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SOAC

STATE-OF-THE-ART CAR

TRANSIT PROPERTY

ENGINEERING TESTS

FINAL TEST REPORT

VOLUME III. DATA REPORT
MBTA, CTS, CTA, SEPTA, PATCO

R. OREN

DECEMBER 1975

FINAL REPORT

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16. Abstract

This three-volume report presents the technical methodology, data samples, and results of tests conducted on the SOAC on six transit-authority properties, namely the New York City Transit Authority (NYCTA), Massachusetts Bay Area Transportation Authority (MBTA), Cleveland Transit System (CTS), Chicago Transit Authority (CTA), Southeastern Pennsylvania Transportation Authority (SEPTA), and the Port Authority Transit Corporation (PATCO). These tests were conducted during the course of the SOAC Operation and Demonstration Program which occurred between April 1974 and April 1975. The UMTA-sponsored Urban Rail Supporting Technology Program, for which TSC is Systems Manager, emphasizes three major development task areas: facilities, technology, and test programs. Test-program development comprises three subareas: vehicle testing, ways and structures testing, and track-geometry measurement. The objective of the SOAC program is to demonstrate the current state of the art in rail-rapid-transit vehicle technology, with passenger convenience and operating efficiency as primary goals. The initial phase of the SOAC Engineering Test Program provided a set of SOAC engineering data and provided some advancement to the methodology for providing transit-vehicle comparisons. The objective of this phase of the Test Program was to compare tests at the TTC with operations on the SOAC Demonstration Program Transit Authorities. This objective is met by the presentation of the test data and results in this report.

Volume I contains a program description and summaries of the test sites and data results. Volume II contains the test data report for the NYCTA tests. Volume III contains the test data reports for the tests at MBTA, CTS, CTA, SEPTA, and PATCO.

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PREFACE

This test report, presenting the results of tests on the State-of-the-Art Cars, derives from the efforts of two agencies of the U.S. Department of Transportation: the Rail Programs Branch of the Urban Mass Transportation Administration's Office of Research and Development and the Transportation Systems Center.

UMTA's Rail Programs Branch is conducting programs to improve urban rail transportation systems. The Transportation Systems Center (TSC) is supporting UMTA by providing systems management for the Rail Programs Branch's Urban Rail Supporting Technology Program (URSTP) in the design, construction and operation of UMTA test facilities, the analysis and testing of vehicles and components, and the development of key technological data. This test report stems from the second of the four URSTP tasks: facility development, test and evaluation, technology development, and application engineering.

Boeing Vertol Company had previously been engaged by UMTA as systems manager for the Urban Rapid Rail Vehicle and Systems Program (Contract DOT-UT-10007). One phase of this vehicle and component development program is the design, development, and demonstration of two State-of-the-Art Cars (SOAC) whose primary objective is to demonstrate the best current technology in rail rapid transit car design.

Following selection by Boeing and UMTA, the St. Louis Car Division of General Steel Industries built and delivered two SOAC cars to USDOT's High Speed Ground Test Center (HSGTC), Pueblo, Colorado in September 1972 for developmental and acceptance testing. This test facility permits the use of known track and grade conditions for test operations (without interfering with revenue service); it also allows a large-scale test plan to be completed in a relatively short period of time. (UMTA's Rail Transit Test Track at the HSGTC became available for rail rapid transit vehicle testing in August 1972.)

In February 1973, TSC awarded Boeing Vertol Company the contract to perform engineering tests on the SOAC vehicles. The objective of this program was to provide engineering data on the SOAC and to develop further the General Vehicle Test Plan methodology for providing vehicle comparisons (defined in GSP-064). This methodology for controlling test variables by standardizing procedures and data requirements was developed in 1972 and was successfully checked by a series of tests using NYCTA R-42 type cars on the initial track section in March 1972.

The results of this initial phase of the program was reported in a six volume report, SOAC State-of-the-Art Car Engineering Tests at Department of Transportation High Speed Ground Test Center Final Test Report, January 1975, UMTA-MA-06-0025-75.

The tests reported in this document are the result of the second phase of the SOAC Engineering test program. From April 1974 through May 1975 the SOACs were on a Demonstration Program through five different transit properties. An each of these properties a simulated revenue service test was performed. The data was analyzed and presented here as a method to compare the TTC with the transit properties and also to promote future comparisons of various vehicles and subsystems with SOAC.

APPENDIX A
TESTING AT BOSTON

1.0 TEST DESCRIPTION

As part of the Operational Test and Evaluation Program, the State-of-the-Art Cars were in the Boston Area from July 25th to September 16, 1974. The period during vehicle setup and checkout was used to install the engineering instrumentation system and to perform the Simulated Revenue Service Tests.

1.1 Test Site

The SOACs were operated in revenue service on the Cambridge - Dorchester Red Line of the MBTA rail rapid transit system (Figure 1-1). This line runs through Cambridge underground from Harvard to Kendall stations. It crosses the Charles River via the Longfellow bridge to the Charles station. It returns to an underground run from Charles to Broadway stations. Beyond Broadway the line is at grade level to the end of the route. The route is split south of Andrew station with one run continuing to Ashmont and the other continuing to Quincy Center (formerly the South Shore Line). The service on the Harvard-Ashmont route is 9 miles long with 14 stations and has a scheduled run time of 22 minutes. The Harvard-Quincy Center route is 11.8 miles, 12 stations and has a scheduled run time of 23 minutes.

1.2 Test Operations

The test plan was to operate the SOACs in simulated revenue service over the test routes. For safety and operational reasons, vehicle operation was entirely under the control of MBTA personnel during the tests. The only requirement imposed by the test was to maintain the normal scheduled service as close as possible and to simulate the normal station stop by opening the car doors on the side opposite to the station platform.

The test runs were conducted late at night and early morning hours in order to have minimum interference with revenue service. The scheduling worked well during the MBTA tests for there were few work crews out on the tracks during the test period and no incidents occurred which would influence the test runs.

A set of test runs was accomplished on the evening of August 9th. As the test progressed it became apparent that the vehicles had excessive wheel flats which induced a non-characteristic vibration in the car body ride quality.

The vehicles were subsequently scheduled through a wheel truing operation and the tests were repeated on August 13, 1975. No significant events occurred to detract from the validity of these tests runs and it is the August 13th data which is presented here.

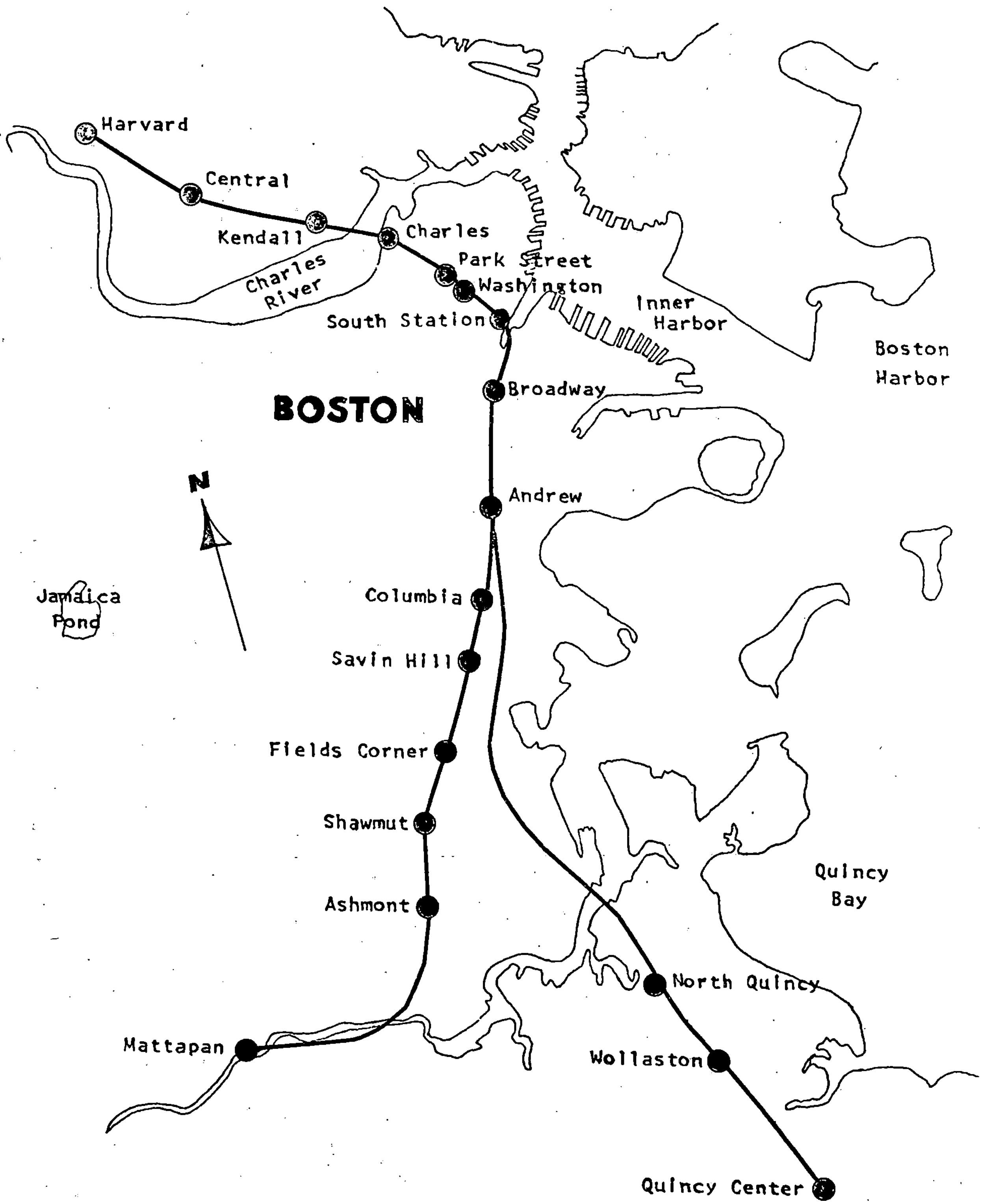


Figure 1—1. Cambridge-Dorchester Red Line of the MBTA

2.0 TEST PROCEDURES

Pretest

1. Mount all required sensors
2. Calibrate Instrumentation System
3. Brief Test Crew on Test Operations

   NOTE:

   One vehicle is instrumented for noise measurements, avoid other than normal conversation.

Test

1. Operate the vehicles in a simulated revenue service, i.e. maintain the given schedule.
2. Provide a nominal 10 second door opening at each scheduled stop.
3. Provide voice commentary on instrumentation recording during progress of test.
4. Maintain a manual log of events during the test run, correlated to the instrumentation system records.
5. Monitor various preselected data channels to ascertain validity of test run.
6. The Test Controller will terminate the test if:
   - (a) An extended delay or train shutdown occurs
   - (b) One or more required data channels malfunction
   - (c) The test vehicle is not operating properly

   Advise Test Controller of any abnormal operations or events that occur during the test run.

3.0 INSTRUMENTATION

The SOAC Instrumentation System was used for this series of tests. This system is described in detail in Volume VI of State-of-the-Art Car (SOAC) Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Test Report, UMTA-MA-06-0025-75-6, January 1975. A synopsis is included below.

3.1 Ride Qualities, Structural and Performance Tests

Electrical signals from the vehicle mounted transducers are conducted by cables to an interface panel which is connected to an instrumentation console containing two magnetic tape recorders, two light beam oscillographs, a time code generator, a temperature recorder and signal conditioners. Any 28 selected test parameters can be recorded on tape and displayed on the oscillographs. In addition, wheel speeds may be recorded directly on the oscillographs; total power is recorded on tape and displayed on a mechanical counter. The time code generator provides signals that are recorded on both tape and the oscillograph. The oscillographs provide quick-look data to evaluate test progress and results during testing (See Figure 3-1).

3.2 Noise Tests

The instrumentation used for noise measurement consisted of a 1" condenser microphone with battery operated cathode follower and a 1/4" single channel tape recorder.

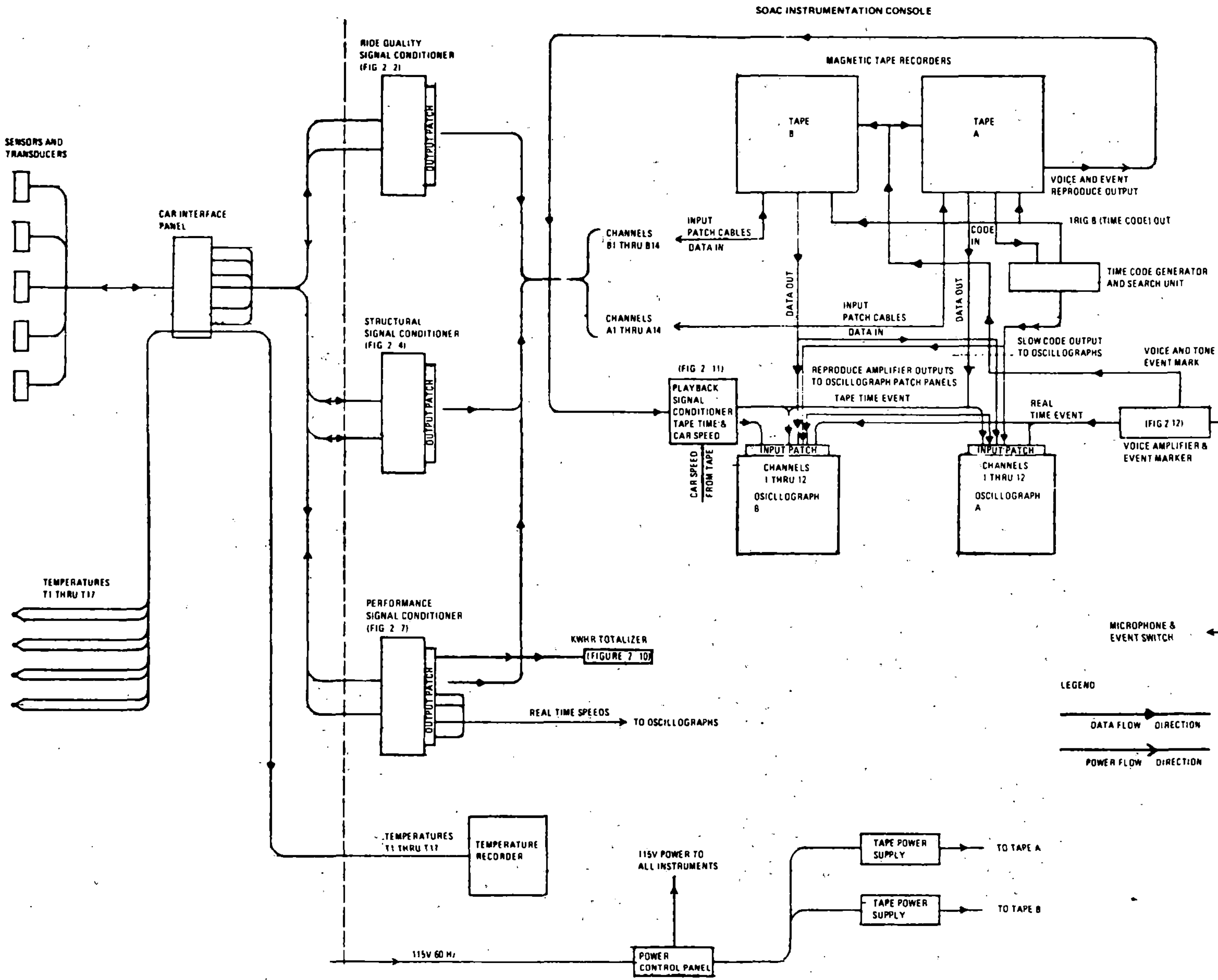


Figure 3–1. SOAC Instrumentation System Block Diagram

4.0 DATA

The parameters recorded during the property tests are described in Tables 4-1 and 4-2. The definition of the parameter measurements is contained in Appendix A, Standard Outputs for SOAC Property Tests.

Data was recorded for the roundtrip routes noted in the Test Description Section. All of the data was recorded on analog tapes and processed to provide three types of outputs.

Time History Charts

Station Summary Tables

Frequency Histograms

4.1 Time History Charts

A slow chart speed strip-out of certain parameters is included in this report. The purpose of these charts is to provide an indication of the maximum levels of parameters during various phases of the run. The complete run is described on the charts including station stops and any particularities that occurred. A series of time histories at a high chart speed is included to illustrate the cyclical nature of the data. These charts are a single time frame for all parameters and are representative of the worst case conditions exhibited for a particular test run.

Intermediate parameters, such as a weighted (filtered) car body acceleration are shown on some charts.

4.2 Station Summary

A summation or summary of specific parameters is made by each station stop. These include test running time and distance for comparison to the property's schedule. Power consumption, motor duty cycle parameters are also summarized by station to indicate the relative sizing of the SOAC propulsion with respect to operations on the property. Station stops and maximum speeds are also shown as another indicator of vehicle operation in a scheduled service environment.

Table 4–1. SOAC Revenue Service Data

PARAMETER DESIGNATION NO.	DESCRIPTION	RANGE
301	Longitudinal Acceleration	± 0.25 g's
302	Line Voltage	0 to 1000 VDC
303	Line Current	0 to 2000 ADC
304	No. 1 Truck Armature Voltage	0 to 1200 VDC
305	No. 1 Truck Armature Current	0 to 1000 ADC
306	No. 1 Truck Field Current	± 50 ADC
307	No. 2 Truck Armature Voltage	0 to 1200 VDC
308	No. 2 Truck Armature Current	0 to 1000 ADC
309	No. 2 Truck Field Current	± 50 ADC
310	"P" Wire Current	0 to 1.00 ADC
317	Total Power Consumption	1 Pulse/0.1 KWHR
315	Speed	0 to 80 MPH
318	Brake Cylinder Pressure	0 to 100 psig

List A

STANDARD OUTPUTS

RECORDED	PRESENTED	PRELIMINARY ANALYSIS
AP/A	Format(3)	Format(4)
LVD/A	None	-
LCD/A	None	-
MAVD/A	None	-
MACD/A	None	RMS-MAC/A
MFCD/A	None	RMS-MFC/A
MAVD/A	None	-
MACD/A	None	-
MFCD/A	None	-
CS/A	None	Format(3)
PCC/A	Format(2)	Format(2)
VS/A	Format(3)	Format(4)
BCP/A	None	-

Table 4–2. SOAC

PARAMETER DESIGNATION NO.	DESCRIPTION
101	Front Truck, Forward Axle, Righthand Wheel Journal Box Vertical Acceleration
102	Front Track, Forward Axle, Righthand Wheel Journal Box Lateral Acceleration
103	Front Truck, Forward Axle Lefthand Wheel Journal Box Vertical Acceleration
115	Mid Car Centerline Vertical Acceleration
116	Mid Car Centerline Lateral Acceleration
120	Forward Car Centerline Vertical Acceleration
121	Forward Car Centerline Lateral Acceleration
219	Truck Frame Upper Strain Gage
220	Truck Frame Lower Strain Gage
221	Pitch Angular Acceleration
222	Roll, Angular Acceleration
223	Yaw, Angular Acceleration
-	Interior Sound Pressure

Revenue Service Data List B

RANGE	STANDARD OUTPUTS RECORDED	PRESENTED	PRELIMINARY ANALYSIS
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	-
± 0.25 g's	AC/A	Format(3)	RRV/A(1), (3)
± 0.25 g's	AC/A	Format(3)	RRH/A(1), (3)
± 0.25 g's	AC/A	Format(3)	RRV/A(1)
± 0.25 g's	AC/A	Format(3)	RRH/A(1)
± 6348 psi	STP	Format(3)	Fromat(4)
± 6348 psi	STP	Format(3)	-
± 1.5 Rad/sec/sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
40 to 120 dB(re 2 x 10^{-5} N/M^2)	SP/A	NL/A(1)	NL/A(2)

4.3 Frequency Histograms

These distributions are an indication of the ratio of time that a parameter is at a particular level with respect to the time to complete a roundtrip scheduled service run. These parameters may be used to describe how the vehicle was driven, the track conditions, and how the vehicle responded to these conditions.

5.0 DATA DISCUSSION

The vehicle operation was such that SOAC No. 2, the instrumented car, was leading and running in the forward direction for the Harvard to Ashmont and Harvard to Quincy Center runs. For these runs the vehicle longitudinal acceleration has a positive value for startup. During the Ashmont to Harvard and Quincy Center to Harvard runs, SOAC 2 was trailing and running in the reverse direction.

As defined in Section 4 there are three forms of data. These forms are discussed below with respect to three categories:

(1) Operation

How the vehicle is operated and maintained schedule.

(2) Environment

Track and truck conditions.

(3) Response

How the vehicle responded to operational environment.

Figures 5-1 through 5-15 present the frequency histograms for the MBTA Tests. Figure 5-16 is a sample of the interior noise level time history. The remaining time histories are shown in Figures 5-17 through 5-36. Table 5-1 is a summary of some of the test parameters and is taken from the histograms and time histories. Tables 5-2 through 5-5 are the Station Summaries with power consumption.

5.1 Operation

The Station Summary Tables show that SOAC maintained the MBTA schedule reasonably well for the Harvard-Ashmont run. However, the test time was somewhat longer than scheduled for the Harvard-Quincy Center runs. This time difference occurred mainly between the North Quincy and Andrew stations. The crossover between the Ashmont and Quincy center lines is between these two stations. The speed time-history charts reveal that SOAC was limited to low speed in this area. Apparently, there were special operating restrictions placed on the SOAC in this area.

The maximum vehicle acceleration is shown on the time-histories to be 2.73 mph/second, and the maximum braking is 3.80 mph/second. This braking rate is abnormally high for the SOAC, and could have contributed to the wheel flats described in the Test Operations section earlier.

The Station Summaries show that 14 percent of the total test time was spent in a station. The speed frequency histogram shows 18.7 percent of the time in the speed range of 0 to 5 mph. This speed frequency histogram also shows 17.5 percent of the time was spent in the 15 to mph band. An analysis of the SOAC performance and the MBTA schedules indicates that the most efficient vehicle operation occurs with the major proportion of time in the 35 to 40 mph speed band. This is based on average station spacing and block speeds.

The power consumption for the Harvard-Quincy Center run averaged 7.37 KWH/Mile for the station spacing of 1.19 miles, and a block speed of 25.9 mph. On the Harvard-Ashmont line, with a 23.3 mph block speed and a .69 mile distance between stations, the power consumption was 7.01 KWHR/Mile.

The RMS armature current indicates the relative sizing of the SOAC propulsion system with respect to the route described. The SOAC motors have a continuous rating of 175 hp (460 amps) and a one hour rating of 230 hp (600 amps). The Harvard-Ashmont run drew 270 amperes (RMS) or 59 percent of the rated value. The most severe cycle occurred between Ashmont and Shawmut stations. The easiest cycle was between Columbia and Andrew stations which reflects the special operating restrictions for SOAC mentioned above. Another light cycle occurred between Fields Corner and Savin Hill stations, where the time-histories show a definite 25 mph speed limit. On the Harvard-Quincy Center run the current drawn per motor was 290 amperes (RMS). This is 63 percent of their rated value. The most severe cycle occurred between North Quincy and Wollaston stations.

