation during the response decay. For the medium damping case, left side data are shown in Figures 5-42a and -44a. These data lend further support to the above correlation remarks.

The following are typical response data demonstrating experimental and theoretical result correlation:

Run	Damp.	Body Accel. (g's) Fwd	Body Accel. (g's) Aft	Rt. Levitation Susp. Defl. (in.) Fwd	Rt. Levitation Susp. Defl. (in.) Aft	Rt. Cushion Force (lb) Fwd	Rt. Cushion Force (lb) Aft	
42-36	Med.	.46	.37	.87	.77	1500	2820	Test
		.35	.32	.77	.84	2800	3400	Anal
42-38	High	.41	.48	.84	.86	1250	3870	Test
		.35	.32	.70	.77	2650	3270	Anal

5.4.5 Improved Correlation with Damping Changes in Simulation

In previous sub-sections, references have been made to apparent high damping in the analytical predictions. As investigation of analytical damping changes which will result in better correlation with the test results follows. A ramp-step (Test Log 101-Run 42-34) is chosen for the test case since the sharp edged end of the ramp produces a large response with typical decay characteristics which emerge above the ambient response data.

The predicted versus experimental response for Run 42-34 using nominal values of actuator damping (72 psi/(in^3/sec)$^{2/3}$) and friction (110 lb) are shown in Figures 5-49 through 5-56. These nominal damping and friction values were obtained from vendor measurements on the actuator. Comparison of responses shows that predicted initial response due to the step correlates well but that the predicted values decay more quickly than experimental.

To evaluate this discrepancy analytical predictions were made using several combinations of reduced values of actuator damping and friction. The combination of actuator damping coefficient lowered to 50 psi/$(in^3/sec)^{2/3}$ and the actuator friction force made negligible results in a much improved correlation, particularly during response decay. The results, with the parameter values plus a small (20%) reduction in air spring volume to attain frequency correlation, are shown in Figures 5-57 through 5-64. It is interesting to note that the post perturbation response of the high frequency (17 Hz) acceleration data also improved in amplitude and hence correlation. With this increased response comes an increased awareness of the sharp spike in the analytical data that is not apparent in the test data. This occurs about .11 seconds downstream of the initial off-ramp pulse (see Figures 5-58 and 5-59). At this speed this equates exactly to the cushion length. Since the analysis assumes a rectangular cushion, off-ramp passage results in an instantaneous loss of the leading or trailing edge jet perimeter. On the vehicle, however, the rounded leading and trailing edges results in a more gradual perimeter loss. This extra spike can also be seen in the cushion force data (Figure 5-62).

Further improvements in correlation are not made at this point since the results demonstrate that further measurements of secondary suspension properties on the vehicle are required to form a proper basis for correlation.

Guidance Cushion Suspension							
Air Spring Pressure, psi →			20	40		60	
Damper Setting →			0°	0°	30°	0°	30°
Levitation Cushion Suspension Damping	Levitation Air Spring Volume, in³						
42°	470						(I)
35°	1130		(B)	(N)			(J)
35°	470		(A)	(F)	(G)	(M)	(H)
0°	1130		(C)	(O)			(L)
0°	470		(D)	(E)			(K)

Suspension Configuration

Test Log	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
92-99	X														
97		X													
99		X	X	X											
100					X	X	X								
101								X							
102								X	X	X	X	X			
103								X			X		X		
104					X	X								X	X
105					X	X									

Figure 5-1 Tested Variations in Suspension Characteristics

No Auxiliary Volume ($v_A = 0$)

F_o = Air Spring Load at h = 7.75 in.

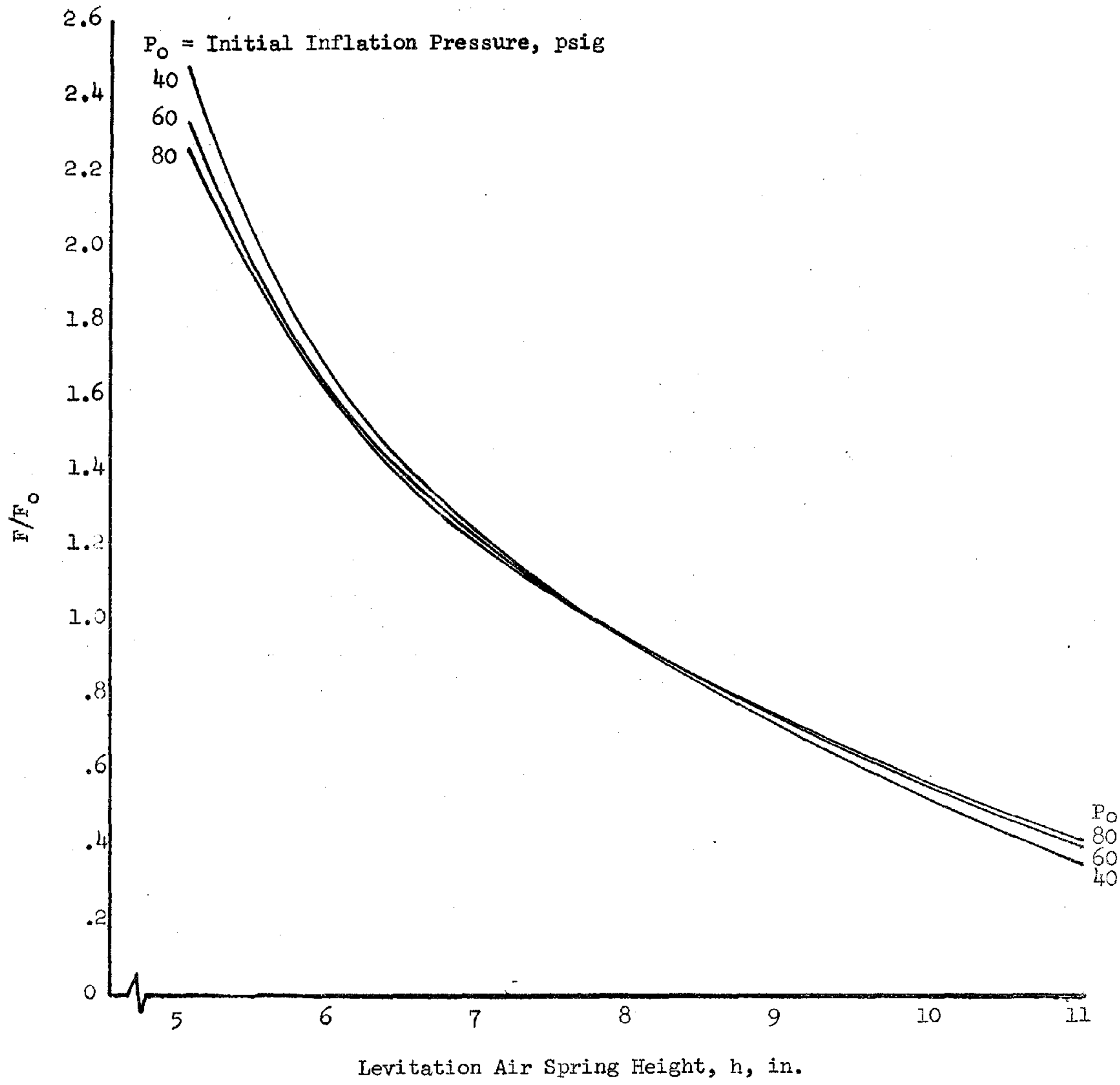


Figure 5-2a Calculated Dynamic Load Ratio for Levitation Cushion Air Spring

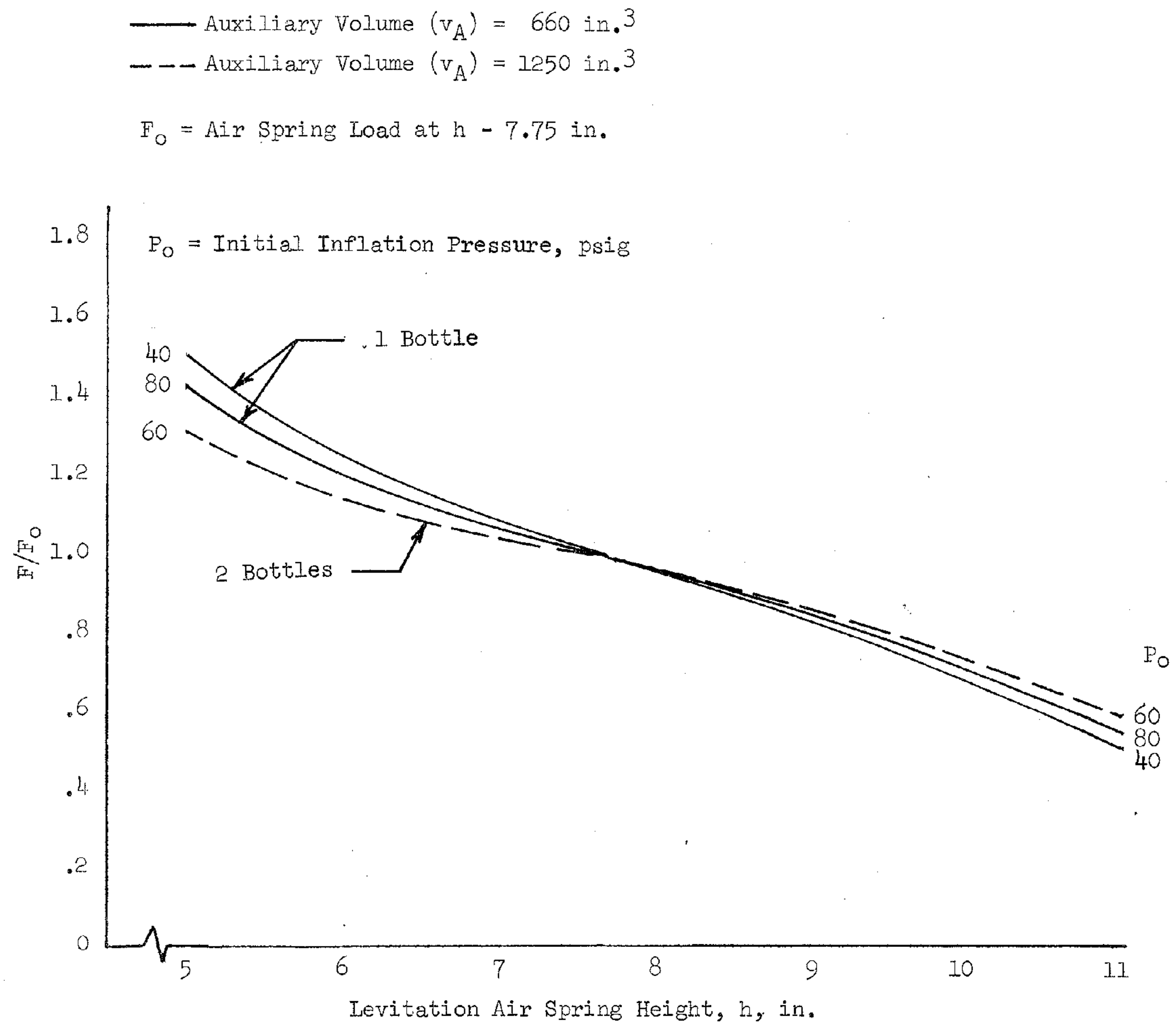


Figure 5-2b Calculated Dynamic Load Ratio for Levitation Cushion Air Spring

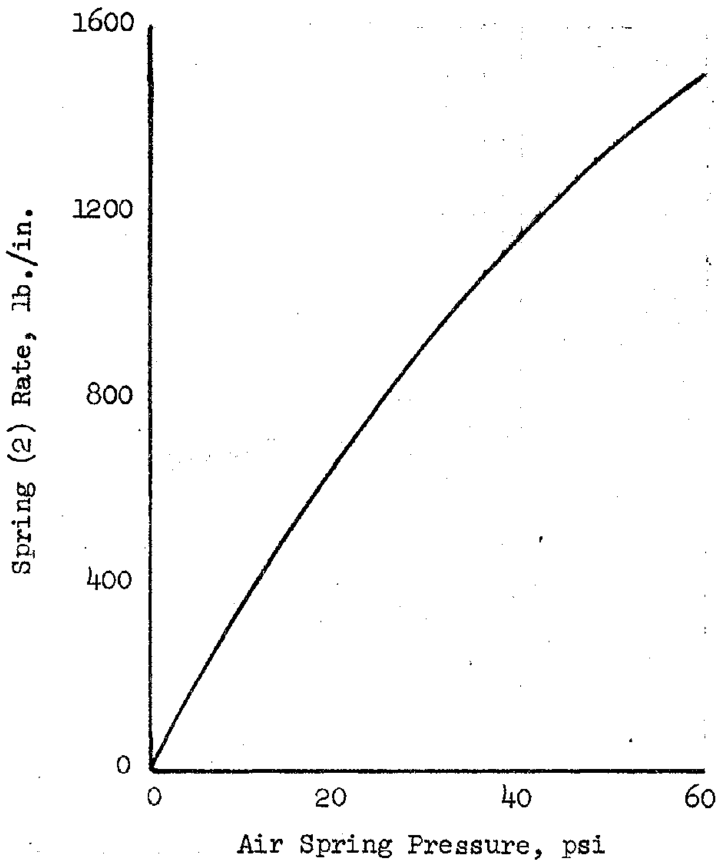


Figure 5-3 Guidance Cushion Spring Rate

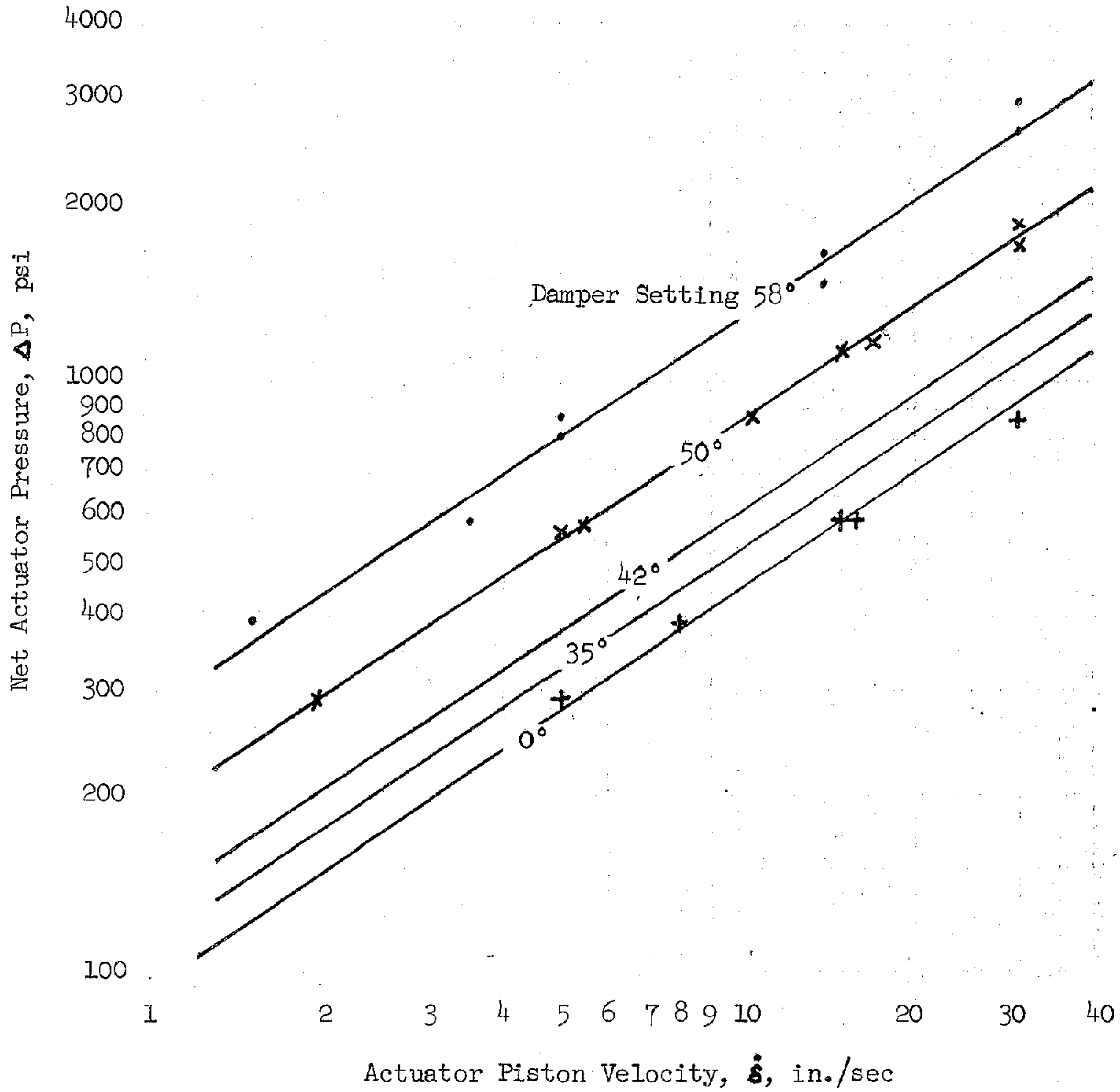


Figure 5-4 Levitation Cushion Actuator Damping

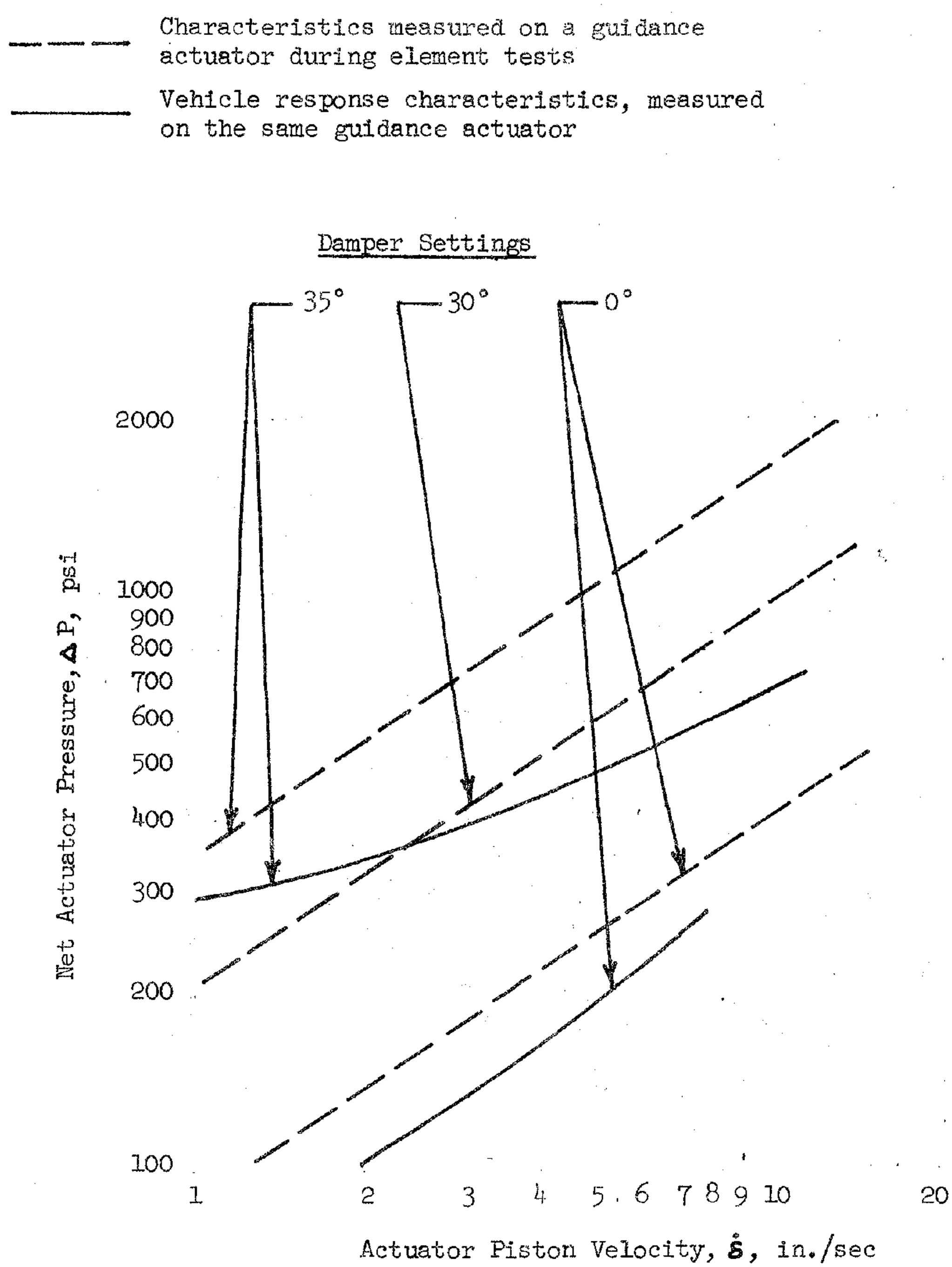


Figure 5-5 Guidance Cushion Actuator Damping

Perturbation Height (in)	Air Spring Volume (in)	Damper Setting (deg)	TLRV Speed (fps)	Air Duct (psi)	Config.	Test Log	Run No.	Body Vertical Acceleration At Step/Ambient (g,DA) Fwd	Mid	Aft	Cushion Vertical Acceleration At Step/Ambient (g,DA) LFL	RFL	LRL	RRL
1/2	470	35	77	4.0	A	97	*	.180/.080*	-	.130/.050*	-	-	-	-
3/4	1130	0	85	3.7	C	99	42-28	.180/.075	.090/.068	.125/.035	2.2/.8	3.4/.5	2.6/1.5	3.6/1.9
	1130	35	100	3.8	B	99	26A	.216/.095	.110/.073	.163/.042	2.9/.9	3.8/1.2	-	4.7/2.1
	470	0	85	4.0	D	99	44	.235/.100	.145/.080	.165/.060	1.4/.5	1.7/.5	0.9/.7	2.5/1.2
	470	35	53	4.0	A	98	16	.220/.050	.143/.040	.182/.035	1.8/.9	2.3/.8	2.0/1.2	2.7/2.3
			80	4.0	A	98	18	.260/.085	.140/.060	.160/.050	1.9/.5	2.8/.7	1.9/1.3	5.4/2.3
			60	2.6	A	98	22	.240/.065	.142/.045	.185/.040	2.8/.6	3.5/.9	2.2/1.2	2.2/2.3
			105	4.0	A	99	20	.310/.108	.165/.078	.215/.058	2.7/1.0	5.0/1.0	3.3/1.5	5.0/2.2
1	470	35	62	3.8	H	101	30	.300/.052	.195/.040	.310/.040	3.0/.8	2.2/.8	2.7/1.1	3.4/1.3
			88	3.0	H	101	36	.380/.100	.220/.090	.300/.085	4.0/.6	4.2/.8	3.0/1.0	3.4/1.5
			97	3.8	H	101	34	.390/.110	.215/.090	.300/.070	-	3.3/.9	3.3/1.1	4.0/1.4
	470	42	87	3.6	I	101	38	.340/.100	-	.275/.120	4.8/.6	2.6/.8	3.4/1.0	4.8/2.2
			95	3.6	I	101	42	.365/.100	-	.32/.110	5.2/.8	3.0/.7	3.8/1.0	4.5/2.0
1 Asym	470	0	41	4.0	E	100	44-2	.095/.040	.065/.030	.075/.040	-	2.3/.6	-	4.7/1.3
			74	4.0	E	100	4	.145/.070	.135/.080	.155/.085	-	3.4/.9	-	3.8/1.4
	470	35	103	4.0	F	100	6	.180/.130	.105/.085	.160/.060	-	4.2/.9	-	4.4/1.3
			102	3.8	G	100	8	.153/.130	.105/.085	.120/.070	-	4.2/1.0	-	4.9/1.9
3/4 Active	470	0	80	2.9	D	99	41-4	.165/.055	.062/.070	.180/.072	2.6/1.6	3.0/1.2	1.6/1.2	5.6/1.7

*Average estimated from several runs

Figure 5-6 Tabulation of Vertical Acceleration Responses Over Ramp-Steps

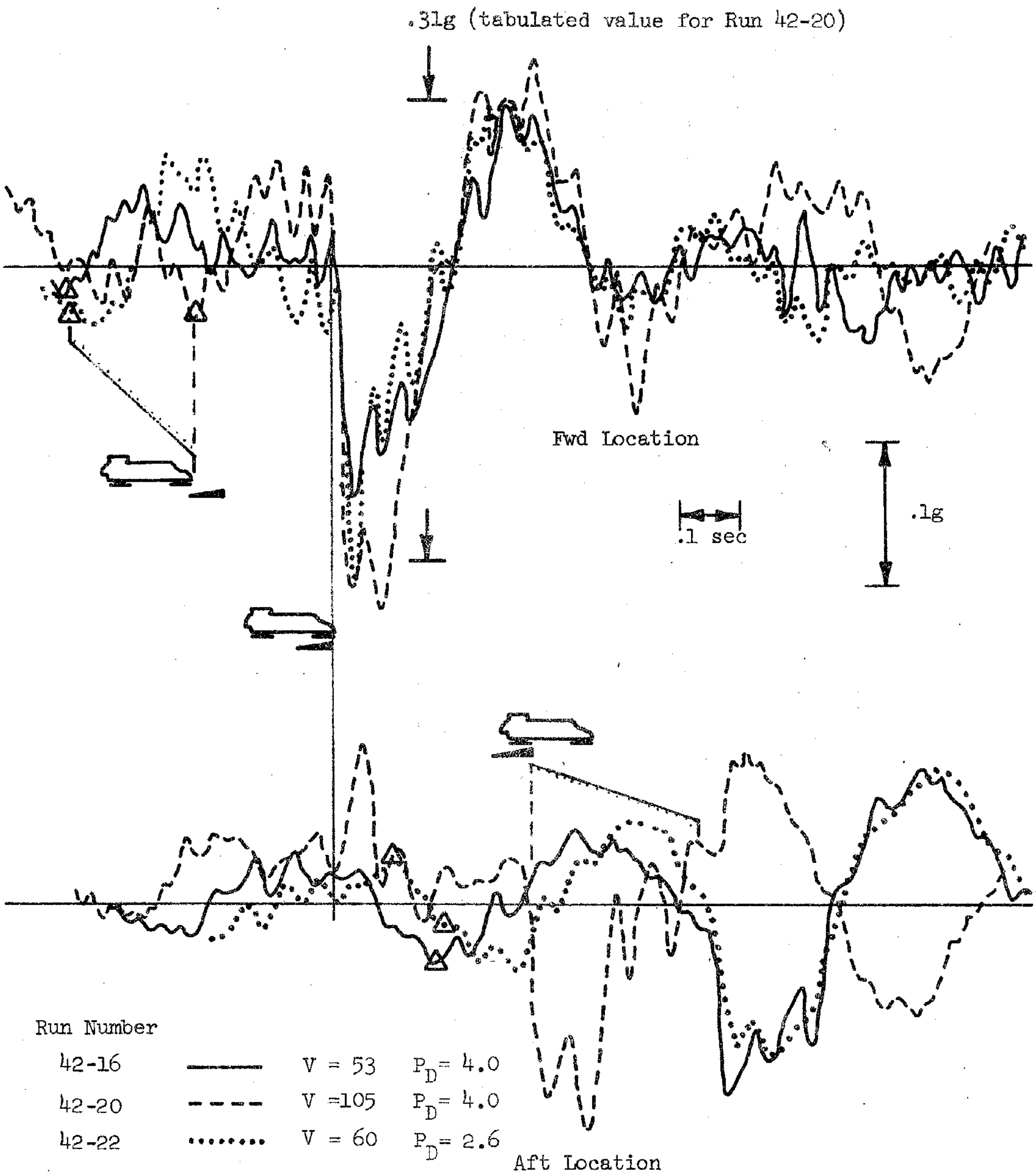


Figure 5-7a Body Vertical Accelerations - 3/4 inch Ramp-Step

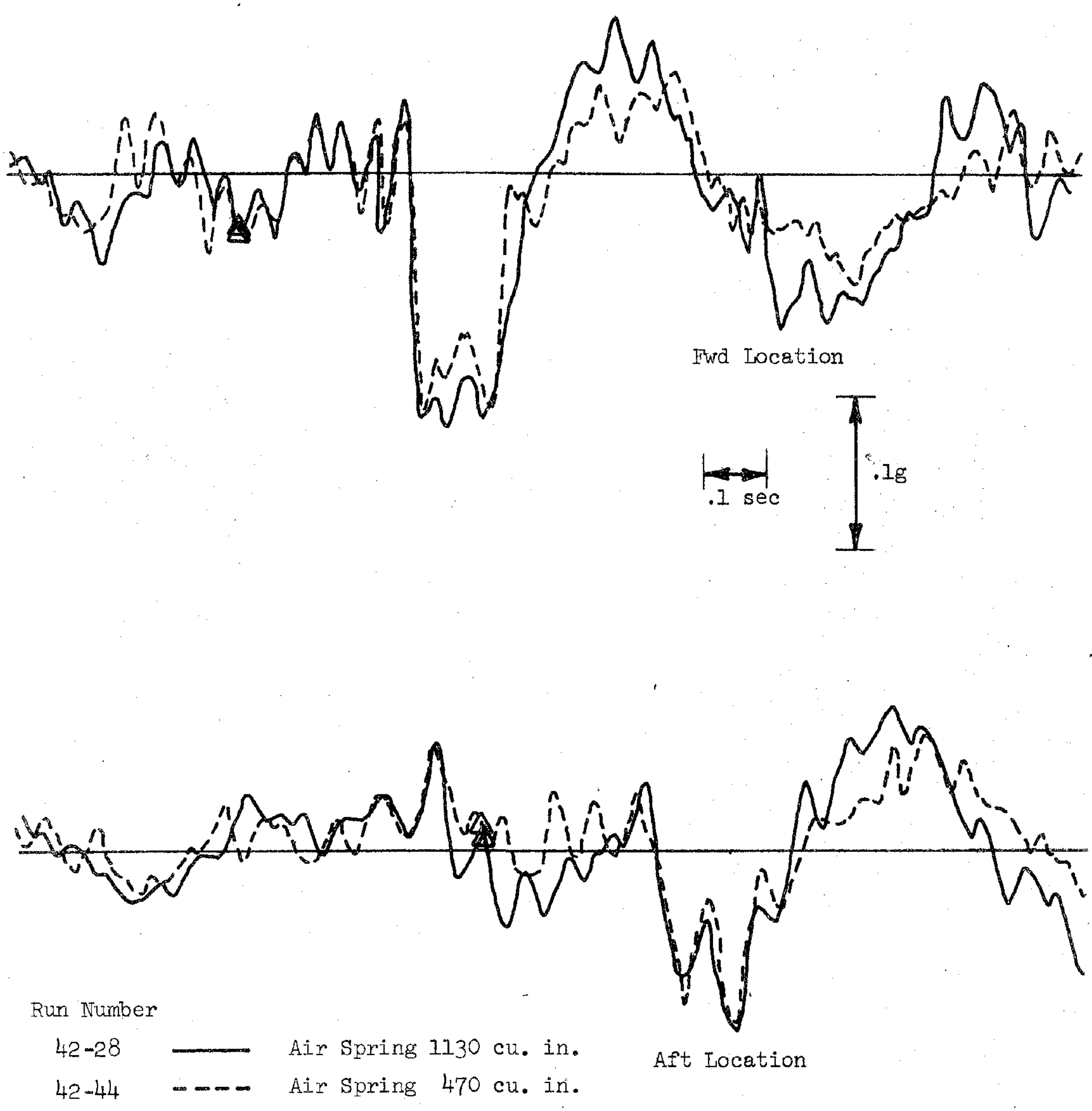


Figure 5-7b Body Vertical Accelerations - 3/4 inch Ramp-Step

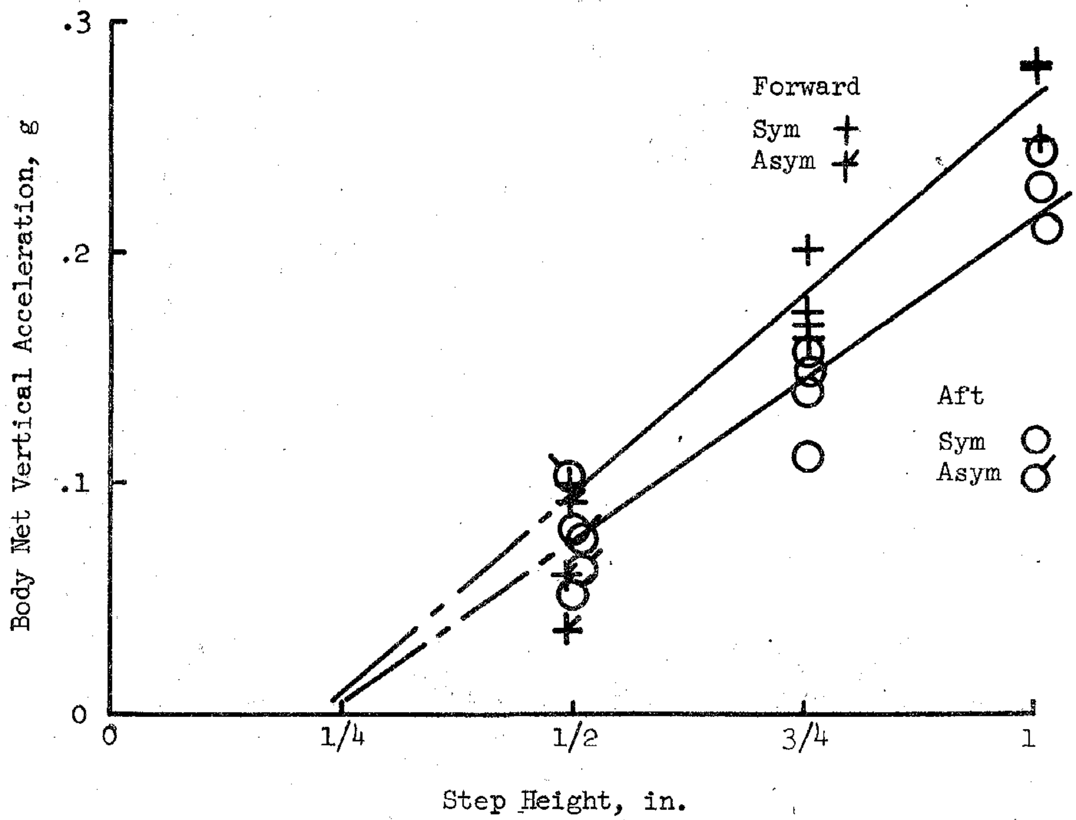


Figure 5-8 Effect of Ramp-Step Height on Body Vertical Acceleration

Test Log	Run	Vel. mph	Levitation Act. Damp. Deg	Levitation A/S in^3	Guidance Act. Damp. Deg.	Guidance A/S Press. psi	Body Accel. g			Rt. Cushion Accel. g		Chassis Susp. Defl. Inches			Cushion Force Lb			Cushion Act. Force Lb			Rt. Guid. Cush. Lat. Defl. Inches	
								Fwd	Aft	Fwd	Aft		Fwd	Aft		Fwd	Aft		Fwd	Aft	Fwd	Aft
101 1" x 25' Ramp Step Symmetric	42-34	68	35	470	30	60	Z	.46	.40	-	4.10	R	.90	.84	R	1100	2710	R	2090	-	..08	.08
							Y	.176	.19	-	-	L	.86	.70	L	-	-	L	1470	1400		
	42-36	60	35	470	30	60	Z	.46	.37	4.0	3.53	R	.87	.77	R	1300	2820	R	1740	560	.07	.07
							Y	.100	.155	-	-	L	.83	.64	L	-	-	L	1550	-		
	42-42	65	42	470	30	60	Z	.435	.42	2.82	4.60	R	.89	.80	R	1300	3510	R	1600	775	.06	.08
							Y	.145	.191	-	-	L	.94	.525	L	-	-	L	1250	-		
102 $1\frac{1}{2}$" x 100' Parabola Symmetric	43-02	39	42	470	30	60	Z	.166	.222	.95	1.93	R	.166	.385	R	-	2050	R	980	-	-	-
	43-04	42	42	470	30	60	Z	.183	.236	1.33	2.0	R	.332	.45	R	-	2030	R	980	-	-	-
	43-06	72	42	470	30	60	Z	.382	.30	1.26	2.57	R	.76	.715	R	900	2480	R	1250	-	.04	.06
							Y	.168*	.168*	-	-	L	.62	.48	L	-	-	L	840	1400		
	43-12	76	35	470	30	60	Z	.450	.315	1.33	2.66	R	.72	.685	R	800	2930	R	1390	490	.06	.08
							Y	.215*	.215*			L	.65	.51	L	-	-	L	1125	-		
	43-14	78	35	1130	30	60	Z	.338	.250	1.34	1.62	R	.80	1.02	R	-	2500	R	1330	-	-	-
	43-16	77	0	470	30	60	Z	.377	.339	1.26	1.62	R	.81	.77	R	-	2940	R	1180	-	-	-
	43-10	77	0	1130	30	60	Z	.285	.282	1.26	1.93	R	.92	1.16	R	-	2600	R	1400	-	-	-
103 $1\frac{1}{2}$" x 100' Parabola Asymmetric	44-12	78	35	470	30	60	Z	.245	.182	-	2.0	R	1.25	.84	R	1000	3050	R	1525	690	.06	.11
							Y	.205	.16			L	.83	.55	L	-	-	L	1110	-		
	44-14	76	35	470	0	60	Z	.220	.195	-	1.50	R	1.25	.77	R	900	2950	R	1690	690	.32	.46
							Y	.183	.165			L	.82	.425	L	-	-	L	1040	-		
103 $1\frac{1}{2}$" x 100' Parabola Asym. (Active)	41-16 Fwd. Lev.	74	35	470	0	60	Z	.203	.198	-	1.685	R	1.36	-	R	1000	2690	R	1810	-	.21	.50
							Y	.189	.166			L	.72	.47	L	-	-	L	770	980		
	41-18 Fwd. Lev. & Guid.	71	35	470	0	60	Z	.228	.149	-	1.76	R	1.03	-	R	600	2250	R	1620	-	1.22	3.55
							Y	.230	.15			L	.88	.36	L	-	-	L	910	910		

*Identical traces Z = Vertical R = Right
Y = Lateral L = Left

Figure 5-9a Summary of Peak Responses

Test Log	Run	Vel mph	Levitation Act. Damp. Deg	Levitation A/S in^3	Guidance Act. Damp. Deg	Guidance A/S Press. psi	Body Accel. g			Rt. Cushion Accel. g		Chassis Susp. Defl. Inches			Cushion Force Lb			Cushion Act Force Lb			Rt. Guid. Cush. Lat. Defl. Inches	
								Fwd	Aft	Fwd	Aft		Fwd	Aft		Fwd	Aft		Fwd	Aft	Fwd	Aft
104 3" x 150' Parabola Symmetric	43-18	36	35	470	0	40	Z	.14	.14	.78	2.2	R	.111	.21	R	1240	1360	R	1200	-	.235	.26
							Y	.087	.065			L	.12	.17	L			L	555	700		
	43-20	56	35	470	0	40	Z	.20	.17	.86	2.1	R	.39	.27	R	1580	1480	R	1160	-	.137	.10
							Y	.12	.072			L	.23	.30	L			L	700	1250		
	43-22	80	35	470	0	40	Z	.26	.20	1.26	2.18	R	.53	.36	R	1920	1920	R	1040	-	.215	.175
							Y	.15	.106			L	.40	.33	L			L	840	1175		
	43-24	51	35	470	0	40	Z	.20	.16	-	1.9	R	.28	.36	R	790	1600	R	1200	-	.118	-
	43-26	78	35	1130	0	40	Z	.20	.20	1.18	2.0	R	.75	.66	R	1050	2060	R	1300	-	.15	.22
							Y	.11	.098			L	.51	.30	L		-	L	900	1180		
	43-30	78	0	1130	0	40	Z	.27	.20	1.575	2.0	R	.89	.81	R	1250	2150	R	1300	-	.155	.20
							Y	.134	.092			L	.71	.46	L			L	975	910		
	43-28	76	0	470	0	40	Z	.25	.19	2.28	2.1	R	.64	.33	R	1570	1690	R	1190	-	.18	.18
							Y	.165	.116			L	.43	.50	L		-	L	850	980		
105 3" x 150' Parabola Symmetric	43-22A	55	35	470	0	40	Z	.22	.18	1.18	2.0	R	.39	.24	R	910	-	R	1110	-	.138	
	43-28A	85	0	470	0	40	Z	.25	.24	2.27	2.0	R	.56	.48	R	1240	2000	R	1110	-	.175	
	43-28B	89	0	470	0	40	Z	.23	.27	1.565	2.6	R	.60	.50	R	1150	1800	R	1120	-	.157	

Z = Vertical R = Right

Y = Lateral L = Left

Figure 5-9b Summary of Peak Responses

Run 43-12 $1\frac{1}{2}$ inch by 100 foot Parabola

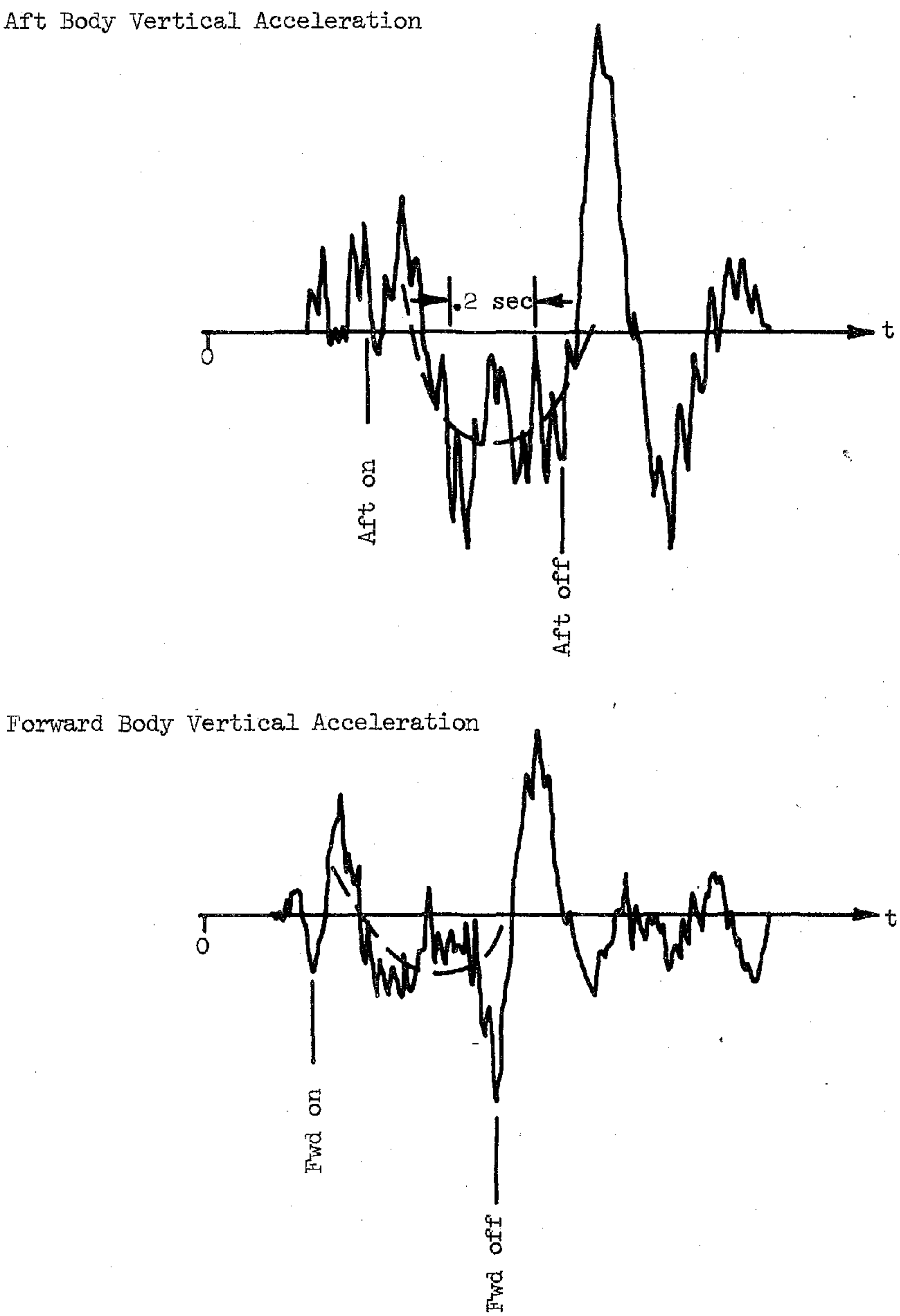
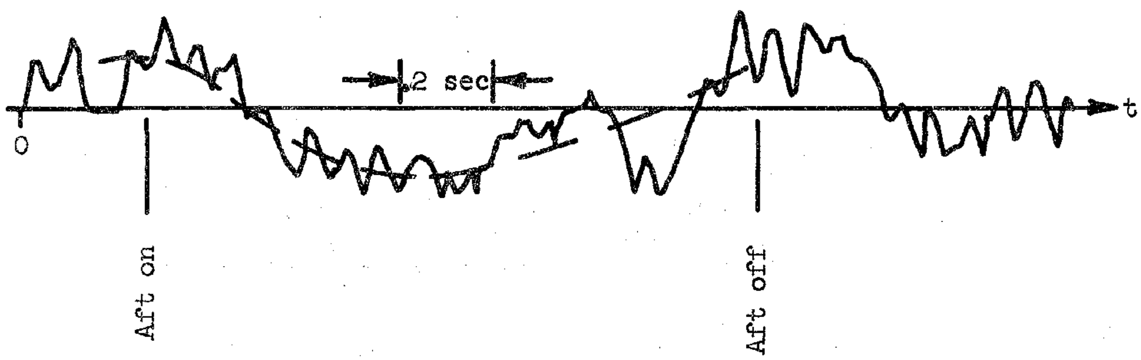


Figure 5-10a Measured Relation of Body Acceleration and Pulse Length

Run 43-22   3 inch by 150 foot Parabola

Aft Body Vertical Acceleration



Forward Body Vertical Acceleration

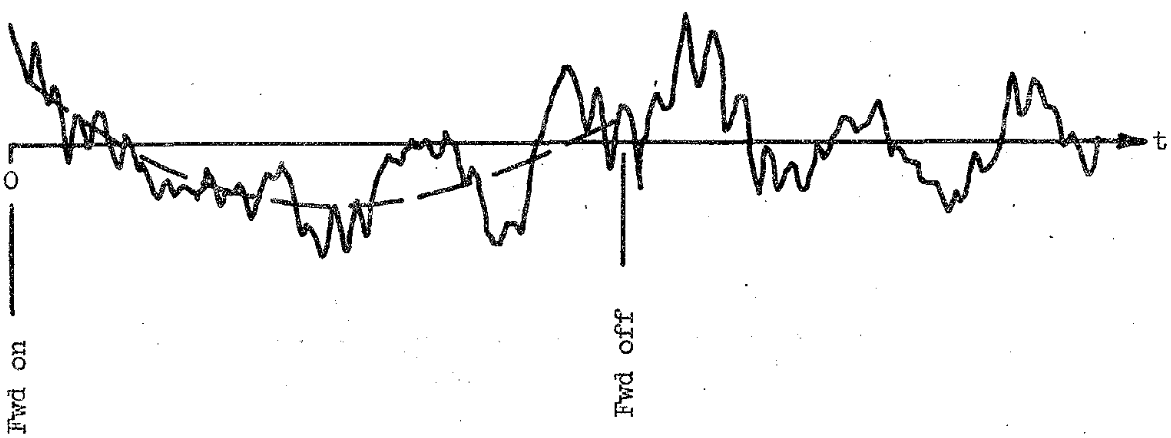


Figure 5-10b Measured Relation of Body Acceleration and Pulse Length

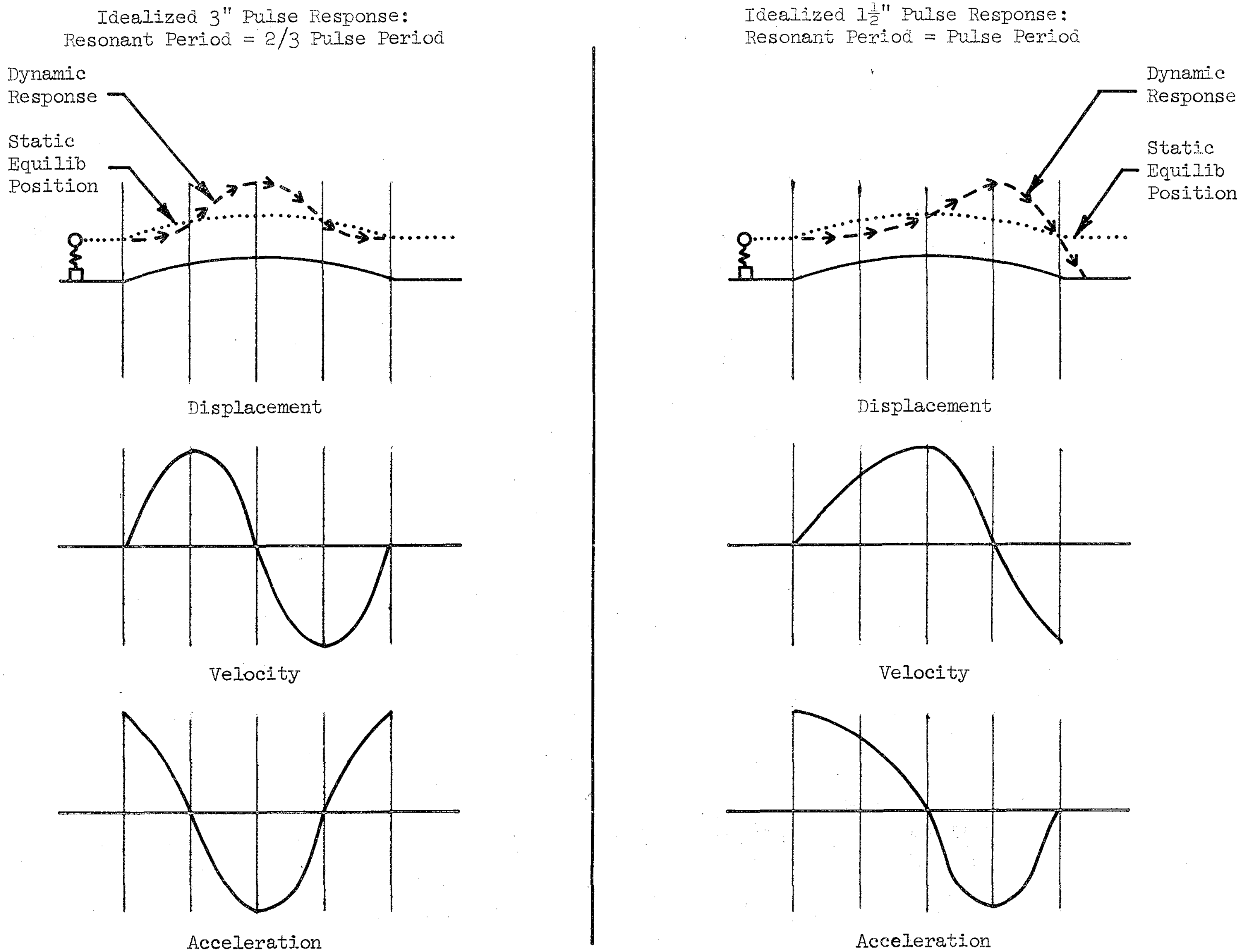


Figure 5-11 Idealized Relation of Body Response and Pulse Length

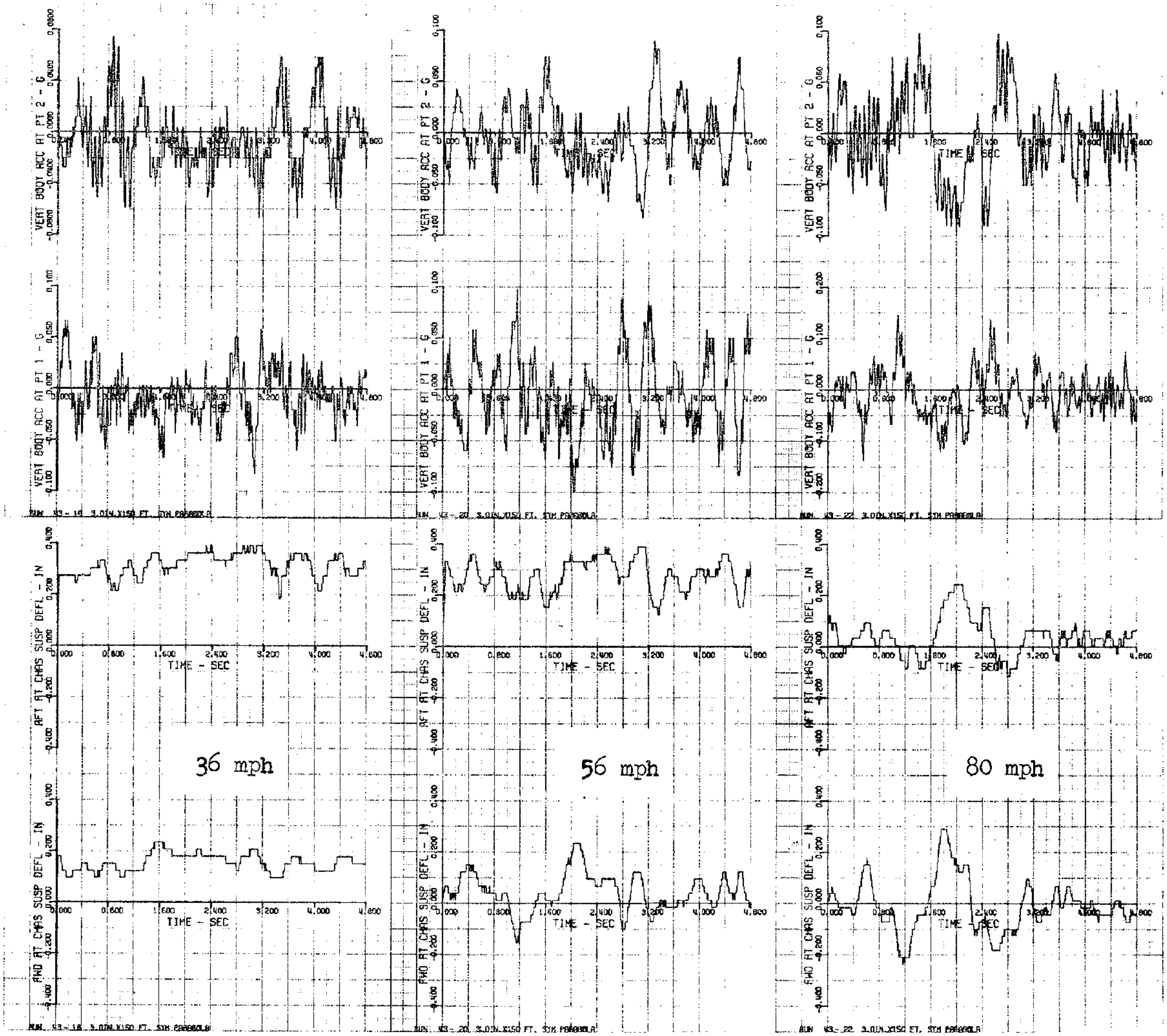


Figure 5-12a   Measured Responses at Several Speeds - 3 inch by 150 foot Parabolic Pulse

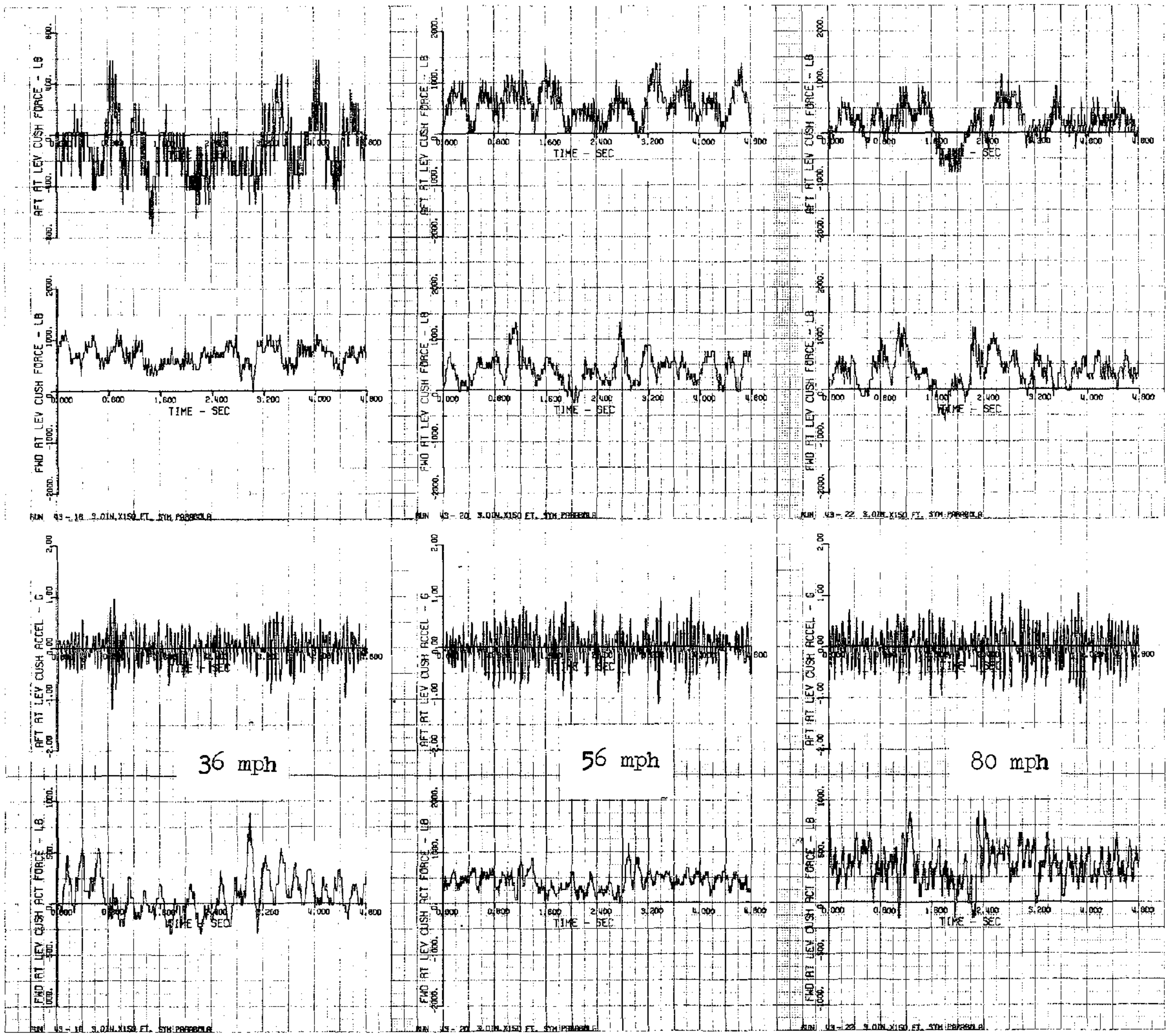


Figure 5-12b Measured Responses at Several Speeds - 3 inch by 150 Foot Parabolic Pulse

Figure 5-12c Measured Responses at Several Speeds - 3 inch by 150 foot Parabolic Pulse

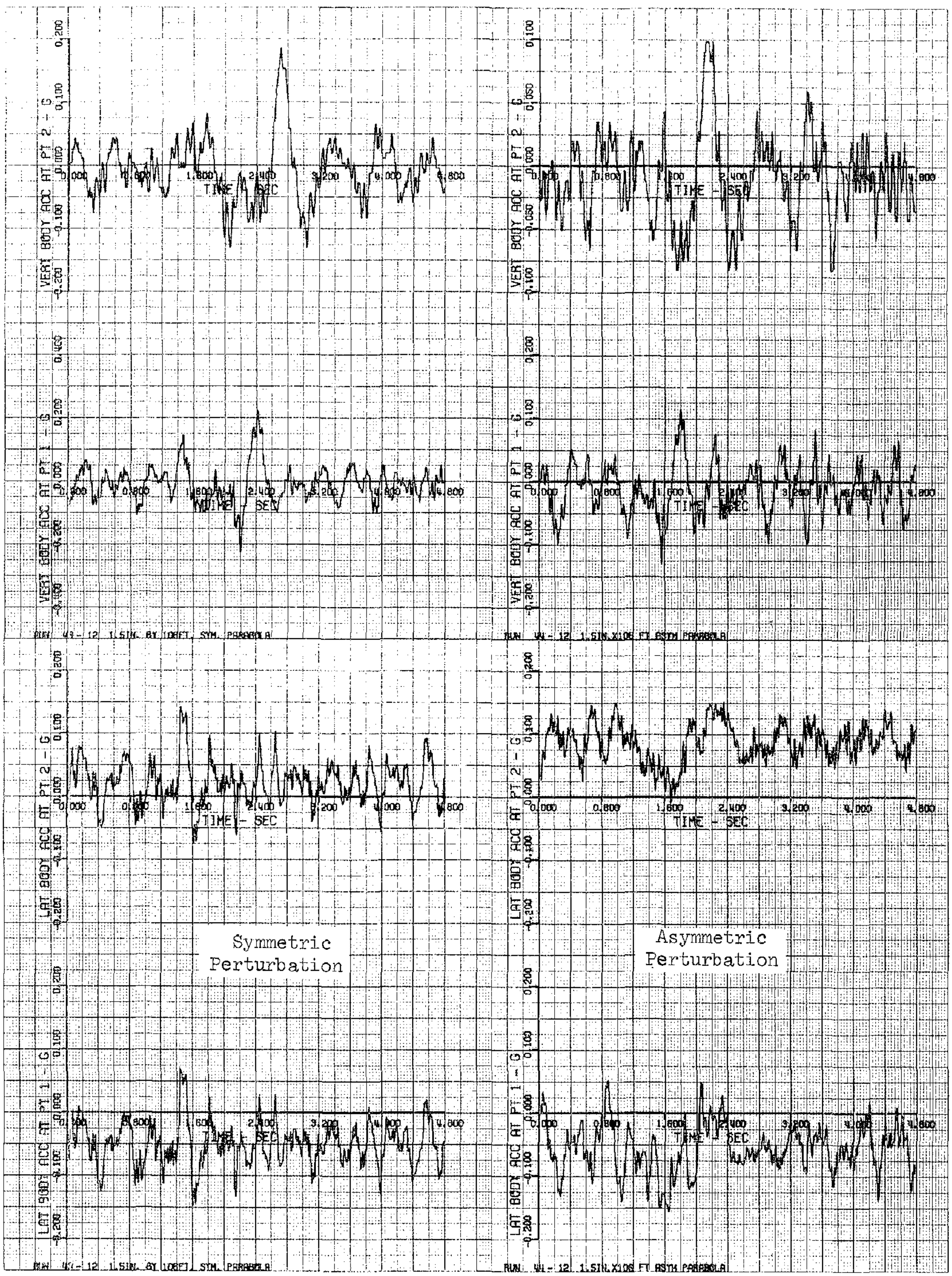


Figure 5-13a Comparison of Measured Symmetric and Asymmetric Response - $1\frac{1}{2}$ inch by 100 foot Parabolic Pulse

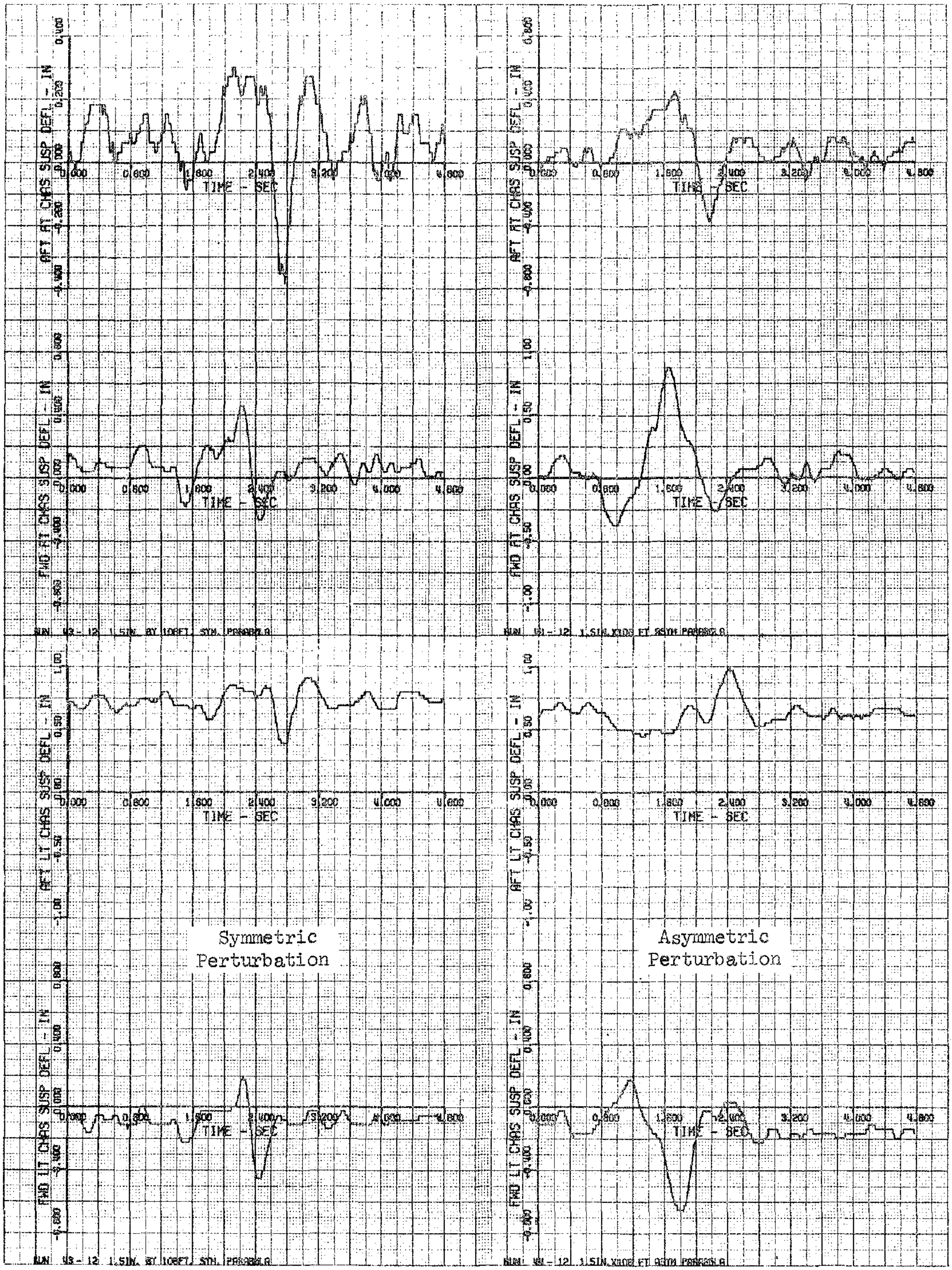


Figure 5-13b Comparison of Measured Symmetric and Asymmetric Response - $1\frac{1}{2}$ inch by 100 foot Parabolic Pulse

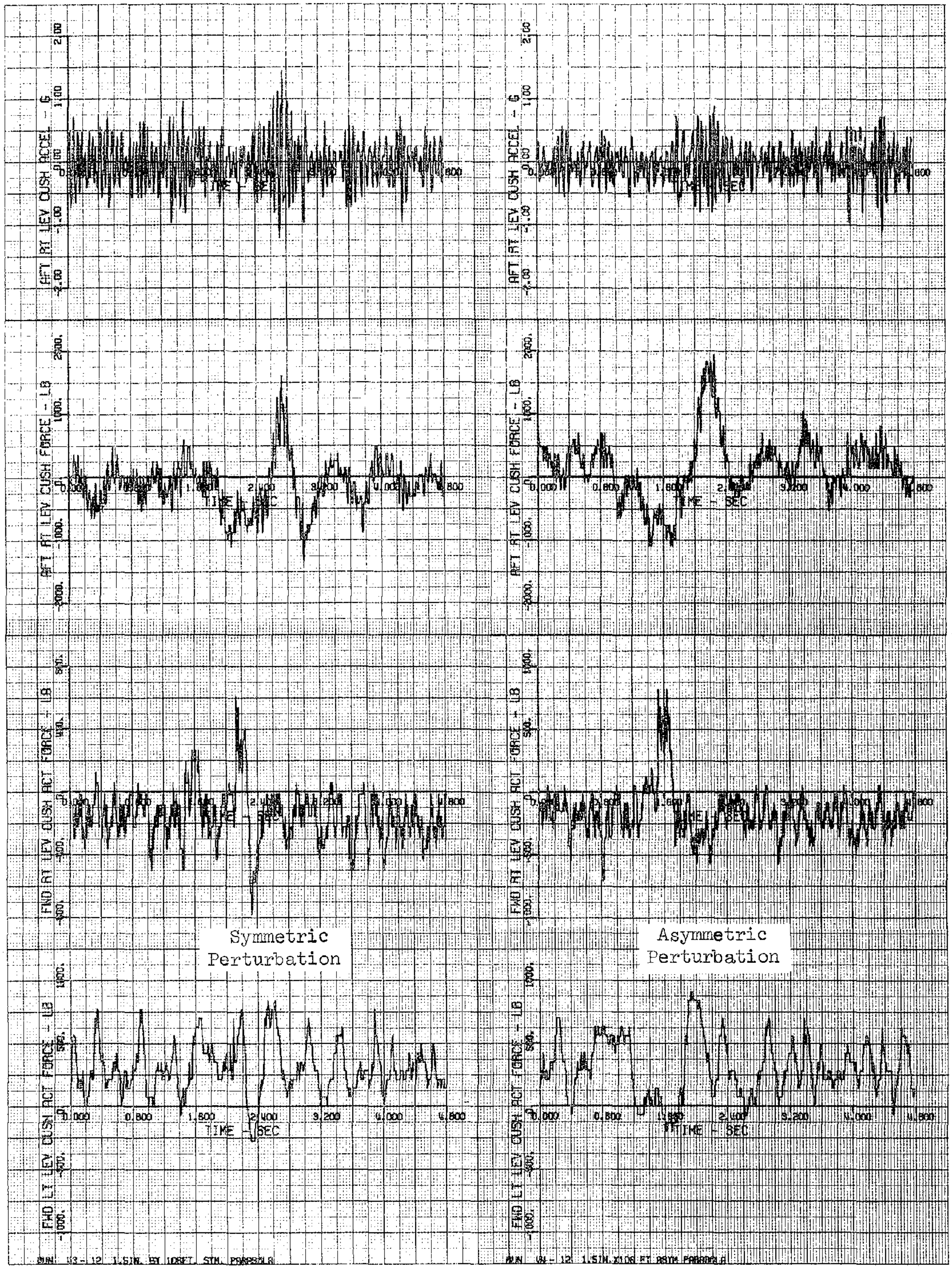


Figure 5-13c Comparison of Measured Symmetric and Asymmetric Response - $1\frac{1}{2}$ inch by 100 foot Parabolic Pulse

Run	Location	Time Sec	Vel in/sec	Force lb	
43-12	Fwd Left	2.32	-5	-587	
		2.52	3.12	427	
				1014	vs. 1125 lb P-P measured
	Fwd Right	2.32	-5.35	-605	
		2.20	5.72	637	
				1242	vs. 1390 lb P-P measured
44-12	Fwd Left	2.0	3.5	459	
		-1.6	-2.25	-342	
				801	vs. 1110 P-P measured
	Fwd Right	1.64	3.1	420	
		1.78	-3.85	-490	
				910	vs. 1250 P-P measured (locally)

Figure 5-14 Sample Comparisons of Actuator Forces - Computed versus Measured

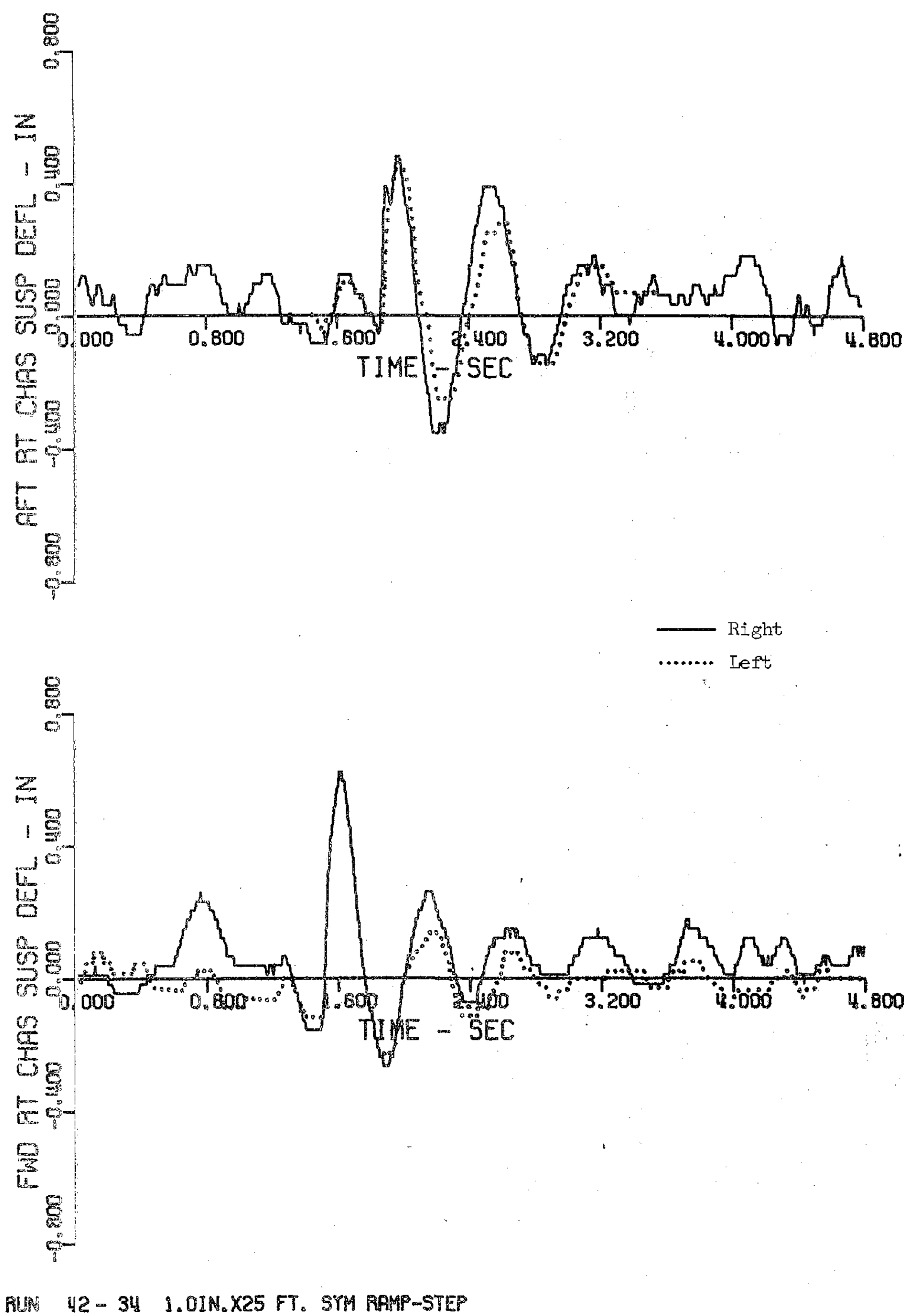


Figure 5-15 Measured Asymmetric Response to Symmetric Excitation - 1 inch by 25 foot Ramp-Step

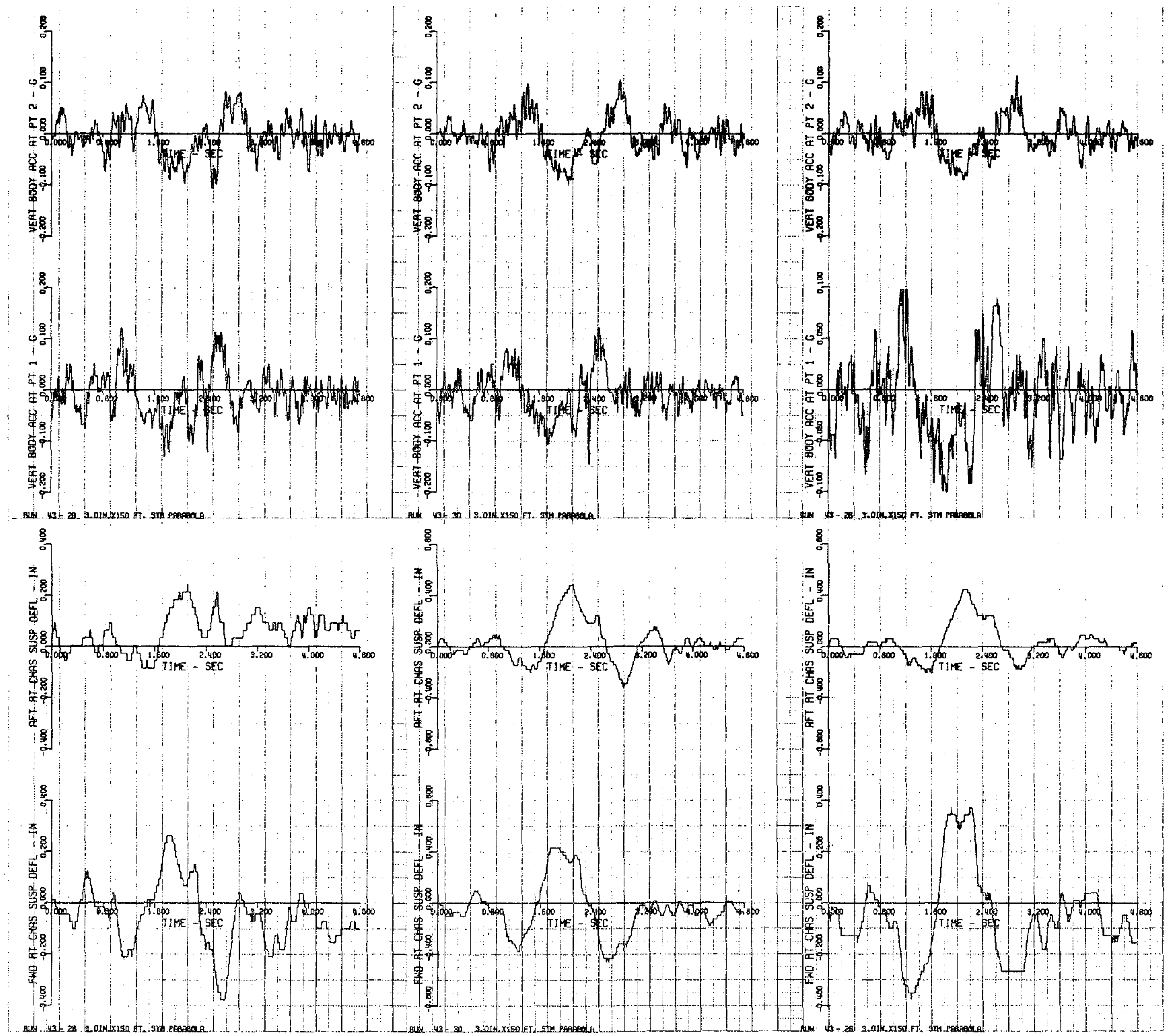


Figure 5-16a Measured Response for Various Suspension Settings - 3 inch by 150 foot Parabolic Pulse

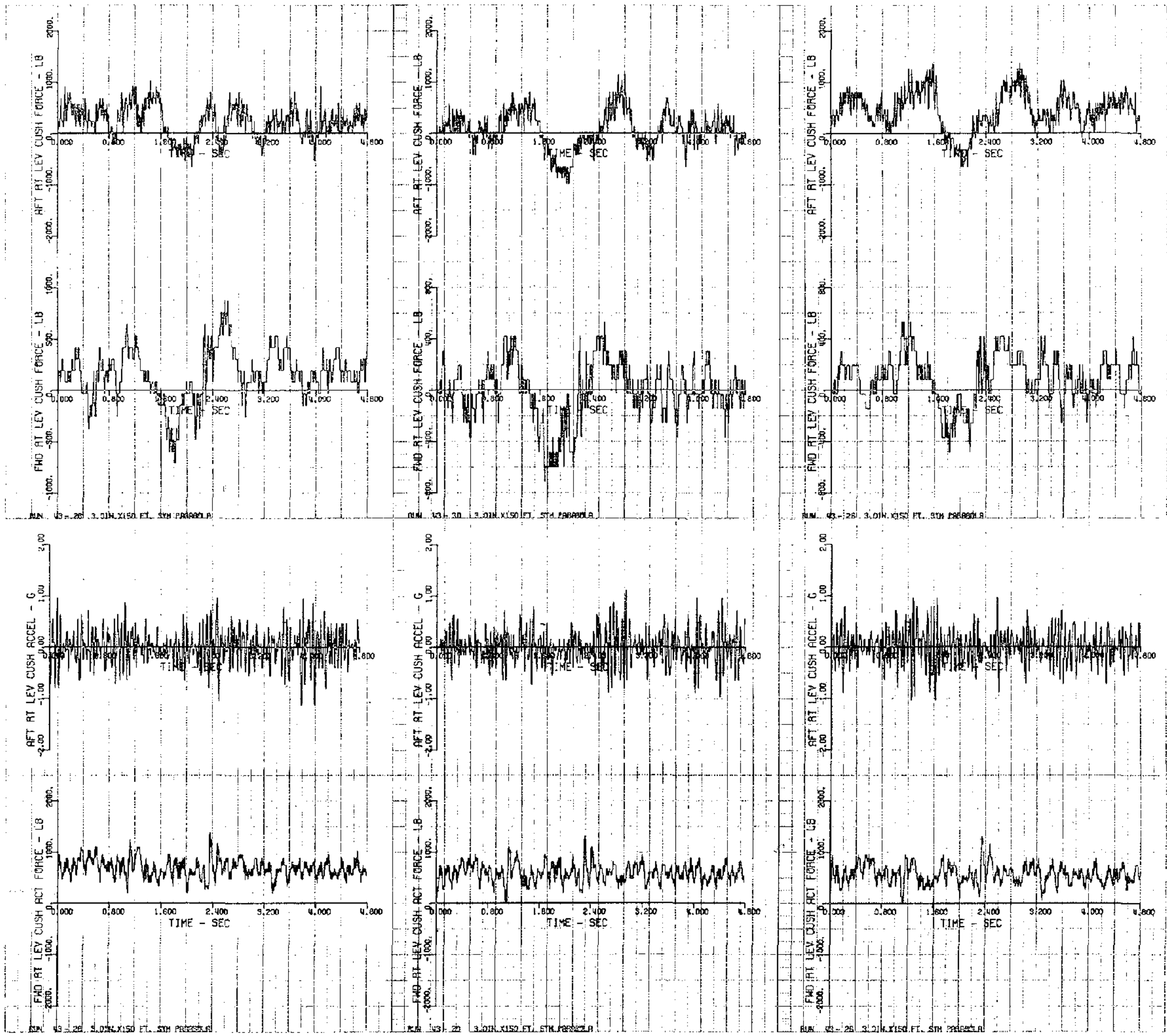


Figure 5-16b Measured Response for Various Suspension Settings - 3 inch by 150 foot Parabolic Pulse

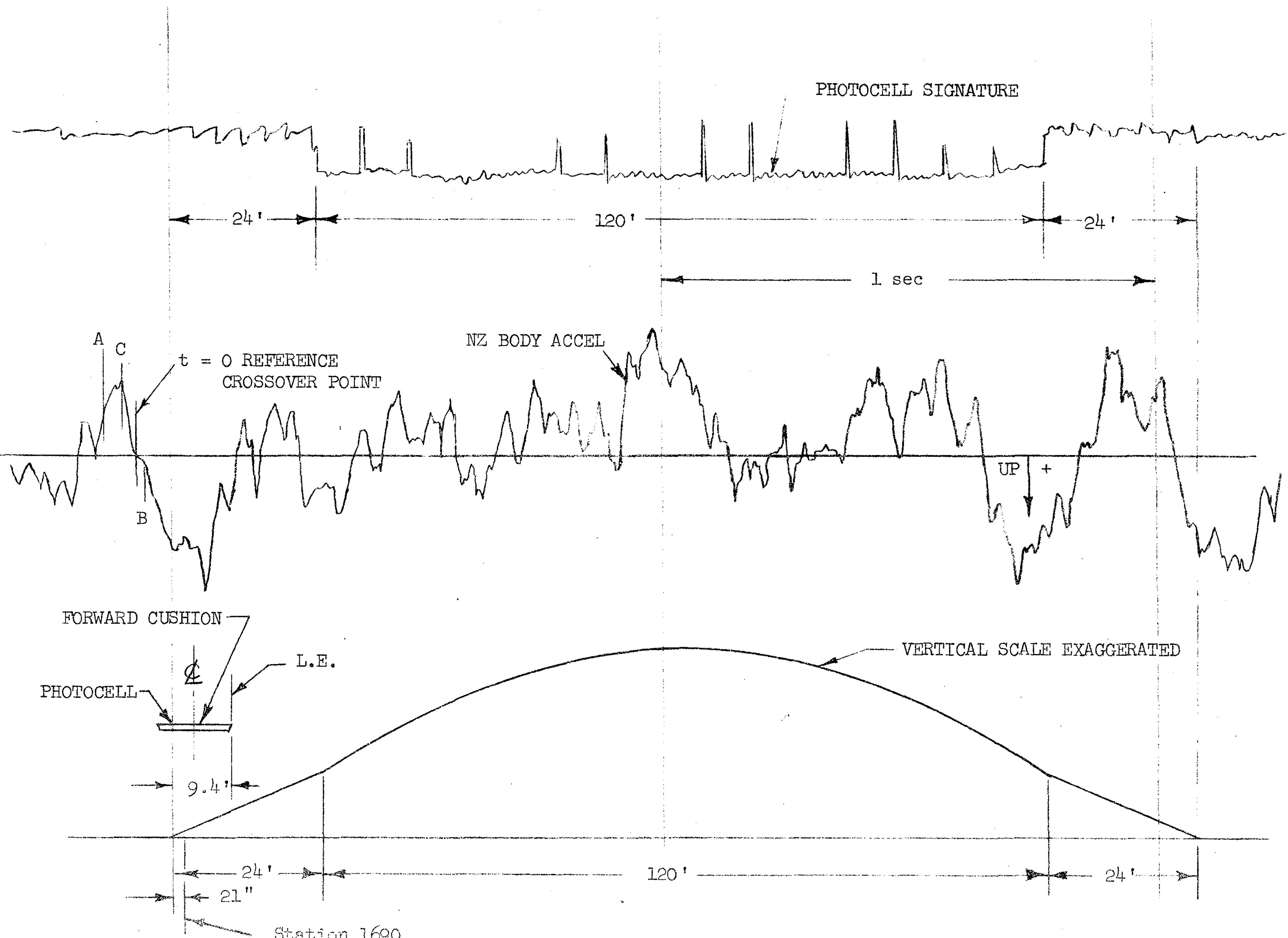


Figure 5-17 Photocell Signature for 150 foot Parabola

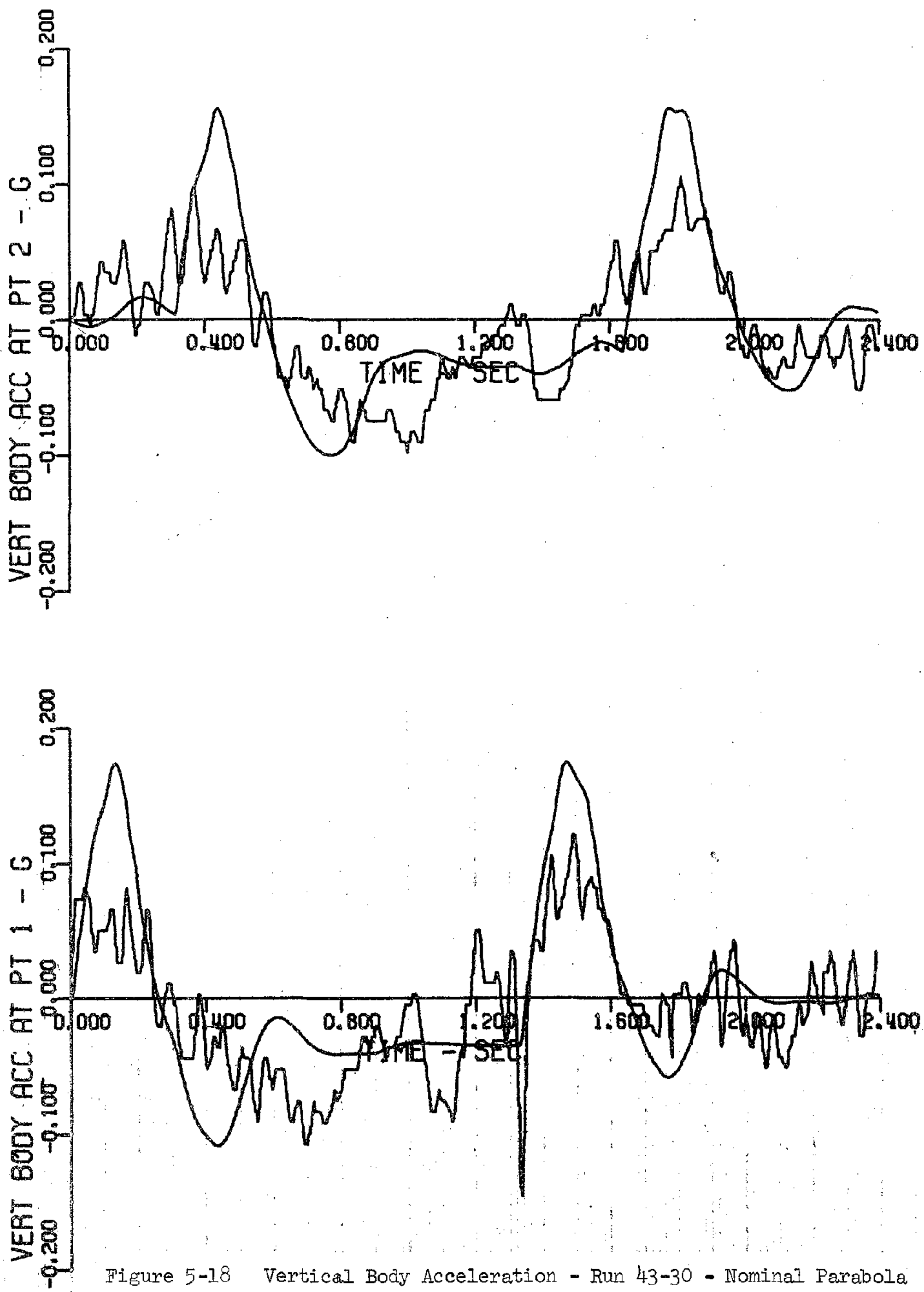
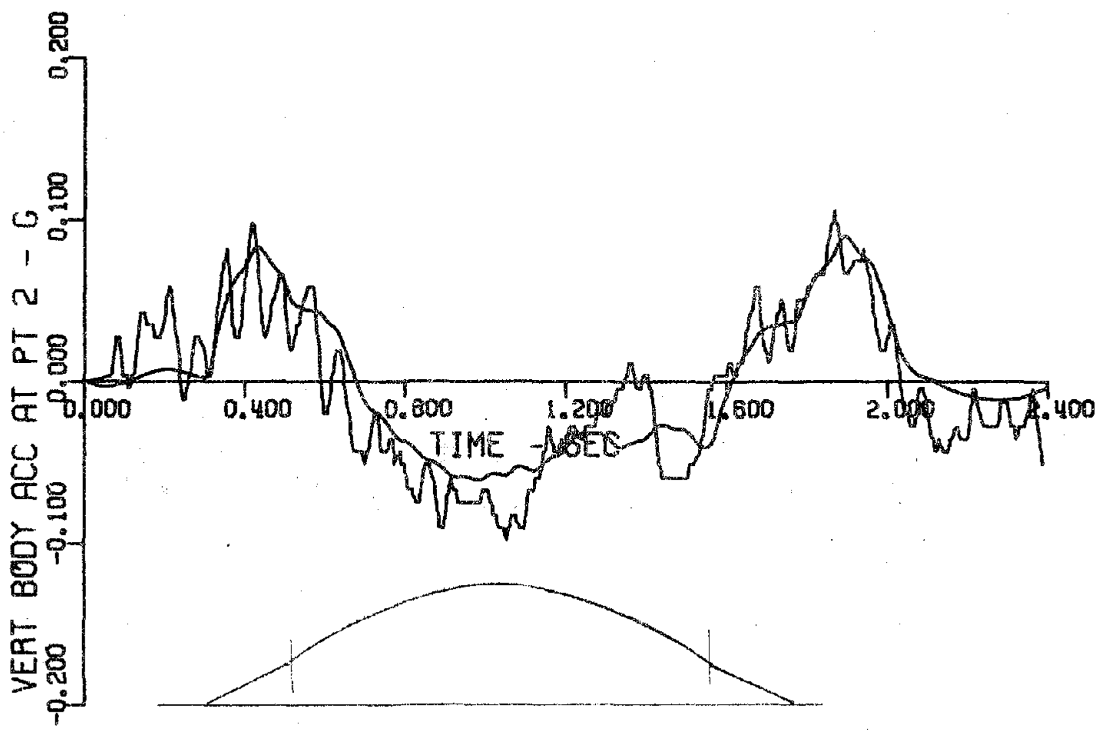