5.2 Environment

It is intended that the journal box accelerations and the truck frame stress levels be used as indicators of track roughness. Summary values for these parameters are shown in Table 5-1. The 50th% value is a statistical quantity. For these tests it assumes a linear distribution of acceleration levels within a class interval (Example: 1 to 2 gs). The value is read as 50 percent of the time the journal box vertical acceleration is at ± .75 gs or less. The 95th% is read similarly. The maximum values are from the time-history charts. The "nominal" value is an average, or 50th%, for the time that the vehicle is moving.

The time history charts show the journals receiving quite a few vertical shocks up to 20 gs. These shocks occurred most regularly between Harvard and Central stations. Also noted on the time histories is the failure of the lateral journal box accelerometer during the Harvard and Quincy Center runs.

It should be mentioned that the truck frame stress levels reflect dynamic loading only. Passenger load and car weight do not influence this parameter.

5.3 Response

The car body Ride Roughness and Noise Level parameters are the indicators of how the vehicle responded to the operation and environment. Ride Roughness is a vibration parameter which is weighted according to human response characteristics in riding comfort. This technique is similar to using the "A" weighing on sound pressure to yield Noise Levels. Noise Level and Ride Roughness are related to "human responses". Both of these parameters are described in the Standard Outputs section of this report.

Summary Ride Roughness values are shown in Table 5-1. The fast chart speed time histories show the mid-car vertical acceleration to have a substantial level during the Shawmut to Ashmont run. The value is ± .069 gs at 8 Hz. The speed trace for this record shows the car was operating around 45 mph. Eight hertz is the wheel revolution frequency for the SOAC 30 inch wheels at 45 mph. In addition, the SOAC car body has a second body bending mode at 8 hz and is sensitive to this frequency. Wheel flats have been known to drive the SOAC car body into this vibration, but the wheels were "turned down" prior to this test run. Subsequent to the tests the wheels were measured and found to be out-of-round as a result of the "wheel turning" operation. Consequently the SOAC Ride Quality data for these MBTA tests must be reported as what the vehicle did, and should not be constricted as how the car is capable of riding.

From the same fast chart speed time histories another characteristic of the SOAC is evident; the 1.2 hertz lateral acceleration. At the mid car point the acceleration level is ± .063 gs. This characteristic is more noticeable as vehicle roll where the angular acceleration level is ± .46 radians per second per second.

Interior Noise Level data was taken in the middle of the non-instrumented vehicle, at a seated passenger ear level. The Engineering Tests at the Transit Test Center indicate this is the quietest point in the car. The table below reports the statistical quantities calculated from the combined runs on the MBTA:

L(99)	L(90)	L(50)	L(10)	L(1)	L(EQ)
65.0	66.5	68.8	76.0	81.5	72.7

Table 5–1. Summary Values for SOAC Operating on

	50TH %
Journal Box Vertical Acceleration (G)	± .75
Journal Box Lateral Acceleration (G)	± 1.50
Truck Frame Stress (PSI)	± 160
Forward Car Vertical Acceleration (G)	.017
Mid Car Vertical Acceleration (G)	± .023
Forward Car Lateral Acceleration (G)	± .018
Mid Car Lateral Acceleration (G)	± .016
Longitudinal Ride Roughness (GRMS)	.006
Forward Car Vertical Ride Roughness (GRMS)	.015
Mid Car Vertical Ride Roughness (GRMS)	.011
Forward Car Lateral Ride Roughness (GRMS)	.009
Mid Car Lateral Ride Roughness (GRMS)	.006
Pitch (RAD/Sec-Sec)	± .054
Roll (RAD/Sec-Sec)	± .055
Yaw (RAD/Sec-Sec)	± .050

the MBTA Red Line

"NOMINAL"	95TH %	MAXIMUM
± .88	± 5.5	± 20.
± 1.88	± 8.5	± 17.5
± 182	± 680	-
.020	.075	± .250
± .027	± .091	± .250
± .021	± .071	± .125
± .018	± .058	± .088
.007	.017	.050
.019	.060	.150
.014	.054	.120
.011	.030	.075
.007	.019	.035
± .060	± .098	± .239
± .062	± .160	± .420
± .058	± .095	± .100

Table 5–2. Station Summary I

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	POWER CONSUMPTION KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Harvard Street	0	0	0	0	0	0	0	0	0	0
2	Central Street	.95	1.65	1.09	2.32	6.44	5.91	293.7	24.2	18.0	48
3	Kendall Street	.96	1.95	1.07	2.58	6.08	5.68	257.7	19.9	42.0	49
4	Charles Street	.72	1.78	.81	2.36	6.87	8.48	239.8	30.8	18.0	34
5	Park Street	.56	1.40	.60	1.92	4.57	7.62	291.1	25.8	16.8	42
6	Washington Street	.21	1.17	.24	1.14	1.79	7.46	268.7	24.1	15.6	24
7	South Station	.27	1.15	.31	1.30	2.31	7.46	280.2	23.1	14.4	30
8	Broadway Street	.83	2.08	.92	2.36	6.02	6.54	261.1	20.1	26.4	49
9	Andrew Street	.83	1.87	.94	1.96	6.87	7.31	317.8	29.0	19.2	50
10	Columbia Street	.74	1.97	.84	2.34	6.18	7.36	230.4	31.1	19.2	37
11	Savin Hill	.70	1.56	.76	2.02	6.06	7.97	313.1	29.0	18.0	44
12	Fields Corner	1.00	2.30	1.05	3.16	6.96	6.63	191.0	31.9	18.0	26
13	Shawmut Street	.53	1.90	.65	1.70	4.95	7.61	302.3	24.4	18.0	44
14	Ashmont Street	.62	1.22	.71	1.84	5.53	7.79	310.0	26.5	18.0	48
					T O T A L	70.64	7.07	271.0	25.0		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	8.97	9.99
Time	22.00	27.00
Block Speed	24.5	22.4
Station Dwell	30.	20.1
Station Spacing	.69	.77

Table 5–3. Station Summary II

STATION		SCHEDULE		TEST		POWER CONSUMPTION					
NO.	NAME	DISTANCE (MILES)	TIME (MINUTES)	DISTANCE (MILES)	TIME (MINUTES)	KWHR	KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Ashmont Street	0	0	0	0	0	0	0	0	0	0
2	Shawmut Street	.62	1.20	.69	1.60	5.68	8.24	345.7	28.3	20.4	48
3	Fields Corner	.58	1.45	.66	1.76	4.46	6.76	281.3	25.9	10.8	40
4	Savin Hill	1.00	2.32	1.13	2.94	5.57	4.93	182.9	29.4	15.6	26
5	Columbia Street	.70	1.58	.79	2.56	5.64	7.14	232.8	19.7	57.6	42
6	Andrew Street	.74	2.03	.83	2.70	4.81	5.80	175.9	24.5	19.2	26
7	Broadway Street	.83	1.89	.94	1.88	6.66	7.09	303.1	23.1	15.6	50
8	South Station	.84	1.98	.92	1.92	5.67	6.17	278.9	21.4	15.6	50
9	Washington	.27	1.13	.31	1.26	3.36	10.84	271.3	28.3	15.6	30
10	Park Street	.21	1.10	.24	1.04	2.80	11.68	296.8	26.5	18.0	26
11	Charles Street	.56	1.72	.60	1.62	5.85	9.75	321.6	24.4	21.6	46
12	Kendall Street	.74	1.60	.81	1.88	4.53	5.59	280.3	21.2	15.6	40
13	Central Street	.96	1.95	1.07	2.02	7.11	6.65	299.5	22.9	16.8	50
14	Harvard	.97	2.05	1.09	2.14	7.79	7.15	299.9	22.4	16.8	50
					T O T A L	69.95	6.94	270.0	24.5		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	9.02	10.08
Time	22.00	25.32
Block Speed	24.6	23.9
Station Dwell	30.0	19.9
Station Spacing	.69	.78

Table 5–4. Station Summary III

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	POWER CONSUMPTION KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Harvard Street	0	0	0	0	0	0	0	0	0	0
2	Central Street	.96	2.17	1.09	2.18	7.10	6.51	289.4	25.1	14.4	49
3	Kendall Street	.95	2.33	1.07	2.80	6.62	6.19	233.7	18.9	57.6	49
4	Charles Street	.72	2.10	.81	2.28	6.46	7.97	243.9	26.7	16.8	37
5.	Park	.56	1.65	.61	2.26	4.78	7.83	251.5	22.1	15.6	38
6	Washington Street	.21	1.17	.23	1.12	2.00	8.71	271.9	26.2	16.8	24
7	South Street	.27	1.08	.32	1.30	2.36	7.39	268.1	22.2	15.6	26
8	Broadway Street	.83	2.42	.91	2.00	6.21	6.83	286.3	20.4	24.0	49
9	Andrew Street	.83	2.25	.95	2.00	7.12	7.49	295.6	22.9	18.0	50
10	North Quincy St.	4.43	5.00	4.75	8.50	30.90	6.51	296.6	25.6	32.4	64
11	Wollaston Street	.76	1.08	.93	2.64	9.96	10.71	352.5	29.9	19.2	52
12	Quincy Center	1.27	1.90	1.42	3.20	10.02	7.05	327.1	23.8	16.8	56
					T O T A L	93.53	7.15	290.0	24.5		

TEST RUN SUMMARY

	SCHEDULED	TEST
Distance	11.79	13.09
Time	23.15	30.28
Block Speed	30.6	25.9
Station Dwell	18.8	22.5
Station Spacing	1.07	1.19

Table 5–5. Station Summary IV

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	SECONDS	MAX. SPEED (MPH)
1	Quincy Center	0	0	0	0	0	0	0	0	0	0
2	Wollaston Street	1.27	1.57	1.42	2.92	9.88	6.95	295.0	26.8	21.6	62
3	North Quincy St.	.76	1.33	.91	2.46	7.59	8.34	298.0	24.2	20.4	57
4	Andrew Street	4.43	4.75	4.75	9.72	35.92	7.56	320.7	27.6	24.0	63
5	Broadway Street	.83	2.33	.94	2.22	7.41	7.88	277.0	26.4	18.0	49
6	South Street	.83	2.34	.91	2.30	6.90	7.58	244.1	25.1	18.0	50
7	Washington Street	.27	1.00	.32	1.40	3.33	10.42	202.6	28.8	19.2	26
8	Park	.21	1.08	.23	1.14	2.96	12.87	263.2	27.6	18.0	26
9	Charles	.56	1.90	.61	1.60	5.58	9.14	307.1	24.9	15.6	45
10	Kendall Street	.72	2.07	.81	1.86	5.59	6.90	308.6	24.0	15.6	49
11	Central Street	.95	2.28	1.07	2.32	6.84	6.39	264.5	24.3	16.8	49
12	Harvard Street	.96	2.50	1.09	2.44	7.14	6.55	261.2	22.5	21.6	49
					TOTAL	99.14	7.59	291.0	26.1		

TEST RUN SUMMARY

	SCHEDULED	TEST
Distance	11.79	13.06
Time	23.15	30.38
Block Speed	30.6	25.8
Station Dwell	17	19.0
Station Spacing	1.07	1.19

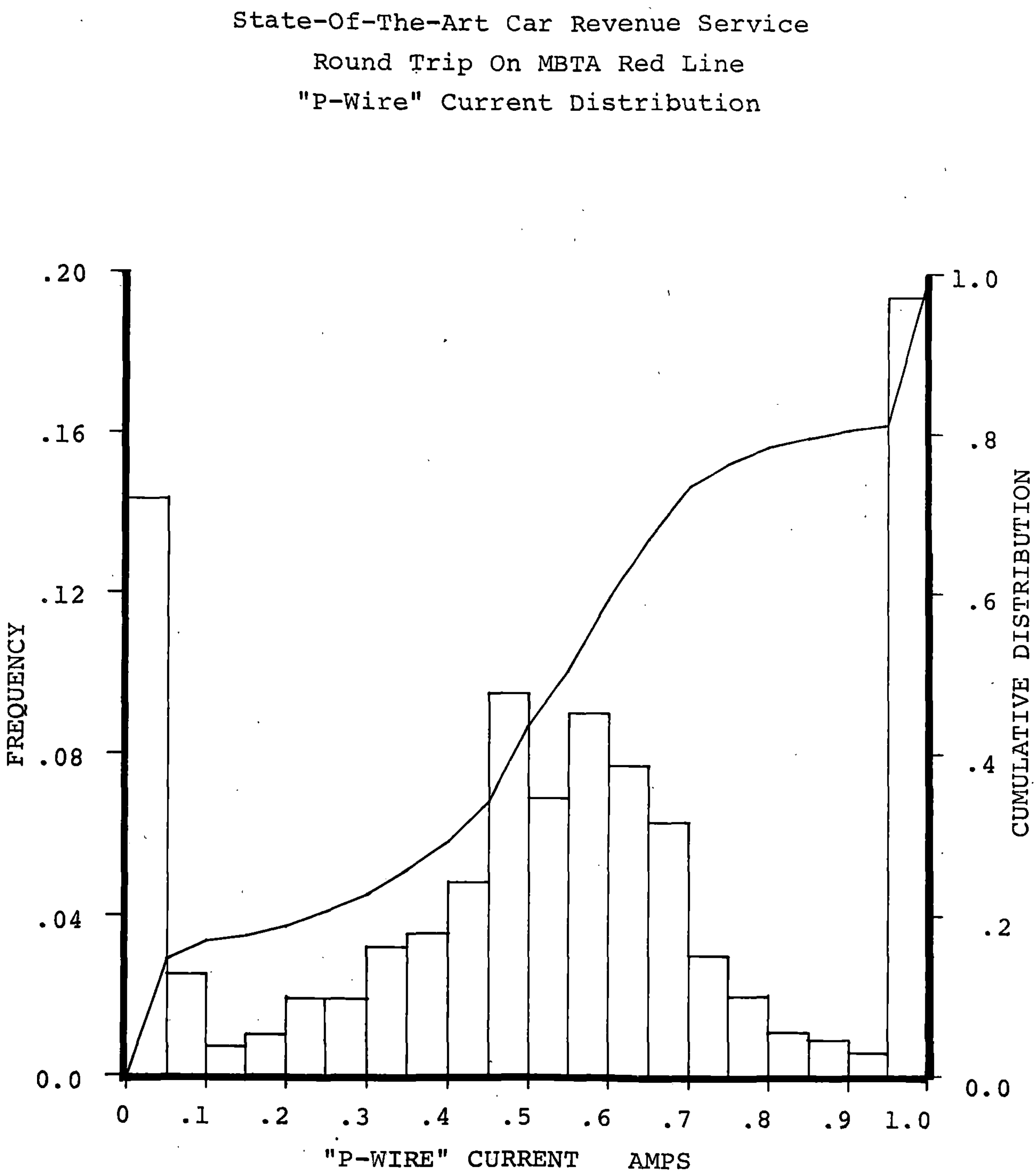


Figure 5–1. "P-Wire" Current Distribution

State-Of-The-Art Car Revenue Service
Round Trip On MBTA Red Line
Vehicle Speed Distribution

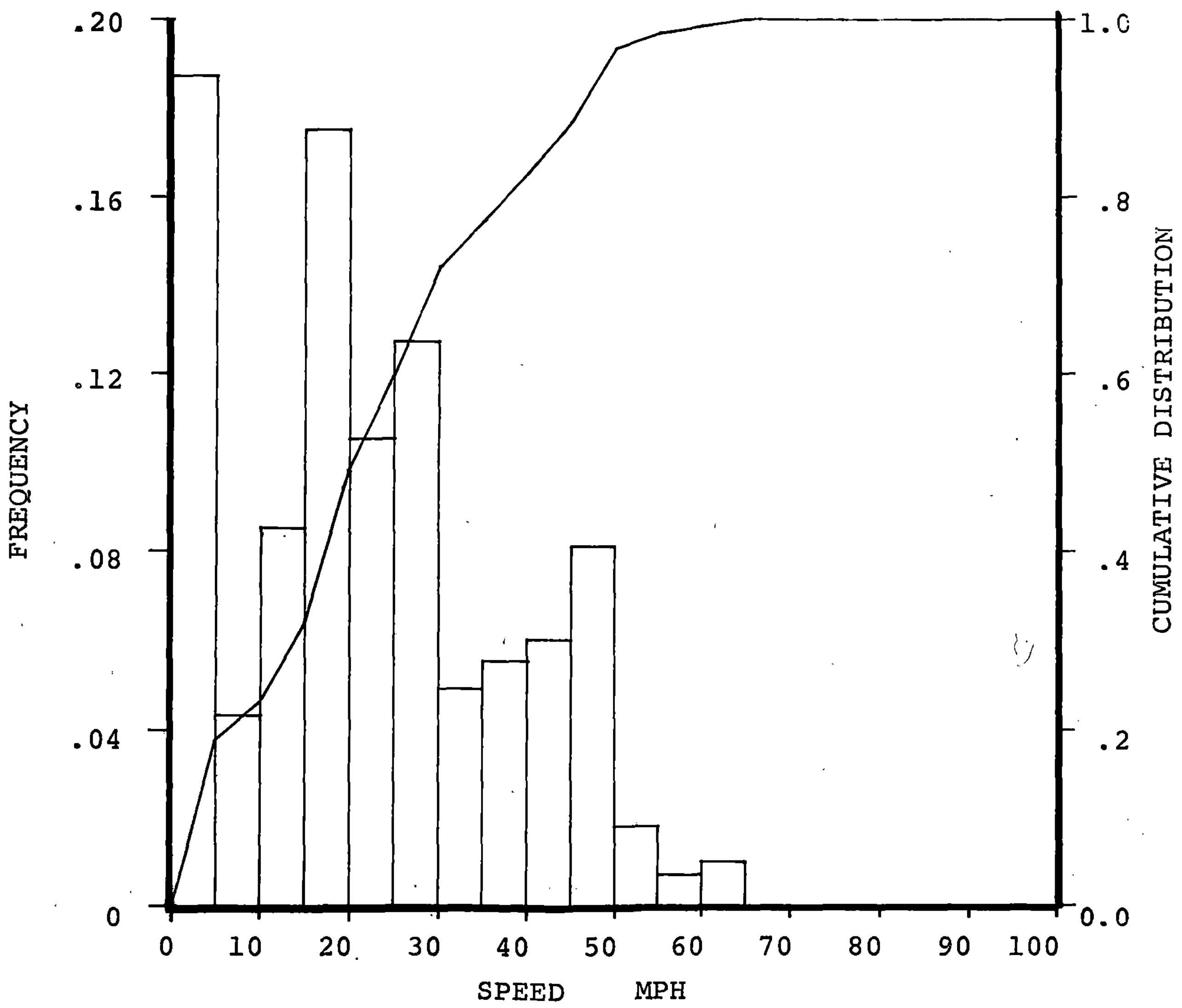


Figure 5–2. Vehicle Speed Distribution

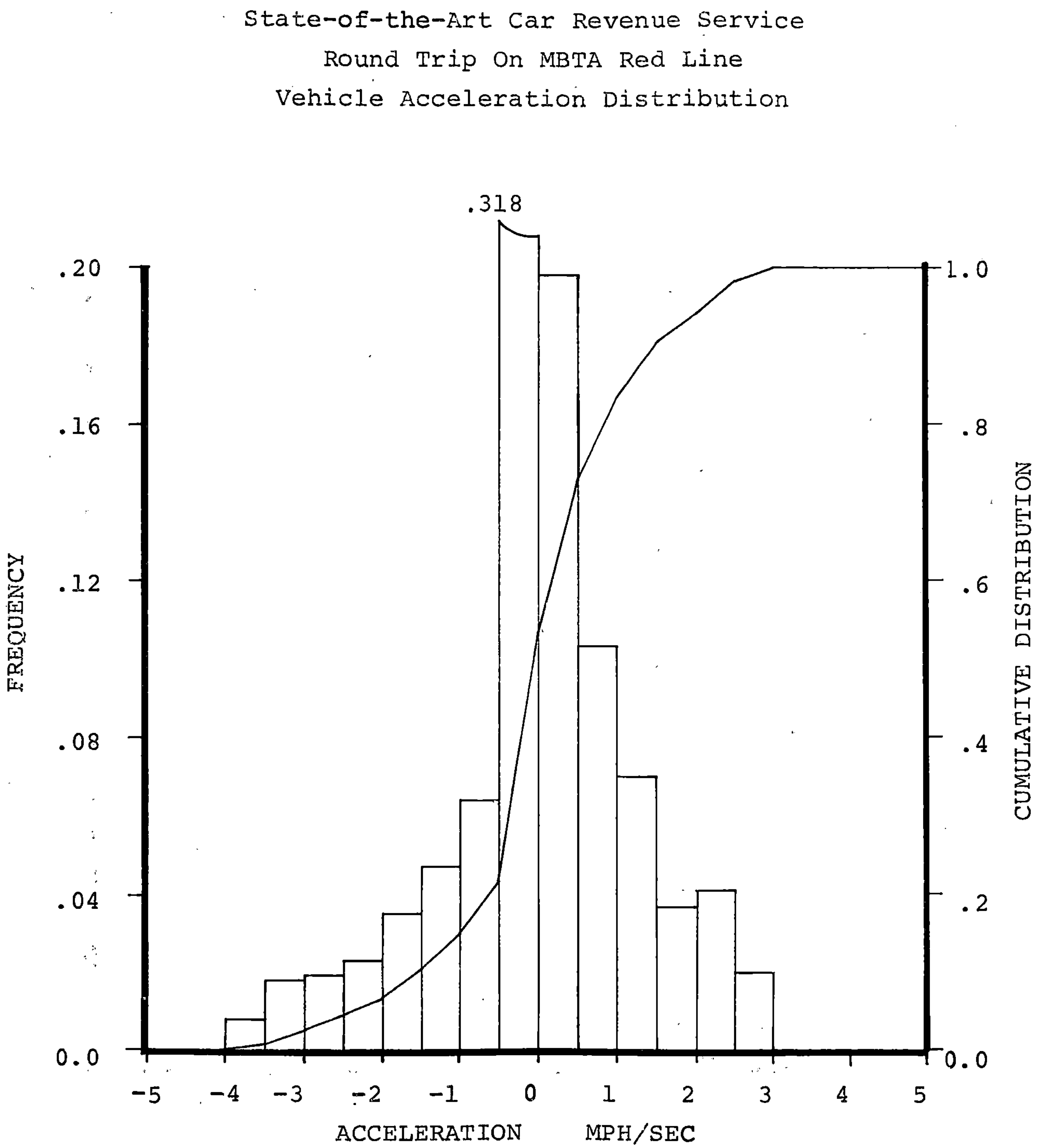


Figure 5–3. Vehicle Acceleration Distribution

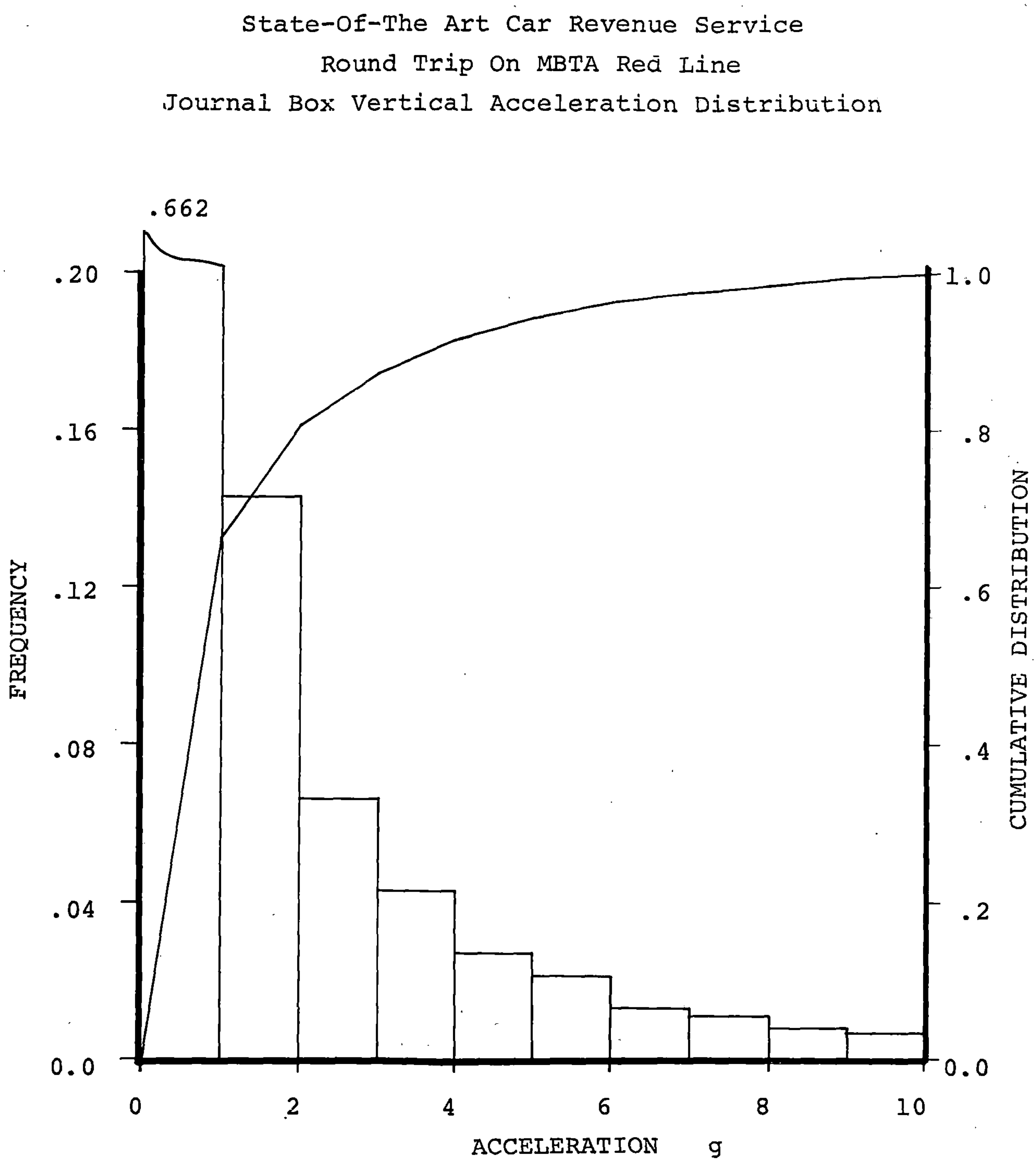


Figure 5–4. Journal Box Vertical Acceleration Distribution

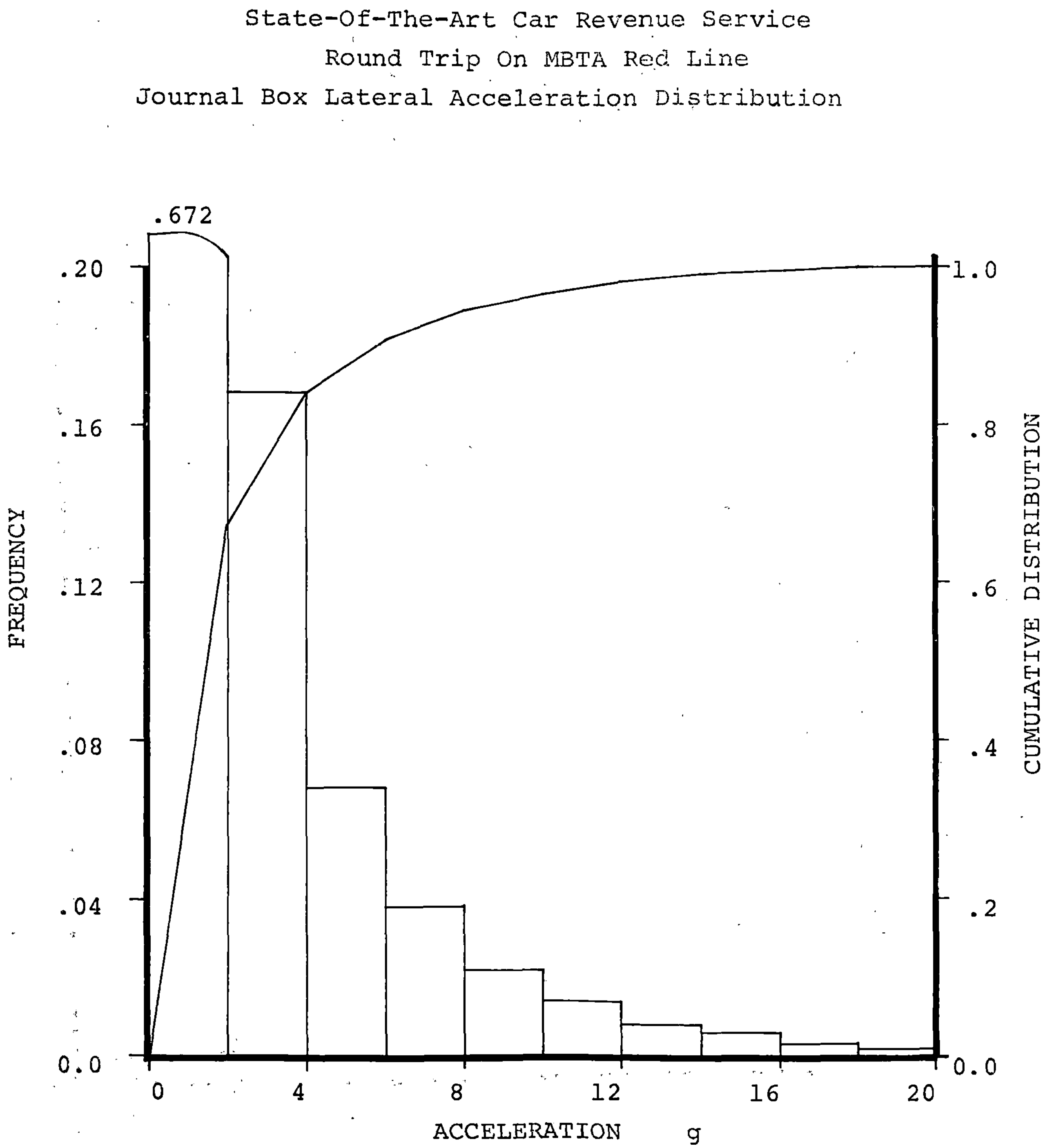


Figure 5–5. Journal Box Lateral Acceleration Distribution

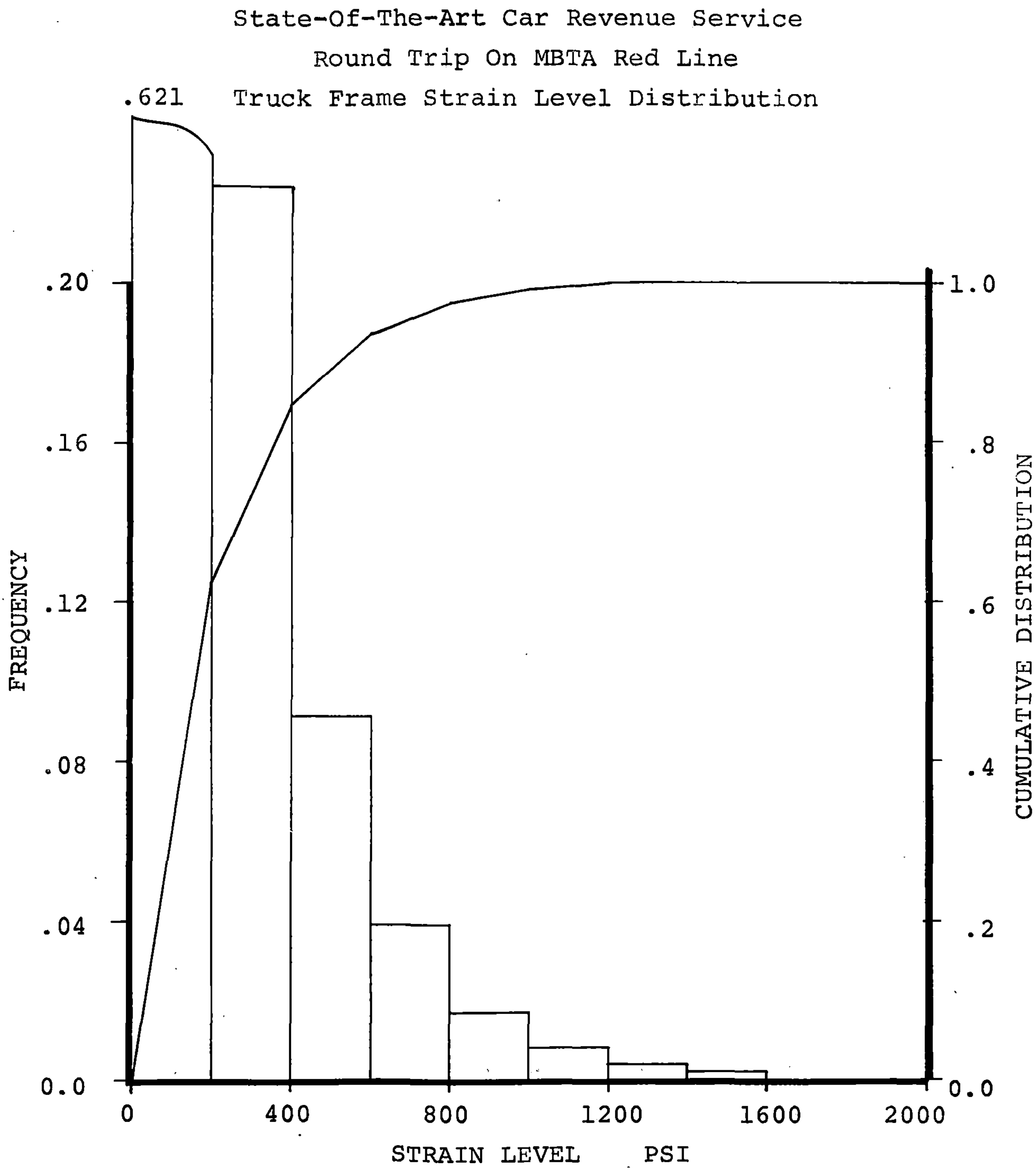


Figure 5–6. Truck Frame Strain Level Distribution

State-Of-The-Art Car Revenue Service
Round Trip On MBTA Red Line
Longitudinal Ride Roughness Distribution