Figure 5-18 Vertical Body Acceleration - Run 43-30 - Nominal Parabola

RUN 43 - -30 TL-104 15 02 13 77 MPH 3.0 IN X 150 FT PARABOLA



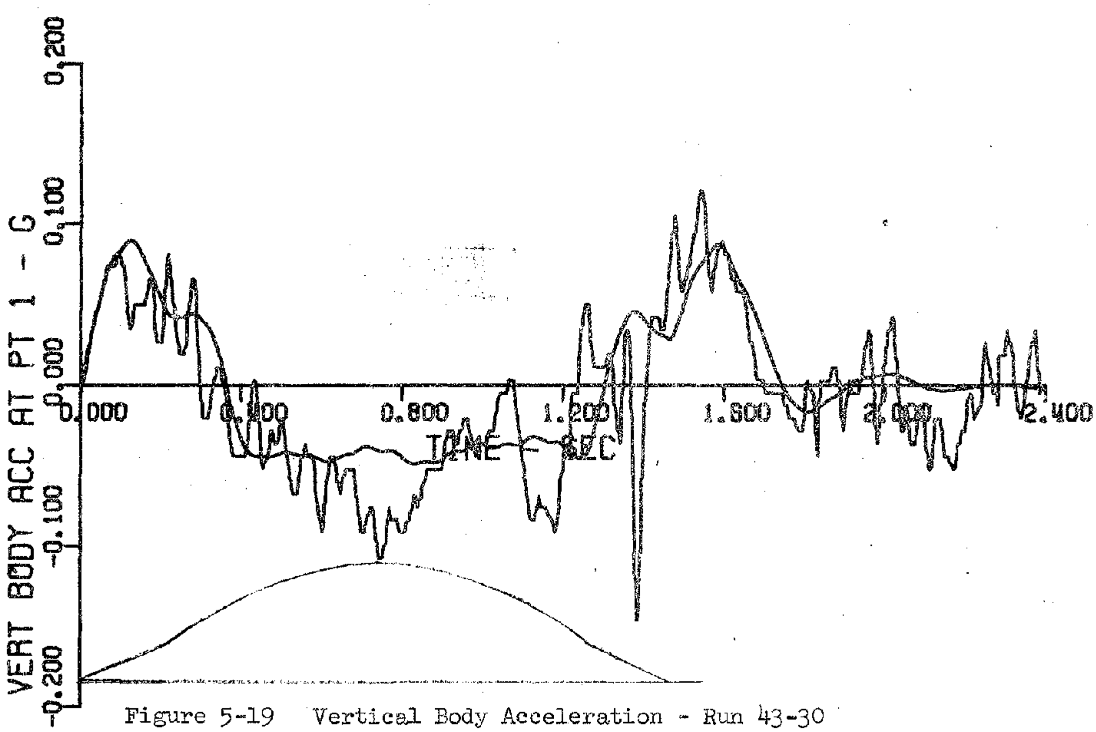


Figure 5-19 Vertical Body Acceleration - Run 43-30

RUN 43 - -30 TL-104 15 02 13 78 MPH 3.0 IN X 150 FT PARABOLA

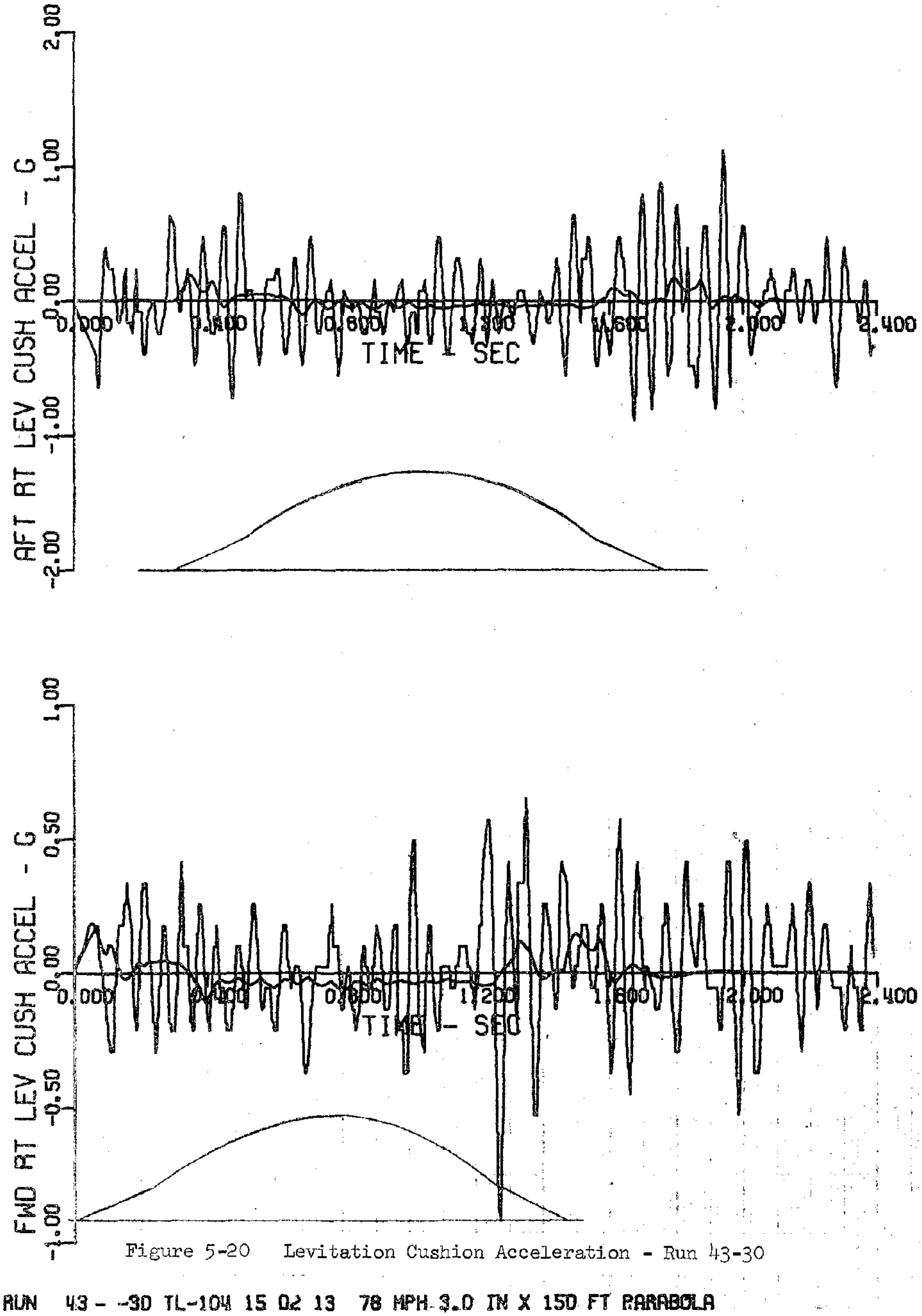


Figure 5-20 Levitation Cushion Acceleration - Run 43-30

RUN 43 - -30 TL-104 15 02 13 78 MPH 3.0 IN X 150 FT PARABOLA

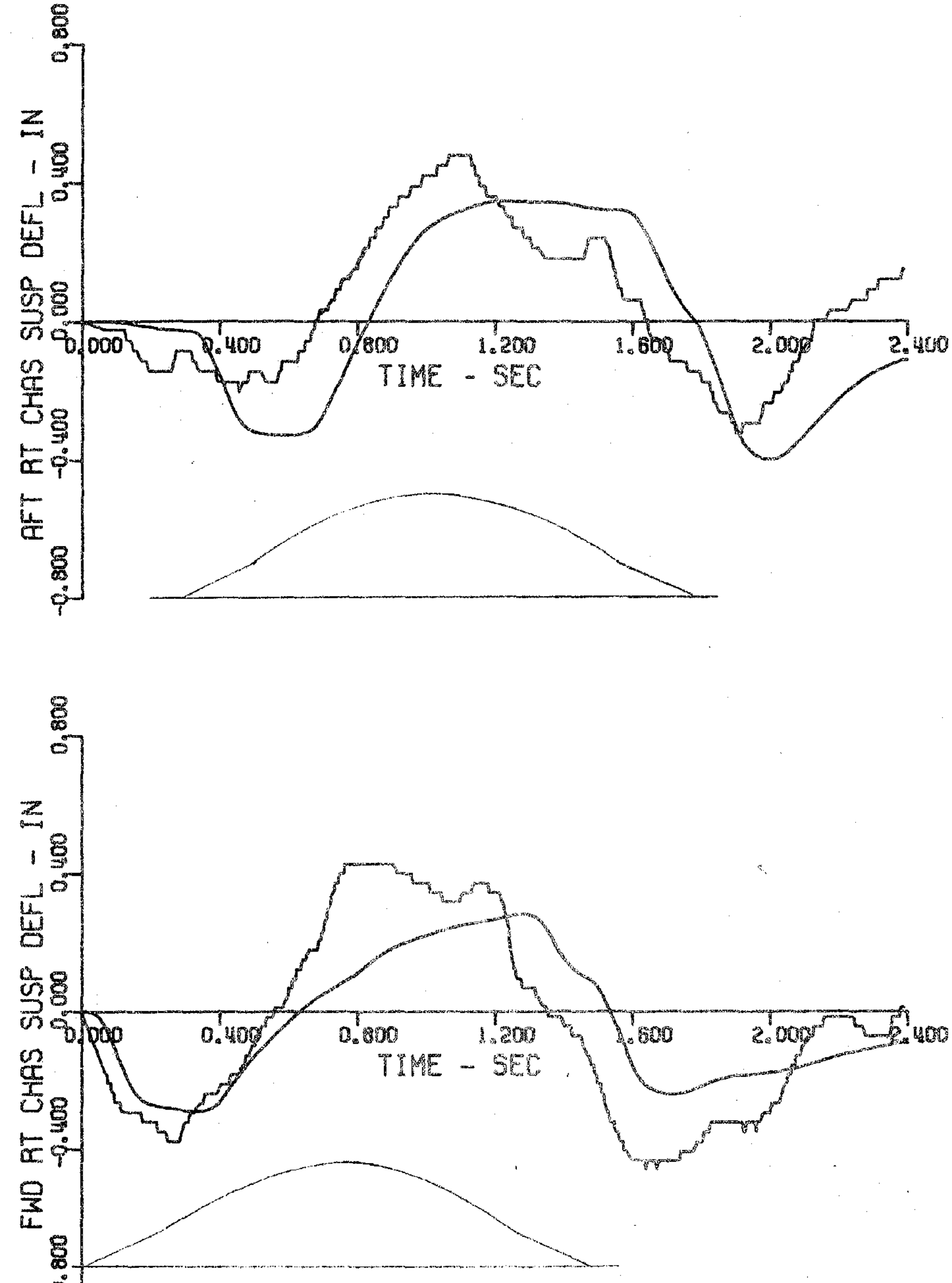


Figure 5-21 Chassis Suspension Deflection - Run 43-30

RUN 43 - -30 TL-104 15 02 13 78 MPH-3.0 IN X 150 FT PARABOLA

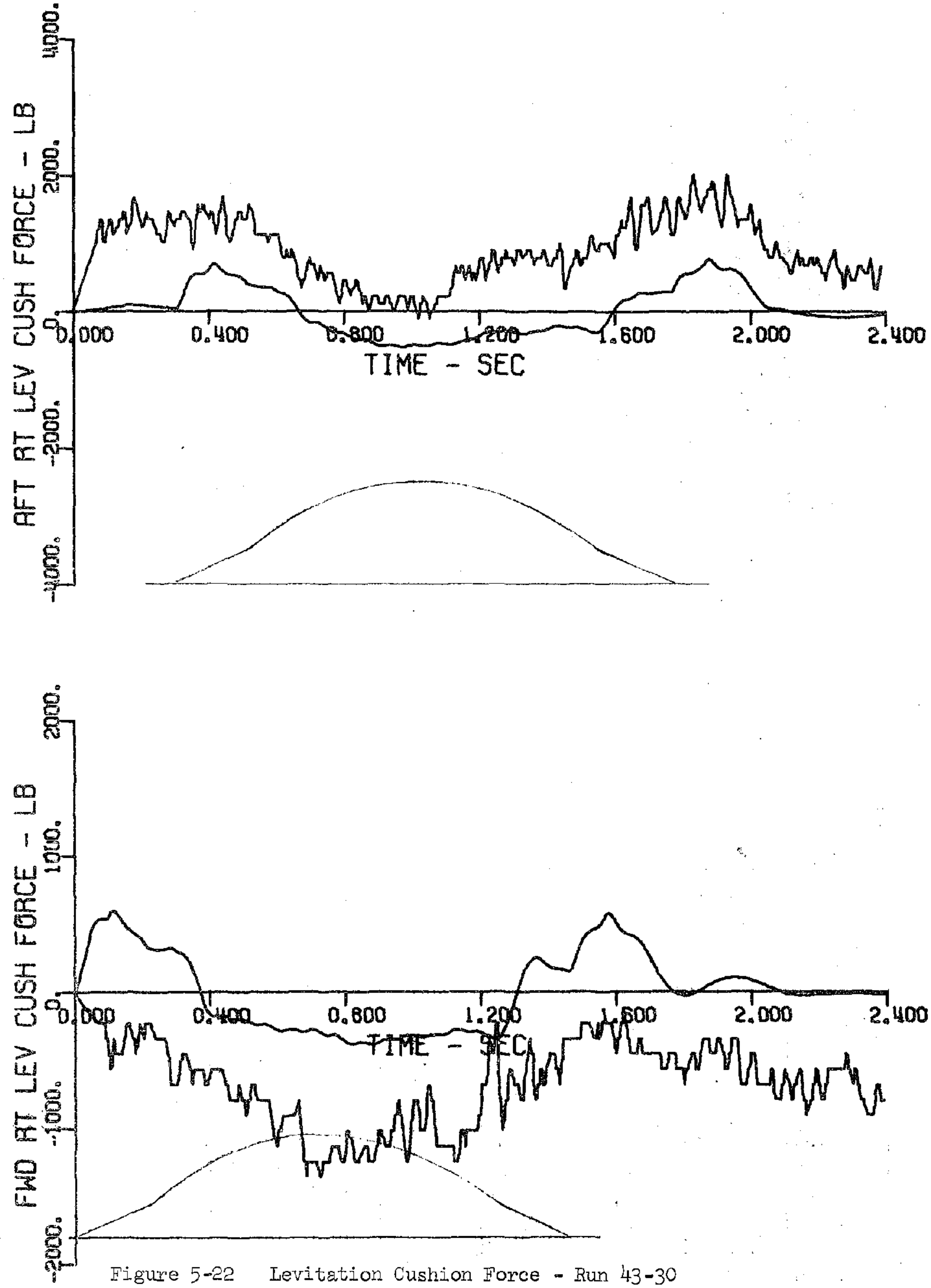


Figure 5-22 Levitation Cushion Force - Run 43-30

RUN 43 - -30 TL-104 15 02 13 78 MPH 3.0 IN X 150 FT PARABOLA

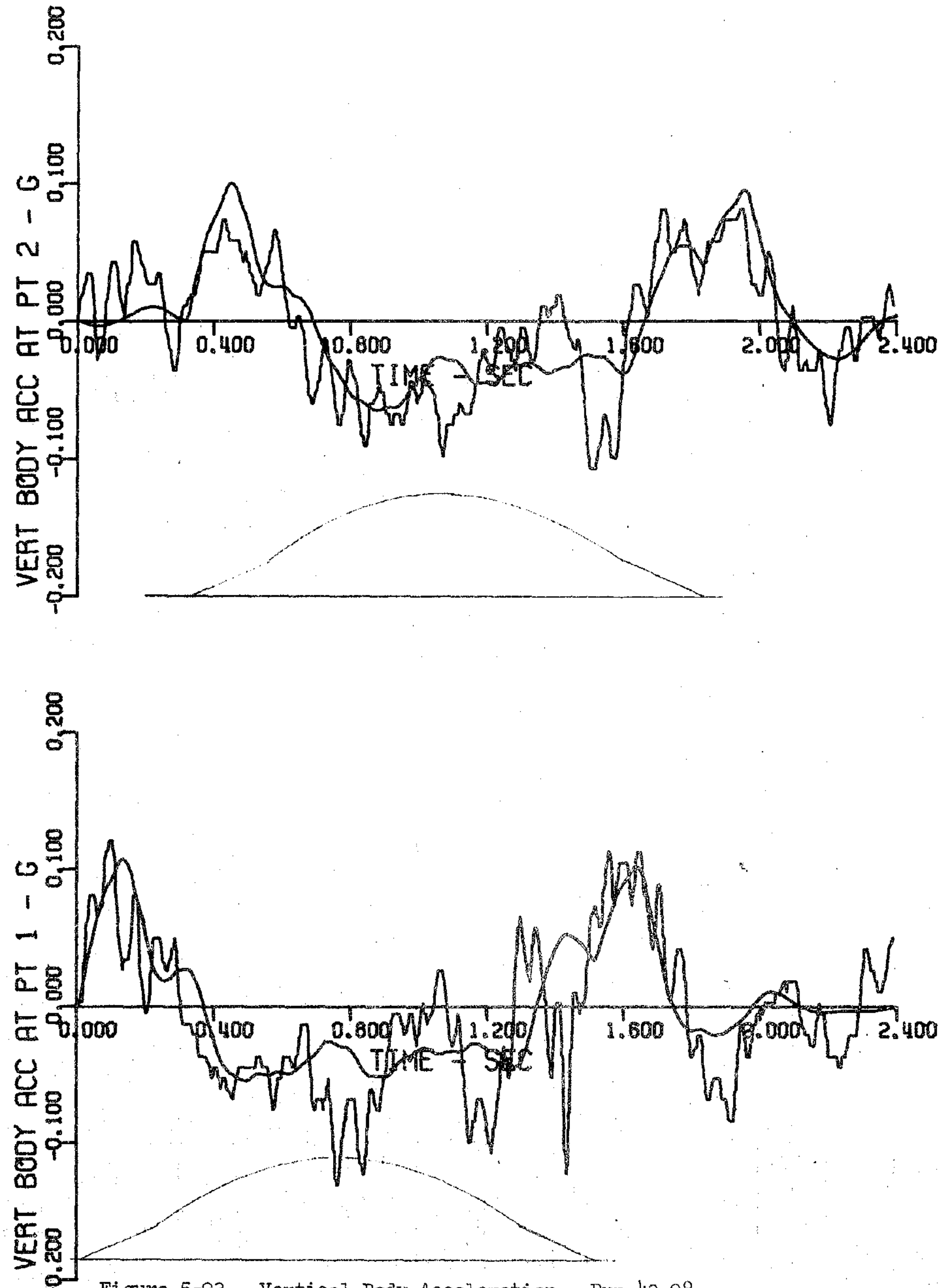


Figure 5-23 Vertical Body Acceleration - Run 43-28

RUN 43 - 28 TL-104 16 02 04 76 MPH 3.0 IN X 150 FT PARABOLA

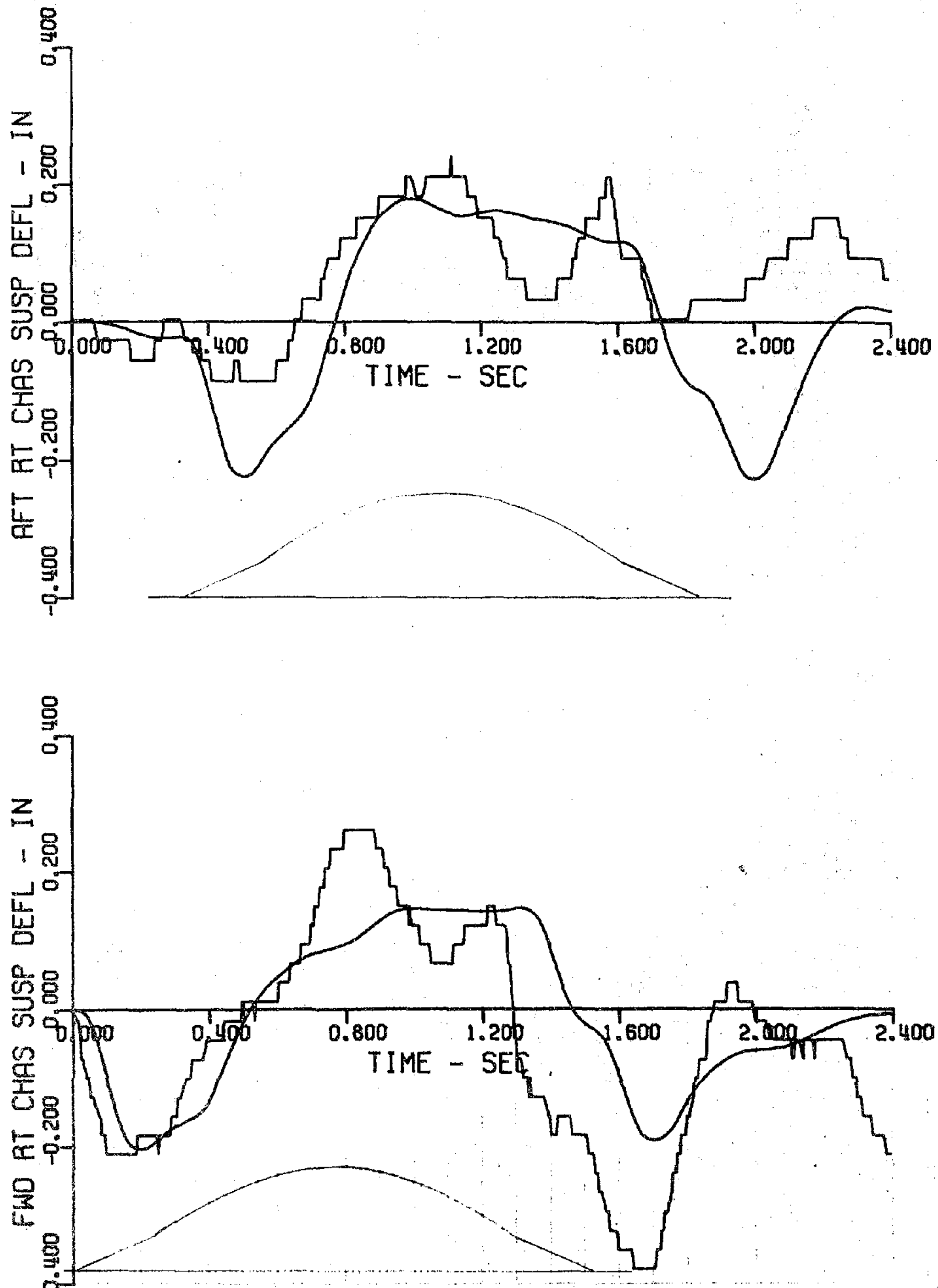


Figure 5-24 Chassis Suspension Deflection - Run 43-28

RUN 43 - 28 TL-104 16 02 04 76 MPH 3.0 IN X 150 FT PARABOLA

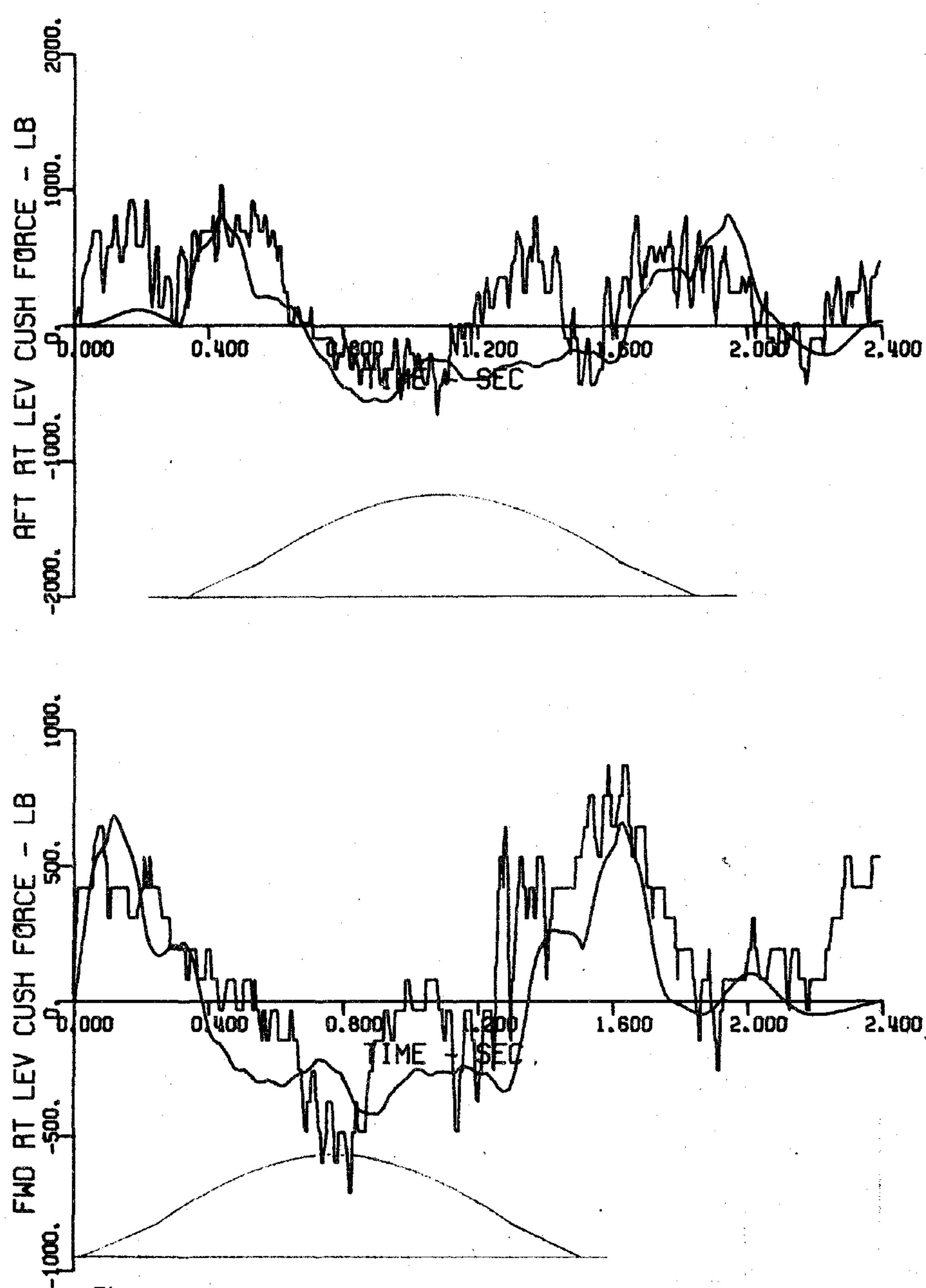


Figure 5-25 Levitation Cushion Force - Run 43-28

RUN 43 - 28 TL-104 16 02 04 76 MPH 3.0 IN X 150 FT PARABOLA

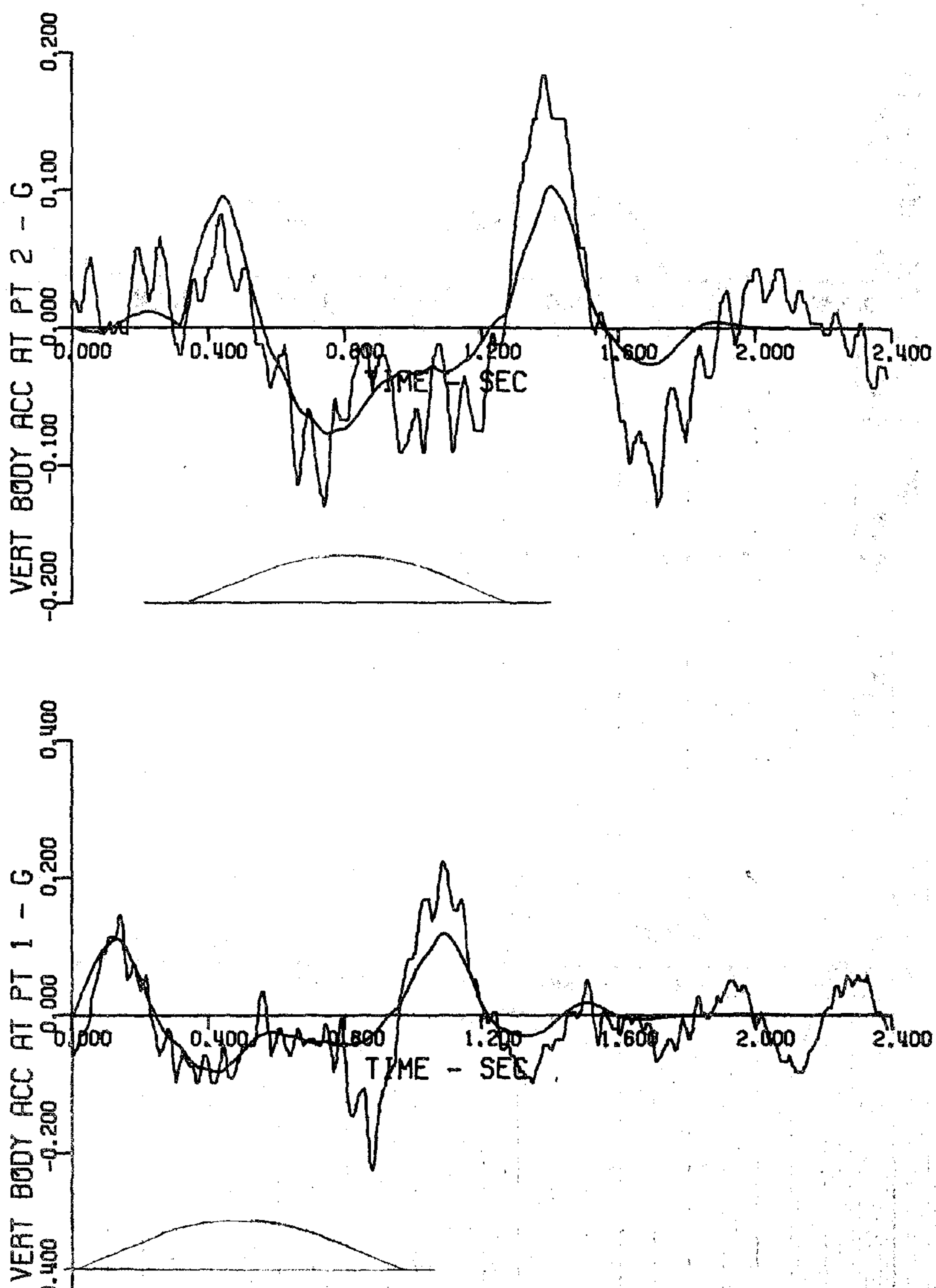
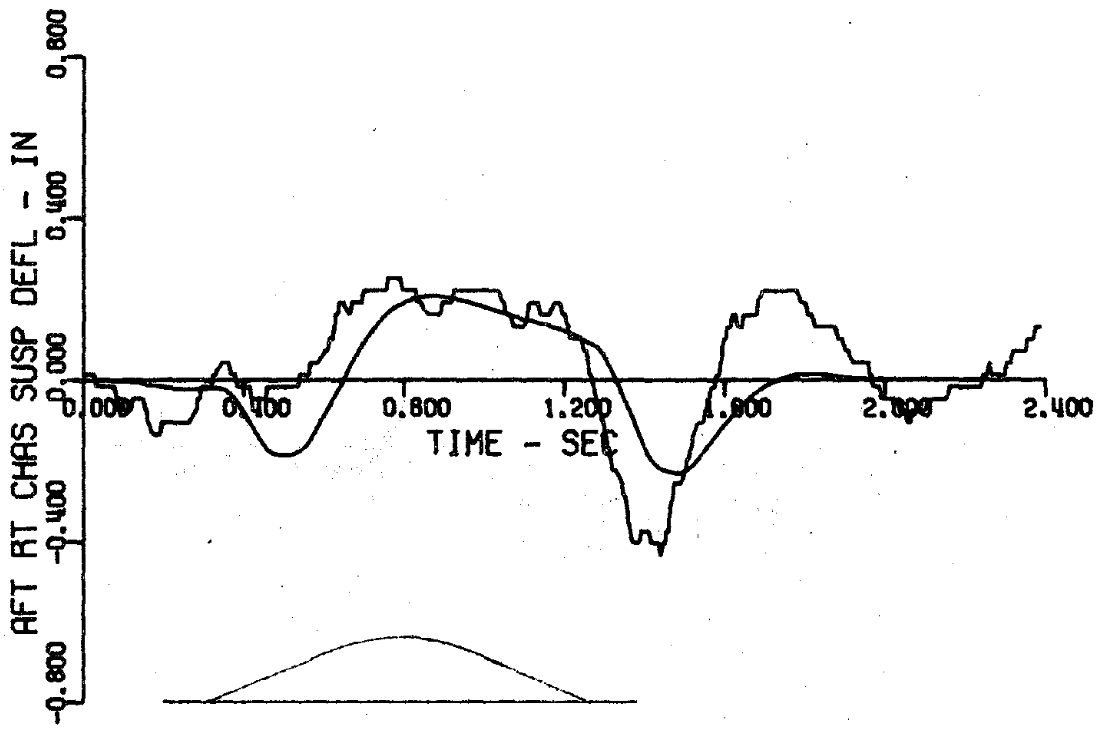


Figure 5-26 Vertical Body Acceleration - Run 43-12

RUN 43 - 12 TL-102 11 52 17 76 MPH 1.5 IN X 106 FT PARABOLA



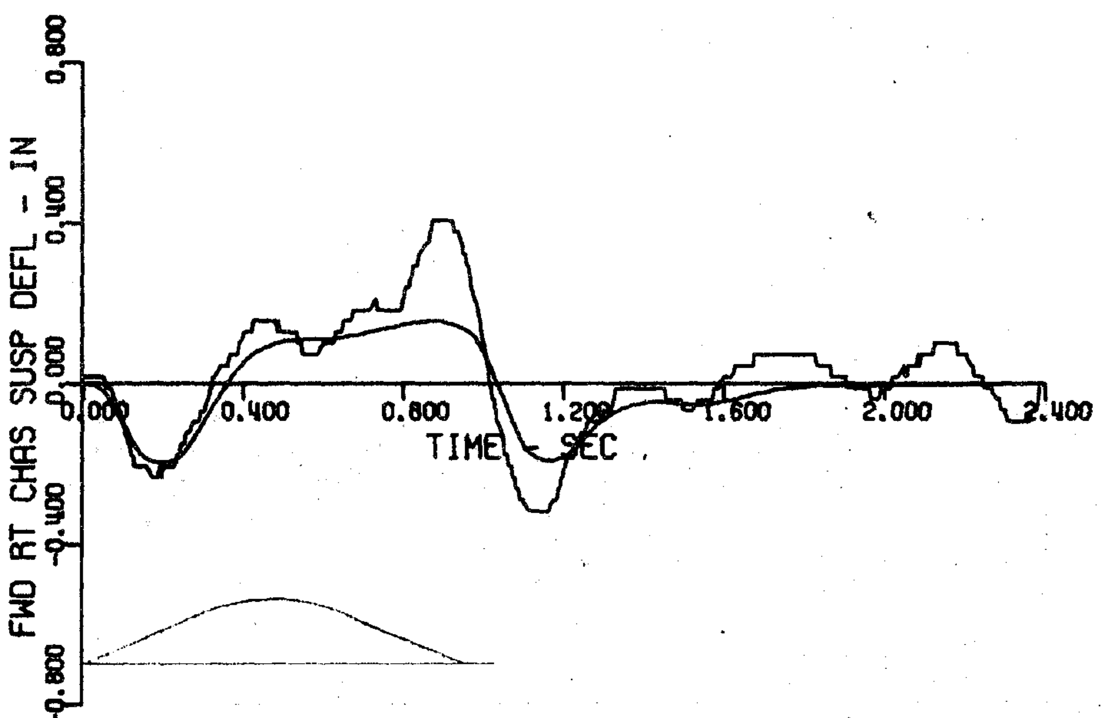


Figure 5-27 Chassis Suspension Deflection - Run 43-12

RUN 43 - 12 TL-102 11 52 17 78 MPH 1.5 IN X 106 FT PARABOLA

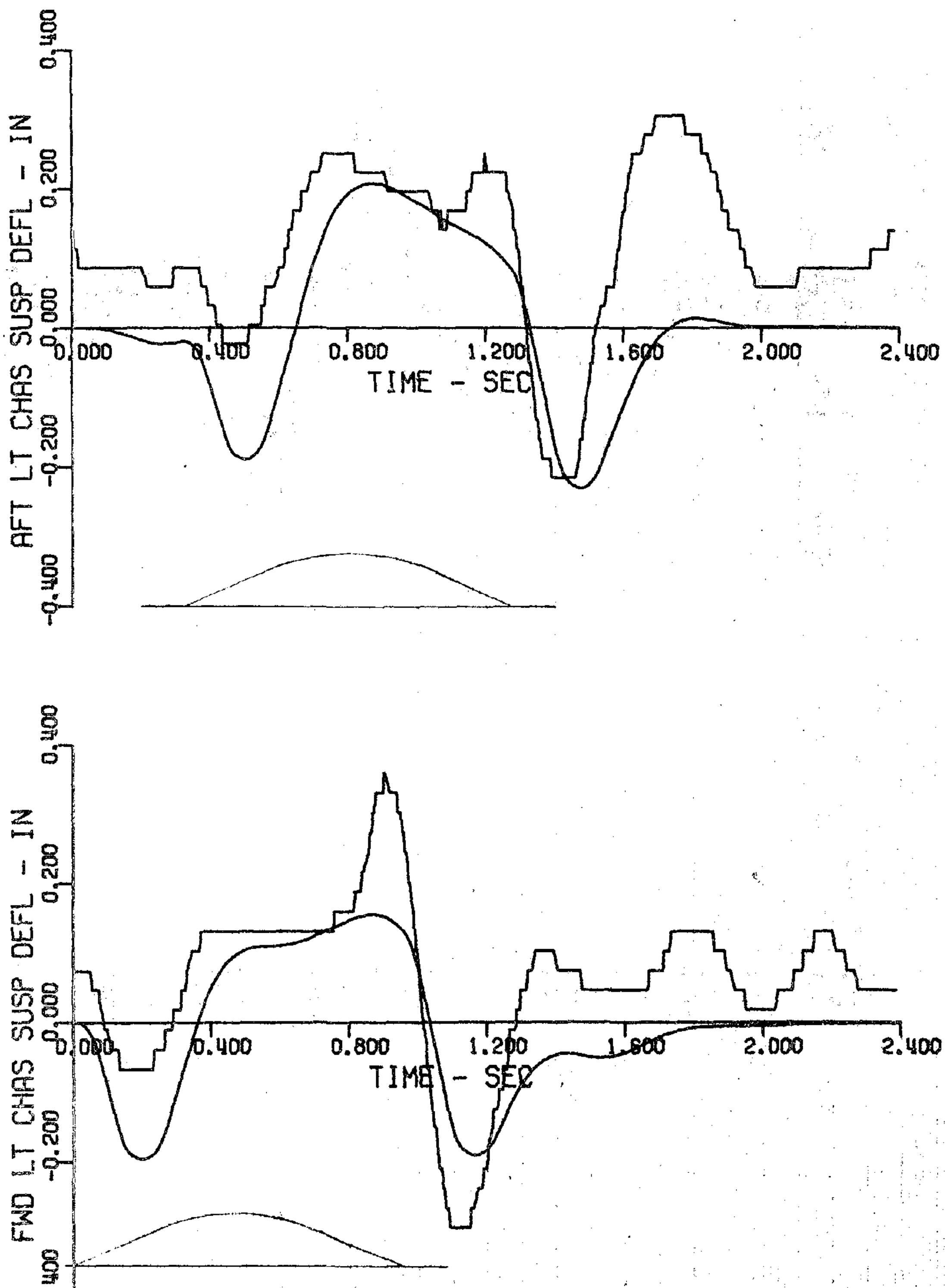


Figure 5-28 Chassis Suspension Deflection - Run 43-12

RUN 43 - 12 TL-102 11 52 17 76 MPH-1.5 IN X 106 FT PARABOLA

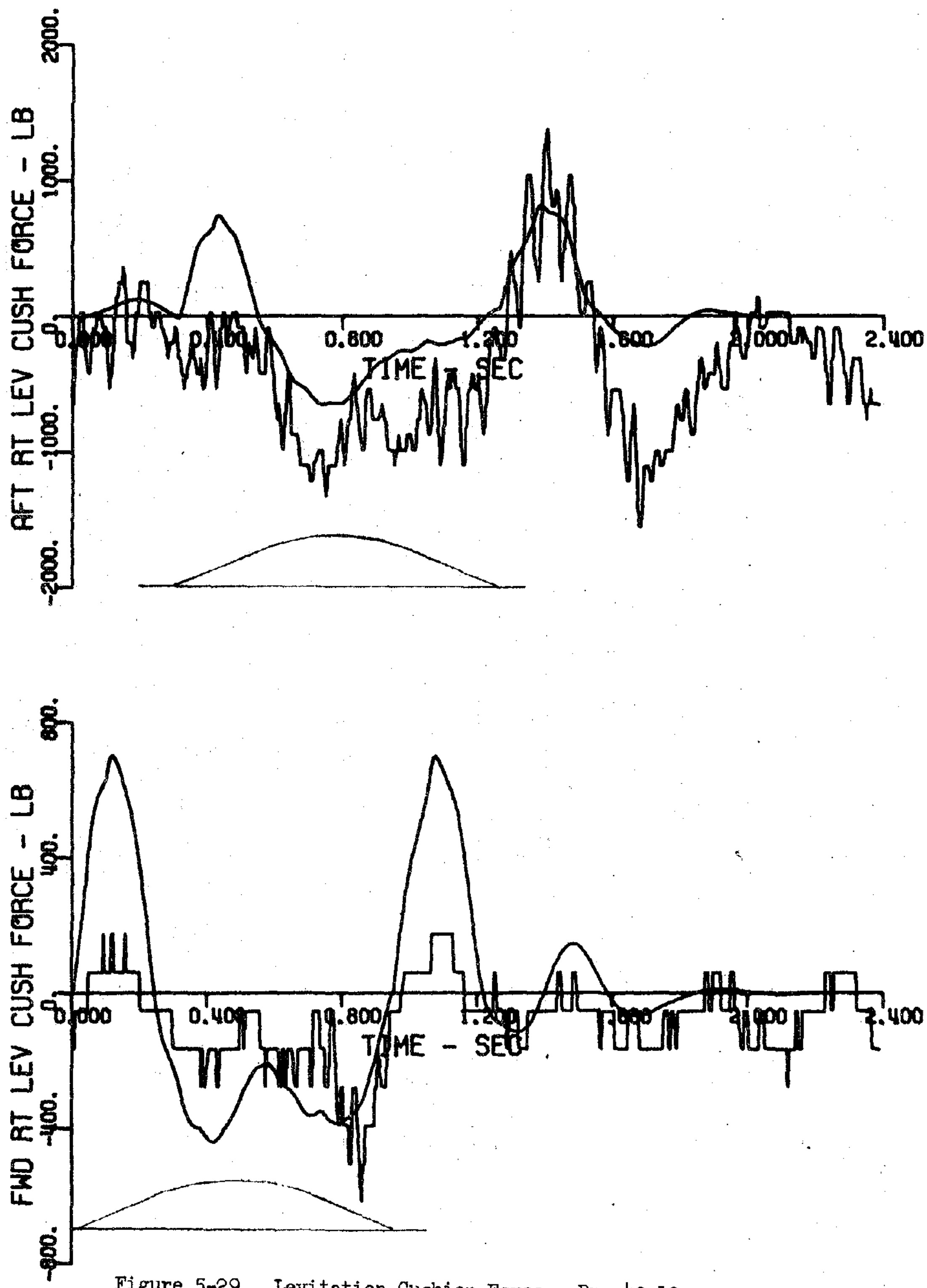
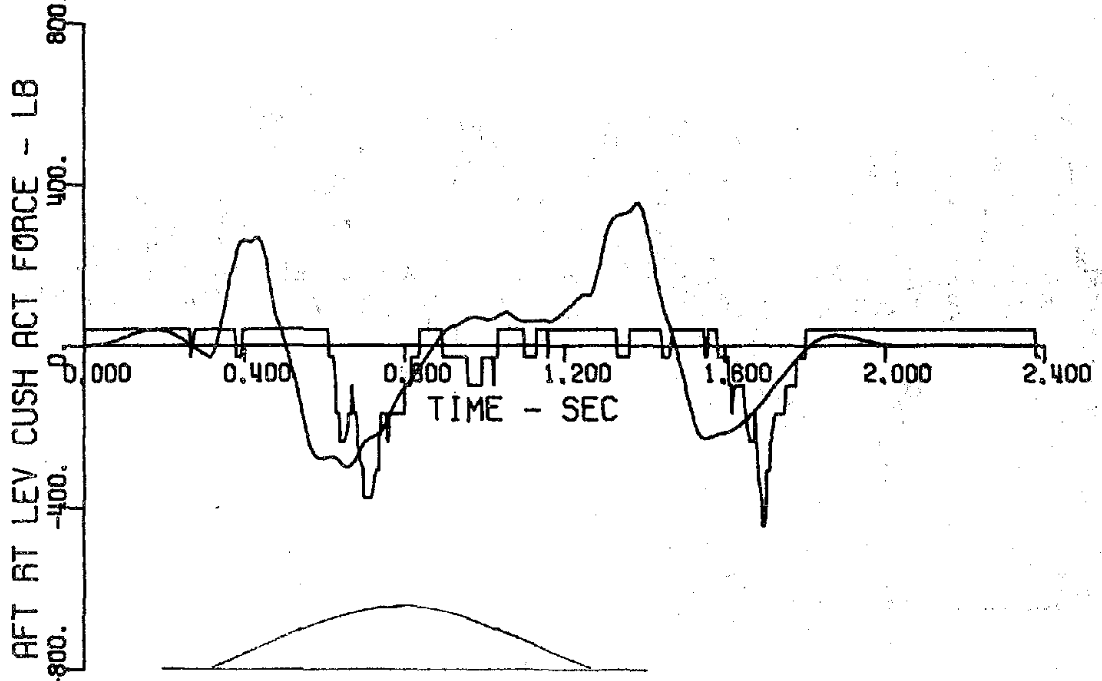


Figure 5-29 Levitation Cushion Force - Run 43-12

RUN 43 - 12 TL-102 11 52 17 76 MPH 1.5 IN X 106 FT PARABOLA



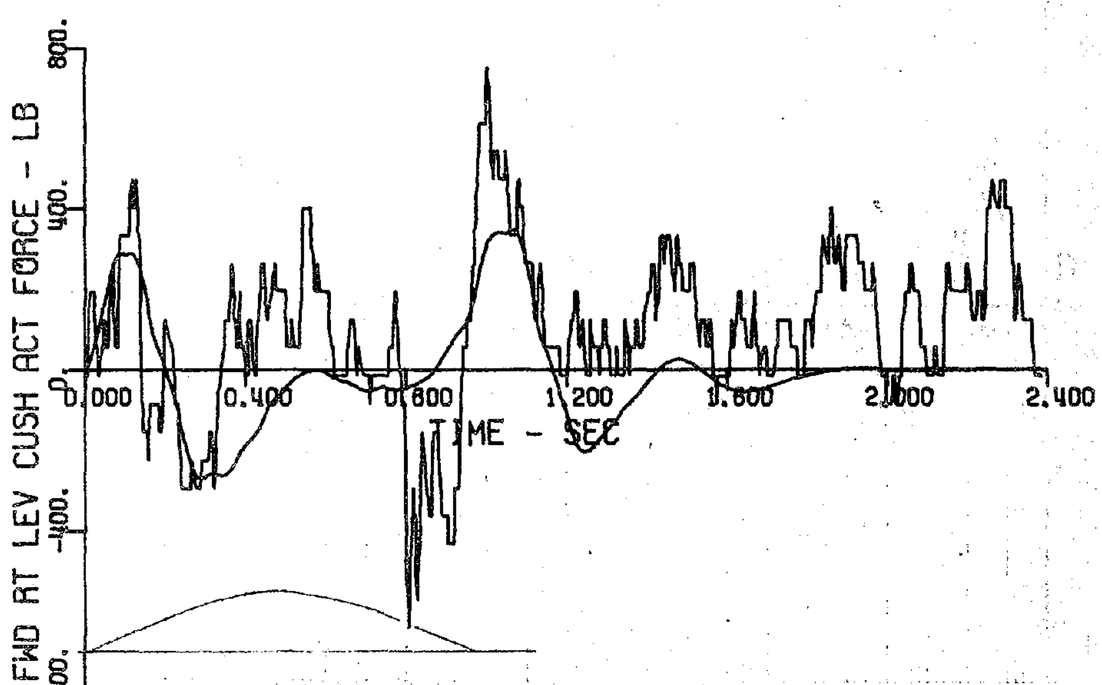


Figure 5-30 Levitation Cushion Actuator Force - Run 43-12

RUN 43 - 12 TL-102 11 52 17 76 MPH 1.5 IN X 106 FT PARABOLA

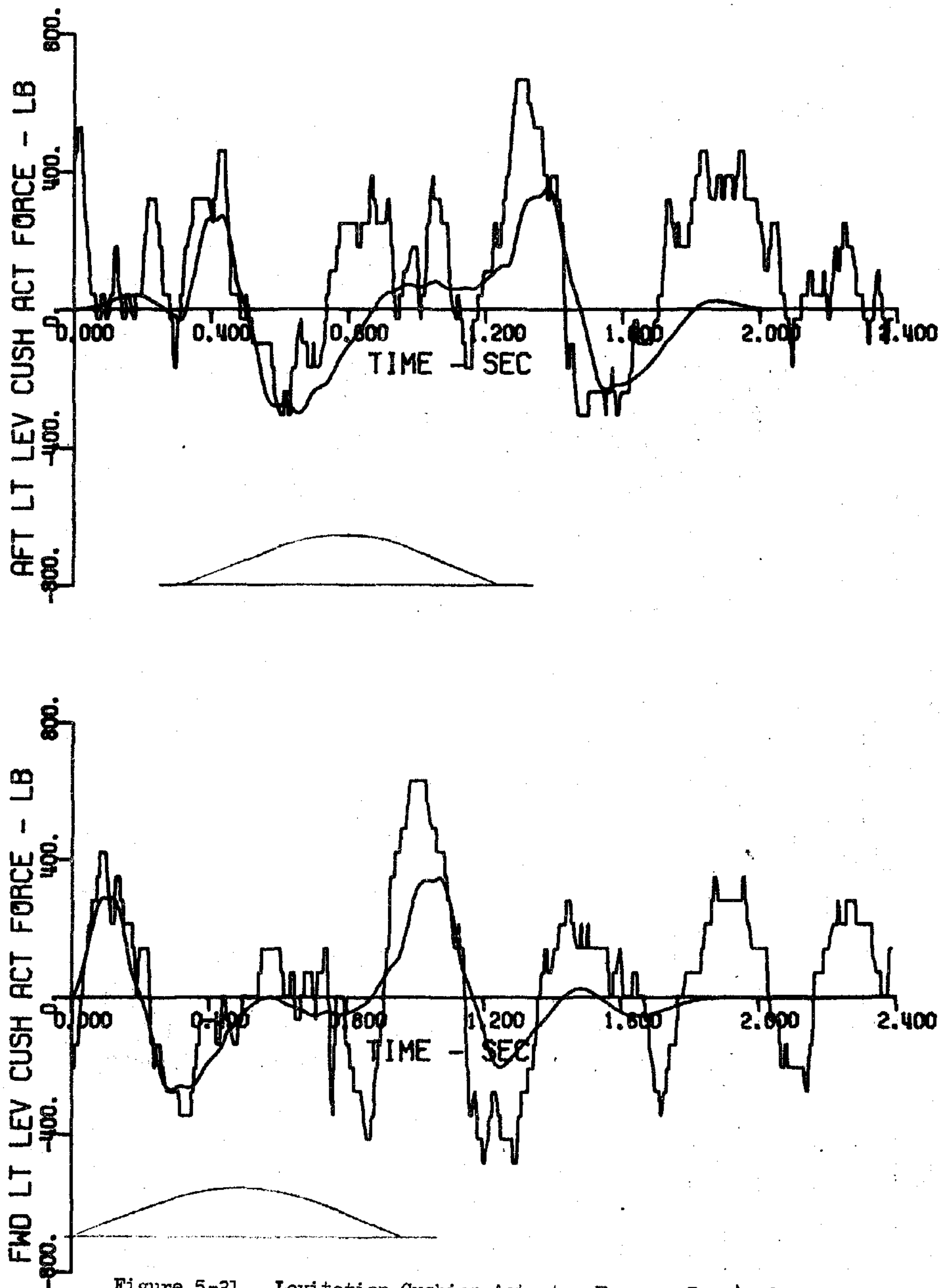


Figure 5-31 Levitation Cushion Actuator Force - Run 43-12

RUN 43 - 12 TL-102 11 52 17 76 MPH 1.5 IN X 106 FT PARABOLA

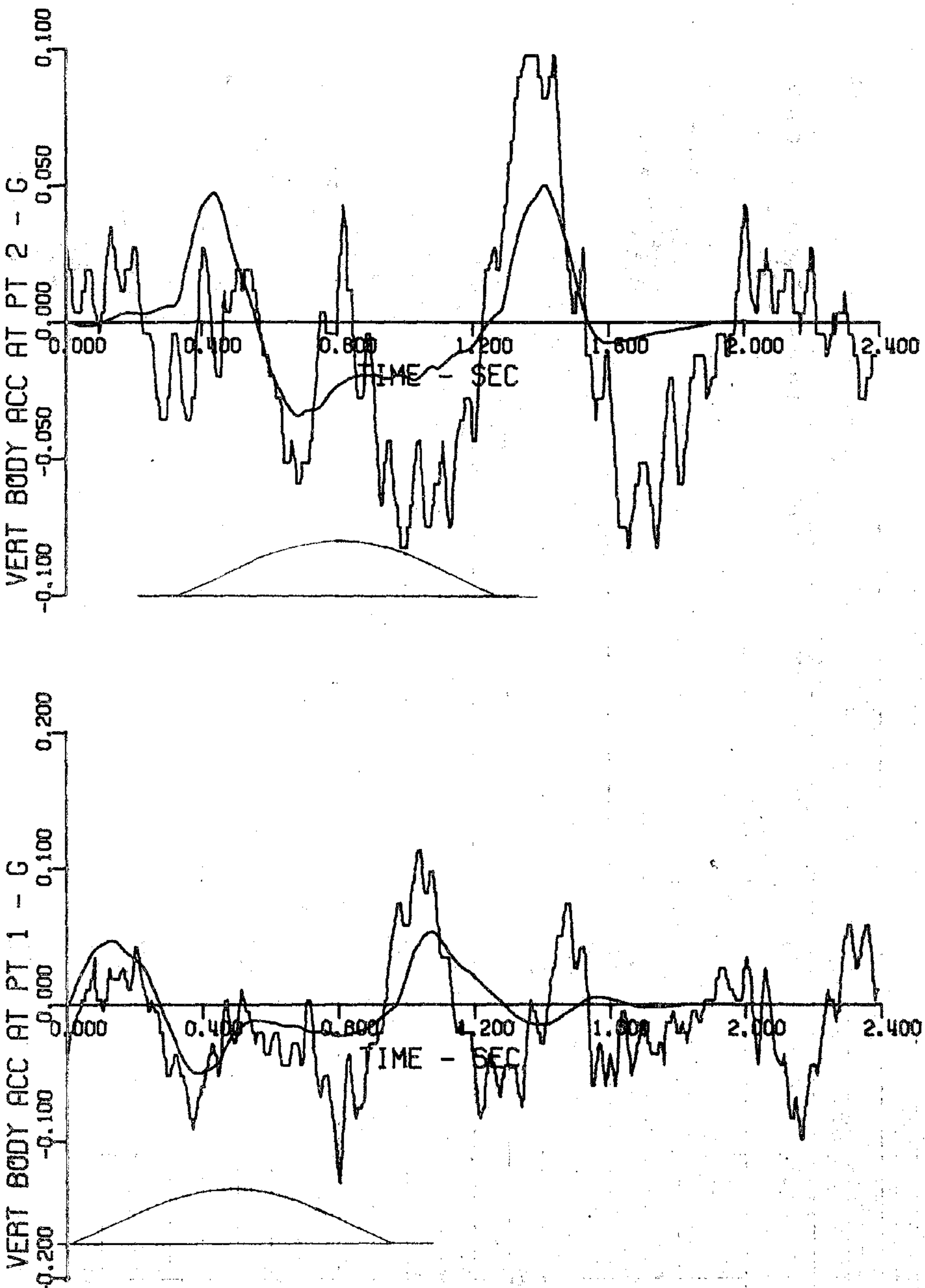
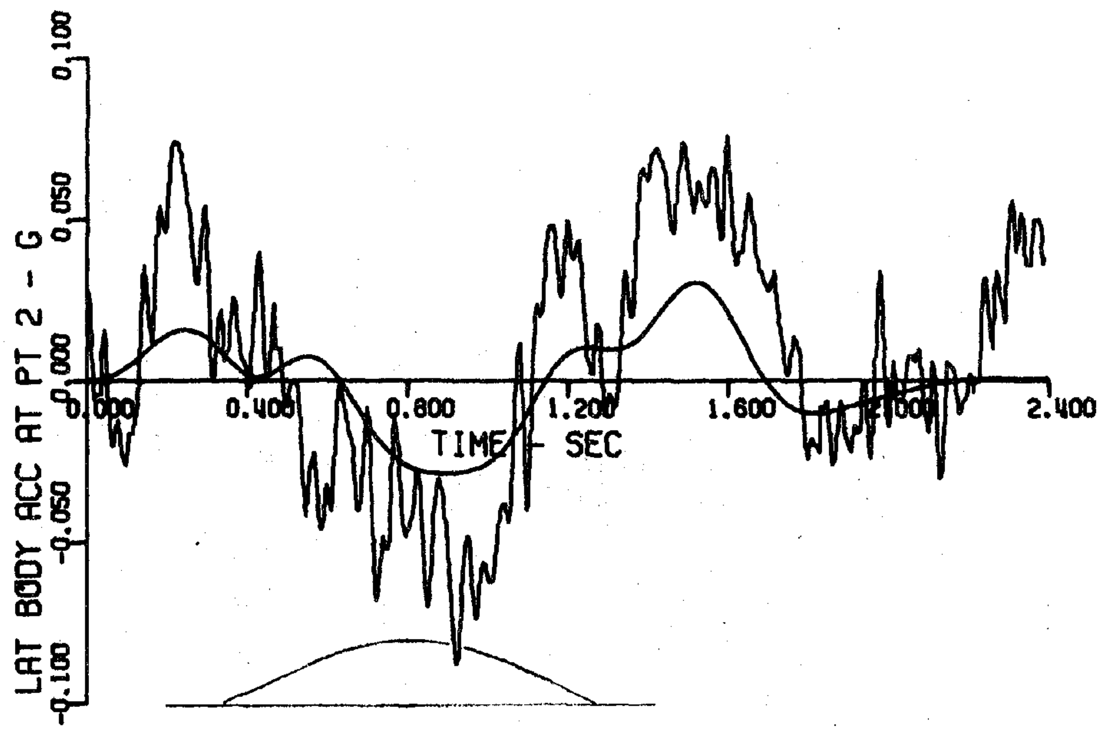


Figure 5-32 Vertical Body Acceleration - Run 44-12

RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASTM PARABOLA



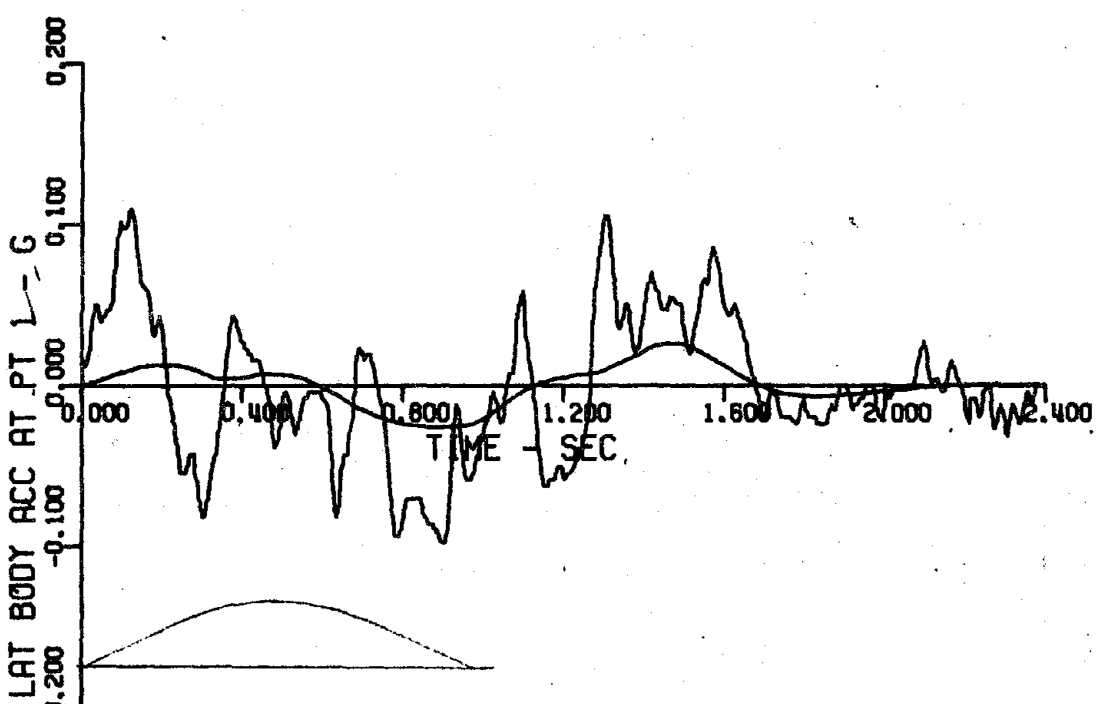


Figure 5-33 Laterial Body Acceleration - Run 44-12

RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 108 FT ASYM PARABOLA

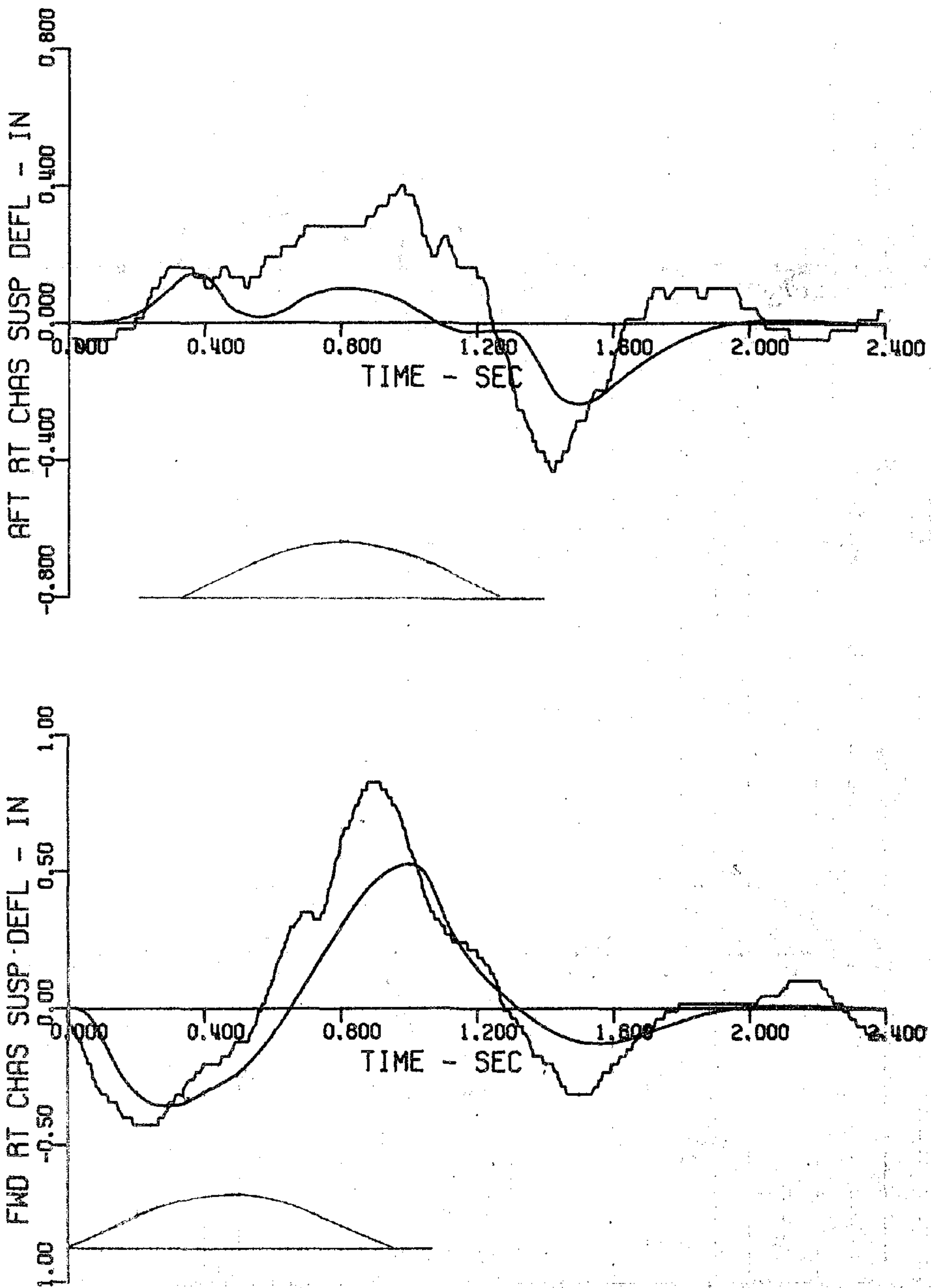
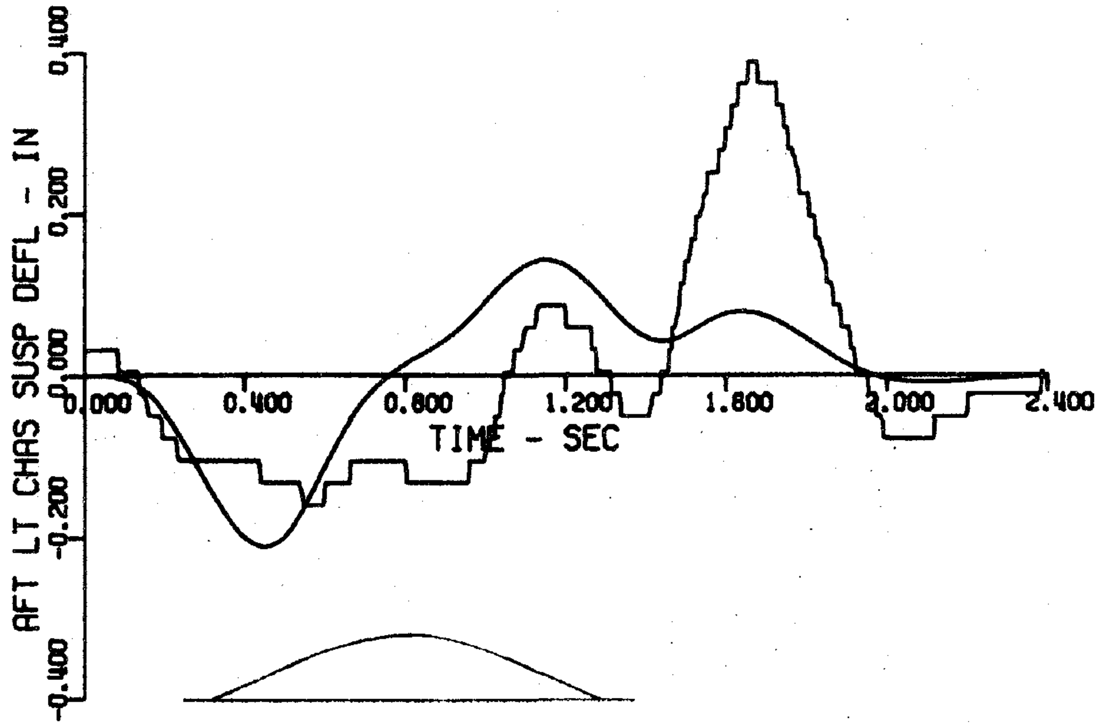


Figure 5-34 Right Chassis Suspension Deflection - Run 44-12

RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASYM PARABOLA



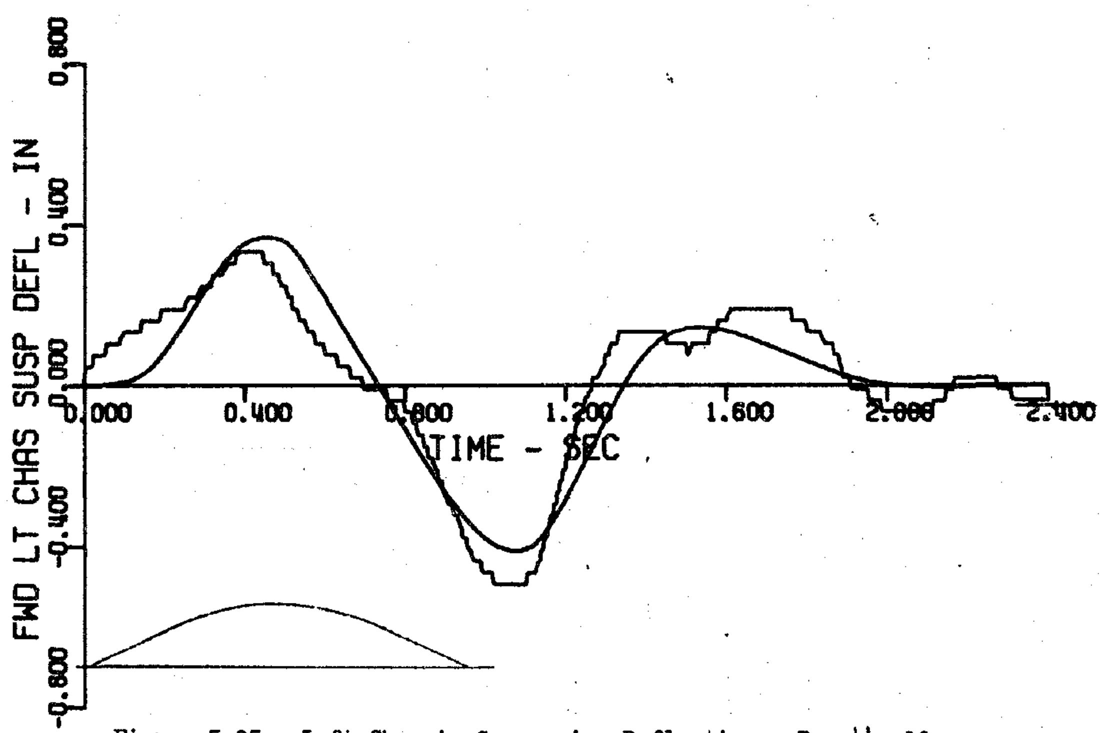


Figure 5-35 Left Chassis Suspension Deflection - Run 44- 12

RUN 44- 12 TL-103 11 14 54 75 MPH 1.5 IN X 108 FT ASYM PARABOLA

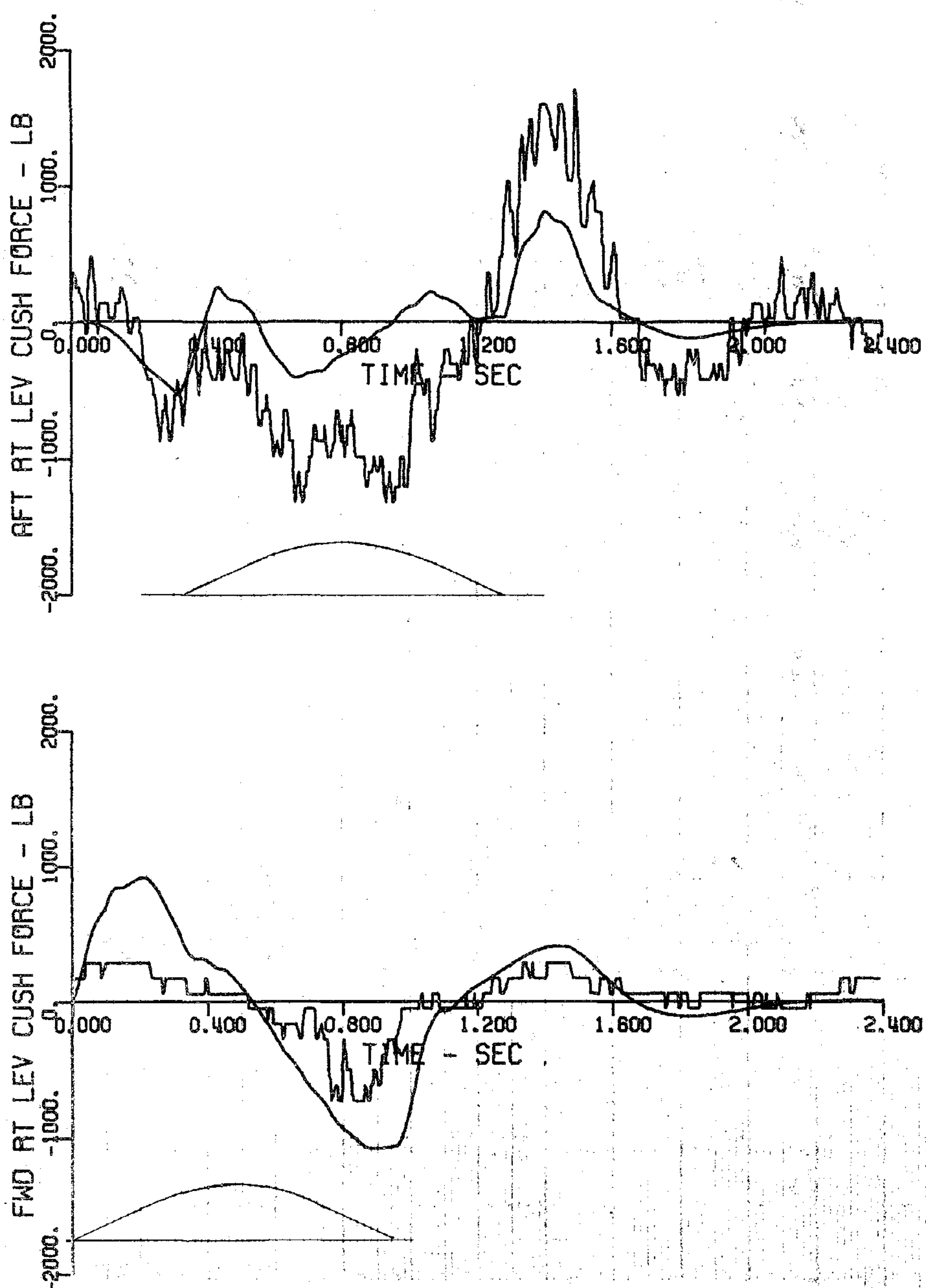


Figure 5-36 Right Levitation Cushion Force - Run 44-12

RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASYM PARABOLA

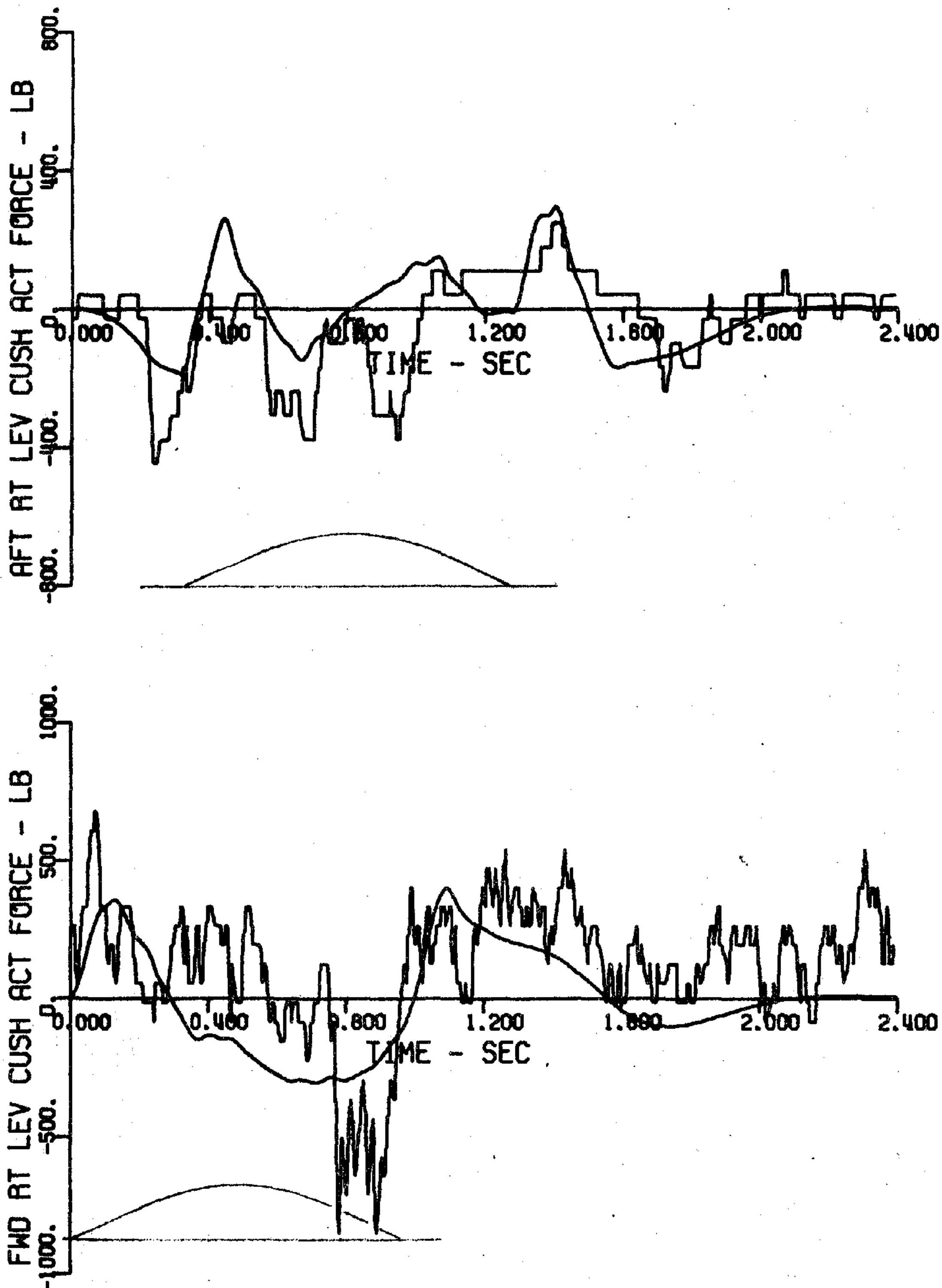


Figure 5-37 Right Levitation Cushion Actuator Force - Run 44-12

RUN 44- 12 TL-103 11 14 54 75 MPH 1.5 IN X 108 FT ASYM PARABOLA

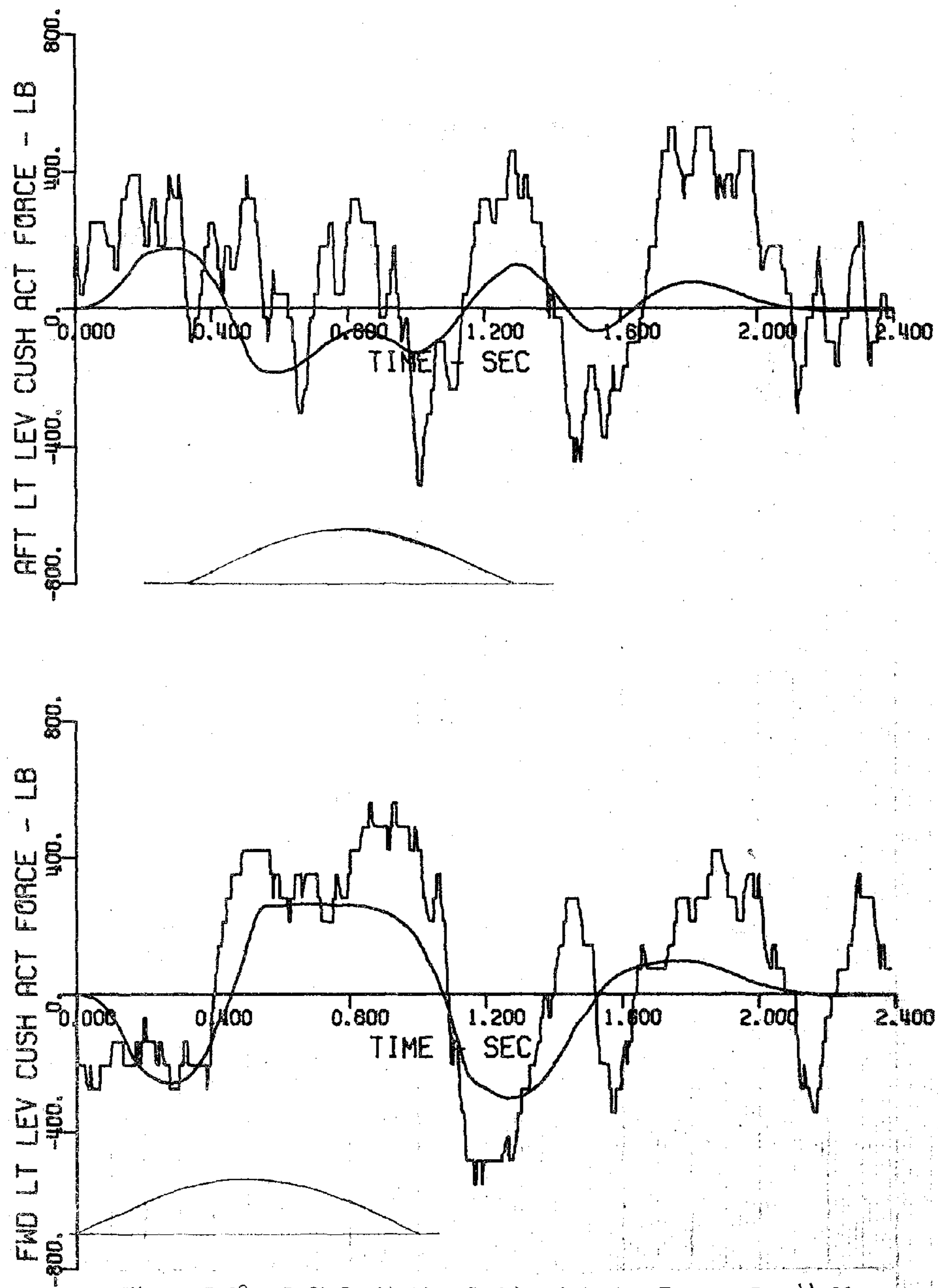
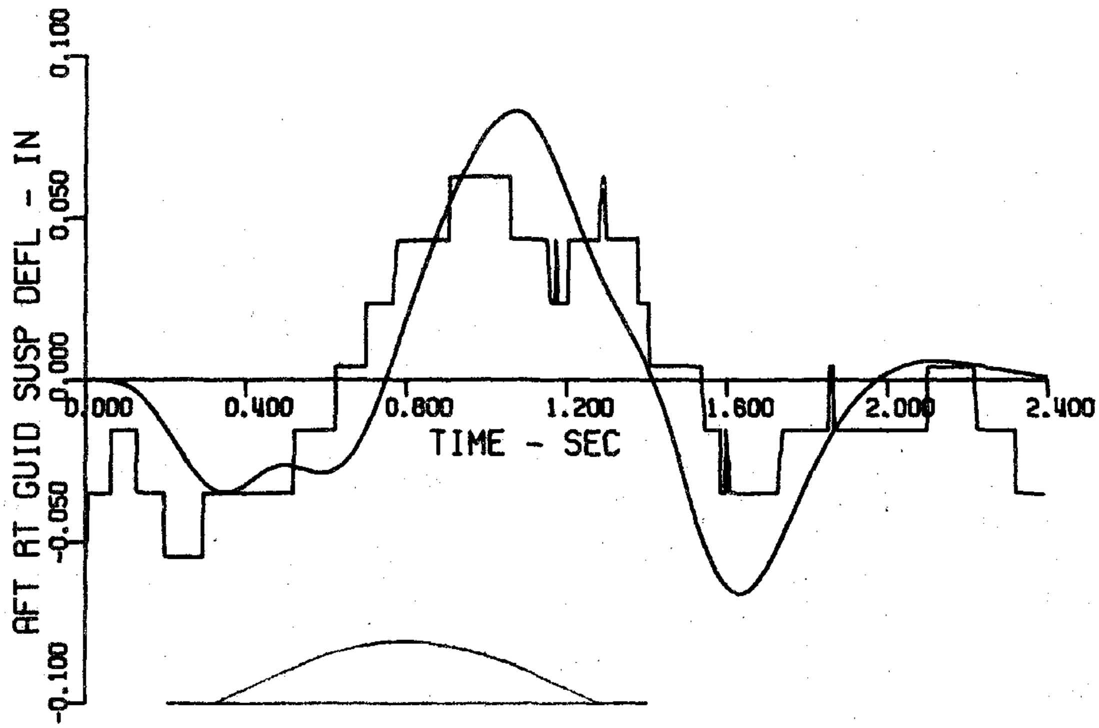


Figure 5-38 Left Levitation Cushion Actuator Force - Run 44-12

RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASYM PARABOLA



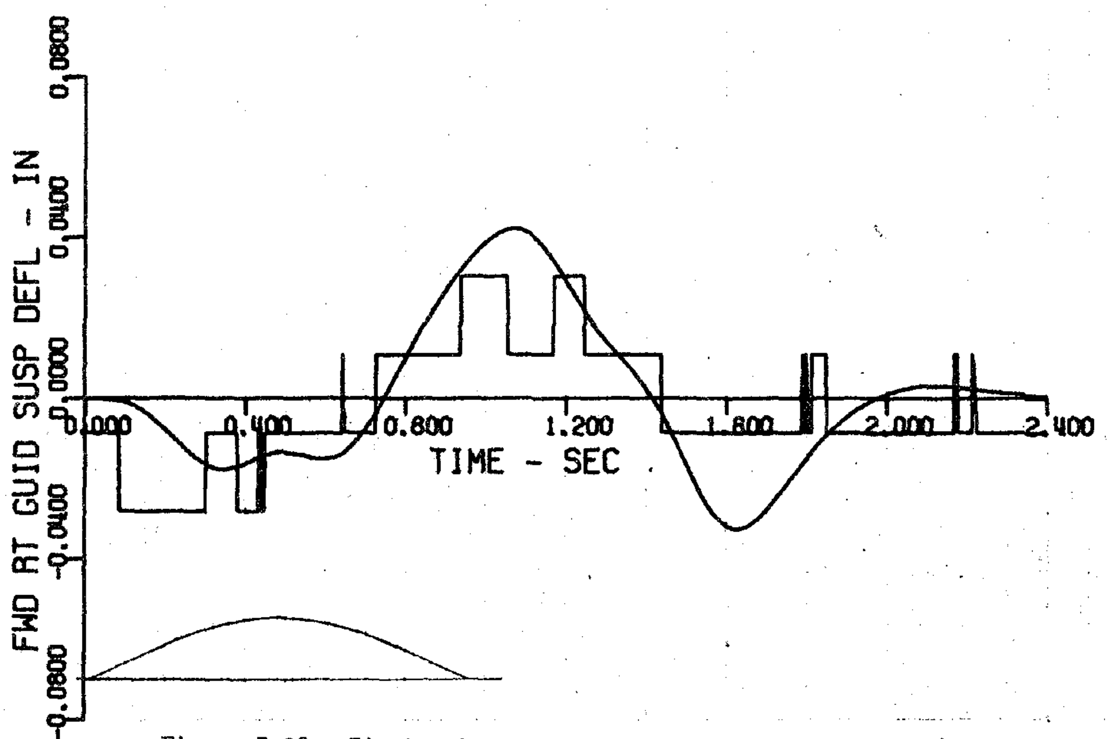


Figure 5-39 Right Guidance Suspension Deflection - Run 44-12

RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASTM PARABOLA

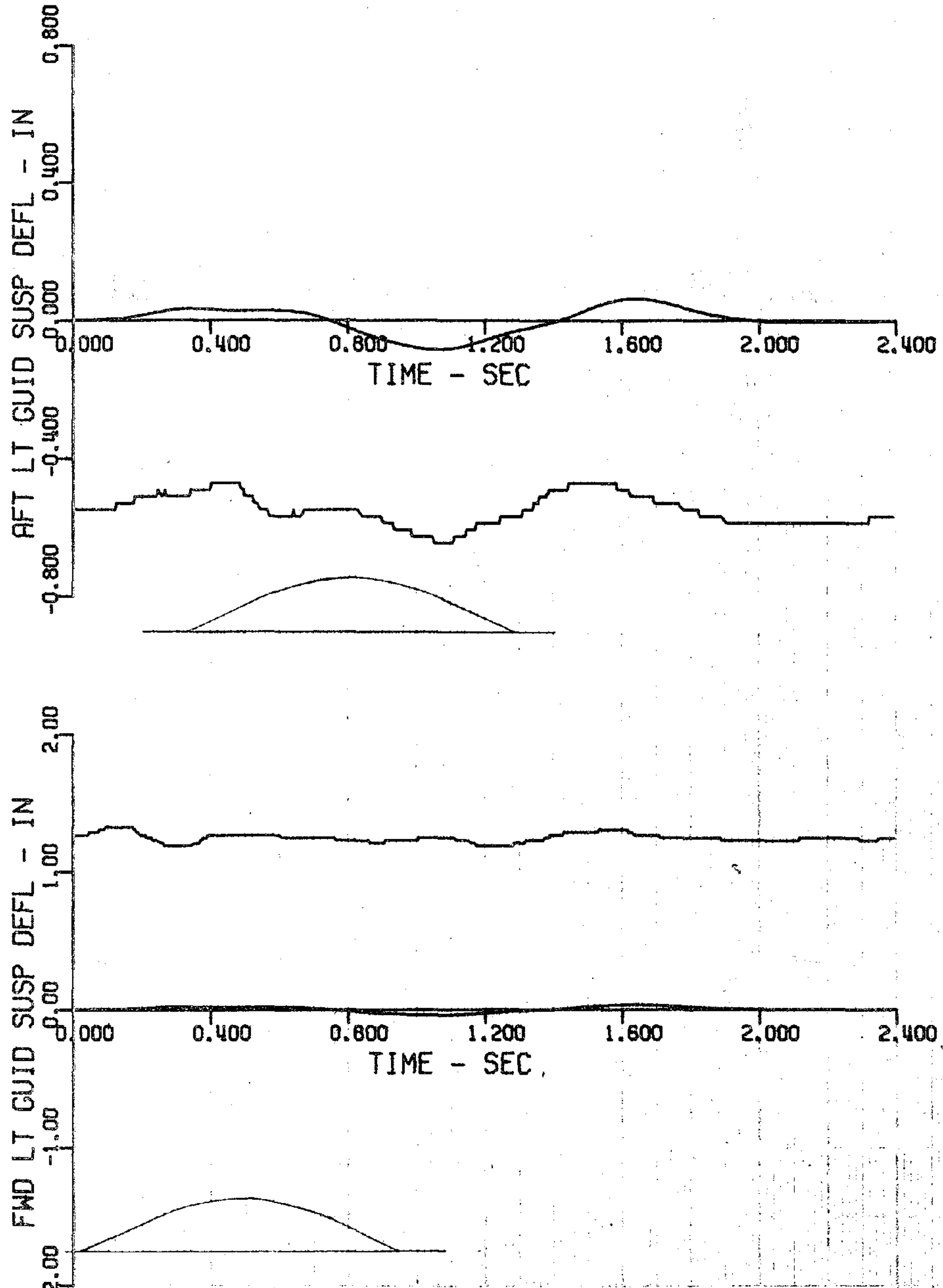


Figure 5-40 Left Guidance Suspension Deflection - Run 44-12

RUN 44- 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASYM PARABOLA

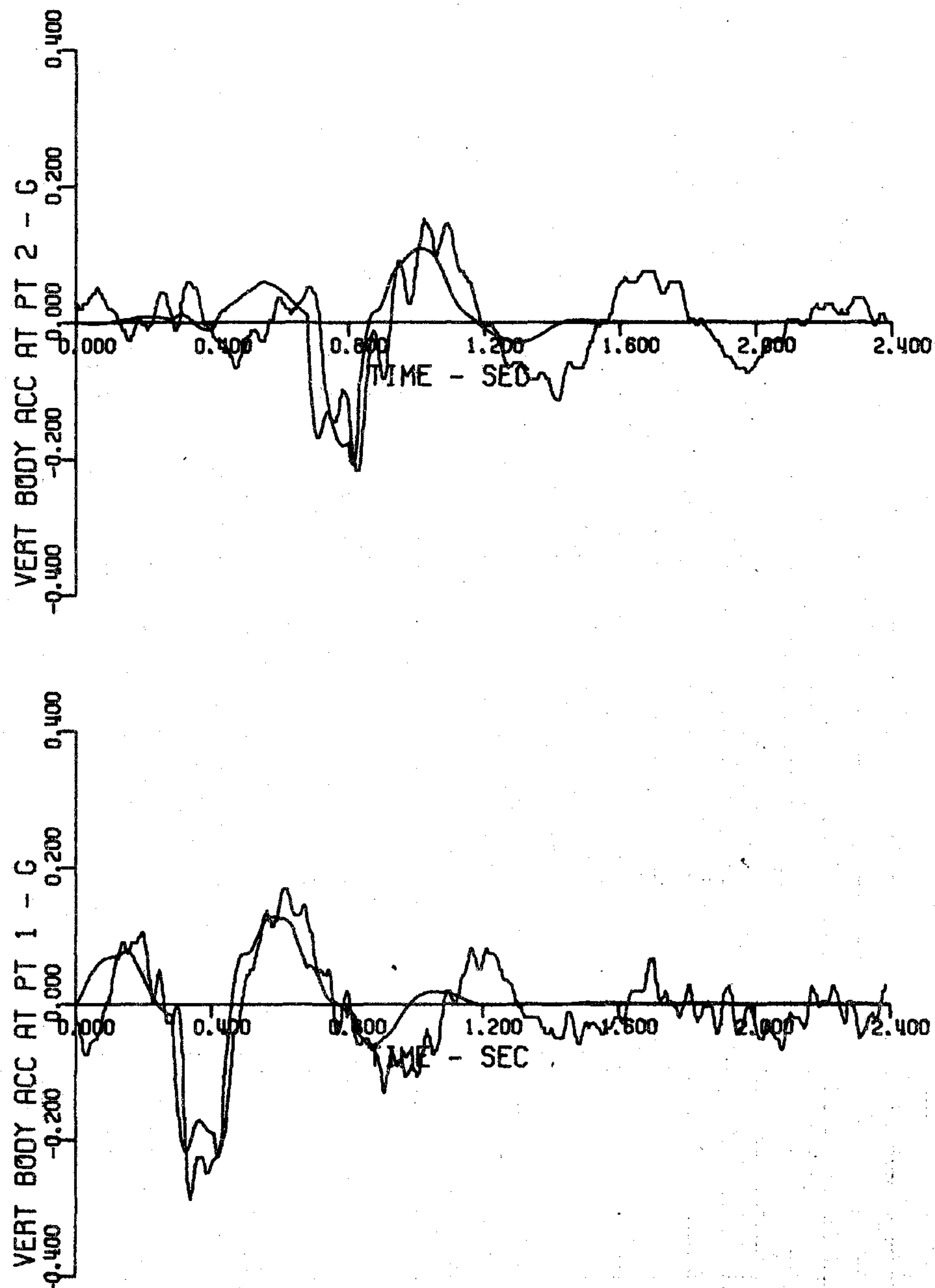
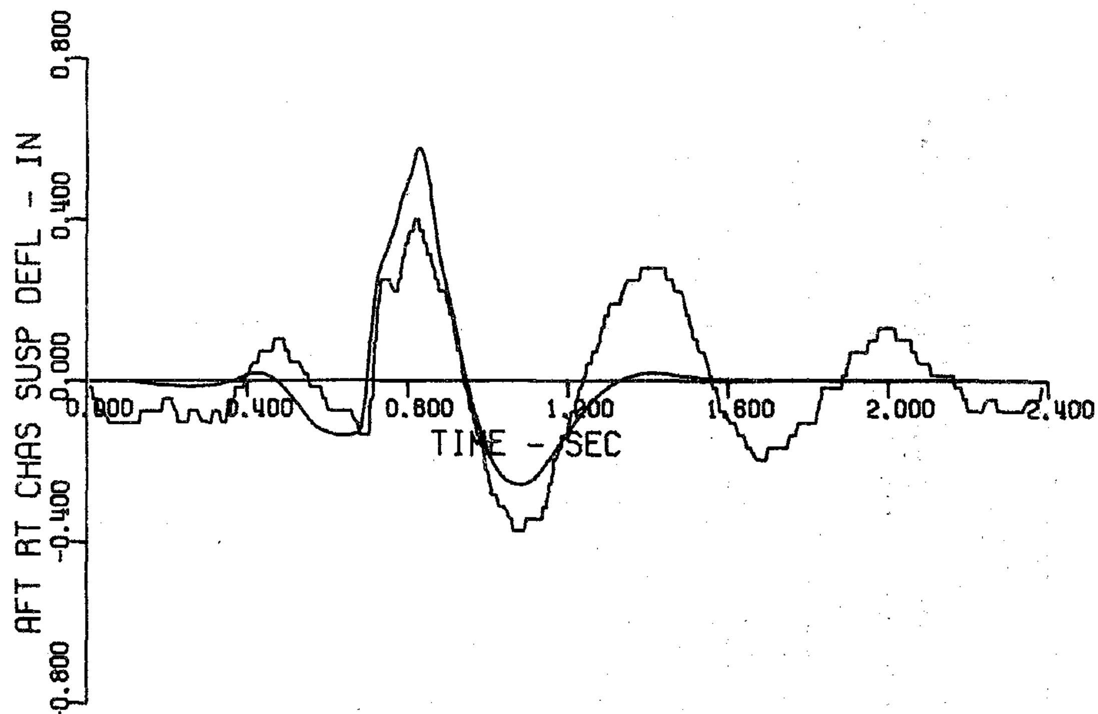