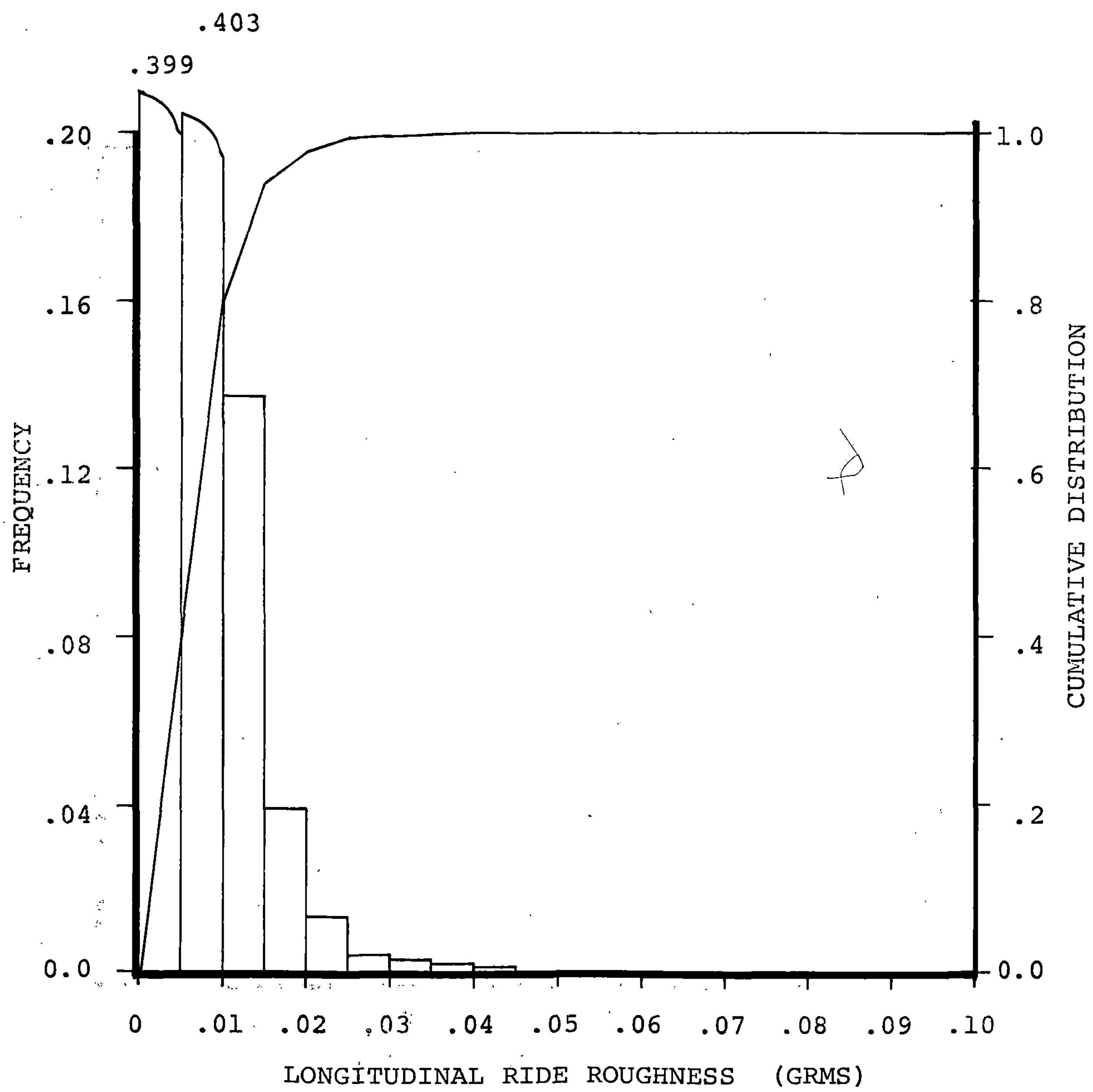


Figure 5–7. Longitudinal Ride Roughness Distribution

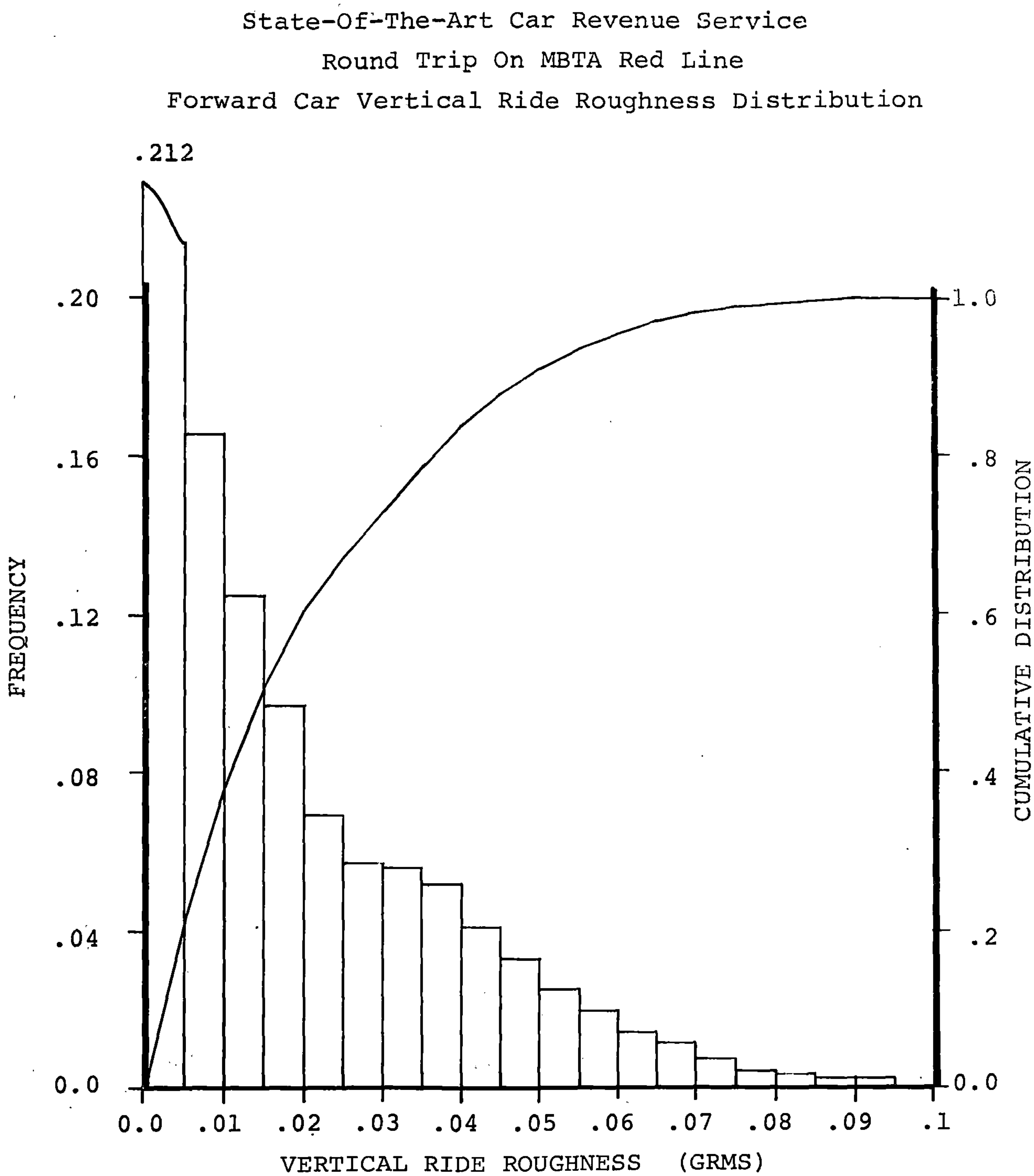


Figure 5–8. Forward Car Vertical Ride Roughness Distribution

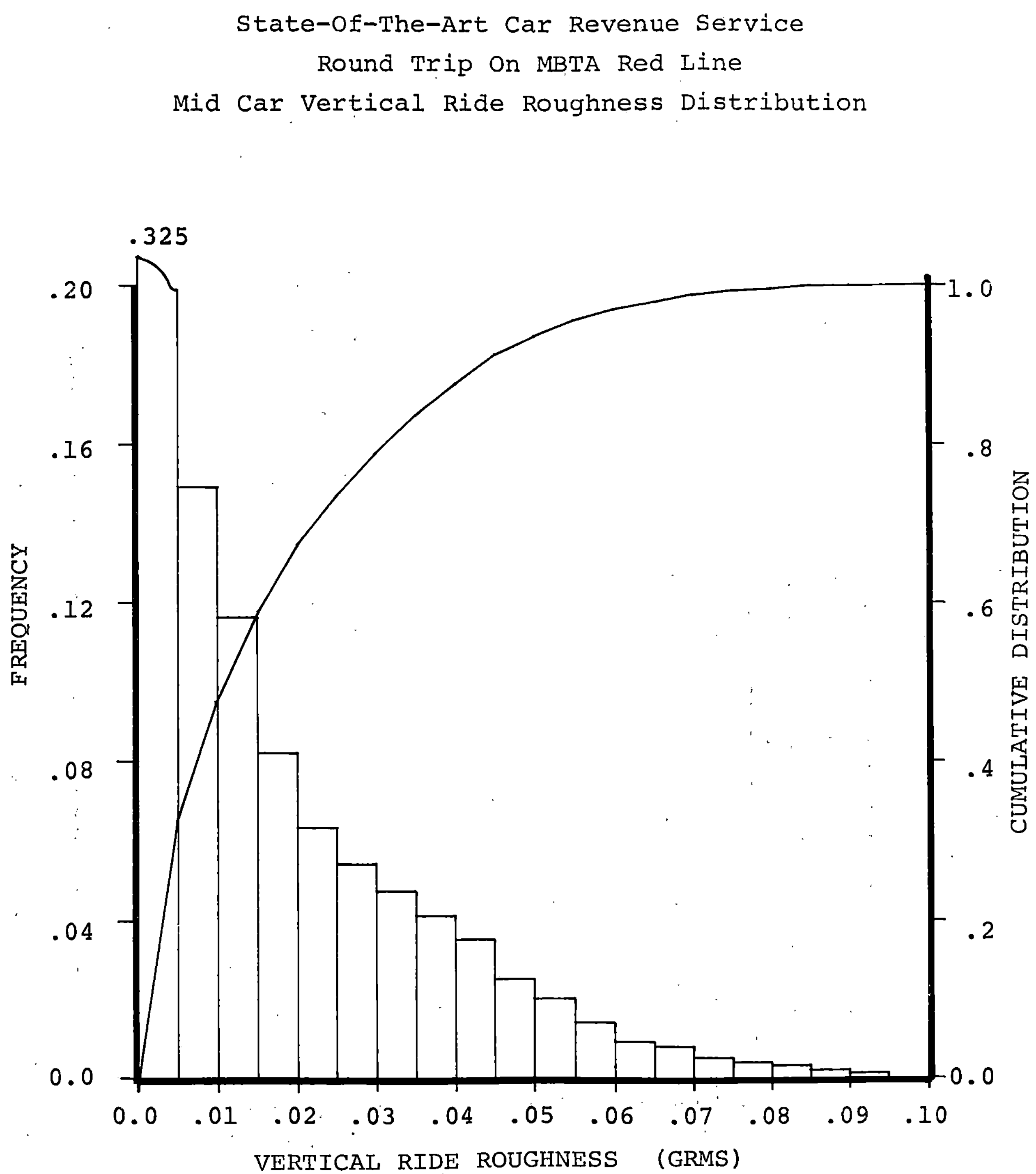


Figure 5–9. Mid-Car Vertical Ride Roughness Distribution

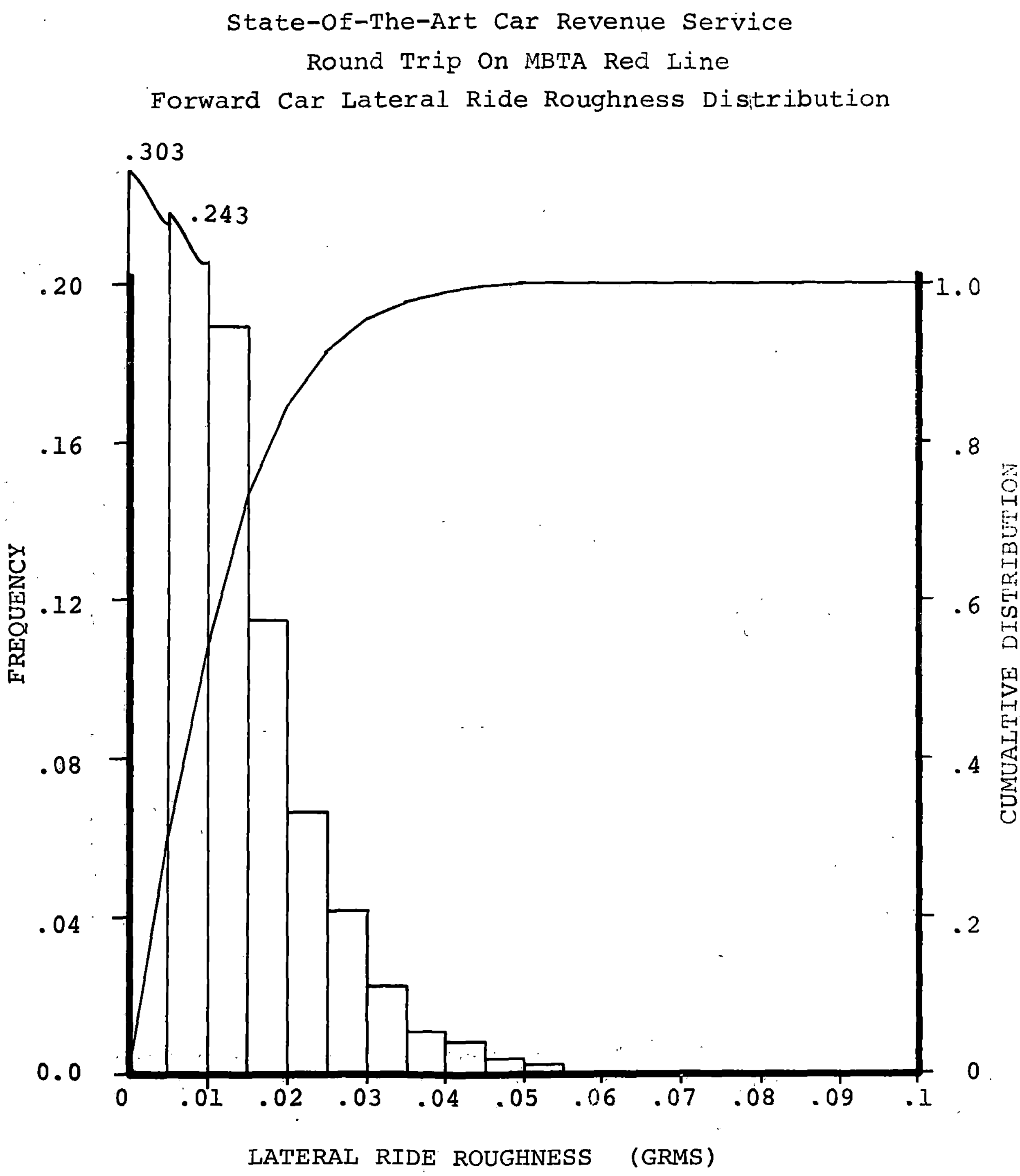


Figure 5–10. Forward Car Lateral Ride Roughness Distribution

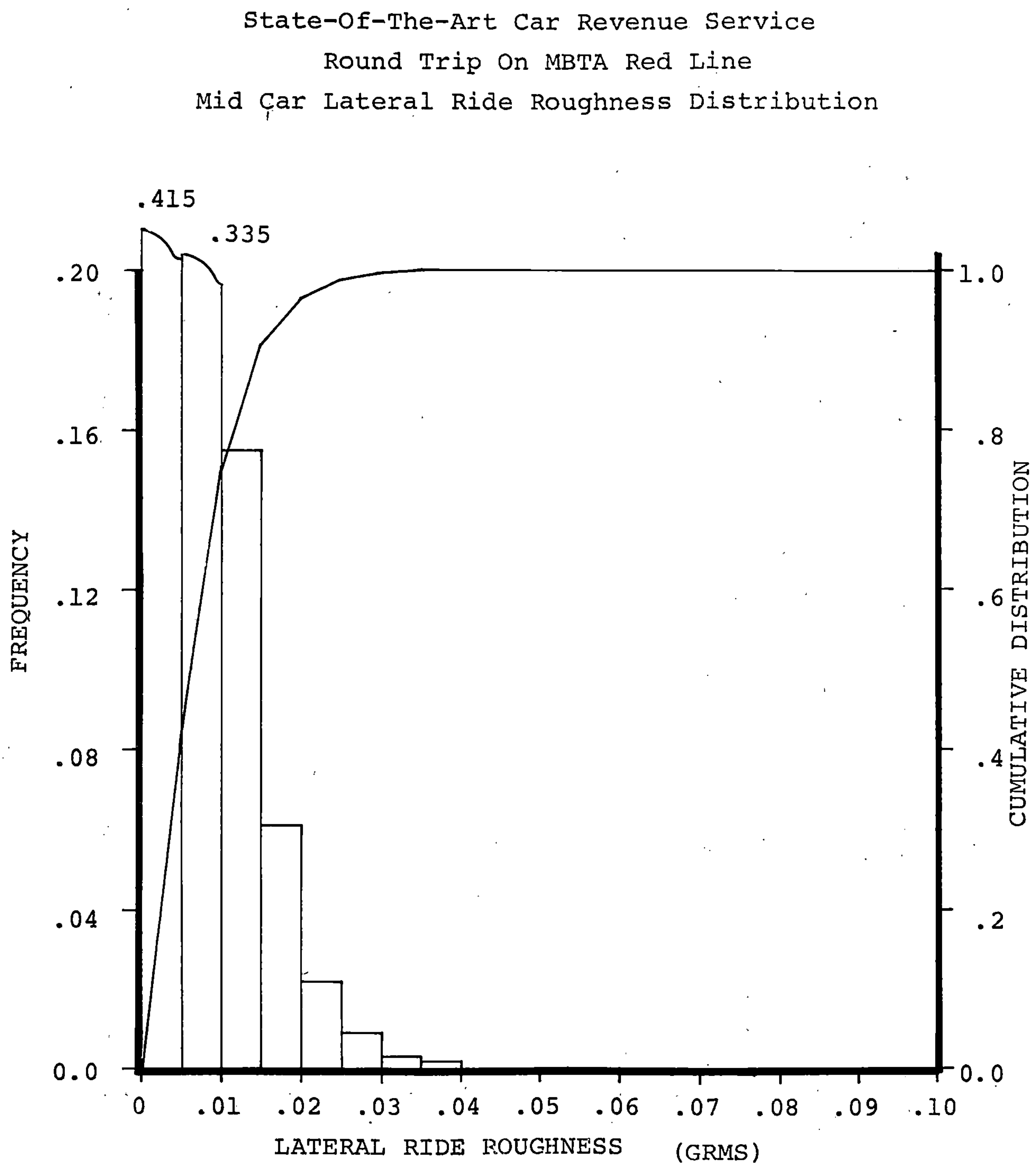


Figure 5—11. Mid-Car Lateral Ride Roughness Distribution

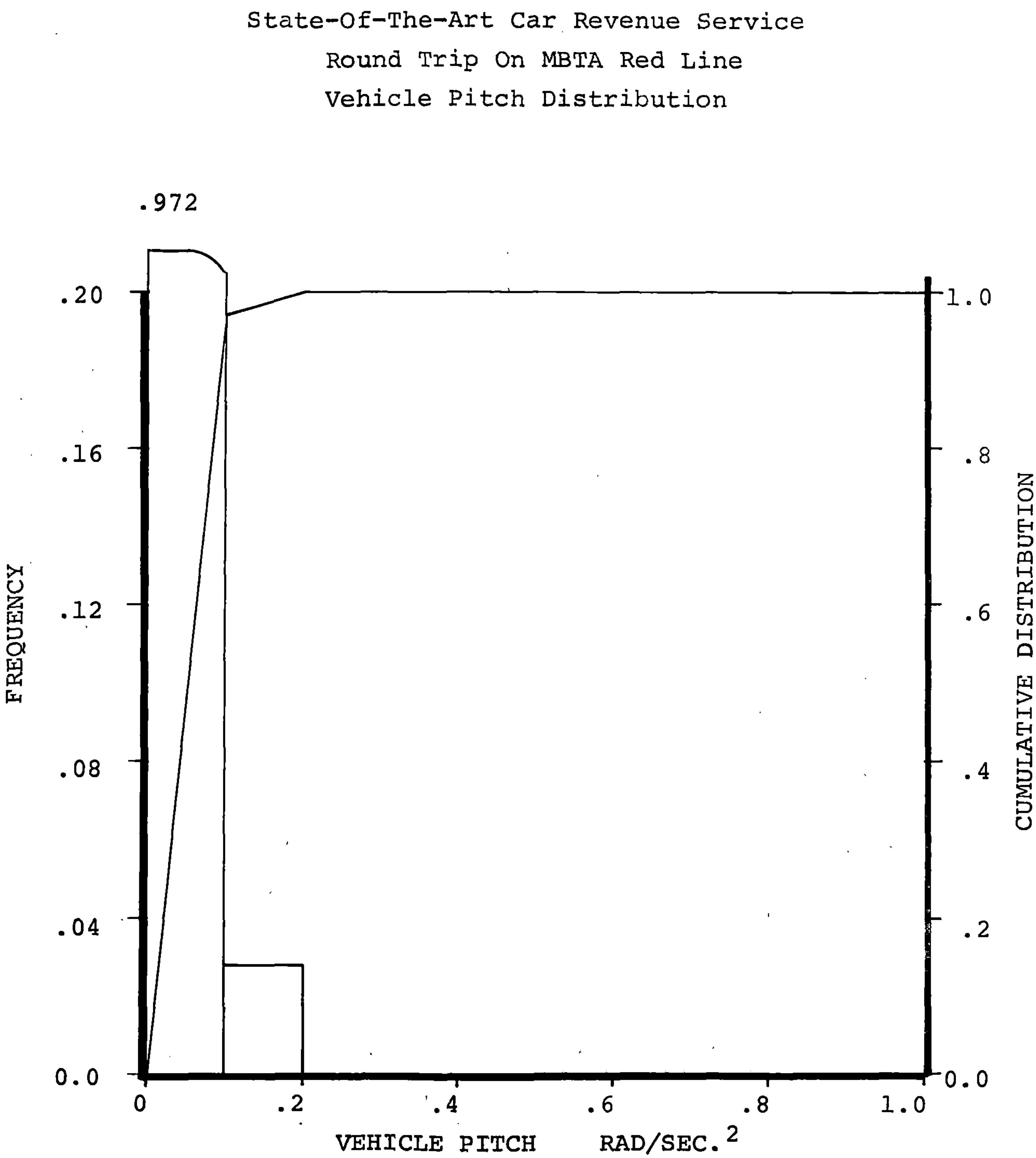


Figure 5–12. Vehicle Pitch Distribution

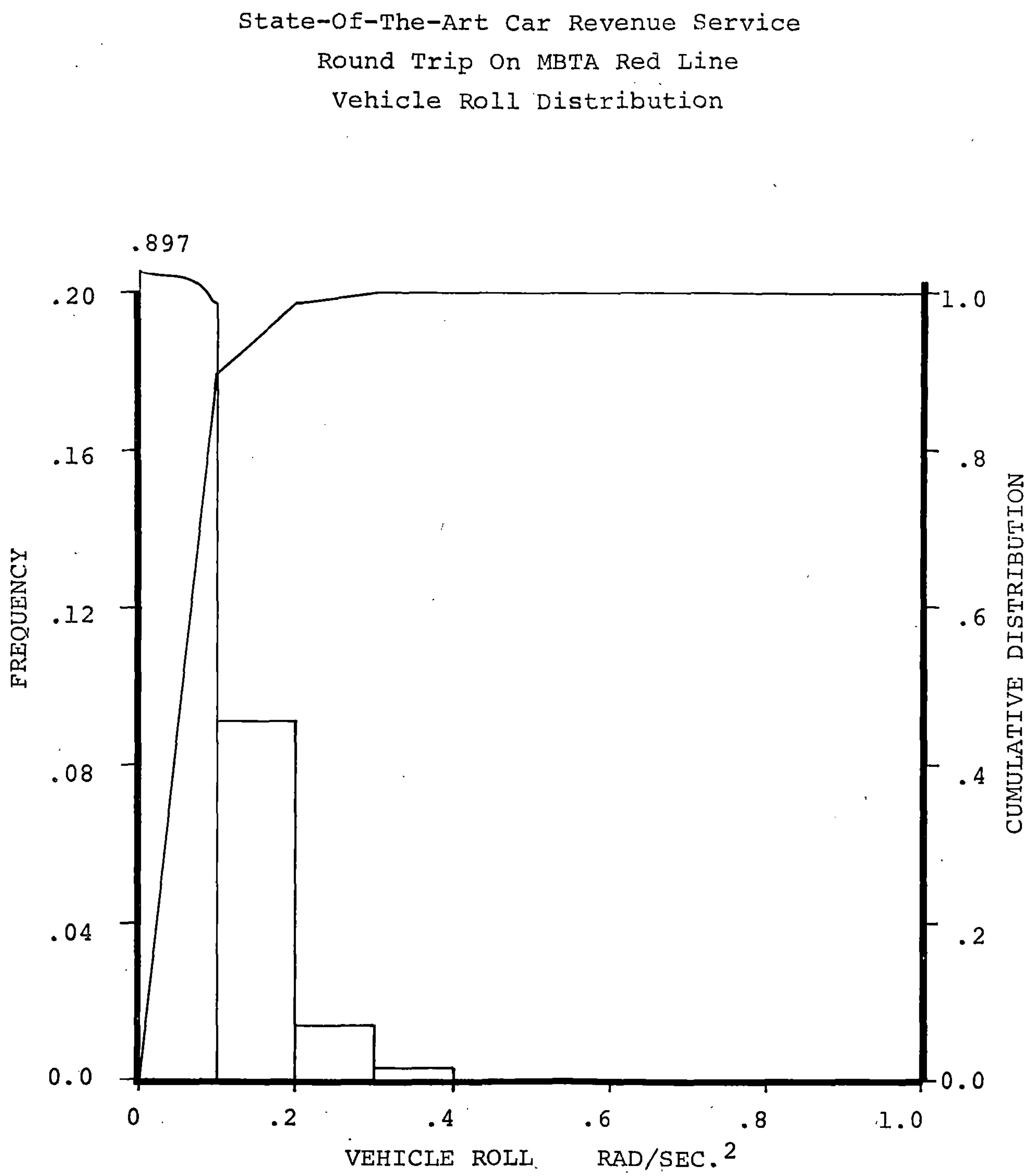


Figure 5–13. Vehicle Roll Distribution

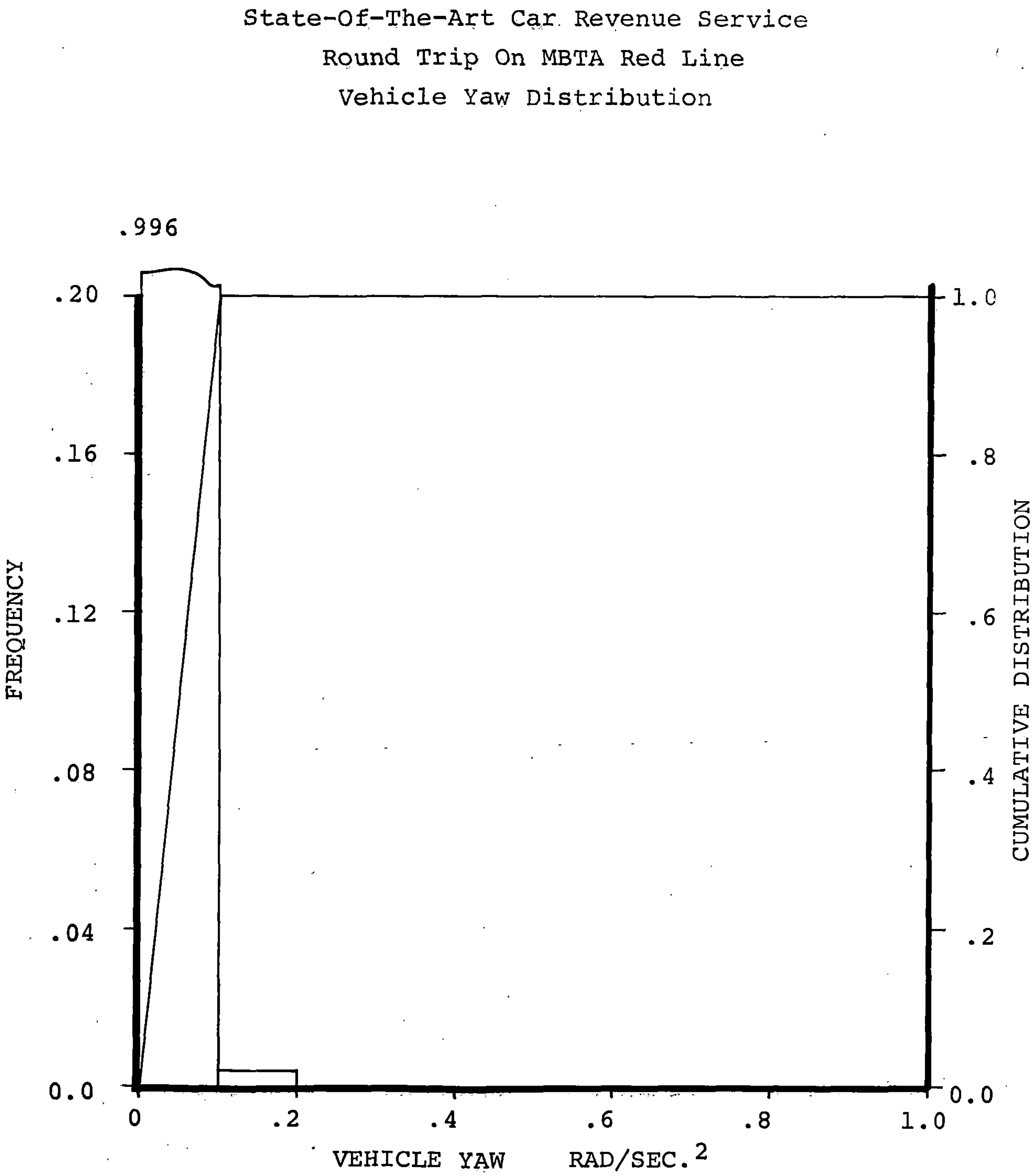


Figure 5–14. Vehicle Yaw Distribution

State-Of-The-Art Car
Revenue Service On The MBTA Red Line
Interior Noise Level Distribution

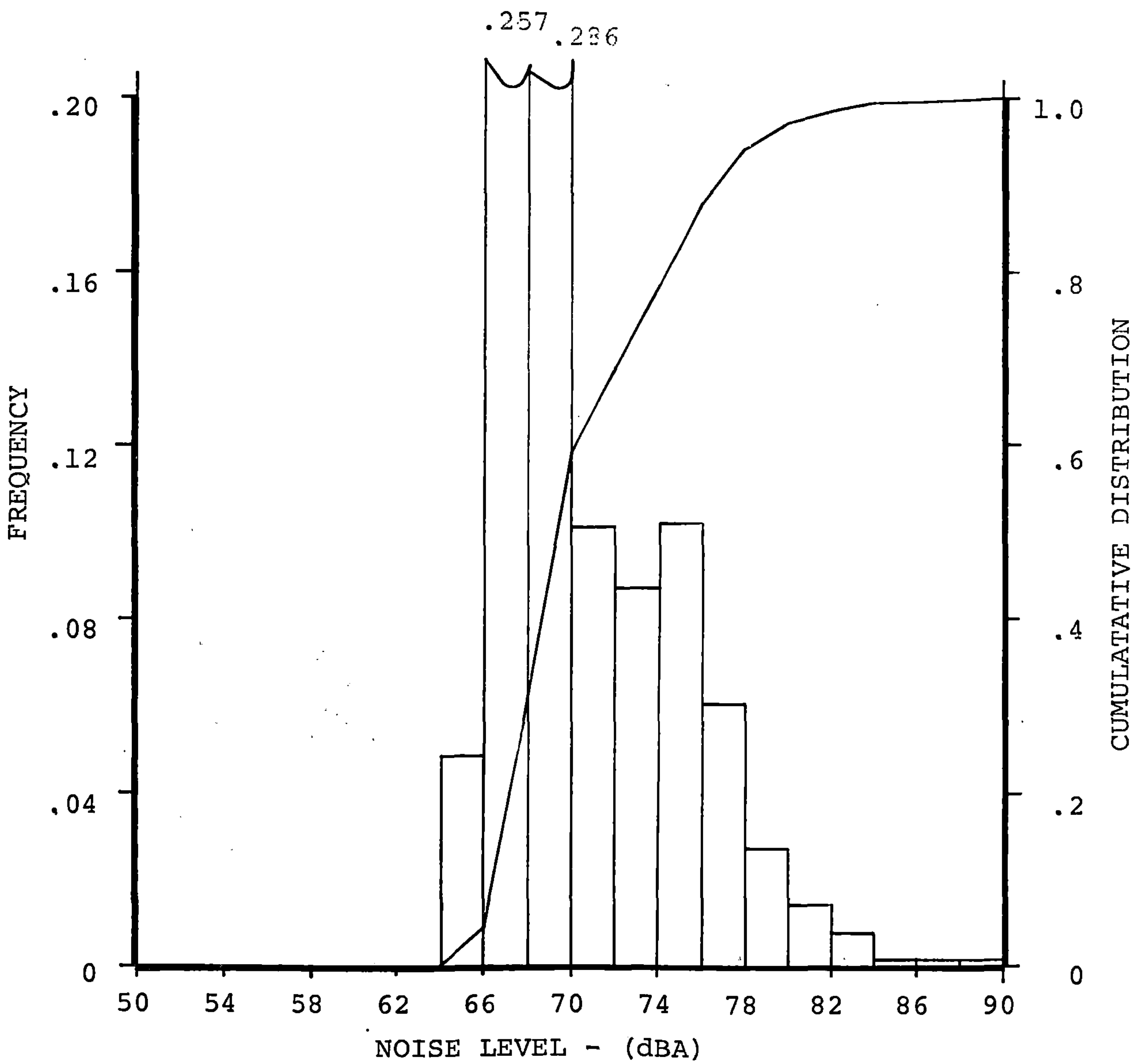


Figure 5–15. Interior Noise Level Distribution

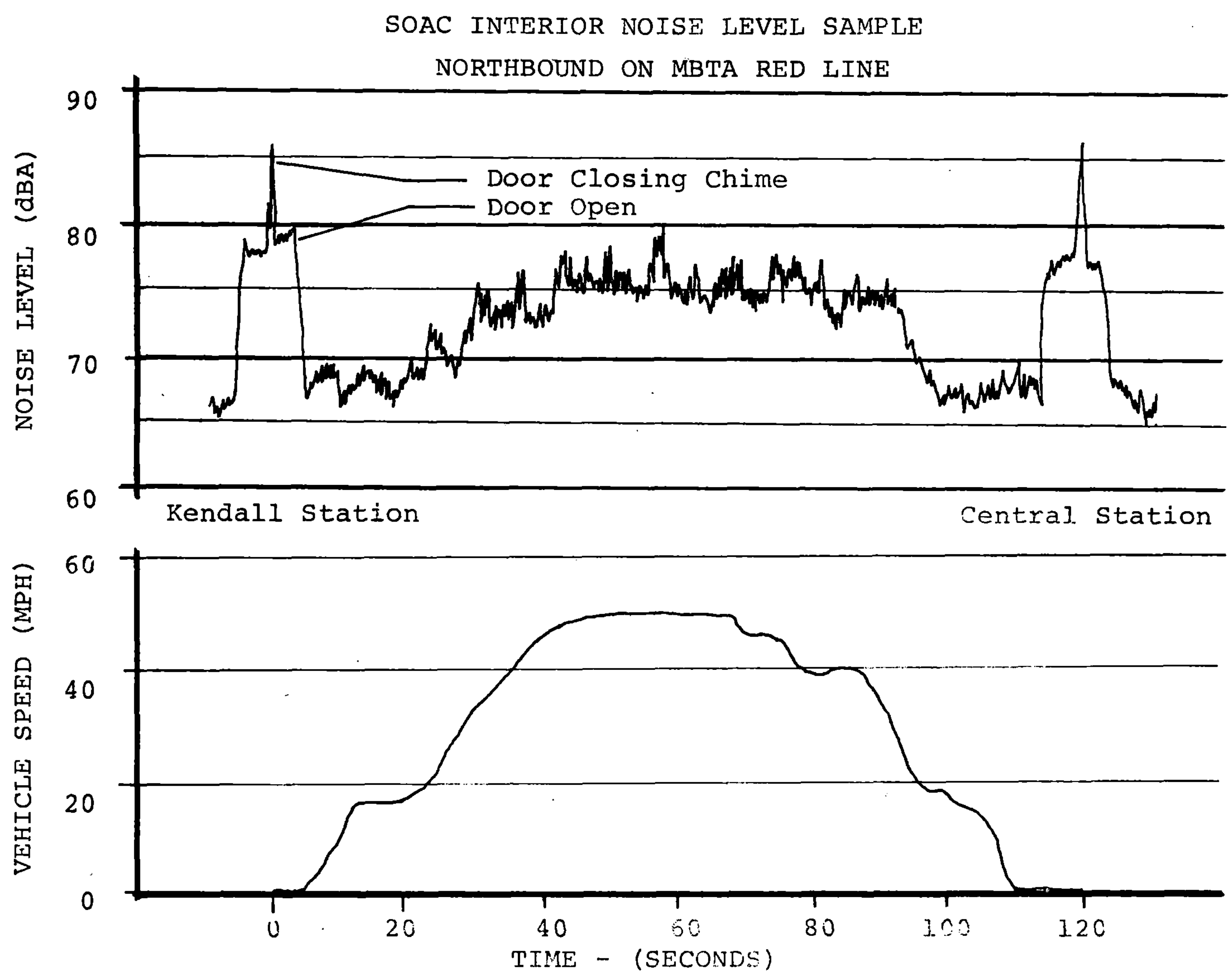


Figure 5–16. Interior Noise Level Sample Time History Chart

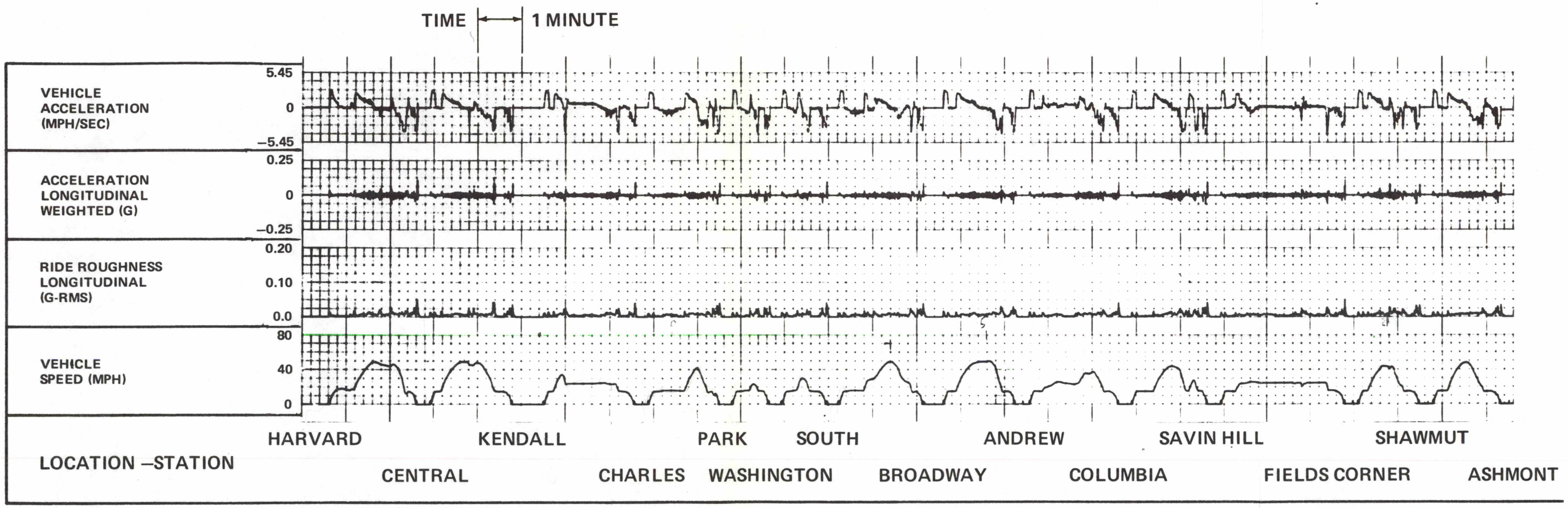


Figure 5–17. Vehicle Acceleration and Speed Time History Chart (H–A)

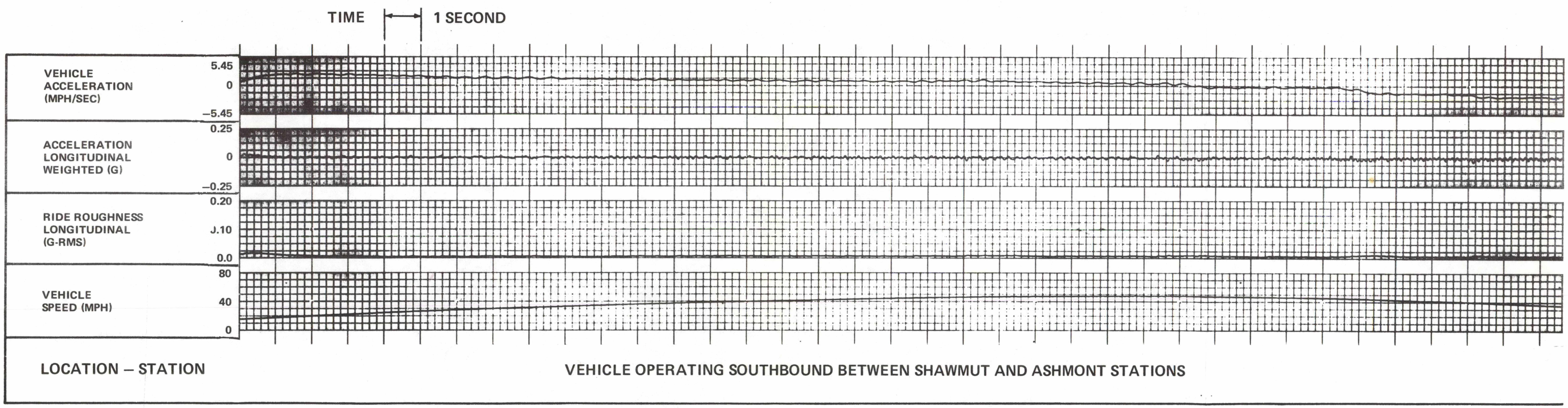


Figure 5—18. Vehicle Acceleration and Speed Time History Chart (~)

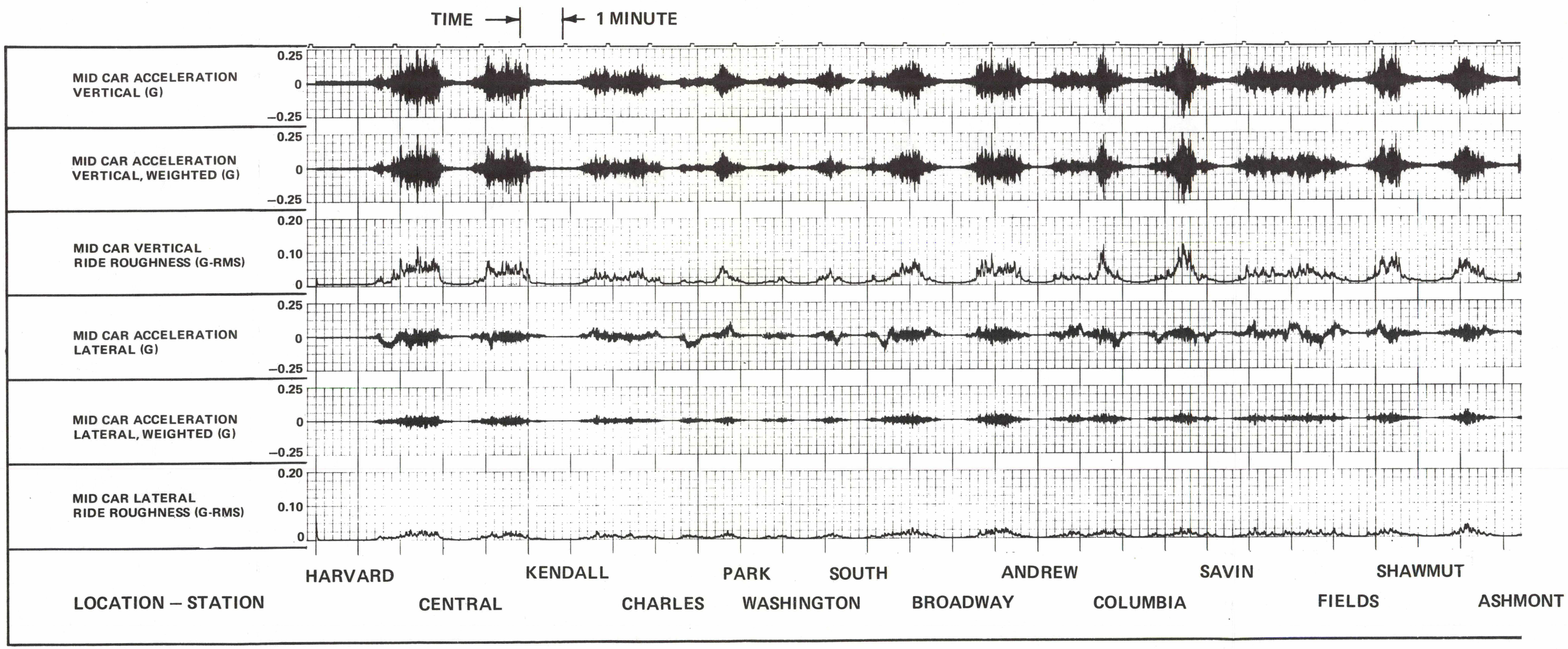


Figure 5–19. Mid-Car Acceleration Time History Chart (H–A)

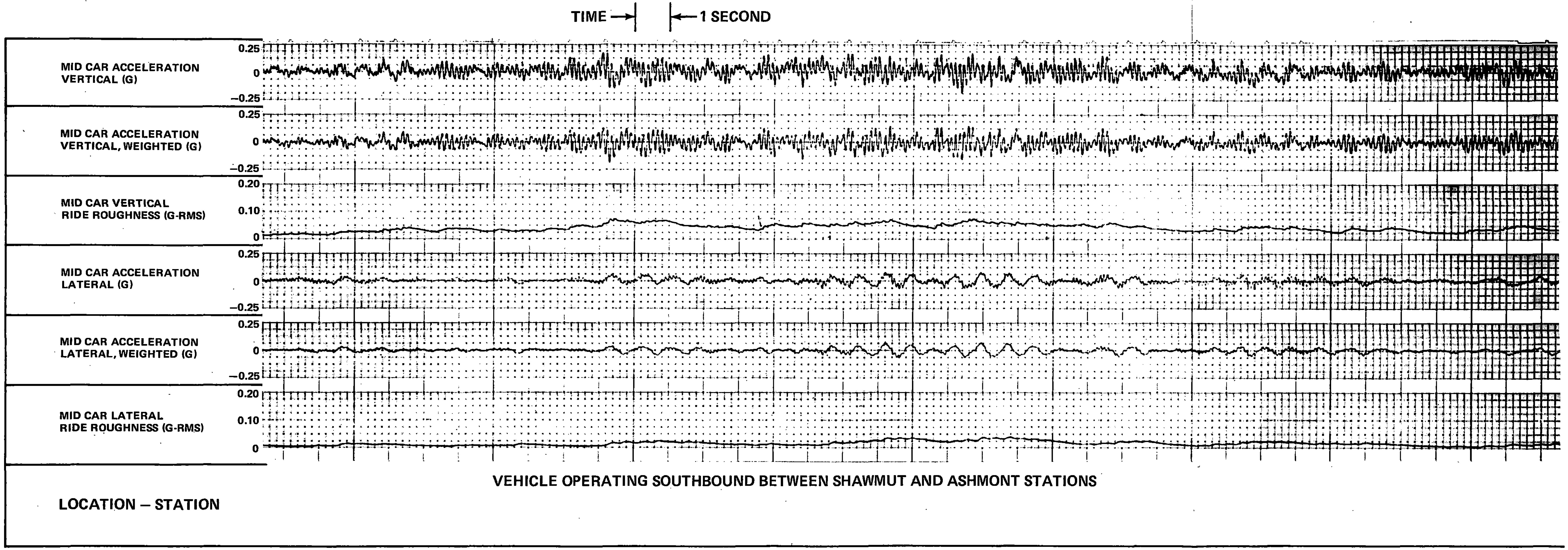


Figure 5–20. Mid-Car Acceleration Time History Chart (~)

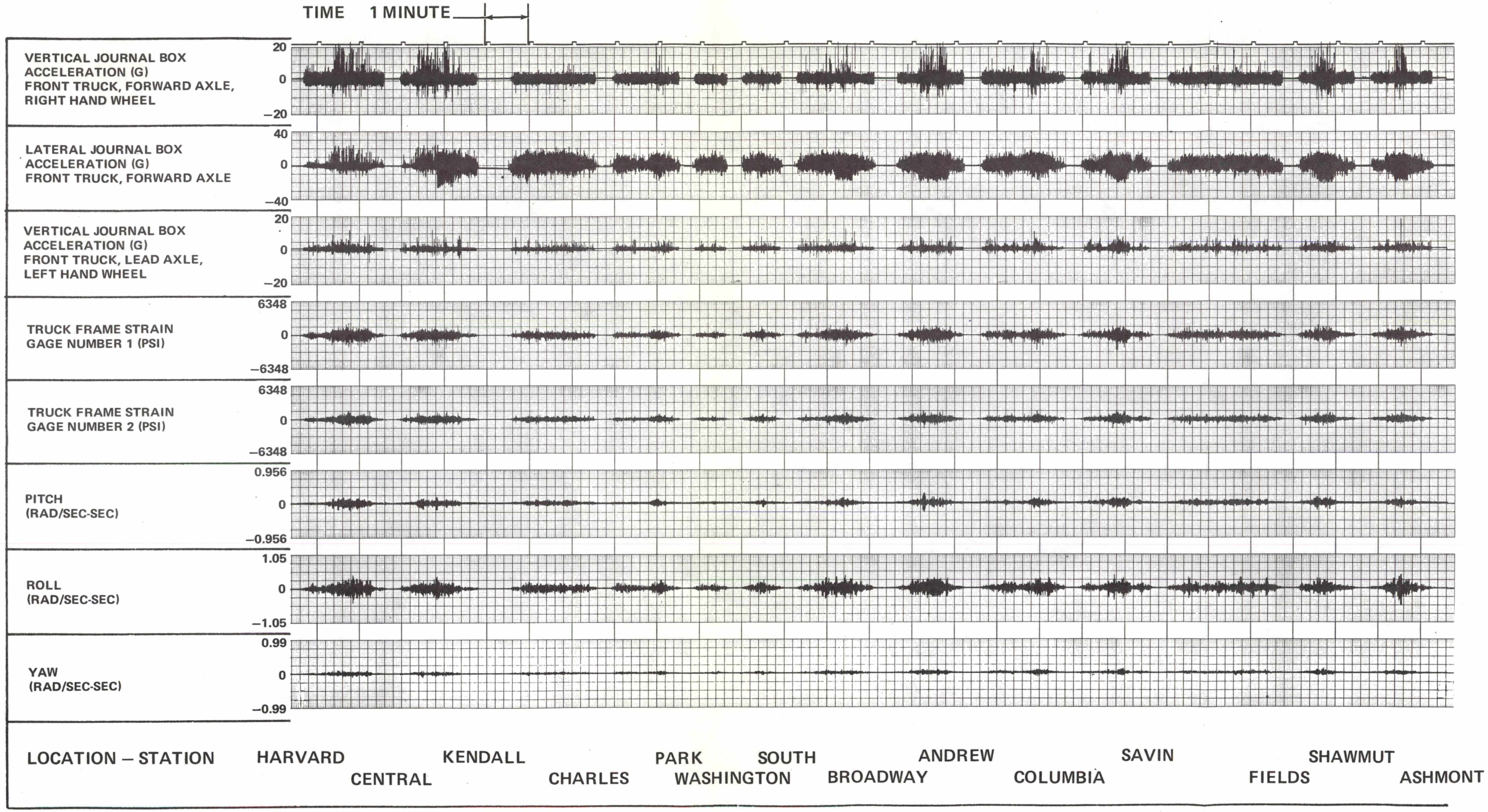


Figure 5–21. Journals, Truck Frame, and Angular Acceleration Time History Chart (H–A)

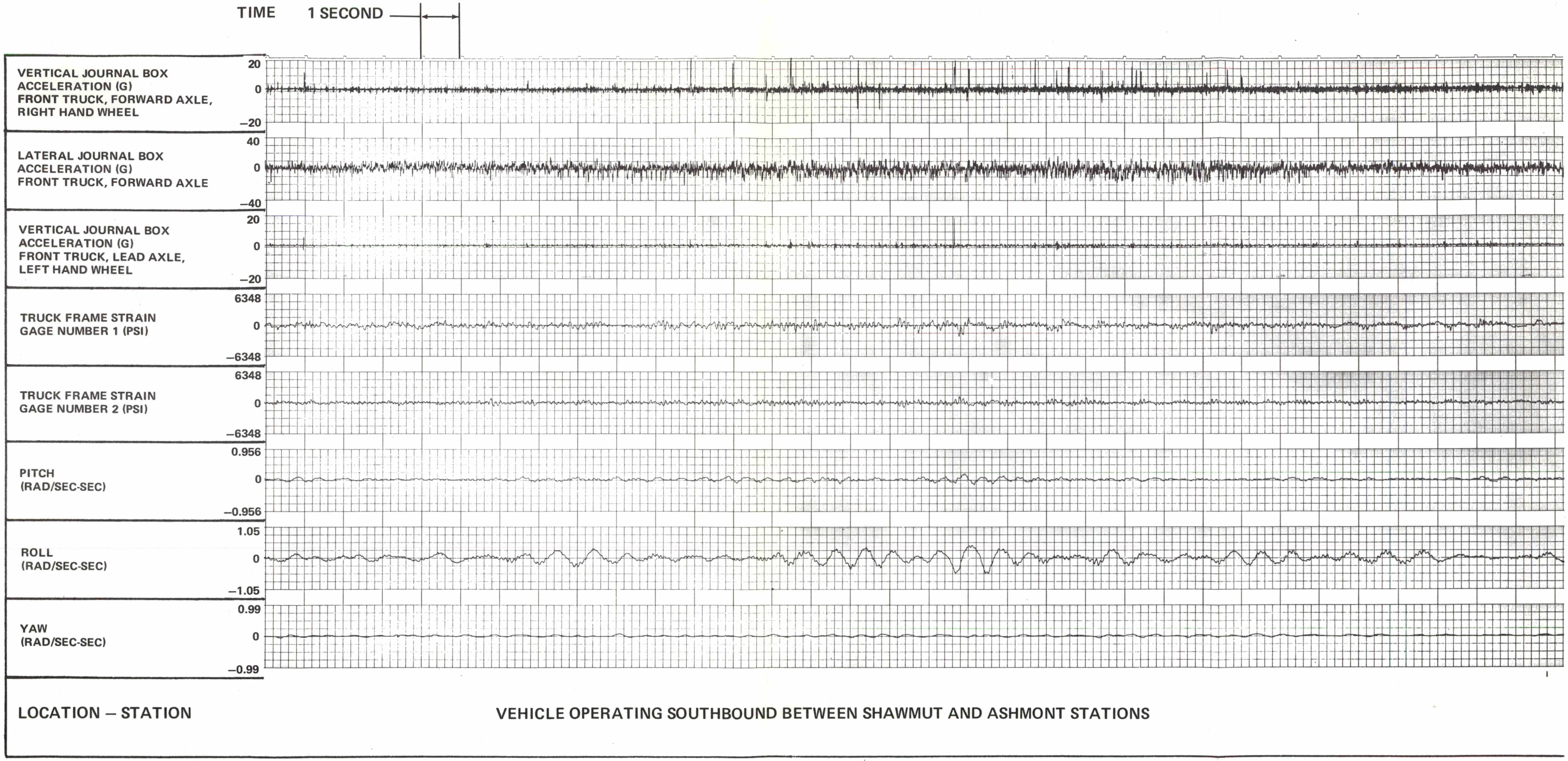


Figure 5–22. Journals, Truck Frame, and Angular Acceleration Time History Chart (~)

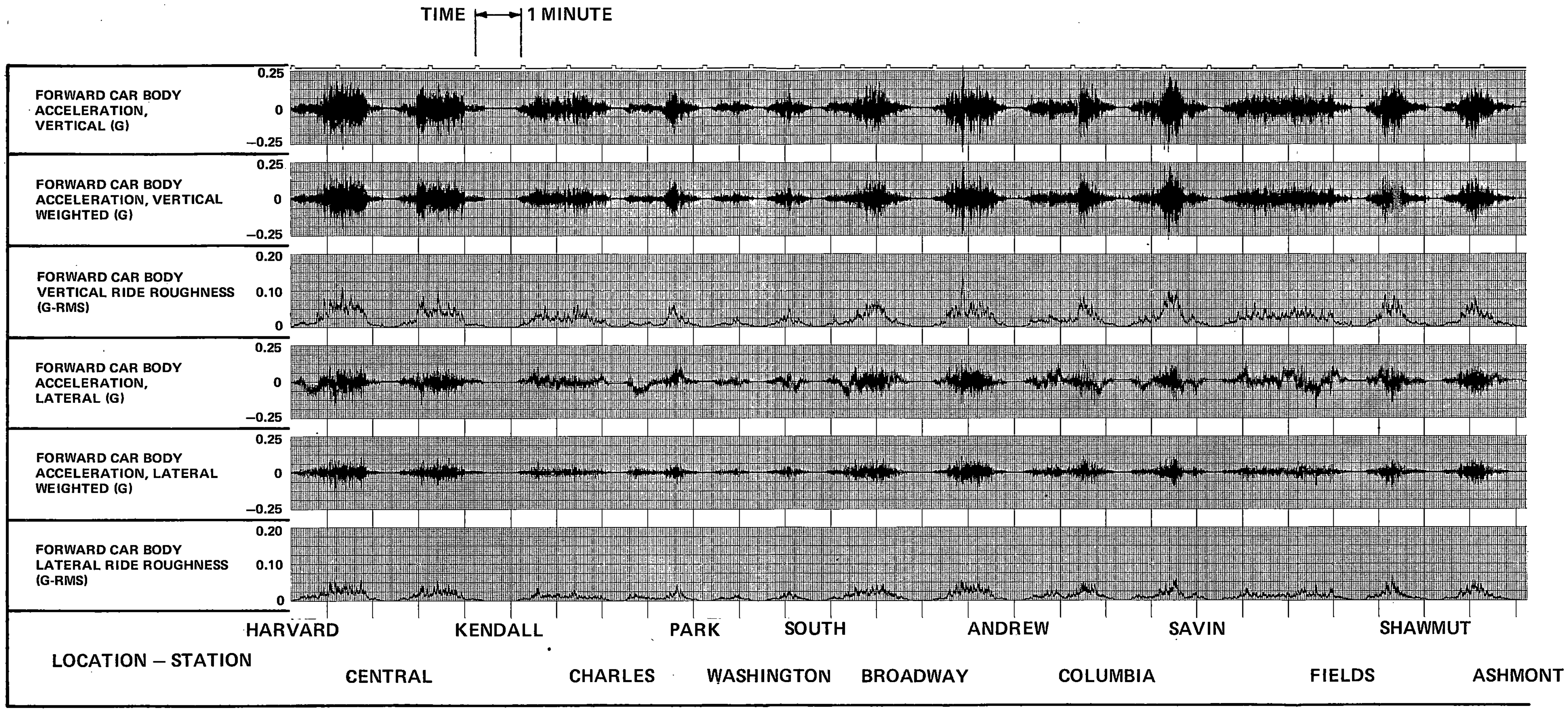


Figure 5–23. Forward Car Acceleration Time History Chart (H–A)