Figure 5-41 Vertical Body Acceleration - Run 42-36

RUN 42- 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP



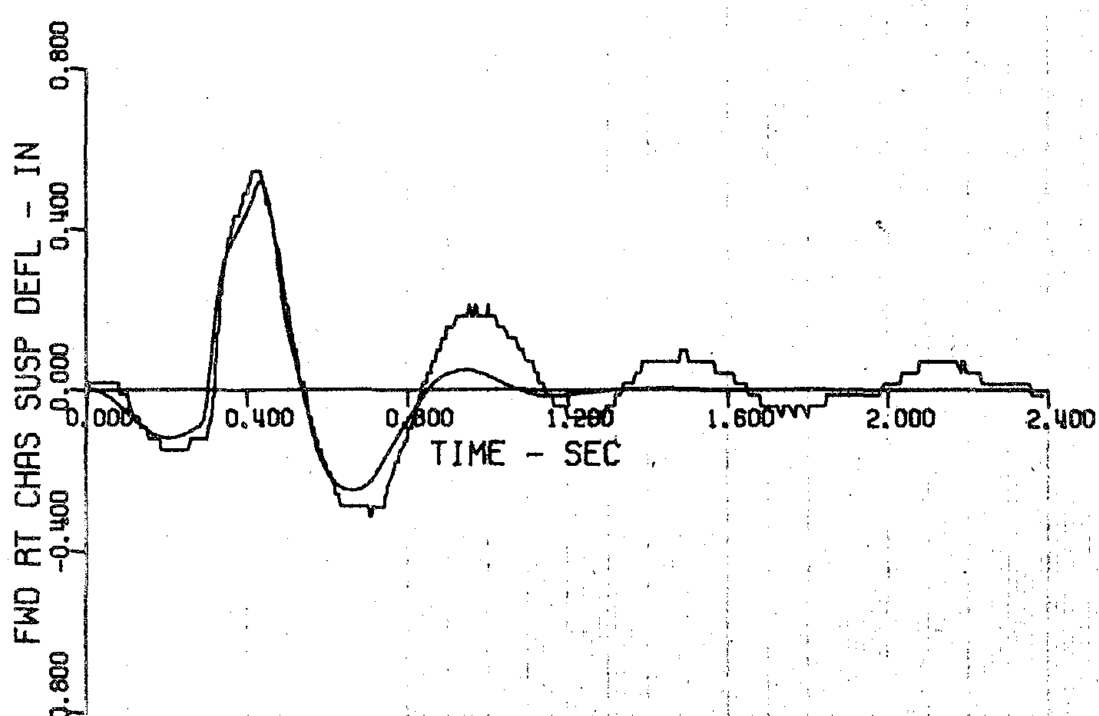
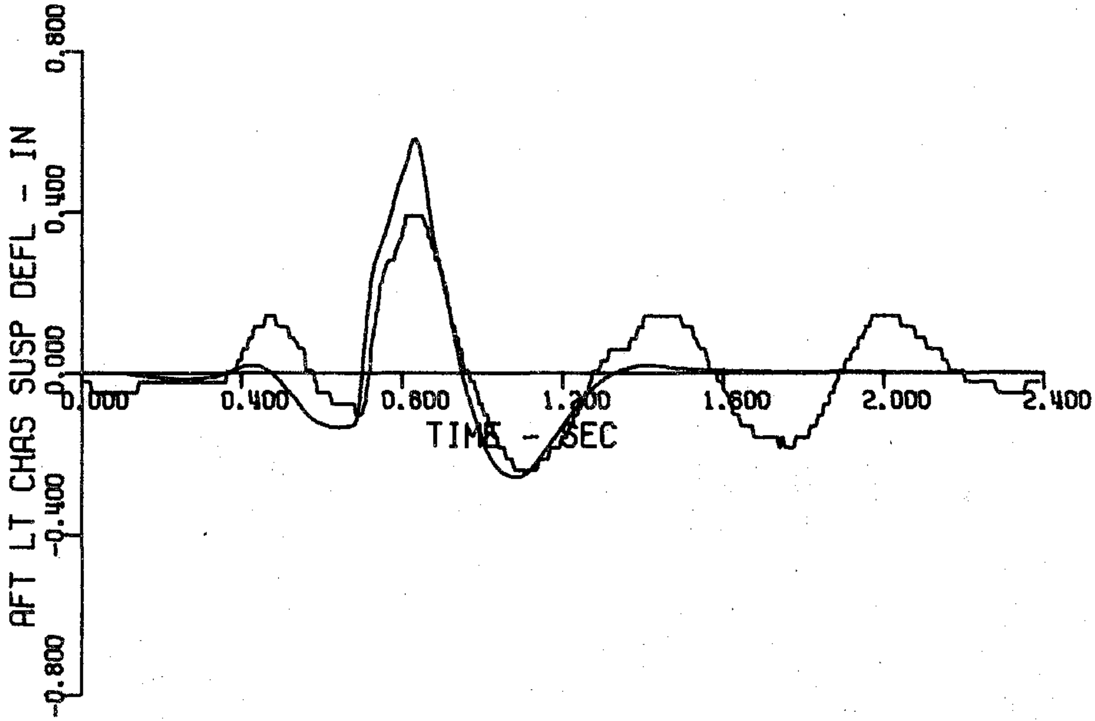


Figure 5-42 Right Chassis Suspension Deflection - Run 42-36

RUN 42 - 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP



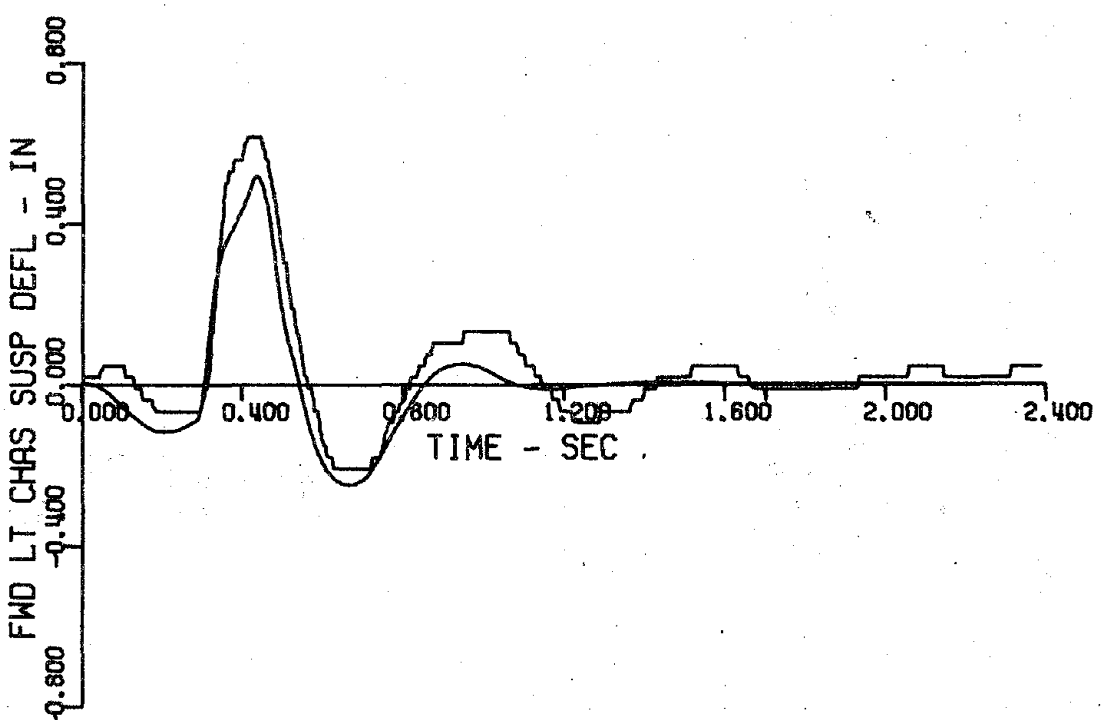
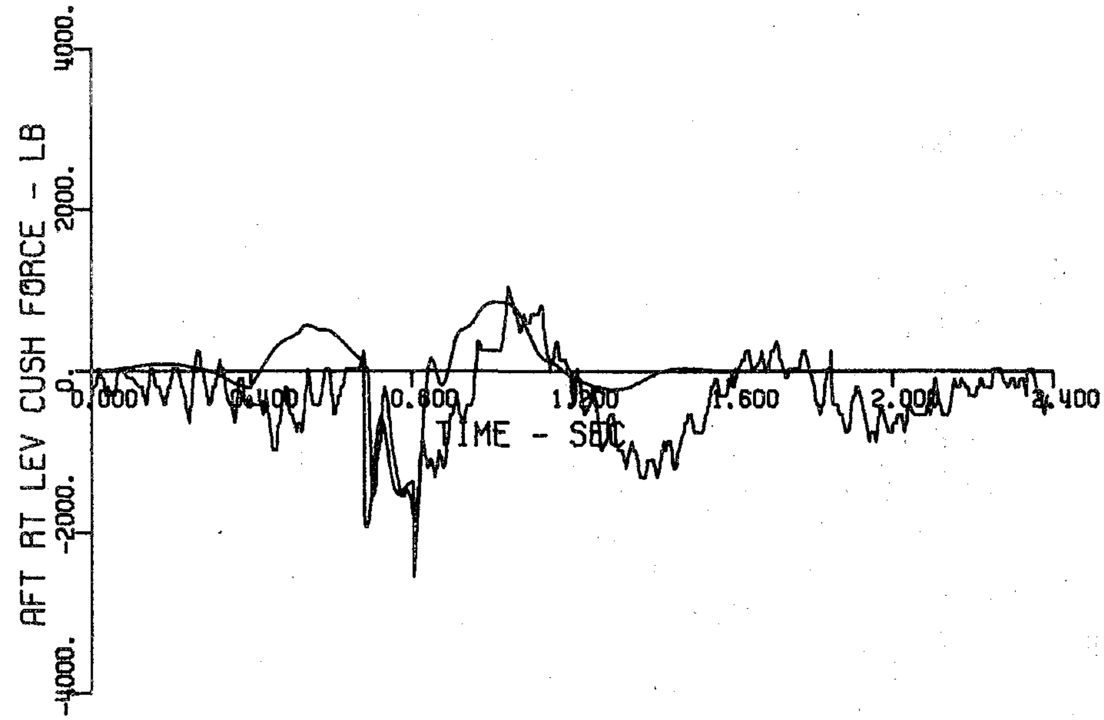


Figure 5-42a Left Chassis Suspension Deflection - Run 42-36

RUN 42 - 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP



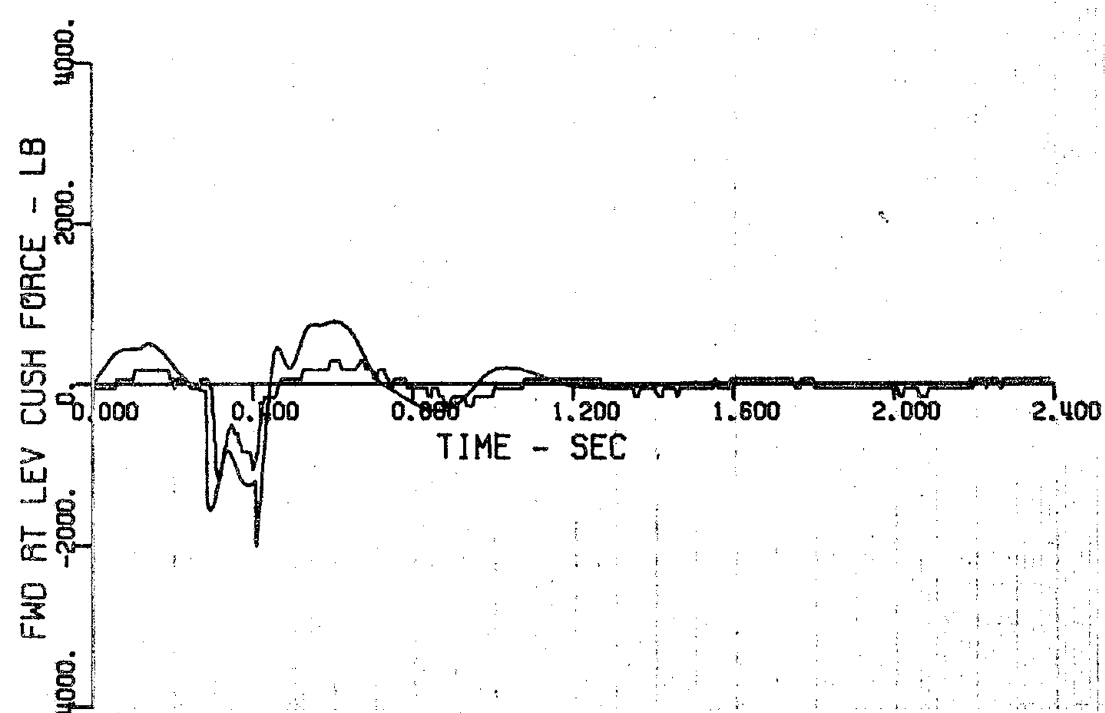
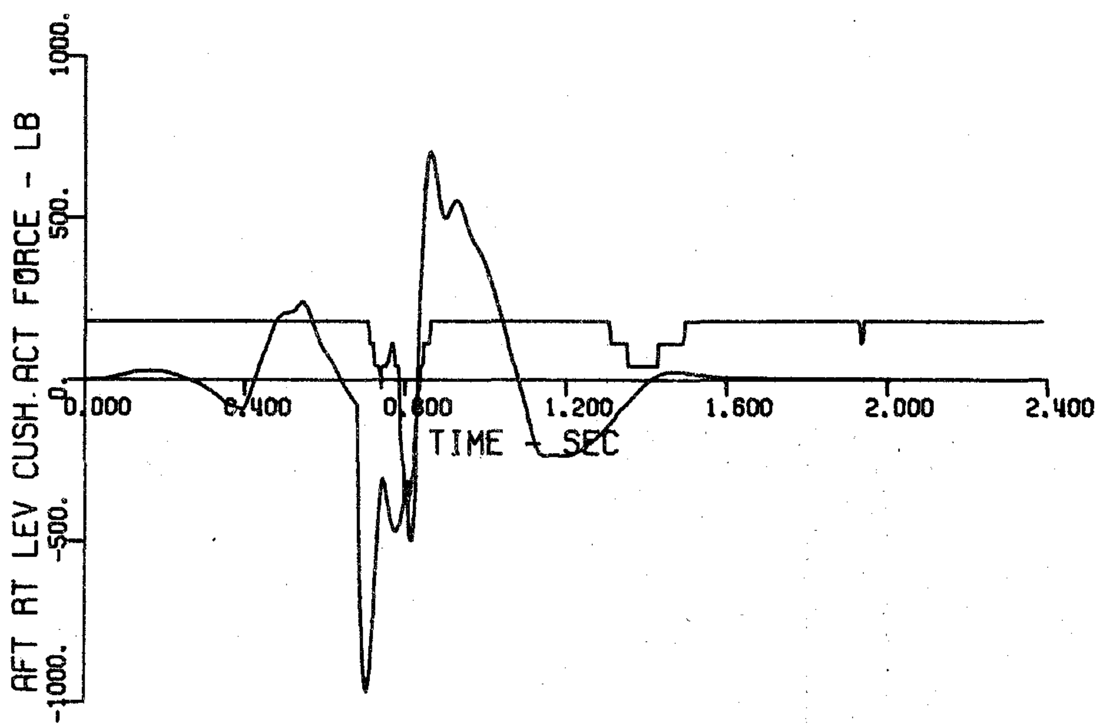


Figure 5-43 Right Levitation Cushion Force - Run 42-36

RUN 42- 36 TL-101 10 38 W6 60 MPH 1.0 IN X 25 FT RAMP



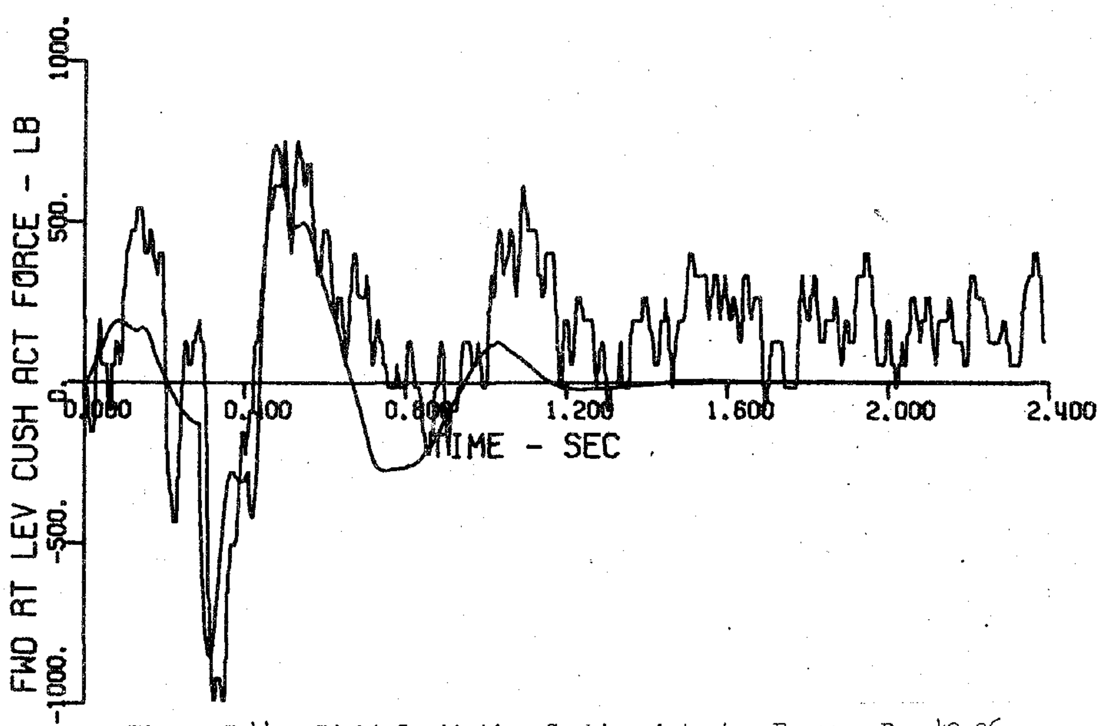


Figure 5-44 Right Levitation Cushion Actuator Force - Run 42-36

RUN 42 - 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP

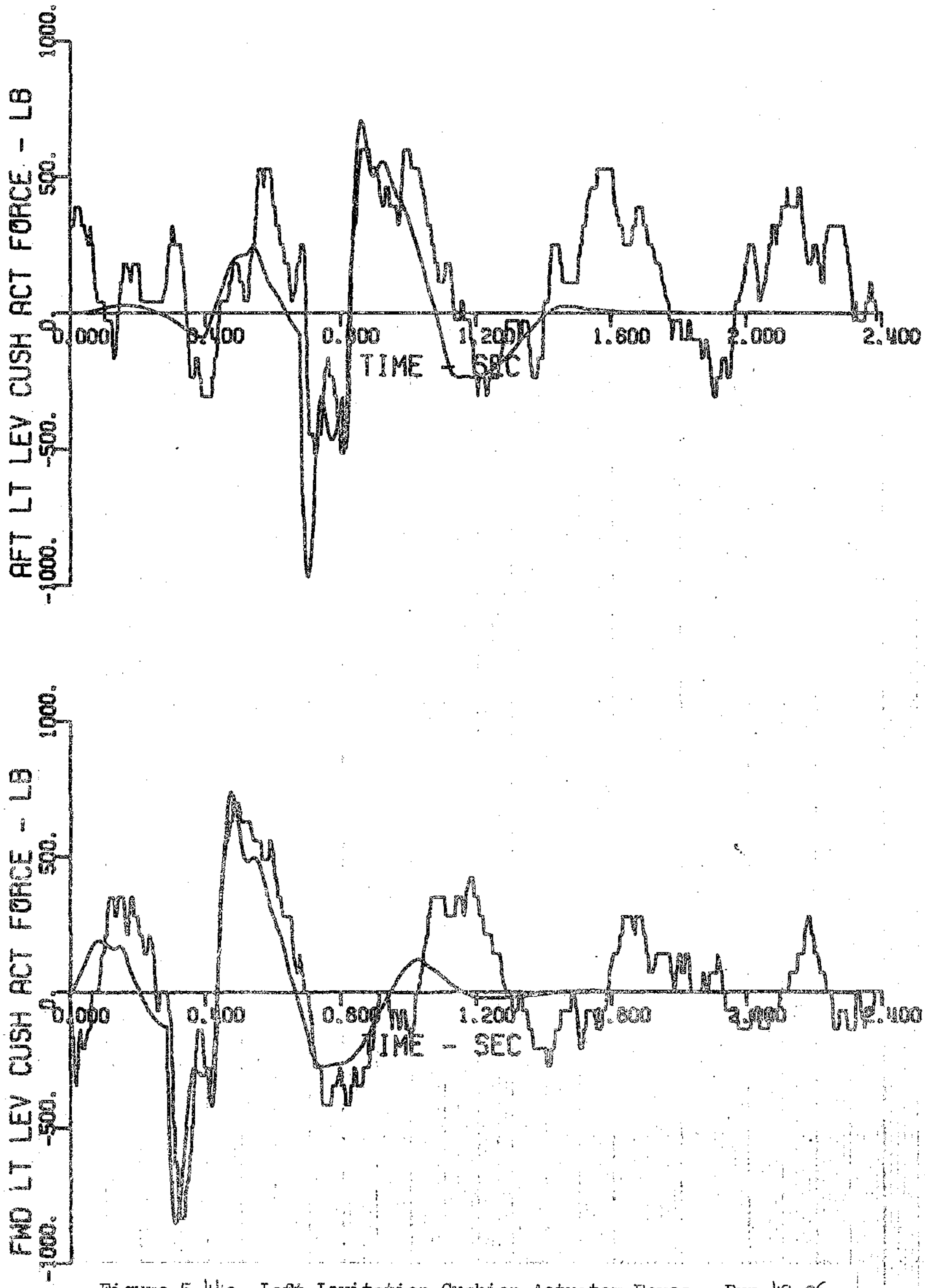
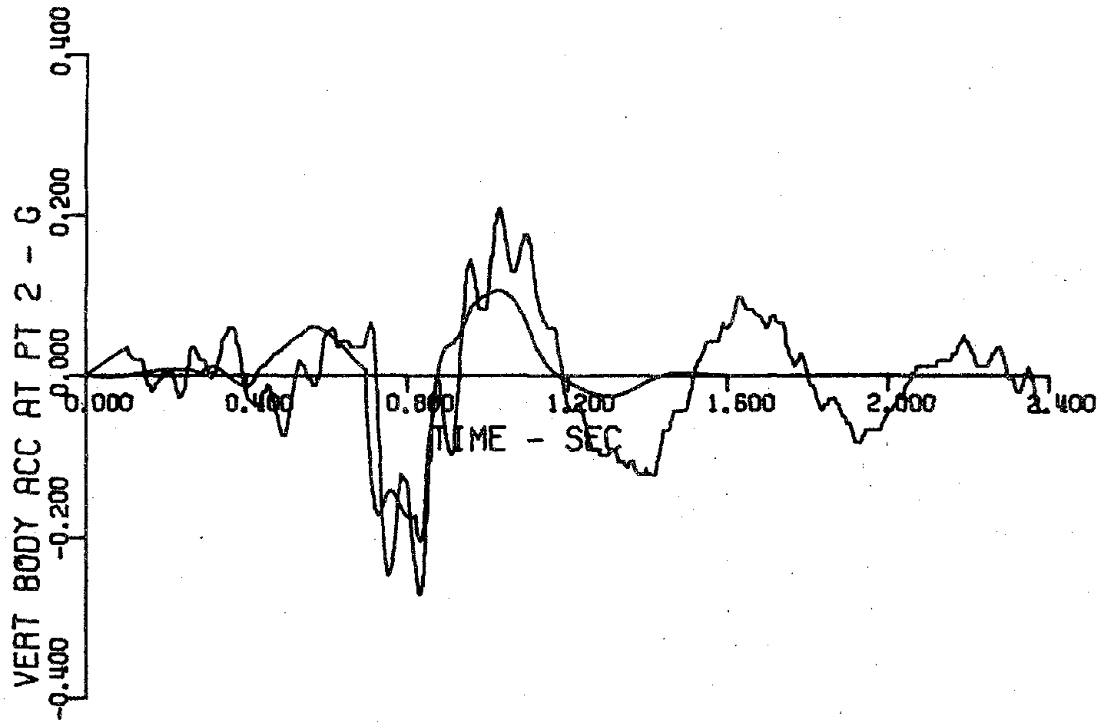


Figure 5-44a Left Levitation Cushion Actuator Force - Run 42-36

RUN 42- 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP



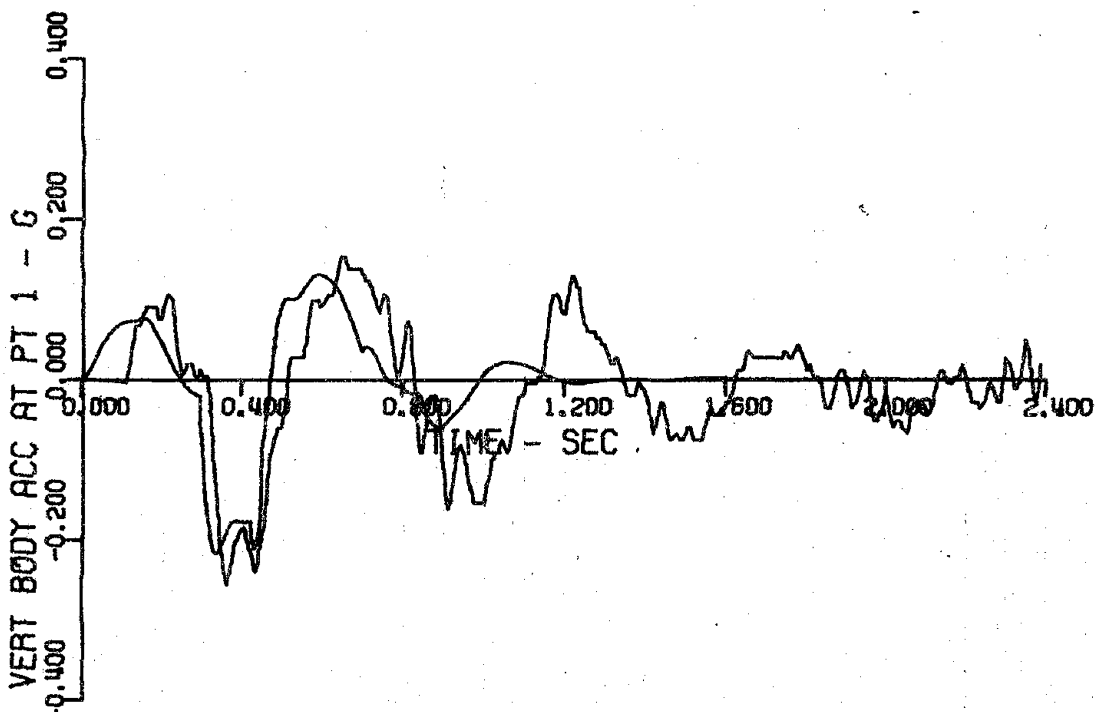
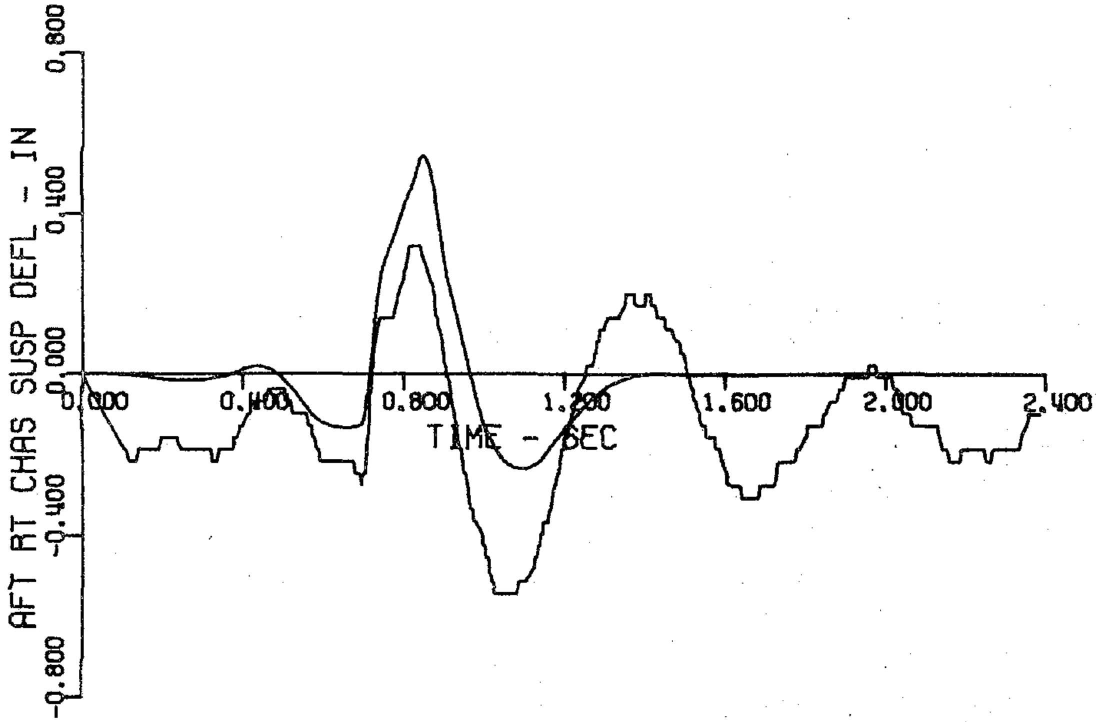


Figure 5-45 Vertical Body Acceleration - Run 42-38

RUN 42- 38 TL-101 16 54 41 59 MPH 1.0 IN X 25 FT RAMP



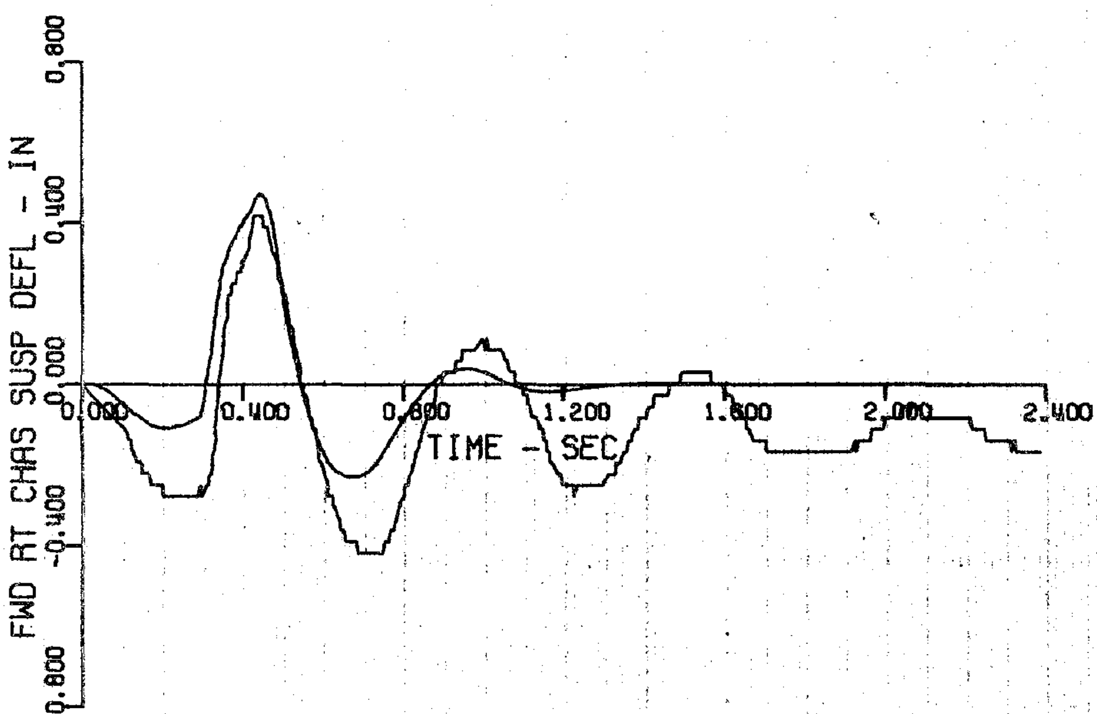


Figure 5-46 Right Chassis Suspension Deflection - Run 42-38

RUN 42 - 38 TL-101 16 54 41 59 MPH 1.0 IN X 25 FT RAMP

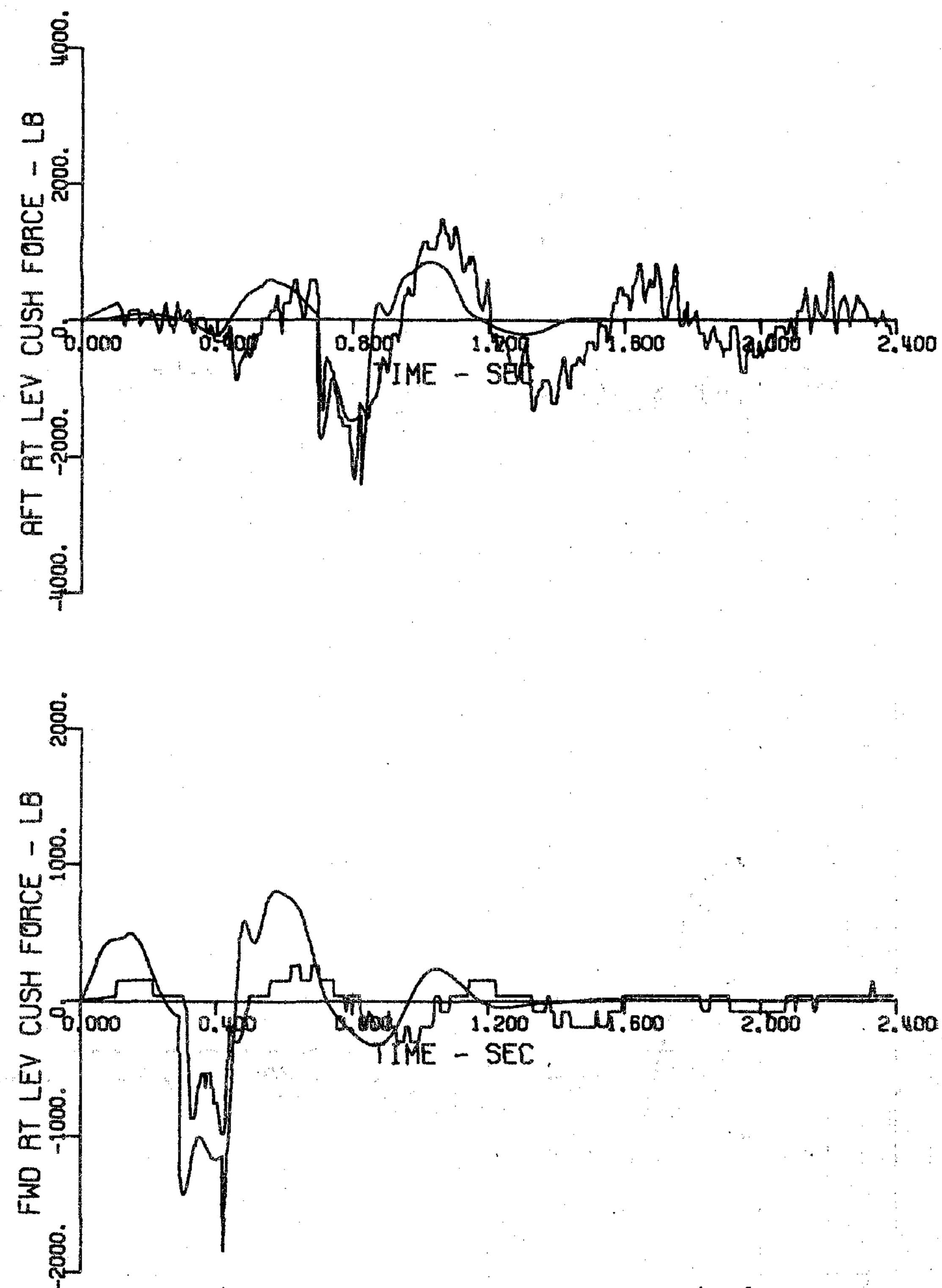
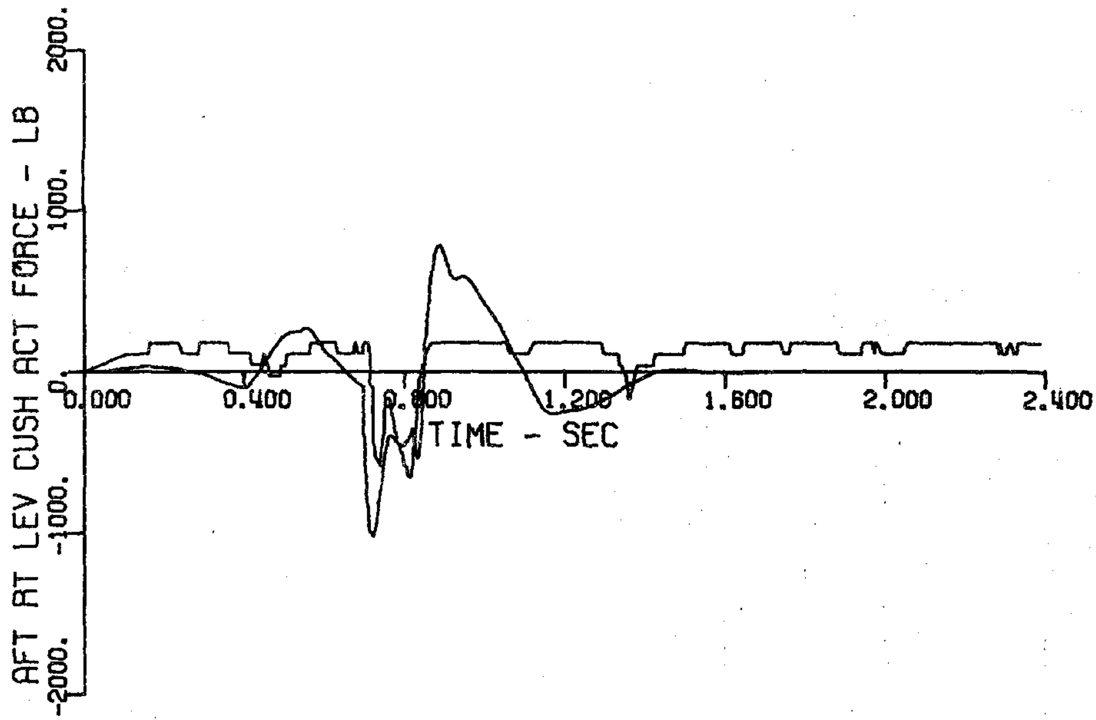


Figure 5-47 Right Levitation Cushion Force - Run 42-38

RUN 42 - 38 TL-101 16 54 41 59 MPH 1.0 IN X 25 FT RAMP



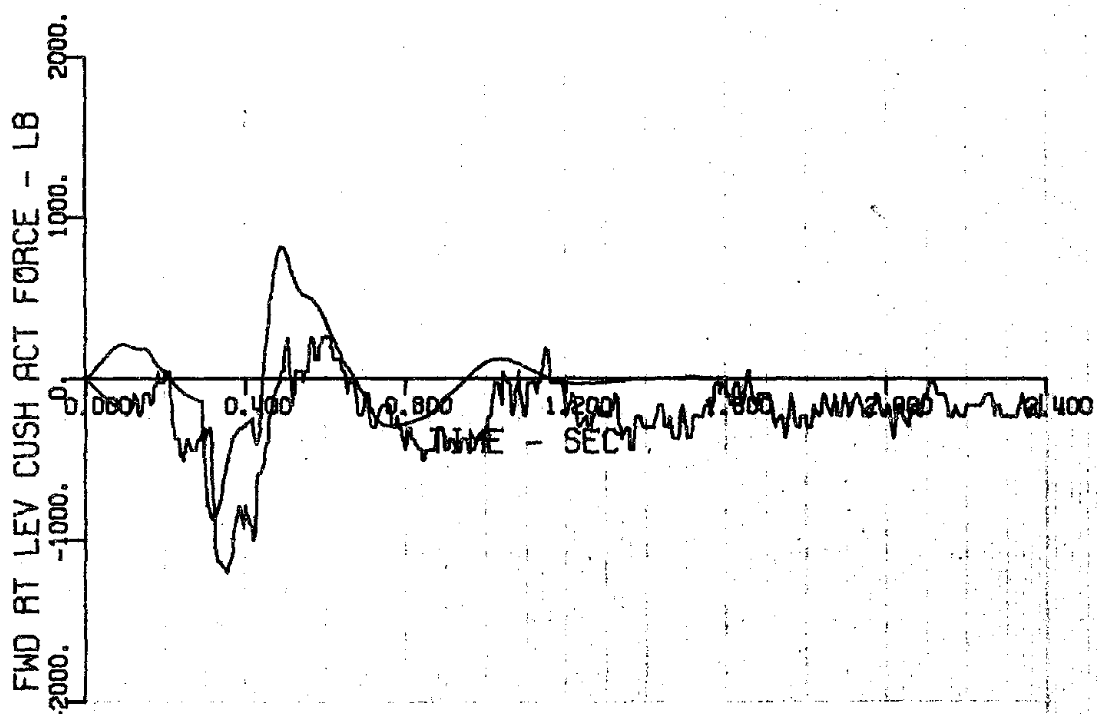


Figure 5-48 Right Levitation Cushion Actuator Force - Run 42-38

RUN 42- 38 TL-101 16 54 41 59 MPH 1.0 IN X 25 FT RAMP

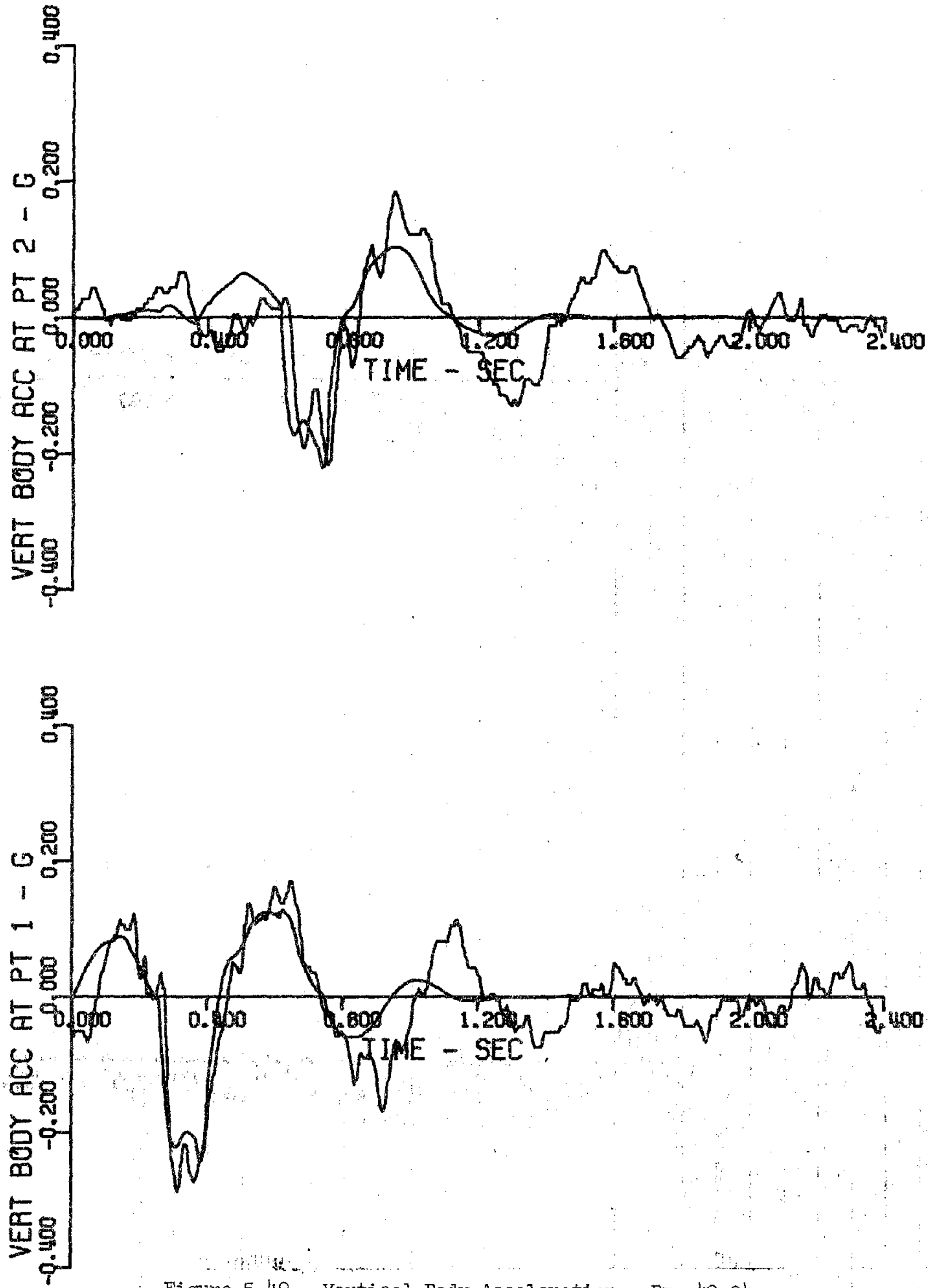


Figure 5-49 Vertical Body Acceleration - Run 42-34

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

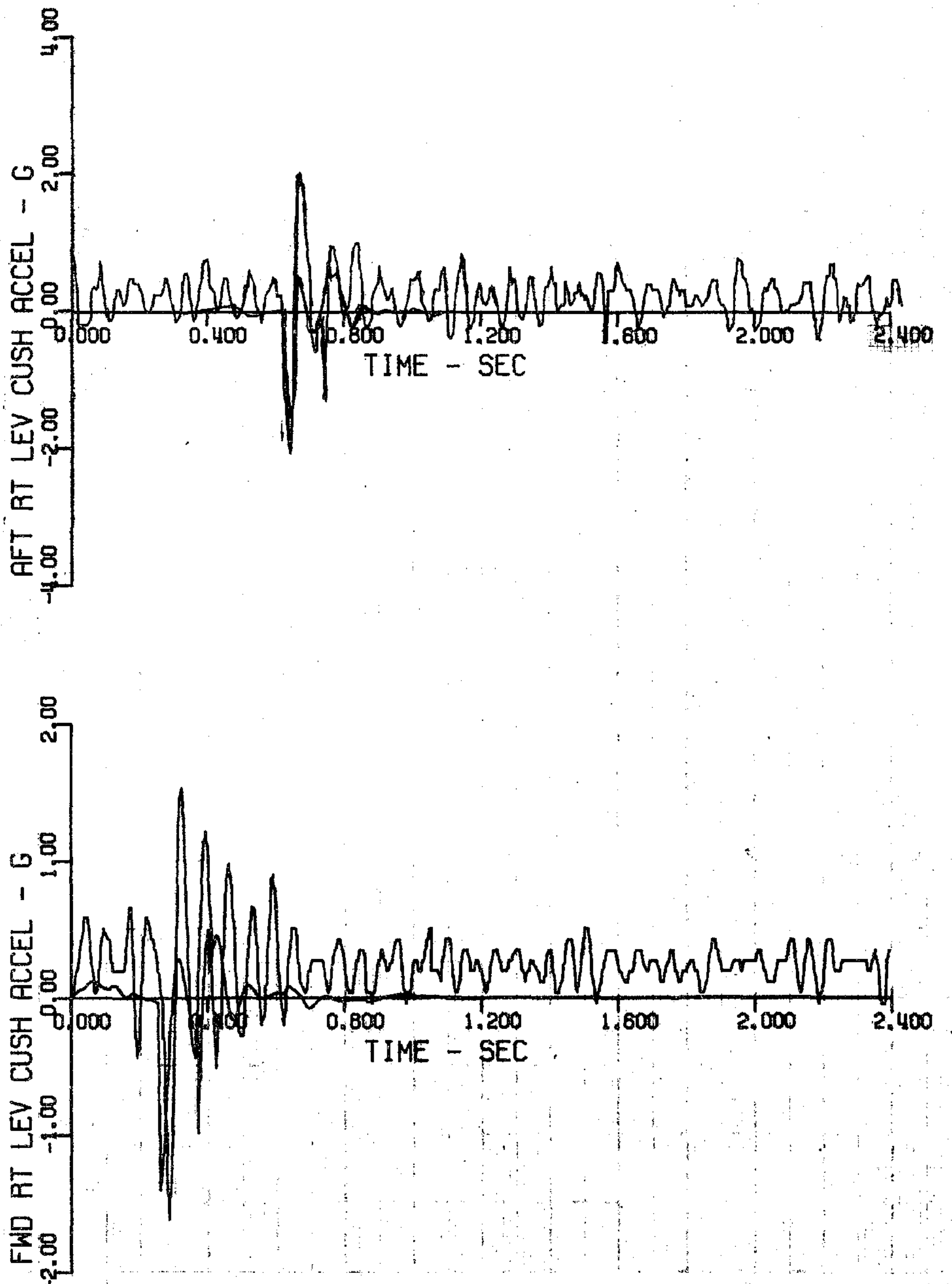
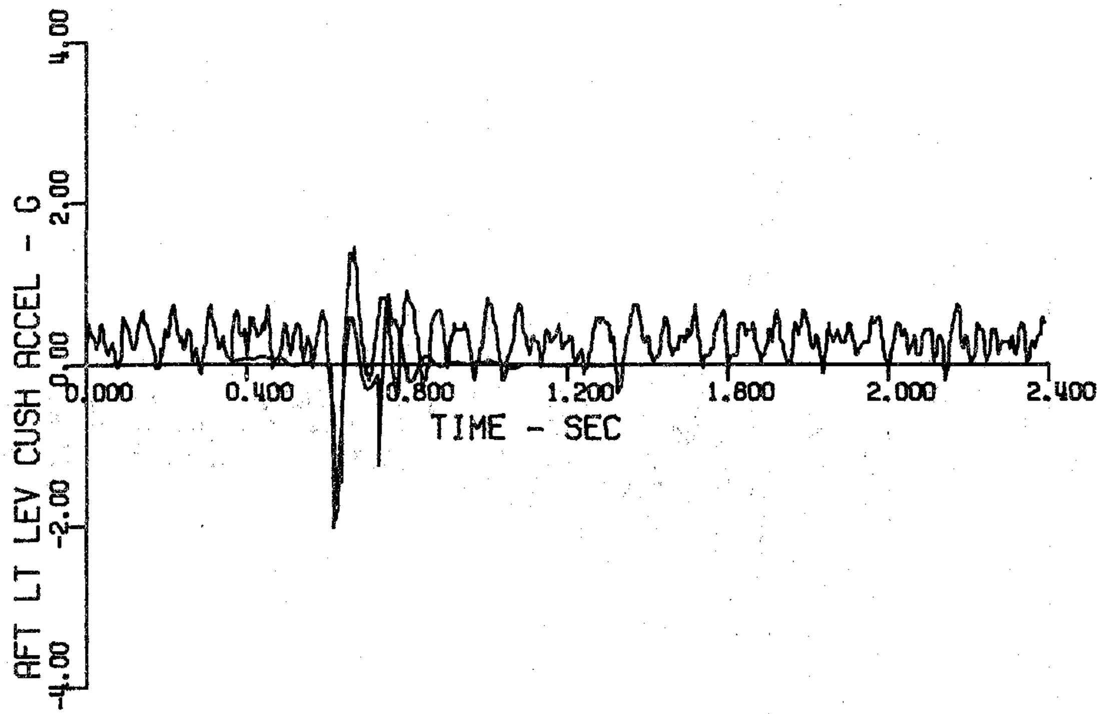


Figure 5-50 Right Levitation Cushion Acceleration - Run 42-34

RUN - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAM



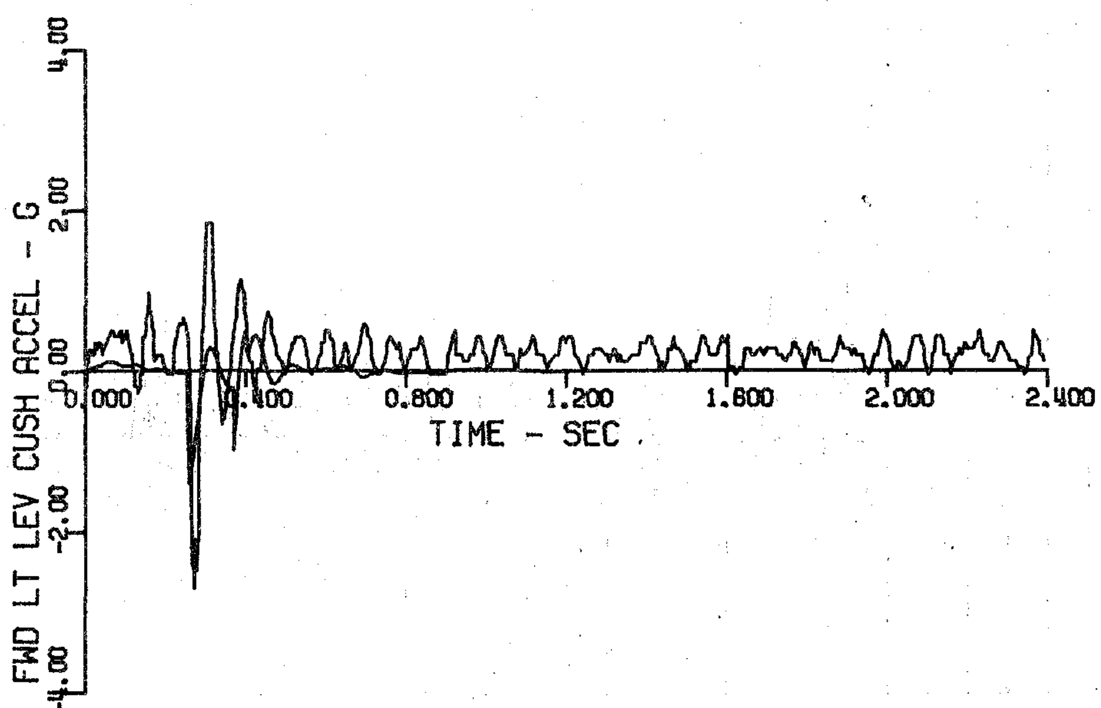
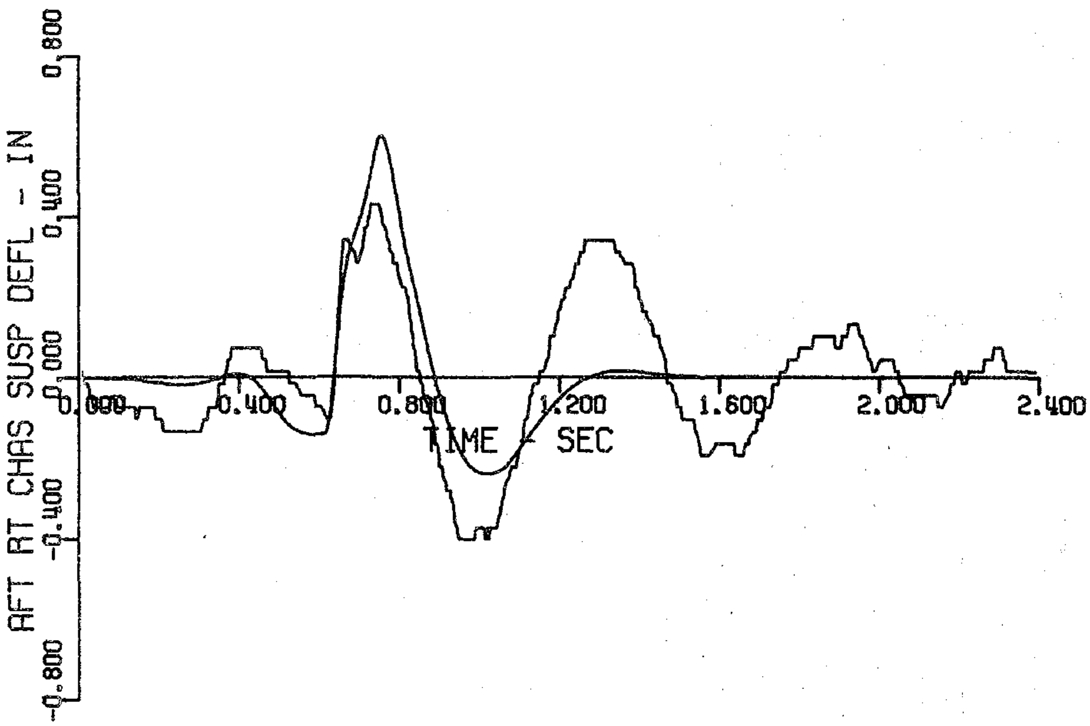


Figure 5-51 Left Levitation Cushion Acceleration - Run 42-34

RUN 42- 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP



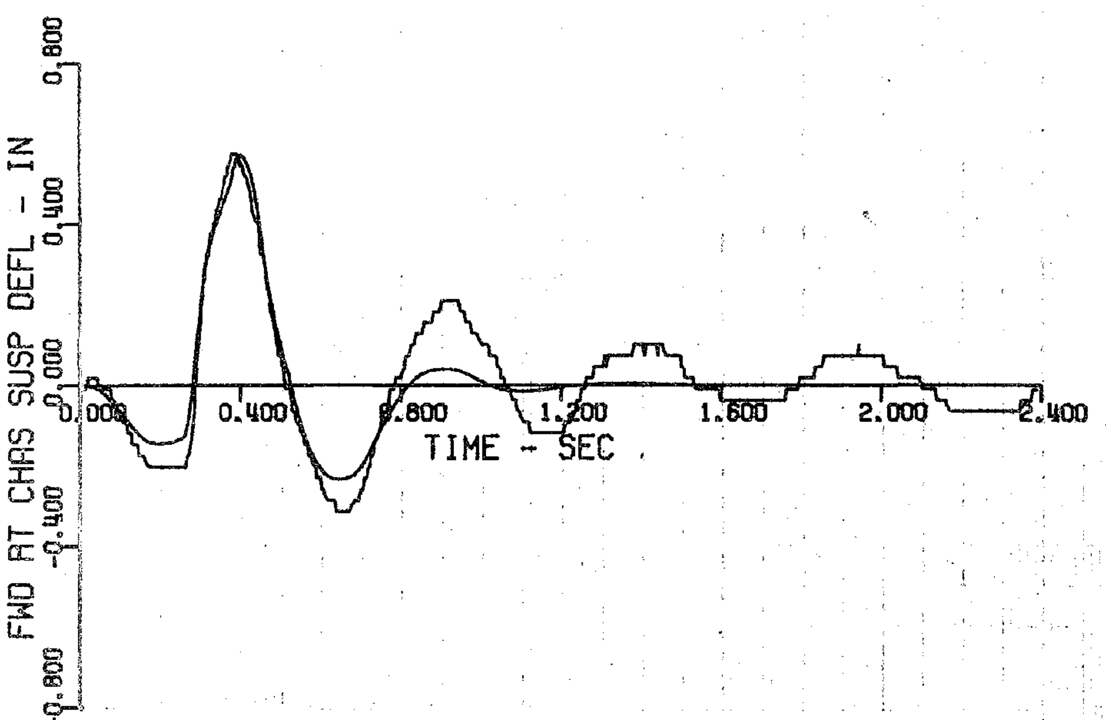


Figure 5-52 Right Chassis Suspension Deflection - Run 42-34

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

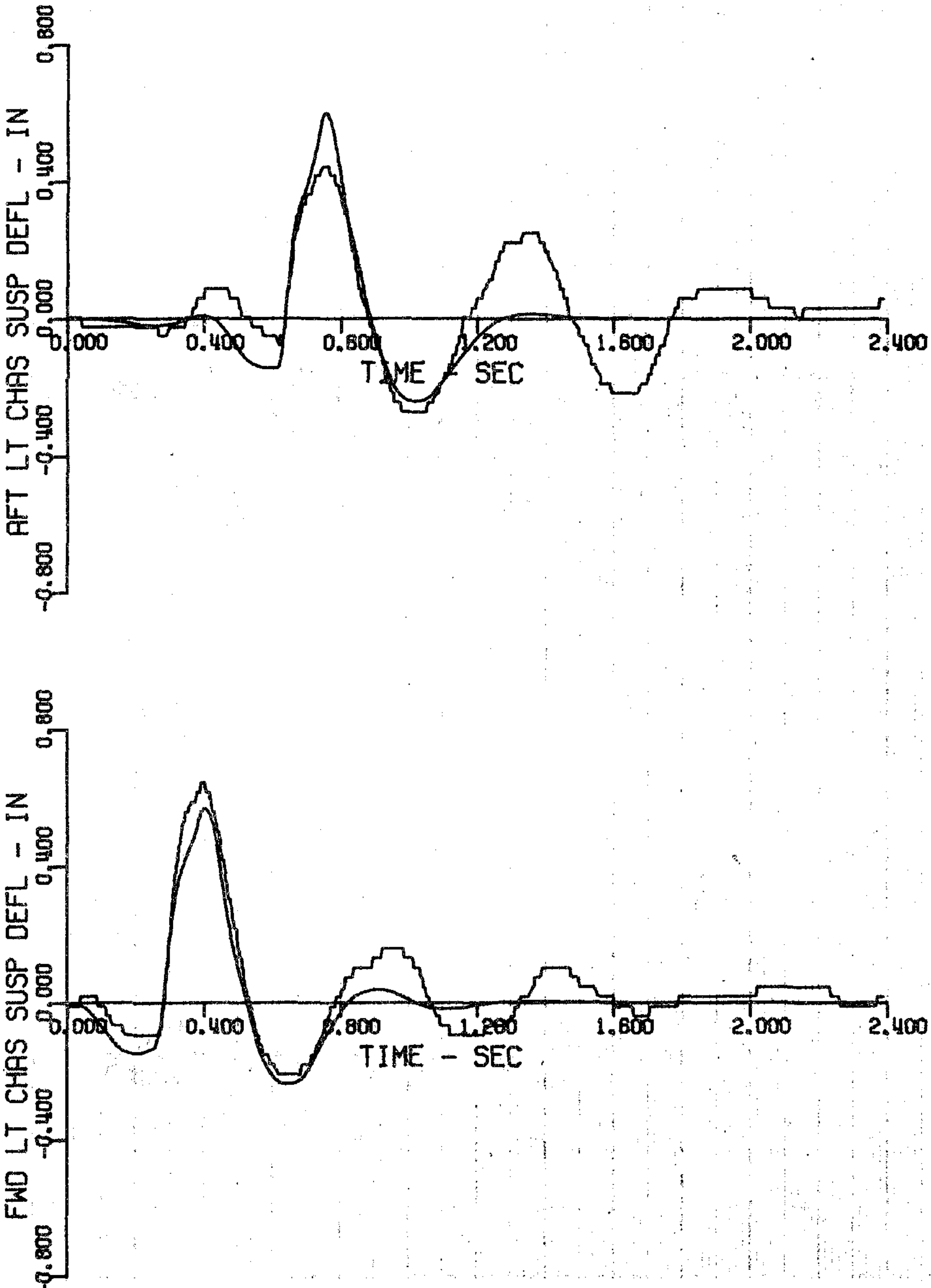
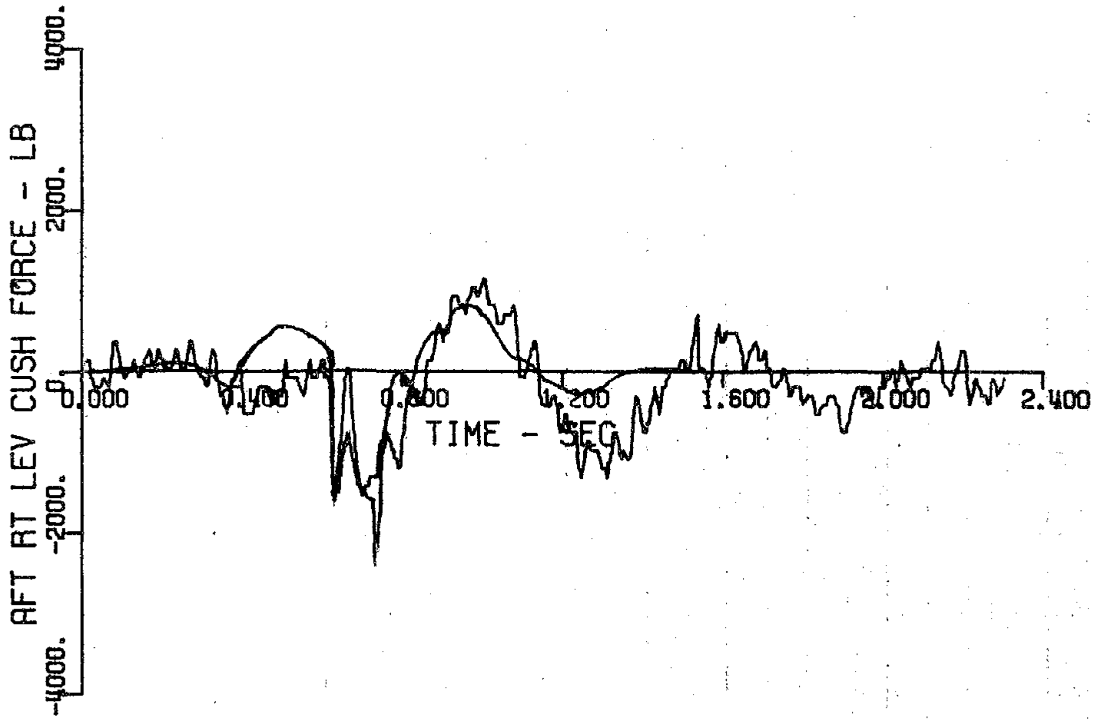


Figure 5-53 Left Chassis Suspension Deflection - Run 42-34

RUN 42- 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP



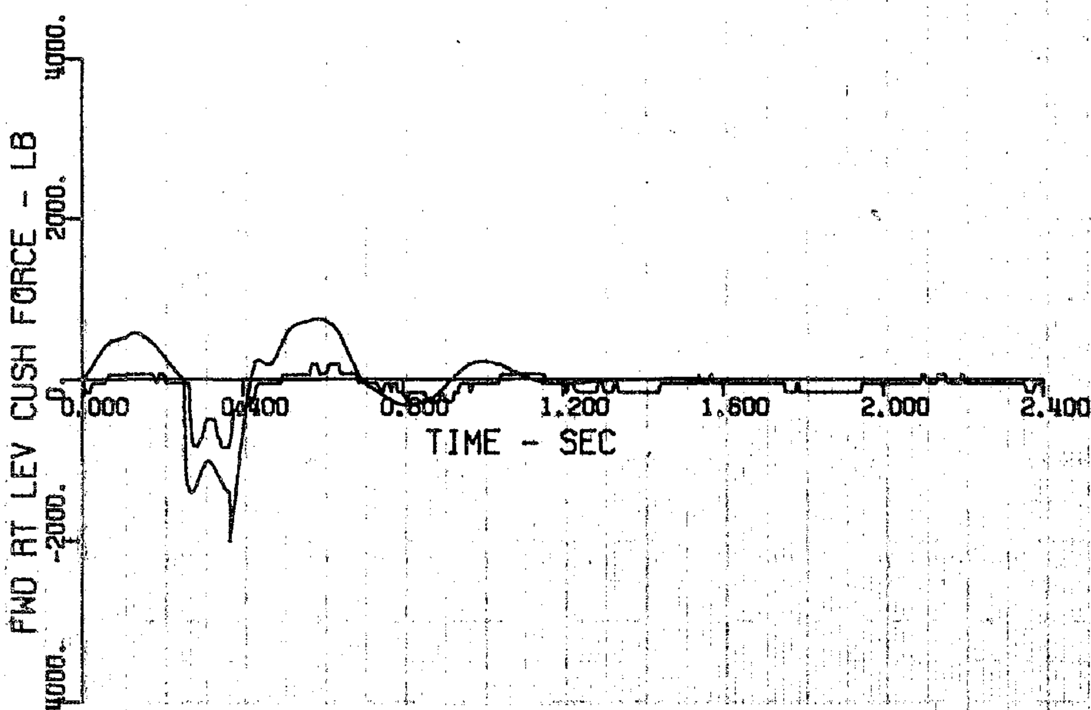


Figure 5-54 Right Levitation Cushion Force - Run 42-34

RUN 42- 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

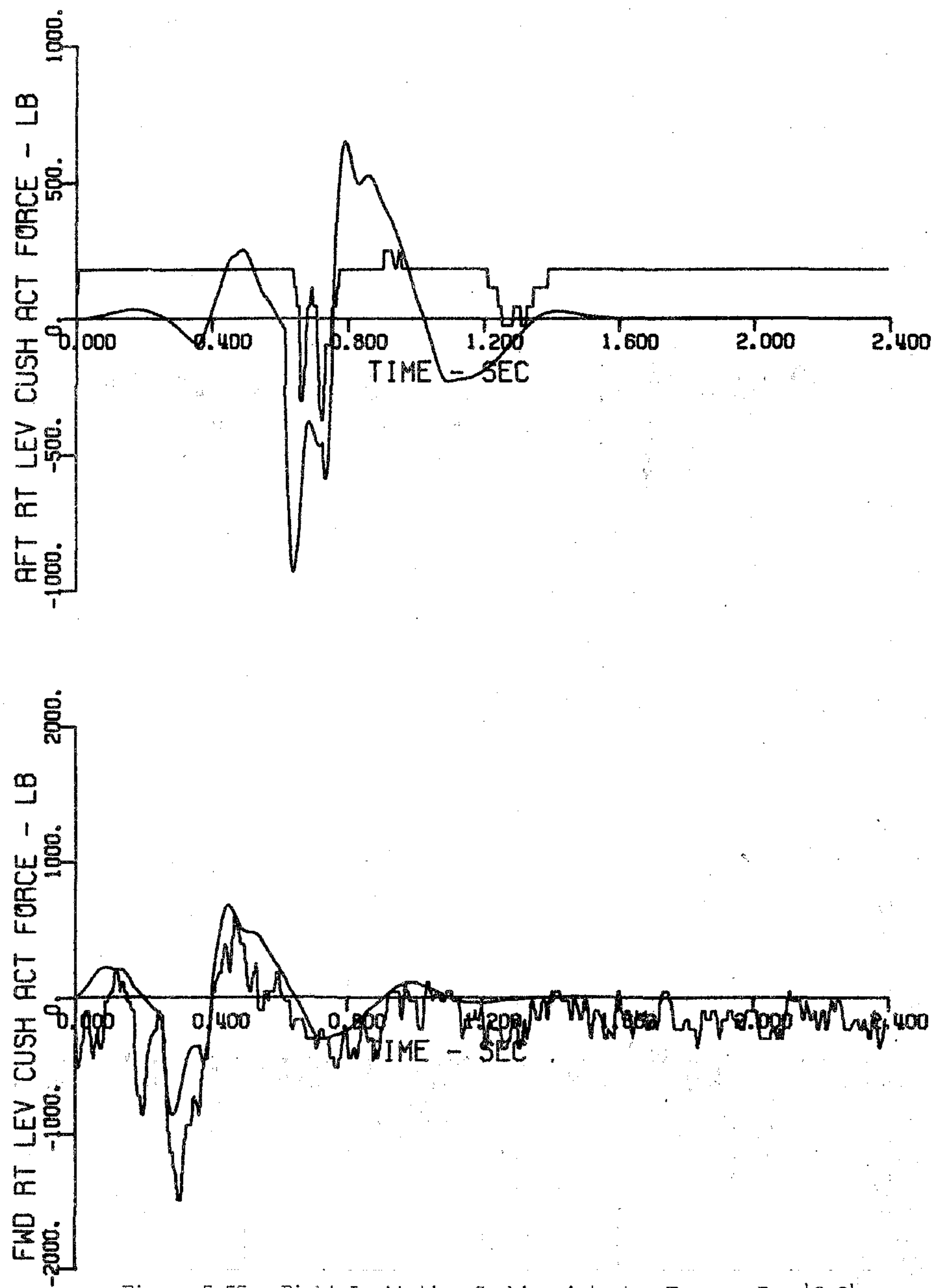


Figure 5-55 Right Levitation Cushion Actuator Force - Run 42-34

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

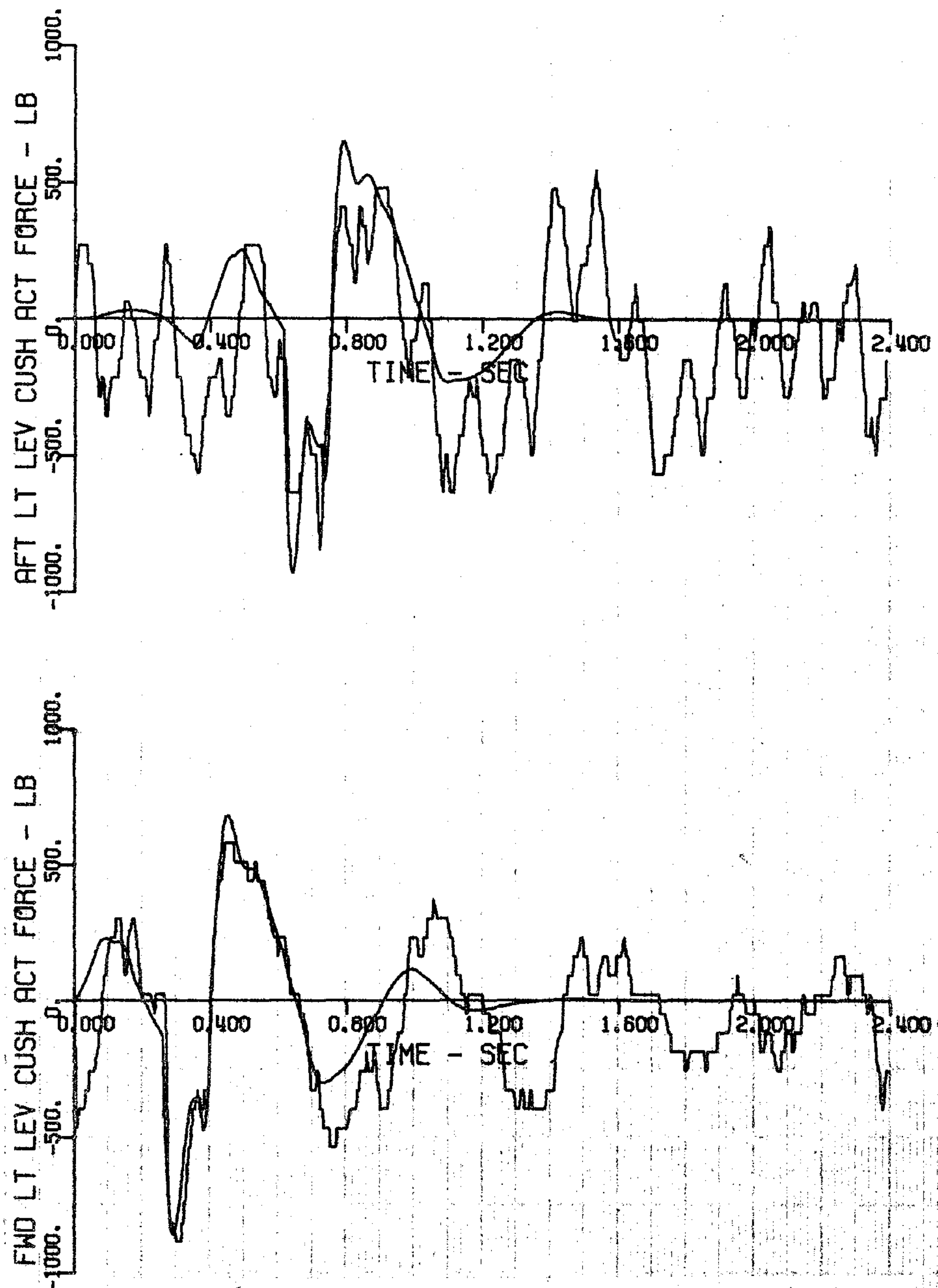


Figure 5-56 Left Levitation Cushion Actuator Force - Run 42-34

RUN 42- 34 TL-101 10 19 58 67 MPH 1.0 IN X 25 FT RAMP

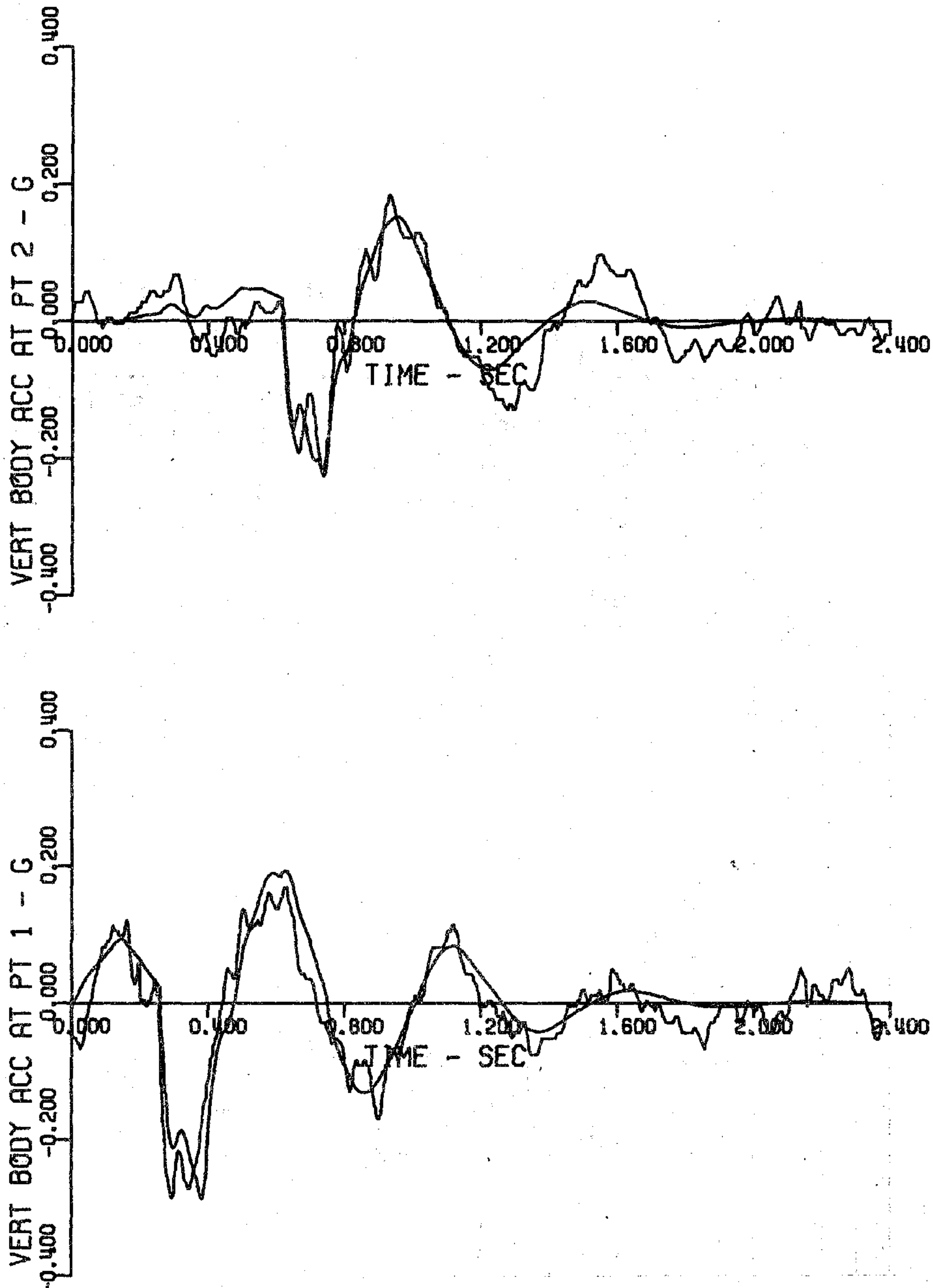
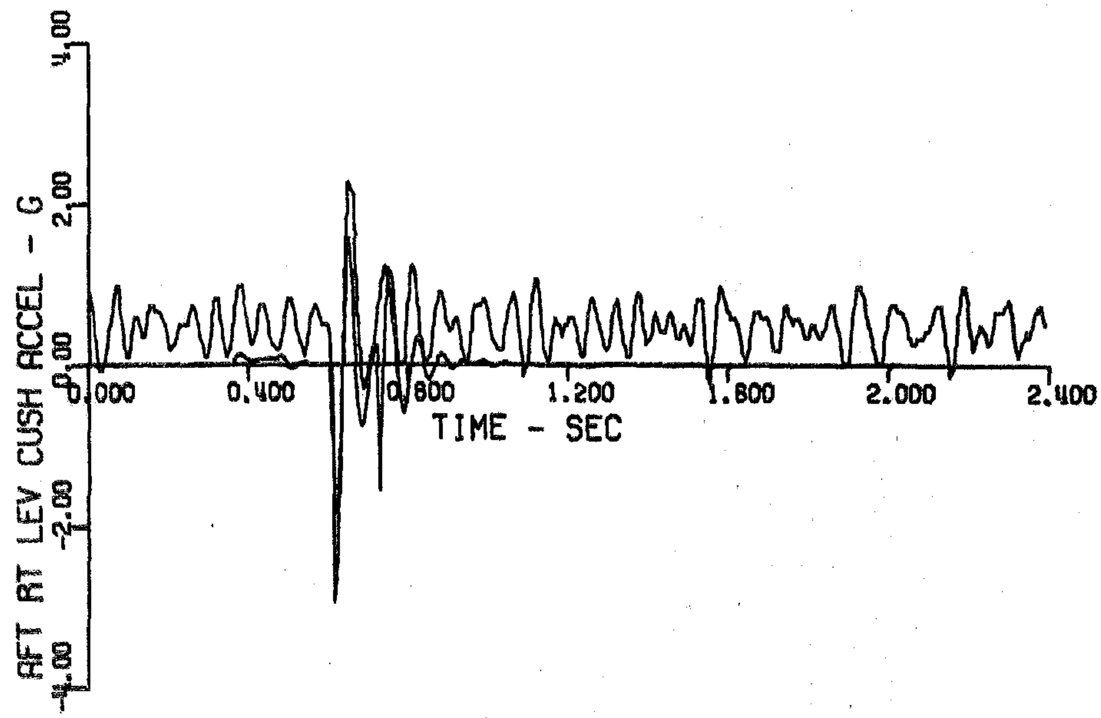


Figure 5-57 Vertical Body Acceleration - Run 42-34 (Simulation Mod.)

RUN 42- 34 TL-101 10 19 56 87 MPH 1.0 IN X 25 FT RAMP



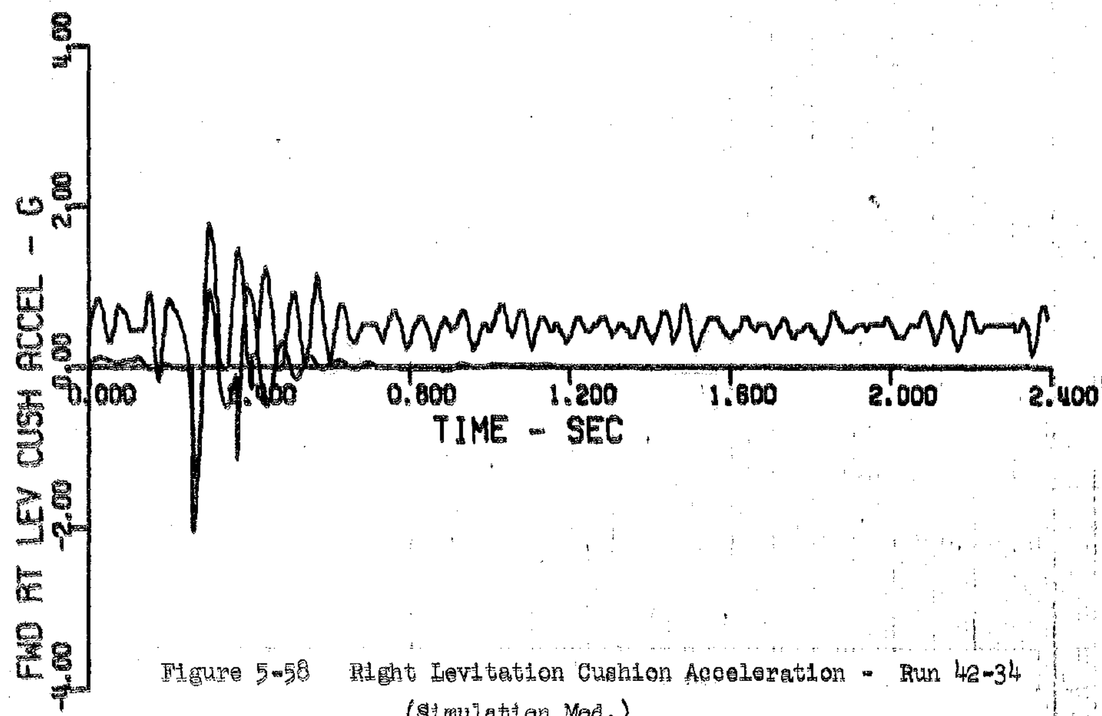
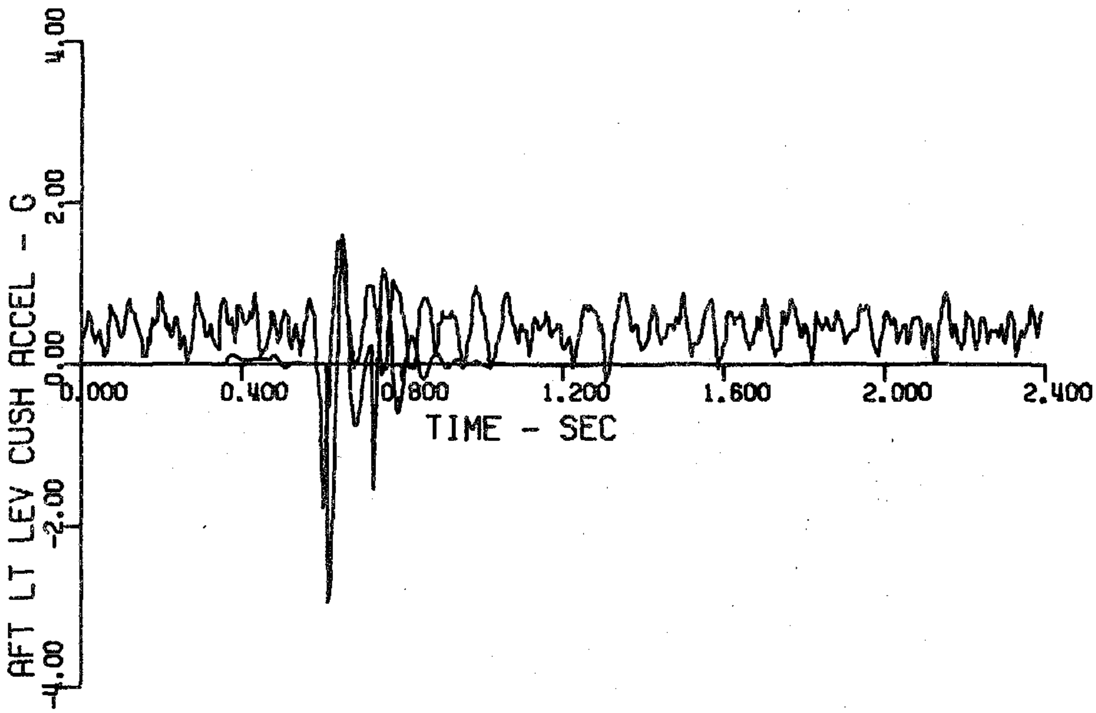


Figure 5-58 Right Levitation Cushion Acceleration - Run 42-34
(Simulation Mod.)

RUN 42- 34 TL-101 10 19 58 87 MPH 1.0 IN X 25 FT RAMP



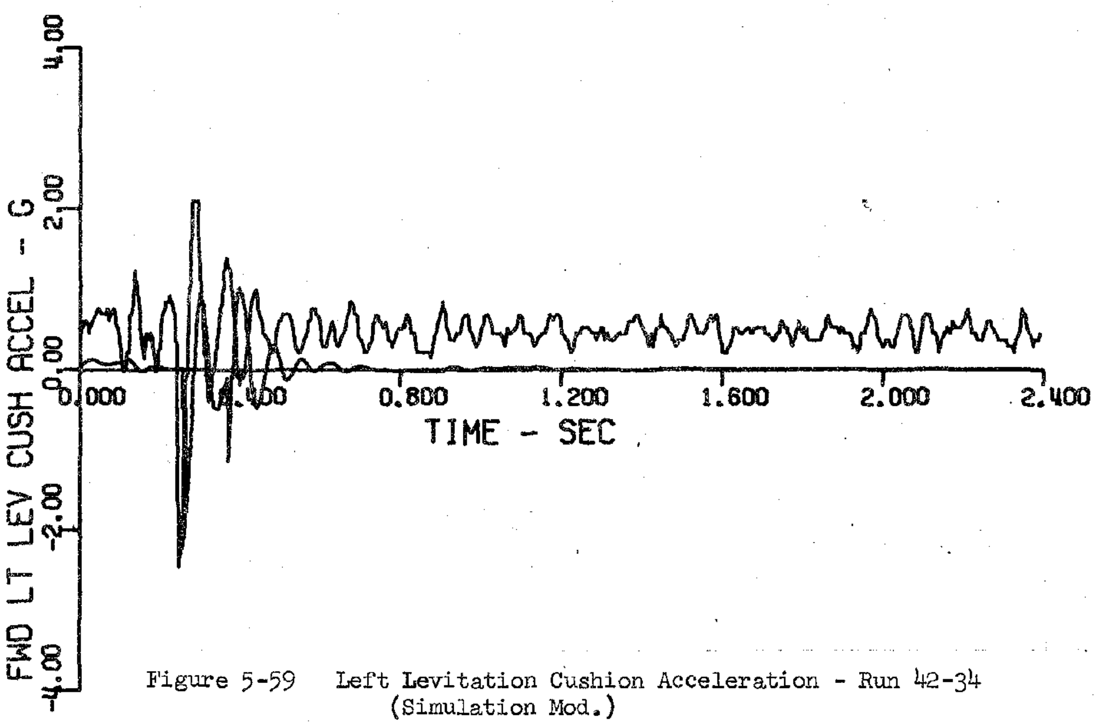


Figure 5-59 Left Levitation Cushion Acceleration - Run 42-34
(Simulation Mod.)