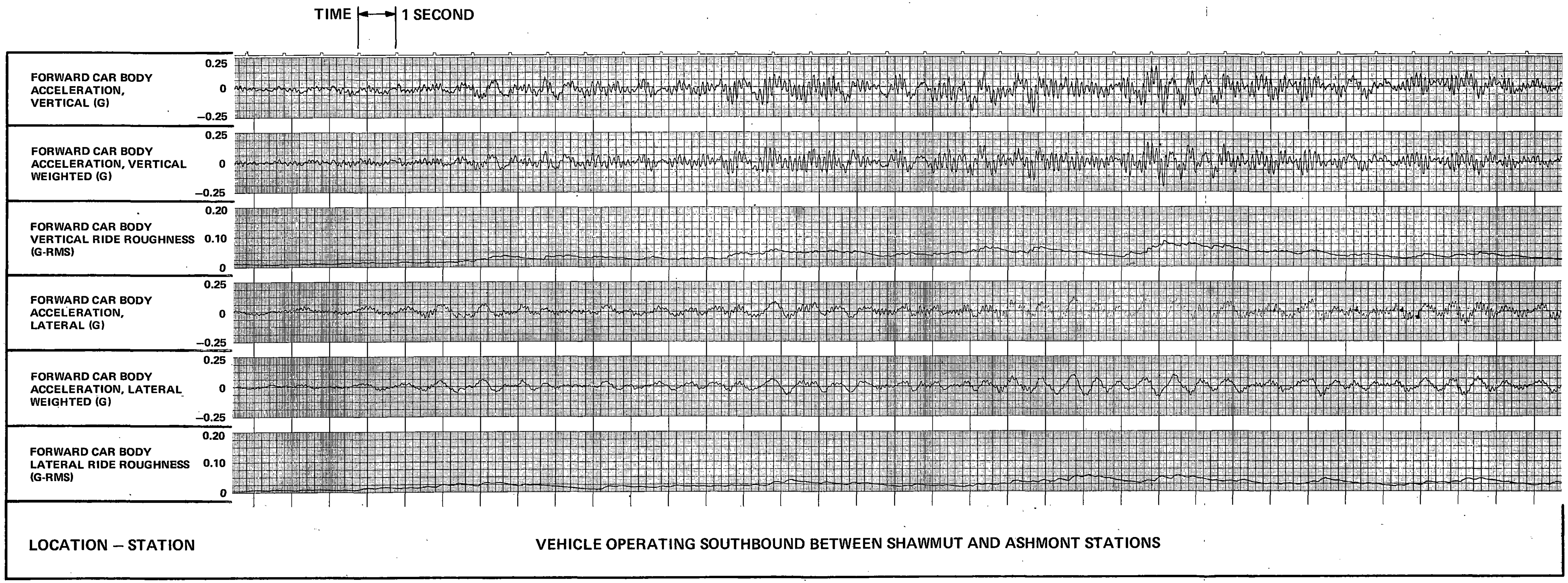


Figure 5–24. Forward Car Acceleration Time History Chart (~)

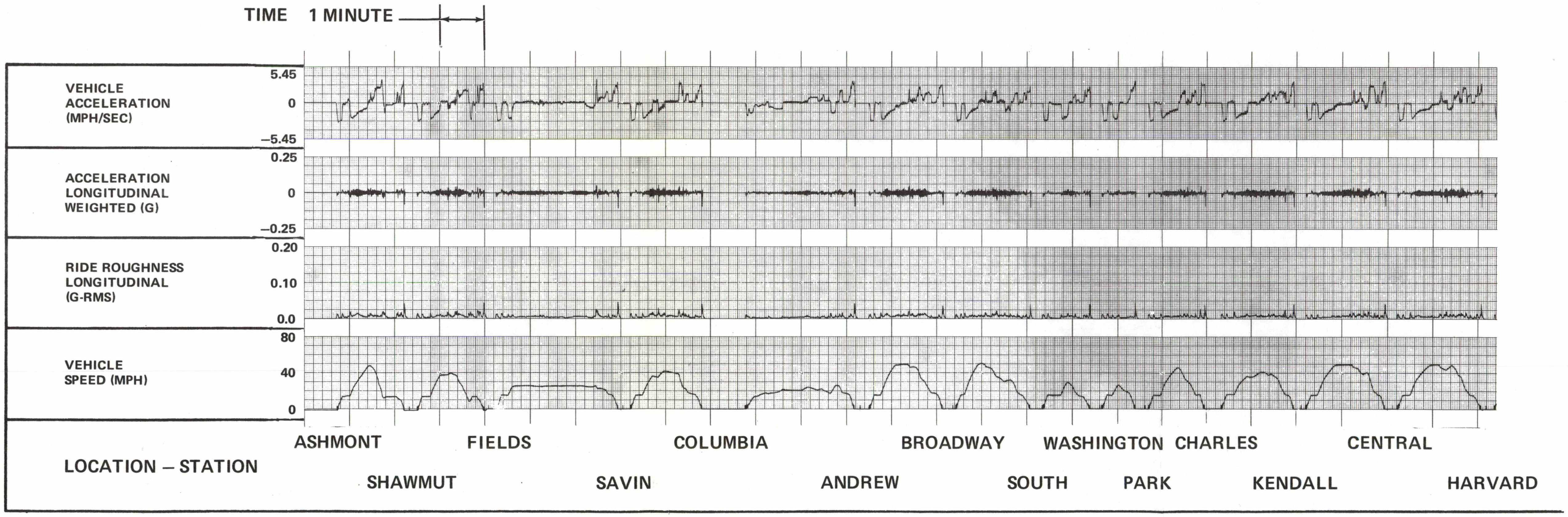


Figure 5–25. Vehicle Acceleration and Speed Time History Chart (A–H)

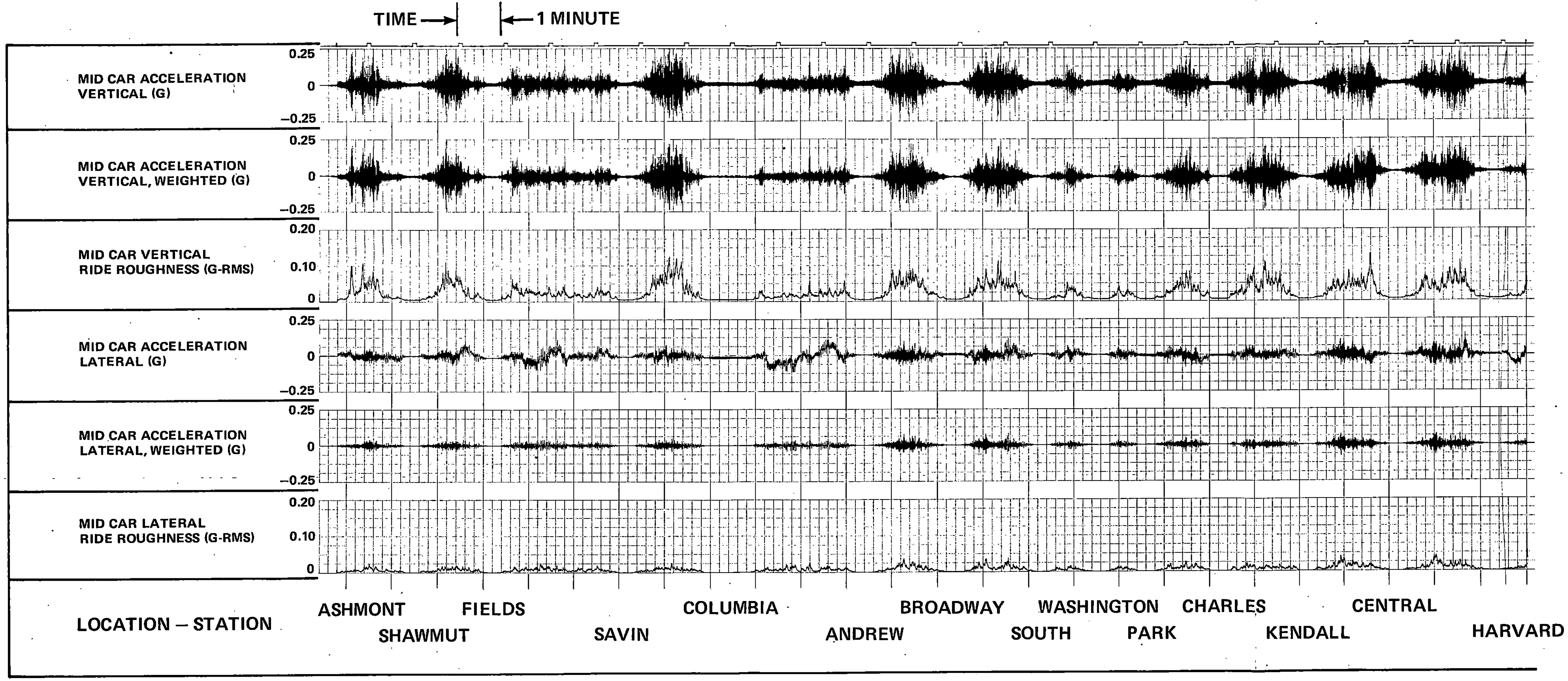


Figure 5–26. Mid-Car Acceleration Time History Chart (A–H)

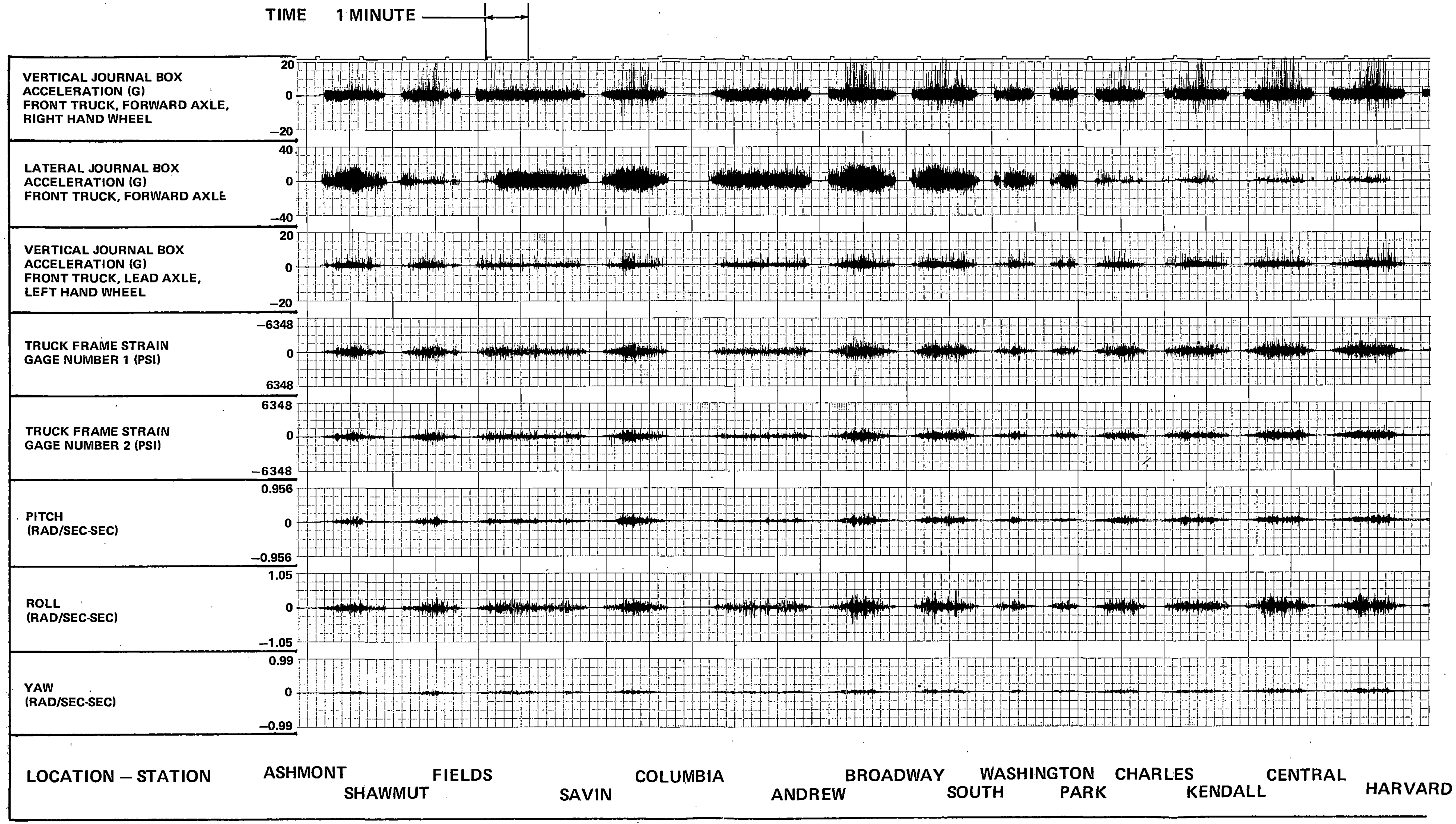


Figure 5–27. Journals, Truck Frame, and Angular Acceleration Time History Chart (A–H)

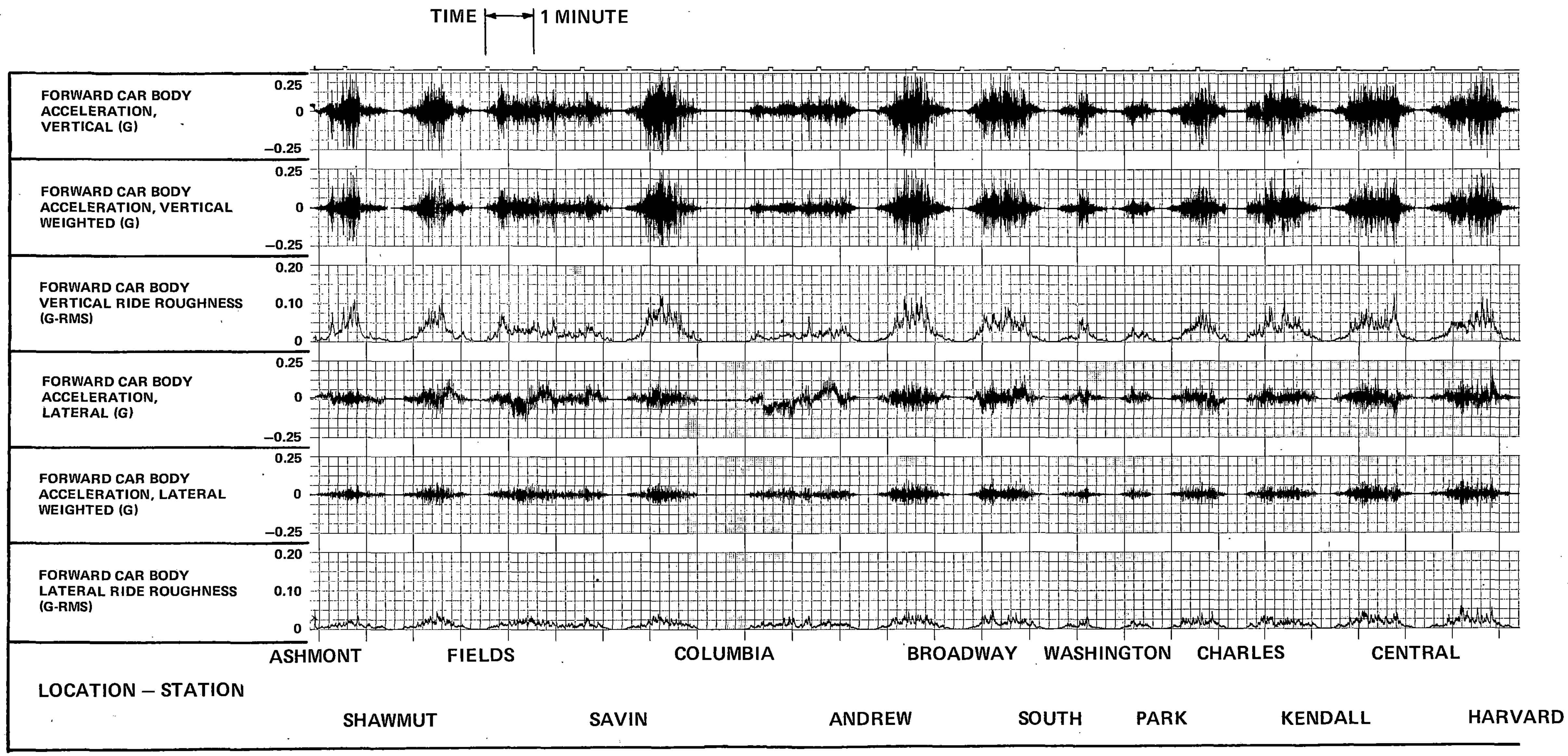


Figure 5–28. Forward Car Acceleration Time History Chart (A–H)

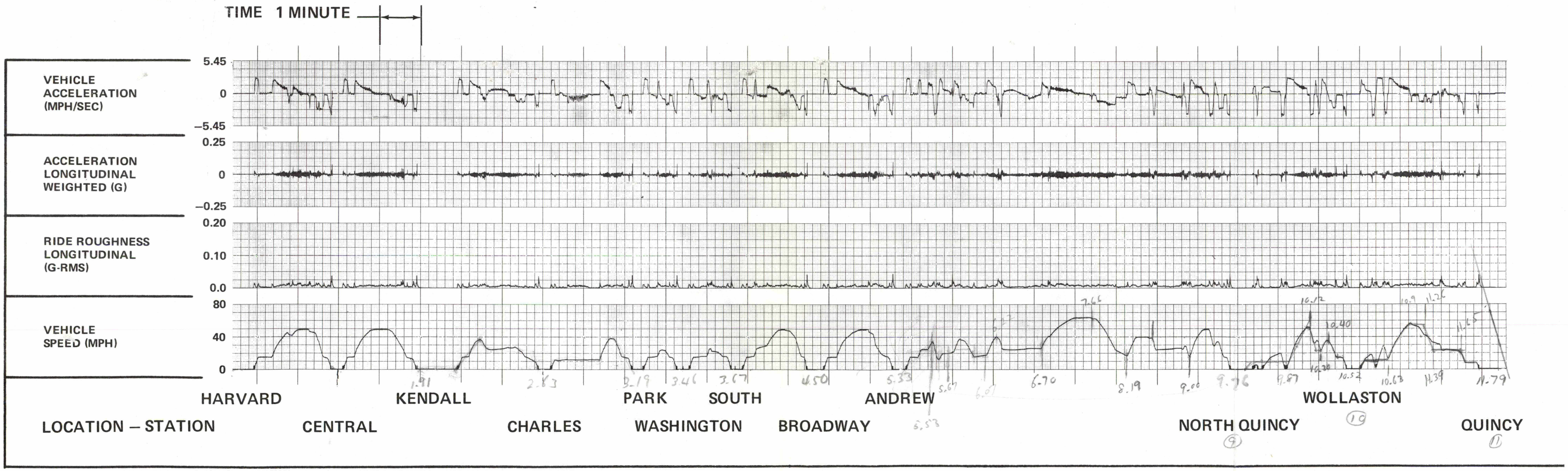


Figure 5–29. Vehicle Acceleration and Speed Time History Chart (H–Q)

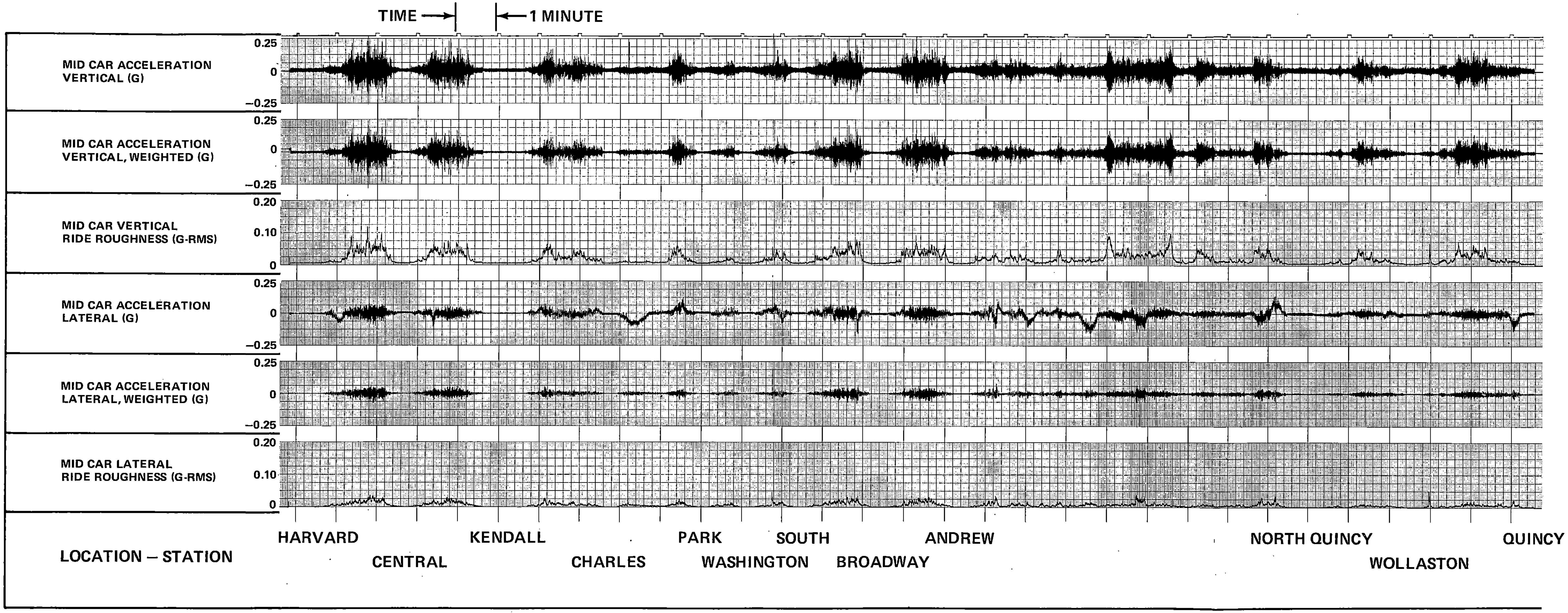


Figure 5–30. Mid-Car Acceleration Time History Chart (H–Q)

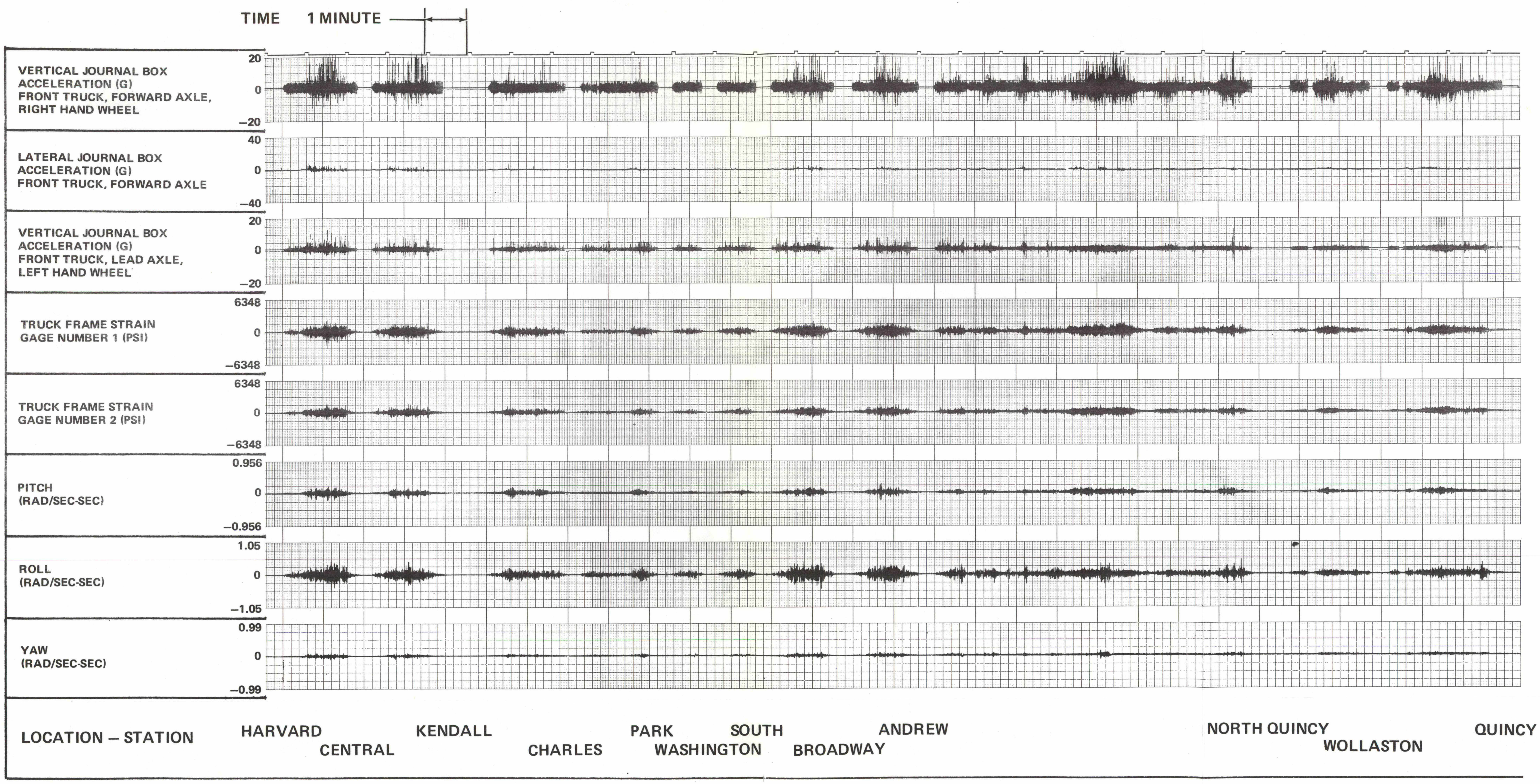


Figure 5–31. Journals, Truck Frame, and Angular Acceleration Time History Chart (H–Q)

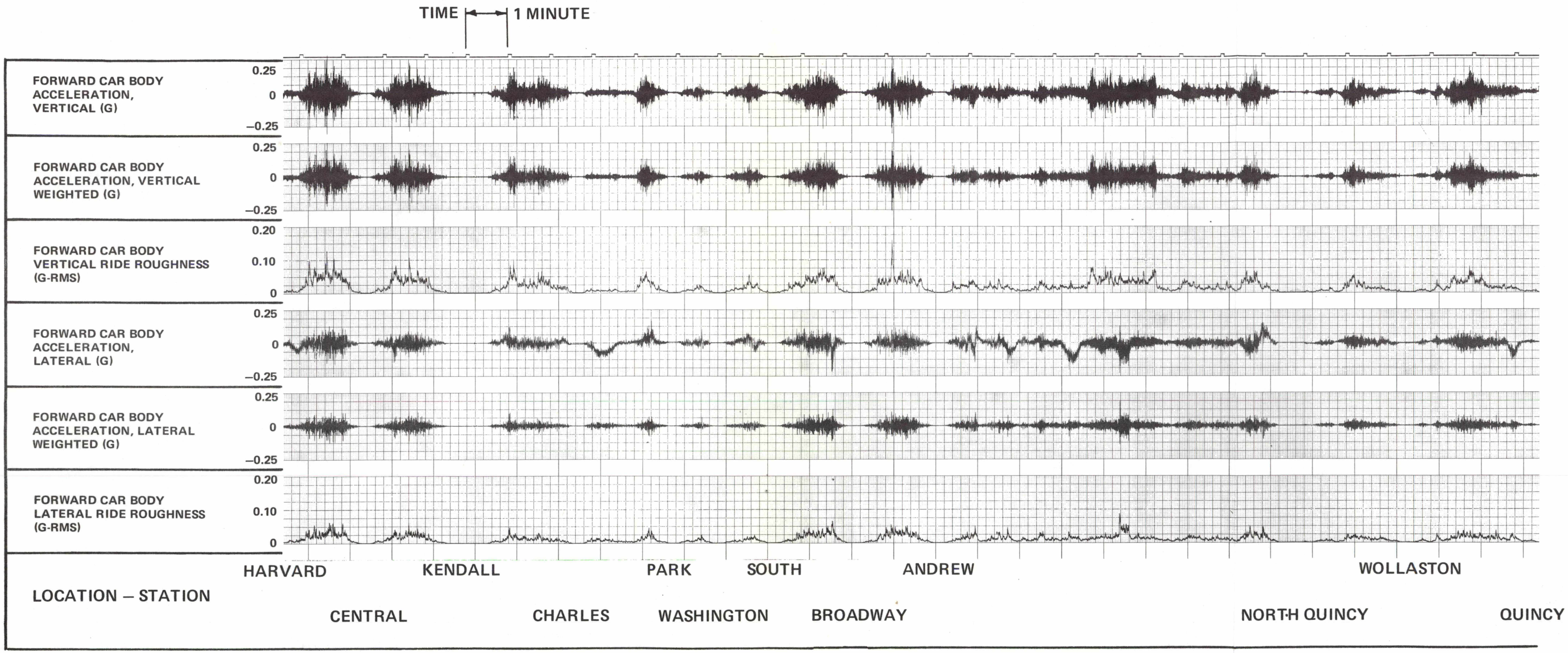


Figure 5–32. Forward Car Acceleration Time History Chart (H–Q)

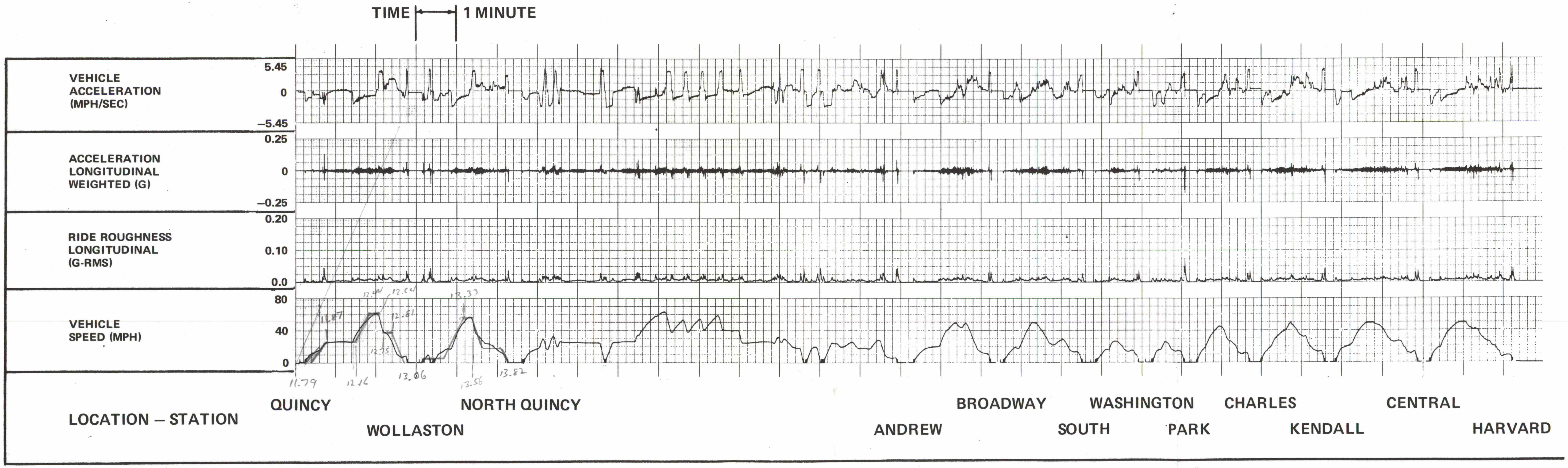


Figure 5–33. Vehicle Acceleration and Speed Time History Chart (Q–H)

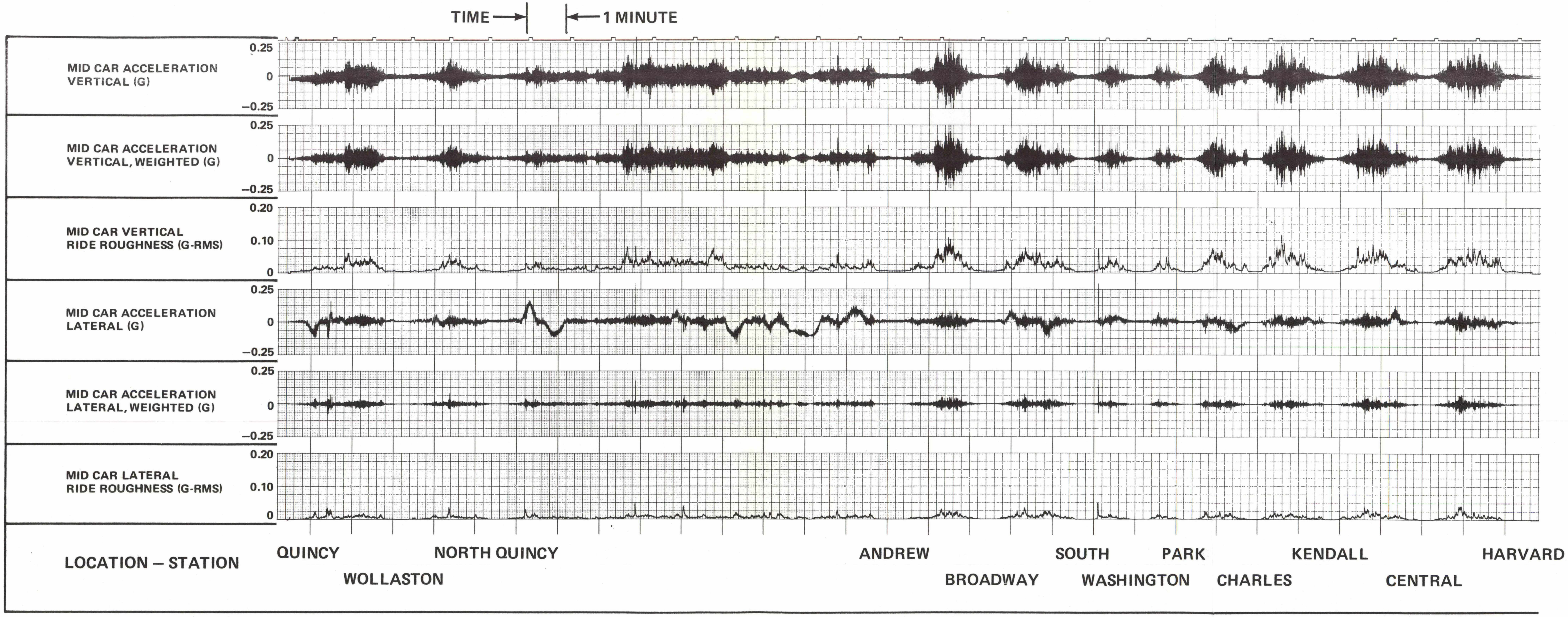


Figure 5–34. Mid-Car Acceleration Time History Chart (Q–H)

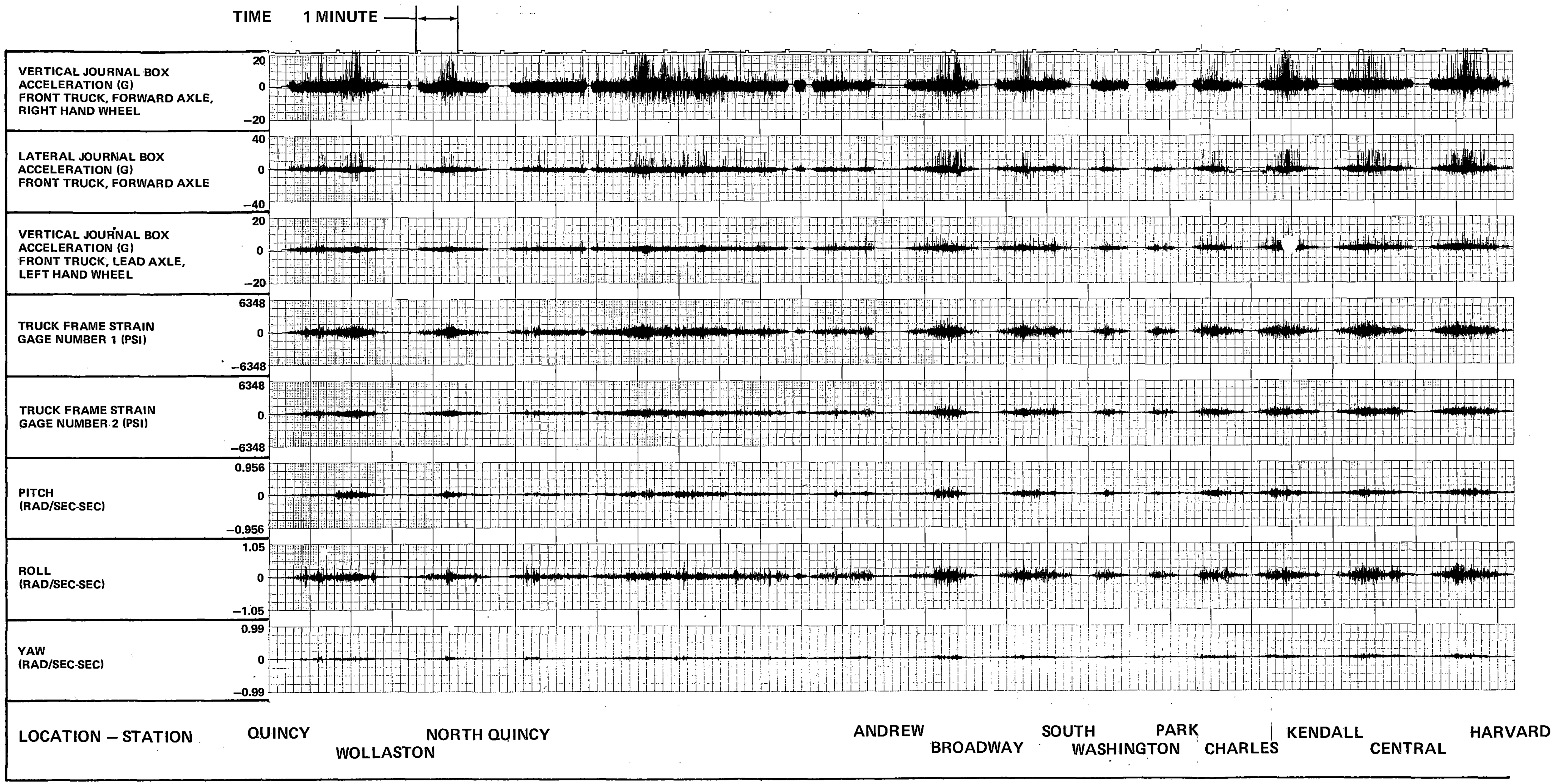


Figure 5–35. Journals, Truck Frame, and Angular Acceleration Time History Chart (Q–H)

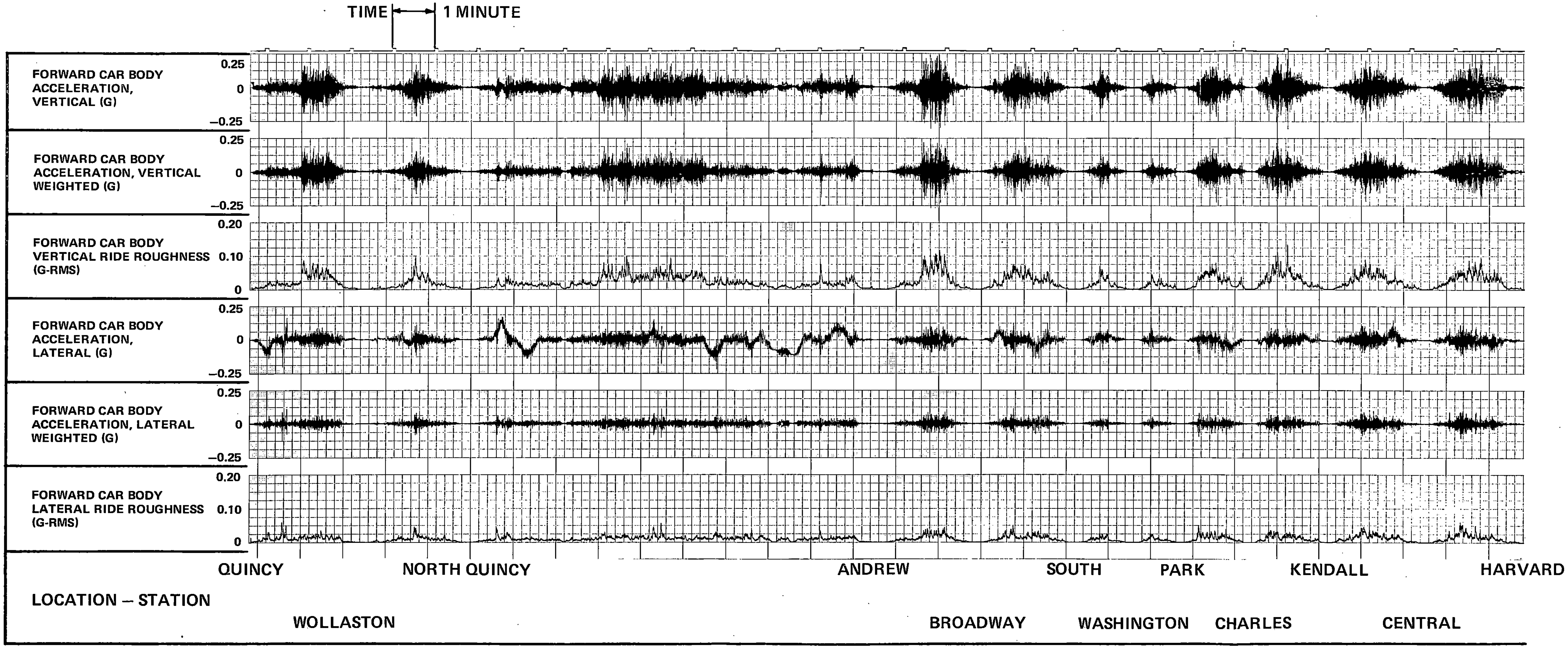


Figure 5–36. Forward Car Acceleration Time History Chart (Q–H)

APPENDIX B
TESTING AT CLEVELAND

1.0 TEST DESCRIPTION

As part of the Operational Test and Evaluation Program, the State-of-the-Art Cars were in the Cleveland Area from September 23rd to December 16th, 1974. The period during vehicle set-up and checkout was used to install the engineering instrumentation system and to perform the Simulated Revenue Service Tests.

1.1 Test Site

The SOACs were operated in revenue service on the CTS rapid transit system which runs from the Cleveland Hopkins Airport, runs northeast through downtown Cleveland and terminates at Windermere Station in East Cleveland. The route is 19.5 miles long, has 18 stations with a scheduled service time of 36 minutes. The line runs at surface level for most of the route. The Public Square Station is underground, being located beneath the Cleveland Union Terminal, and the Airport Terminal is also underground.

1.2 Test Operations

The test plan was to operate the SOACs in a simulated revenue service over the test route. For safety and operational reasons, vehicle operation was entirely under the control of CTS personnel during the tests. The only requirement imposed by the test was to maintain the normal scheduled service as close as possible and to simulate the normal station stops by opening the car doors on the side opposite to the Station platforms.

The test runs were scheduled for and accomplished on the evening of October 16, 1975. Two complete round-trips were recorded, each with different lateral shock absorber settings. This was accomplished because a stiff setting was used on Boston, and a request was made to compare the settings for the subsequent Cleveland Service. Data analysis showed that the shock absorber setting had no effect on the SOAC ride comfort for the Cleveland Service. Either set of data could have been used for this report. In fact, the journal box accelerometer was a problem during this test, the vertical failing during the second run. Therefore the data shown here is from the second run, except for the vertical journal box acceleration distribution which is taken from the first runs. The test times and other parameters indicate that the two tests were essentially the same.

There were no scheduled trains or work crews on the tracks during the tests. There were no incidents which would have an influence on the validity of the test data.