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

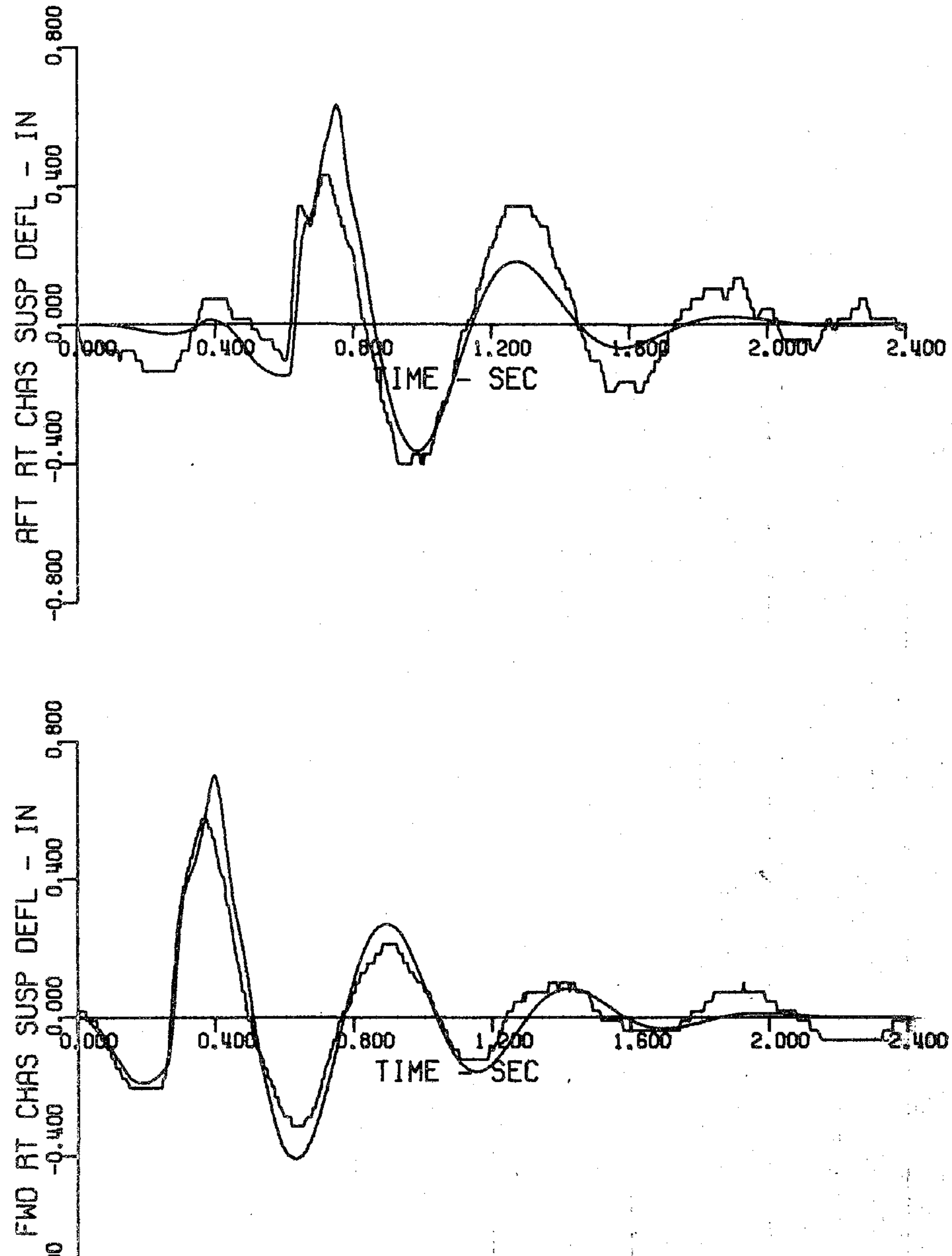
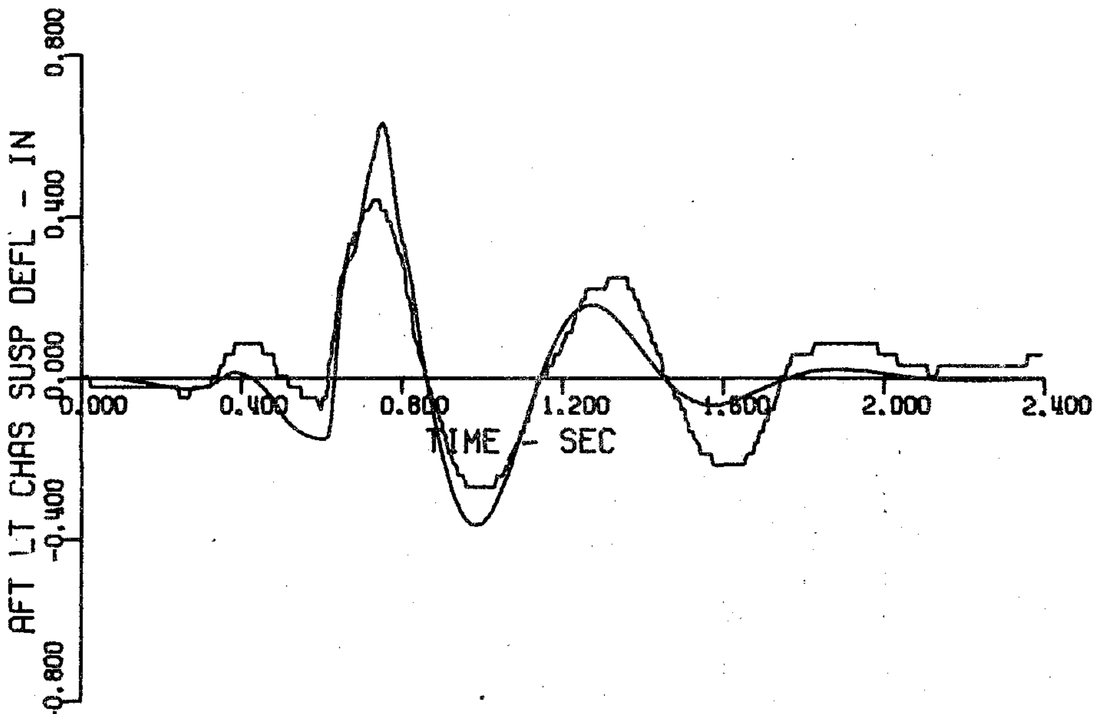


Figure 5-60 Right Chassis Suspension Deflection - Run 42-34 (Simulation Mod.)

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP



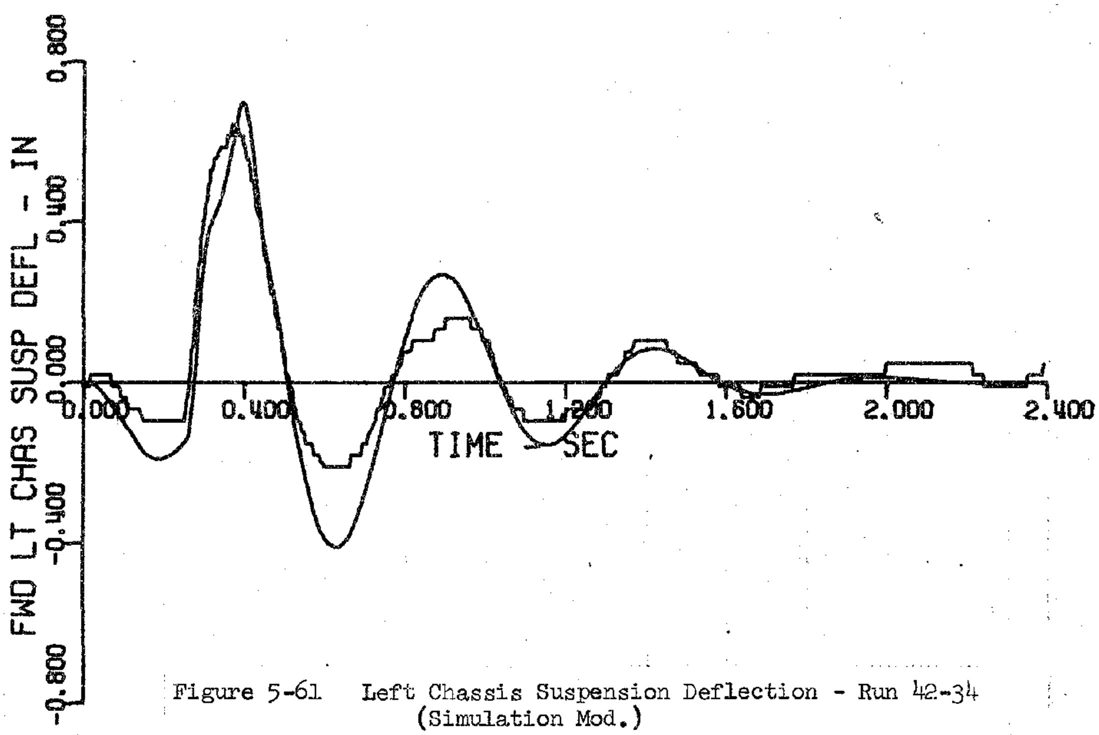


Figure 5-61 Left Chassis Suspension Deflection - Run 42-34 (Simulation Mod.)

RUN 42- 34 TL-101 10 15 SF 67 MPH 1.0 IN X 25 FT RAMP

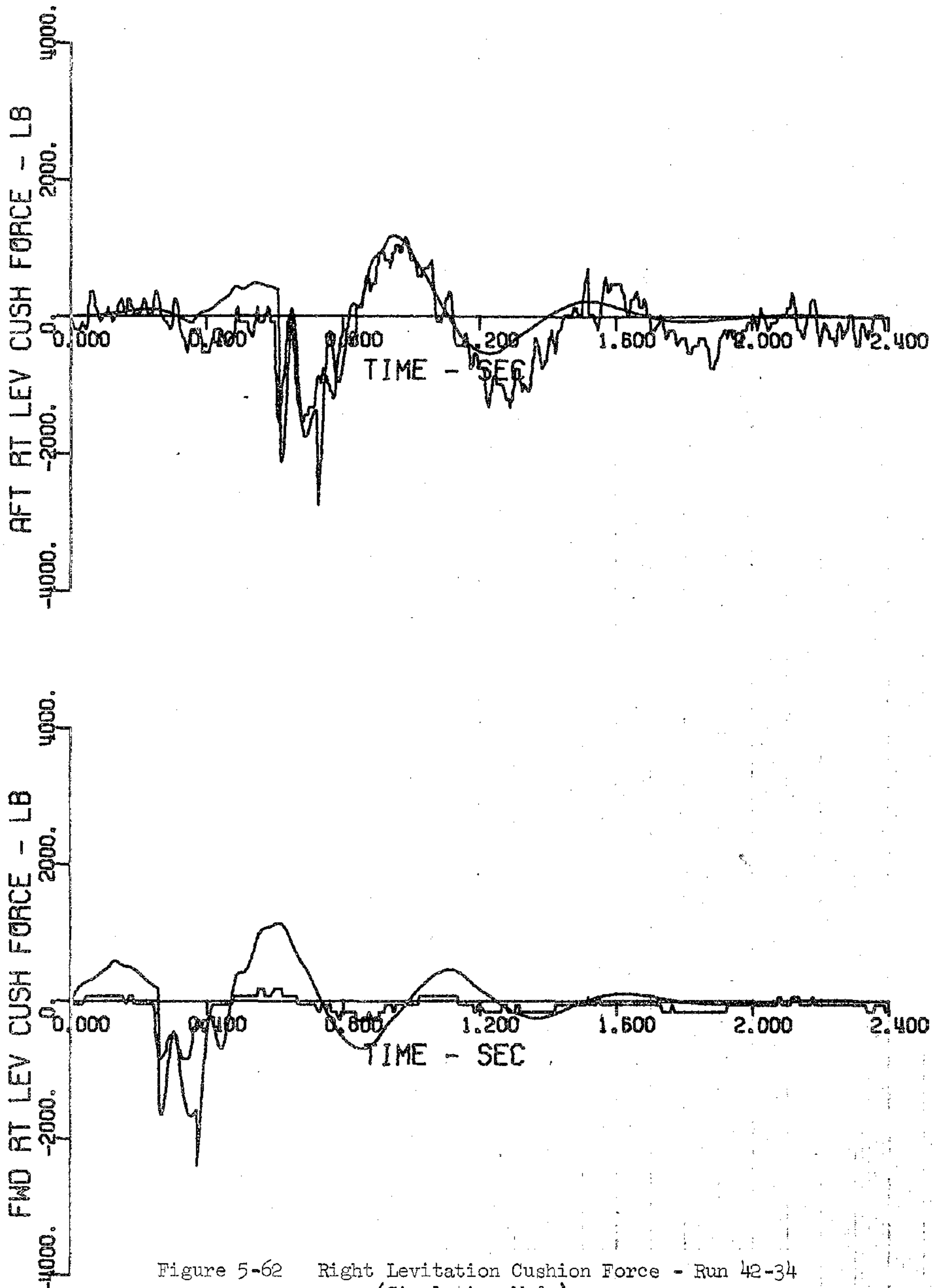


Figure 5-62 Right Levitation Cushion Force - Run 42-34
(Simulation Mod.)

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

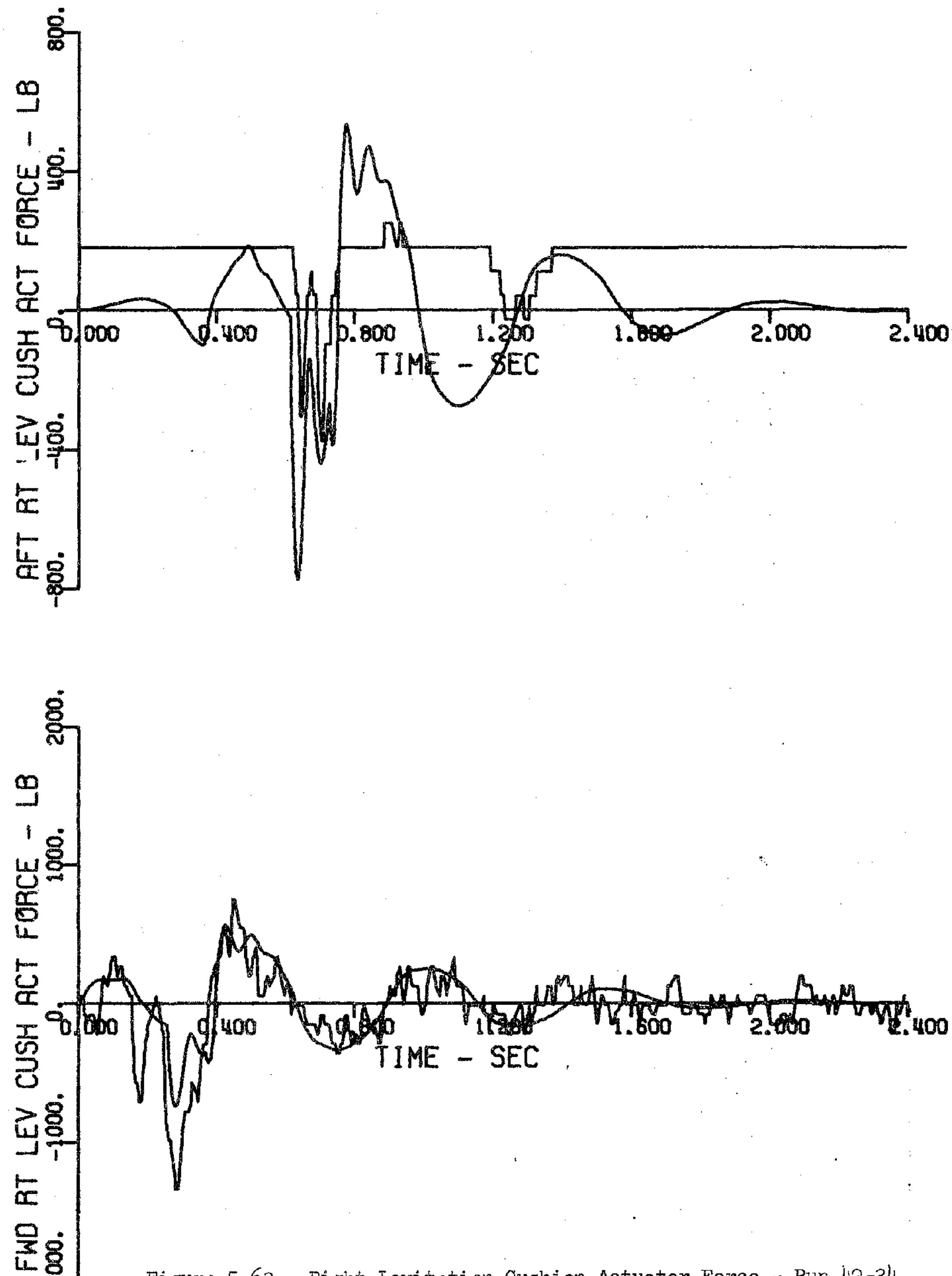


Figure 5-63 Right Levitation Cushion Actuator Force - Run 42-34
(Simulation Mod.)

RUN 42 - 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

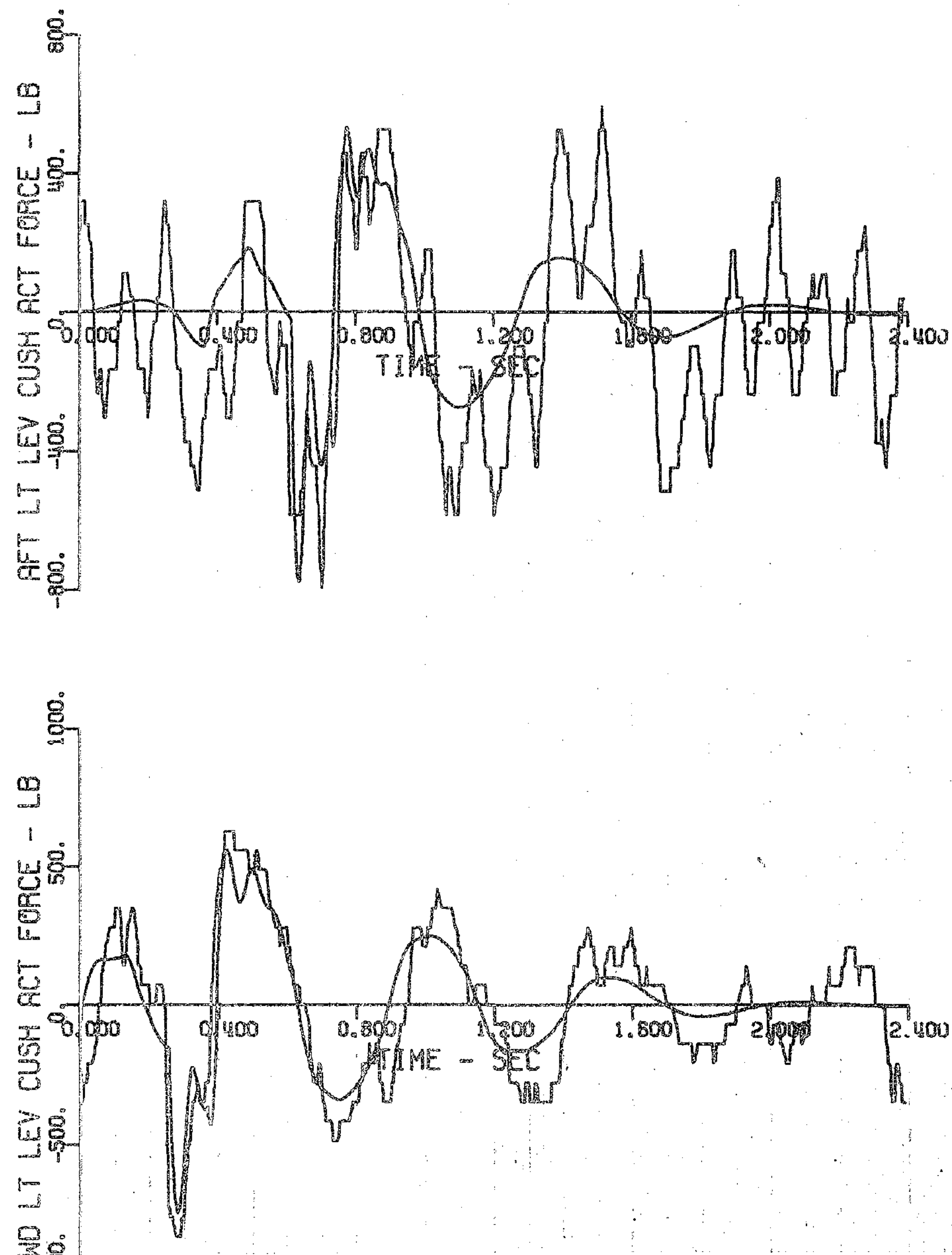


Figure 5-64 Left Levitation Cushion Actuator Force - Run 42-34
(Simulation Mod.)

RUN 42- 34 TL-101 10 19 56 67 MPH 1.0 IN X 25 FT RAMP

6.0 CONCLUSIONS

The TLRV, configured in the Independent Cushion Suspension mode successfully negotiated the guideway design perturbations up to the maximum speed tested, 90 mph. The range of perturbation sizes is adequate to induce responses in the range from imperceptible from "smooth" guideway response to sufficiently large for analytical correlation purposes.

Examination and comparison of the measured response data show that for the speeds tested:

- Vehicle response increases with increasing vehicle speed.
- Ramp-step excitation produces the highest body responses.
- The $1\frac{1}{2}$ inch by 100 foot parabolic pulse produces higher responses than the 3 inch by 150 foot parabola.
- With the exception of levitation suspension deflection, changes in secondary suspension properties (stiffness and damping) within vehicle limits produce minor changes in responses.
- Symmetric perturbations produce greater body accelerations than asymmetric.
- The aft suspension of the vehicle is not always symmetric, although equal left/right nominal settings are used.

Comparison of test results with Digital Simulation predictions revealed:

- Detailed description of the "as-built" perturbation shape (as opposed to the theoretical parabola) is important to attain good correlation
- Peak responses to symmetric 1 inch ramp-step perturbation and the 3 inch parabolic pulse is well predicted using design suspension parameters.
- Predictions of peak responses to the $1\frac{1}{2}$ inch parabolic pulse (symmetric and asymmetric) range from good to poor.
- Relatively significant responses occur in the frequency range of 2.5 to 3 Hz which are not predicted by the theoretical results.

The correlation studies showed that design values of damping produced responses which were more highly damped than experimental. Correlation is improved when analytical damping is decreased.

REFERENCES

1. Pierson, J., Tracked Air Cushion Research Vehicle - Test Plan Aeropropelled Mode, Grumman Report PMT-B4-PL73-1, June 1973, Unpublished

2. Fischer, G. and Zapotowski, B., Tracked Levitated Research Vehicle, Periodic Test Summary Report, Primary Suspension - Aeropropelled, Department of Transportation Report FRA-ORD&D 75-28, April 1974, NTIS Accession No. PB 240994/AS

3. Fischer, G. and Zapotowski, B., Tracked Levitated Research Vehicle, Periodic Test Summary Report, Body/Chassis Suspension - Aeropropelled - Smooth Guideway, Grumman Report PMT-B4-R74-2, August 1974, NTIS Accession No. PB243987/AS

4. Zapotowski, B., Tracked Levitated Research Vehicle, Body/Chassis Suspension in Perturbed Guideway - Aeropropelled, Grumman Report PMT-B4-R74-4, November 1974, NTIS Accession No. PB 244-282.

5. Fischer, G. and Zetkov, G., Tracked Levitated Research Vehicle, Periodic Test Summary Report, Independent Cushion Suspension - Aeropropelled - Smooth Guideway, - Grumman Report PMT-B4-R75-1, August 1975. To be published.

6. Zapotowski, B., Tracked Air Cushion Research Vehicle Dynamics Simulation Program Users Manual Addendum, Grumman Report PMT-B4-R75-04, February 1975. NTIS Accession No. PB 242907.

7. Zihal, G., and Heaslip, G., Tracked Levitated Research Vehicle Digital Data Processing and Analysis Program User's Manual, Grumman Report PMT-B4-R74-3, November 1974. Unpublished.

NOTE: Reports with NTIS Accession numbers may be obtained from the National Technical Information Service (NTIS), Springfield, Va. 22151.

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APPENDIX A: TRACKED LEVITATED RESEARCH VEHICLE - INDEPENDENT CUSHION SUSPENSION IN PERTURBED GUIDEWAY - AEROPROPELLED

DIGITAL COMPUTER PLOTS - TEST VERSUS THEORY

APPENDIX A

DIGITAL COMPUTER PLOTS - TEST VERSUS THEORY

This appendix contains those plots of measured responses to perturbations versus theoretical predictions which are not specifically used in the body of the report. These plots were generated by the digital computer program described in Reference 6. All of the test runs analyzed are tabulated in Figure A-1, which also lists the input data which were varied in the analyses. The page reference in the table refers to the body of the report for the plots used there and to the appendix page (A-xx) for the rest of the plots. A complete listing of the analytical input data is given in Figure A-2 with the variable inputs underlined.

In most cases 10 plots (2 per page) are made for each Test Run. These are as follows:

Vertical Body Acceleration at Point 1 (Forward)
Vertical Body Acceleration at Point 2 (Aft)
Forward Right Levitation Cushion Acceleration
Aft Right Levitation Cushion Acceleration
Forward Right Chassis (to Levitation Cushion) Suspension Deflection
Aft Right Chassis (to Levitation Cushion) Suspension Deflection
Forward Right Levitation Cushion Force
Aft Right Levitation Cushion Force
Forward Right Levitation Cushion Actuator Force
Aft Right Levitation Cushion Actuator Force (Listed as inoperative. Use with caution.)

In some cases additional plots for left side measurements are presented; and for asymmetric perturbations, the lateral acceleration and guidance responses are plotted.

Test Log	Run No.	Computer Run Log No.	Perturbation Description	Start Time hr:min:sec	Vel. mph	Lev. Cushion A/S Vol. (2) in^3	Lev. Cush. Act. Damp $psi/(in^3/sec)^{2/3}$	Lev. Cush. Closure Force lbs	Guide. Cush. Closure Force lbs	Page Numbers Report	Page Numbers Appendix
101	42-34	Z819042	1" x 25' Ramp-Step Symmetric	10:19:55.93	66.7	940.	72.	21850.	12274.	124	-
	42-34(mod)	Z473057		10:19:55.95	66.7	750.	50.	21850.	12274.	132	-
	42-36	Z432058		10:38:45.75	60.3	940.	72.	17250.	9690.	114	A-12
	42-38	Z422016		16:54:40.69	59.0	940.	83.	20700.	11628.	120	A-14
	42-42	Z474010		16:18:35.42	65.2	940.	83.	20700.	11628.	-	A-15
102	43-02	Z476007	1½" x 100' Parabola Symmetric	09:28:55.20	39.0	940.	83.	22425	12597.	-	A-20
	43-04	Z823007		09:44:56.17	42.2	940.	83.	21850.	12274.	-	A-25
	43-06	Z428008		10:17:28.56	72.0	940.	83.	23575.	13243.	-	A-30
	43-12	Z413059		11:52:17.82	76.0	940.	72.	23575.	13243.	99	A-35
	43-14	Z821008		12:10:45.48	78.3	940.	72.	23575.	13243.	-	A-37
	43-16	Z489008		13:51:18.03	77.0	940.	62.	23575.	13243.	-	A-42
	43-10	Z414351		14:08:45.12	77.0	2260.	62.	23000.	12920.	-	A-47
103	44-12	Z427057	1½" x 100' Parabola Asymmetric	11:14:54.26	75.0	940.	72.	23000.	12920.	105	A-52
104	43-18	Z854350	3" x 150' Parabola Symmetric	10:40:51.41	36.4	940.	72.	21275.	11951.	-	A-56
	43-20	Z820347		13:07:17.66	56.1	940.	72.	21850.	12274.	-	A-61
	43-22	Z815343		13:22:04.36	80.1	940.	72.	20700.	11628.	-	A-66
	43-24	Z812350		13:34.32.10	51.0	940	72.	17250	9690.	-	A-71
	43-26	Z470337		14:27:07.09	78.3	2260.	72.	20700.	11628.	-	A-75
	43-30	Z474331		15:02:13.70	78.3	2260.	62.	20700.	11628.	92	A-80
	43-28	Z470336		16:02:04.48	75.8	940.	62.	20700.	11628.	96	A-81
105	43-22A	Z810329	3" x 150' Parabola Symmetric	13:04:44.70	55.6	940.	72.	23000.	12920.	-	A-83
	43-28A	Z493329		14:39:07.26	84.7	940.	72.	23000.	12920.	-	A-87
	43-28B	Z497326		15:57:34.67	88.7	940.	72.	23000.	21920.	-	A-92

NOTES:

1. Guidance Cushion Actuator Damping = 156 $psi/(in^3/sec)^{2/3}$ (Test Log 101, 102, 103); = 66 $psi/(in^3/sec)^{2/3}$ (Test Log 104, 105)
2. Guidance Cushion Airspring Load = 4440 lb. (Test Log 101, 102, 103); = 2960 lb. (Test Log 104, 105)

Figure A-1 TLRV Digital Simulation Parameters, Independent Cushion Suspension Mode

```
RUN    44        12  TL-103  11 14 54  75 MPH  1.5 IN X 106 FT ASYM PARABOLA                          DATE      02/15/75

VEHICLE CONDITIONS

CARD 2 DEGREES OF FREEDOM

NDOF     NCONB      NCONS      NGCP       NLCP
  3         1         -1          0          0

CARD 3 TURN GUST AND ACTUATOR EXCITATION

NTURNL   NTURNV     NTURNR     NGUSTL     NGUSTV     NFORCE
  0         0          0          0          0          0

CARD 4  GUIDEWAY AND PROPULSION EXCITATION

NRLV     NLLV       NRGD       NLGD       NFLEX      NTHR
  8         2          0          0          0          0

CARD 5  SUSPENSION CONTROL

KACBC    KACLV      KACGD      KCHBC      KCHLV      KCHGD
  0         0          0          0          0          0

CARD 6  VEHICLE ENVIRONMENT

VEHICLE SPEED      AIR DENSITY         AMBIENT PRESSURE    GRAVITY            AIR SPEC HT RATIO   ORIFICE COEF
       1320.0           0.10000E-06           12.200            386.00             1.4000             100.00

CARD 7  SINUSOIDAL GUIDEWAY ROUGHNESS PARAMETERS

RIGHT LAT AMPL     LEFT LAT AMPL       VERT AMPL           RT LAT WAVELENGTH  LT LAT WAVELENGTH   VERT WAVELENGTH
      0.0                0.0                0.0                 0.0                0.0                0.0

**************************************************************************************************************************

VEHICLE MASS PROPERTIES

CARD 8  BODY MASS PROPERTIES

MASS               ROLL INERTIA        PITCH INERTIA       YAW INERTIA        XZ INERTIA          X CG LOCATION       Z CG LOCATION
       47.900            64450.            0.13000E 07         0.13000E 07        62500.             46.540              11.000

CARD 9  CHASSIS MASS PROPERTIES

MASS               ROLL INERTIA        PITCH INERTIA       YAW INERTIA        XZ INERTIA          X CG LOCATION       Z CG LOCATION
       26.300            60900.            0.91000E 06         0.96000E 06       -12100.             14.100              -4.0000

CARD 10  CUSHION MASS PROPERTIES

LEV CUSH MASS      GUID CUSH MASS
       2.0300            1.1300

**************************************************************************************************************************

VEHICLE GEOMETRY

CARD 11  BASIC VEHICLE GEOMETRY
```

Figure A-2a Typical Input for Digital Simulation, Independent Cushion Suspension Mode

```
CUSHION X OFFSET   BODY CHAS OFFSET   LEV CUSH Y OFFSET  LEV CUSH Z OFFSET  GD CUSH Y OFFSET   ROLL SPR Z OFFSET  LEV SURF Z OFFSET
     209.75             44.000             44.000             26.300             64.600             20.000             33.500

CARD 12  BODY/CHASSIS SUSP LOCATIONS

FWD LAT LINK       AFT LAT LINK       AFT ROLL SUSP      FWD VERT SUSP      AFT VERT SUSP      DRAG LINK Z OFFSET
     231.50             211.25             178.75             226.35             200.85             36.000

CARD 13  CUSHION AND PROPULSION GEOMETRY

GUID CUSH LENGTH   GUID CUSH WIDTH    LEV CUSH LENGTH    LEV CUSH WIDTH     LIM Z OFFSET       AERO THR Z OFFSET  B/C DUCT X OFFSET
     132.00             27.000             132.00             48.000             14.000             62.500             251.25

CARD 14  TEST REFERENCE GEOMETRY

INITIAL GUID STA   POS SENS X OFFSET
     0.0                0.0

*********************************************************************************************************************************

VEHICLE AERODYNAMIC DATA

CARD 15  BODY AERODYNAMIC PROPERTIES

BODY REF AREA      BODY LIFT COEFF    BODY DRAG COEFF    BODY XCP LOC PTCH  BODY ZCP LOC PTCH  BODY CLA
     17000.             0.13000            0.80000E-01        -322.75            0.0                1.4300

CARD 16  BODY AERODYNAMIC PROPERTIES

BODY XCP LOC(YAW)  BODY ZCP LOC(YAW)  BODY YAW DERIV
     18.000             0.0                1.2890

CARD 17  CHASSIS AERODYNAMIC PROPERTIES

CHASSIS REF AREA   CHASSIS LIFT COEF  BODY DRAG COEFF    CHAS XCP LOC PTCH  CHAS ZCP LOC PTCH  CHASSIS CLA
     17000.             0.14000            0.27000            211.25             0.0                17.700

CARD 18  CHASSIS AERODYNAMIC PROPERTIES

CHAS XCP LOC(YAW)  CHAS ZCP LOC(YAW)  CHASSIS YAW DERIV
     0.0                0.0                0.0

*********************************************************************************************************************************

PASSIVE SUSPENSION PROPERTIES

CARD 19 LATERAL LINK AND ROLL SUSPENSION CONSTANTS (BODY/CHASSIS)

FRONT LINK SPRING  REAR LINK SPRING   ROLL LINK SPRING   FRNT LINK DAMPING  REAR LINK DAMPING  ROLL LINK DAMPING
     12000.             12000.             2000.0             69.000             69.000             475.00

CARD 20  SUSPENSION DATA (CHASSIS/GUIDANCE CUSHION)

FWD AIRSPRNG LOAD  REAR AIRSPRNG LD   AIRSPRING AREA     AIRSPRING VOLUME   LINR DAMPING CNST  QUAD DAMPING CNST  AIRSPRNG AREA DRV
     4440.0             4440.0             74.000             580.00             0.0                0.0                11.500

CARD 21 COMPRESSION STROKE SNUBBER DATA (CHASSIS/GUIDANCE CUSHION)

STROKE TO SNUBBER  SNUBBER DAMP CNST  SNUBBER SPRNG CNST
```

Figure A-2b   Typical Input for Digital Simulation, Independent Cushion Suspension Mode

```
       1.8750            0.0                 7370.0

CARD 22  SUSPENSION DATA (CHASSIS/LEVITATION CUSHION)

FRNT AIRSPRG AREA  REAR AIRSPRG AREA  FRNT AIRSPRG VOL   REAR AIRSPRG VOL   LINR DAMPING CNST  QUAD DAMPING CNST
       140.00             140.00            940.00             940.00          0.0                0.0

CARD 23  COMPRESSION STROKE SNUBBER DATA (CHASSIS/LEVITATION CUSHION)

STROKE TO SNUBBER  SNUBBER DAMP CNST  SNUBBER SPRNG CNST
       2.4000             0.0                0.0

CARD 24  VERTICAL SUSPENSION DATA (BODY/CHASSIS)

FRNT AIRSPRG AREA  REAR AIRSPRG AREA  FRNT AIRSPRG VOL   REAR AIRSPRG VOL   LINR DAMPING CNST  QUAD DAMPING CNST
       172.00             172.00            5200.0             5200.0          0.0                0.0

CARD 25  COMPRESSION STROKE SNUBBER DATA (BODY/CHASSIS)

STROKE TO SNUBBER  SNUBBER DAMP CNST  SNUBBER SPRNG CNST
       5.4000             0.0                85000.

CARD 26  GUIDANCE AND LEVITATION CUSHION DATA

GC CLOSURE FORCE   GC JET THICKNESS   GC  LAG TIME       LC CLOSURE FORCE   LC JET THICKNESS   LC  LAG TIME
       12920.          0.90000E-01        0.40000E-02         23000.          0.99000E-01        0.15000E-02

CARD 27  DRAG LINK SUSPENSION PROPERTIES AND AFT DUCT FORCE

DRAG LNK DMP CNST  DRG LNK SPRNG CNST AFT DUCT FORCE
       270.00             10000.            7712.0

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ACTUATOR PROPERTIES (PASSIVE)


THERE ARE TEN ACTUATORS NUMBERED AS FOLLOWED
                  CHASSIS/GUIDANCE CUSHION          CHASSIS/LEVITATION CUSHION      BODY/CHASSIS
                   1-FWD RIGHT                        5-FWD RIGHT                    9-FWD
                   2-FWD LEFT                         6-FWD LEFT                    10-REAR
                   3-REAR RIGHT                       7-REAR RIGHT
                   4-REAR LEFT                        8-REAR LEFT

CARD 28  DEADBAND STROKE  CHASSIS/GUIDANCE CUSHION ACTUATORS

ACTUATOR 1         ACTUATOR 2         ACTUATOR 3         ACTUATOR 4
      0.0                0.0                0.0                0.0

CARD 29  DEADBAND STROKE CHASSIS/LEVITATION CUSHION AND BODY CHASSIS ACTUATORS

ACTUATOR 5         ACTUATOR 6         ACTUATOR 7         ACTUATOR 8         ACTUATOR 9         ACTUATOR 10
      0.0                0.0                0.0                0.0                0.0                0.0

CARD 30  ACTUATOR AREAS AND DEADBAND SPRING RATES

ACT  1-4 AREA      ACT  5-8 AREA      ACT 9 AND 10 AREA  ACT 1-4 SPRNG RT   ACT  5-8 SPRNG RT  ACT 9 AND 10 SPRNG RT
       1.2870             1.7830            2.5940             445.00            251.00              88.000

CARD 31  ACTUATOR TOTAL TENSION STROKE AND STROKE TO TENSION SNUB
```

Figure A-2c   Typical Input for Digital Simulation,
Independent Cushion Suspension Mode

```
TOTAL ACT 1-4     TOTAL ACT 5-8     TOTAL ACT 9-10    SNUB ACT 1-4      SNUB ACT 5-8      SNUB ACT 9-10
      2.2500            3.0000            6.0000            2.0000            2.6000            5.4500

CARD 32  MAXIMUM AND MINIMUM SNUBBING ORIFICE AREAS

MAX AREA ACT 1-4  MAX AREA ACT 5-8  MAX AREA ACT 9-10 MIN AREA ACT 1-4  MIN AREA ACT 5-8  MIN AREA ACT 9-10
   0.67000E-02       0.44000E-02       0.64000E-02       0.20000E-03       0.20000E-03       0.20000E-03
CARD 33  DAMPING CONSTANTS -CHASSIS/GUIDANCE CUSHION ACTUATORS

ACTUATOR 1        ACTUATOR 2        ACTUATOR 3        ACTUATOR 4
      156.00            156.00            156.00            156.00
CARD 34  DAMPING CONSTANTS -CHASSIS/GUIDANCE CUSHION AND BODY CHASSIS ACTUATORS

ACTUATOR 5        ACTUATOR 6        ACTUATOR 7        ACTUATOR 8        ACTUATOR 9        ACTUATOR 10
      72.000            72.000            72.000            72.000            30.000            30.000

CARD 35  ACTUATOR FRICTION SLOPE AND CHASSIS/GUIDANCE CUSHION ACTUATOR FRICTION (COMPRESSING)

FRICTION SLOPE    ACT 1 FRICTION    ACT 2 FRICTION    ACT 3 FRICTION    ACT 4 FRICTION
      250.00            90.000            90.000            90.000            90.000
CARD 36  CHASSIS/LEVITATION CUSHION AND BODY/CHASSIS  ACTUATOR FRICTION (COMPRESSING)

ACT 5 FRICTION    ACT 6 FRICTION    ACT 7 FRICTION    ACT 8 FRICTION    ACT 9 FRICTION    ACT 10 FRICTION
      110.00            110.00            110.00            110.00            110.00            110.00
CARD 37  CHASSIS/GUIDANCE CUSHION ACTUATOR FRICTION FRICTION (EXTENDING)

ACT 1 FRICTION    ACT 2 FRICTION    ACT 3 FRICTION    ACT 4 FRICTION
      90.000            90.000            90.000            90.000

CARD  38 CHASSIS/LEVITATION CUSHION AND BODY/CHASSIS (EXTENDING)

ACT 5 FRICTION    ACT 6 FRICTION    ACT 7 FRICTION    ACT 8 FRICTION    ACT 9 FRICTION    ACT 10 FRICTION
      110.00            110.00            110.00            110.00            110.00            110.00

*************************************************************************************************************************************

ACTIVE CONTROL PARAMETERS

 THERE ARE SEVEN ACTIVE SUSPENSION CHANNELS NUMBERED AS FOLLOWS
                                                                   CHANNEL 1 FOWARD VERTICAL (BODY/CHASSIS)
                                                                   CHANNEL 2 REAR VERTICAL (BODY/CHASSIS)
                                                                   CHANNEL 3 FOWARD VERTICAL (CHASSIS/LEVITATION CUSHION)
                                                                   CHANNEL 4 REAR VERTICAL (CHASSIS/LEVITATION CUSHION)
                                                                   CHANNEL 5 ROLL
                                                                   CHANNEL 6 FOWARD LATERAL (CHASSIS/GUIDANCE)
                                                                   CHANNEL 7 REAR LATERAL (CHASSIS/GUIDANCE CUSHION)
ACTUATORS ARE NUMBERED AS GIVEN IN 'ACTUATOR PROPERTIES (PASSIVE)'
WITH ADDITIONAL DATA FOR ROLL IN SIGNAL LIMIT DATA

CARD 39  ACCELERATION GAINS

CHANNEL 1 GAIN    CHANNEL 2 GAIN    CHANNEL 3 GAIN    CHANNEL 4 GAIN    CHANNEL 5 GAIN    CHANNEL 6 GAIN    CHANNEL 7 GAIN
     -120.00           -120.00       0.0               0.0               0.0               0.0               0.0
CARD 40  RATE GAINS
```

Figure A-2d Typical Input for Digital Simulation, Independent Cushion Suspension Mode

```
CHANNEL 1 GAIN     CHANNEL 2 GAIN     CHANNEL 3 GAIN     CHANNEL 4 GAIN     CHANNEL 5 GAIN     CHANNEL 6 GAIN     CHANNEL 7 GAIN
   -600.00            -600.00            0.0                0.0                0.0                0.0                0.0

CARD 41   STROKE GAINS

CHANNEL 1  GAIN    CHANNEL 2 GAIN     CHANNEL 3 GAIN     CHANNEL 4  GAIN    CHANNEL 5 GAIN     CHANNEL 6 GAIN     CHANNEL 7  GAIN
   -1000.0            -1000.0            0.0                0.0                0.0                0.0                0.0

CARD 42   HIGH PASS FILTER POLE ONE DATA

CHANNEL 1 POLE 1   CHANNEL 2 POLE 1   CHANNEL 3 POLE 1   CHANNEL 4 POLE 1   CHANNEL 5 POLE 1   CHANNEL 6 POLE 1   CHANNEL 7 POLE 1
   0.0                0.0                0.0                0.0                0.0                0.0                0.0

CARD 43   HIGH PASS FILTER POLE TWO DATA

CHANNEL 1 POLE 2   CHANNEL 2 POLE 2   CHANNEL 3 POLE 2   CHANNEL 4 POLE 2   CHANNEL 5 POLE 2   CHANNEL 6 POLE 2   CHANNEL 7.POLE 2
   0.0                0.0                0.0                0.0                0.0                0.0                0.0

CARD 44   FLOW GAIN   CHASSIS/GUIDANCE CUSHION ACTUATORS

ACTUATOR 1 GAIN    ACTUATOR 2 GAIN    ACTUATOR 3 GAIN    ACTUATOR 4 GAIN
   0.0                0.0                0.0                0.0

CARD 45   FLOW GAIN   CHASSIS/LEVITATION CUSHION AND BODY/CHASSIS ACTUATORS

ACTUATOR 5 GAIN    ACTUATOR 6 GAIN    ACTUATOR 7 GAIN    ACTUATOR 8 GAIN    ACTUATOR 9 GAIN    ACTUATOR 10 GAIN
   0.0                0.0                0.0                0.0                27.500             27.500

CARD 46   PRESSURE FEEDBACK GAIN   CHASSIS/GUIDANCE CUSHION ACTUATORS

ACTUATOR 1 GAIN    ACTUATOR 2 GAIN    ACTUATOR 3 GAIN    ACTUATOR 4 GAIN
   0.0                0.0                0.0                0.0

CARD 47   PRESSURE FEEDBACK GAIN   CHASSIS/LEVITATION CUSHION AND BODY/CHASSIS ACTUATORS

ACTUATOR 5 GAIN    ACTUATOR 6 GAIN    ACTUATOR 7 GAIN    ACTUATOR 8 GAIN    ACTUATOR 9 GAIN    ACTUATOR 10 GAIN
   0.0                0.0                0.0                0.0                3.2000             3.2000

CARD 48   MAXIMUM SIGNAL LIMIT   CHASSIS/GUIDANCE CUSHION ACTUATORS

ACTUATOR 1 LIMIT   ACTUATOR 2 LIMIT   ACTUATOR 3 LIMIT   ACTUATOR 4 LIMIT
   0.0                0.0                0.0                0.0

CARD 49   MAXIMUM SIGNAL LIMIT   CHASSIS/LEVITATION CUSHION BODY/CHASSIS ACTUATOR AND ROLL CONTROL

ACTUATOR 5 LIMIT   ACTUATOR 6 LIMIT   ACTUATOR 7 LIMIT   ACTUATOR 8 LIMIT   ACTUATOR 9 LIMIT   ACTUATOR 10 LIMIT  ROLL LIMIT
   0.0                0.0                0.0                0.0                0.0                0.0                0.0

CARD 50   MINIMUM SIGNAL LIMIT   CHASSIS/GUIDANCE CUSHION ACTUATORS

ACTUATOR 1 LIMIT   ACTUATOR 2 LIMIT   ACTUATOR 3 LIMIT   ACTUATOR 4 LIMIT
   0.0                0.0                0.0                0.0

CARD 51   MINIMUM SIGNAL LIMIT   CHASSIS/LEVITATION CUSHION, BODY/CHASSIS ACTUATOR AND ROLL CONTROL

ACTUATOR 5 LIMIT   ACTUATOR 6 LIMIT   ACTUATOR 7 LIMIT   ACTUATOR 8 LIMIT   ACTUATOR 9 LIMIT   ACTUATOR 10 LIMIT  ROLL LIMIT
   0.0                0.0                0.0                0.0                0.0                0.0                0.0

CARD 52   CONTROL ACCELEROMETER LOCATION

Z DIST TO FWD      X.DIST TO FWD      X DIST TO REAR     X DIST TO ROLL     Z DIST TO ROLL     Z DIST TO REAR
   0.0                226.35             200.85             0.0                0.0                0.0
```

Figure A-2e   Typical Input for Digital Simulation, Independent Cushion Suspension Mode

```
CARD 53  COMMAND SIGNAL AMPLITUDE (SINUSOIDAL)  CHASSIS/GUIDANCE CUSHION ACTUATORS

AMPL ACTUATOR 1     AMPL ACTUATOR 2     AMPL ACTUATOR 3     AMPL ACTUATOR 4
     0.0                 0.0                 0.0                 0.0

CARD 54  COMMAND SIGNAL AMPLITUDE (SINUSOIDAL)  CHASSIS/LEVITATION CUSHION AND BODY/CUSHION ACTUATORS

AMPL ACTUATOR 5     AMPL ACTUATOR 6     AMPL ACTUATOR 7     AMPL ACTUATOR 8     AMPL ACTUATOR 9     AMPL ACTUATOR 10
     0.0                 0.0                 0.0                 0.0                 0.0                 0.0

CARD 55  COMMAND SIGNAL FREQUFNCY (SINUSOIDAL)  CHASSIS/GUIDANCE CUSHION ACTUATORS

FREQ ACTUATOR 1     FREQ ACTUATOR 2     FREQ ACTUATOR 3     FREQ ACTUATOR 4
     0.0                 0.0                 0.0                 0.0

CARD 56  COMMAND SIGNAL FREQUENCY (SINUSOIDAL)  CHASSIS/LEVITATION CUSHION AND BODY/CHASSIS ACTUATORS

FREQ ACTUATOR 5     FREQ ACTUATOR 6     FREQ ACTUATOR 7     FREQ ACTUATOR 8     FREQ ACTUATOR 9     FREQ ACTUATOR 10    SWEEP RATE
     0.0                 0.0                 0.0                 0.0                 0.0                 0.0                 0.0

************************************************************************************************************************************

FLEXIBLE GUIDEWAY (VERTICAL/ONLY)

CARD 57  FLEXIBLE GUIDEWAY PARAMETERS

BEAM LENGTH         BEAM WT UNIT LNGTH  BEAM RIGIDITY       BEAM CAMBER
     0.0                 0.0                 0.0                 0.0

************************************************************************************************************************************

ACCELERATION MEASUREMENT POINTS

CARD 58  CHASSIS ACCELERATION POINTS X POSITION

POINT 1             POINT 2             POINT 3             POINT 4             POINT 5             POINT 6
     -235.25             213.75              -2.2500             -235.25             213.75              0.0

CARD 59  CHASSIS ACCELERATION POINTS Y POSITION

POINT 1             POINT 2             POINT 3             POINT 4             POINT 5             POINT 6
     0.0                 0.0                 34.000              2.0000              2.0000              0.0

CARD 60  CHASSIS ACCELERATION POINTS Z POSITION

POINT 1             POINT 2             POINT 3             POINT 4             POINT 5             POINT 6
     16.000              3.0000              -8.0000             16.000              1.0000              0.0

CARD 61  BODY ACCELERATION POINTS X POSITION

POINT 1             POINT 2             POINT 3             POINT 4             POINT 5             POINT 6
     -217.00             193.00              13.000              -220.00             197.00              0.0

CARD 62  BODY ACCELERATION POINTS Y POSITION

POINT 1             POINT 2             POINT 3             POINT 4             POINT 5             POINT 6
     0.0                 0.0                 44.000              -3.0000             -3.0000             0.0

CARD 63  BODY ACCELERATION POINTS Z POSITION
```

Figure A-2f Typical Input for Digital Simulation, Independent Cushion Suspension Mode

POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6
-5.0000	-5.0000	-23.000	-1.0000	-1.0000	0.0

****

TIME AND INTEGRATION PARAMETERS

CARD 64 TIME AND INTEGRATION PARAMETERS

INTEGR INCREMENT	STOP TIME	PRINT INCREMENT	PLOT INCREMENT	XLINES
0.10000E-02	2.3990	0.10000E 00	0.70000E-02	10.000

Figure A-2g Typical Input for Digital Simulation, Independent Cushion Suspension Mode

TABLES DATA

TABLE NO= 2 NO OF PTS 3 LOGIC= 0

	X POINTS	Y POINTS
1	2.775E 02	0.0
2	9.135E 02	0.0
3	1.550E 03	0.0

TABLE NO= 4 NO OF PTS 3 LOGIC= 0

	X POINTS	Y POINTS
1	2.775E 02	0.0
2	5.775E 02	1.000E 00
3	5.776E 02	0.0

TABLE NO= 5 NO OF PTS 3 LOGIC= 2

	X POINTS	Y POINTS
1	2.775E 02	0.0
2	8.775E 02	1.500E 00
3	1.478E 03	0.0

TABLE NO= 6 NO OF PTS 3 LOGIC= 2

	X POINTS	Y POINTS
1	2.775E 02	0.0
2	1.178E 03	3.000E 00
3	2.078E 03	0.0

TABLE NO= 8 NO OF PTS 12 LOGIC= 0

	X POINTS	Y POINTS
1	2.775E 02	0.0
2	5.655E 02	1.000E 00
3	5.895E 02	1.060E 00
4	6.855E 02	1.280E 00
5	7.815E 02	1.430E 00
6	8.775E 02	1.500E 00
7	9.495E 02	1.500E 00
8	1.046E 03	1.430E 00
9	1.142E 03	1.280E 00
10	1.238E 03	1.060E 00
11	1.262E 03	1.000E 00
12	1.550E 03	0.0

TABLE NO= 9 NO OF PTS 18 LOGIC= 0

X POINTS Y POINTS

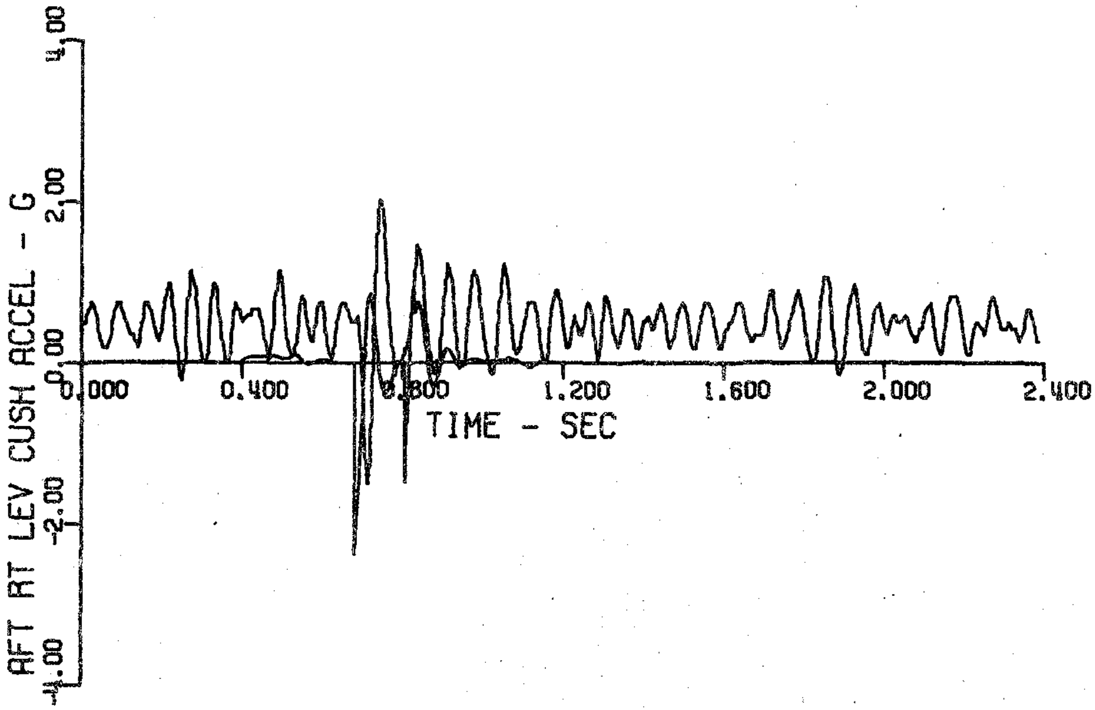
Figure A-2h Typical Input for Digital Simulation, Independent Cushion Suspension Mode

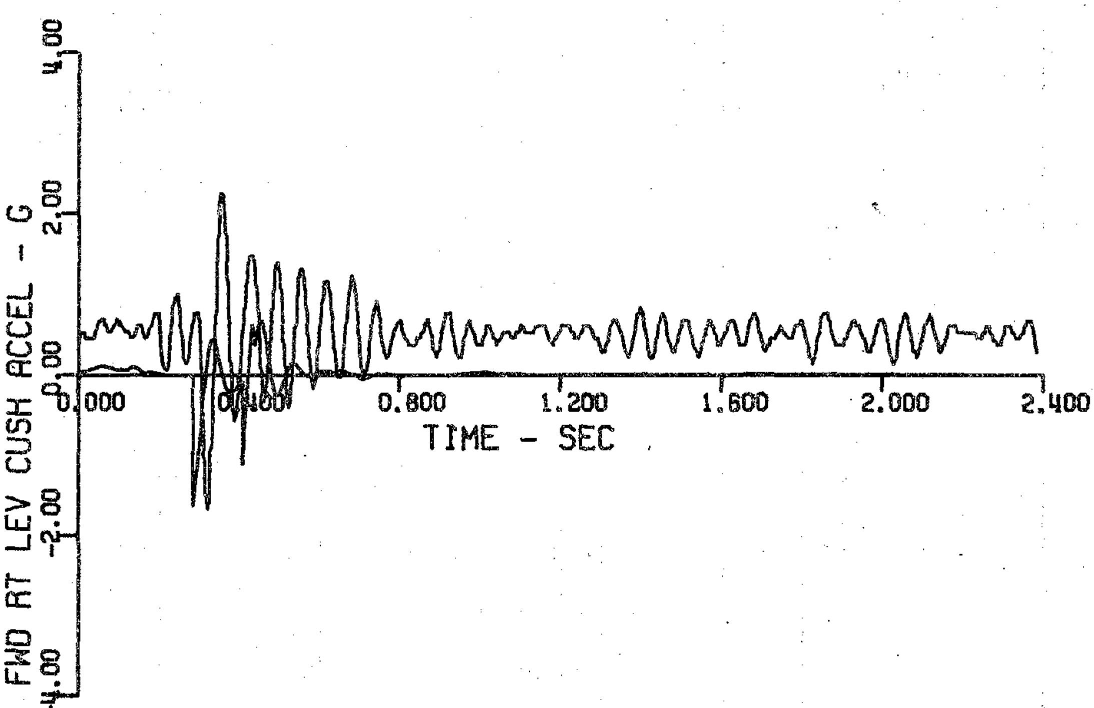
1	2.775E 02	0.0
2	5.655E 02	1.000E 00
3	6.615E 02	1.500E 00
4	7.575E 02	1.920E 00
5	8.535E 02	2.260E 00
6	9.495E 02	2.547E 00
7	1.046E 03	2.766E 00
8	1.142E 03	2.906E 00
9	1.238E 03	3.000E 00
10	1.334E 03	3.000E 00
11	1.430E 03	2.906E 00
12	1.526E 03	2.766E 00
13	1.622E 03	2.547E 00
14	1.718E 03	2.260E 00
15	1.814E 03	1.920E 00
16	1.910E 03	1.500E 00
17	2.006E 03	1.000E 00
18	2.294E 03	0.0

VEHICLE INITIAL TRIM

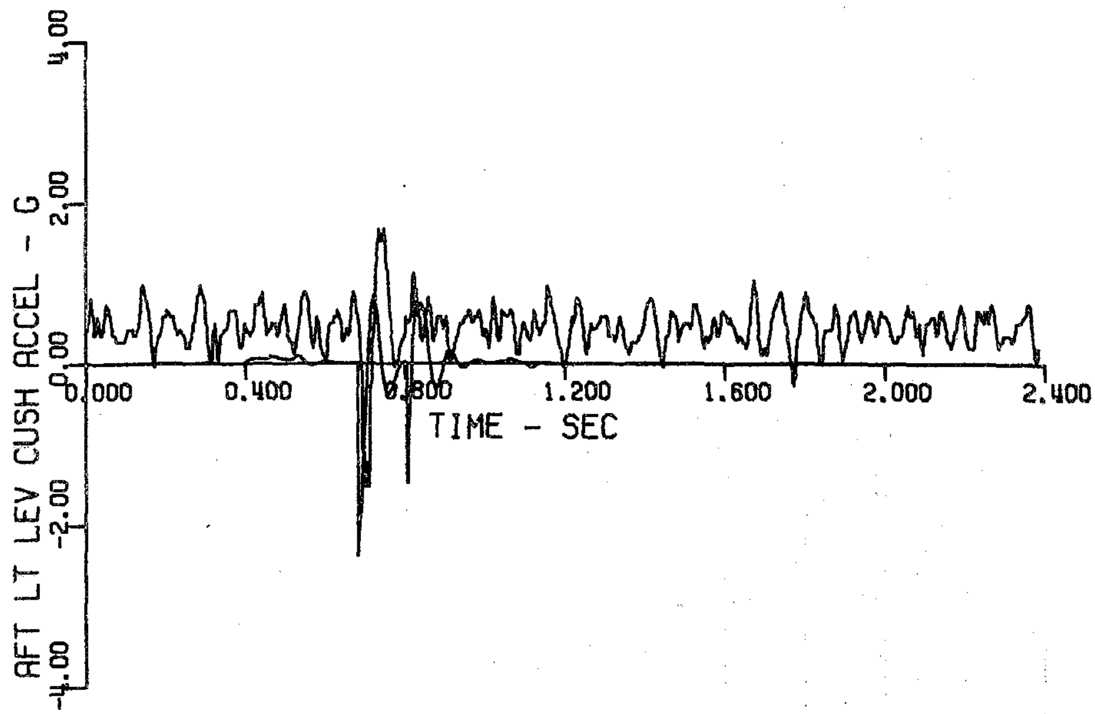
BODY LIFT 192.54	BODY DRAG 118.48	CHASSIS LIFT 207.35	CHASSIS DRAG 399.88
FWD GD ARSPG LOAD 4440.0	AFT GD ARSPG LOAD 4440.0	FWD LEV ARSPG LOAD 6722.9	AFT LEV ARSPG LOAD 8270.1
FWD LEV CUSH LOAD 7506.5	AFT LEV CUSH LOAD 9053.7	FWD B/C ARSPG LOAD 7752.9	AFT B/C ARSPG LOAD 2831.9
FWD GD CUSH GAP 0.64123	AFT GD CUSH GAP 0.64123	FWD LEV CUSH GAP 0.75176	AFT LEV CUSH GAP 0.59367

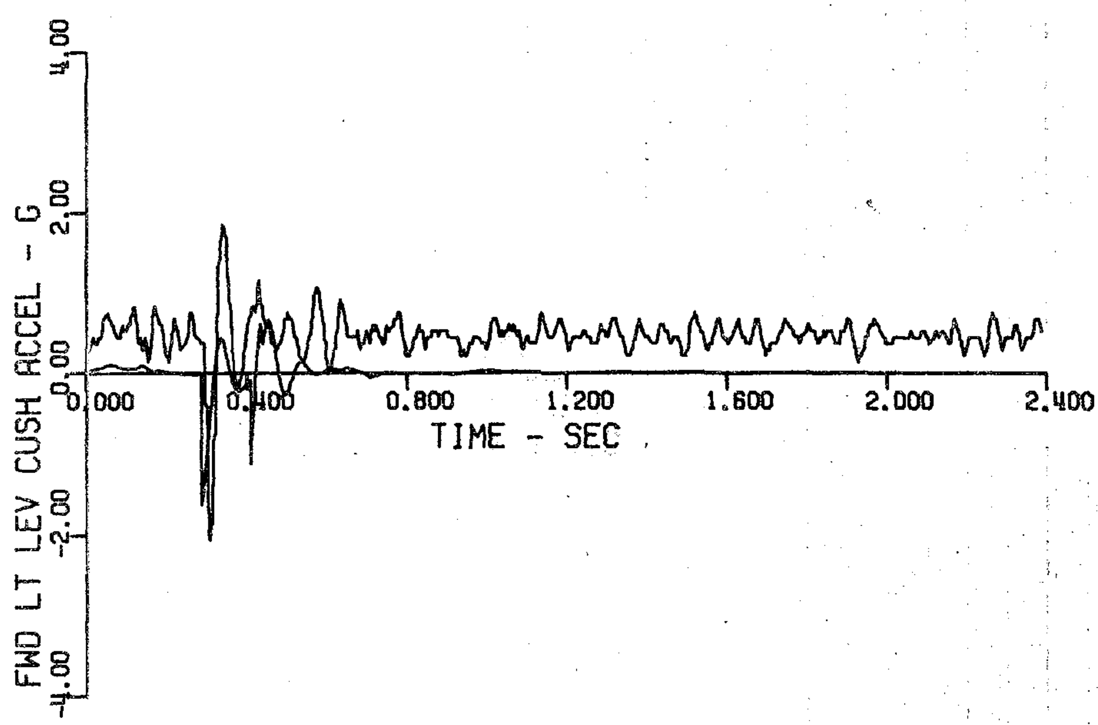
Figure A-2i Typical Input for Digital Simulation, Independent Cushion Suspension Mode



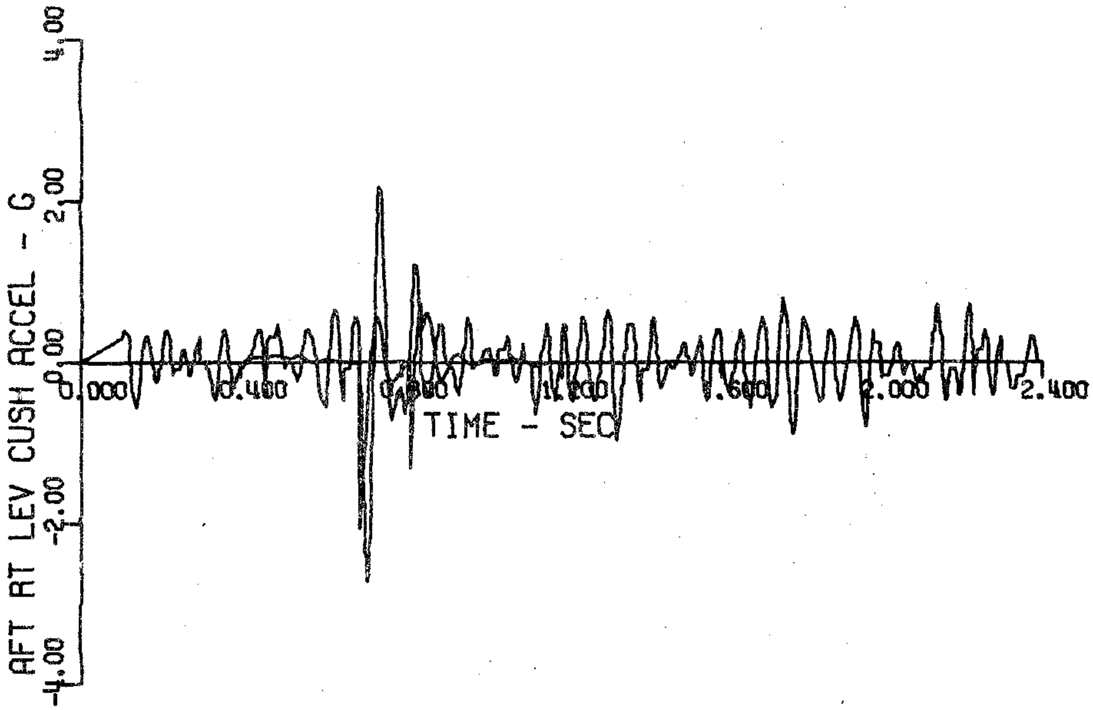


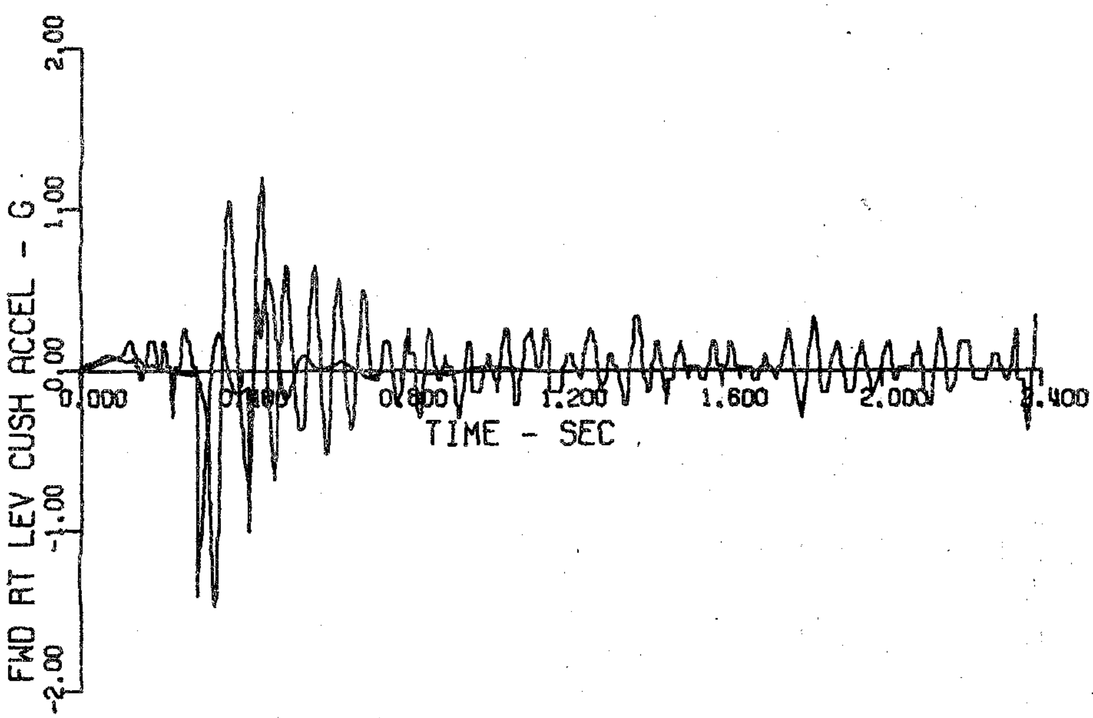
RUN 42- 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP



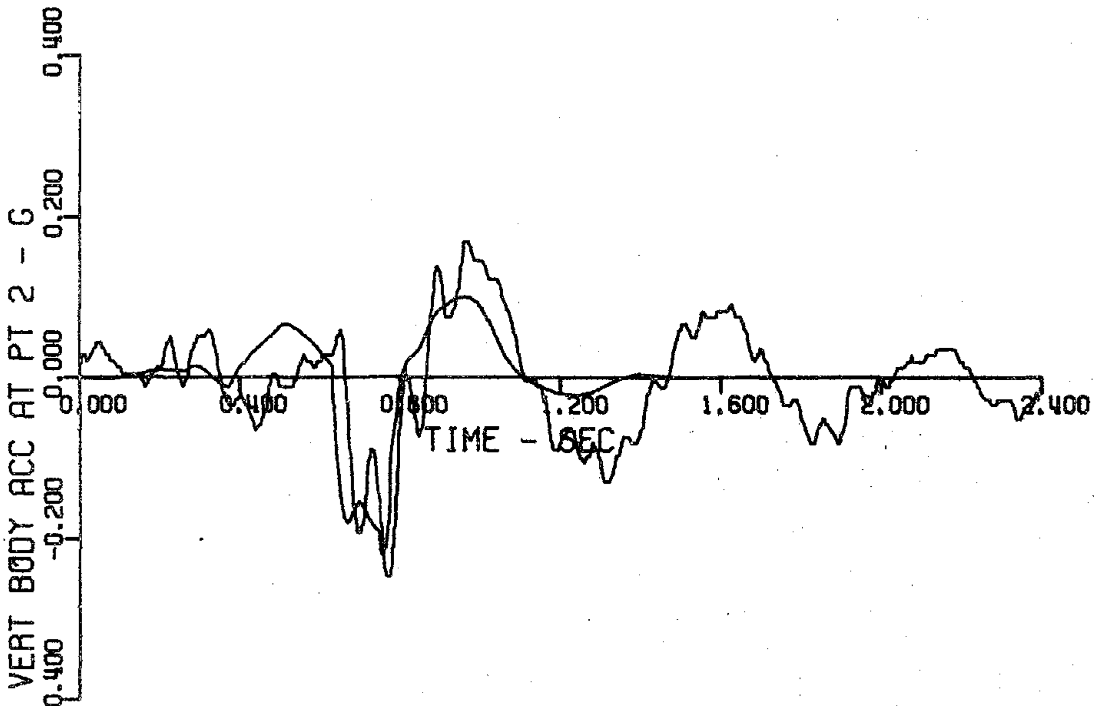


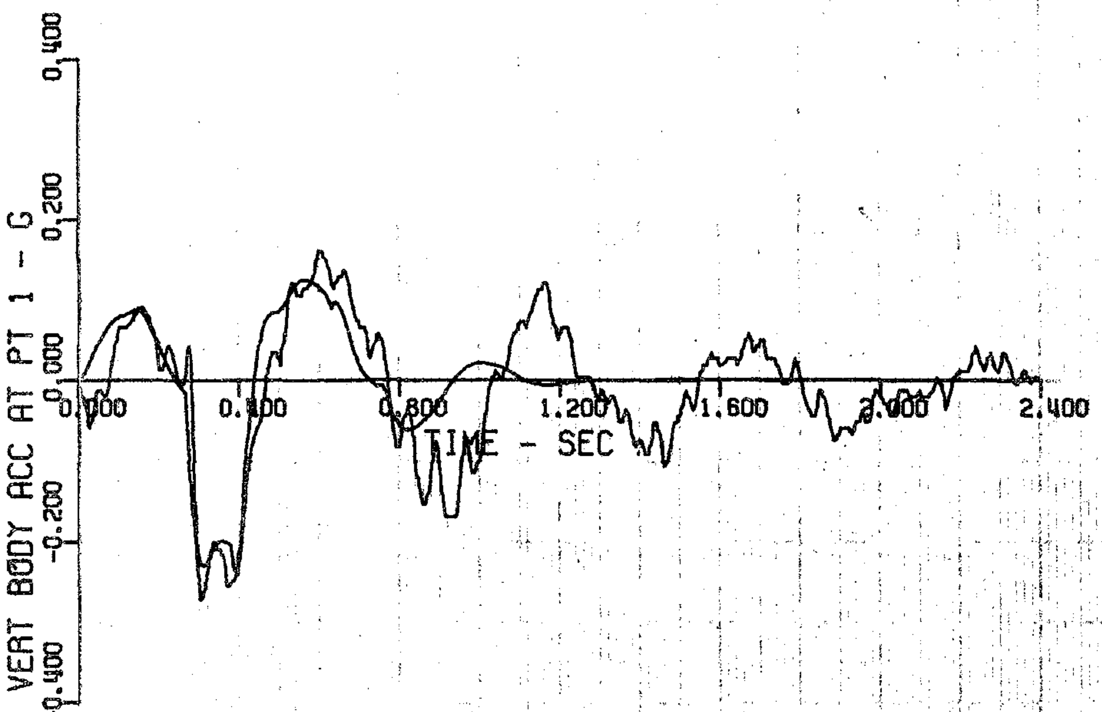
RUN 42 - 36 TL-101 10 38 46 60 MPH 1.0 IN X 25 FT RAMP





RUN 42 - 38 TL-101 16 54 41 59 MPH 1.0 IN X 25 FT RAMP





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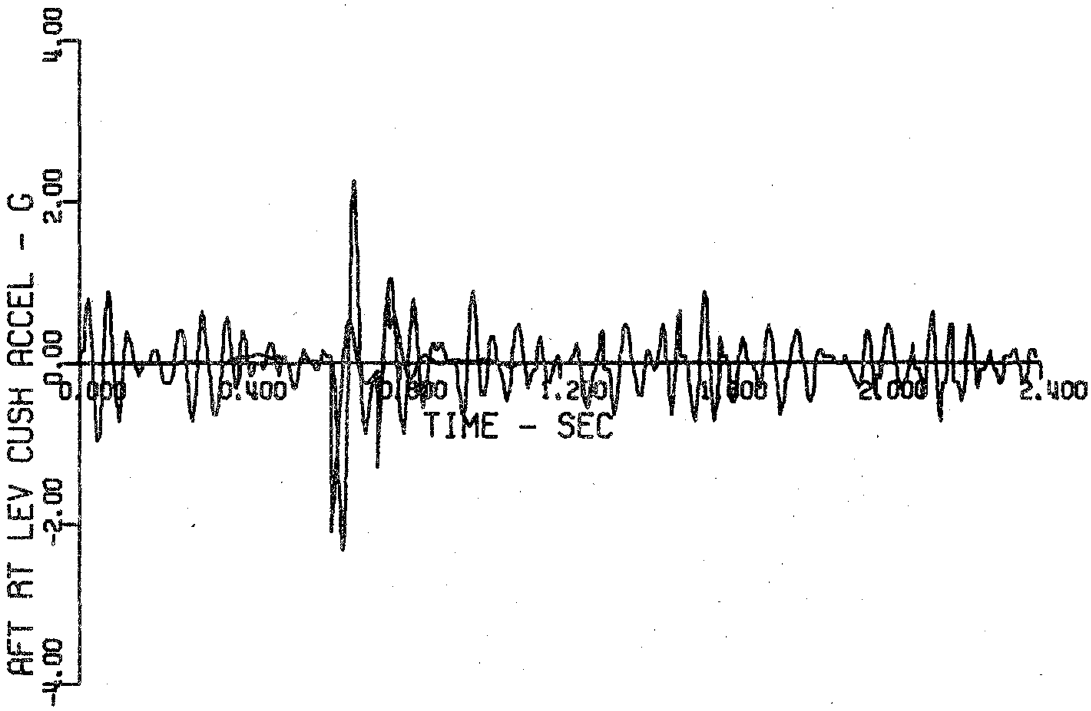
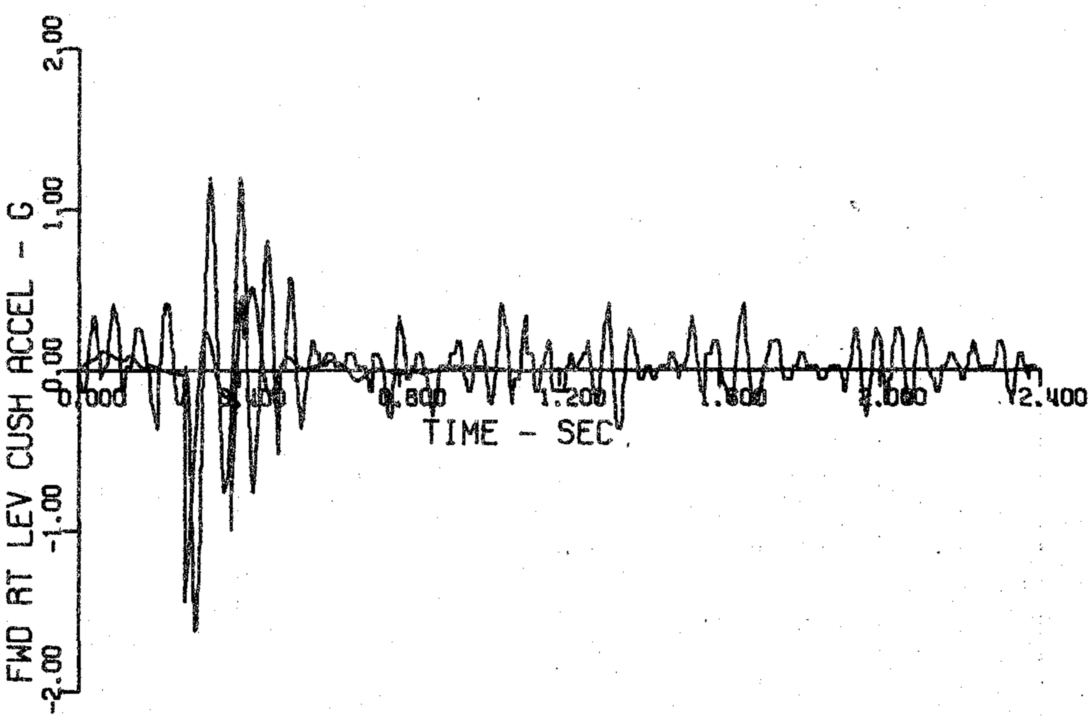
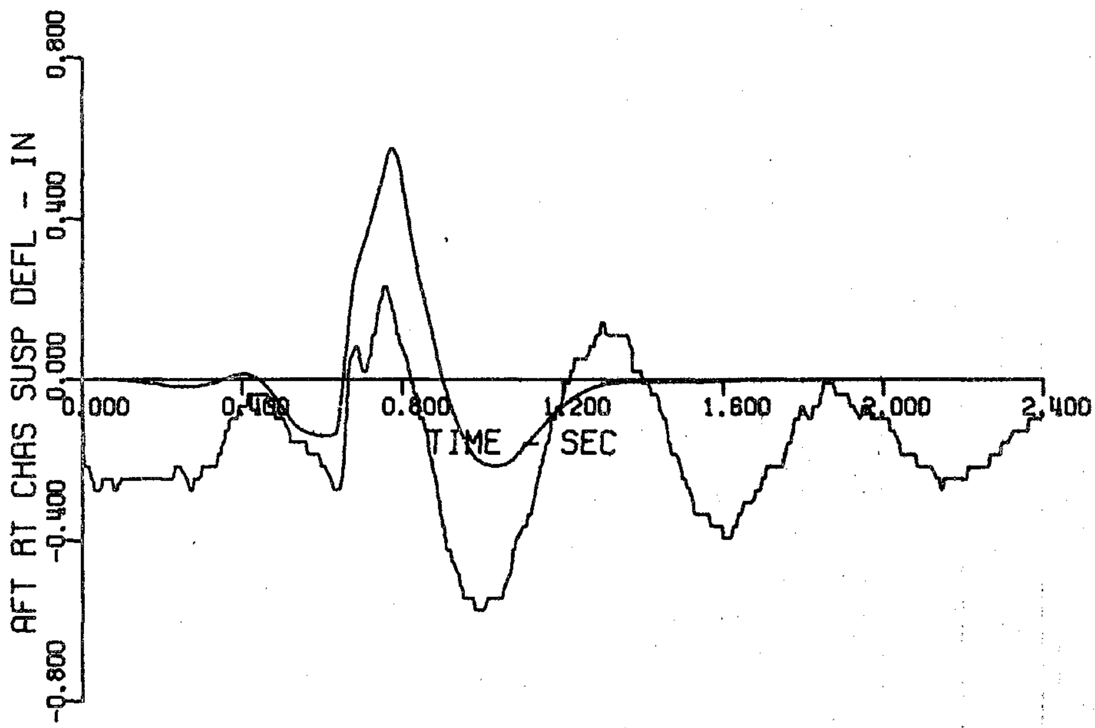
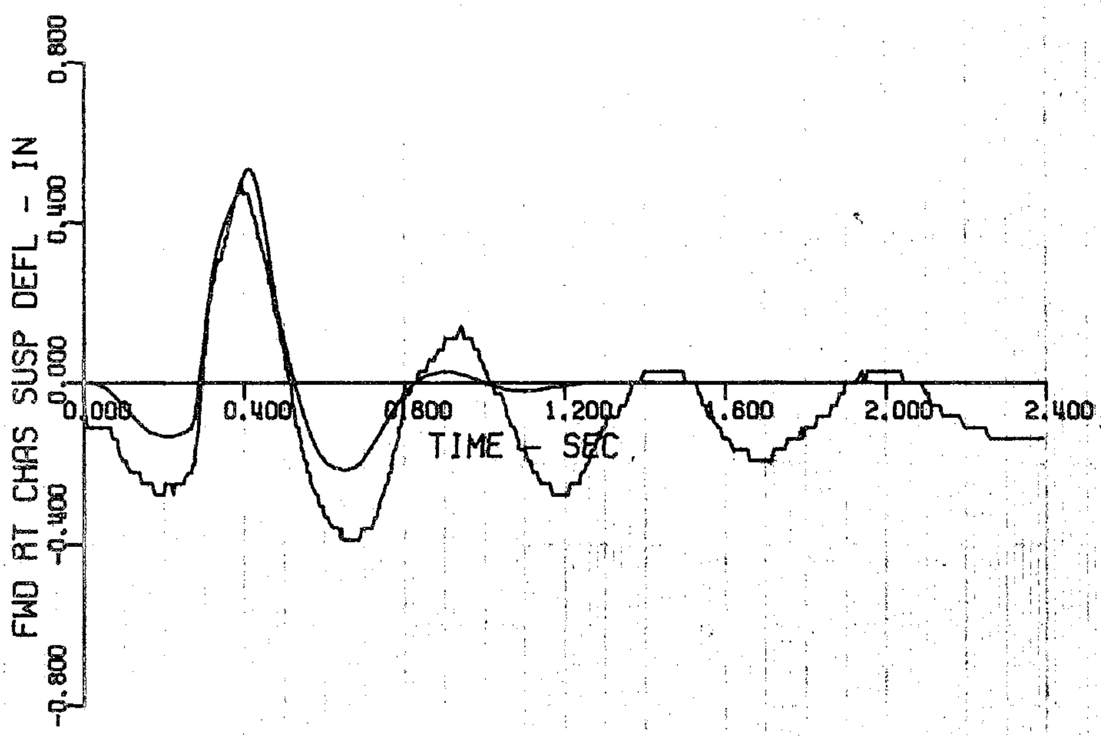




RUN 42 - 42 TL-101 16 18 35 65 MPH 1.0 IN X 25 FT RAMP





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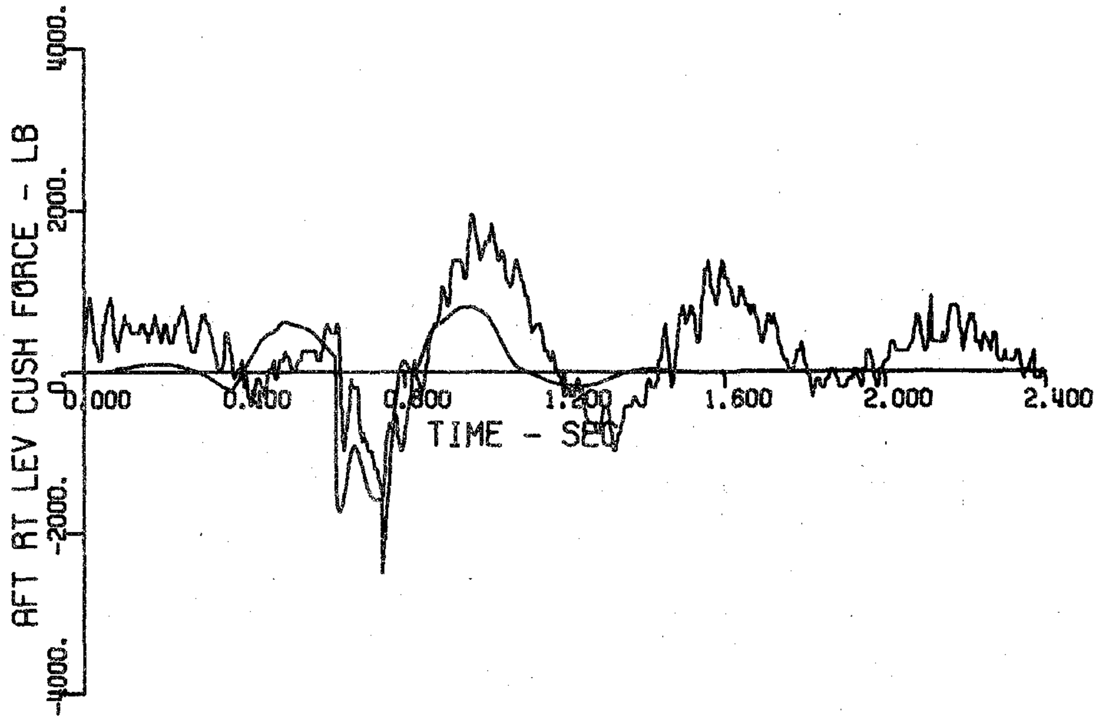

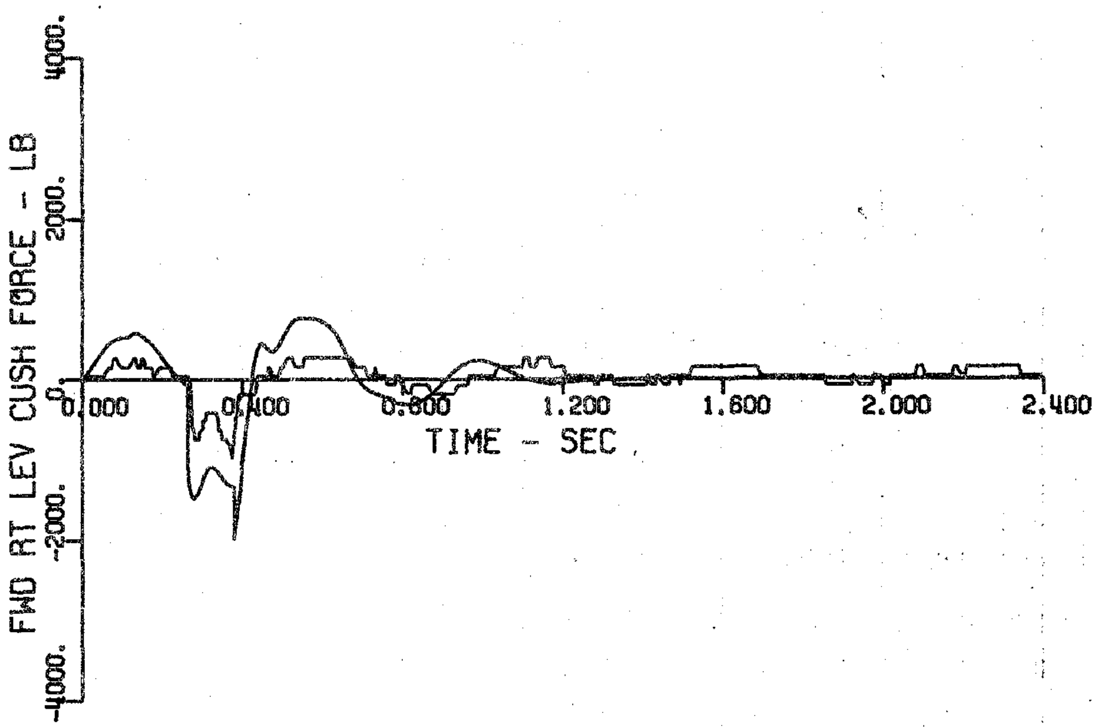

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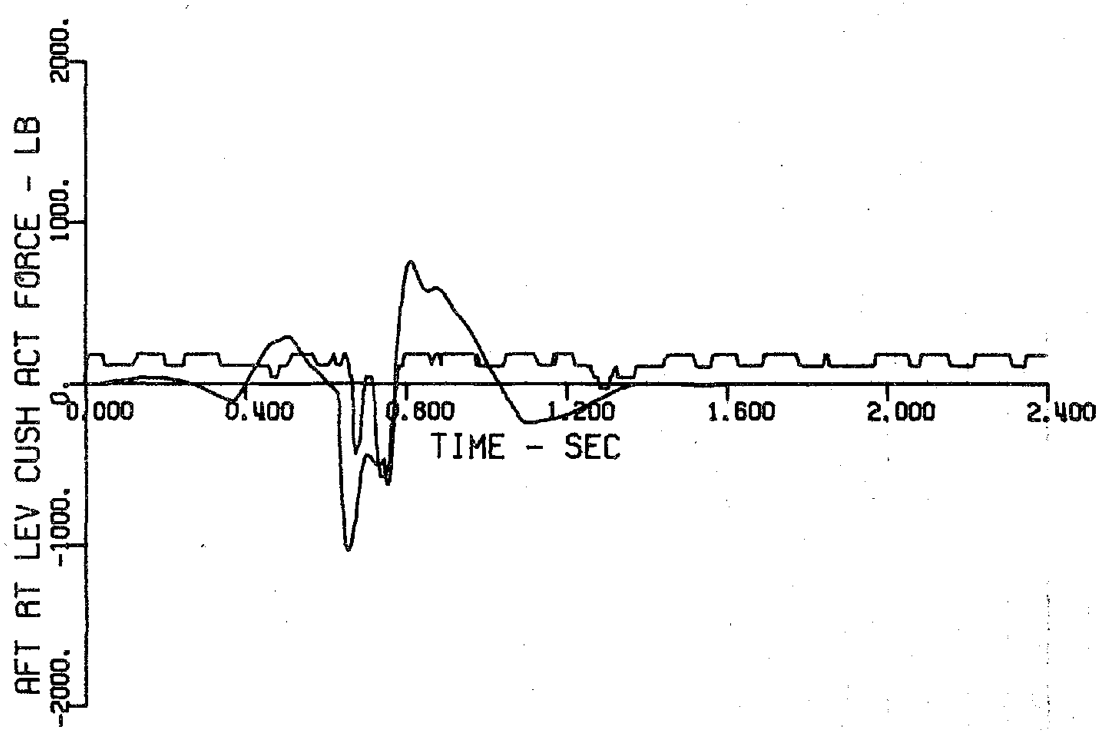
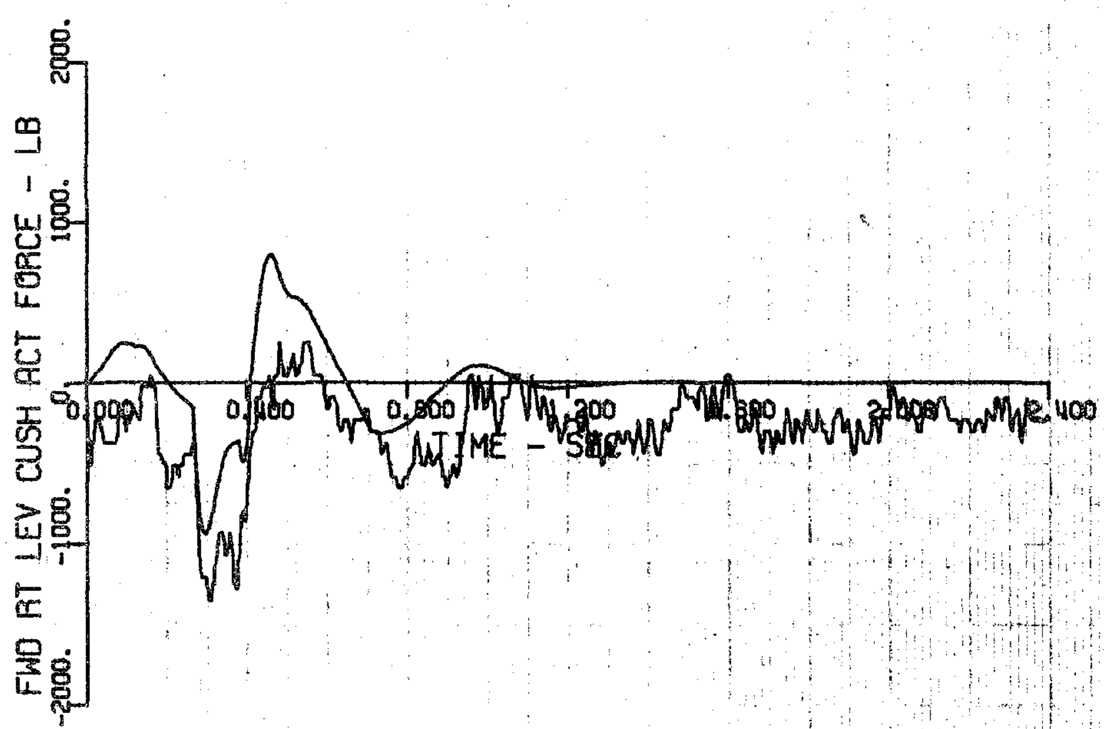
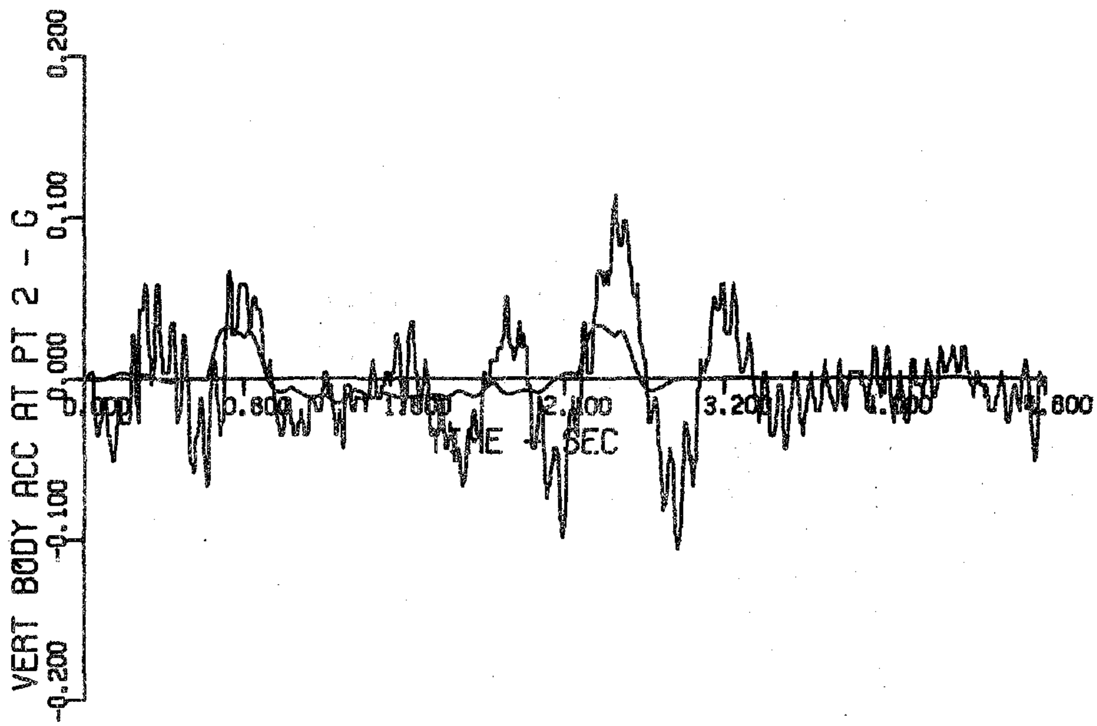
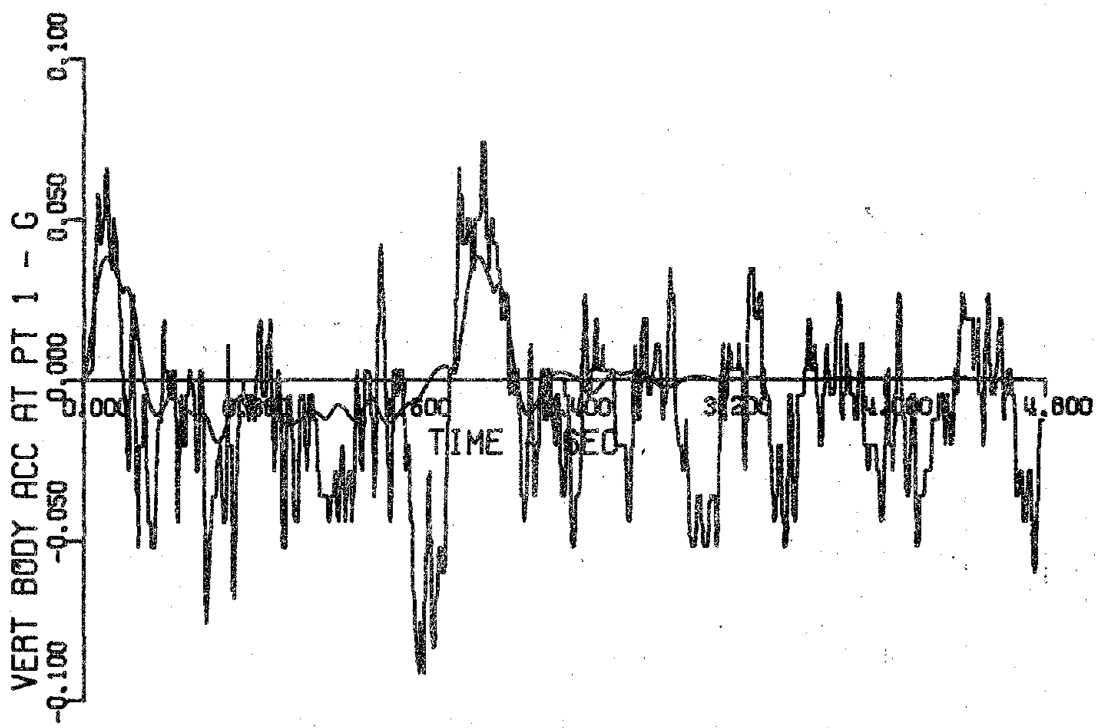


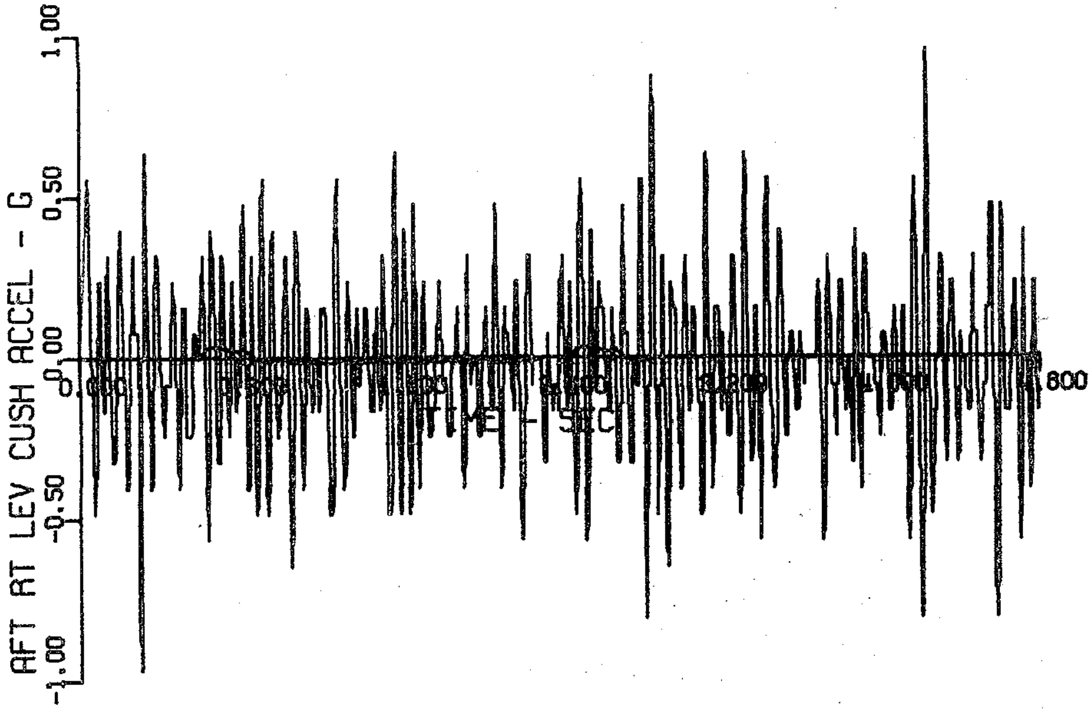


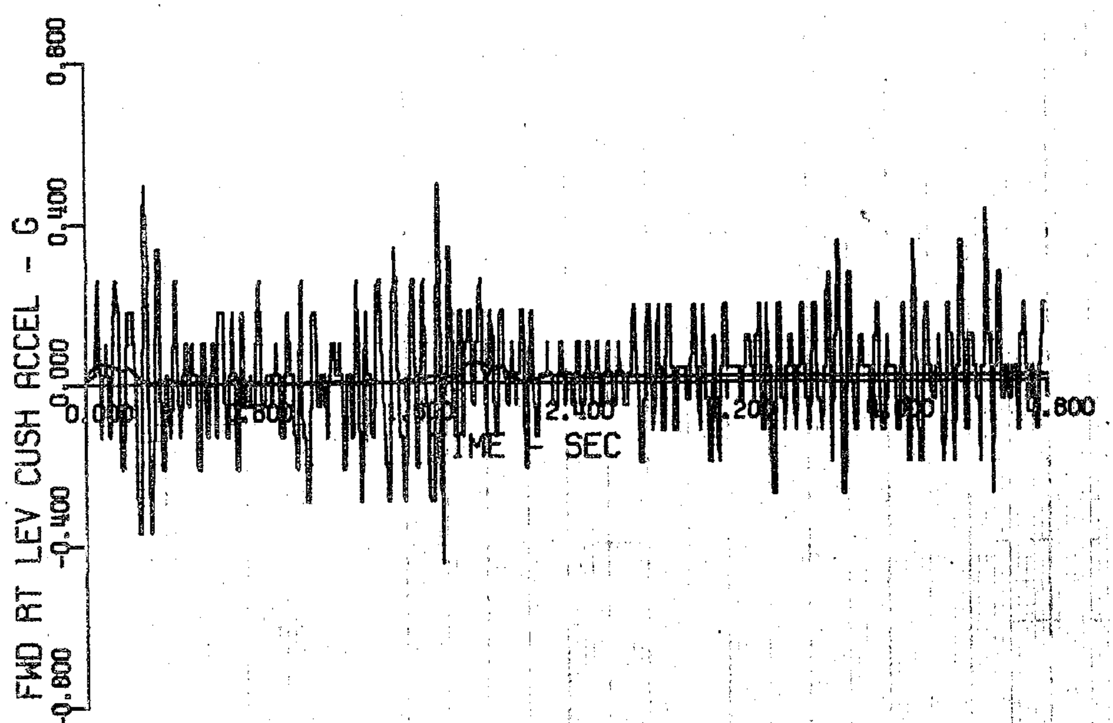
RUN 42 - 42 TL-101 16 18 35 65 MPH 1.0 IN X 25 FT RAMP



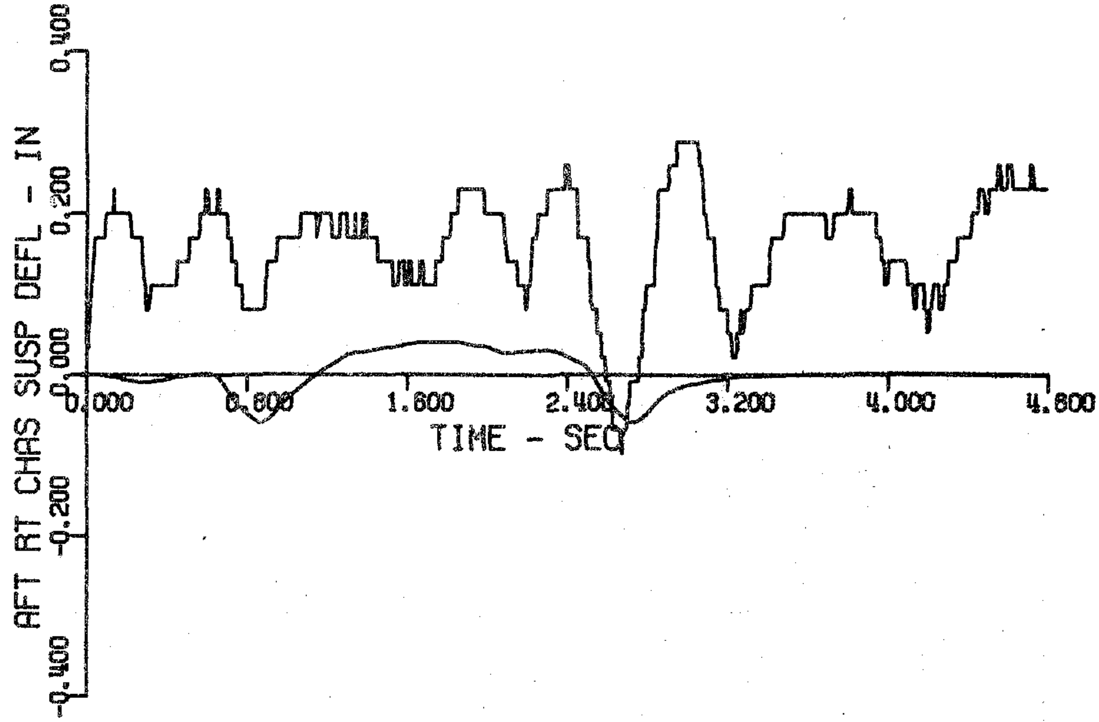


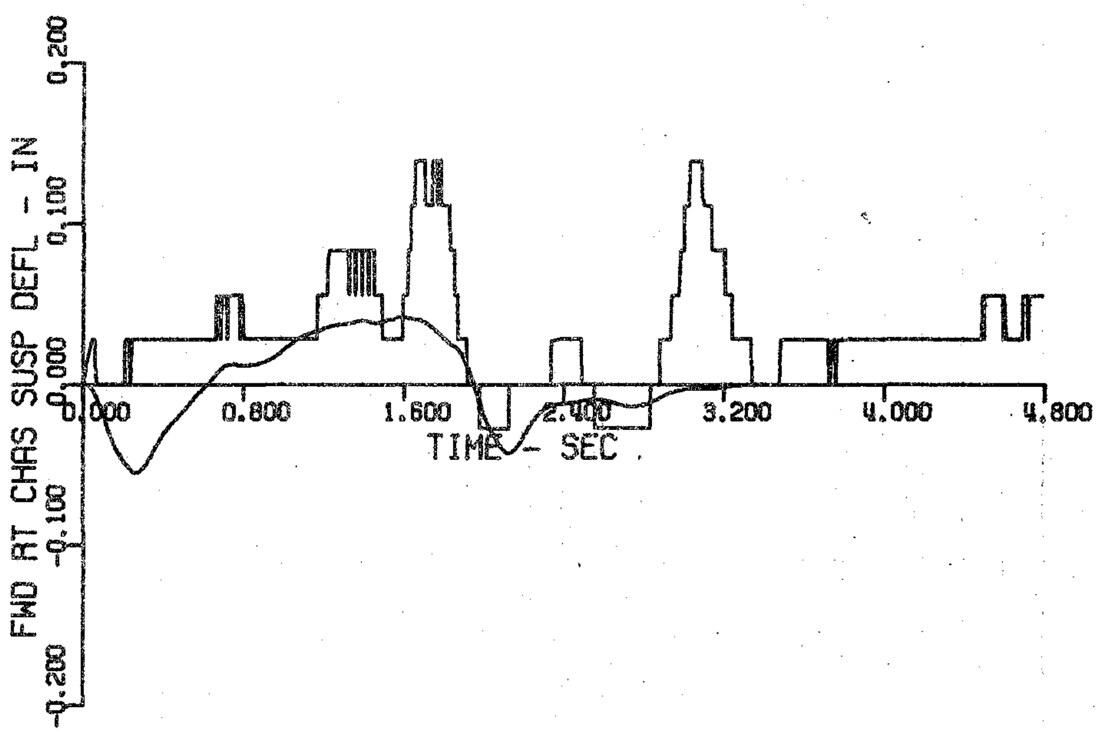
RUN 43- 02 TL-102 09 28 55 39 MPH 1.5 IN X 106 FT PARABOLA



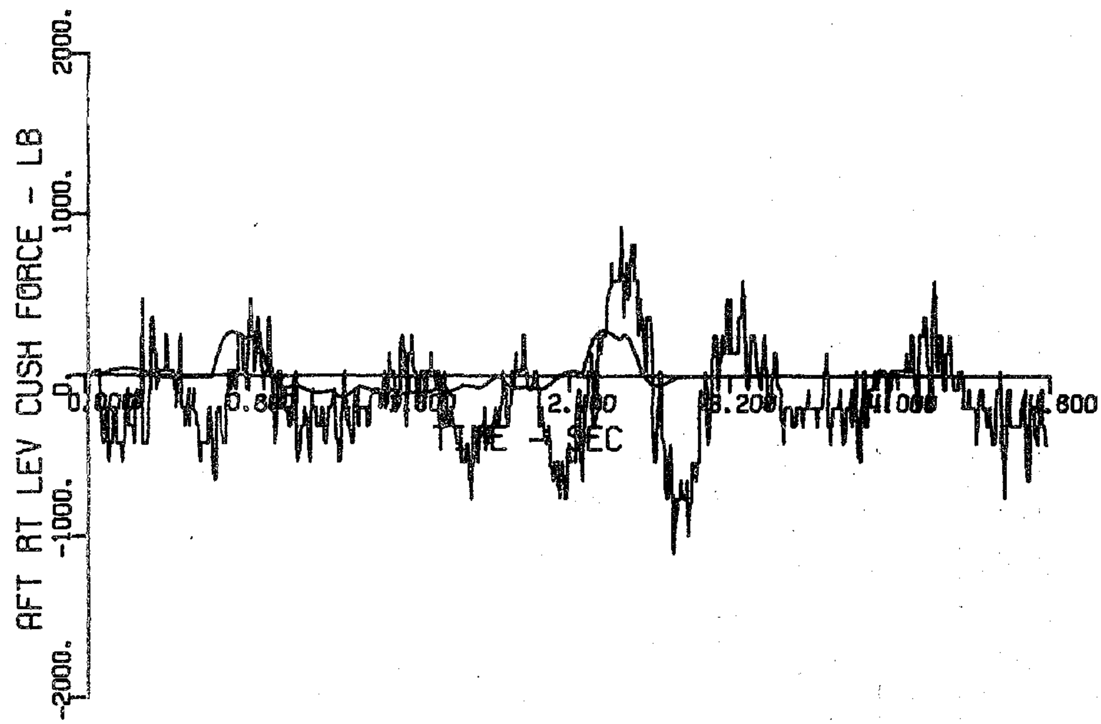


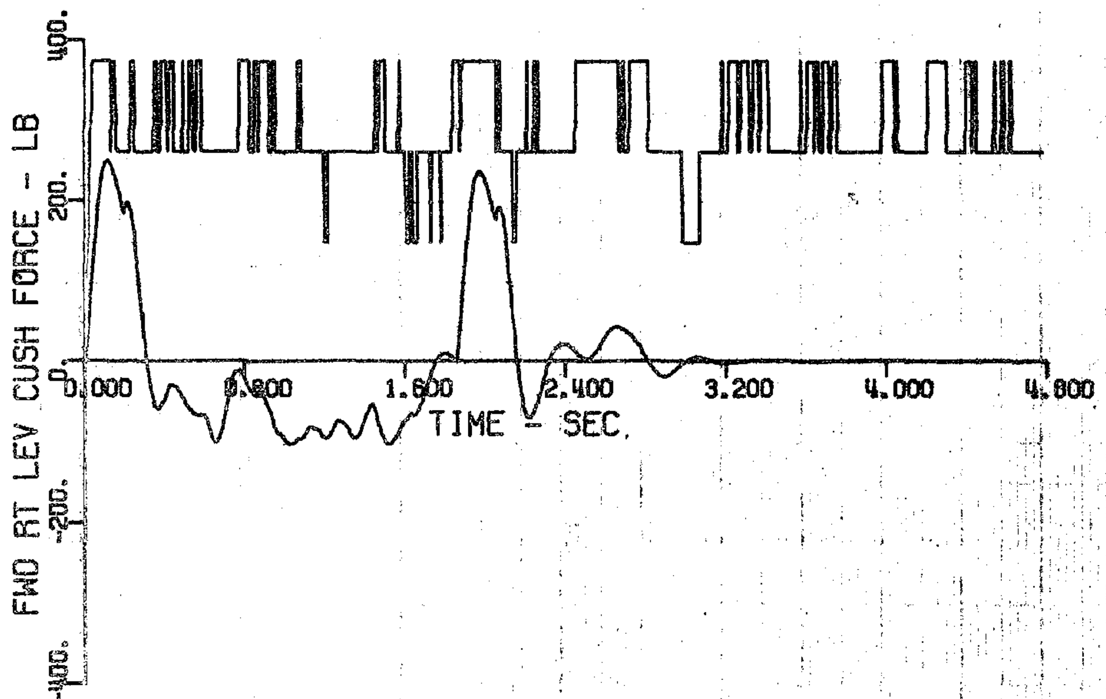
RUN 43 - 02 TL-102 09 28 55 39 MPH 1.5 IN X 106 FT PARABOLA



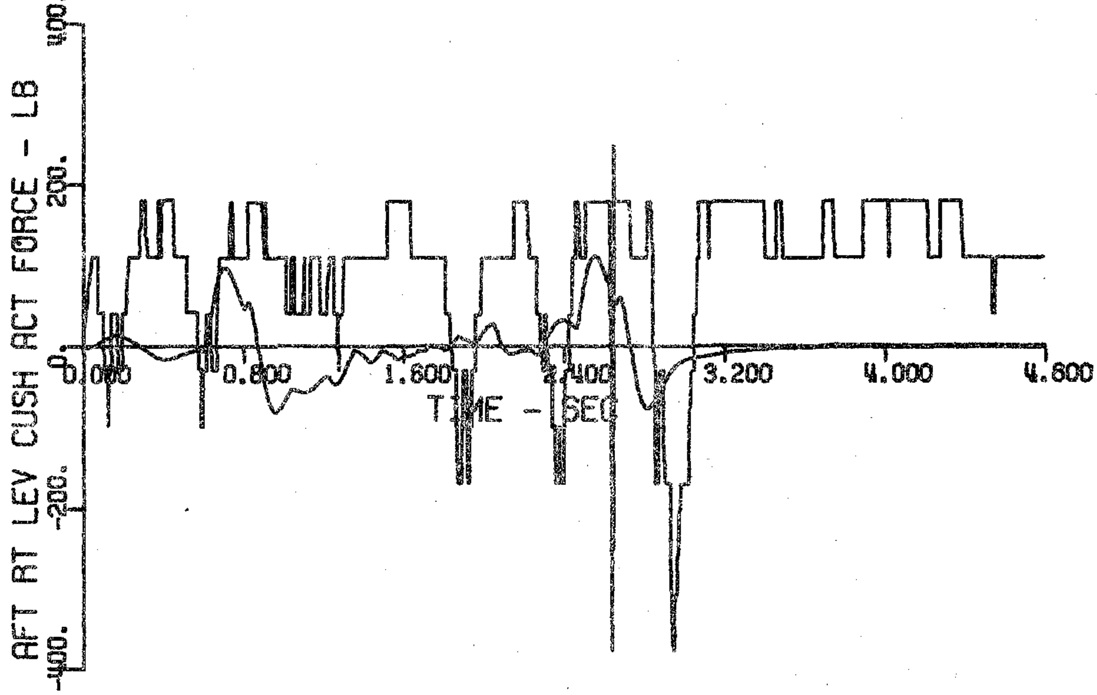


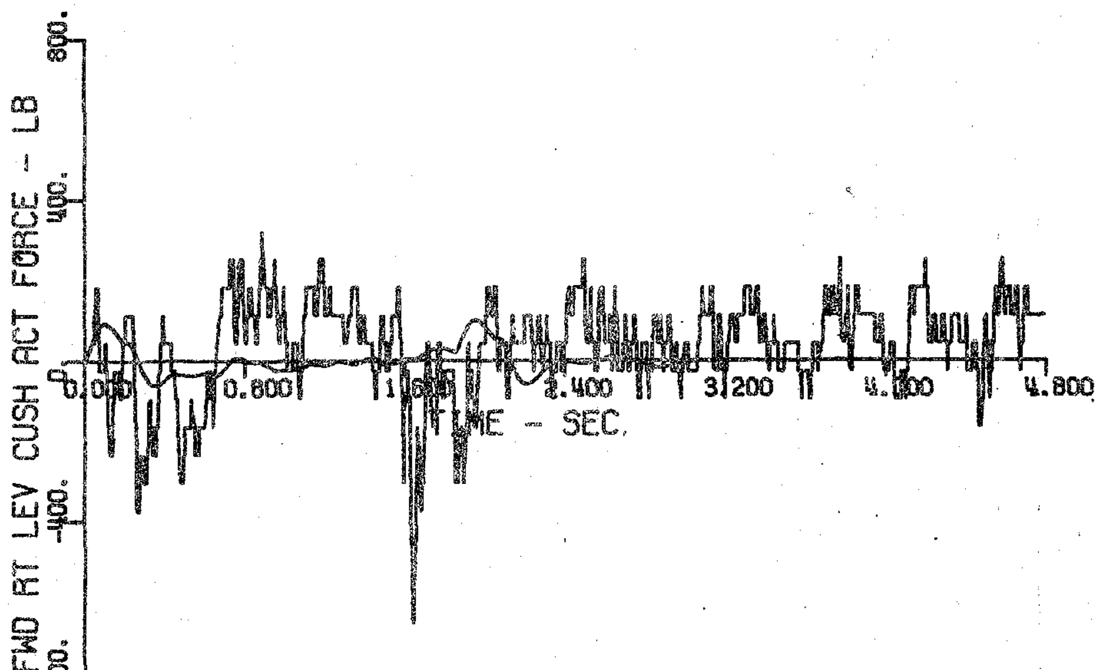
RUN 43- 02 TL-102 09 28 55 39 MPH 1.5 IN X 106 FT PARABOLA





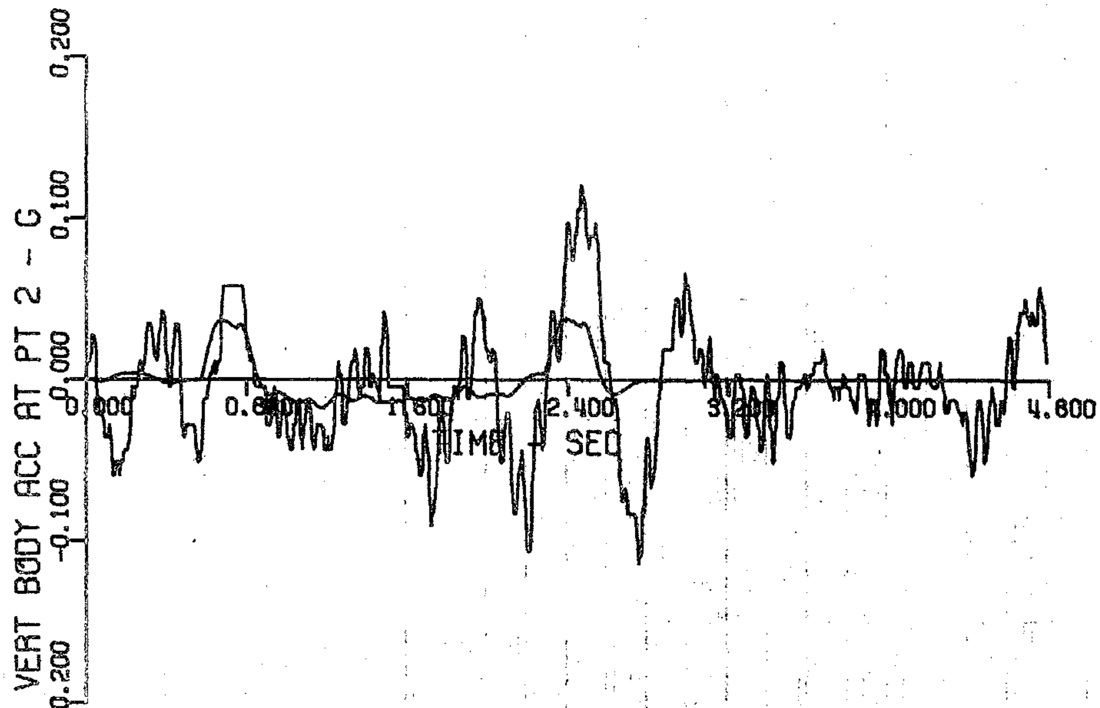
RUN 43 - 02 TL-102 09 28 55 39 MPH 1.5 IN X 106 FT. PARABOLA

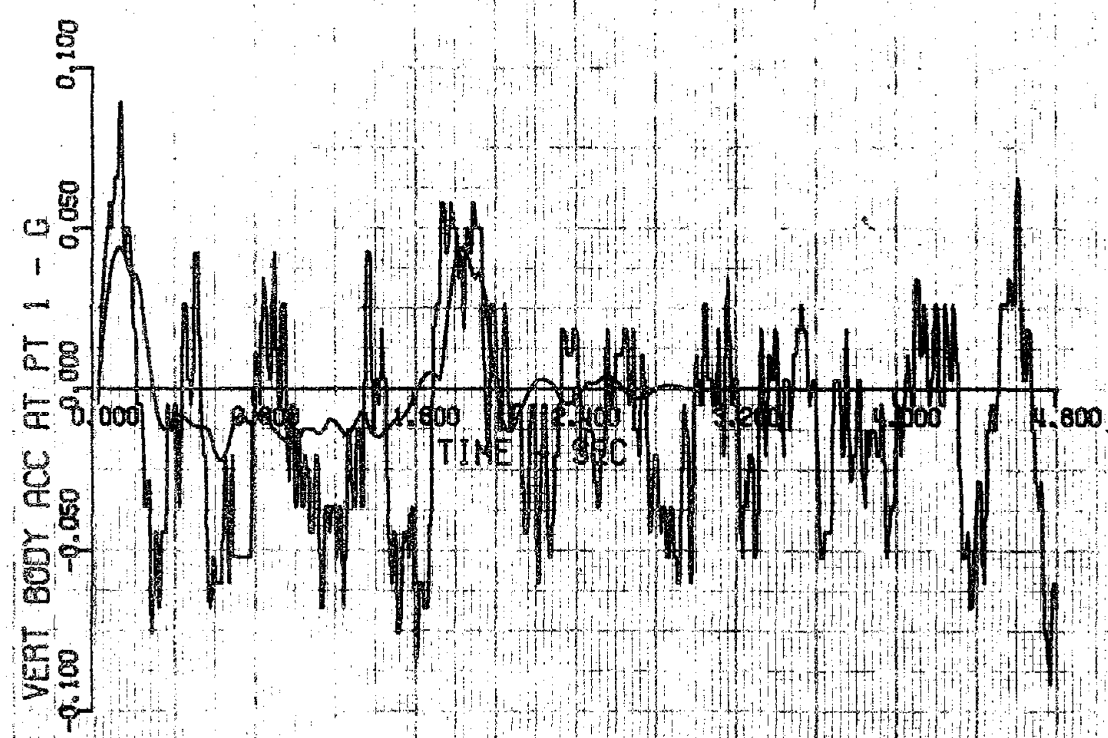




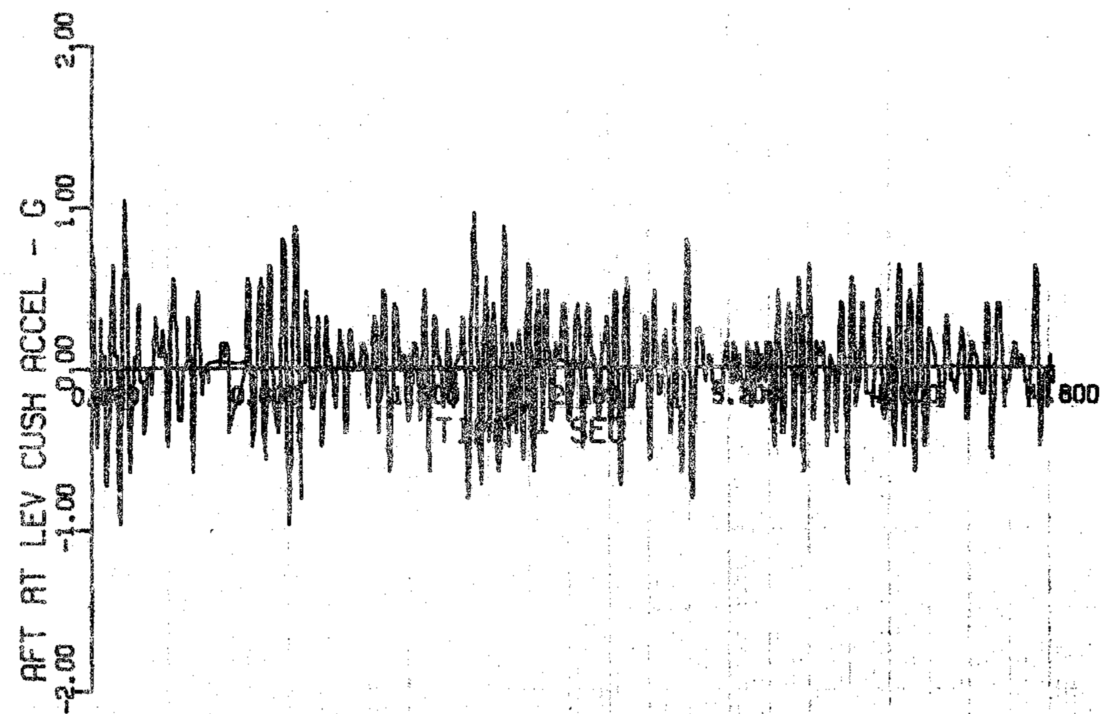
RUN 43 - 02 TL-102 08 26 55 39 MPH 1.5 IN X 106 FT PARABOLA

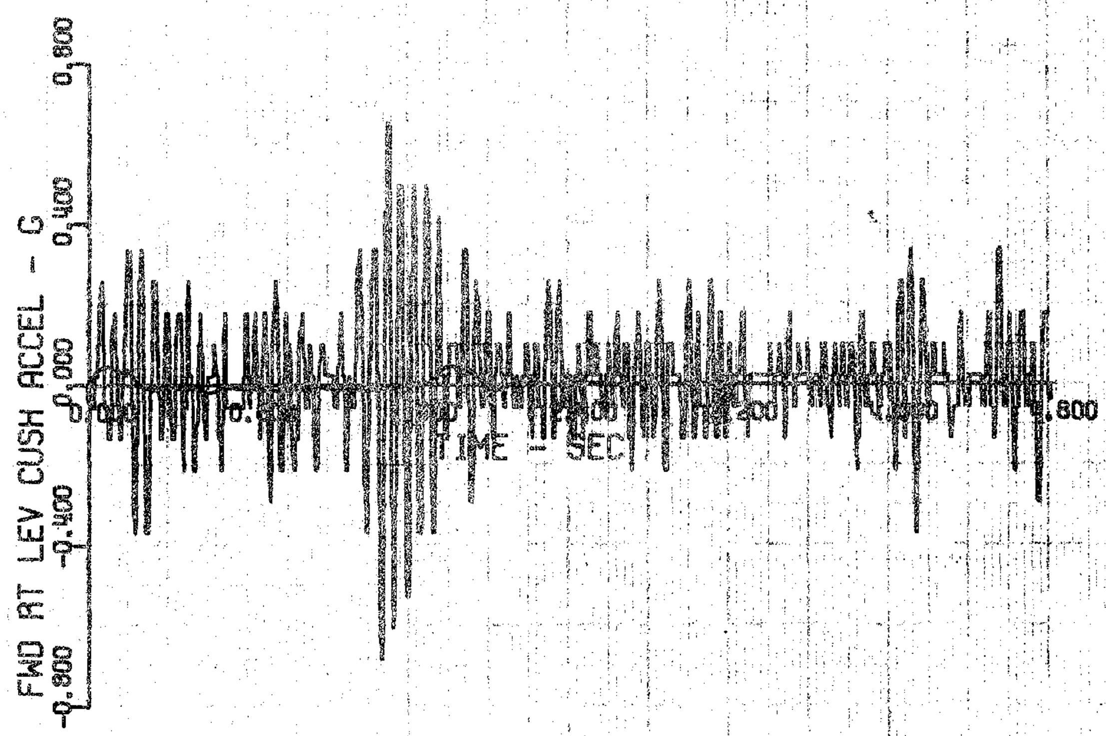
823007



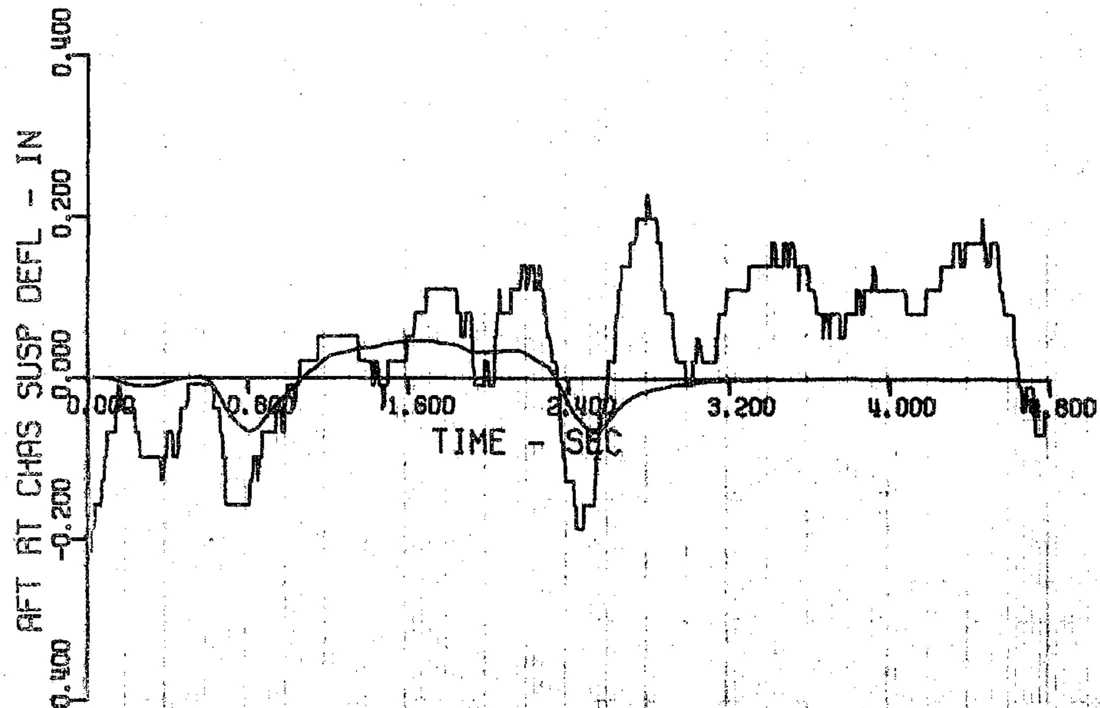


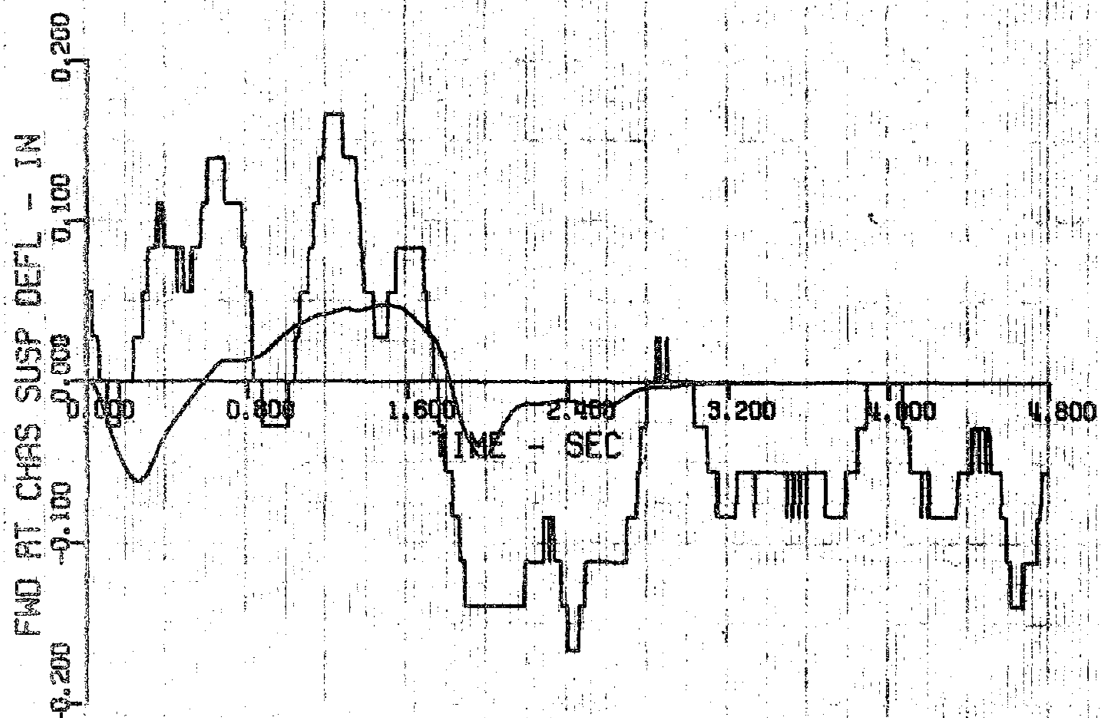
RUN 43- 04 TL-102 08 44 56 42 MPH 1.5 IN X 106 FT PARABOLA



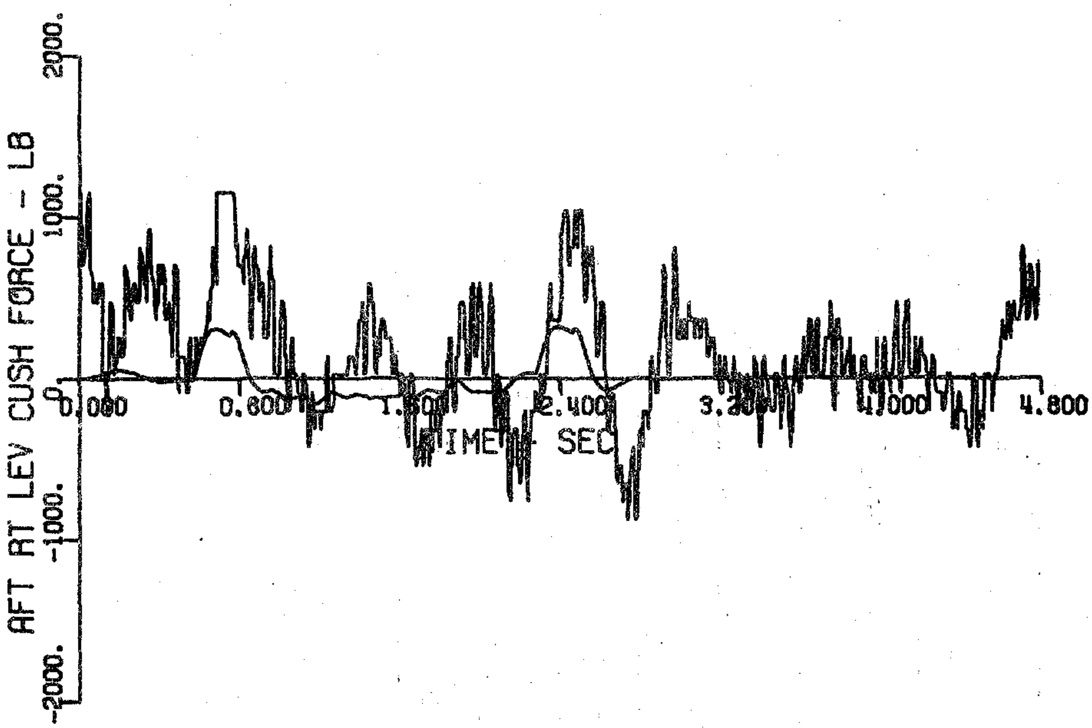


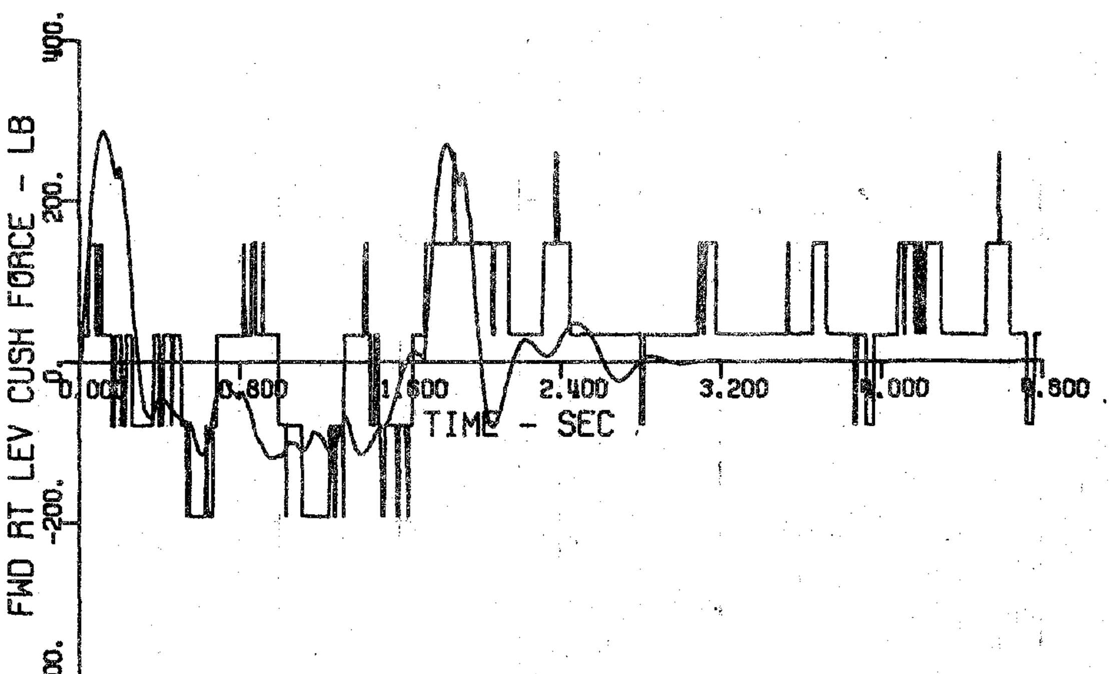
RUN 43 - 04 TL-102 09 44 56 42 MPH 1.5 IN X 106 FT PARABOLA



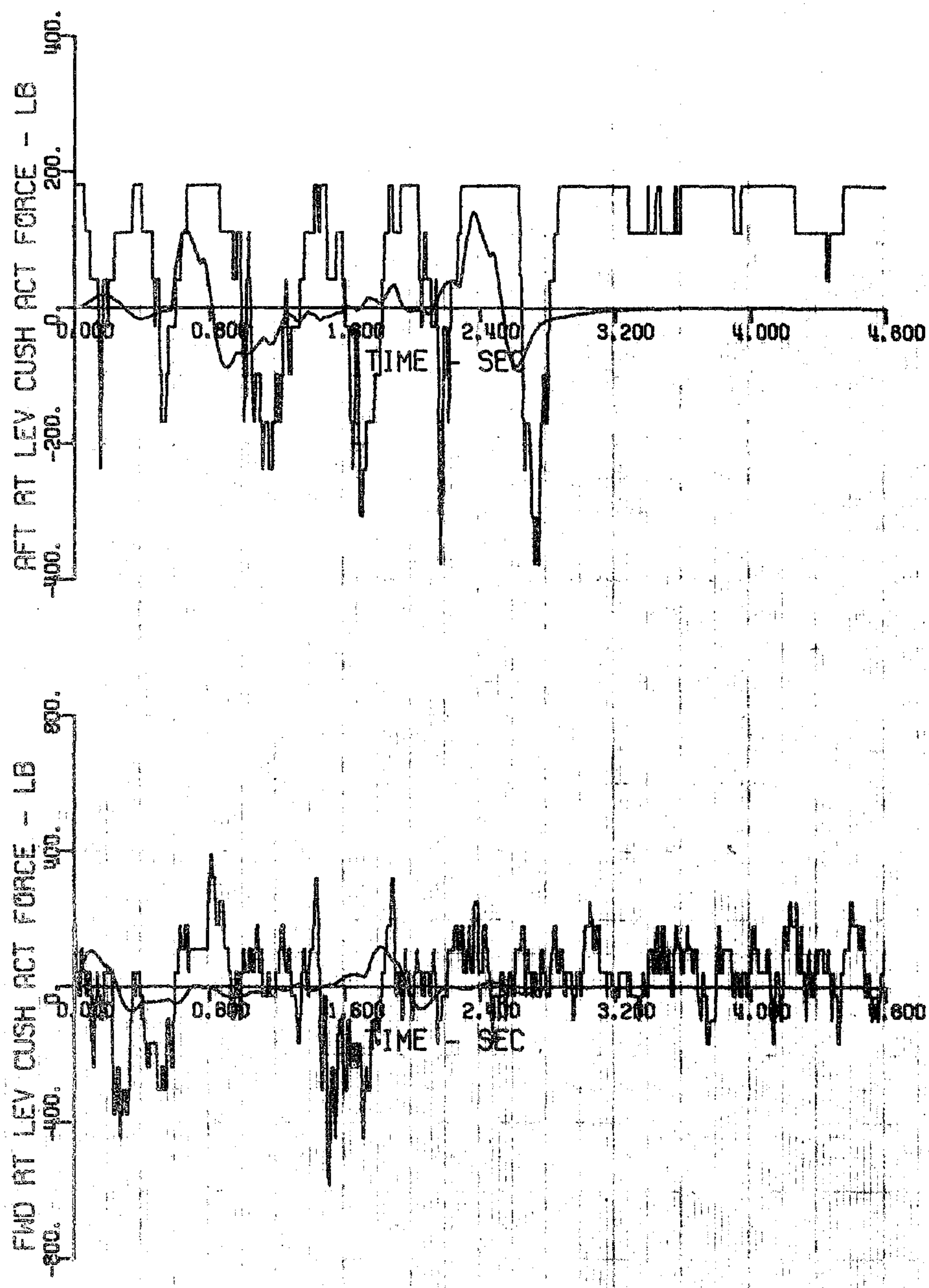


RUN 43 - 04 TL-102 09 44 56 42 MPH 1.5 IN X 106 FT PARABOLA

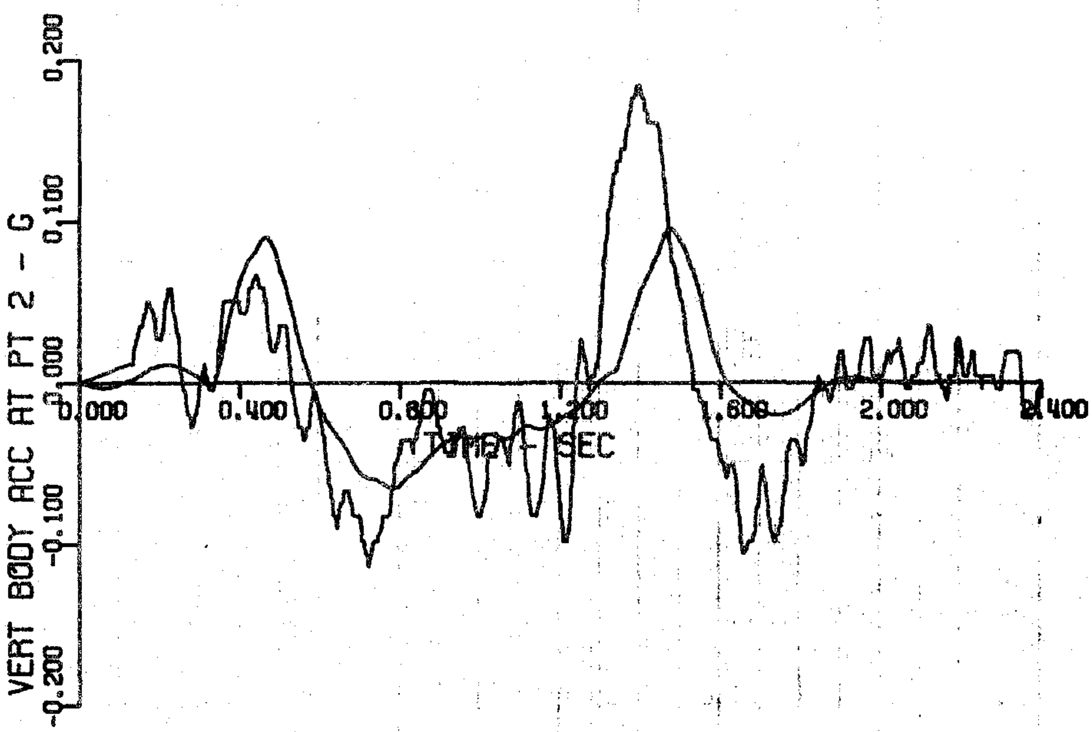


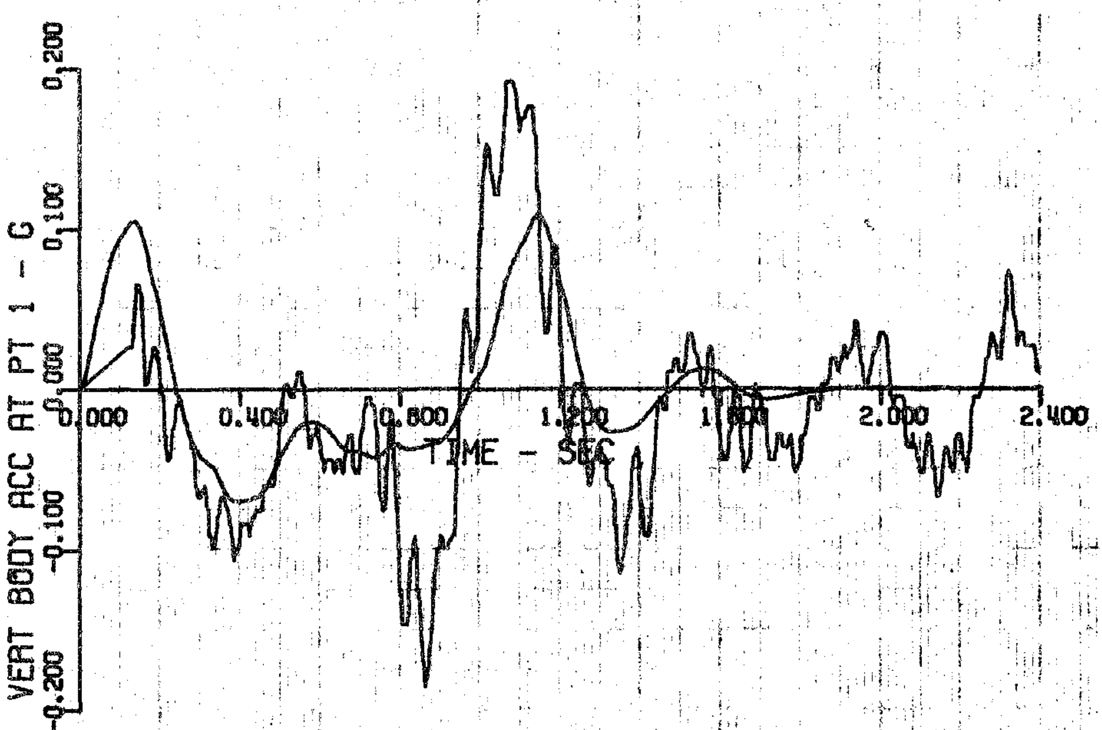


RUN 43 - 04 TL-102 09 44 58 42 MPH 1.5 IN X 106 FT PARABOLA

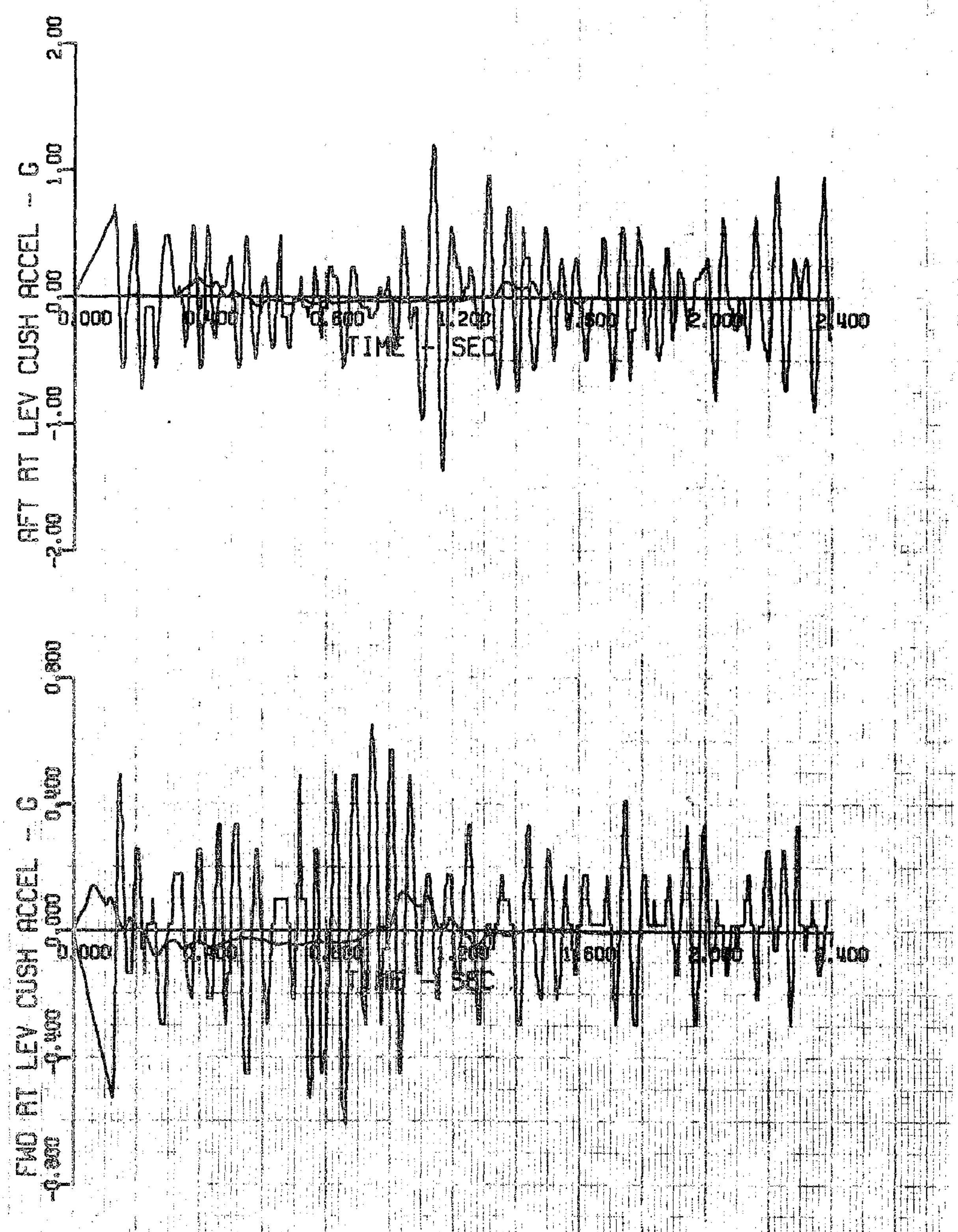


RUN 43 - 04 TL-102 09 44 56 42 MPH 1.5 IN X 106 FT PARABOLA

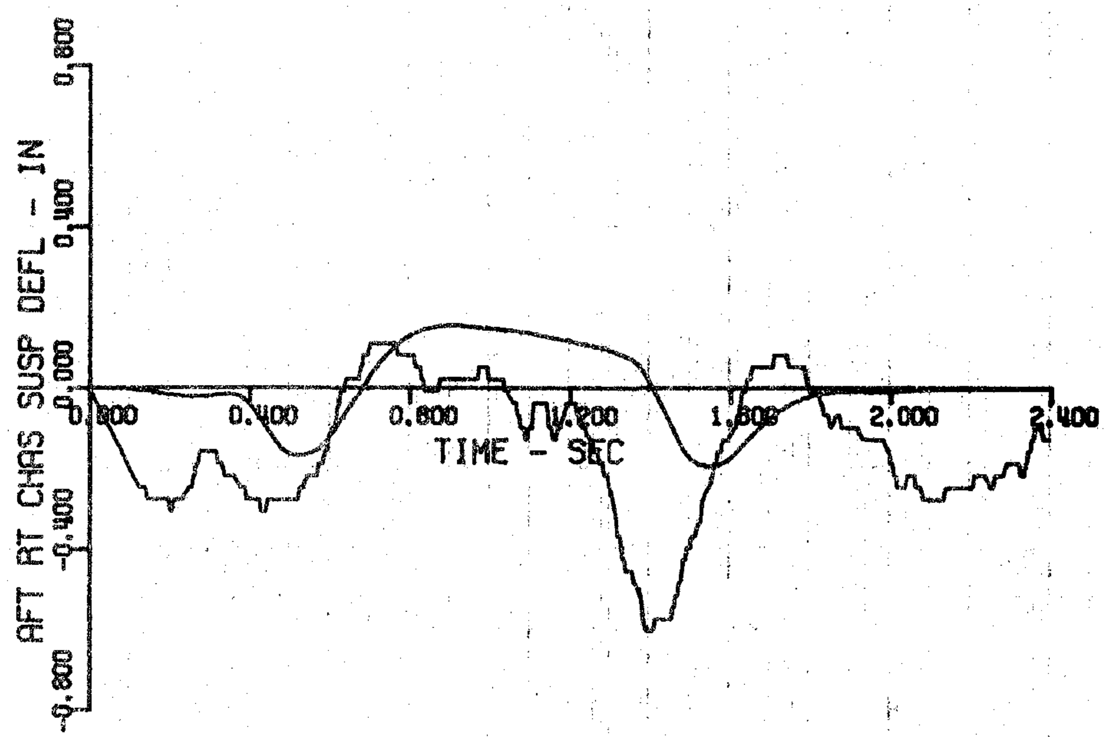


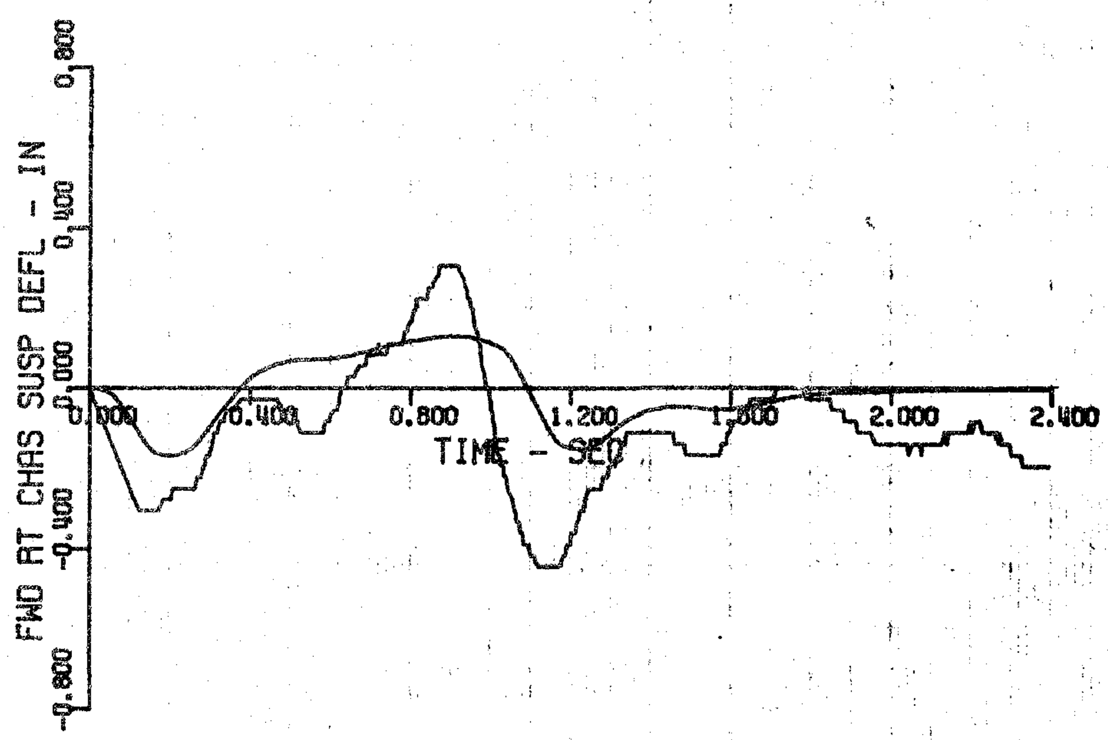


RUN 43 - 08 TL-102 10 17 28 72 MPH 1.5 IN X 106 FT PARABOLA

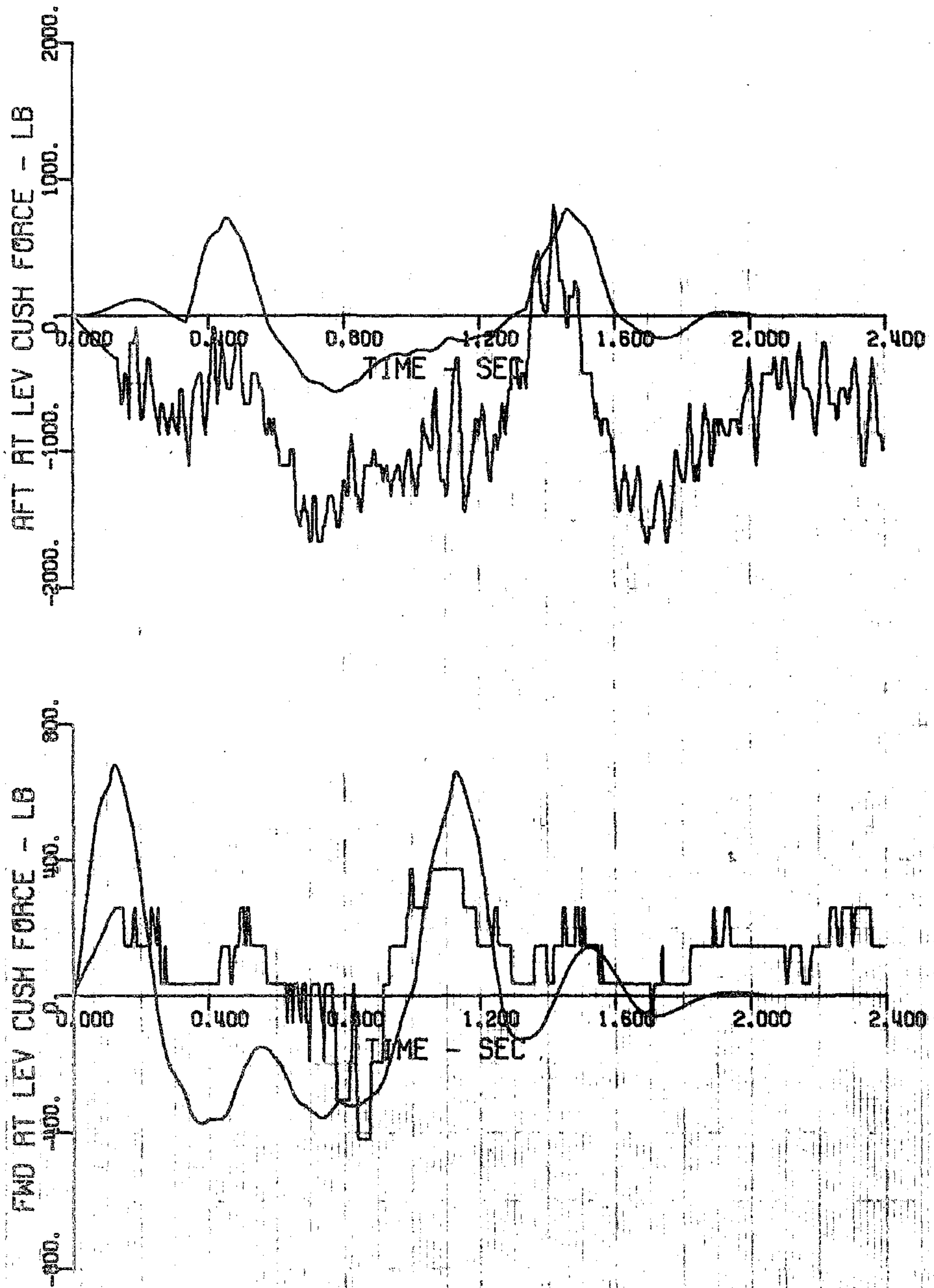


RUN U3- 08 TL-102 10 17 28 72 MPH 1.5 IN X 106 FT PARABOLA

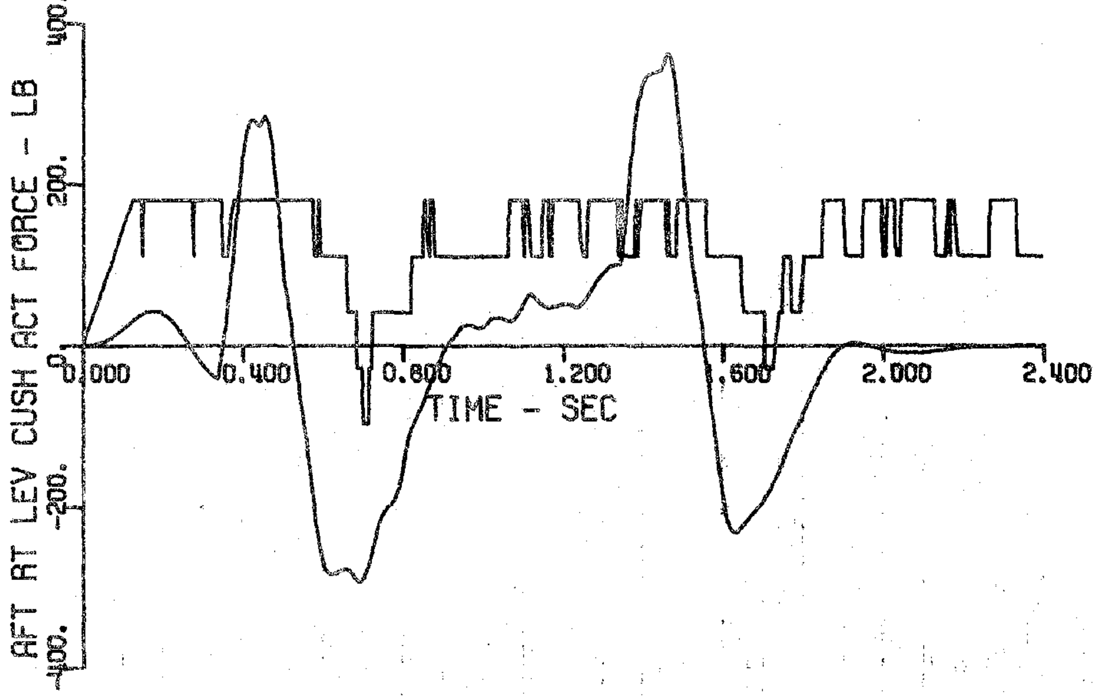


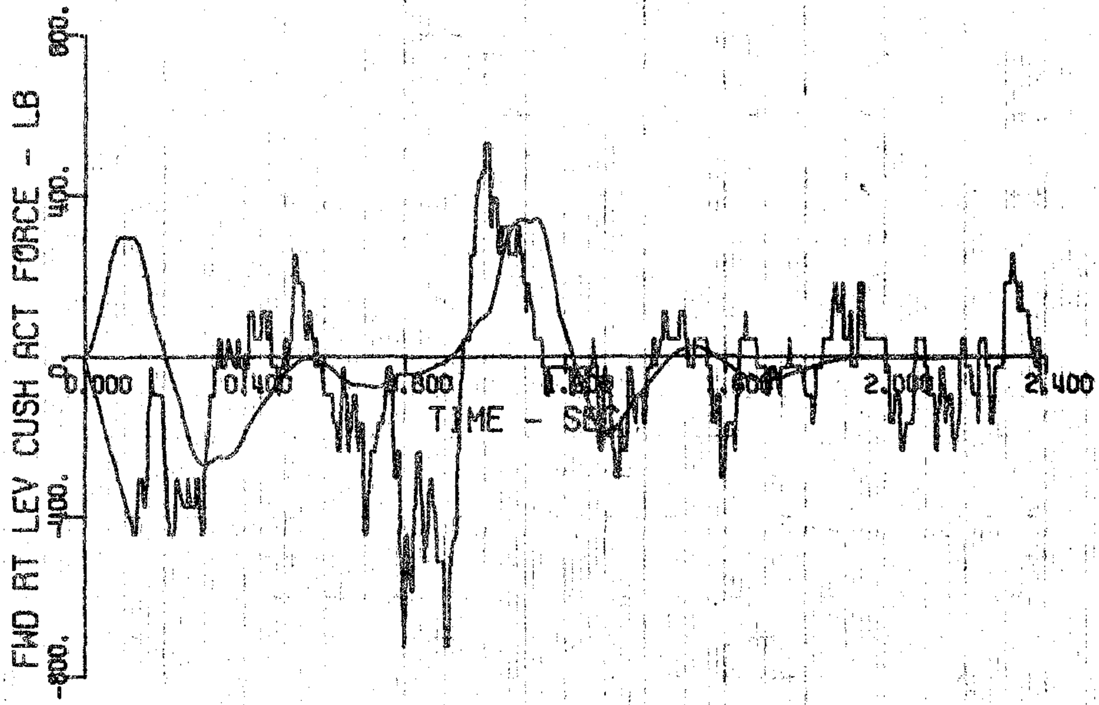


RUN 43 - 06 TL-102 10 17 28 72 MPH 1.5 IN X 106 FT PARABOLA

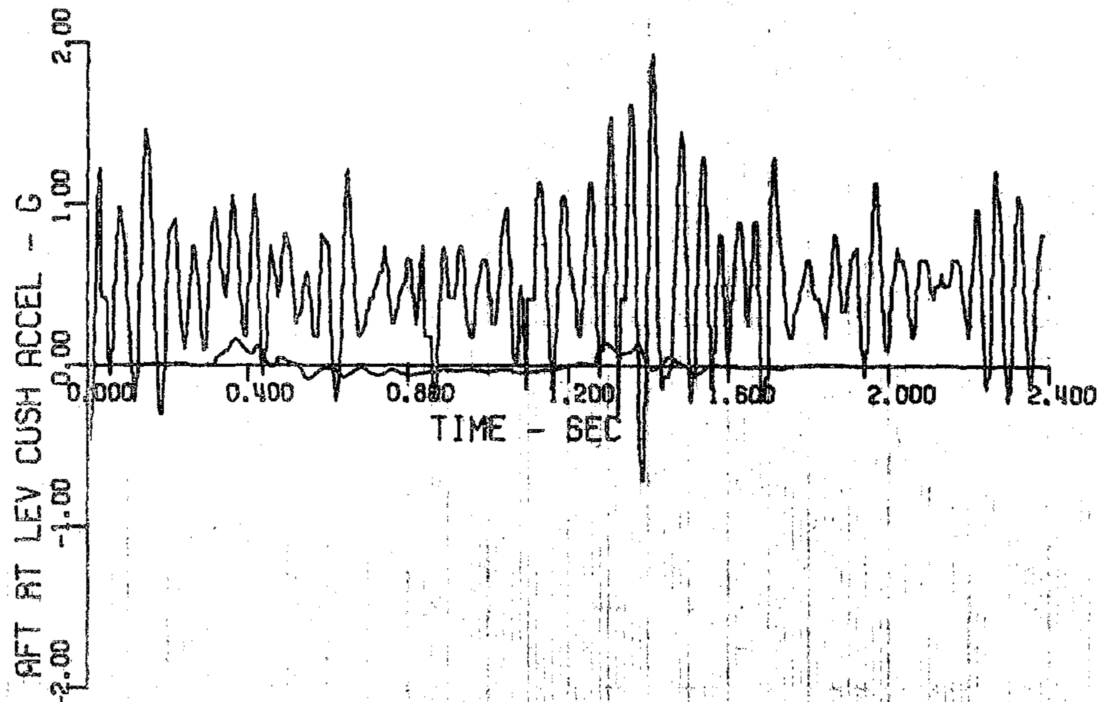


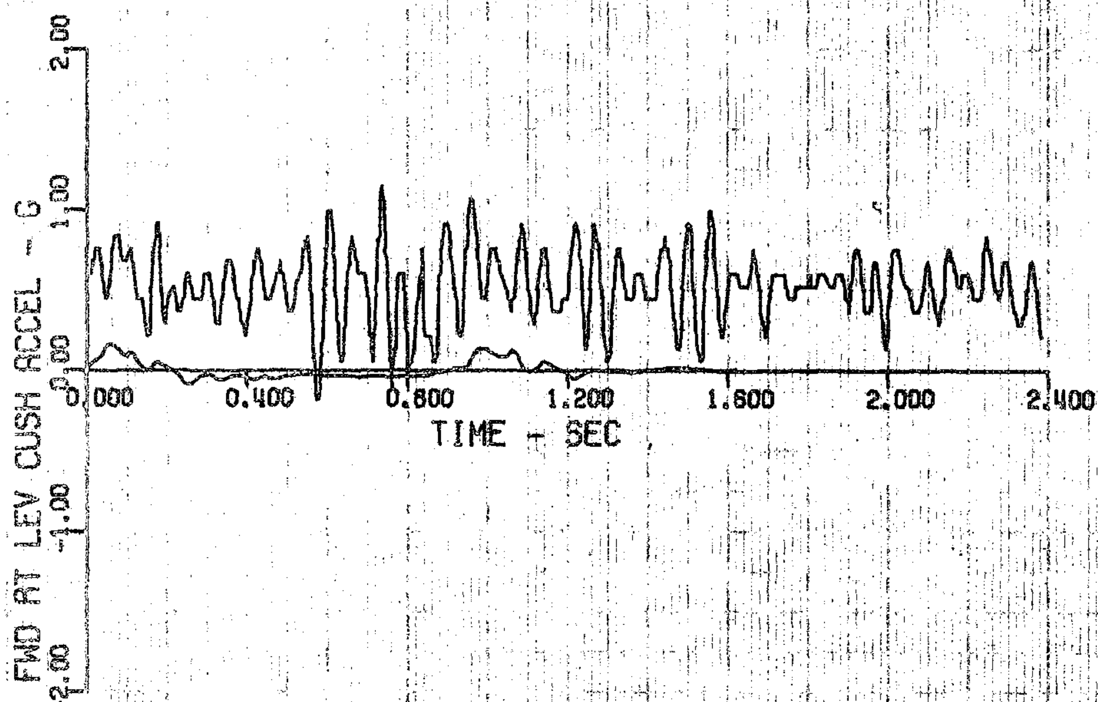
RUN 43 - 06 TL-102 10 17 28 72 MPH 1.5 IN X 106 FT PARABOLA



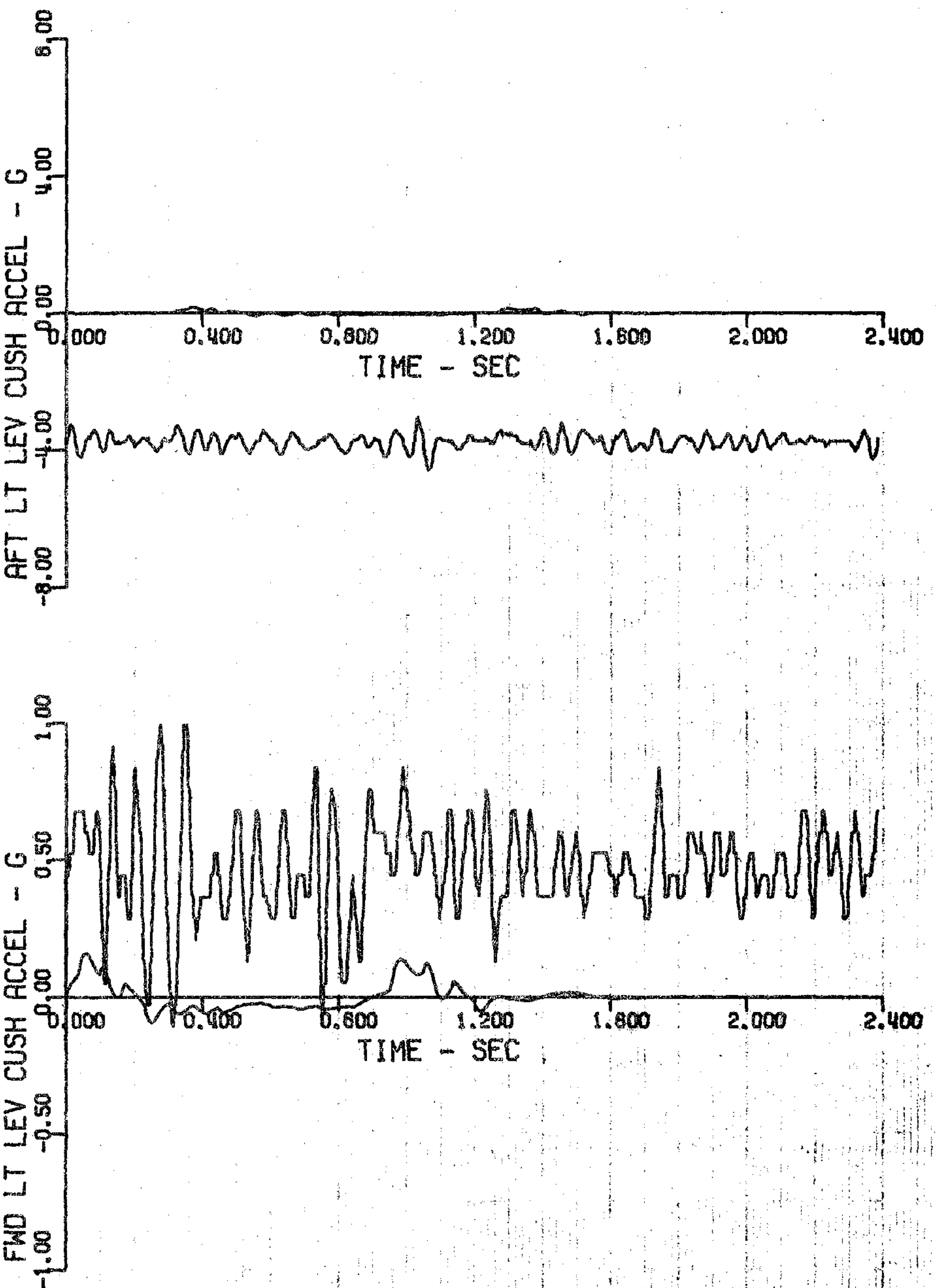


RUN 43 - 06 TL-102 10 17 28 72 MPH 1.5 IN X 106 FT PARABOLA

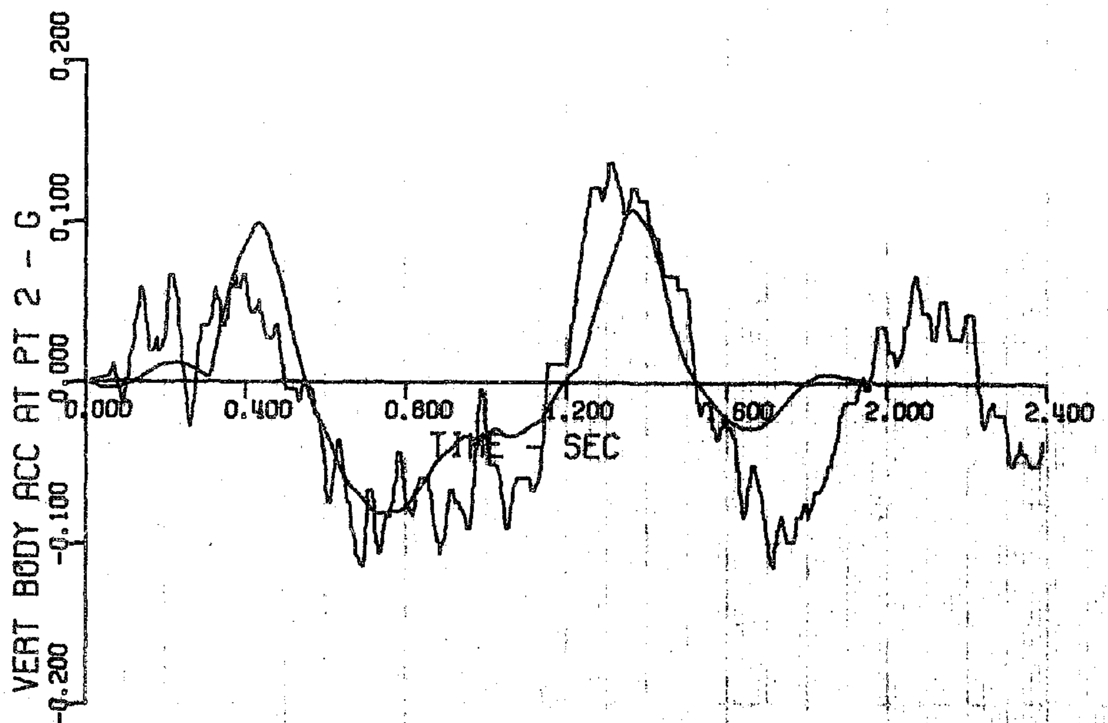


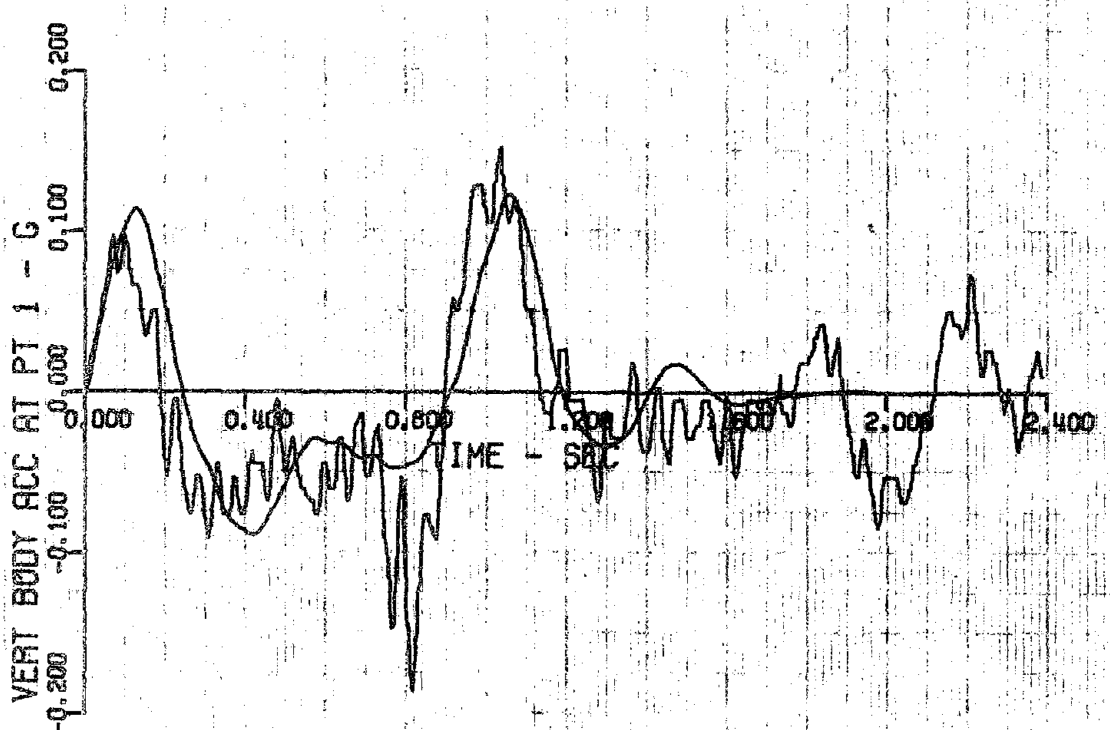


RUN 43 - 12 TL-102 11 52 17.78 MPH 1.5 IN X 106 FT PARABOLA

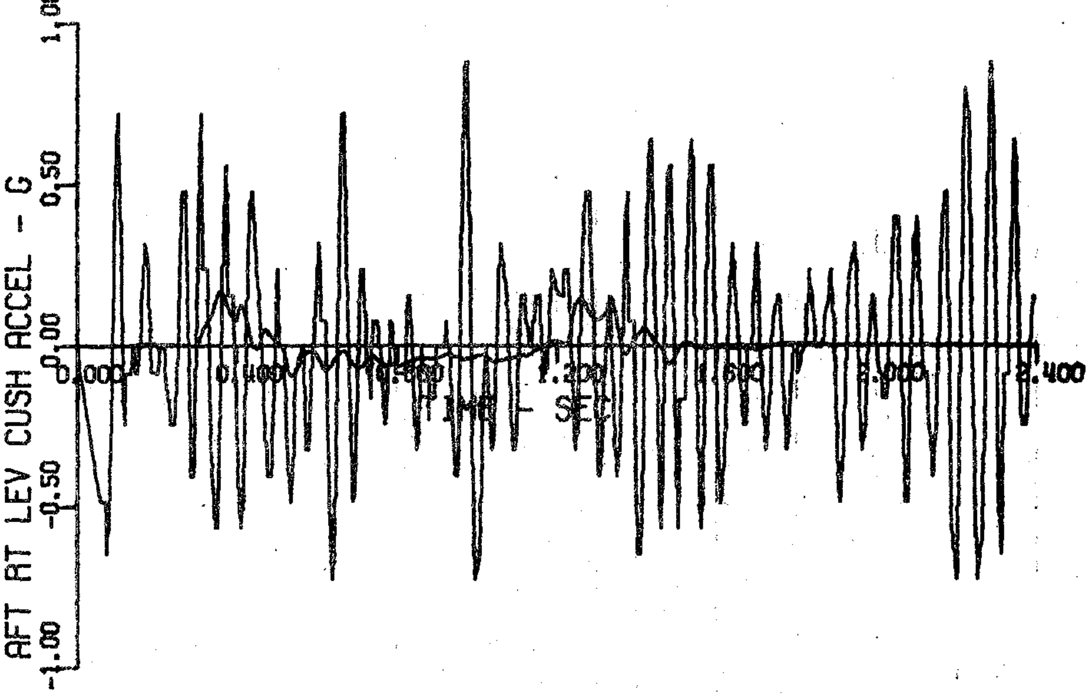


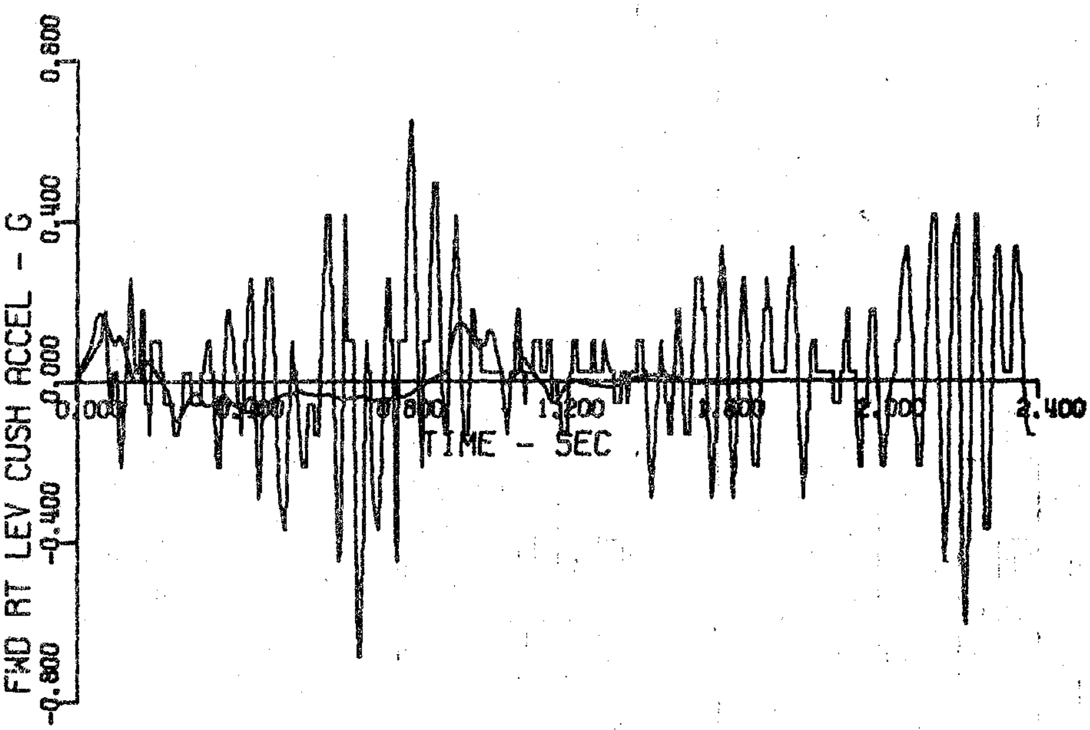
RUN 43 - 12 TL-102 11 52 17 76 MPH 1.5 IN X 106 FT PARABOLA



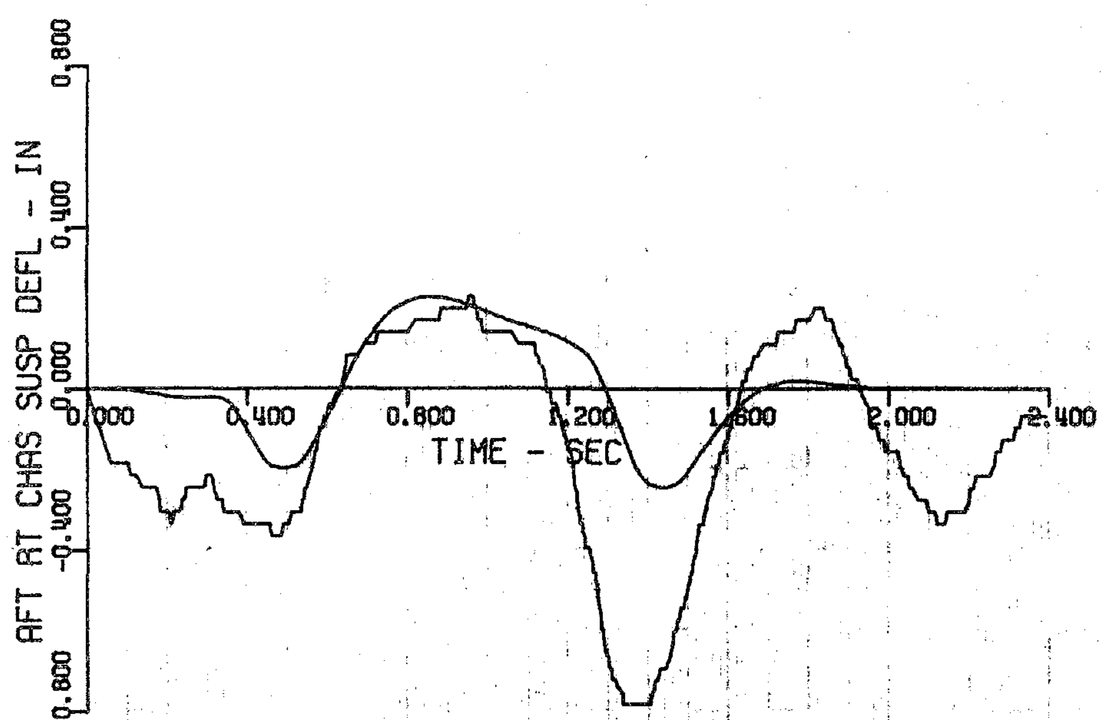


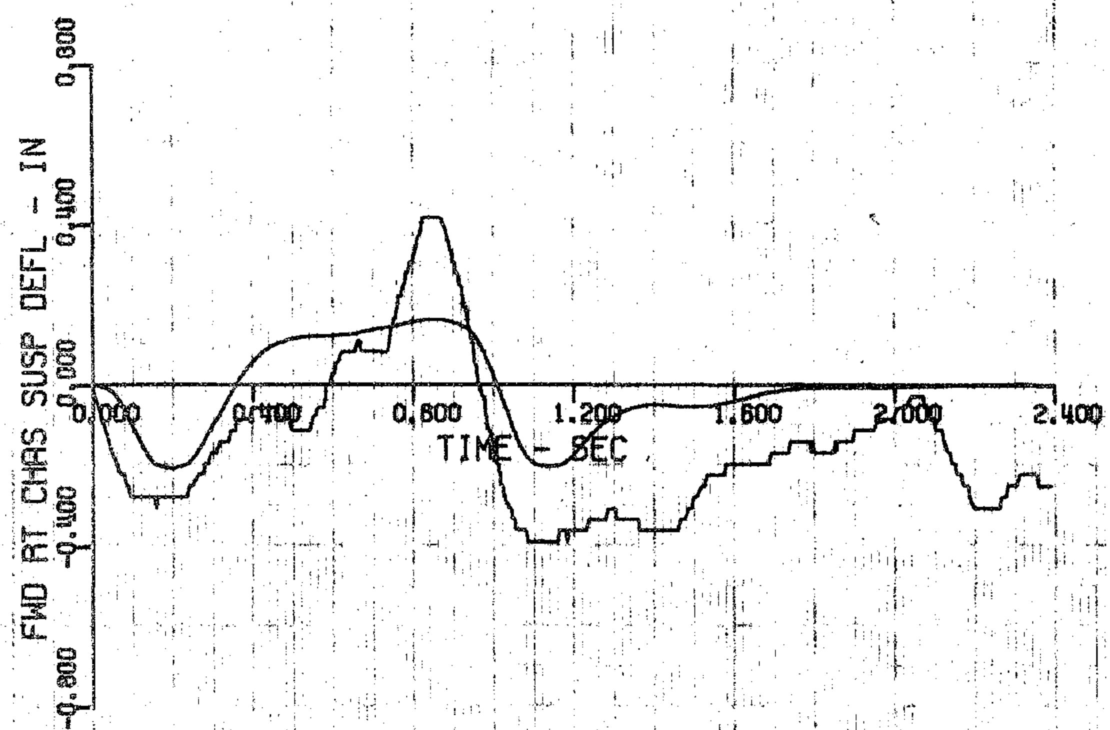
RUN V3- 14 TL-102 12 10 45 78 MPH 1.5 IN X 106 FT PARABOLA



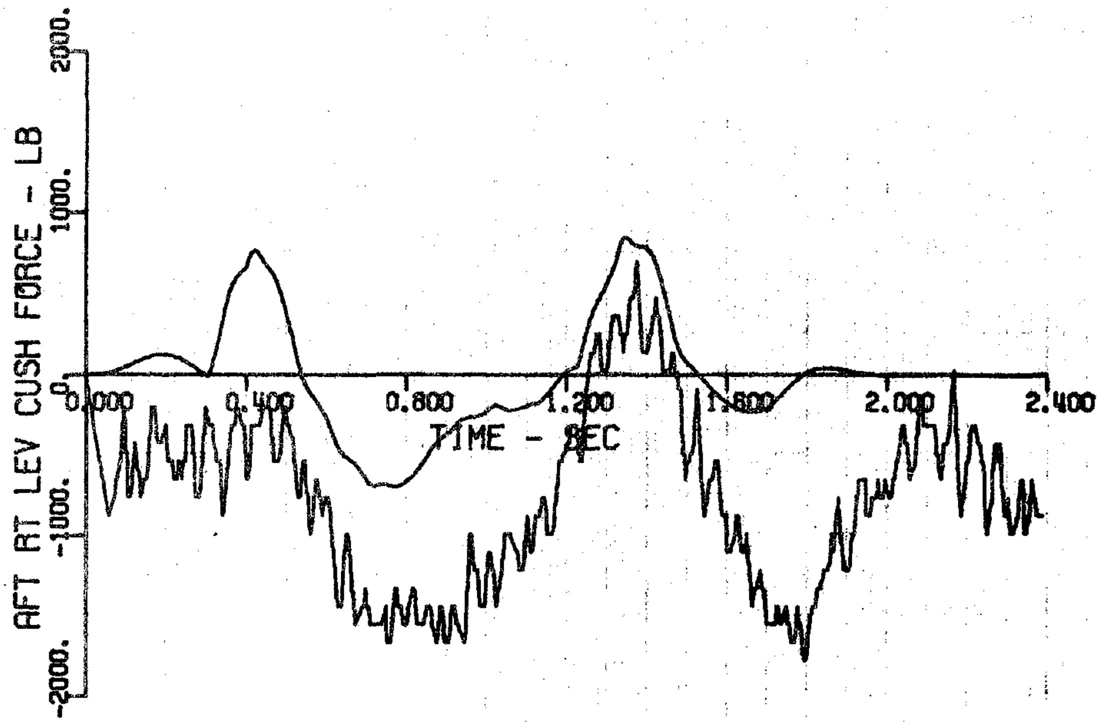


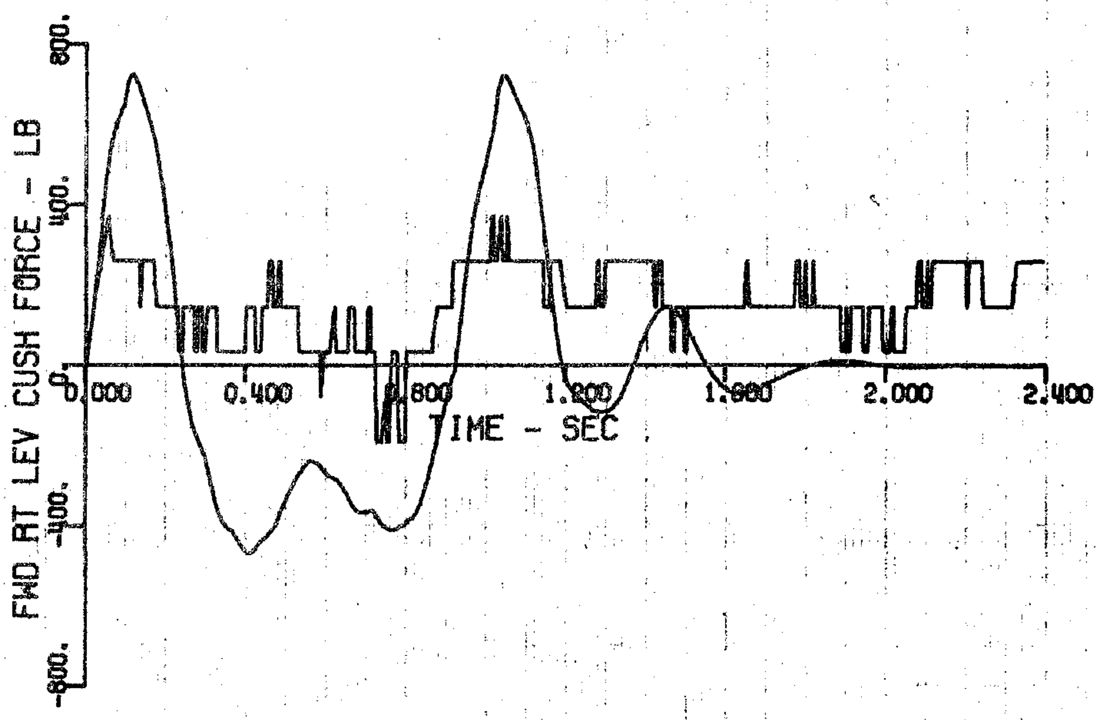
RUN 43 - 14 TL-102 12 10 45 78 MPH 1.5 IN X 106 FT PARABOLA



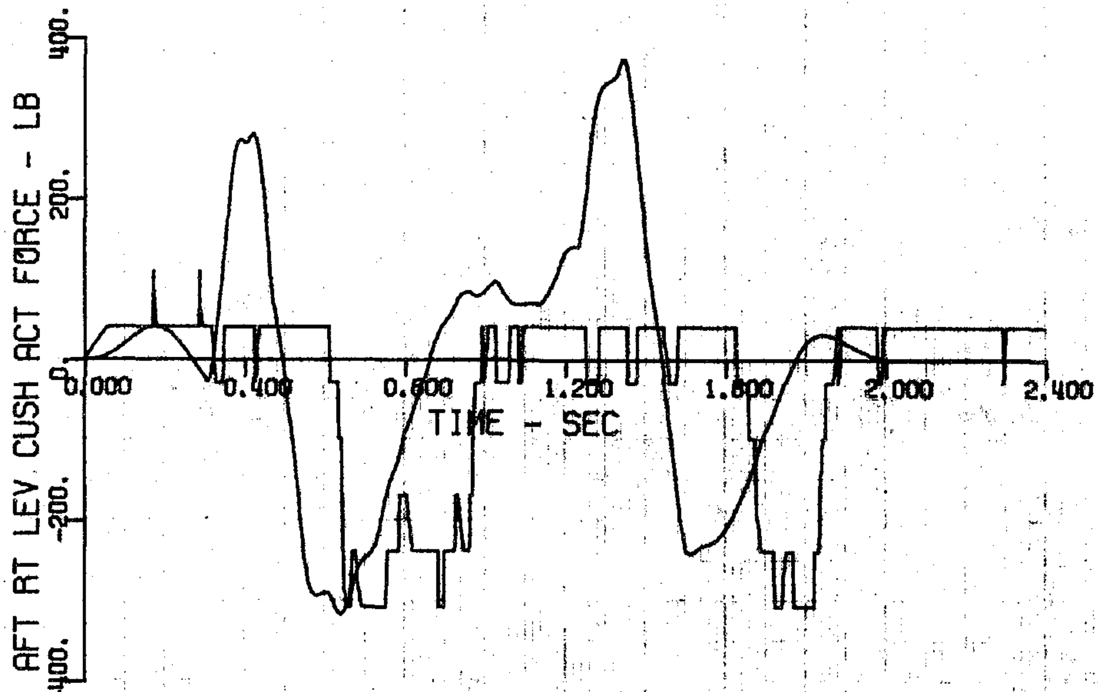


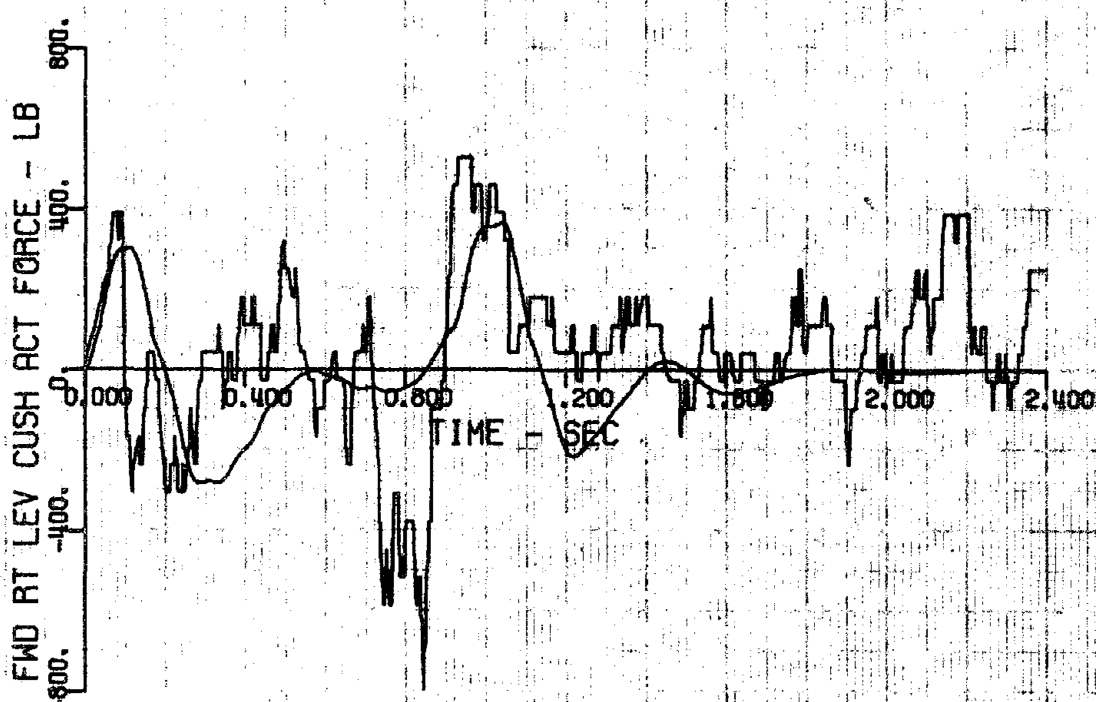
RUN W3 - 1W TL-102 12 10 W5 78 MPH 1.5 IN X 106 FT PARABOLA



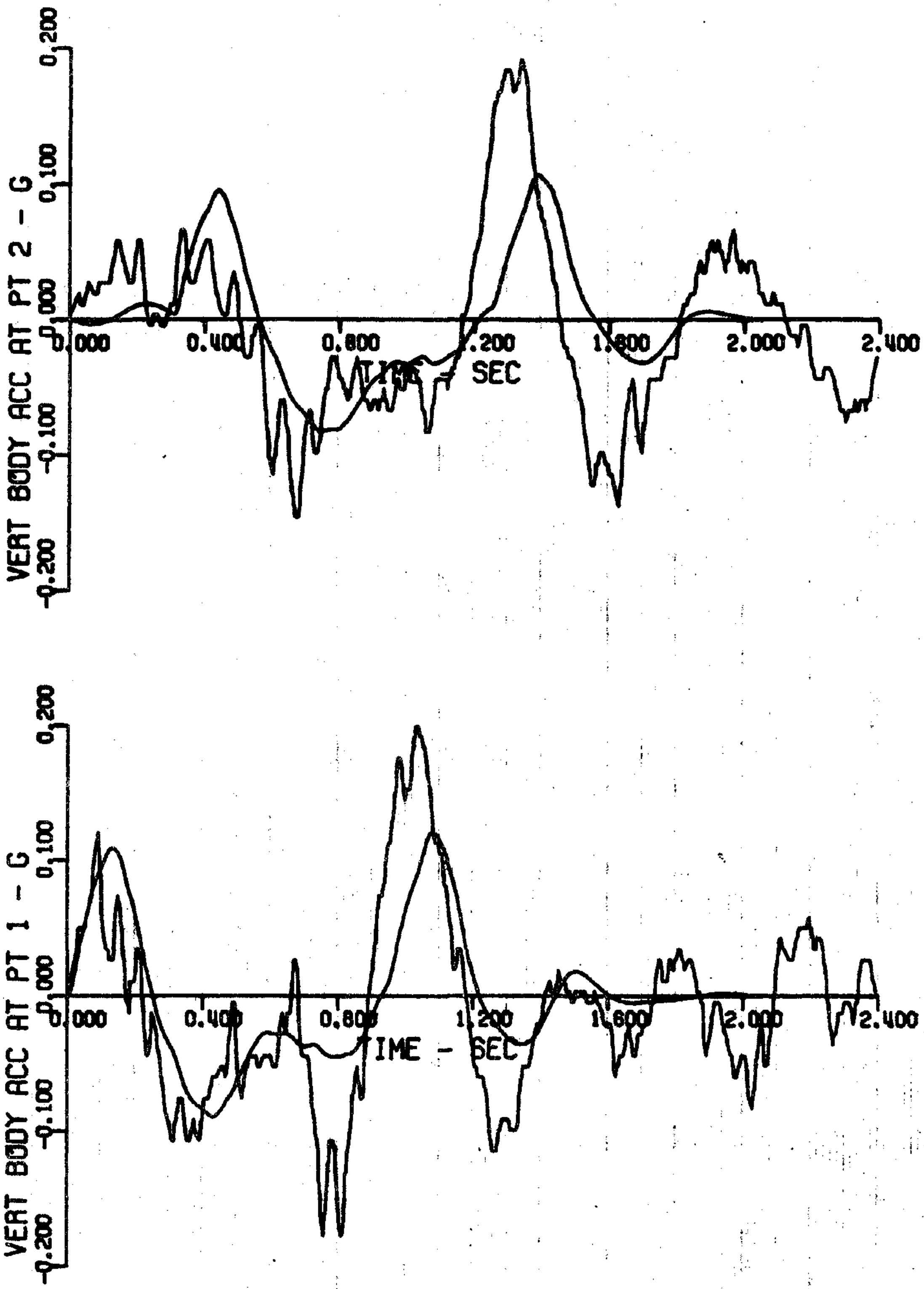


RUN 43 - 14 TL-102 12 10 45 78 MPH 1.5 IN X 106 FT PARABOLA

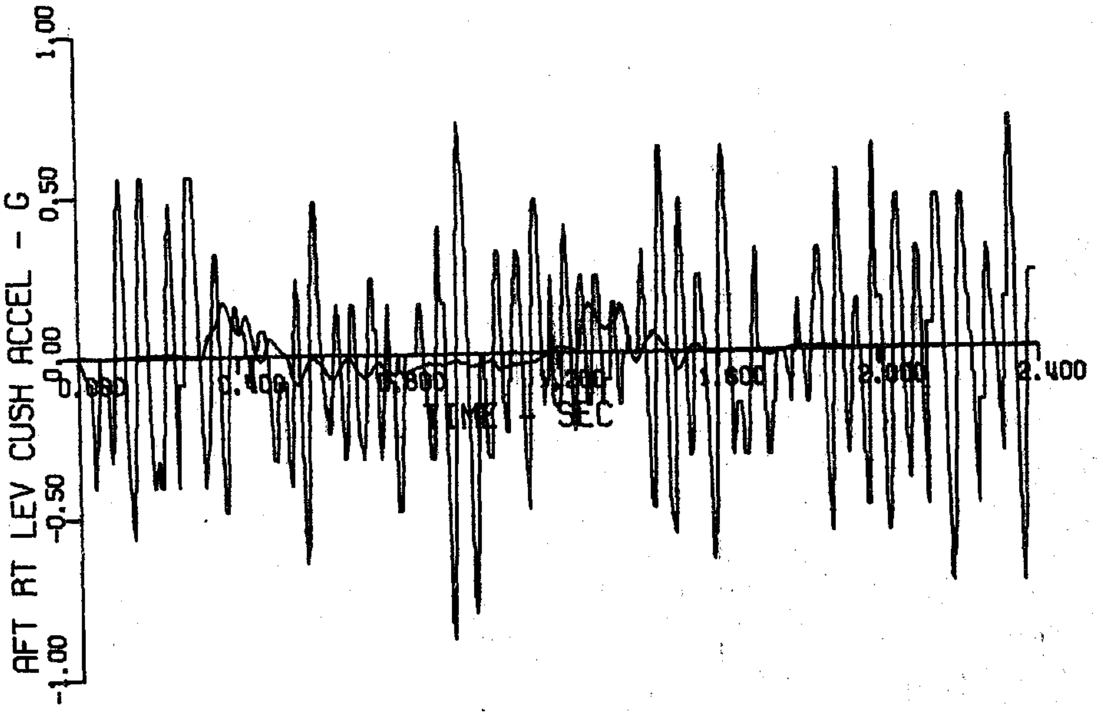


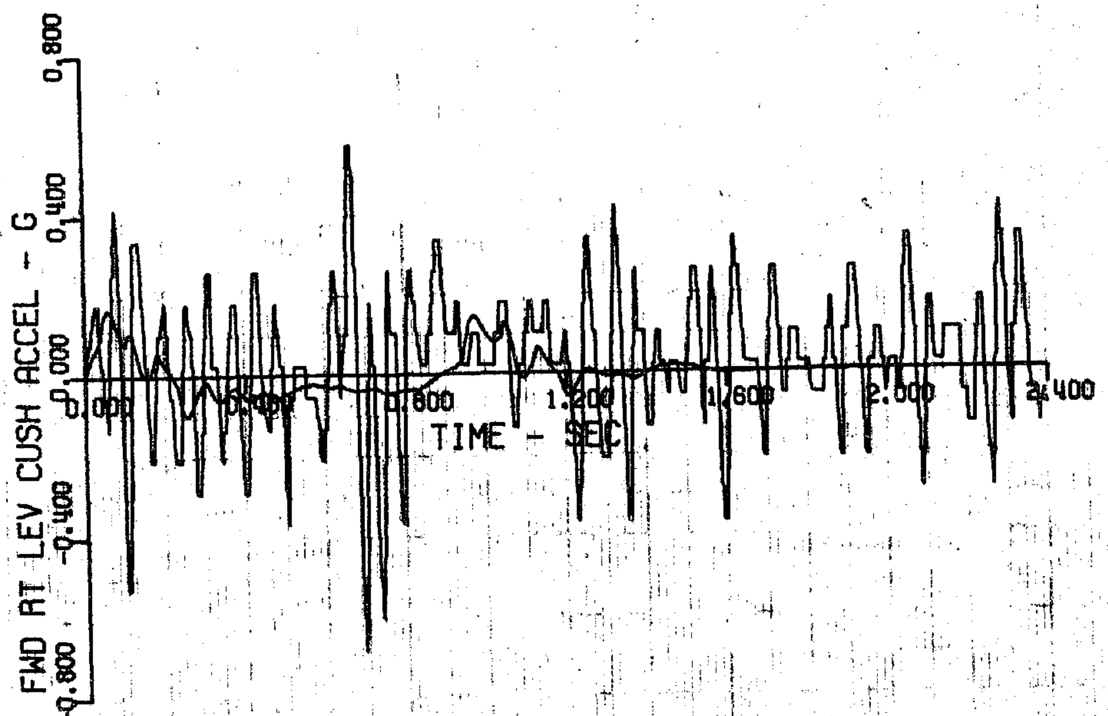


RUN 43 - 14 TL-102 12 10 45 78 MPH 1.5 IN X 106 FT PARABOLA

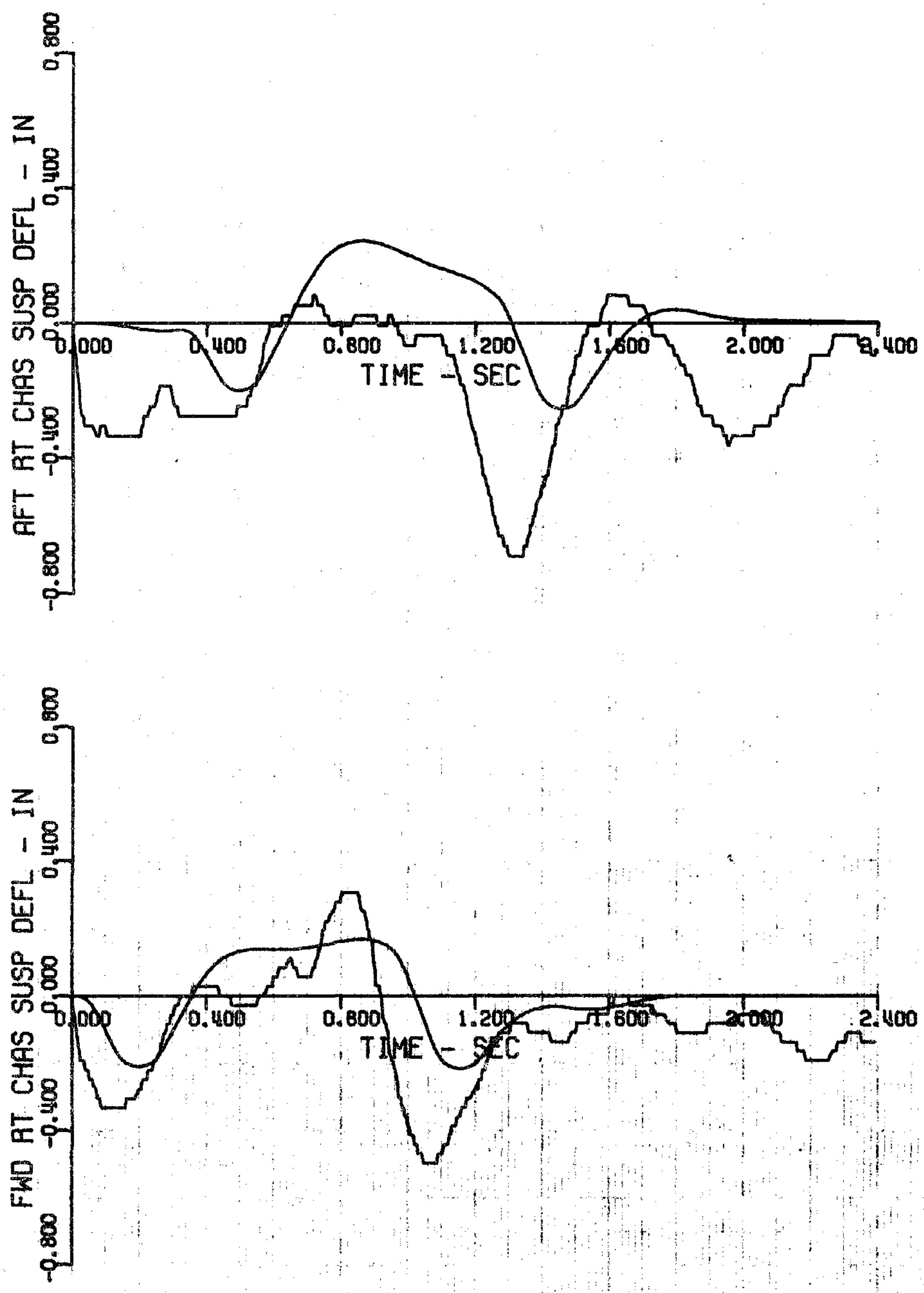


RUN 43- 16 TL-102 13 51 16 77 MPH 1.5 IN X 106 FT PARABOLA

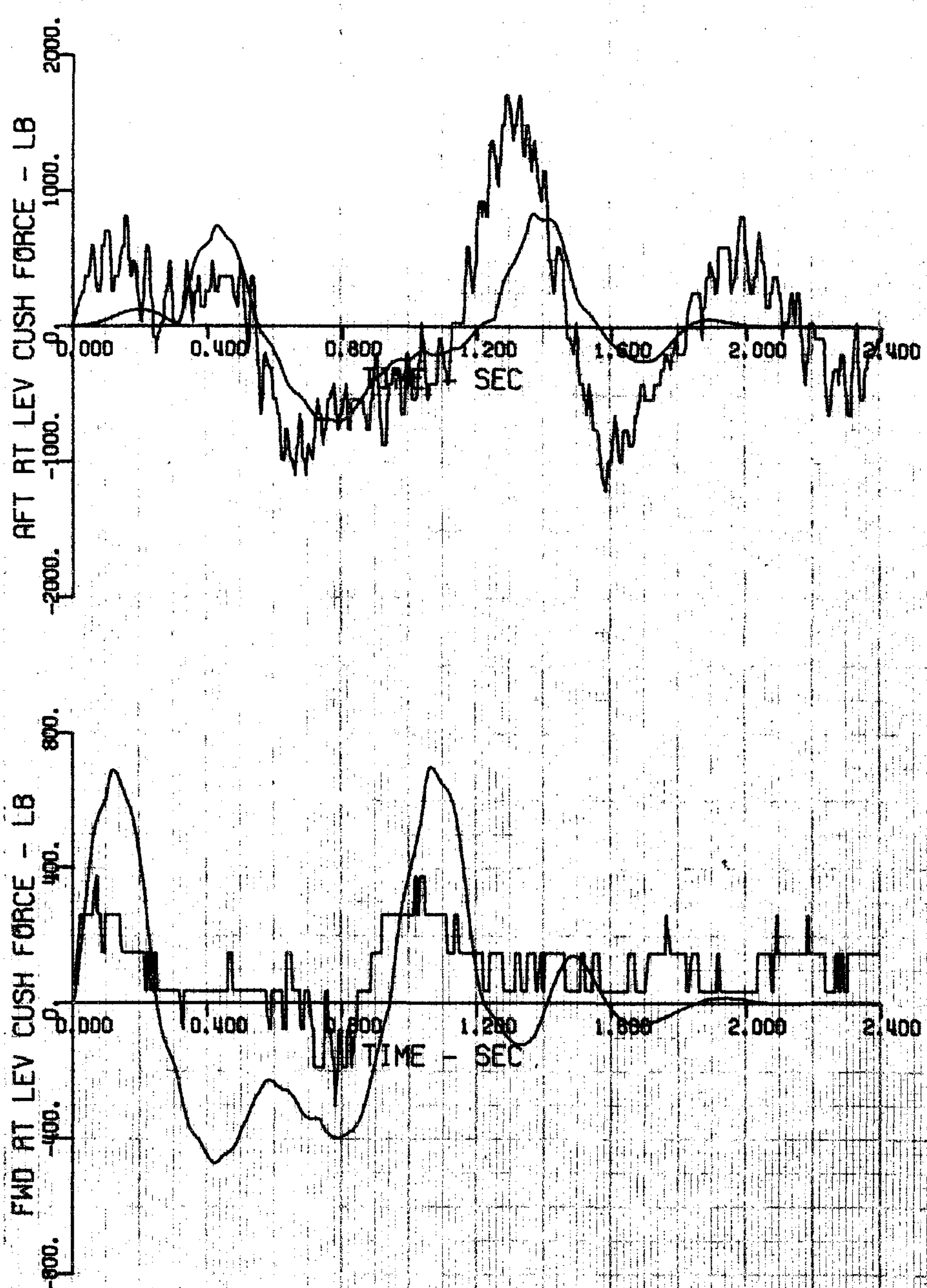




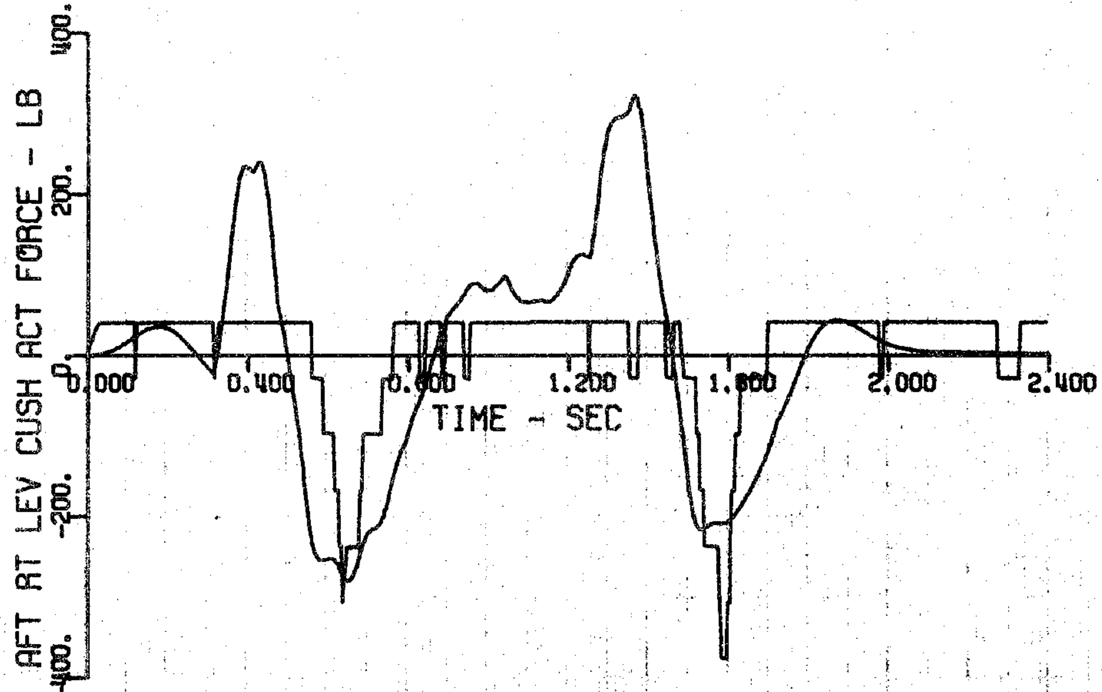
RUN 43- 16 TL-102 13 51 18 77 MPH 1.5 IN X 106 FT PARABOLA

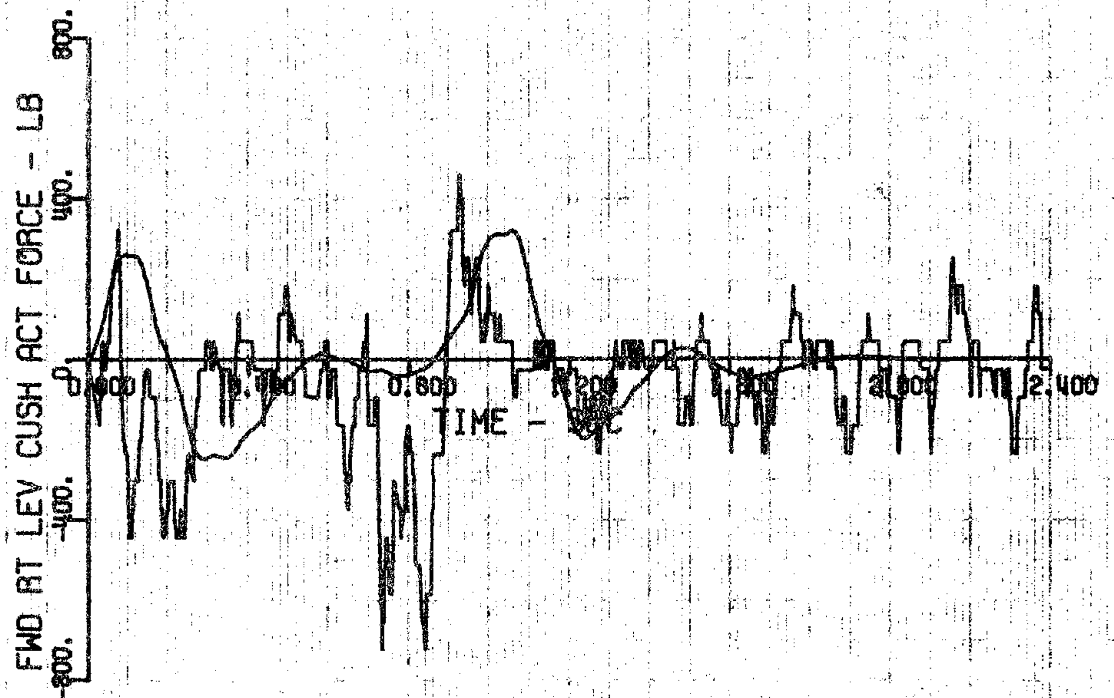


RUN 43 - 16 TL-102 13 51 18 77 MPH 1.5 IN X 106 FT PARABOLA

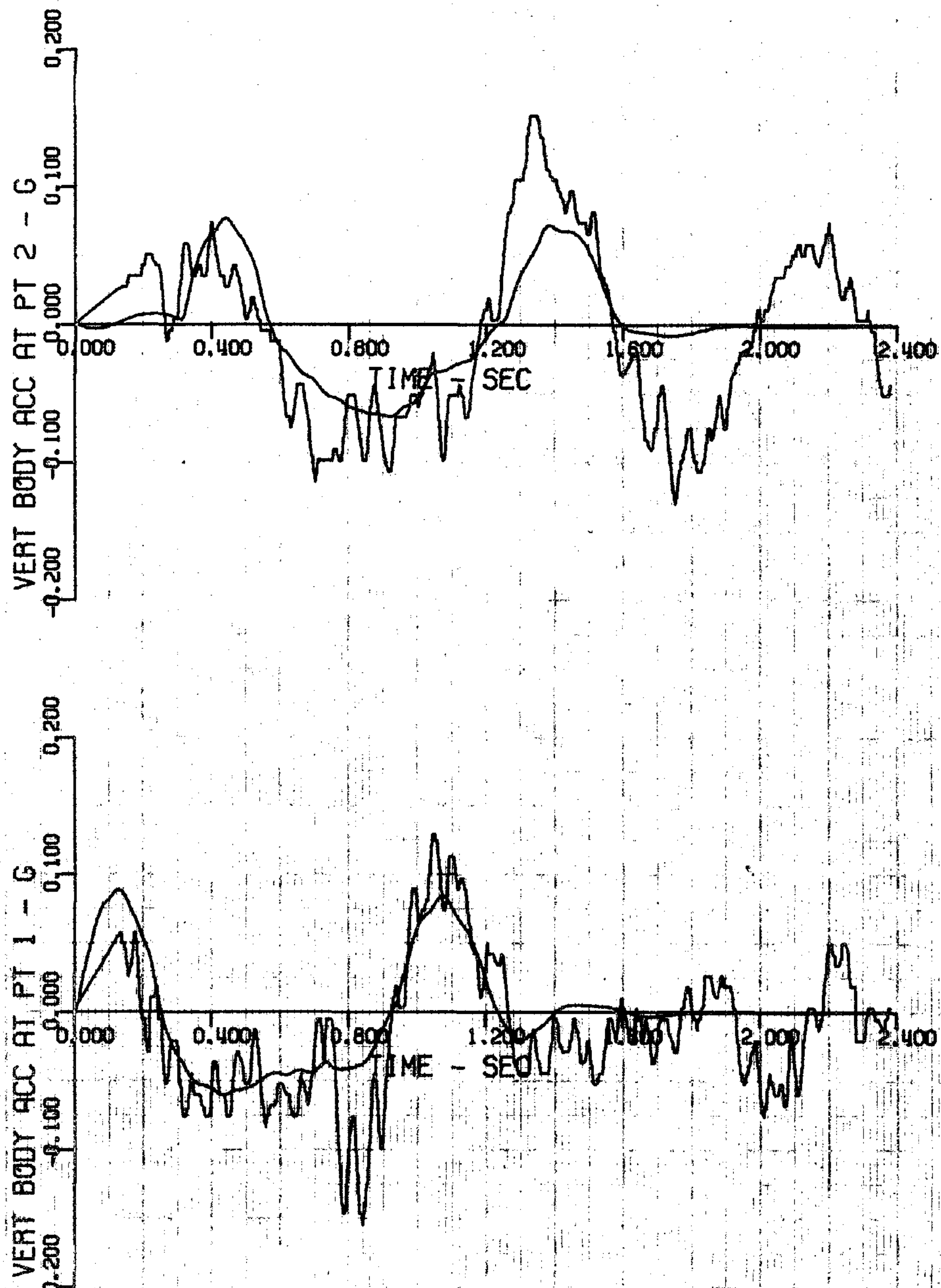


RUN 43 - 16 TL-102 13 51 18.77 MPH 1.5 IN X 106 FT PARABOLA

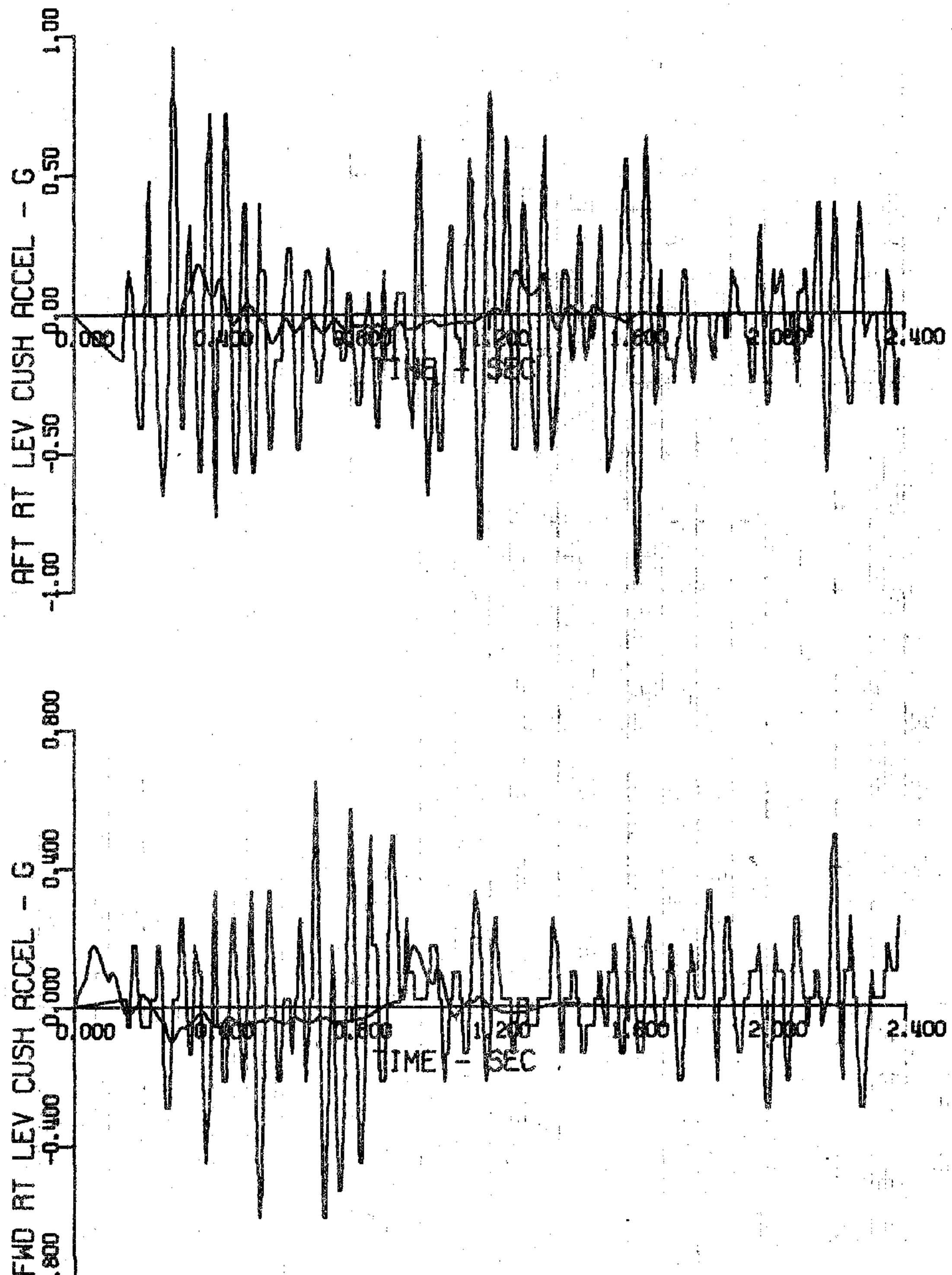




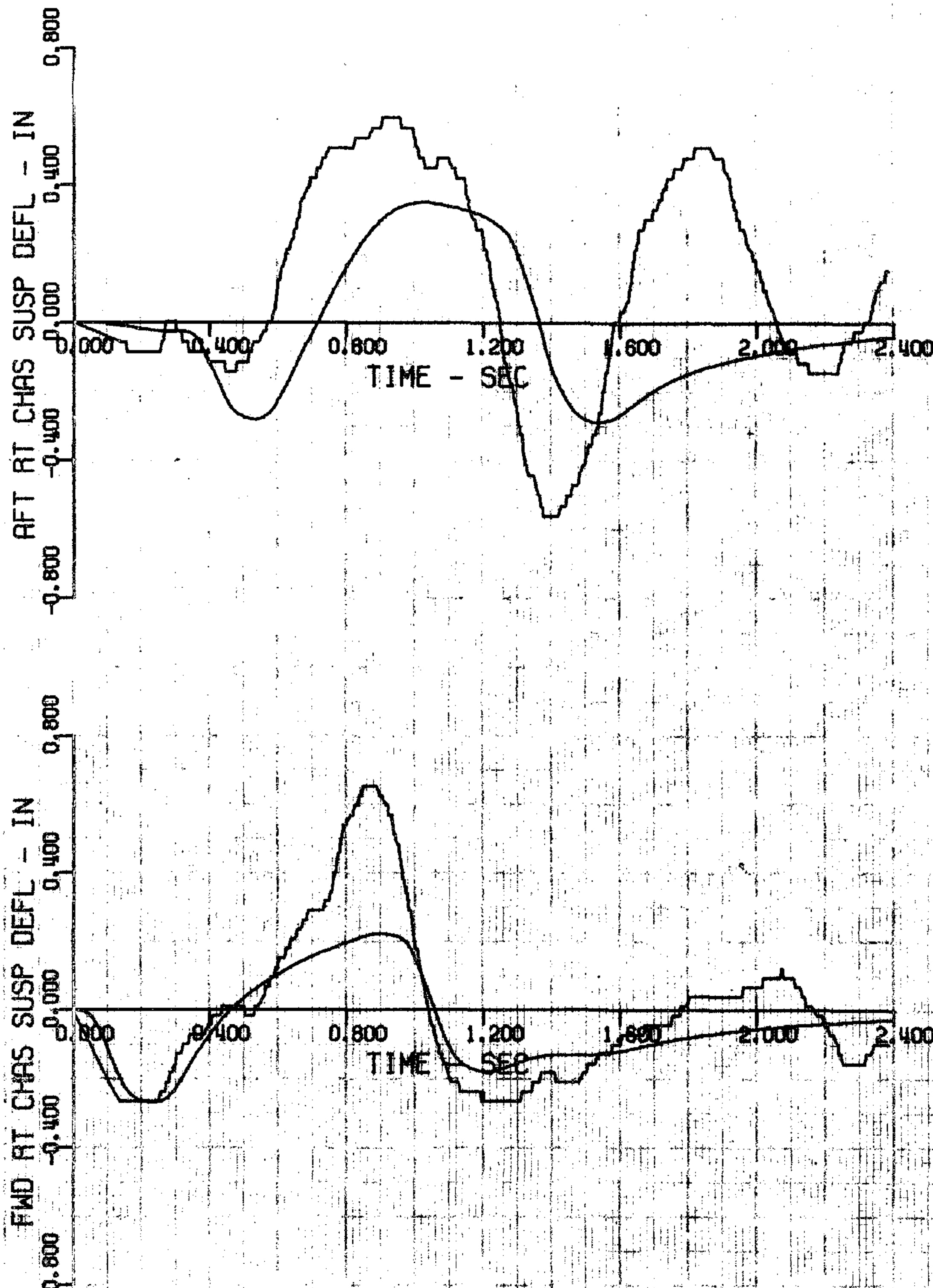
RUN 43- 16 TL-102 13 51 18 77 MPH 1.5 IN X 106 FT PARABOLA



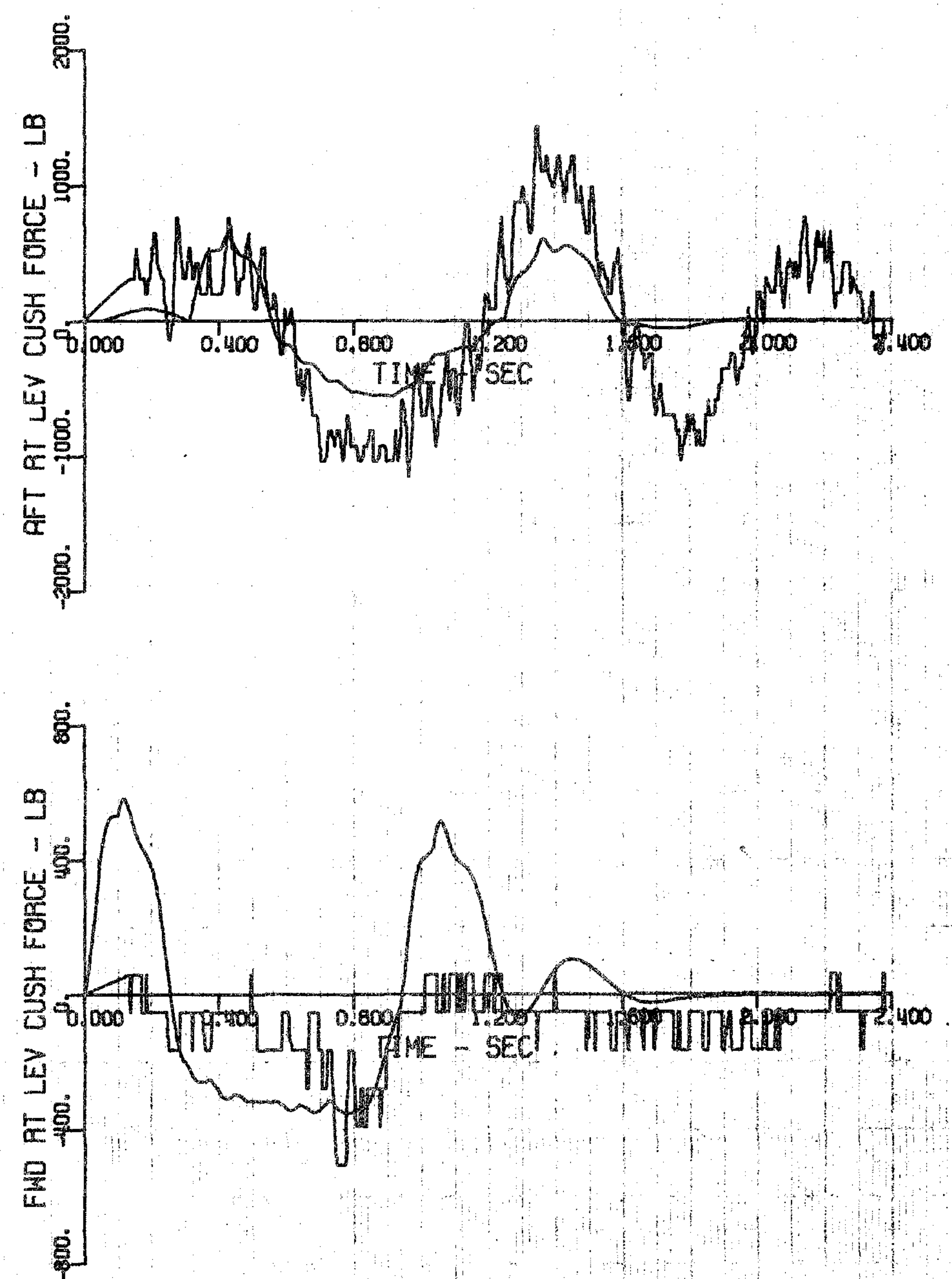
RUN 43 - 10 TL-102 14 06 45 77 MPH 1.5 IN X 106 FT PARABOLA



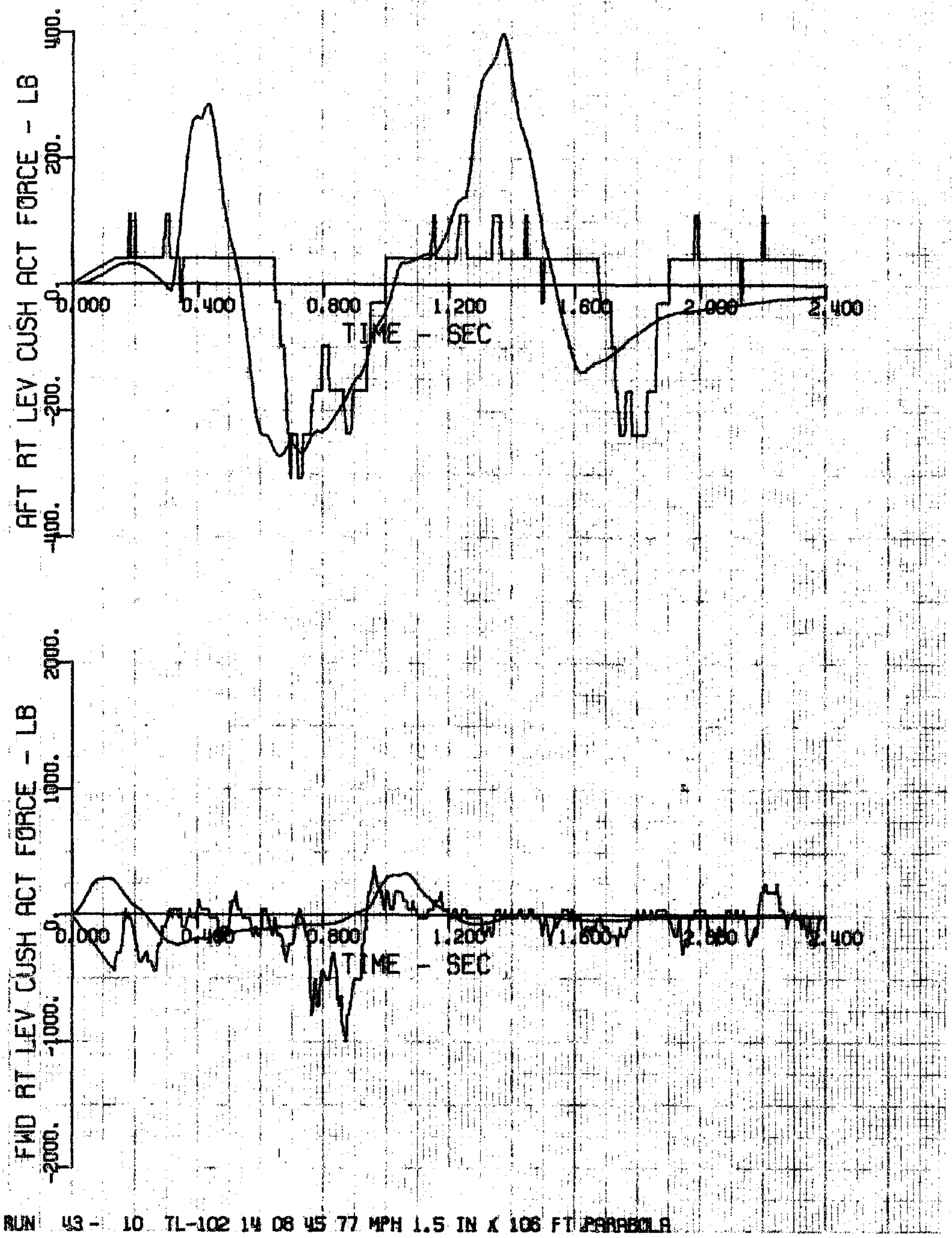
RUN 43 - 10 TL-102 14 08 45.77 MPH 1.5 IN X 106 FT PARABOLA



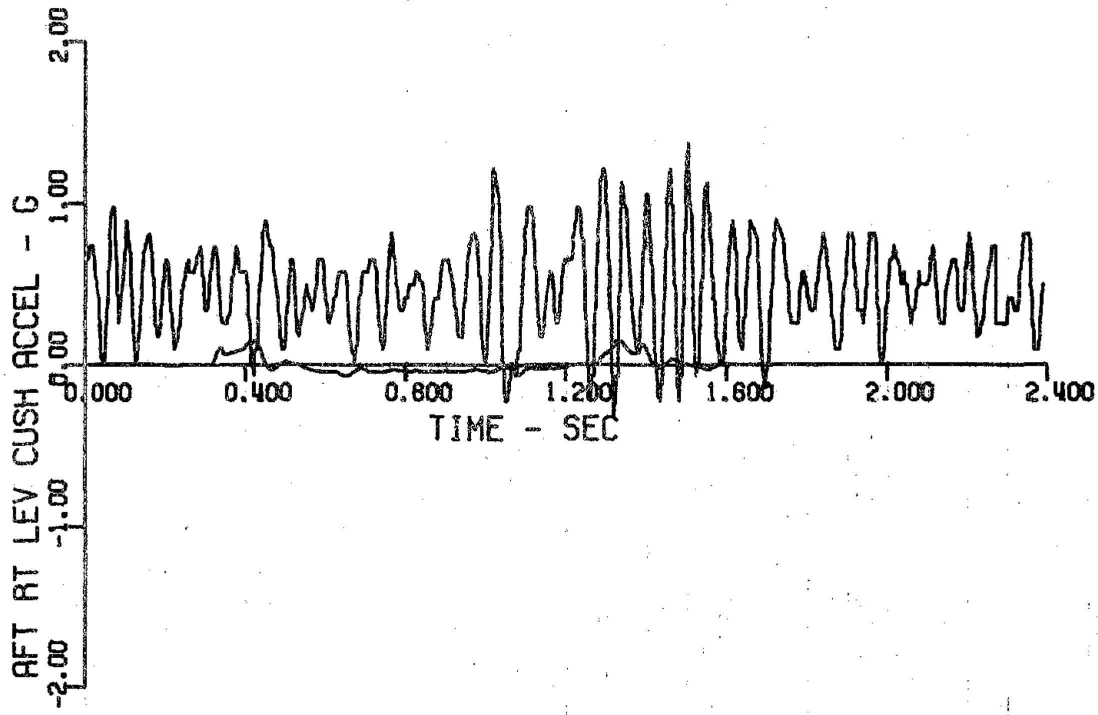
RUN 43 - 10 FL-102 14 08 45 77 MPH 1.5 IN X 106 FT PARABOLA

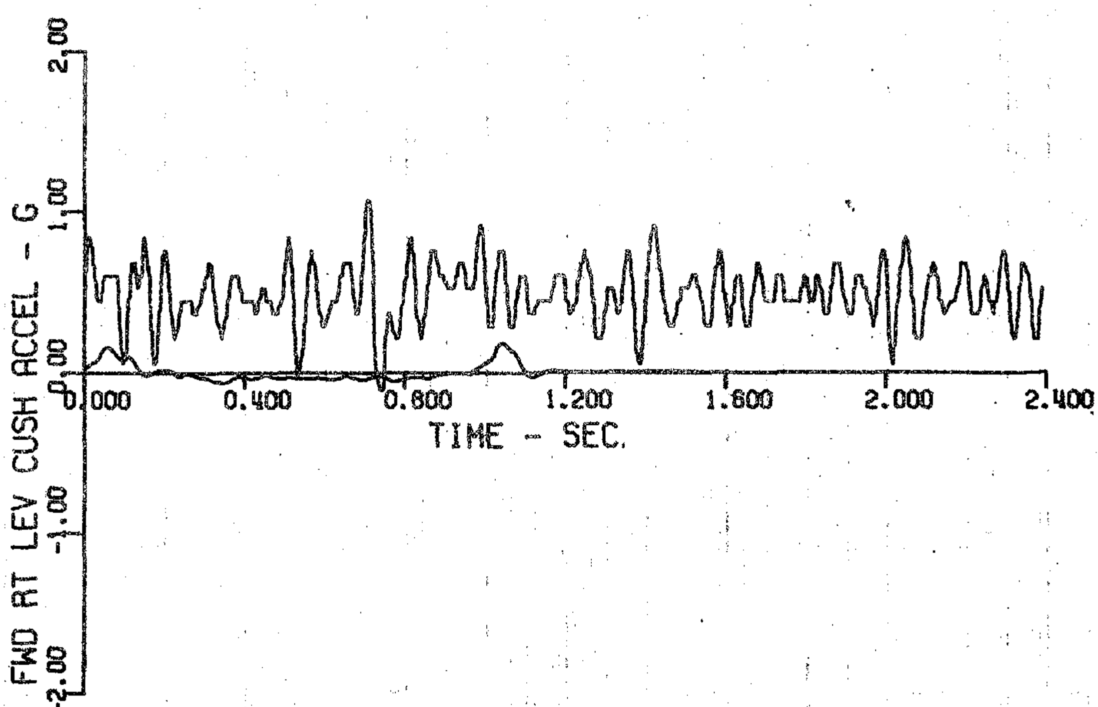


RUN 43 - 10 TL-102 14 08 45 77 MPH 1.5 IN X 108 FT PARABOLA

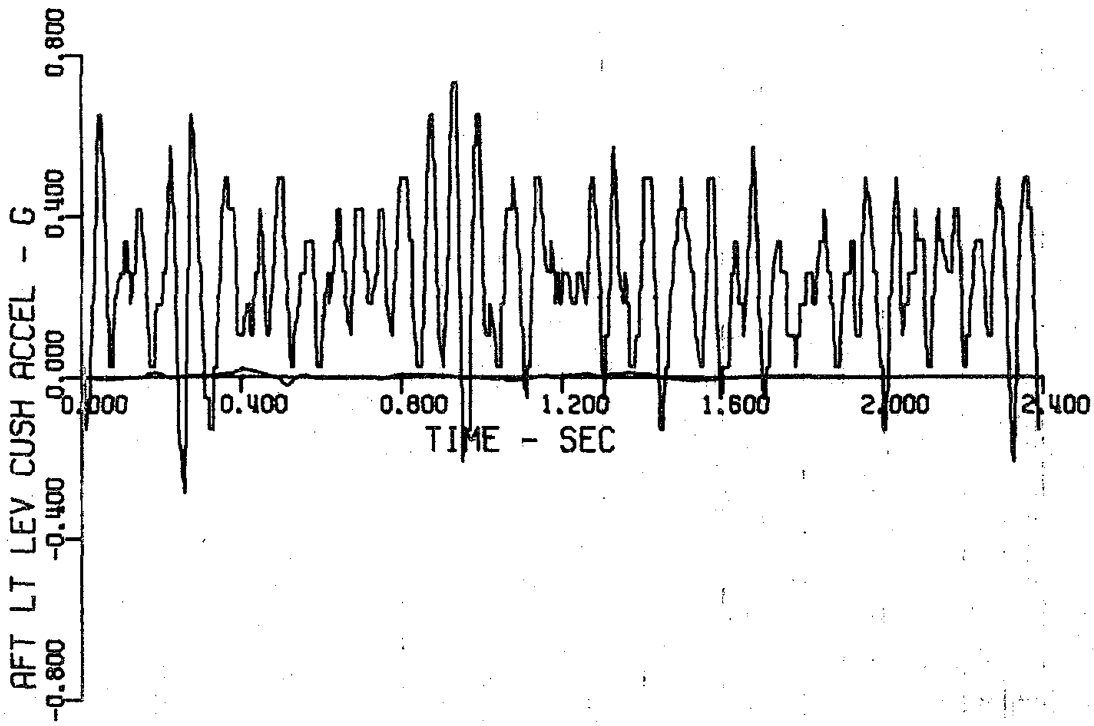


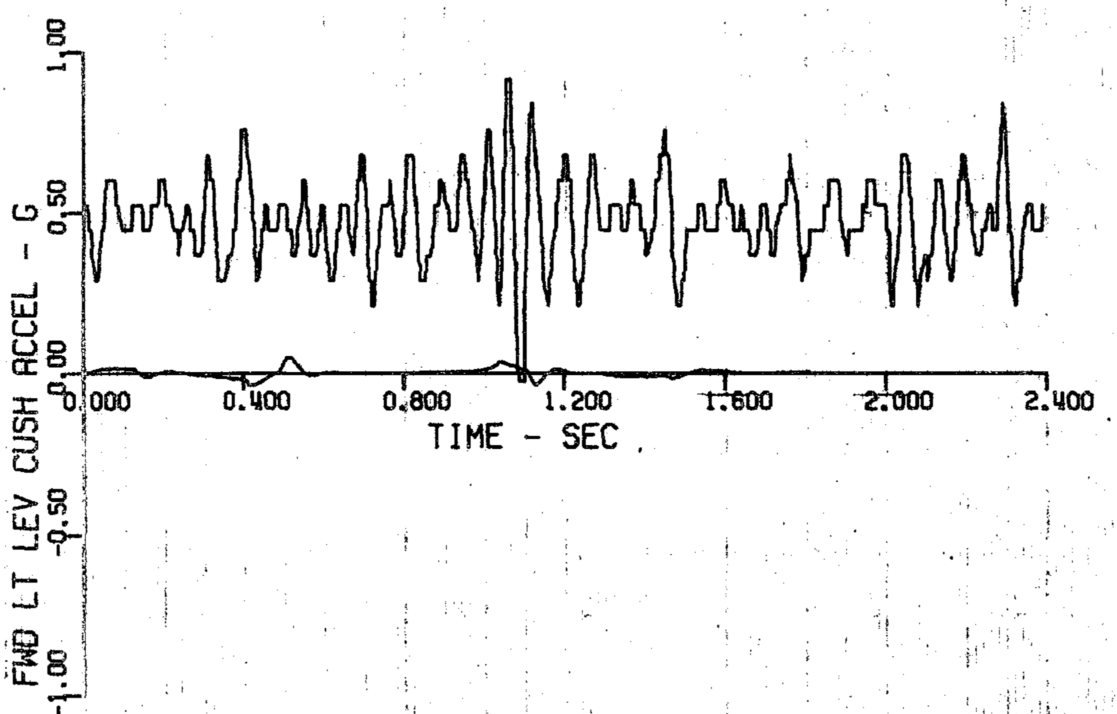
RUN 43 - 10 TL-102 14 08 45 77 MPH 1.5 IN X 106 FT PARABOLA



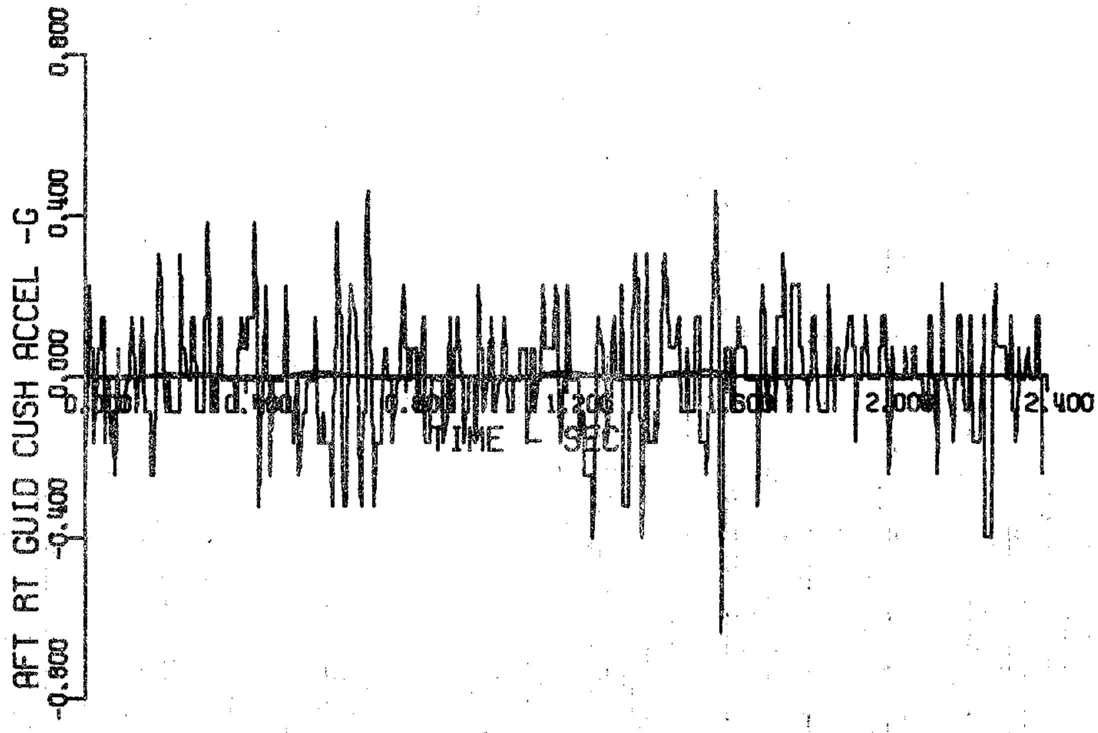


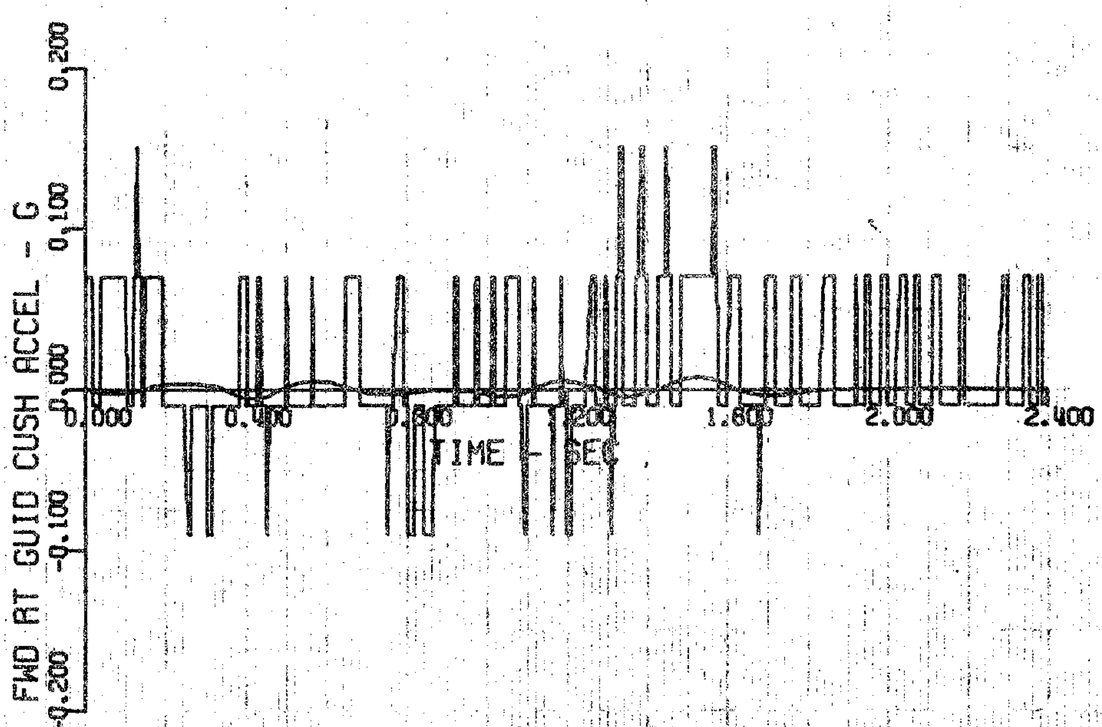
RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ASYM PARABOLA



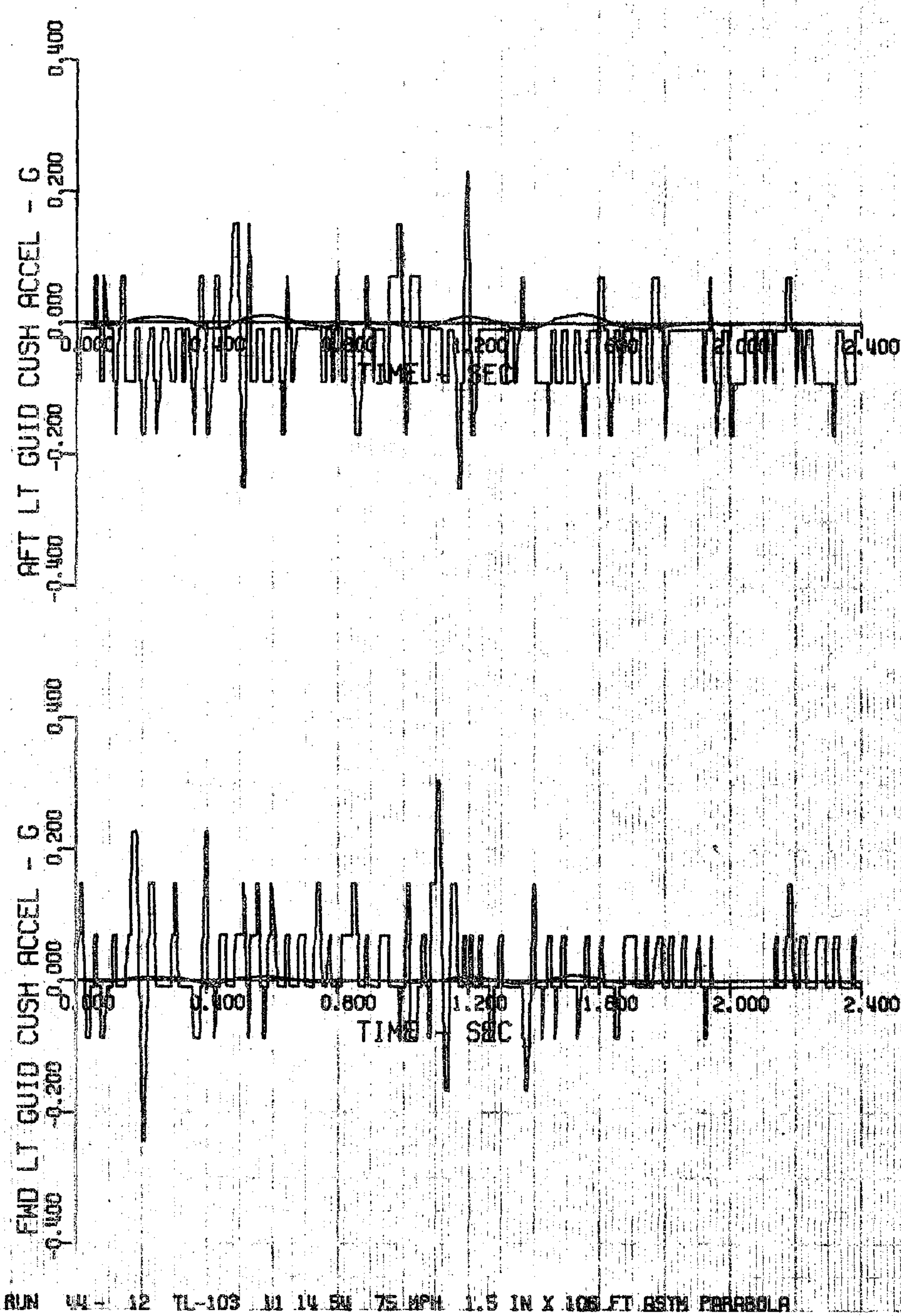


RUN 44 - 12 TL-103 11 14 54 75 MPH 1.5 IN X 106 FT ~~[illegible]~~ PARABOLA

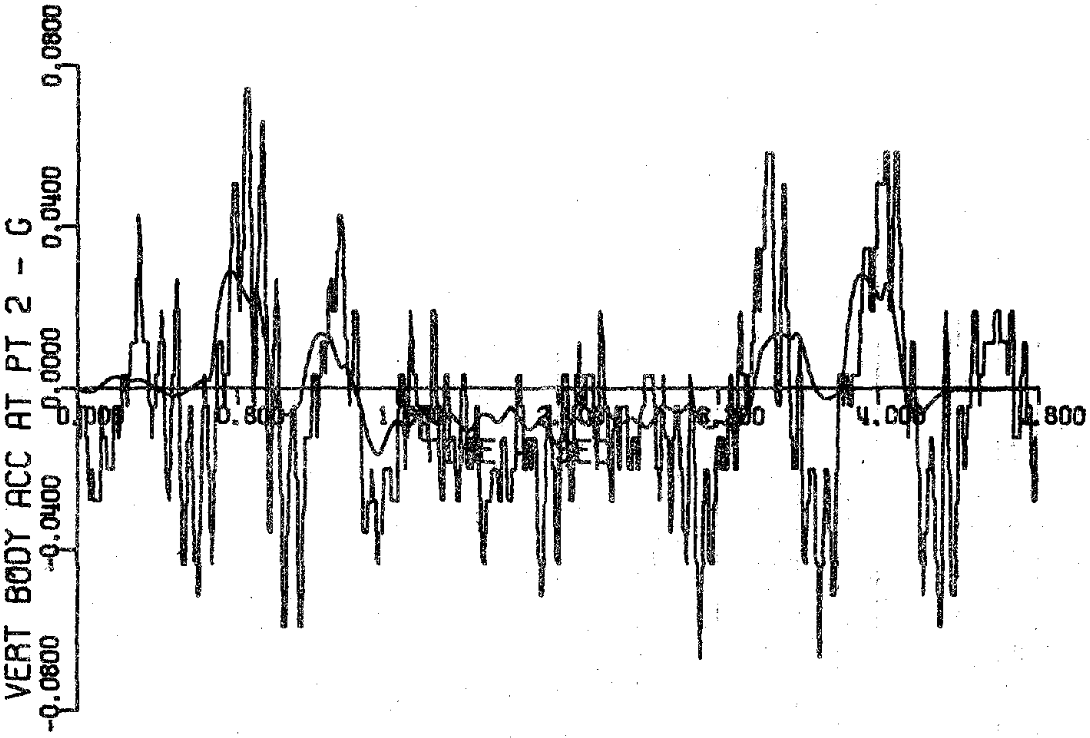


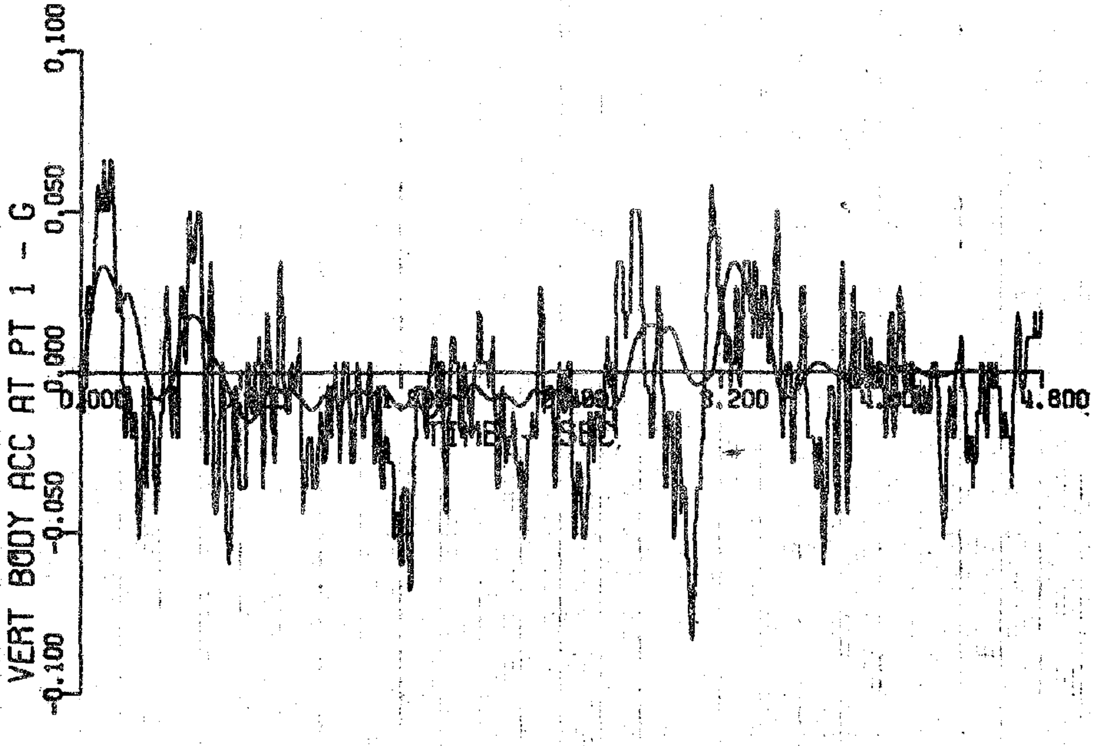


RUN 44- 12 TL-103 11 14 54 75 MPH 1.5 IN X 108 FT ASYM PARABOLA

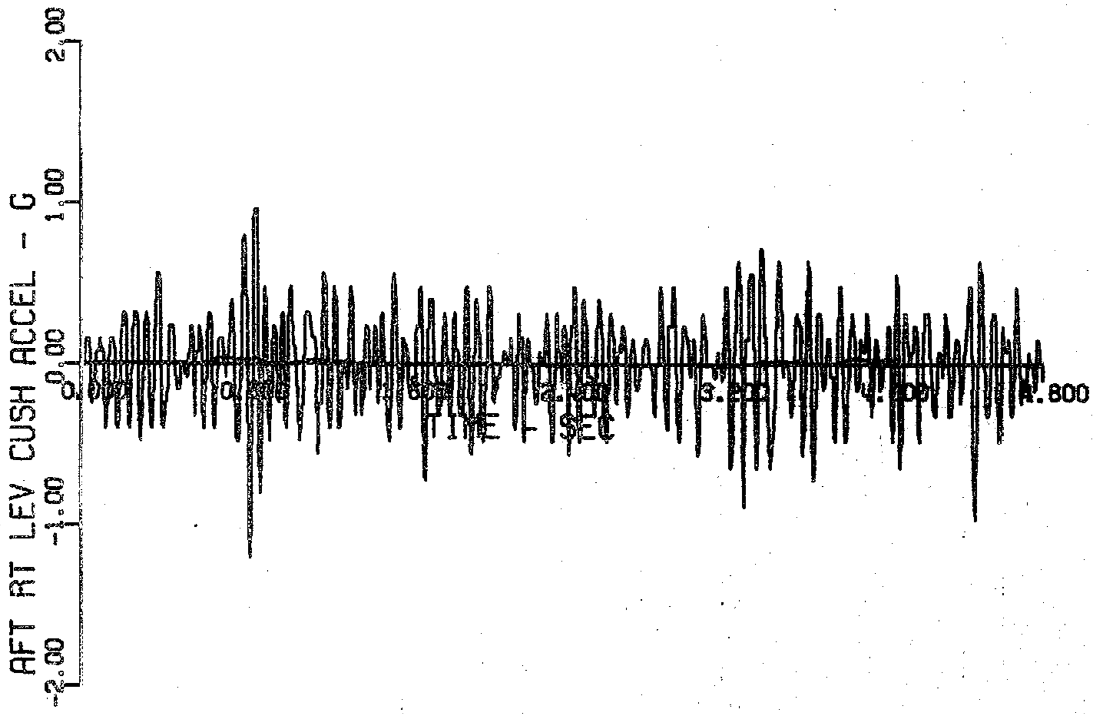


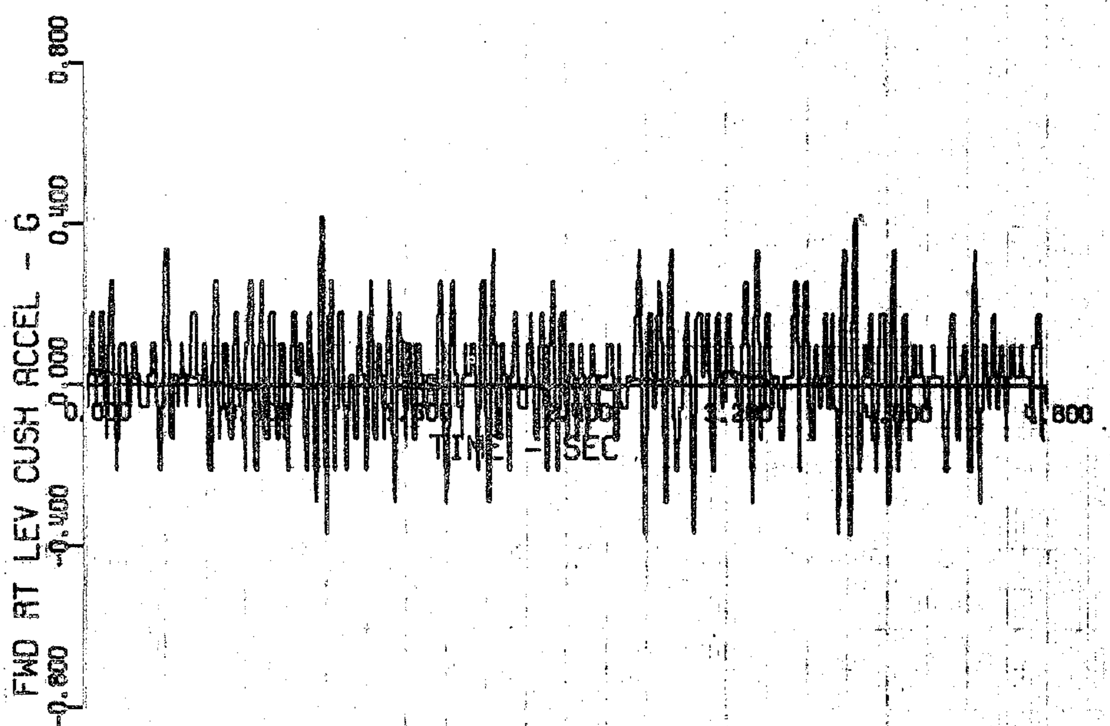
RUN 44- 12 TL-103 W1 14 SW 75 MPH 1.5 IN X 106 FT ASYM PARABOLA



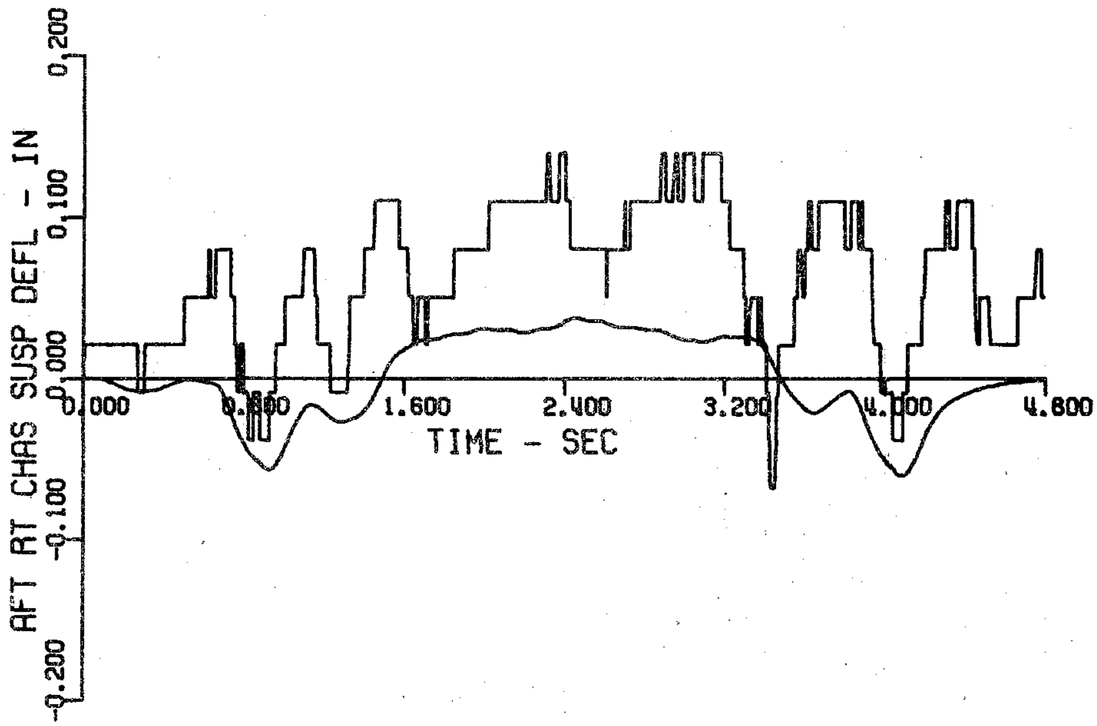


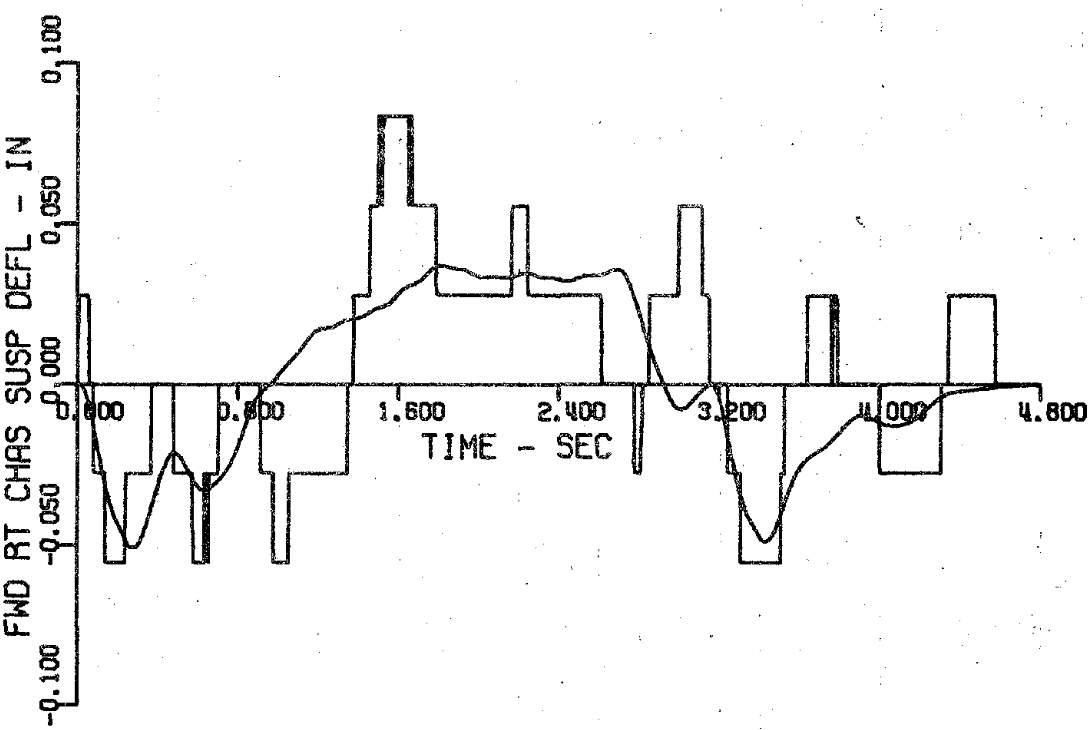
RUN 43 - 18 TL-104 10 40 51 36 MPH 3.0 IN X 150 FT PARABOLA



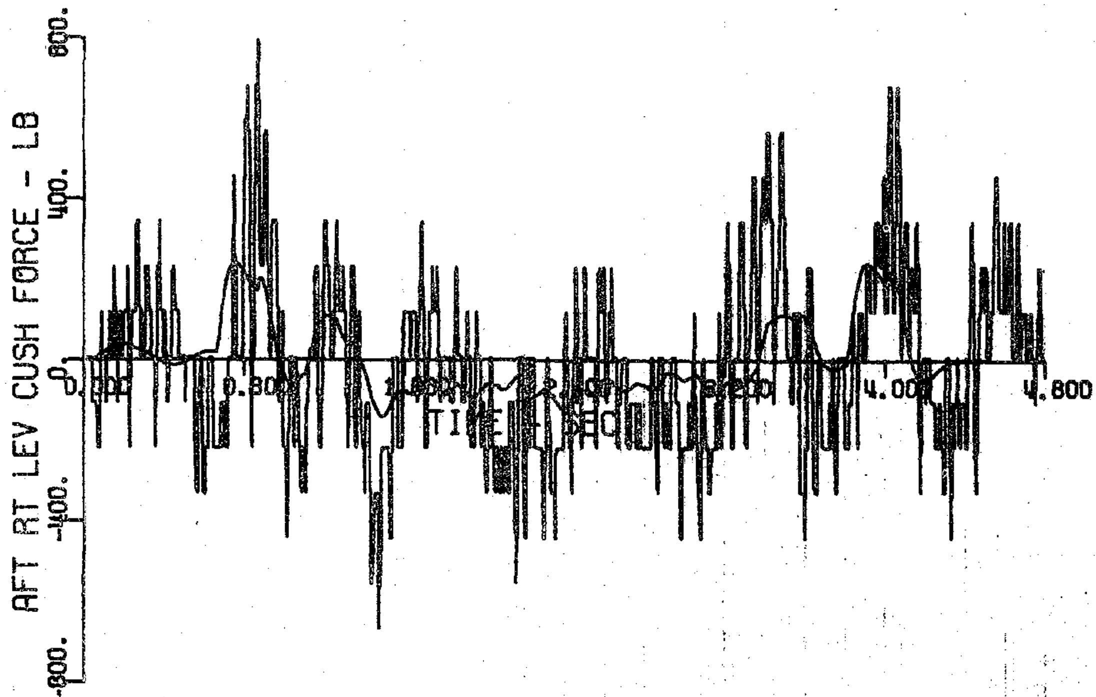


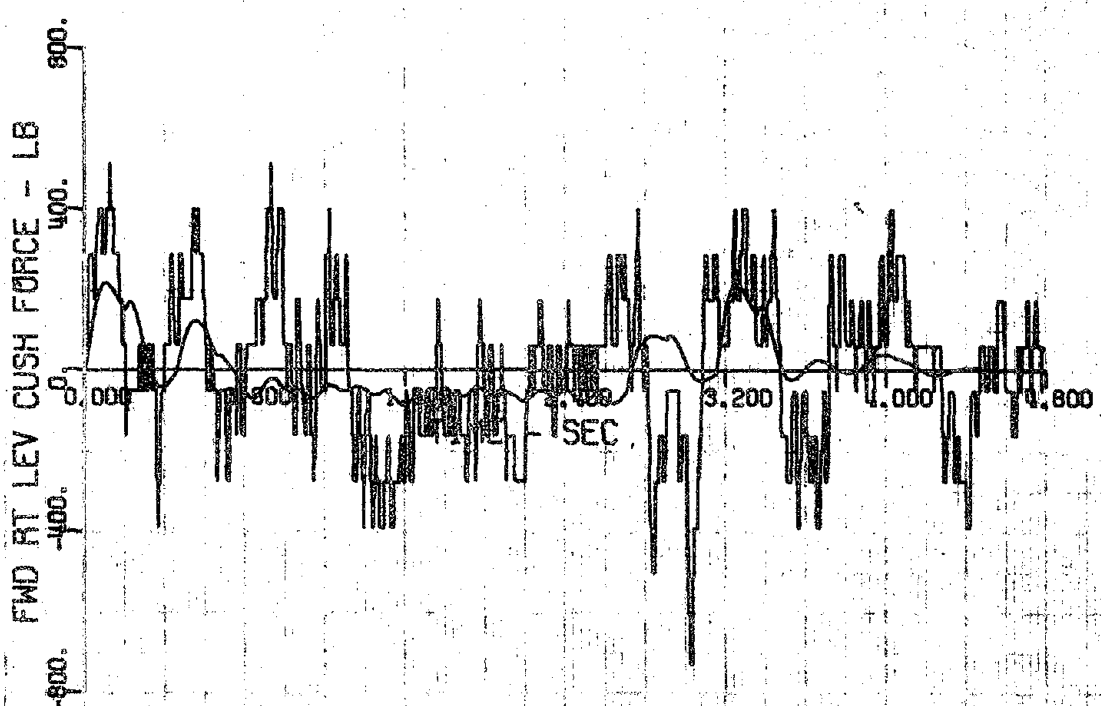
RUN 43 - 18 TL-104 10 40 51 38 MPH 3.0 IN X 150 FT PARABOLA



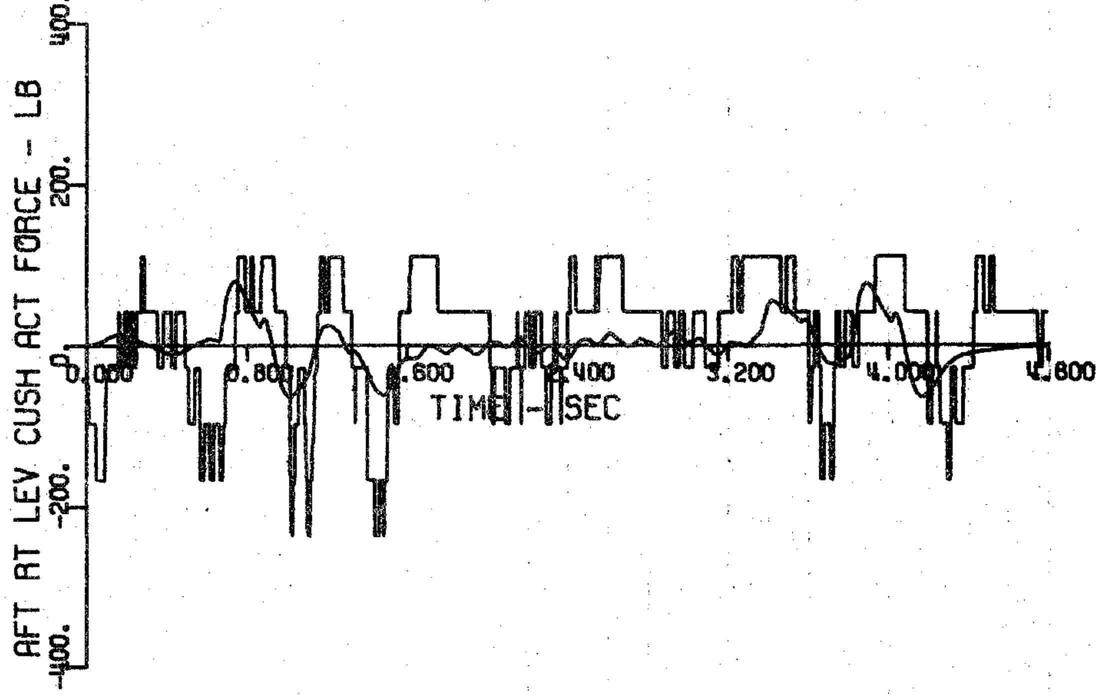


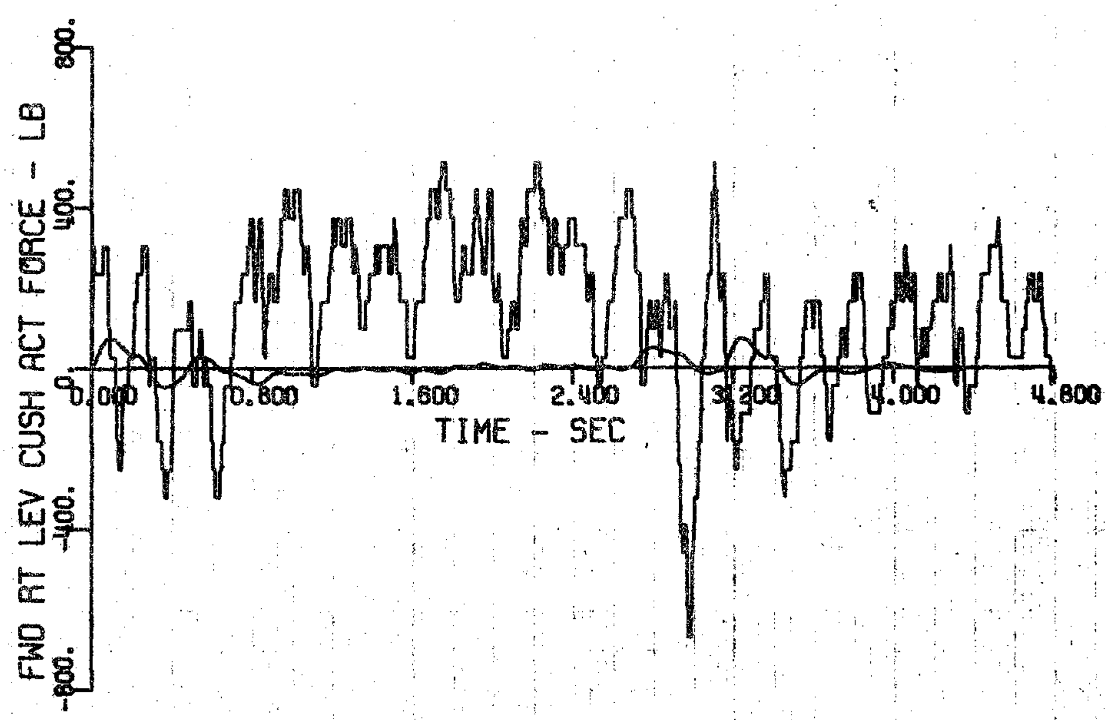
RUN 43 - 18 TL-104 10 40 51 36 MPH 3.0 IN X 150 FT PARABOLA



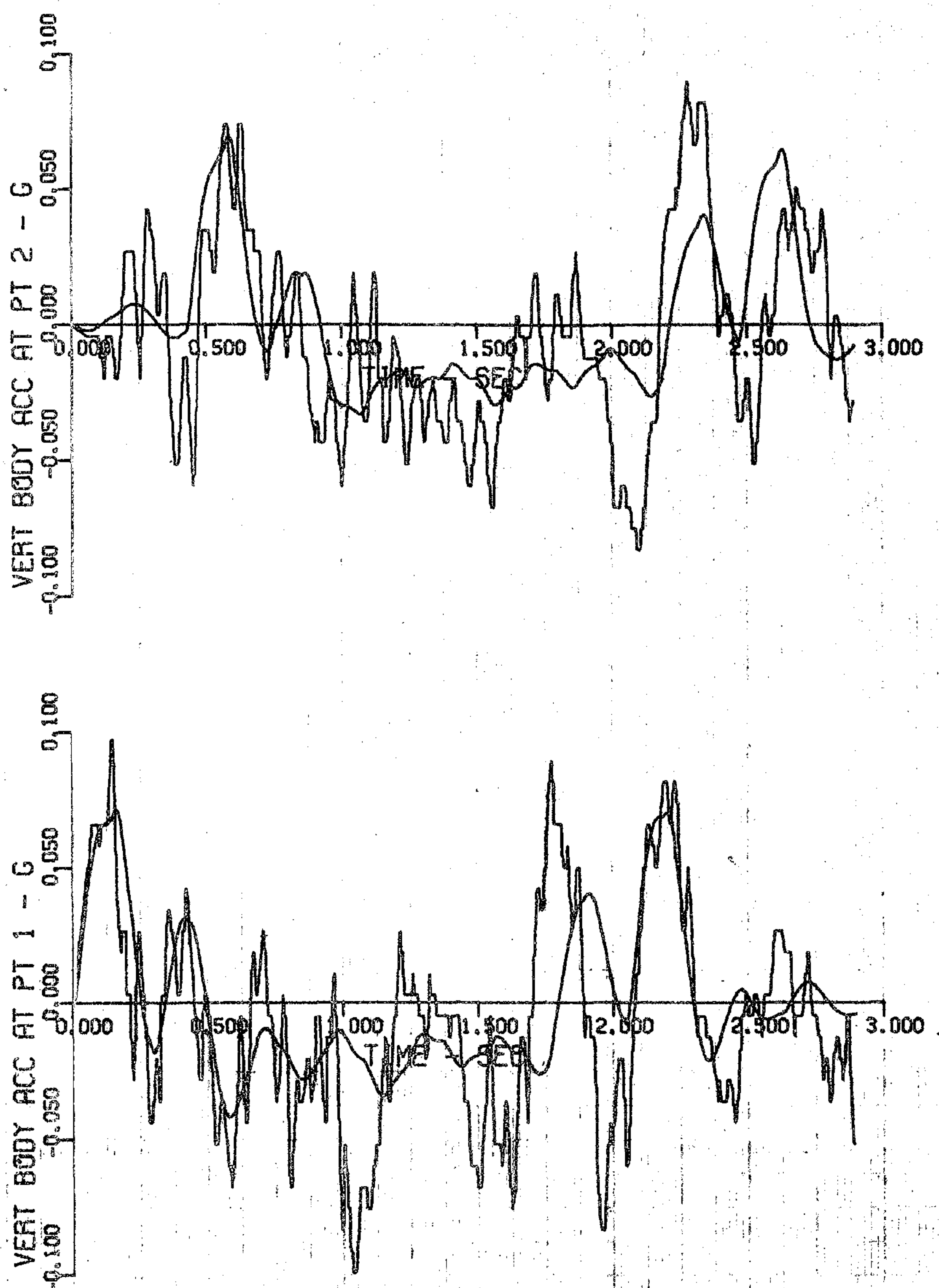


RUN 43 - 18 TL-104 10 40 51 36 MPH 3.0 IN X 150 FT PARABOLA

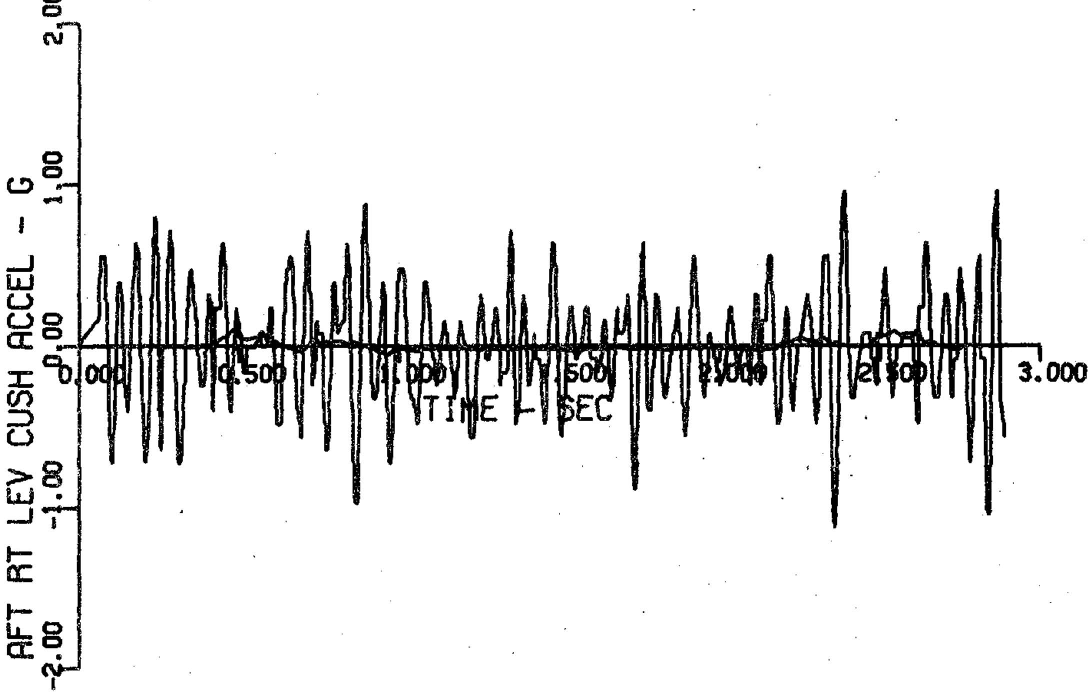


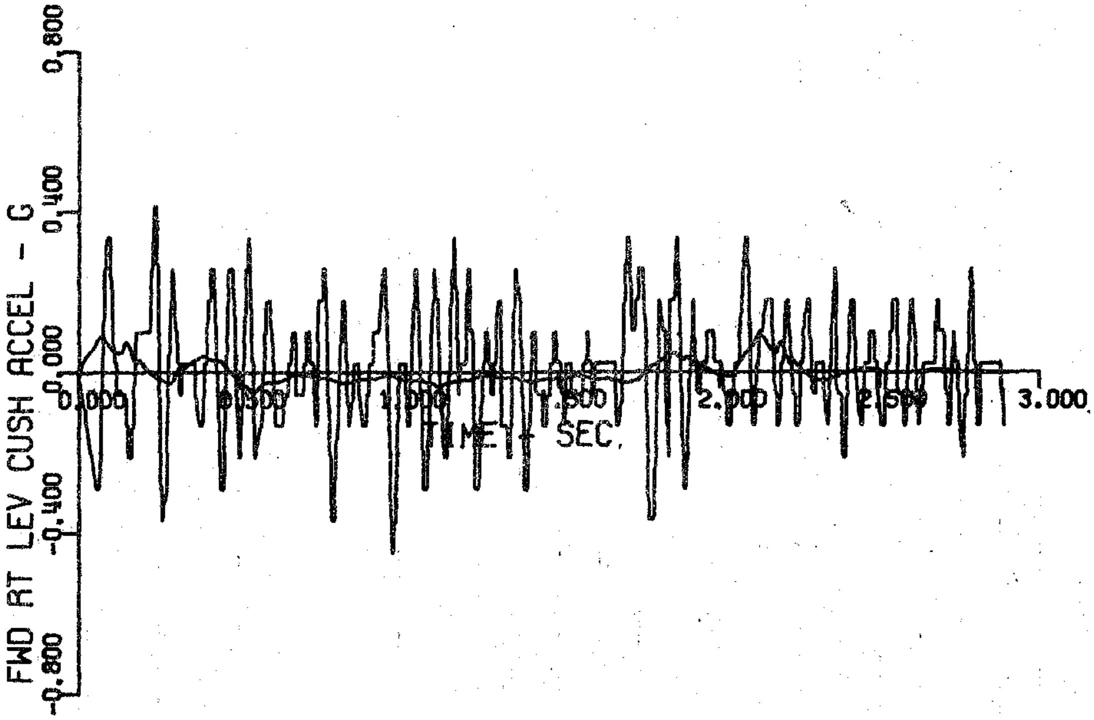


RUN 43 - 18 TL-104 10 40 51 38 MPH 3.0 IN X 150 FT PARABOLA

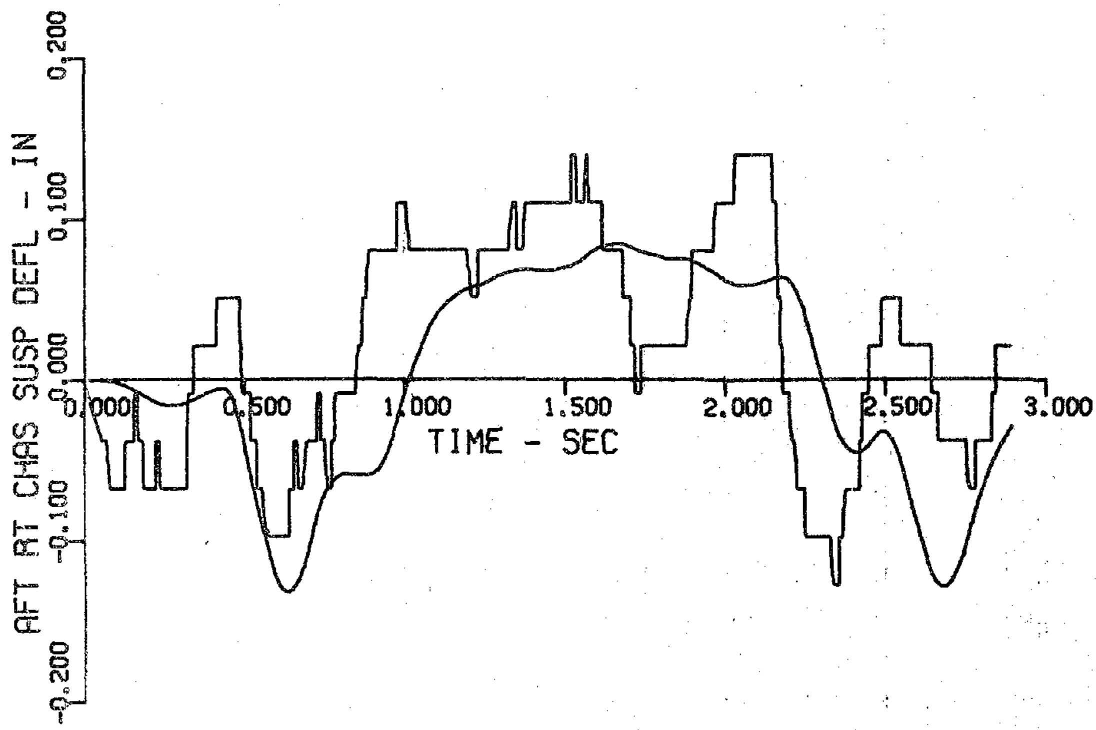


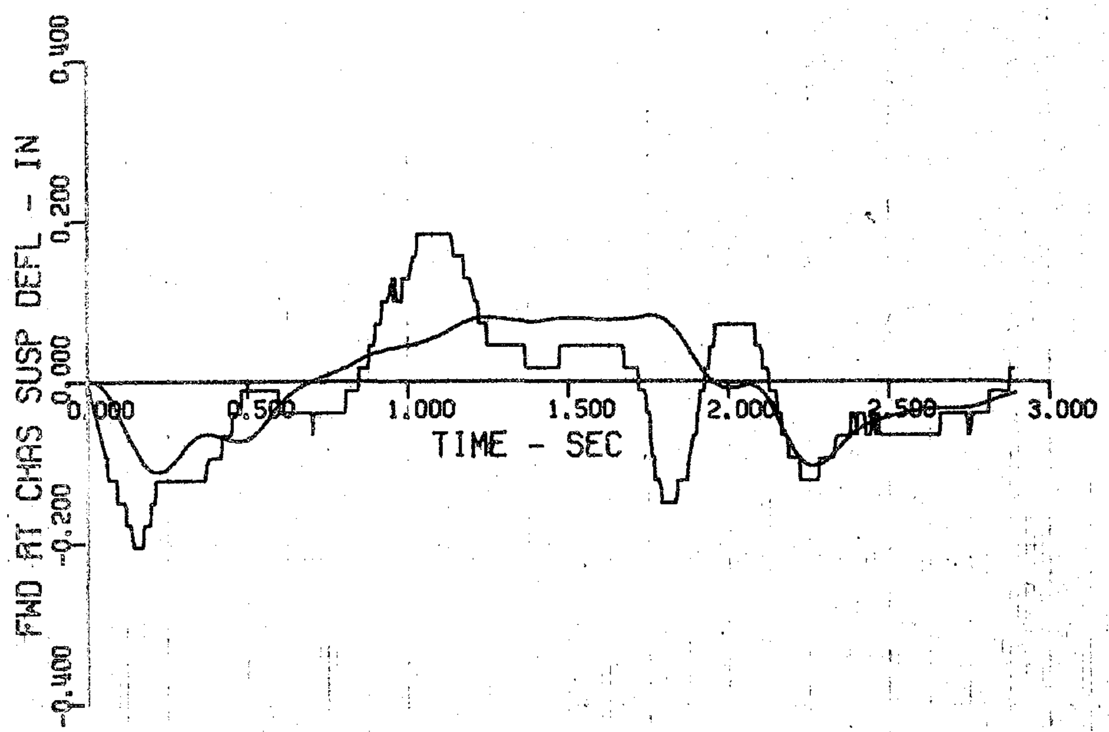
RUN 43 - 20 TL-104 13 07 17 56 MPH 3.0 IN X 150 FT PARABOLA



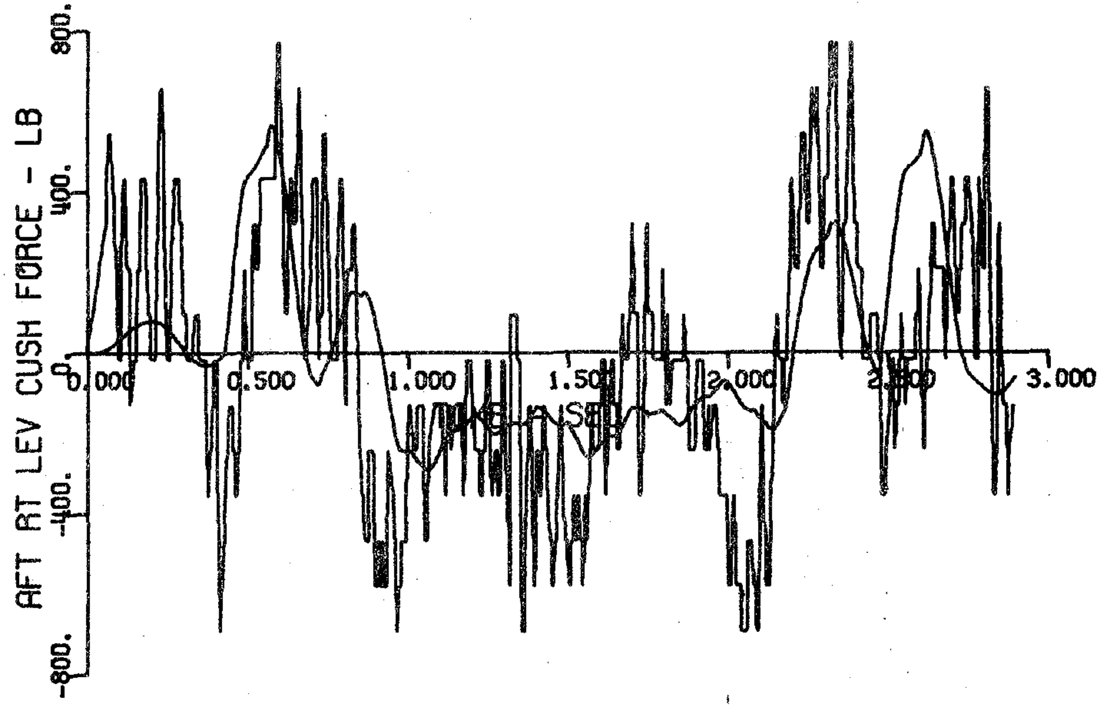


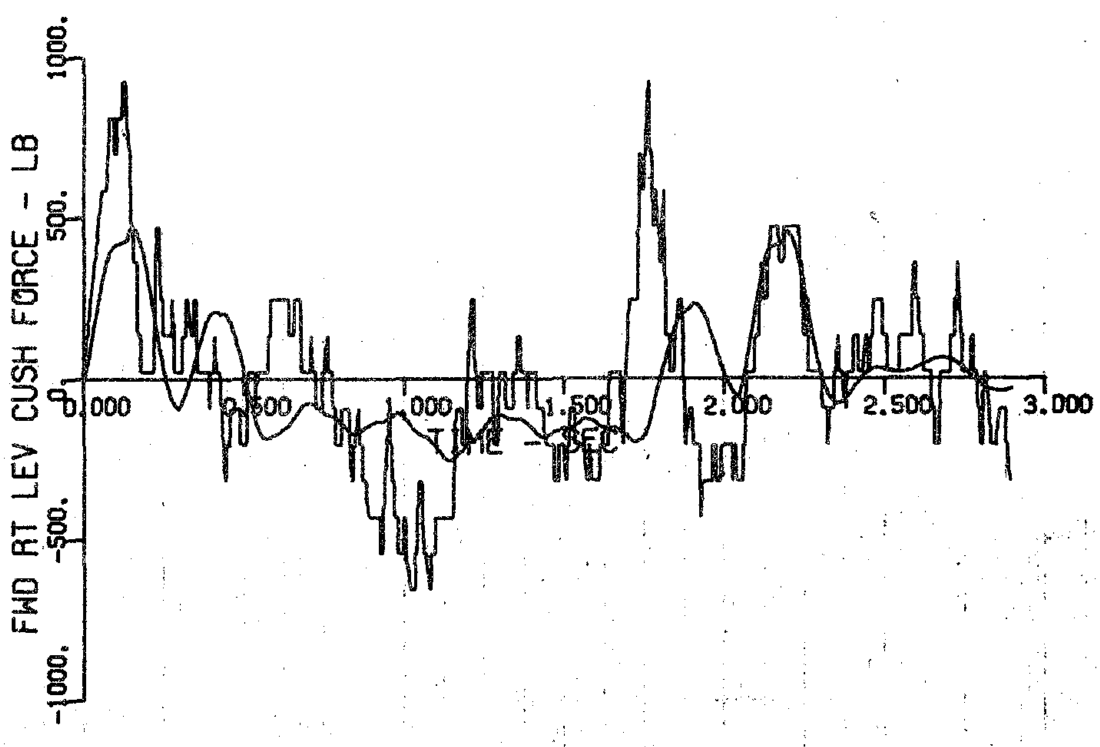
RUN 43 - 20 TL-104 13 07 17 56 MPH 3.0 IN X 150 FT PARABOLA



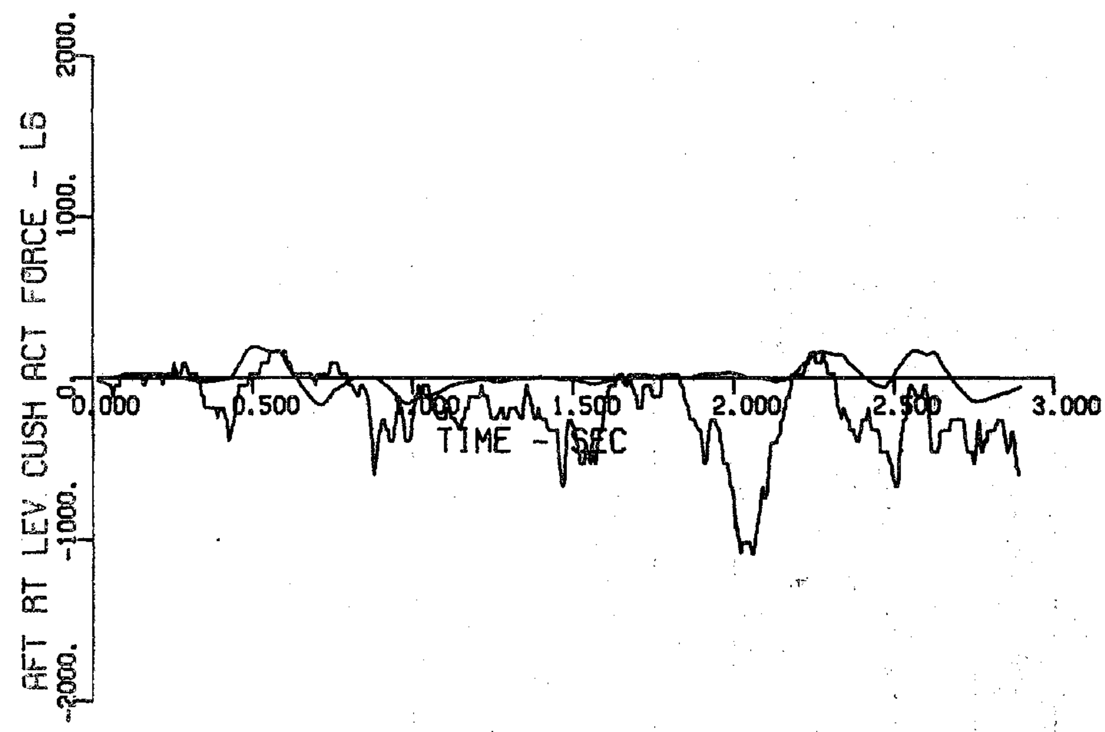


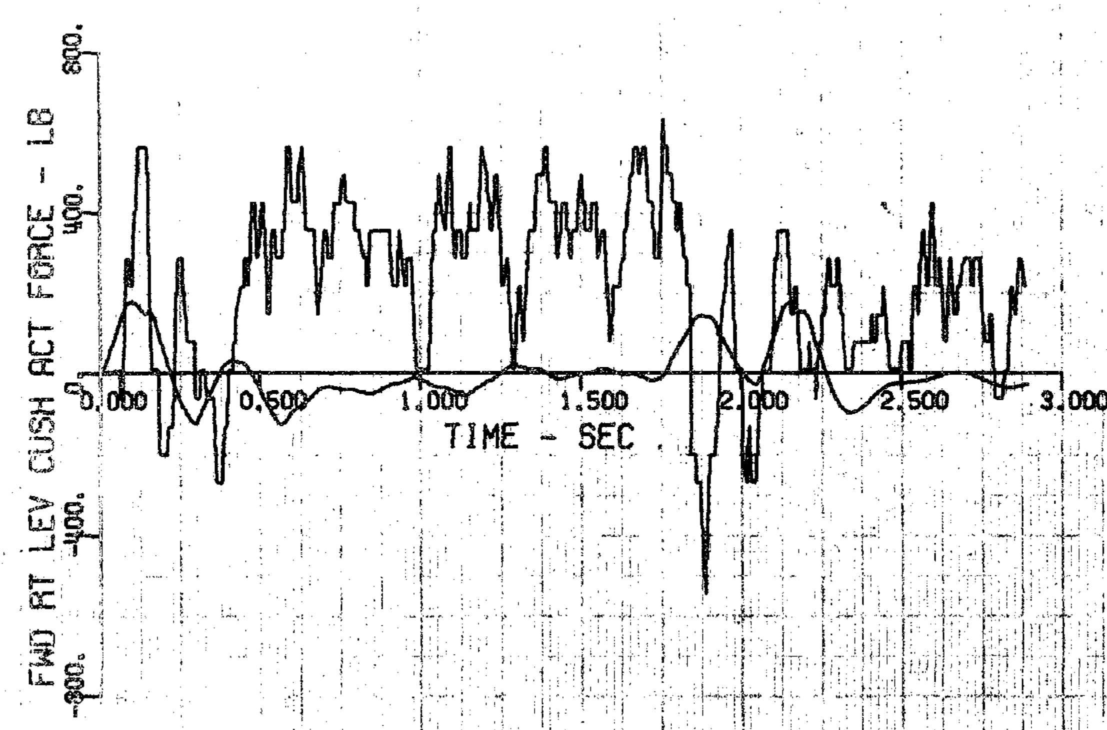
RUN 43 - 20 TL-104 13 07 17 56 MPH 3.0 IN X 150 FT PARABOLA



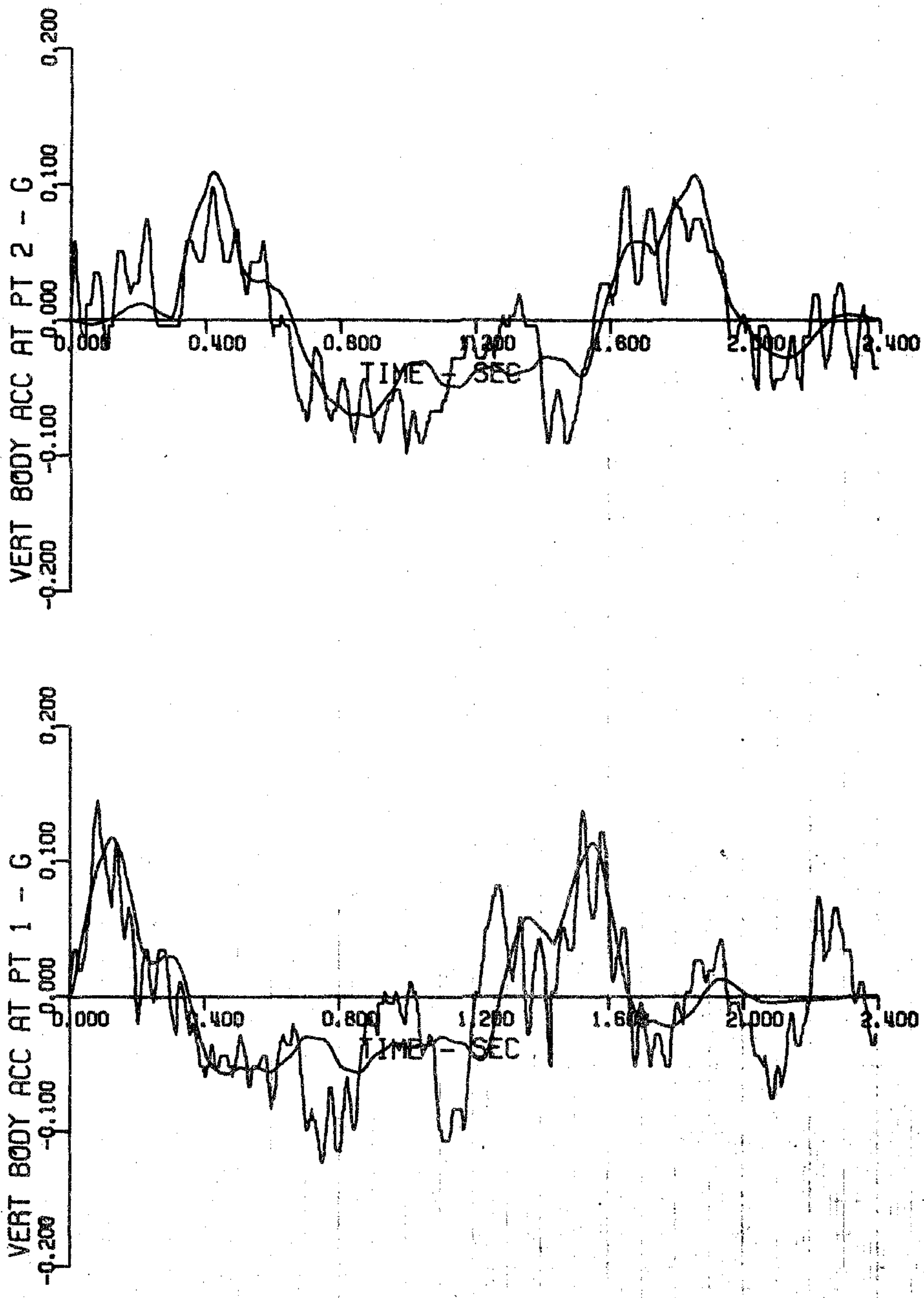


RUN 43- 20 TL-104 13 07 17 56 MPH 3.0 IN X 150 FT PARABOLA

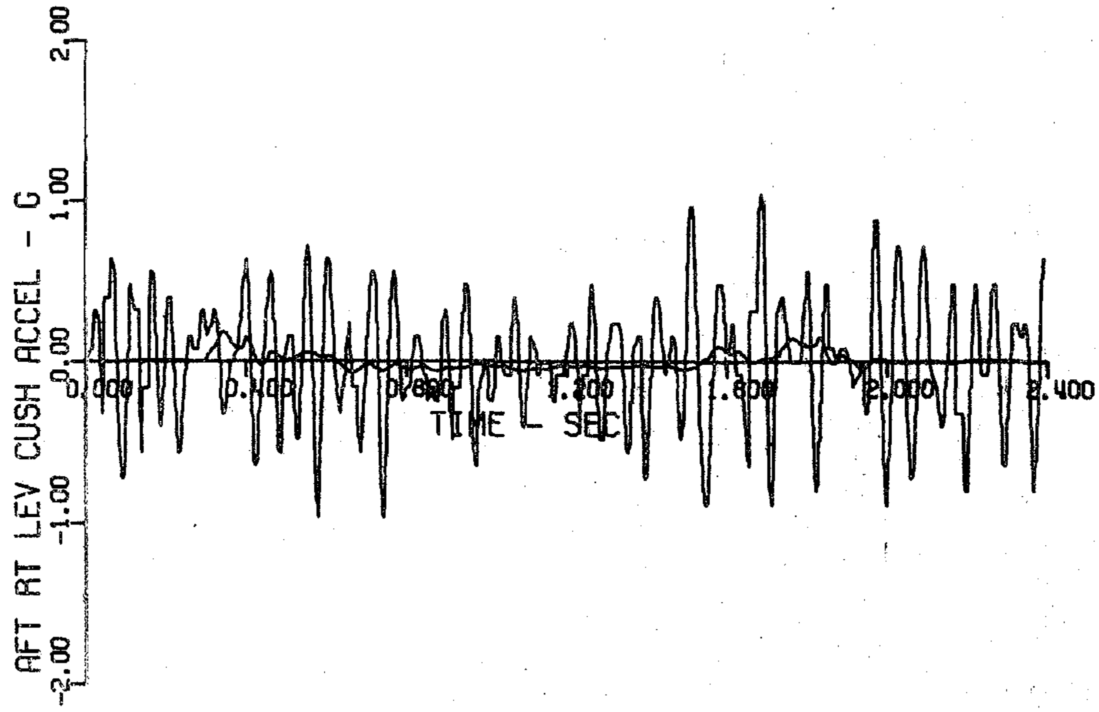


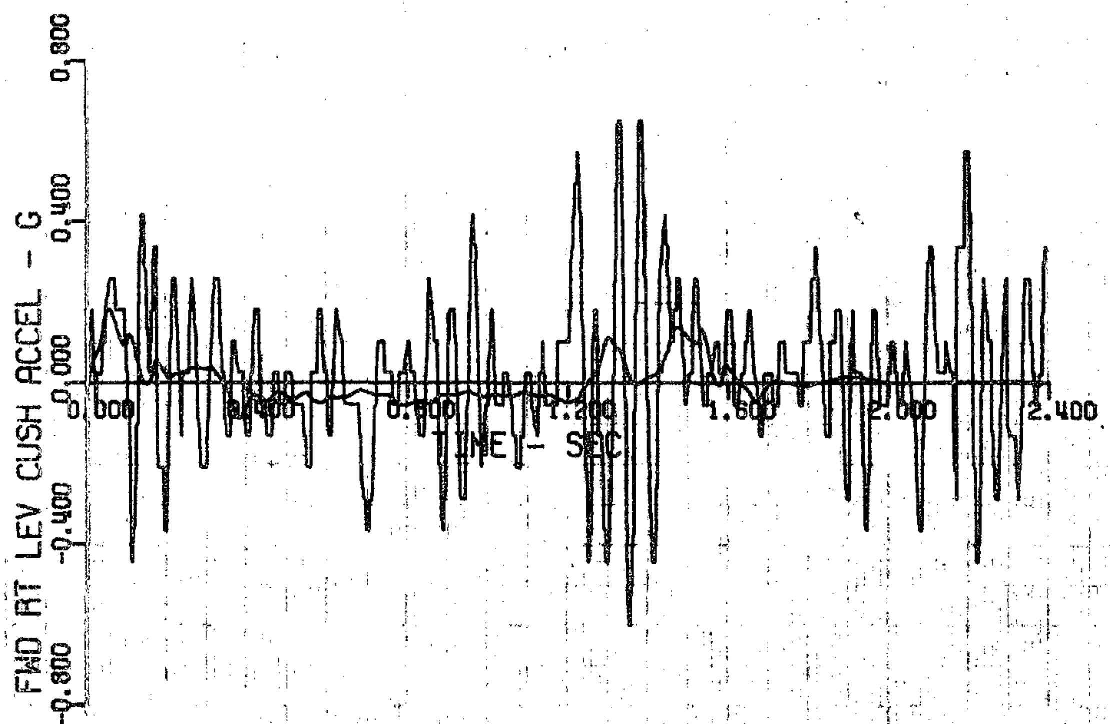


RUN 43 - 20 TL-104 13 07 17 56 MPH 3.0 IN X 150 FT PARABOLA

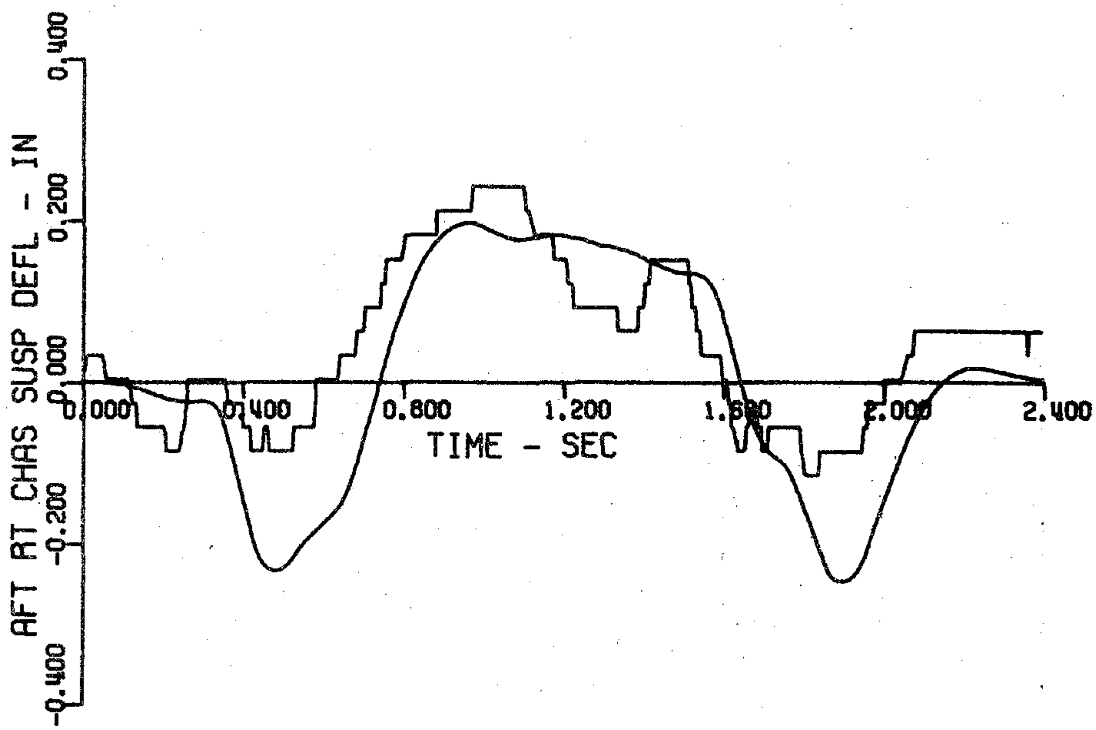


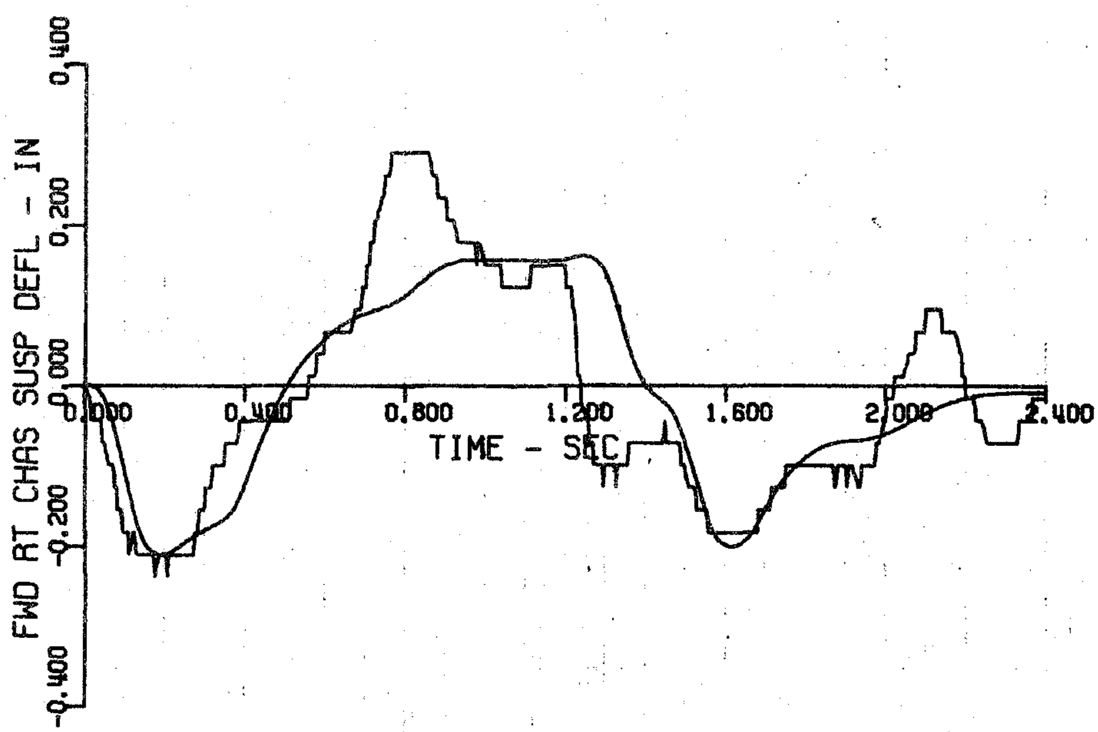
RUN 43- 22 TL-104 13 22 04 60 MPH 3.0 IN X 150 FT PARABOLA



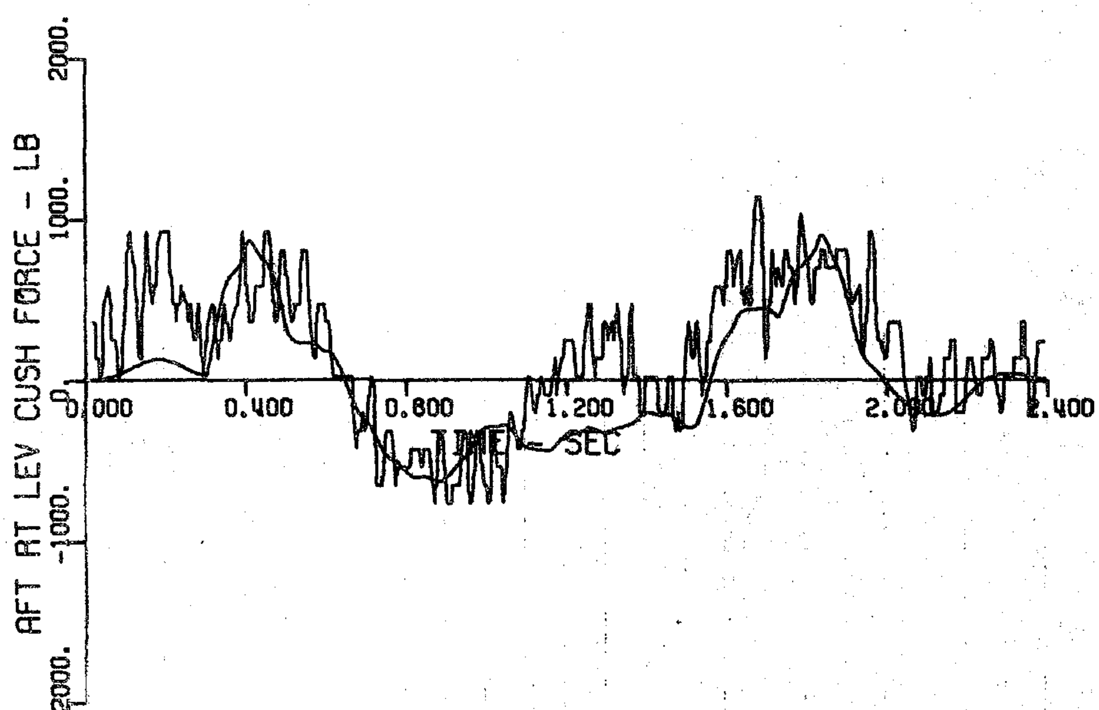


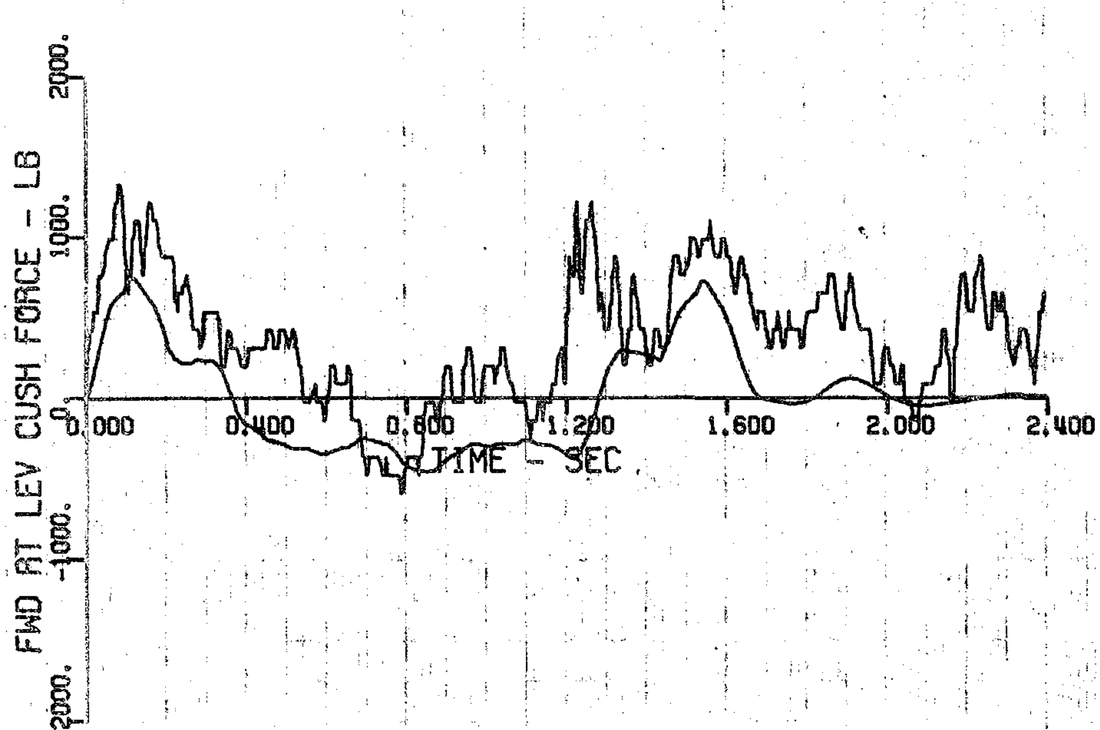
RUN 43 - 22 TL-104 13 22 04 80 MPH 3.0 IN X 150 FT PARABOLA



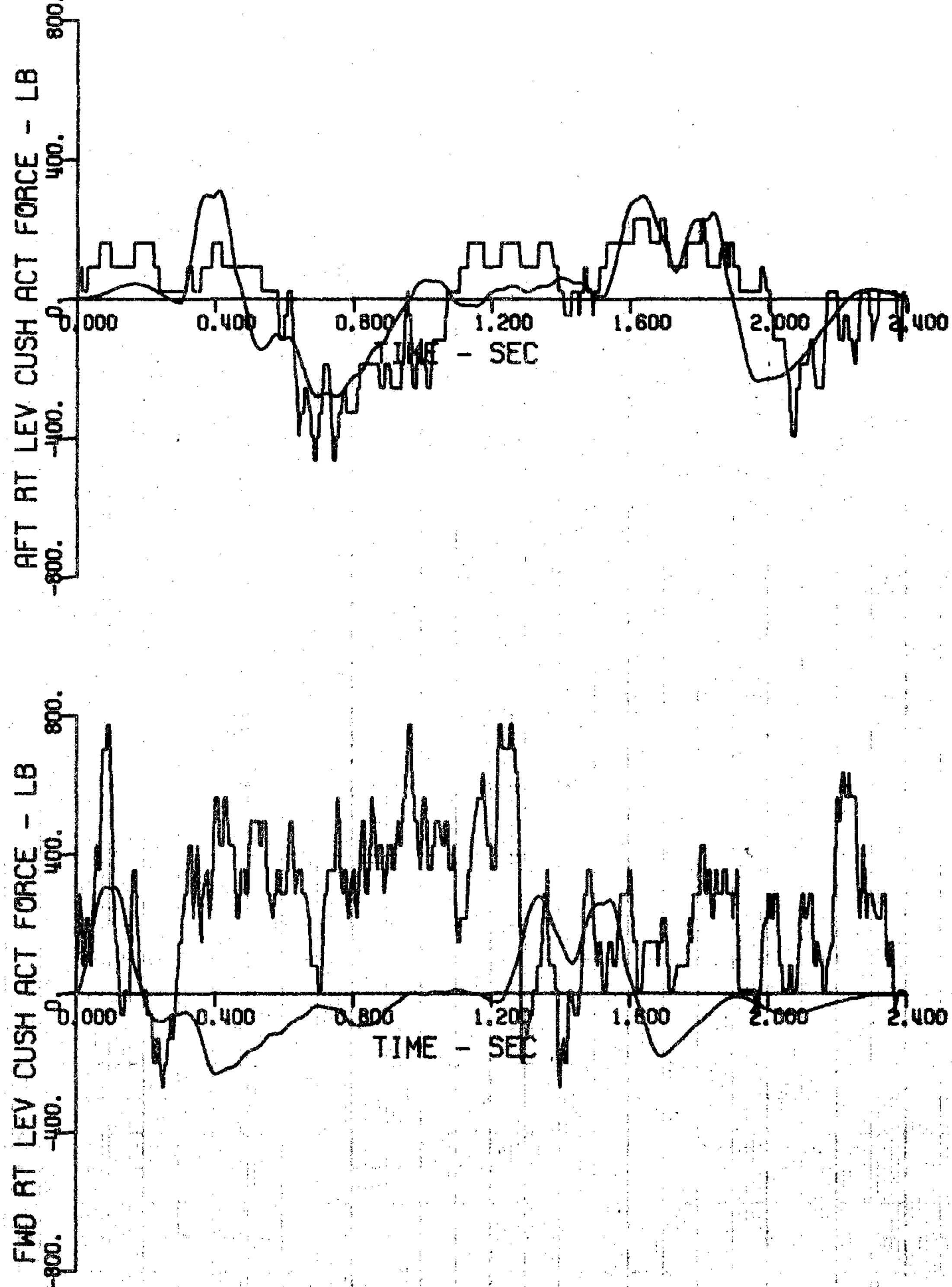


RUN 43 - 22 TL-104 13 22 04 80 MPH 3.0 IN X 150 FT PARABOLA





RUN 43 - 22 TL-104 13 22 04 80 MPH 3.0 IN X 150 FT PARABOLA



RUN 43 - 22 TL-104 13 22 04 80 MPH 3.0 IN X 150 FT.PARABOLA

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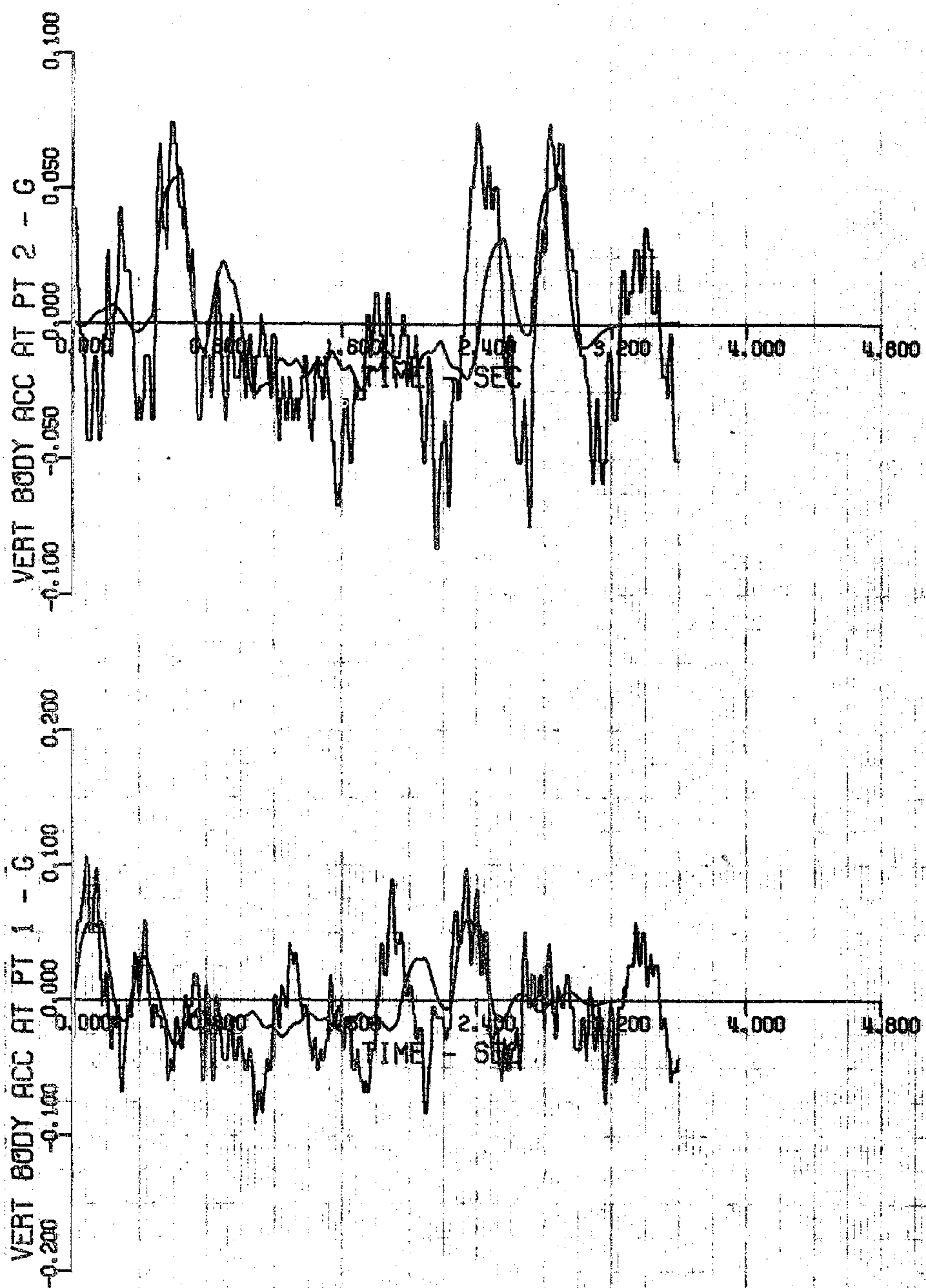
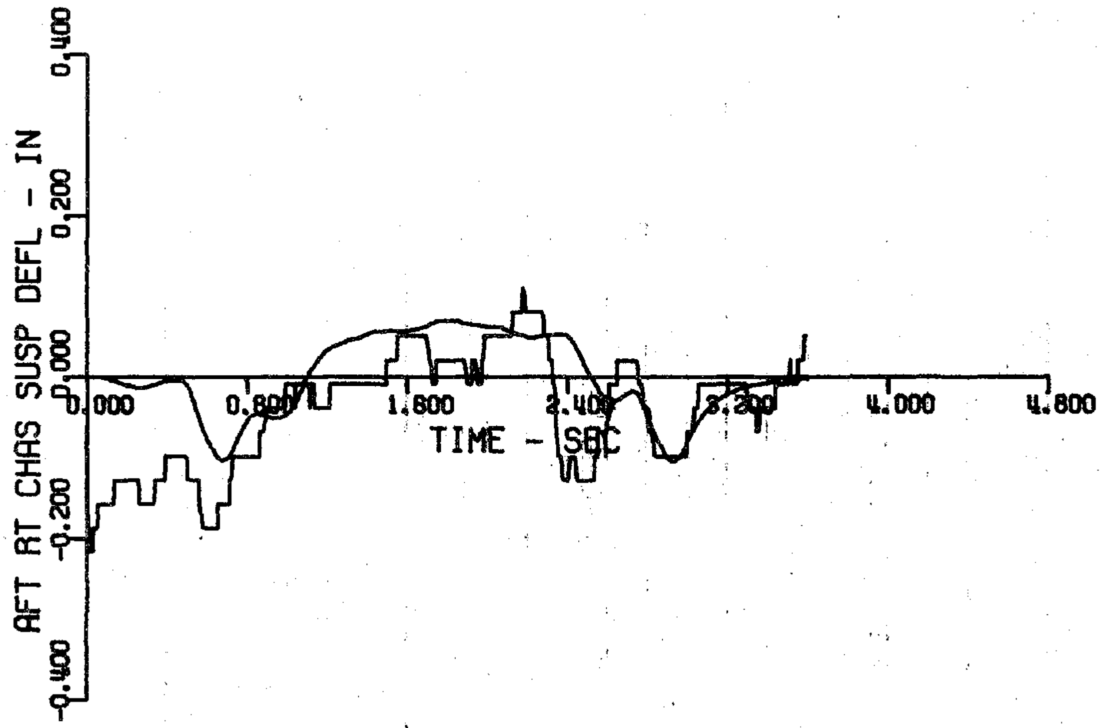
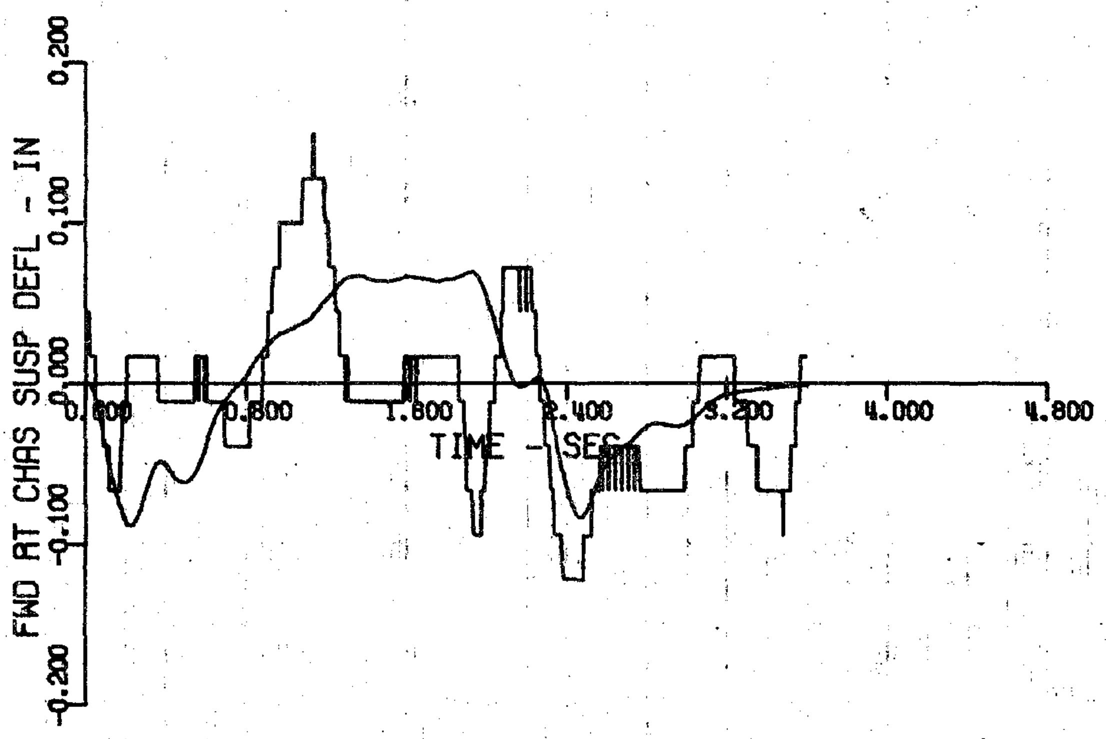
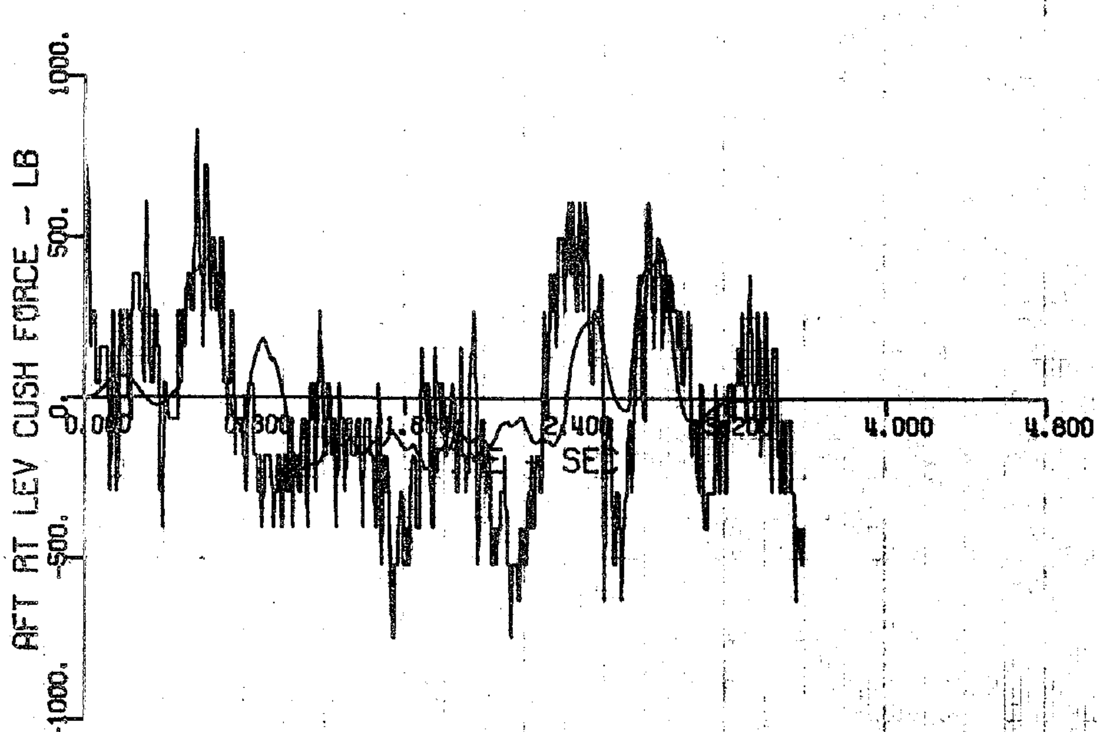


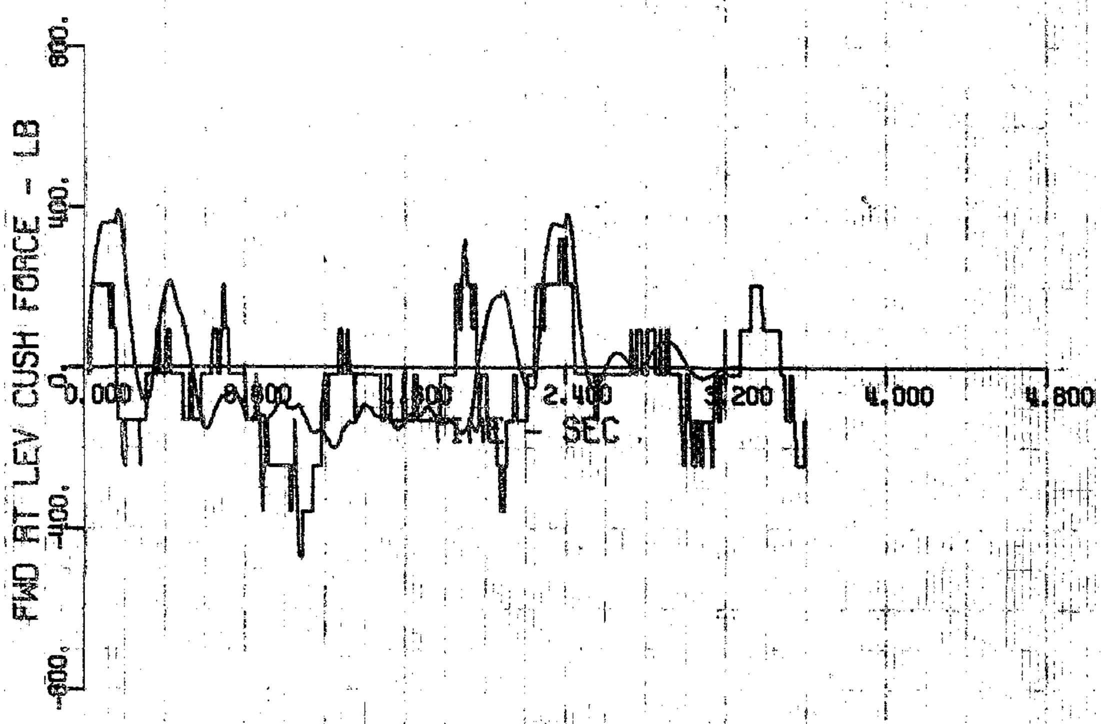
RUN 43 - 24 TL-104 13 34 32 51 MPH 3.0 IN X 150 FT PARABOLA



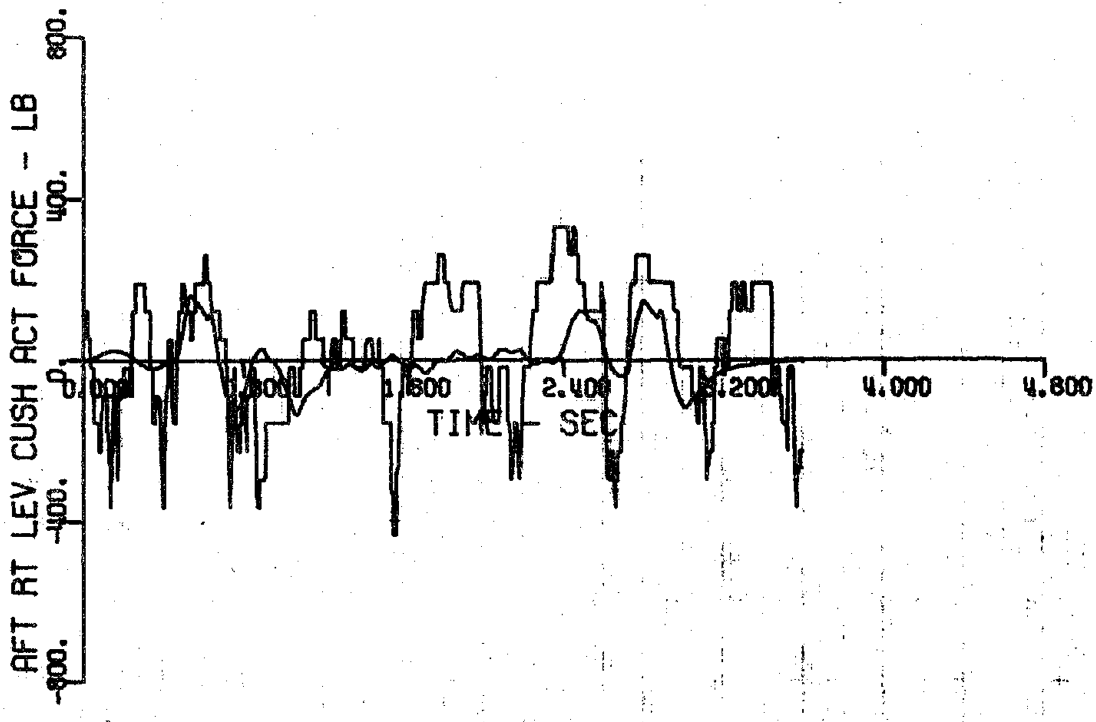


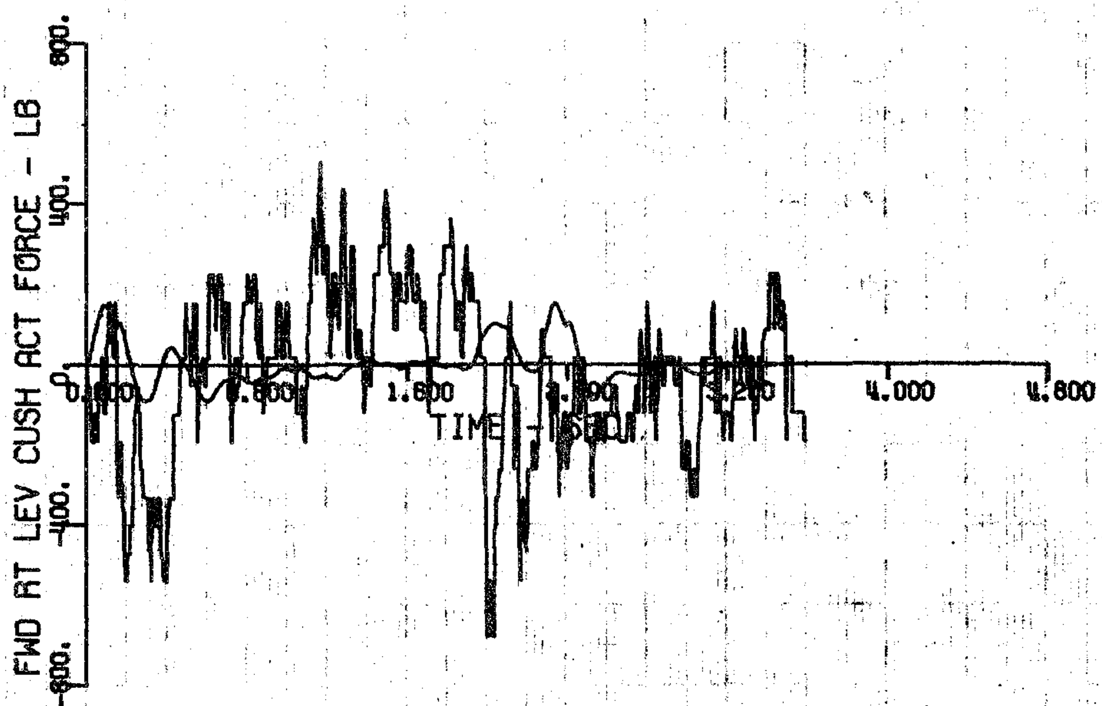
RUN 43 - 24 TL-104 13 34 32 51 MPH 3.0 IN X 150 FT PARABOLA





RUN 43 - 24 TL-104 13 34 32 51 MPH 3.0 IN X 150 FT PARABOLA





RUN 43 - 24 TL-104 13 34 32 51 MPH 3.0 IN X 150 FT PARABOLA

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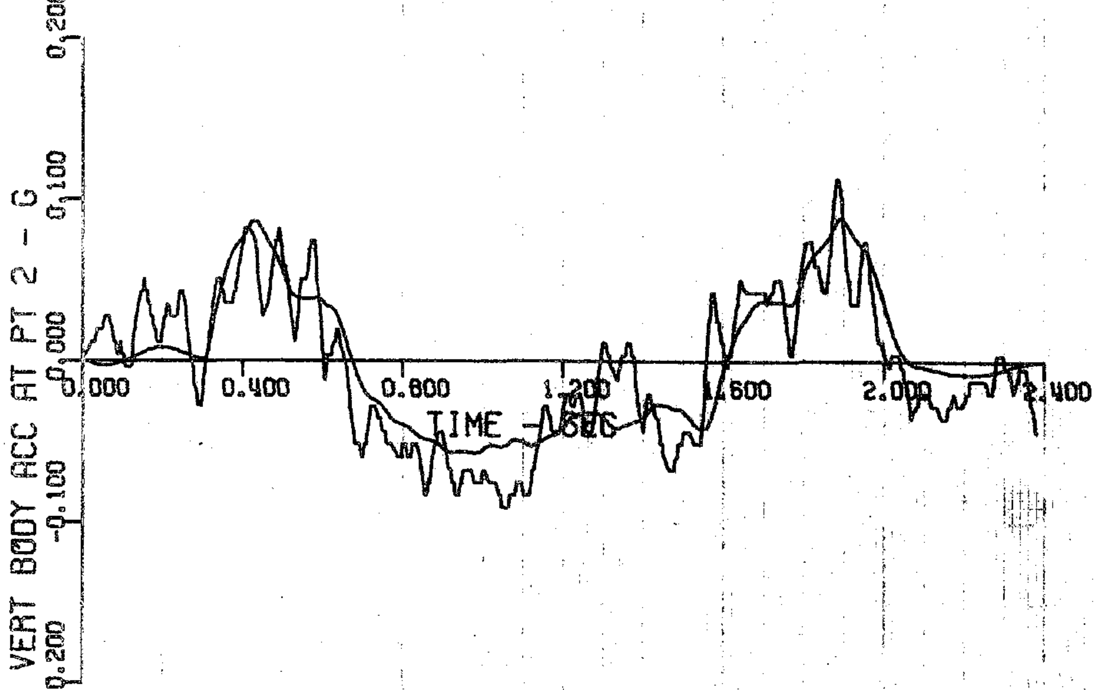
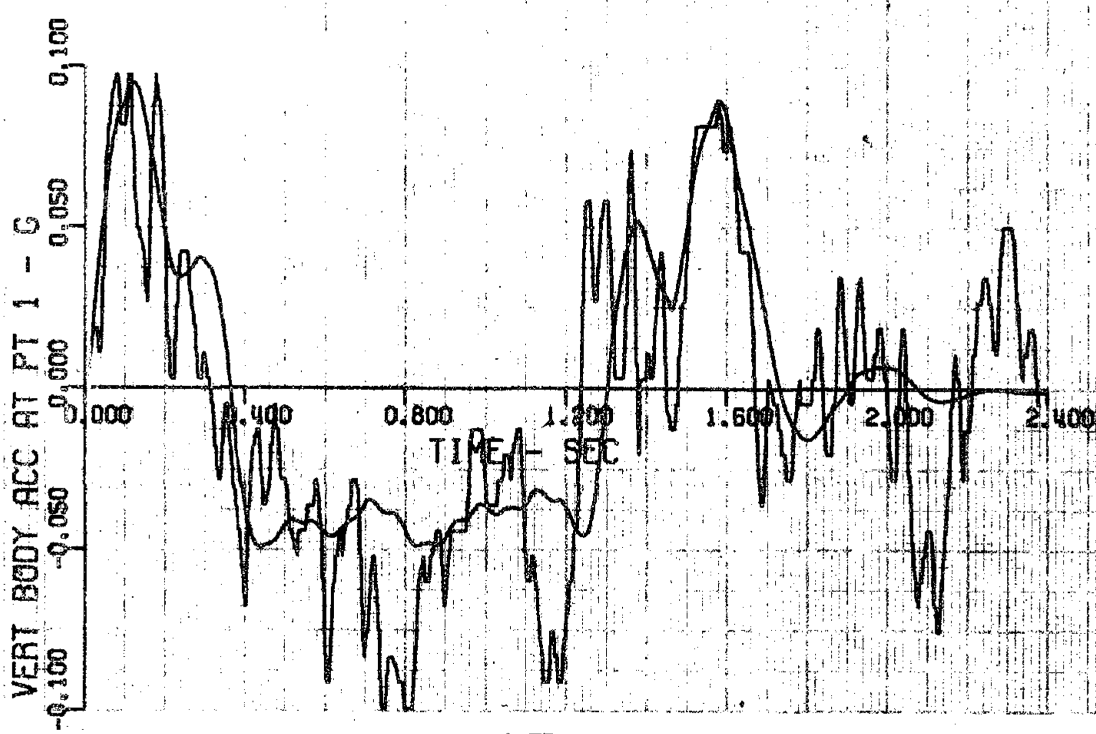
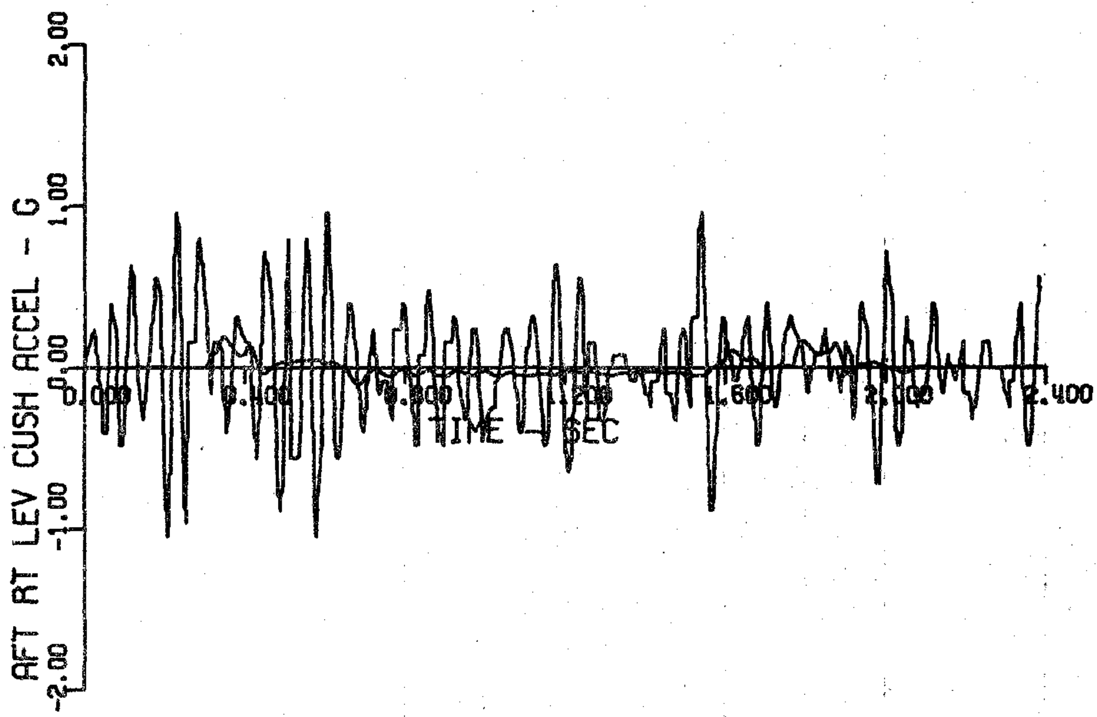
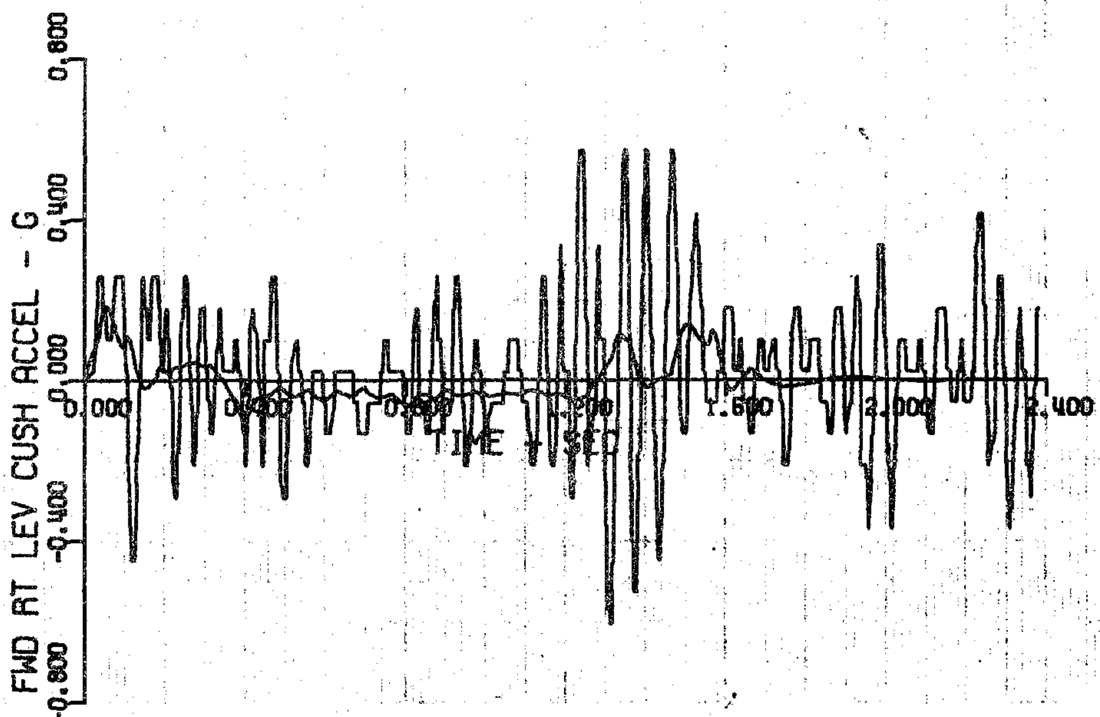


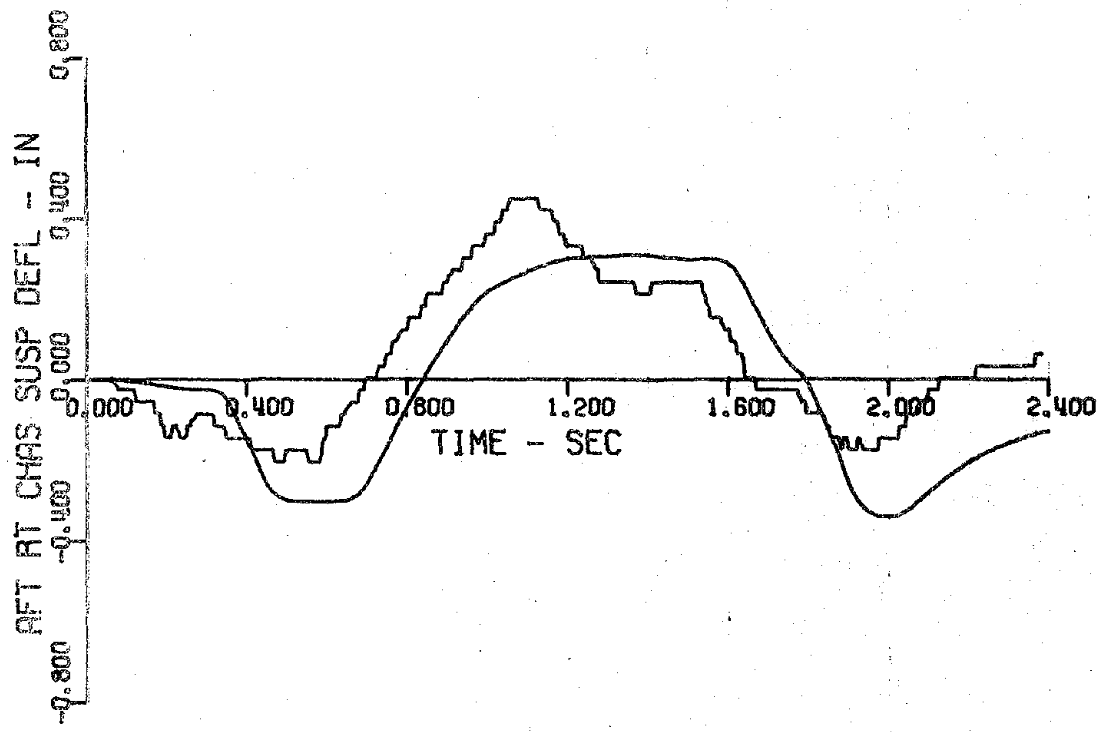


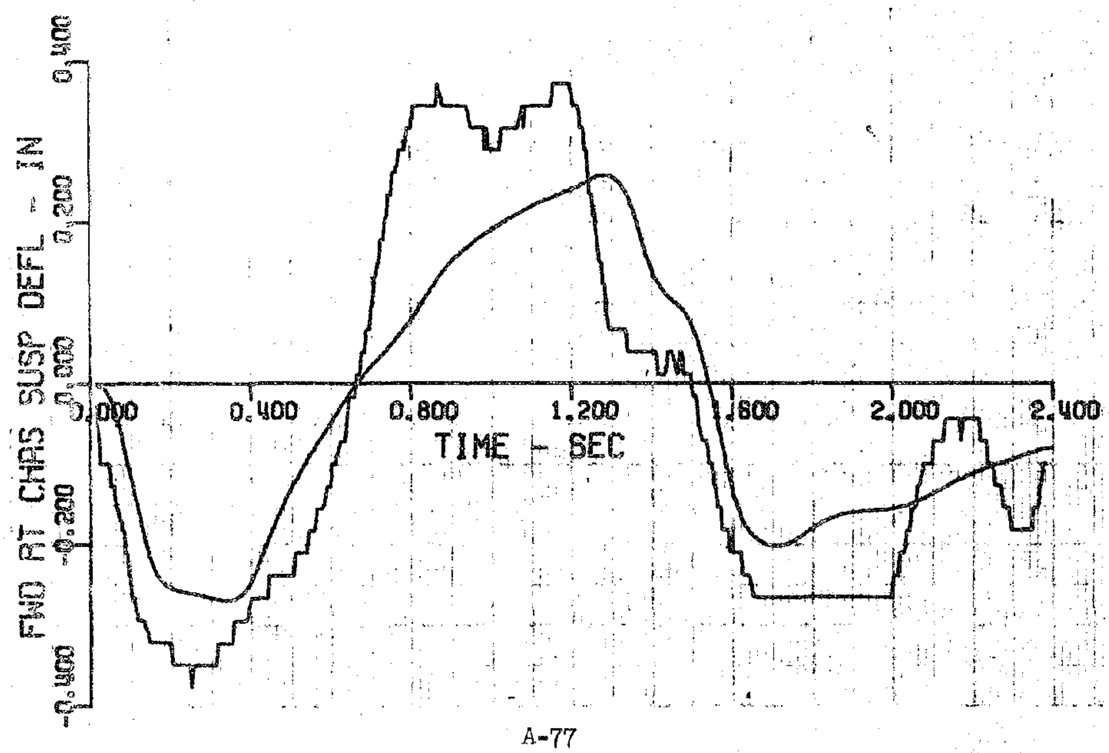
RUN 43 - 26 TL-104 14 27 07 78 MPH 3.0 IN X 150 FT PARABOLA



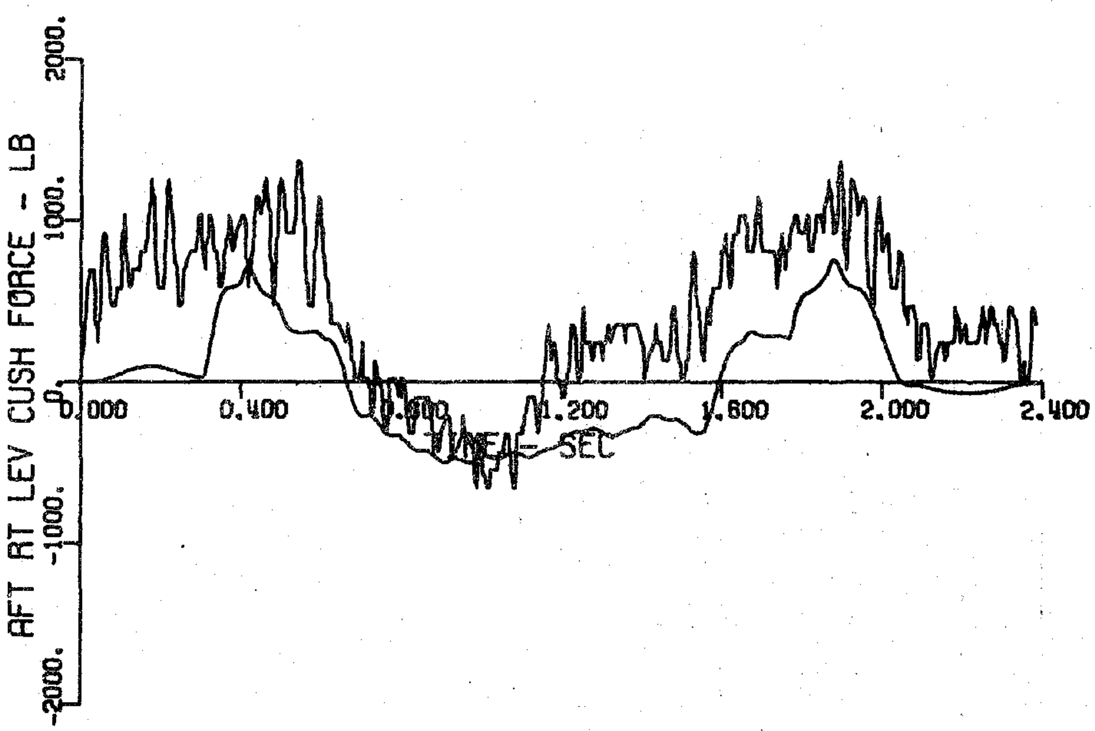


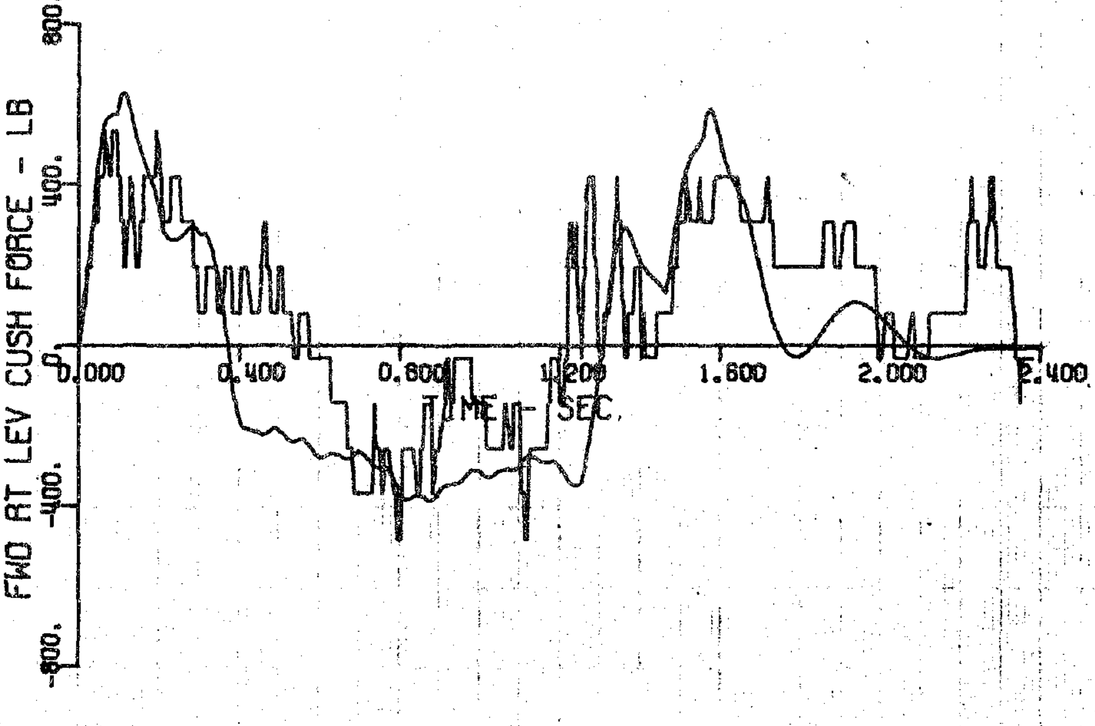
RUN 43 - 26 TL-104 14 27 07 78 MPH 3.0 IN X 150 FT PARABOLA



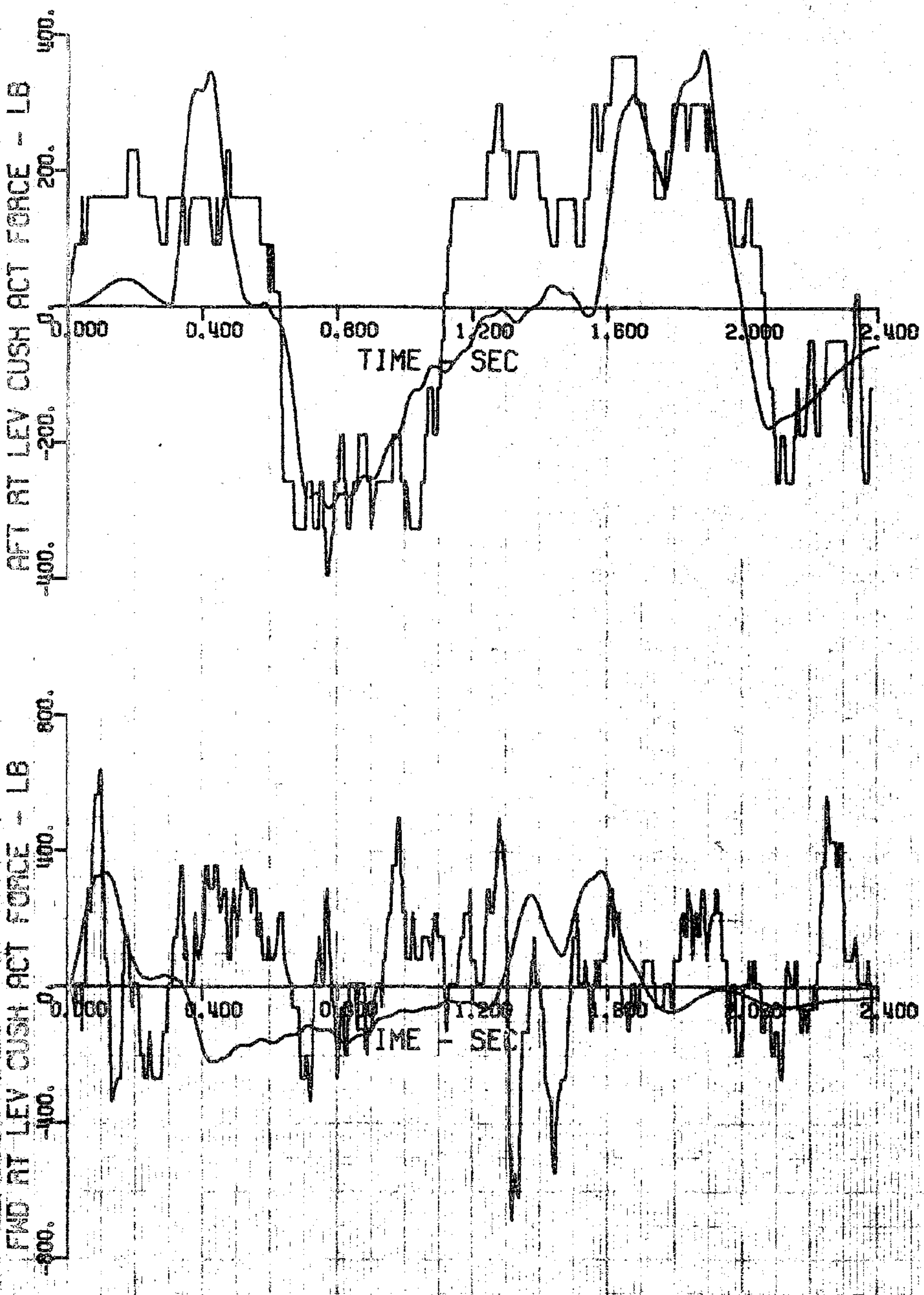


RUN 43 - 26 TL-104 14 27 07 78 MPH 3.0 IN X 150 FT PARABOLA

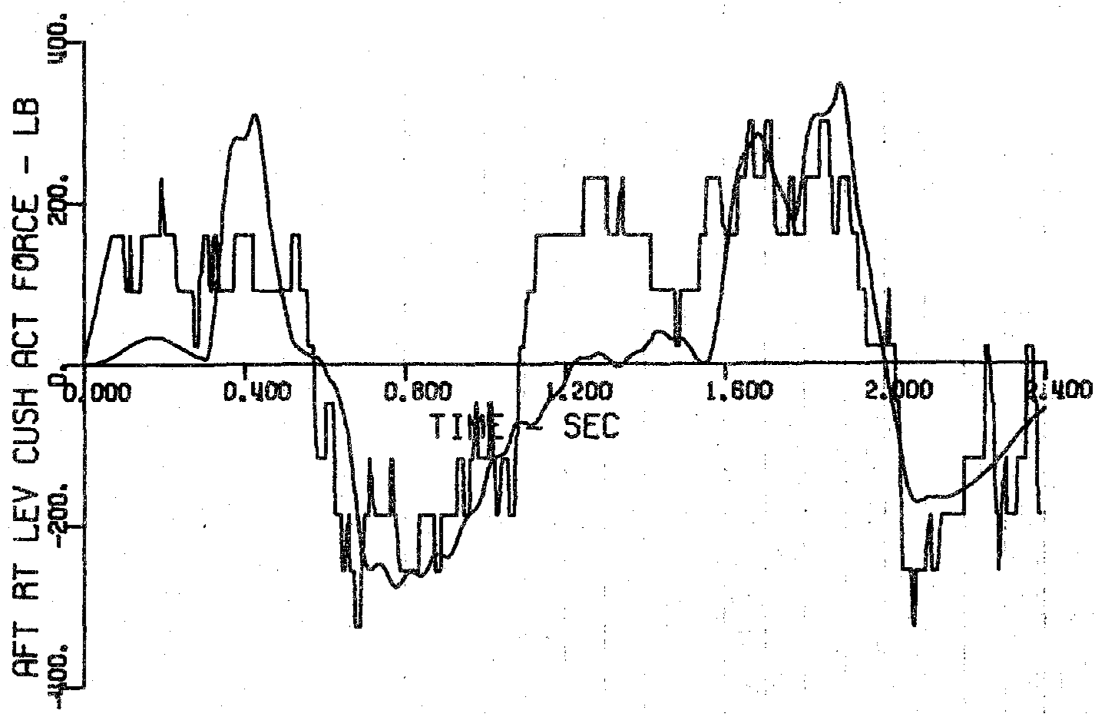


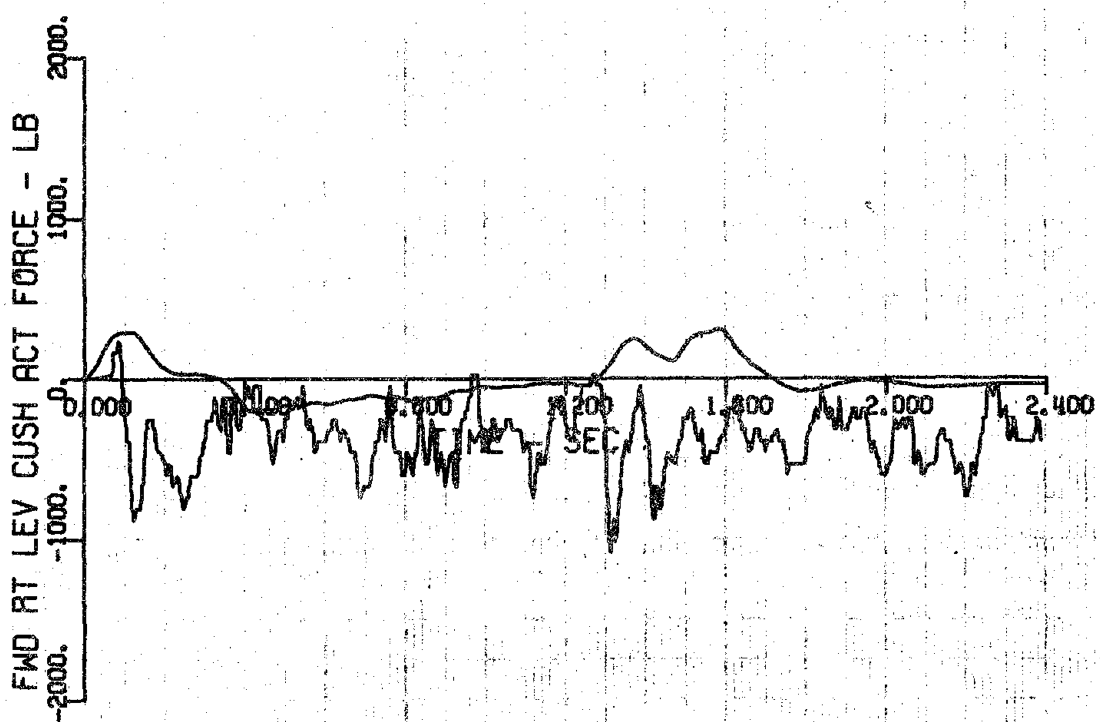


RUN 43 - 26 TL-104 14 27 07 78 MPH 3.0 IN X 150 FT PARABOLA

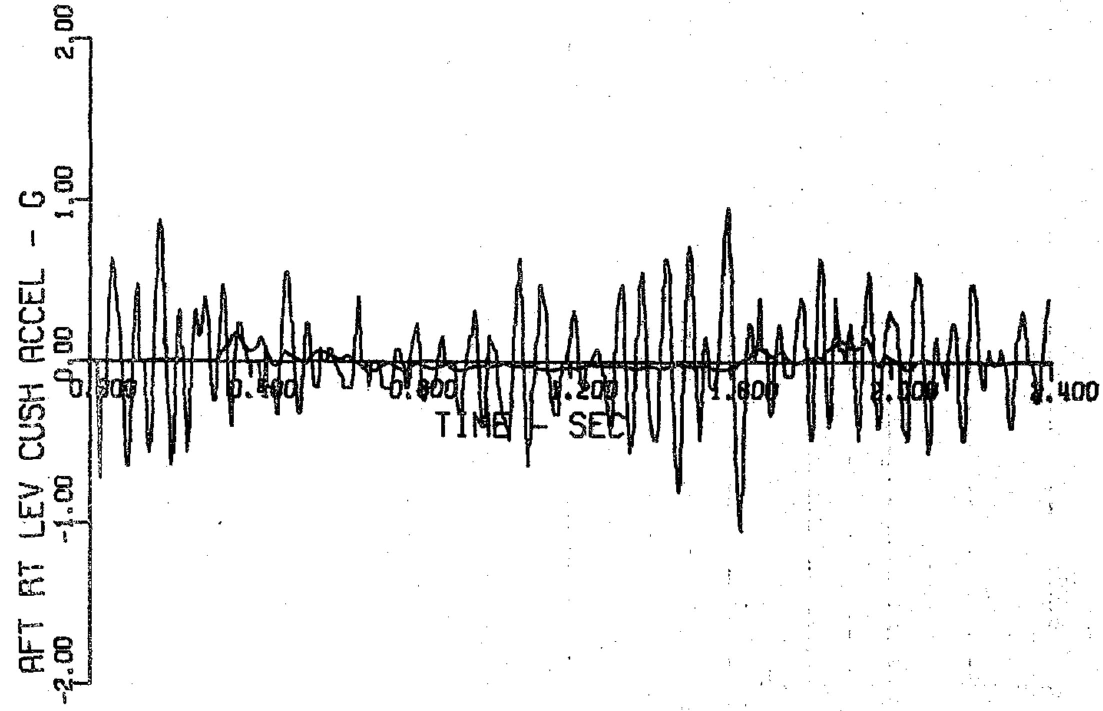


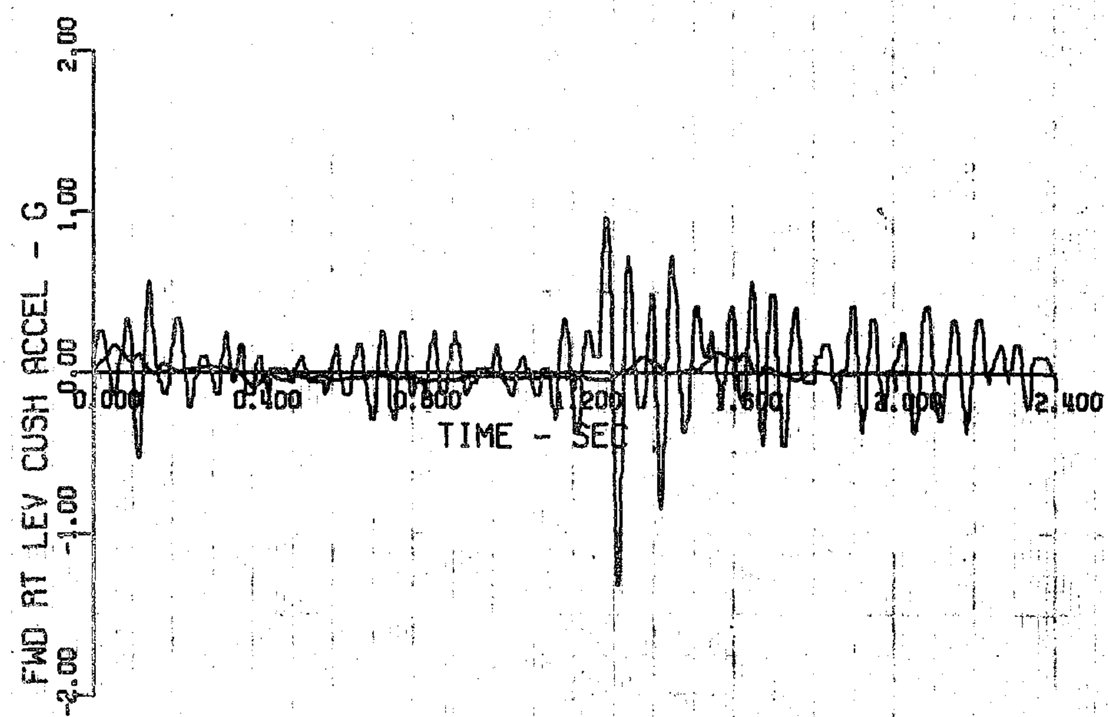
RUN 43- 26 TL-104 1W 27 07 78 MPH 3.0 IN X 150 FT PARABOLA



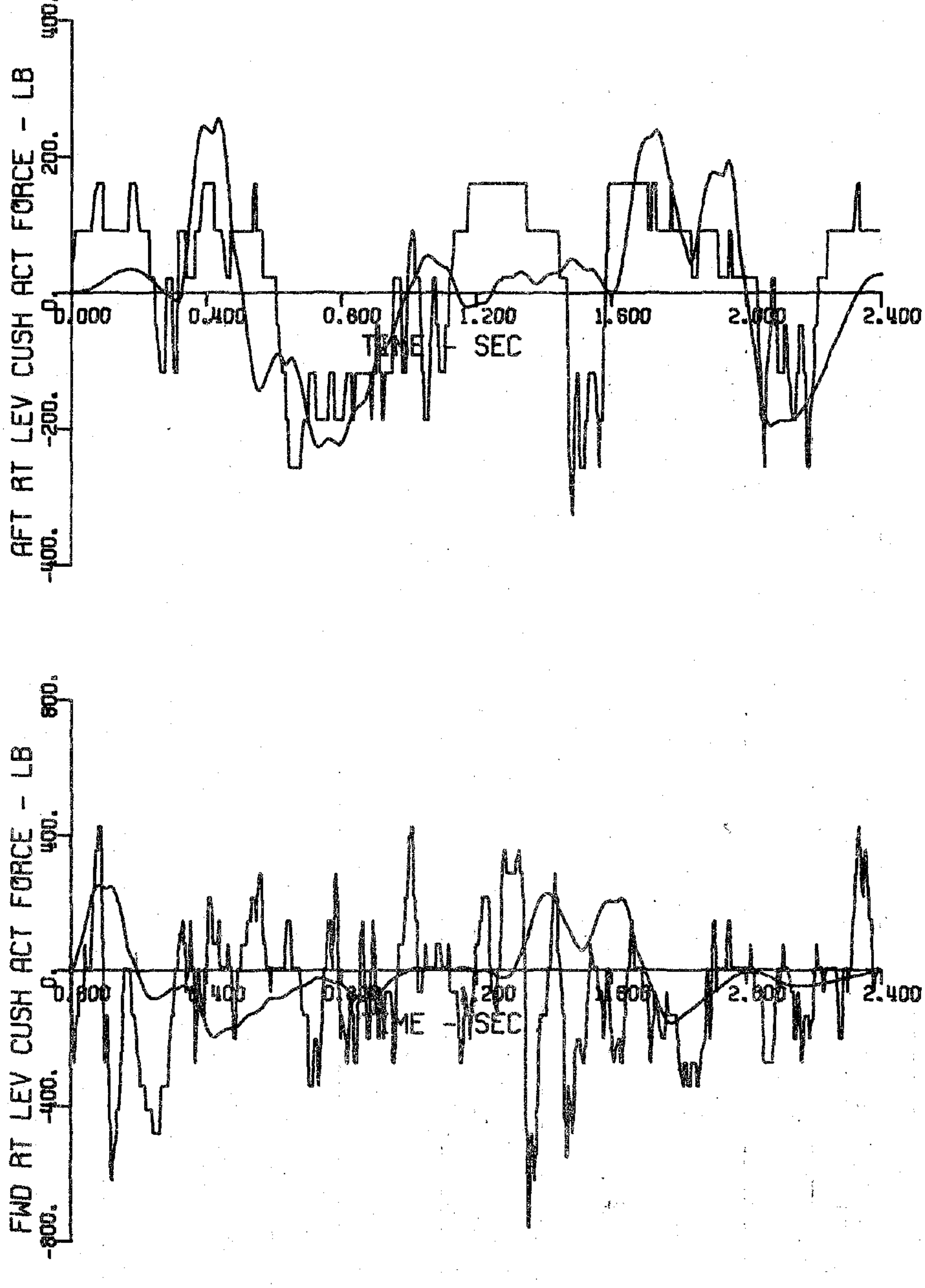


RUN 43 - -30 TL-104 15 02 13 78 MPH 3.0 IN X 150 FT PARABOLA

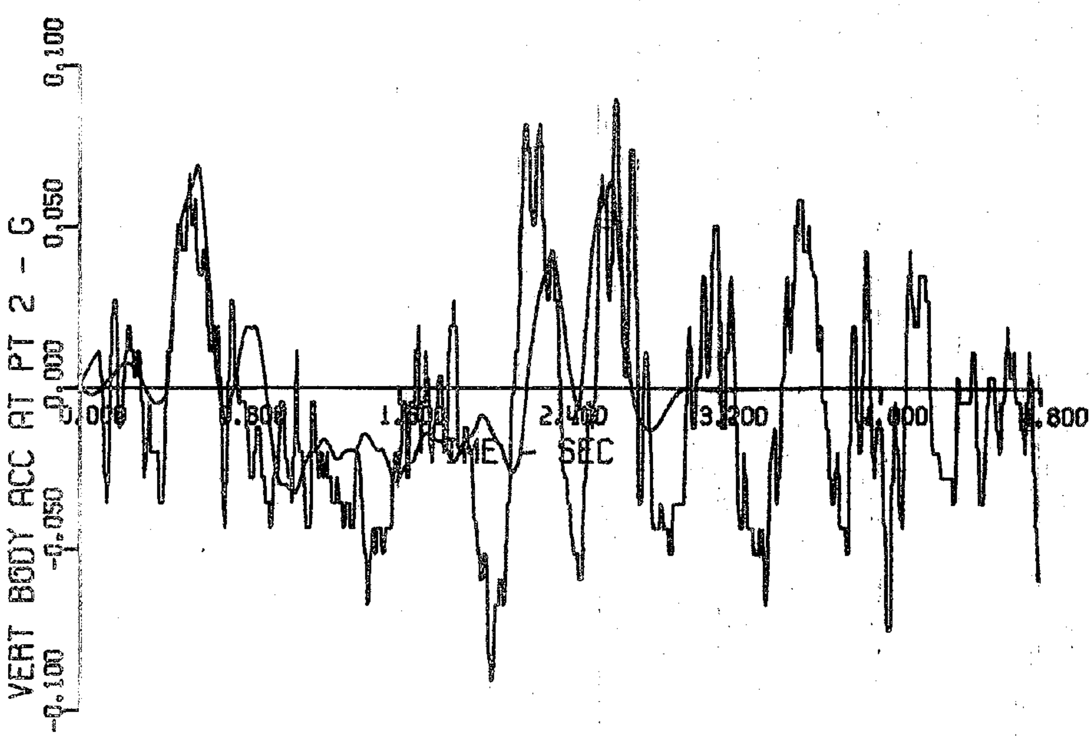


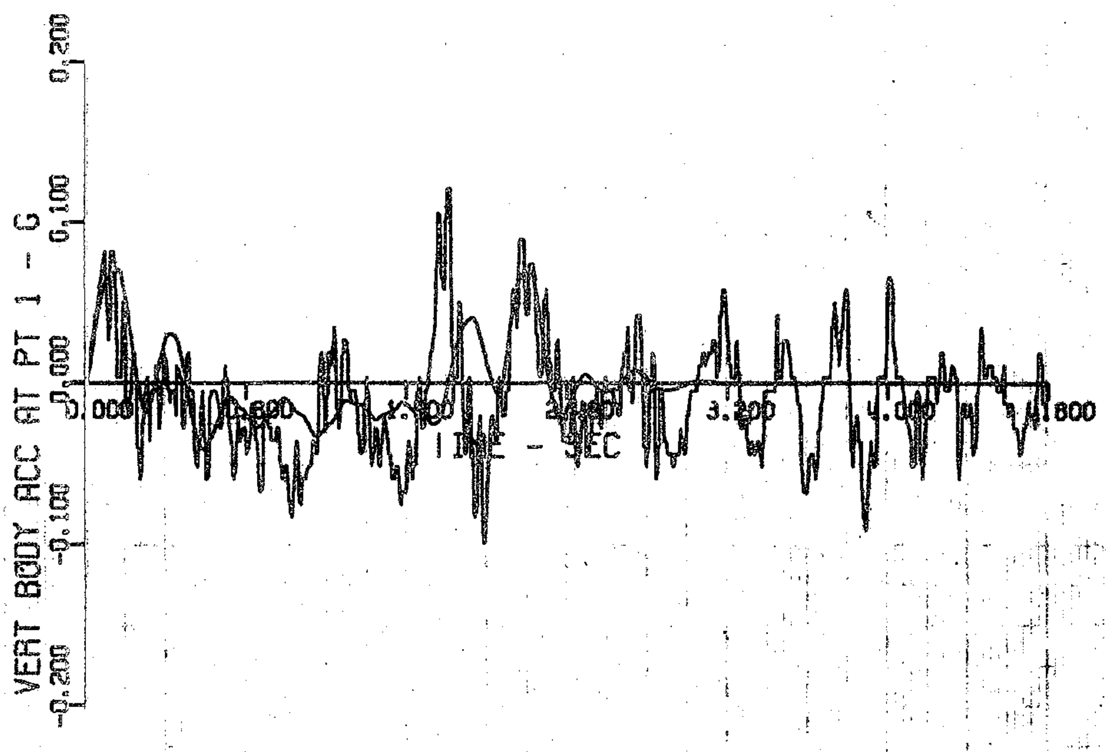


RUN 43 - 28 TL-104 16 02 04 78 MPH 3.0 IN X 150 FT PARABOLA

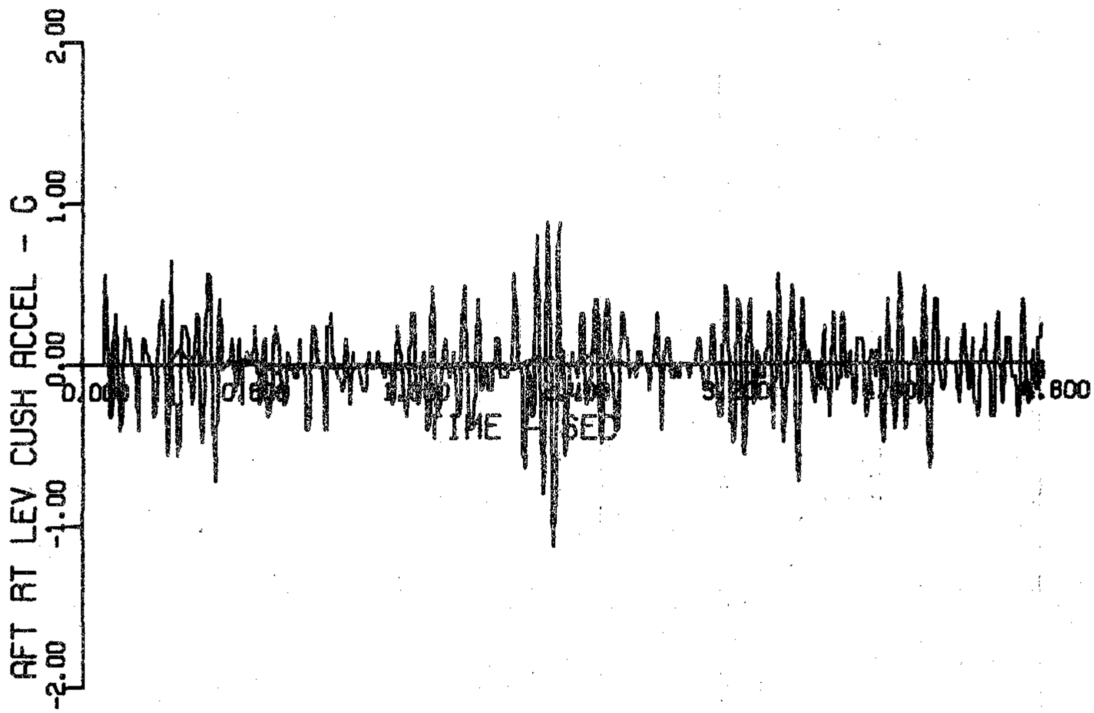


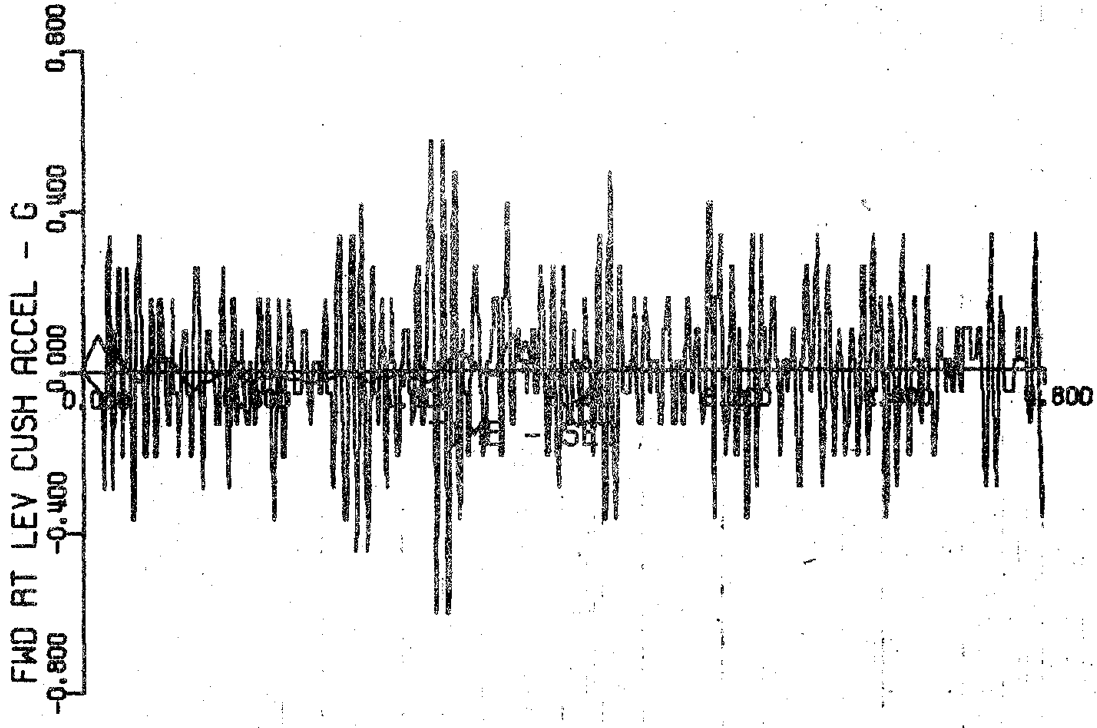
RUN 43 - 28 TL-104 16 02 04 76 MPH 3.0 IN X 150 FT PARABOLA



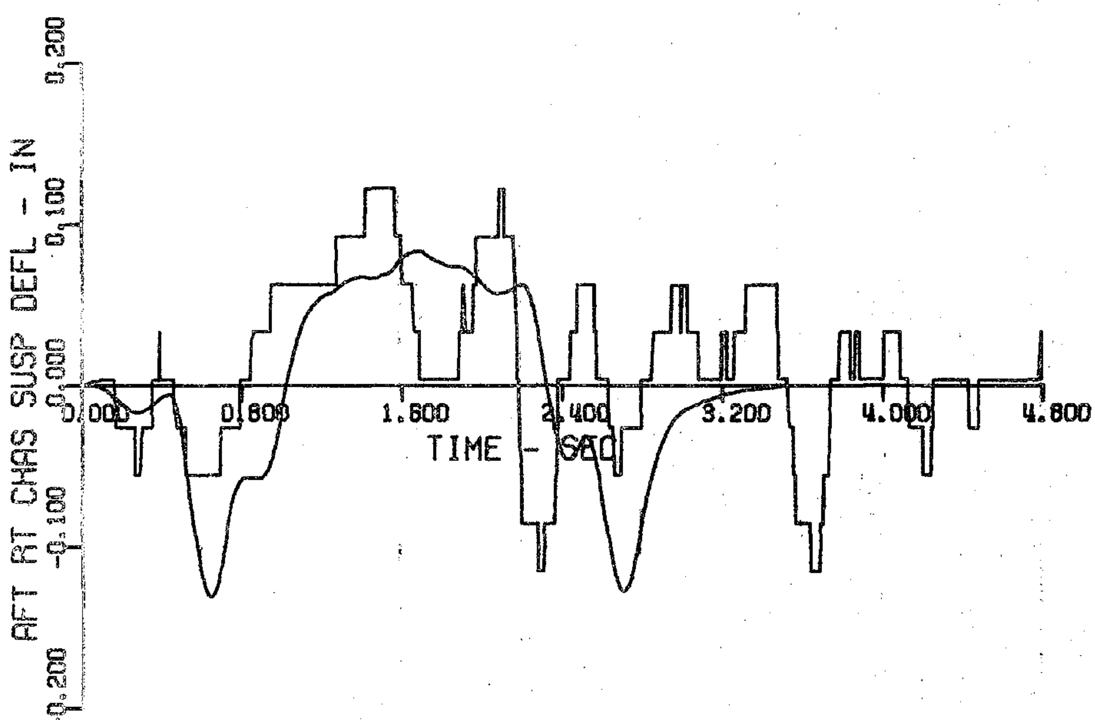


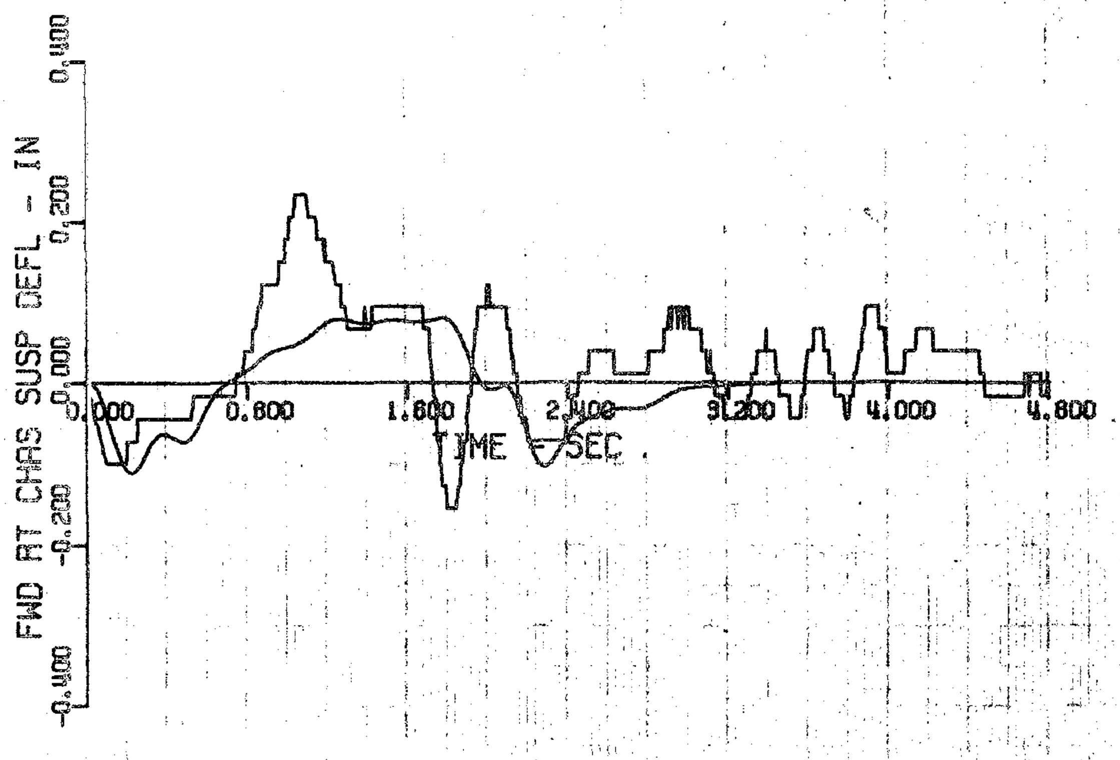
RUN 43-1 22A TL-105 13 04 44 55 MPH 3.0 IN X 150 FT PARABOLA



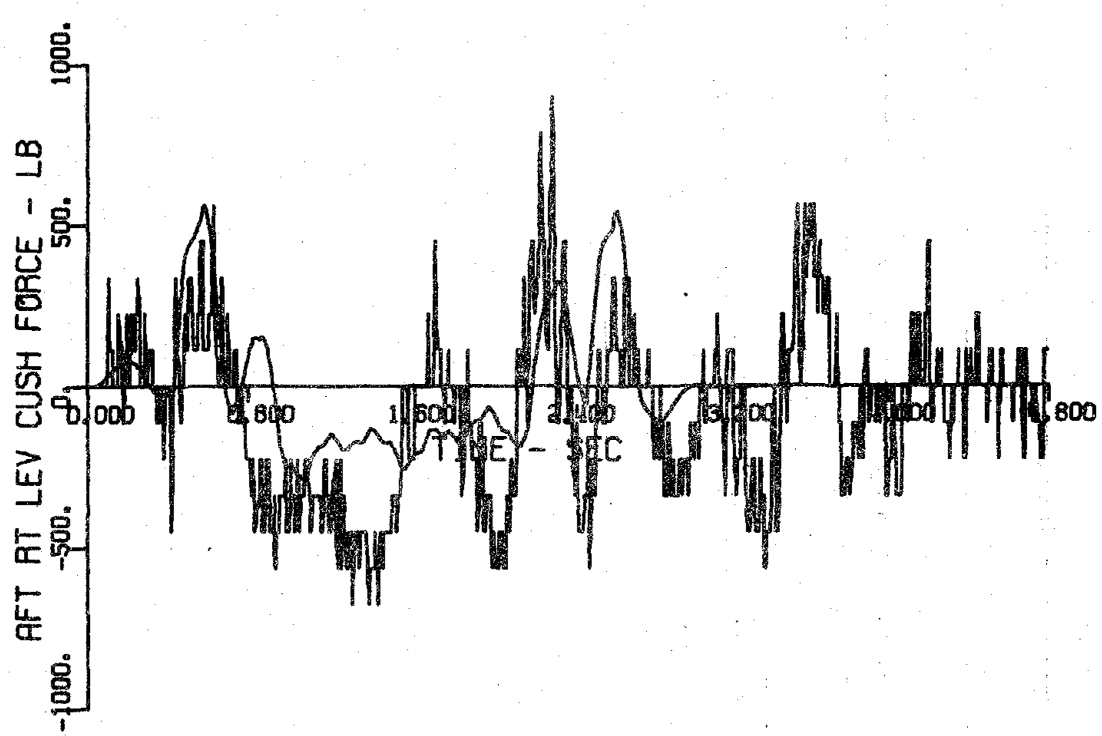


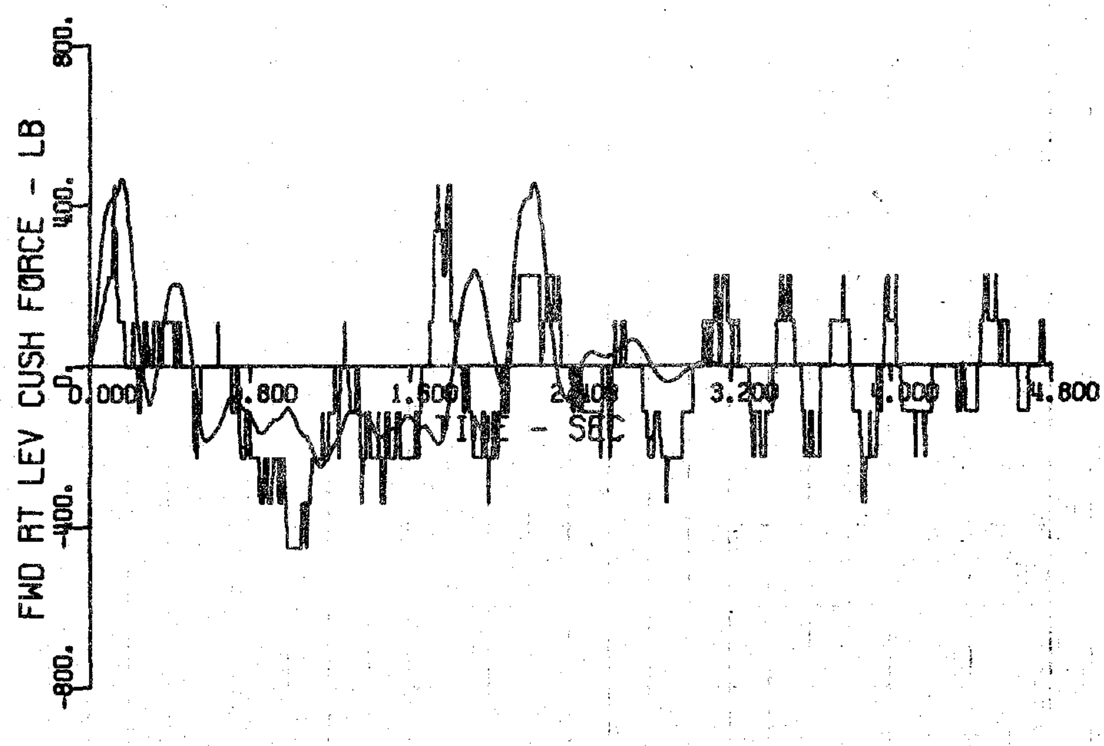
RUN 43 - 22A TL-105 13 04 44 55 MPH 3.0 IN X 150 FT PARABOLA



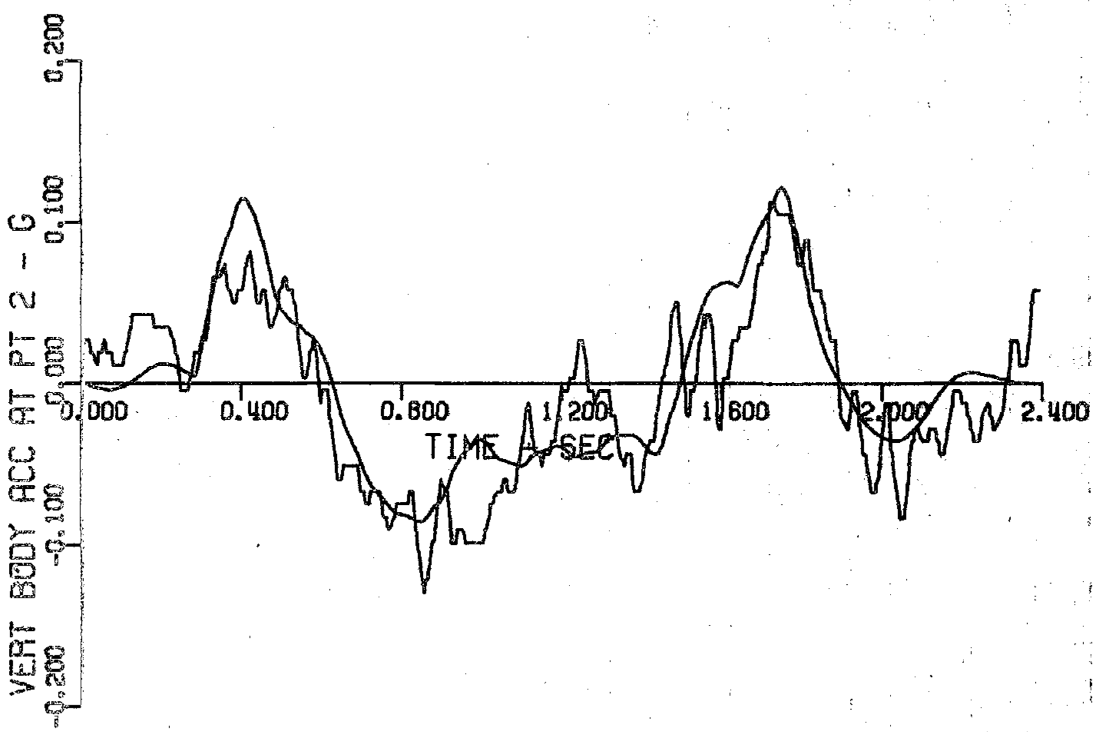


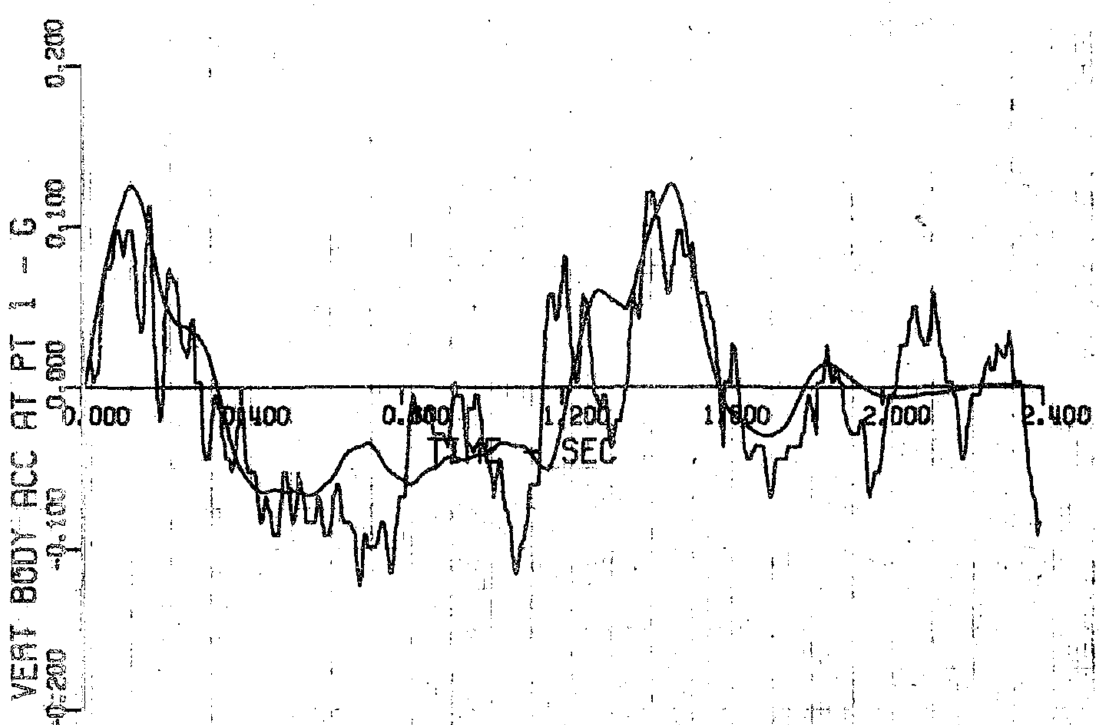
RUN 43 - 22A TL-105 13 OH WA 55 MPH 3.0 IN X 150 FT PARABOLA



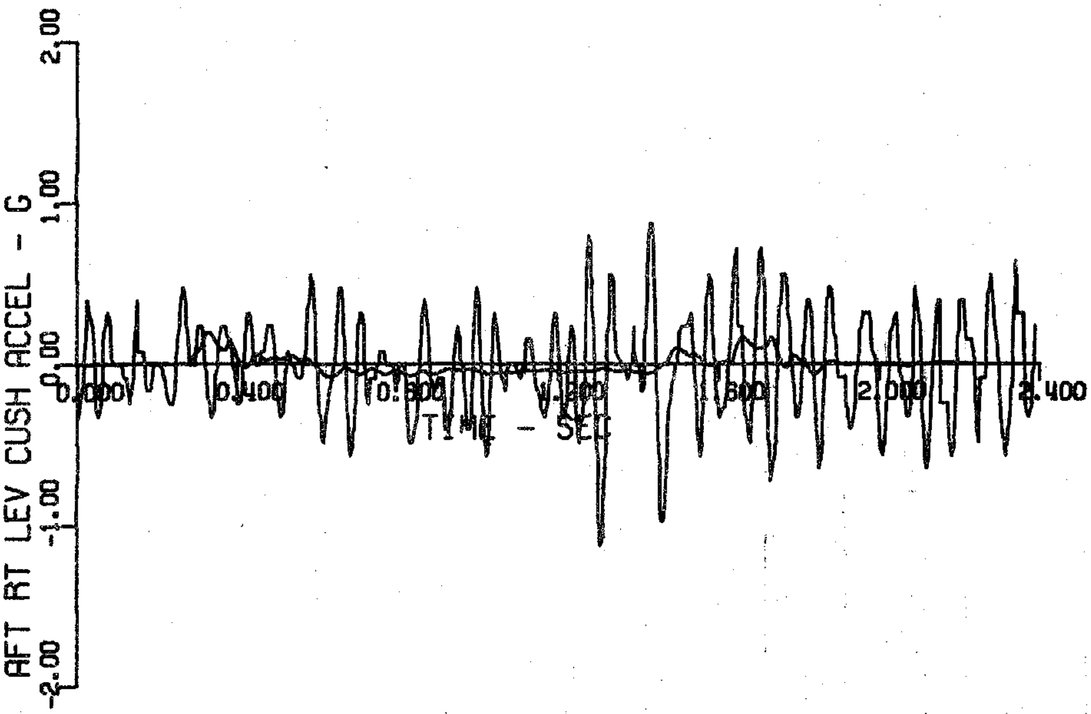


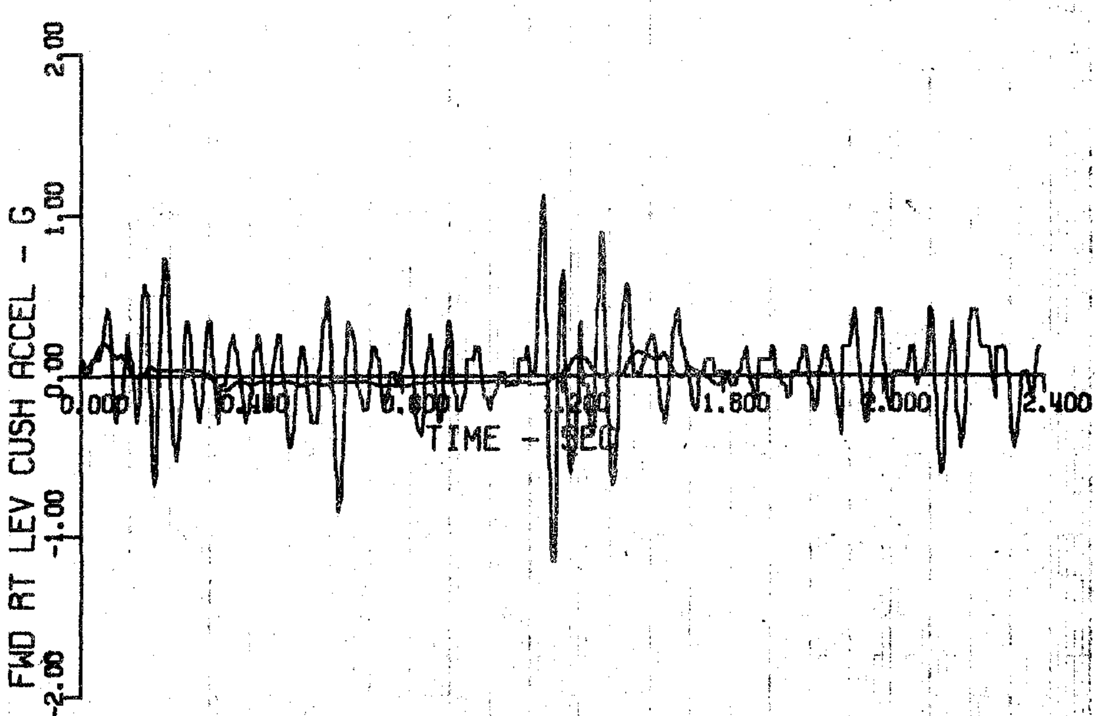
RUN 43 - 22A TL-105 13 OW 44 55 MPH 3.0 IN X 150 FT PARABOLA



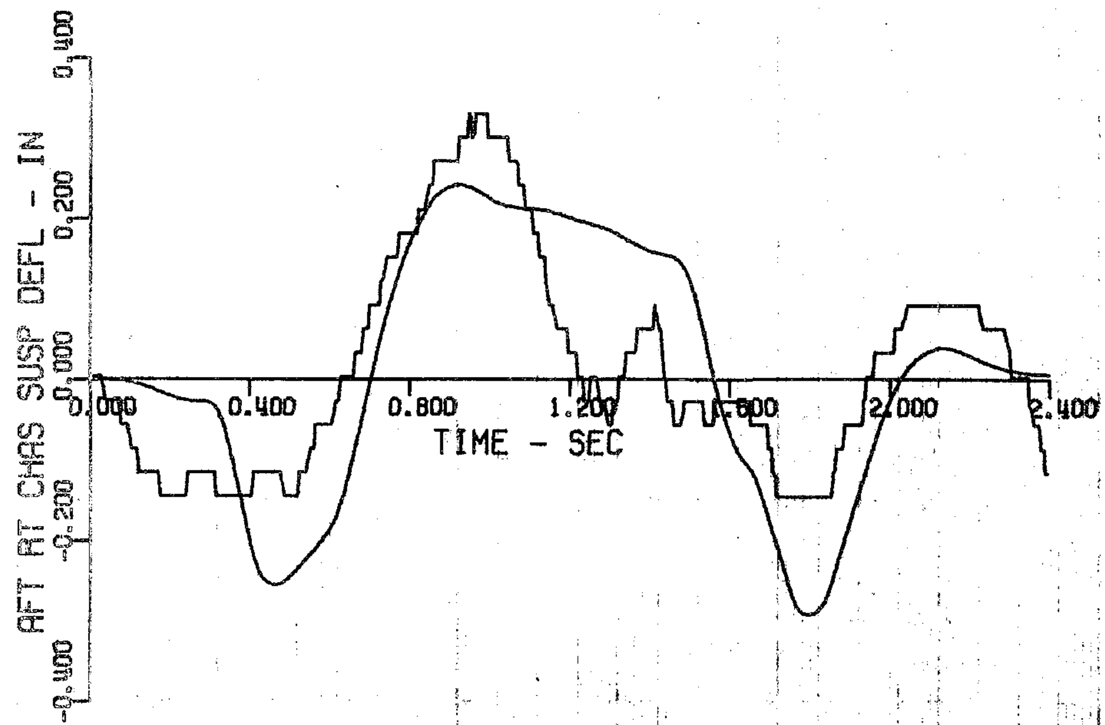


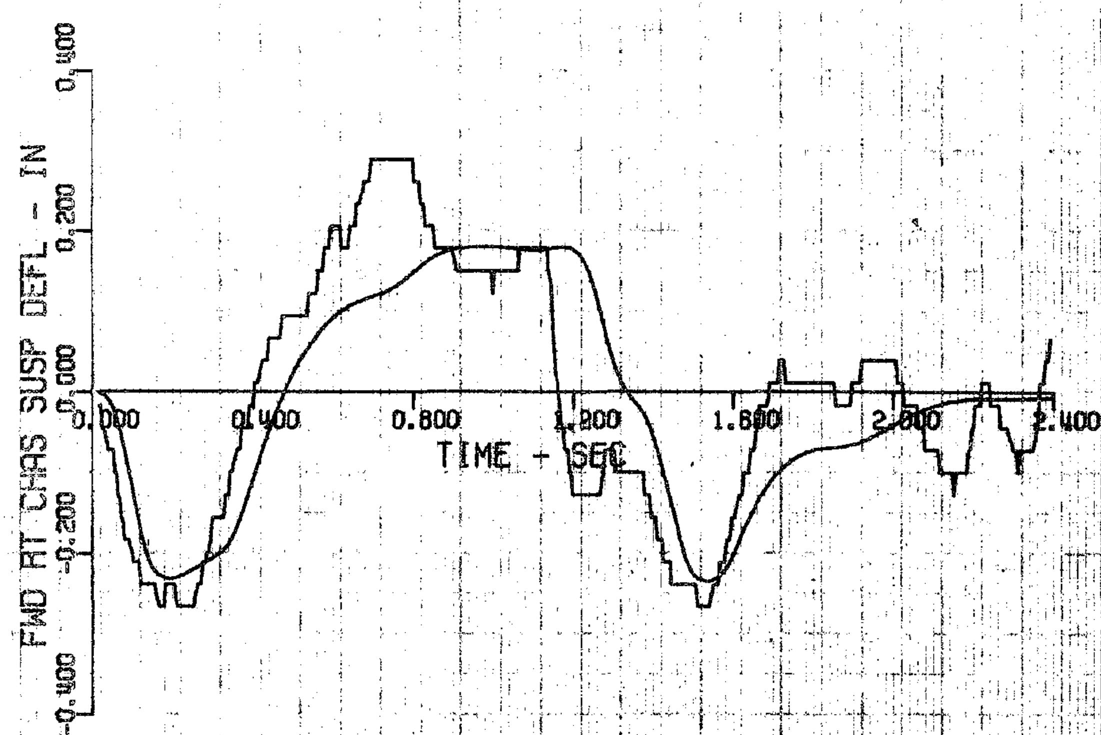
RUN 43 - 28A TL-105 14 39 07 85 MPH 3.0 IN X 150 FT PARABOLA



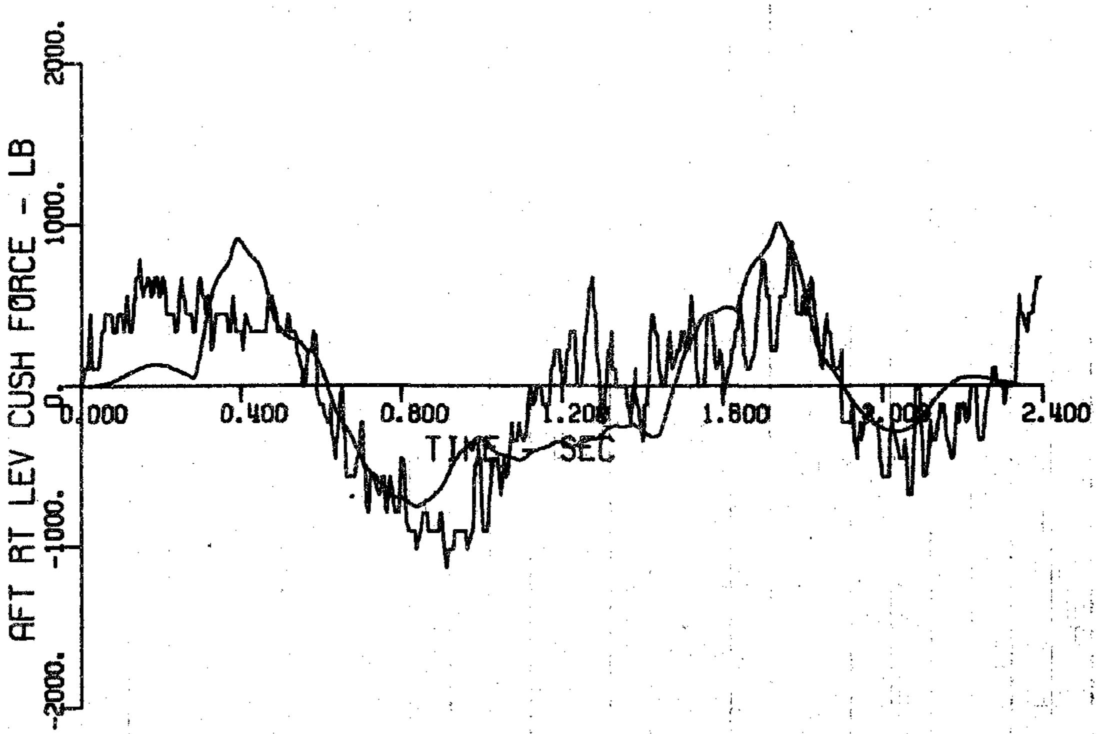


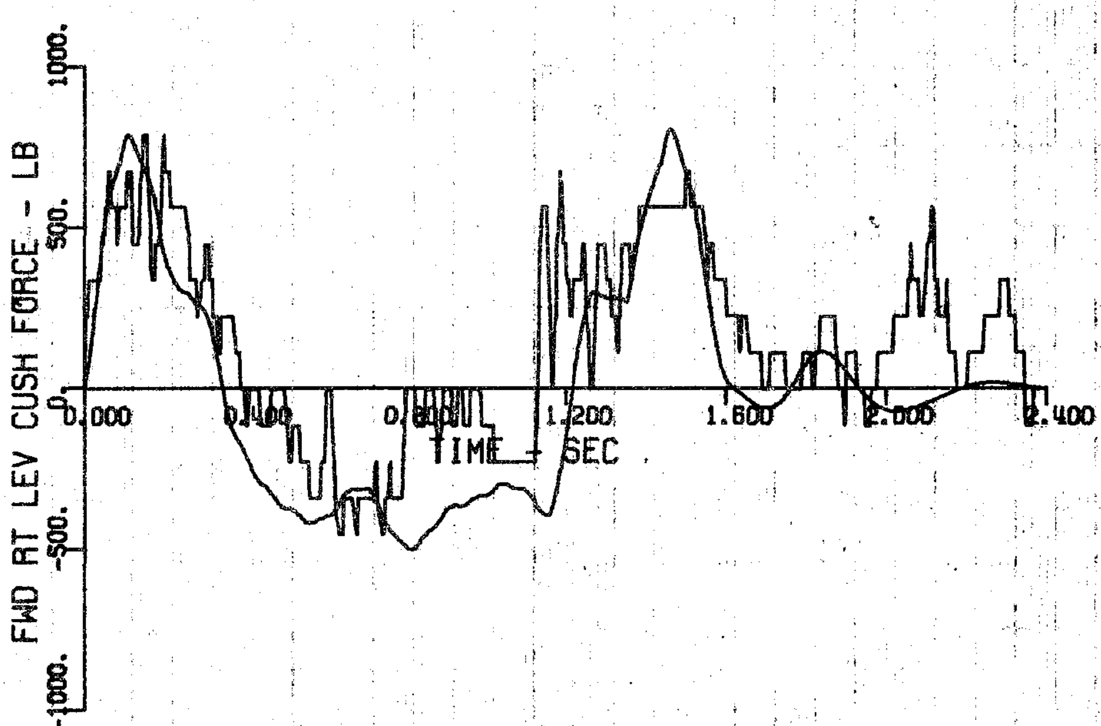
RUN 43 - 28A TL-105 14 39 07 85 MPH 3.0 IN X 150 FT PARABOLA



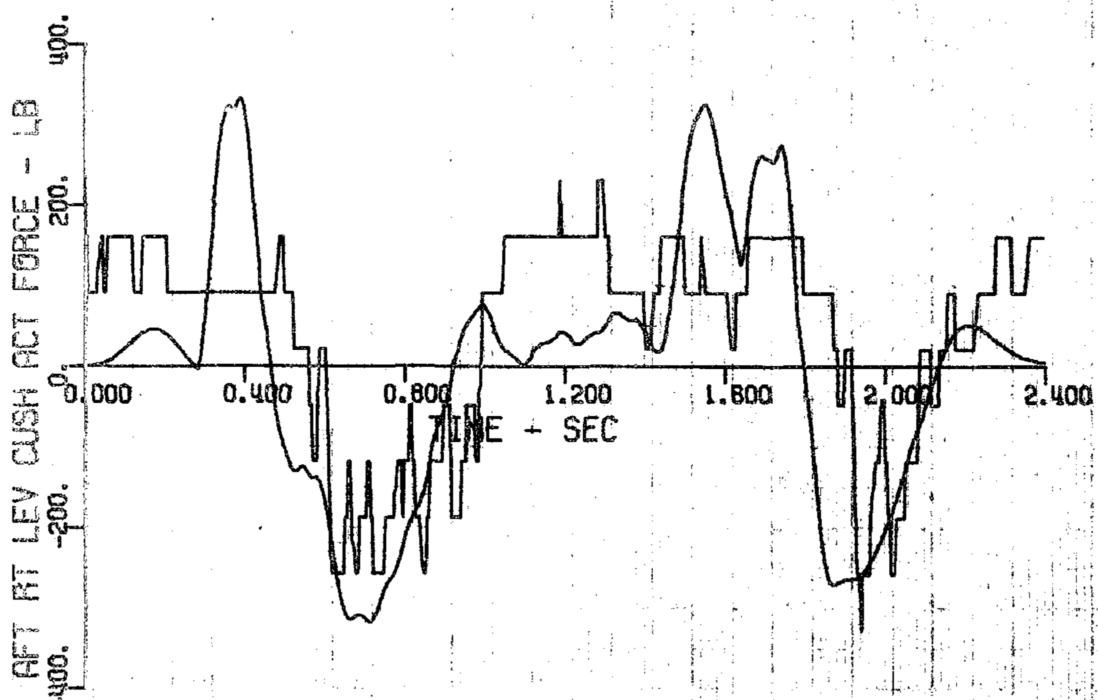


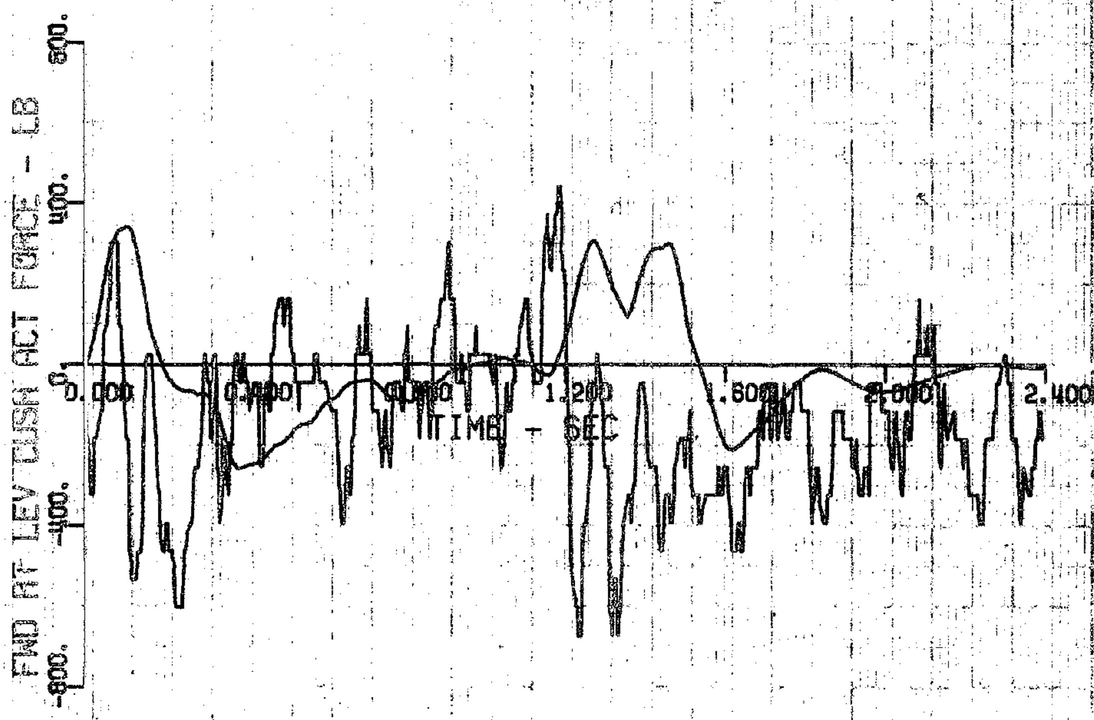
RUN 43 - 28A TL-105 14 39 07 85 MPH 3.0 IN X 150 FT PARABOLA



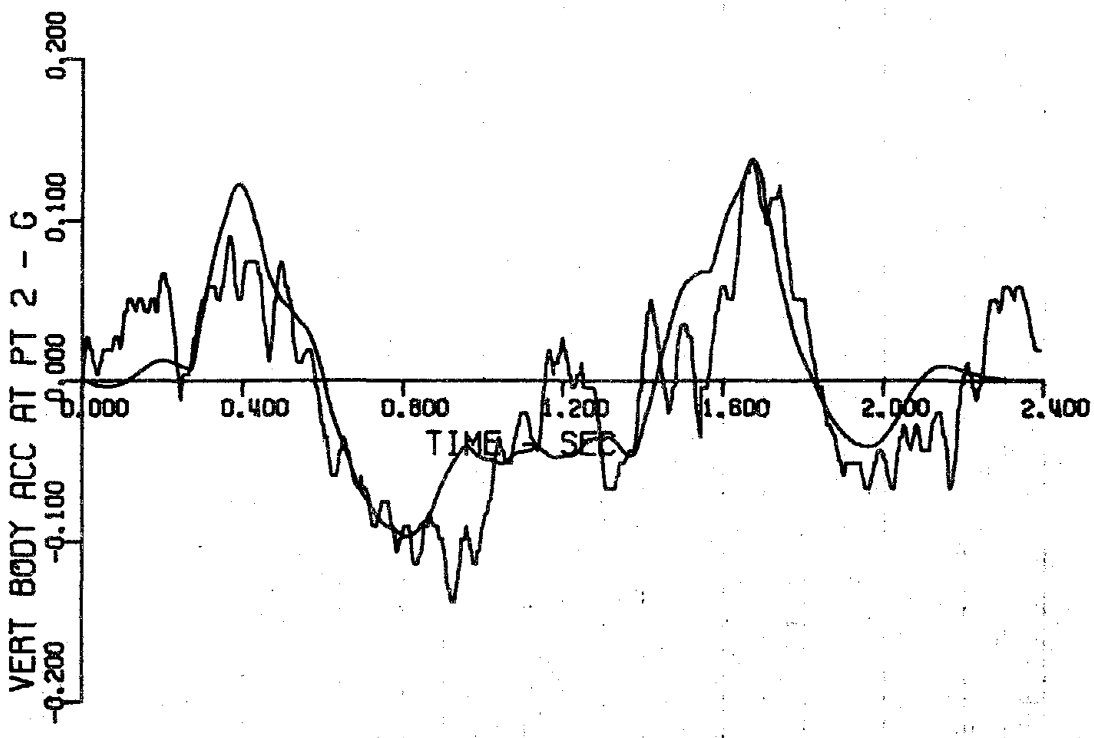


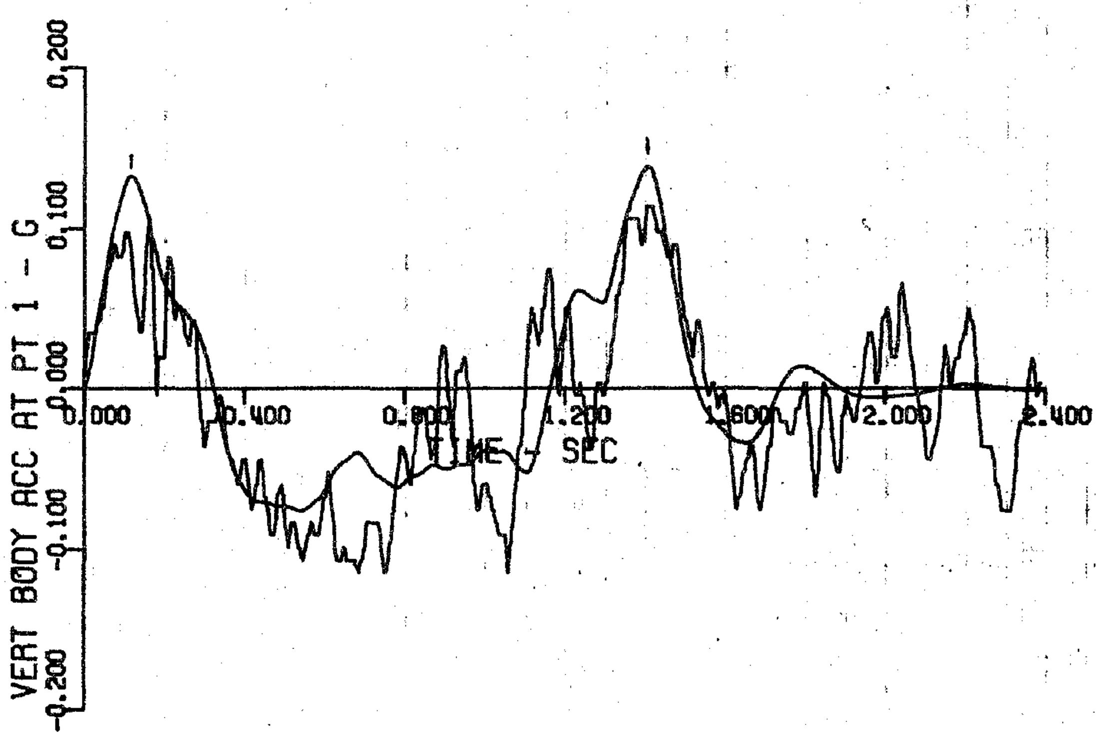
RUN 43 - 28A TL-105 14 39 07 65 MPH 3.0 IN X 150 FT PARABOLA



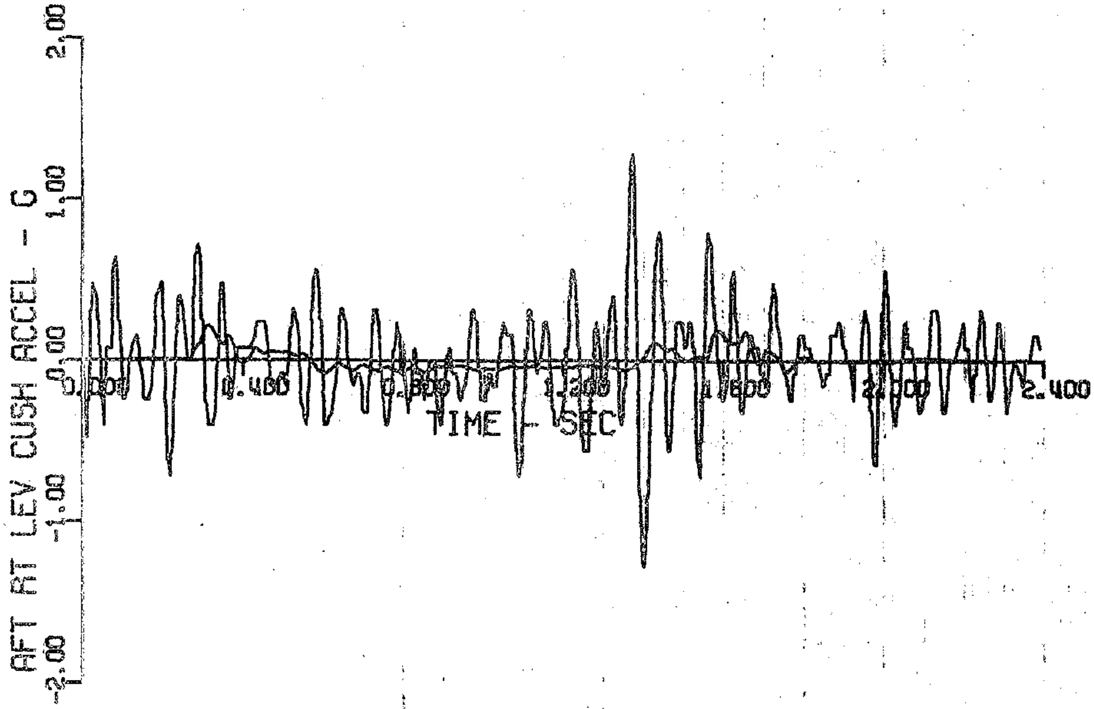


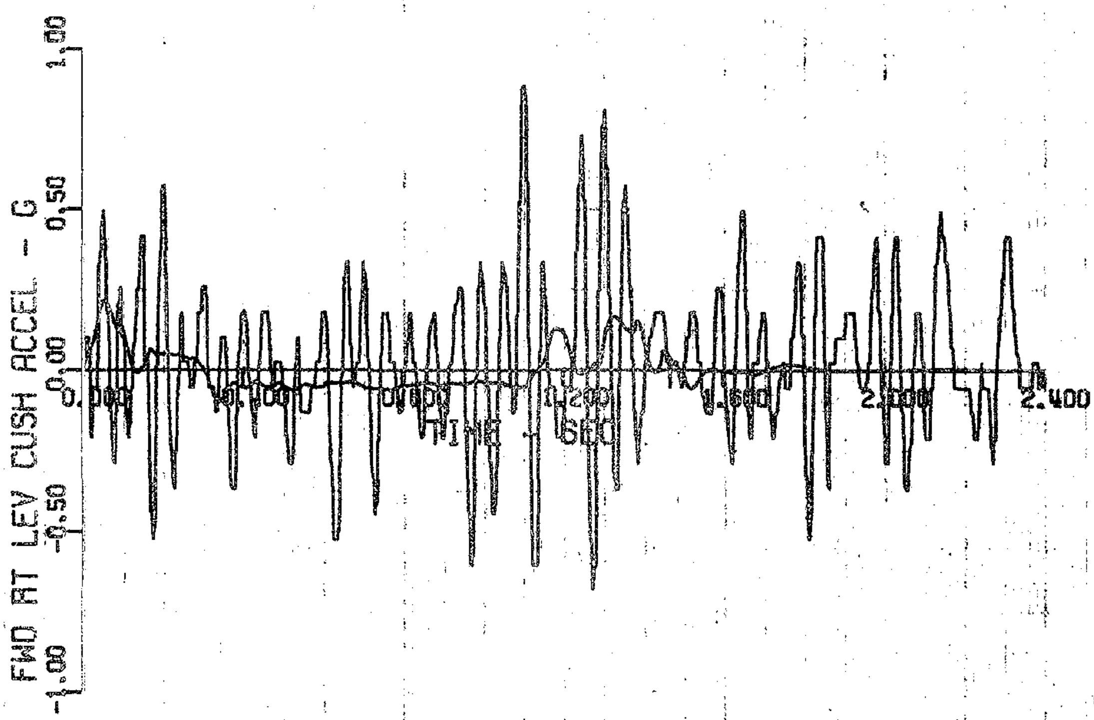
RUN 43 - 28A TL-105 1U 39 07 85 MPH 3.0 IN X 150 FT PARABOLA



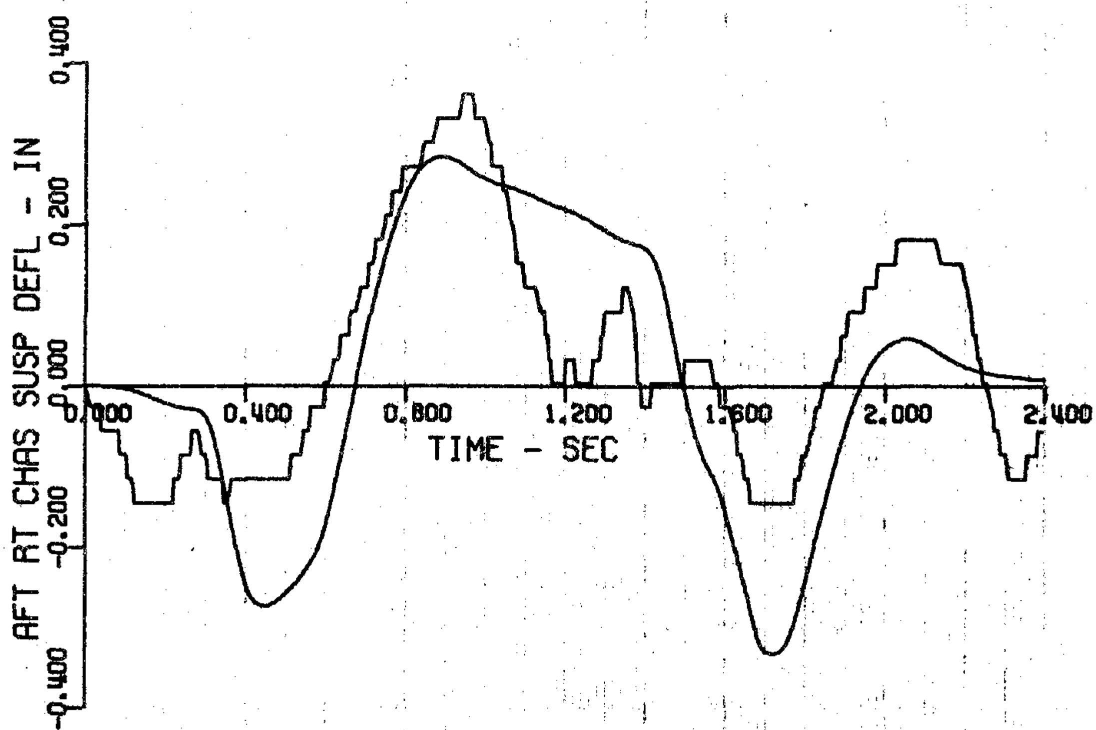


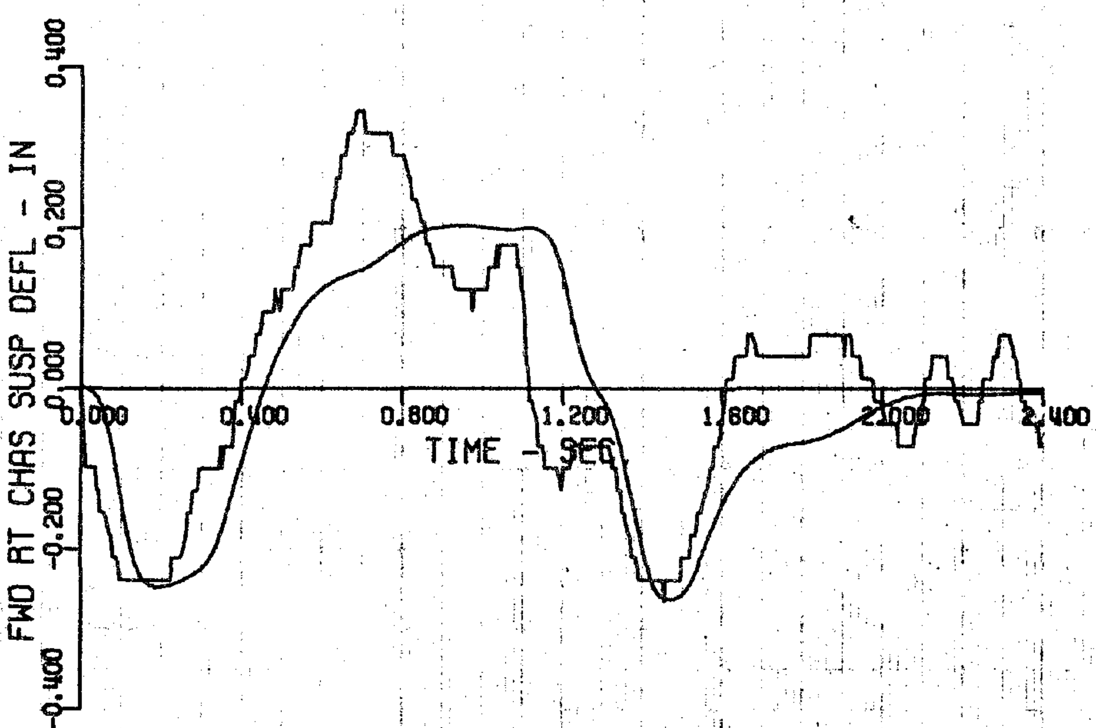
RUN 43 288 TL-105 15 57 34 69 MPH 3.0 IN X 150 FT PARABOLA



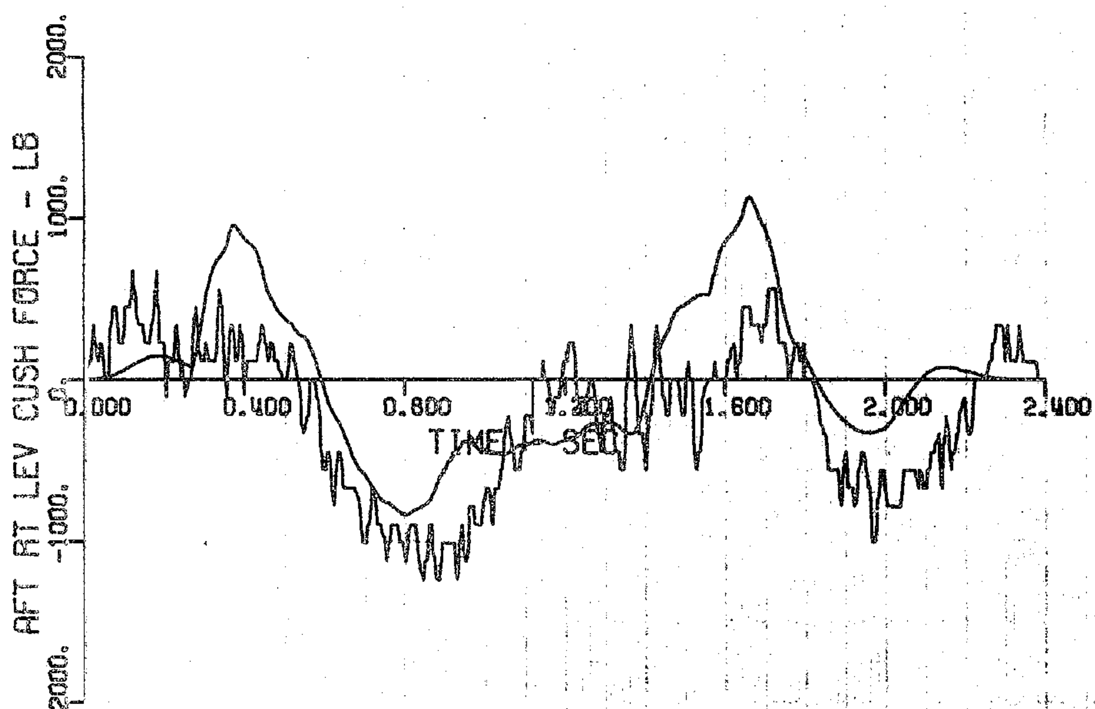


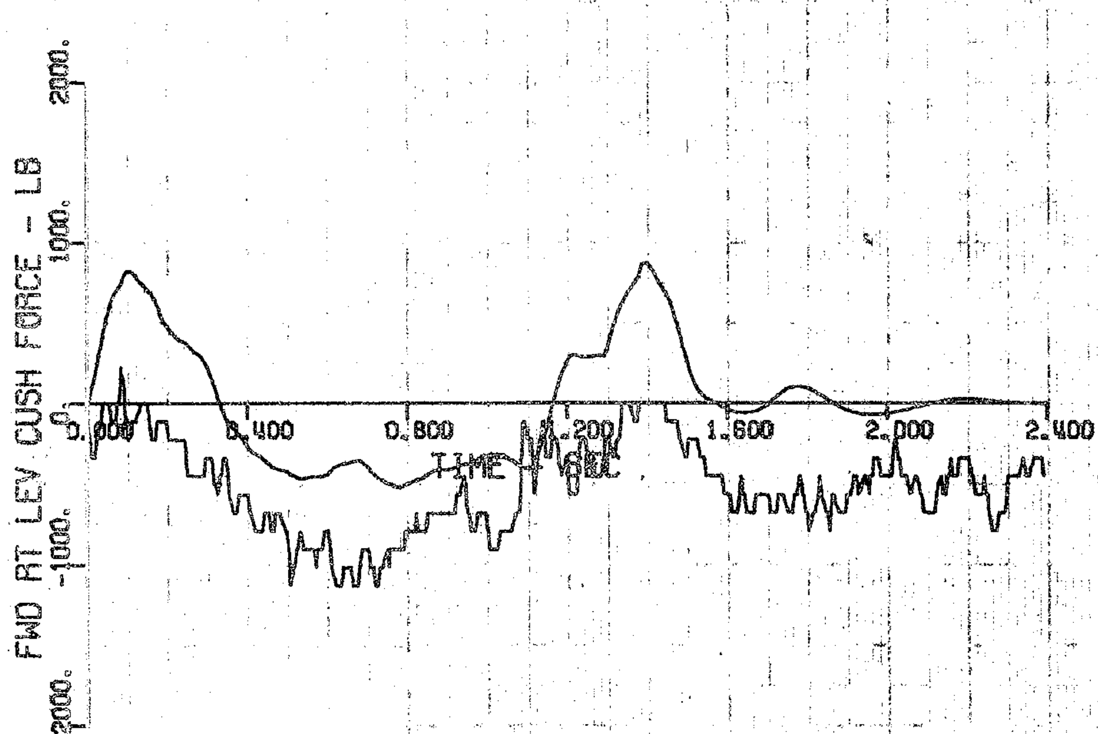
RUN 43 - 288 TL-105 15 57 34 89 MPH 3.0 IN X 150 FT PARABOLA



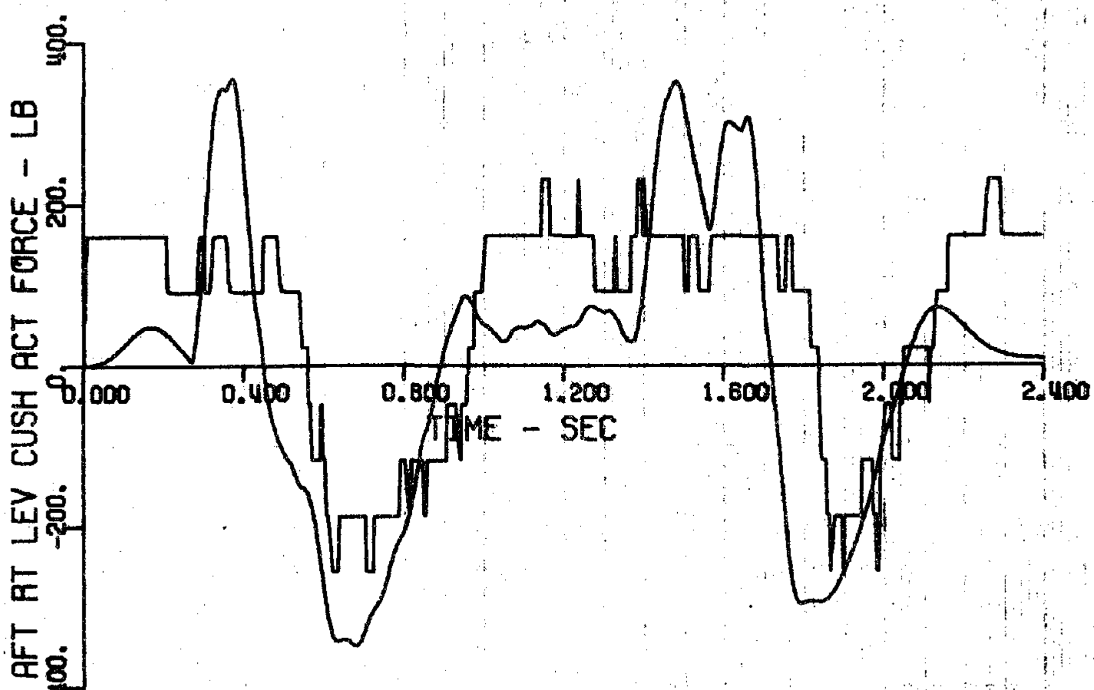


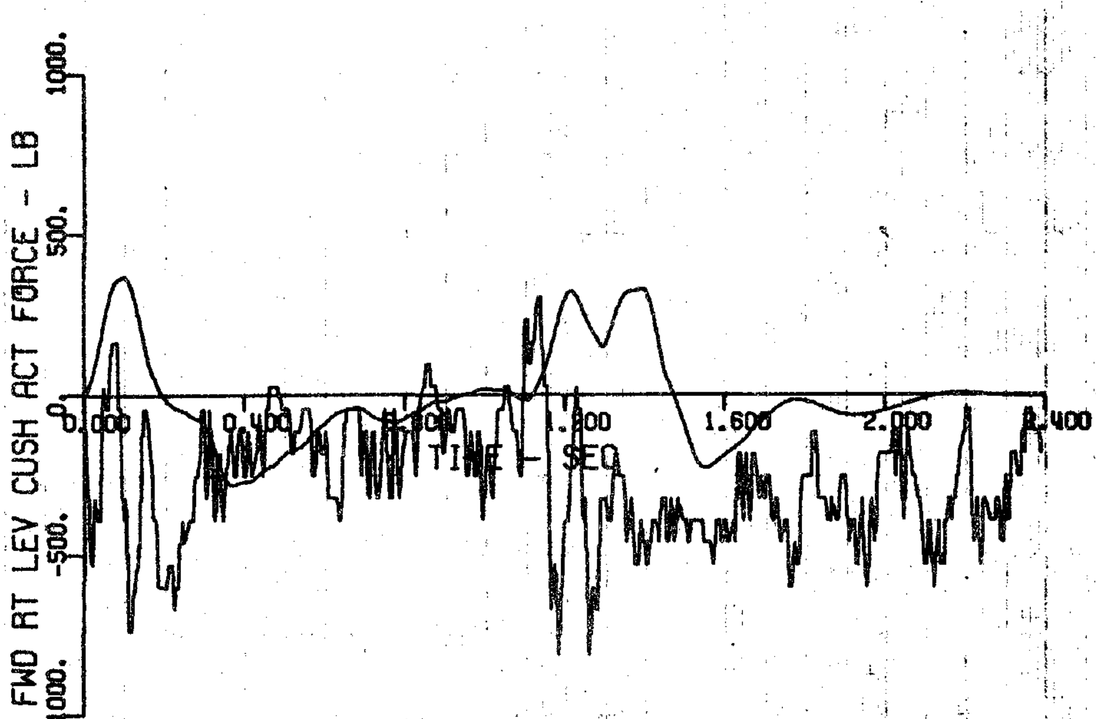
RUN 43 - 288 TL-105 15 57 34 89 MPH 3.0 IN X 150 FT PARABOLA





RUN 43 - 288 TL-105 15 57 34.89 MPH 3.0 IN X 150 FT PARABOLA





RUN 43 - 288 TL-105 15 57 34 88 MPH 3.0 IN X 150 FT PARABOLA

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