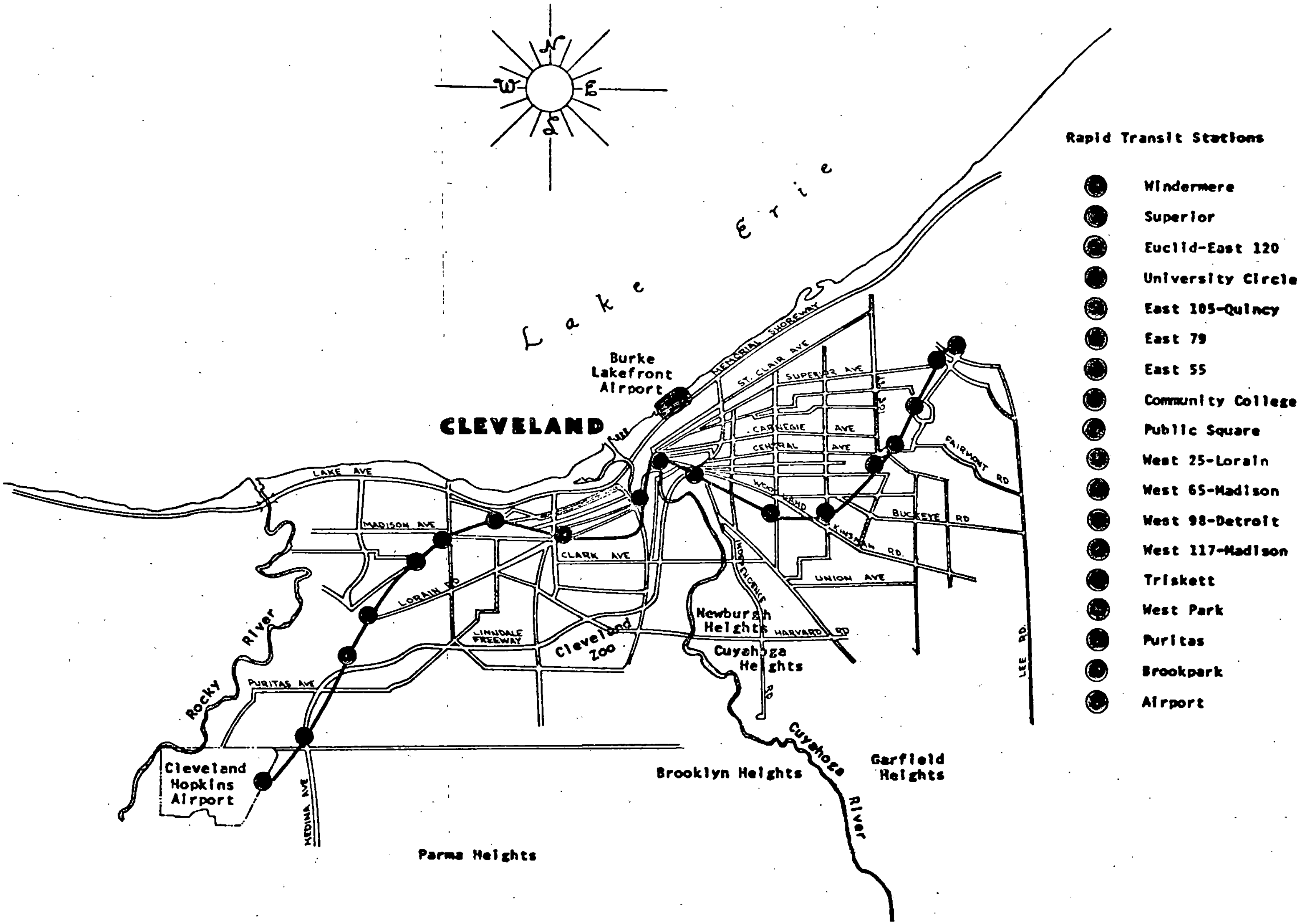


Figure 1—1. Cleveland Rapid Transit System

2.0 TEST PROCEDURES

Pretest

1. Mount all required sensors
2. Calibrate Instrumentation System
3. Brief Test Crew on Test Operations

   NOTE:

   One vehicle is instrumented for noise measurements, avoid other than normal conversation.

Test

1. Operate the vehicles in a simulated revenue service, i.e. maintain the given schedule.
2. Provide a nominal 10 second door opening at each scheduled stop.
3. Provide voice commentary on instrumentation recording during progress of test.
4. Maintain a manual log of events during the test run, correlated to the instrumentation system records.
5. Monitor various preselected data channels to ascertain validity of test run.
6. The Test Controller will terminate the test if:
   (a) An extended delay or train shutdown occurs
   (b) One or more required data channels malfunction
   (c) The test vehicle is not operating properly

   Advise Test Controller of any abnormal operations or events that occur during the test run.

3.0 INSTRUMENTATION

The SOAC Instrumentation System was used for this series of tests. This system is described in detail in Volume VI of State-of-the-Art Car (SOAC) Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Test Report, UMTA-MA-06-0025-75-6, January 1975. A synopsis is included below.

3.1 Ride Qualities, Structural and Performance Tests

Electrical signals from the vehicle mounted transducers are conducted by cables to an interface panel which is connected to an instrumentation console containing two magnetic tape recorders, two light beam oscillographs, a time code generator, a temperature recorder and signal conditioners. Any 28 selected test parameters can be recorded on tape and displayed on the oscillographs. In addition, wheel speeds may be recorded directly on the oscillographs; total power is recorded on tape and displayed on a mechanical counter. The time code generator provides signals that are recorded on both tape and the oscillograph. The oscillographs provide quick-look data to evaluate test progress and results during testing (See Figure 3-1).

3.2 Noise Tests

The instrumentation used for noise measurement consisted of a 1" condenser microphone with battery operated cathode follower and a 1/4" single channel tape recorder.

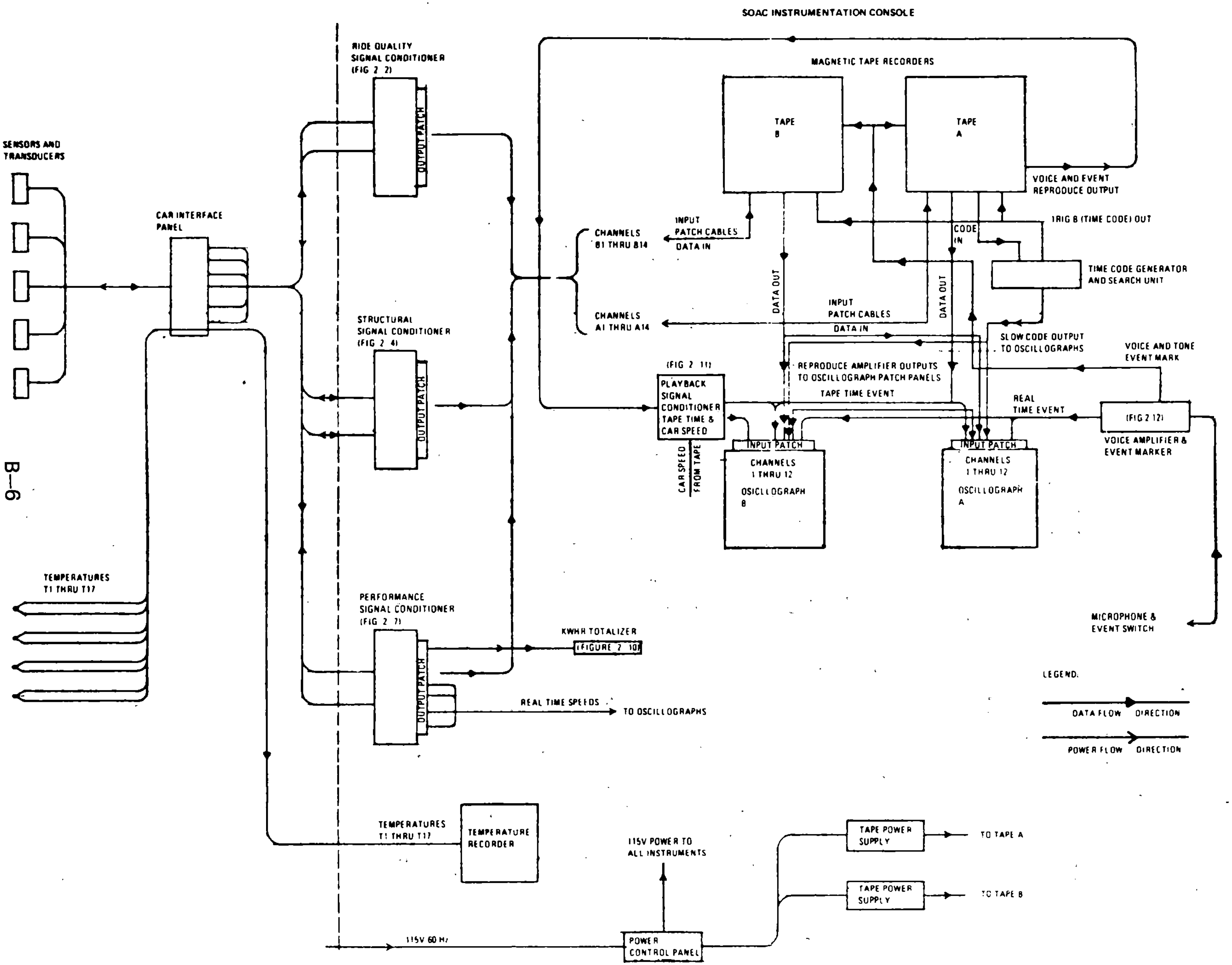


Figure 3–1. SOAC Instrumentation System Block Diagram

4.0 DATA

The parameters recorded during the property tests are described in Tables 4-1 and 4-2. The definition of the parameter measurements is contained in Appendix A, Standard Outputs for SOAC Property Tests.

Data was recorded for the roundtrip routes noted in the Test Description Section. All of the data was recorded on analog tapes and processed to provide three types of outputs.

Time History Charts

Station Summary Tables

Frequency Histograms

4.1 Time History Charts

A slow chart speed strip-out of certain parameters is included in this report. The purpose of these charts is to provide an indication of the maximum levels of parameters during various phases of the run. The complete run is described on the charts including station stops and any particularities that occurred. A series of time histories at a high chart speed is included to illustrate the cyclical nature of the data. These charts are a single time frame for all parameters and are representative of the worst case conditions exhibited for a particular test run.

Intermediate parameters, such as a weighted (filtered) car body acceleration are shown on some charts.

4.2 Station Summary

A summation or summary of specific parameters is made by each station stop. These include test running time and distance for comparison to the property's schedule. Power consumption, motor duty cycle parameters are also summarized by station to indicate the relative sizing of the SOAC propulsion with respect to operations on the property. Station stops and maximum speeds are also shown as another indicator of vehicle operation in a scheduled service environment.

Table 4—1. SOAC Revenue Service Data List A

PARAMETER			STANDARD OUTPUTS		
DESIGNATION NO.	DESCRIPTION	RANGE	RECORDED	PRESENTED	PRELIMINARY ANALYSIS
301	Longitudinal Acceleration	± 0.25 g's	AP/A	Format(3)	Format(4)
302	Line Voltage	0 to 1000 VDC	LVD/A	None	-
303	Line Current	0 to 2000 ADC	LCD/A	None	-
304	No. 1 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
305	No. 1 Truck Armature Current	0 to 1000 ADC	MACD/A	None	RMS-MAC/A
306	No. 1 Truck Field Current	± 50 ADC	MFCD/A	None	RMS-MFC/A
307	No. 2 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
308	No. 2 Truck Armature Current	0 to 1000 ADC	MACD/A	None	-
309	No. 2 Truck Field Current	± 50 ADC	MFCD/A	None	-
310	"P" Wire Current	0 to 1.00 ADC	CS/A	None	Format(3)
317	Total Power Consumption	1 Pulse/0.1 KWHR	PCC/A	Format(2)	Format(2)
315	Speed	0 to 80 MPH	VS/A	Format(3)	Format(4)
318	Brake Cylinder Pressure	0 to 100 psig	BCP/A	None	-

Table 4–2. SOAC

PARAMETER DESIGNATION NO.	DESCRIPTION
101	Front Truck, Forward Axle, Righthand Wheel Journal Box Vertical Acceleration
102	Front Track, Forward Axle, Righthand Wheel Journal Box Lateral Acceleration
103	Front Truck, Forward Axle Lefthand Wheel Journal Box Vertical Acceleration
115	Mid Car Centerline Vertical Acceleration
116	Mid Car Centerline Lateral Acceleration
120	Forward Car Centerline Vertical Acceleration
121	Forward Car Centerline Lateral Acceleration
219	Truck Frame Upper Strain Gage
220	Truck Frame Lower Strain Gage
221	Pitch Angular Acceleration
222	Roll, Angular Acceleration
223	Yaw, Angular Acceleration
-	Interior Sound Pressure

Revenue Service Data List B

RANGE	STANDARD OUTPUTS RECORDED	PRESENTED	PRELIMINARY ANALYSIS
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	-
± 0.25 g's	AC/A	Format(3)	RRV/A(1), (3
± 0.25 g's	AC/A	Format(3)	RRH/A(1), (3
± 0.25 g's	AC/A	Format(3)	RRV/A(1)
± 0.25 g's	AC/A	Format(3)	RRH/A(1)
± 6348 psi	STP	Format(3)	Fromat(4)
± 6348 psi	STP	Format(3)	-
± 1.5 Rad/sec/sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
40 to 120 dB(re 2 x 10^{-5} N/M^2)	SP/A	NL/A(1)	NL/A(2)

4.3 Frequency Histograms

These distributions are an indication of the ratio of time that a parameter is at a particular level with respect to the time to complete a roundtrip scheduled service run. These parameters may be used to describe how the vehicle was driven, the track conditions, and how the vehicle responded to these conditions.

5.0 DATA DISCUSSION

The vehicle operation was such that SOAC No. 2, the instrumented car, was leading and running in the forward direction for the Windermere to Airport run. For this run, the vehicle longitudinal acceleration has a positive value for vehicle start-up. SOAC No. 2 ran in the reverse direction for the Airport to Windermere run.

As defined in Section 4 there are three forms of data. These forms are discussed below with respect to three categories:

(1) Operation

How the vehicle is operated and maintained schedule.

(2) Environment

Track and truck conditions.

(3) Response

How the vehicle responded to operational environment.

Figure 5-1 through 5-15 present the frequency histograms for the CTS tests. Figure 5-16 is a sample of the interior noise level time history. The remaining time histories are shown in Figures 5-17 through 5-36. Table 5-1 is a summary of some of the test parameters and is derived from the histograms and time histories. Tables 5-2 and 5-3 are the Station Summaries with power consumption.

5.1 Operation

The Station Summaries show that SOAC run times were 8 and 19 minutes longer than the published schedule times. The basic reason for this is twofold. First, the tests were run during the car introduction phase of the program and the drivers were going through a learning process. The second reason is the schedule itself which seems to be optimistic. The best that SOAC was able to accomplish during the revenue service program was around 4 minutes over schedule run time. Again from the Station Summaries, the extra run time is spread across the total route, with a particular delay being the approach to the Public Square Station.

The maximum acceleration from the time history charts is 3.27 mph/sec and the maximum brake rate is 3.0 mph/sec. Both of these values are within the SOAC specification.

The Station Summaries show that 12 percent of the test time was spent standing in a station. This compares to the histogram data for the speed distribution, which shows 20 percent of the test time in the 0 to 5 mph band.

Interestingly, the "P-Wire" distribution reveals a driving technique of the CTS operators while driving the SOAC. The major levels of "P-Wire" are between .5 to .7 amps. This is the slow acceleration and maintain speed level. A relatively small percentage of time was spent commanding full or larger acceleration rates. An even smaller amount of time was spent requiring full braking. The 12 percent station stop time is shown in the "P" = 0 amp. This very "soft" driving technique is again seen in the time history charts with vehicle acceleration and speed. Apparently the SOAC was eased out of stations and up to speed and very softly "braked" into a station. This is inconsistent with observations of normal CTS operations and must be attributed to the "newness" of the SOAC.

The SOAC consumed 216 KWHR completing the roundtrip. For the 42.4 measured miles this is a power consumption of 5.1 KWHR/Mile. For the 39 schedule miles it is 5.5 KWHR/Mile.

Neither leg of the route taxed the SOAC propulsion system. The SOAC has a continuous rating of 460 amps (RMS). The westbound leg required 195 amps (RMS) or 42 percent of the rating and the eastbound leg was 249 amps (RMS) for 54 percent of rating.

5.2 Environment

The journal accelerations and truck stress levels are intended to be indicators of track conditions. Summary values for these parameters are shown in Table 5-2. The 50th percentile is a statistical quantity taken from the cumulative distributions. It assumes a linear distribution of values within each class interval (e.g. 1-2 gs). The value is read as 50 percent of the time the vertical journal box acceleration was at or lower than 1.3 gs. The 95th percentile is read similarly. The "nominal" value is the 50th percentile for the time the vehicle is in motion.

As mentioned earlier, the vertical journal box accelerometer failed during the test run for which the remaining data is shown. The distribution shown for vertical journal acceleration is taken from a separate test run.

5.3 Response

Ride Roughness and Noise Levels are parameters which are related to "human responses". Ride Roughness is a ride comfort rating of vibration levels, and Noise Level is a hearing comfort rating of sound pressure levels. The parameters are described in the Standard Outputs Section of this report. A summary of values for the CTS tests appears on Table 5-1.

Some values for the car body acceleration levels are also shown in Table 5-1. In the time history charts the dominant frequency for the mid car vertical parameter is 7.5 Hertz. This is the car body second bending mode. For the forward car location the 7.5 hertz is apparent, but the dominant frequency is 1.5 Hertz. This is the suspension system natural frequency.

Interior Noise Level data was taken in the middle of the non instrumented car at a seated person's ear level. The original engineering tests at TTC indicate this is the quietest point in the car. The statistical quantities derived from the test data are:

L(99)	L(90)	L(50)	L(10)	L(1)	L(EQ)
65	66	67	70	74	71

A sample of the Noise Level Time History is shown in Figure 5-16.

Table 5–1. Summary Values for SOAC Operating on the CTS Airport Line

	50TH %	" NOMINAL "	95TH %	MAXIMUM
Journal Box Vertical Acceleration (G)	± 1.3	± 1.4	± 4.7	-
Journal Box Lateral Acceleration (G)	± 1.3	± 1.5	± 7.8	± 15.0
Truck Frame Stress (PSI)	± 160	± 180	± 680	± 2222
Forward Car Vertical Acceleration (G)	± .018	± .020	± .075	± .281
Mid Car Vertical Acceleration (G)	± .019	± .021	± .070	± .225
Forward Car Lateral Acceleration (G)	± .018	± .020	± .066	± .134
Mid Car Lateral Acceleration (G)	± .016	± .018	± .055	± .125
Longitudinal Ride Roughness (GRMS)	.005	.006	.012	.050
Forward Car Vertical Ride Roughness (GRMS)	.012	.016	.050	.175
Mid Car Vertical Ride Roughness (GRMS)	.011	.013	.045	.115
Forward Car Lateral Ride Roughness (GRMS)	.011	.013	.032	.088
Mid Car Lateral Ride Roughness (GRMS)	.007	.008	.019	.053
Pitch (RAD/Sec-Sec)	± .050	± .060	± .100	± .263
Roll (RAD/Sec-Sec)	± .060	± .070	± .184	± .525
Yaw (RAD/Sec-Sec)	± .050	± .060	± .095	± .099

Table 5–2. Station Summary I

SPEED	STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
	1	Windermere Street	0	0	0	0	0	0	0	0	0	0
35	2	Superior	.67	1.0	.76	2.60	3.93	5.17	162.6	24.9	20.4	38
35	3	Euclid E. 120th St.	.88 1.55	2.0	.99	2.32	4.72	4.77	195.0	28.2	17.2	38
30	4	University Circle	.87 2.42	1.0	.98	2.66	4.38	4.47	177.0	23.7	34.8	35
30	5	Quincy E. 105th St.	.65 3.07	2.0	.72	1.82	3.95	5.49	241.1	31.7	18.0	35
40	6	East 79th Street	1.17 4.24	2.0	1.30	2.64	5.11	3.93	189.4	23.6	16.8	45
30	7	East 55th Street	1.05 5.29	2.0	1.20	4.44	5.85	4.88	175.9	21.1	99.6	35
30	8	Community College	.90 6.19	2.0	.93	2.70	4.59	4.94	146.6	25.8	18.0	35
40	9	Public Square	1.65 7.84	3.0	1.93	6.26	8.38	4.34	121.3	20.5	13.8	40
30	10	Lorain W. 25th St.	1.05 8.89	2.0	1.18	3.94	7.41	6.27	159.0	29.6	16.8	34
40	11	Madison W. 65th St.	1.94 10.83	3.5	2.12	4.12	9.05	4.27	173.6	26.8	16.8	47
45	12	Detroit W. 98th St.	1.29 12.12	2.5	1.38	2.96	7.14	5.17	208.6	28.1	15.6	48
25	13	Madison W. 117th St.	1.46 13.58	1.5	1.17	3.44	6.58	5.62	167.7	28.6	18.0	32
35	14	Triskett Street	1.07 14.65	2.0	1.20	3.04	6.47	5.39	166.3	25.0	19.2	37
50	15	West Park	.77 15.42	1.5	.86	2.16	5.68	6.60	270.6	21.3	19.2	48
55	16	Puritas Street	1.23 16.65	2.5	1.41	2.58	7.74	5.49	273.9	23.1	16.8	54
55	17	Brookpark	1.80 18.45	2.5	1.91	3.08	9.84	5.15	284.0	20.7	16.8	54
35	18	Airport	1.09 19.54	3.0	1.25	4.14	7.29	5.83	238.0	27.9	21.6	36
						TOTAL	108.11	5.08	195.4	23.3		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	19.54	21.29
Time	36.00	54.90
Block Speed	32.6	23.3
Station Dwell	30.7	23.5
Station Space	1.15	1.25

Table 5—3. Station Summary II

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	POWER CONSUMPTION KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Airport	0	0	0	0	0	0	0	0	0	0
2	Brookpark	1.09	3.0	1.26	3.96	7.39	5.87	177.1	31.6	19.2	35
3	Puritas Street	1.80	2.5	1.91	3.20	8.17	4.28	244.4	18.8	18.0	55
4	West Park	1.28	2.5	1.41	2.32	6.85	2.95	299.9	18.1	18.0	55
5	Triskett Street	.77	1.5	.87	1.76	5.40	3.07	343.4	23.2	16.8	52
6	Madison W. 117th St.	1.07	2.0	1.18	2.02	4.88	2.41	294.1	22.5	16.8	50
7	Detroit W. 98th St.	1.46	1.5	1.08	2.74	6.04	2.20	264.8	25.9	21.6	48
8	Madison W. 65th St.	1.29	2.5	1.46	2.70	6.62	2.45	240.5	20.2	19.2	48
9	Lorain W. 25th St.	1.94	3.5	2.14	3.88	10.03	4.69	206.1	24.2	19.2	48
10	Public Square	1.05	2.0	1.21	3.20	6.10	5.04	240.0	22.5	19.2	45
11	Community College	1.65	3.0	1.89	4.32	8.55	4.53	159.7	27.4	15.6	49
12	E. 55th Street	.90	2.0	.95	2.18	4.58	4.82	213.0	28.5	19.2	38
13	E. 79th Street	1.05	2.0	1.17	2.28	7.44	6.36	305.2	24.9	16.8	45
14	Quincy E. 105th St.	1.17	2.0	1.28	2.06	7.72	6.03	343.2	20.0	18.0	55
15	University Circle	.65	2.0	.72	1.64	4.73	6.56	284.7	25.8	16.8	41
16	Euclid E. 120th St.	.87	1.0	.98	2.02	5.02	5.13	254.1	24.7	16.8	44
17	Superior Street	.88	2.0	.99	2.04	5.22	5.27	261.7	21.9	19.2	46
18	Windermere	.67	1.0	.76	2.44	4.01	5.28	197.5	26.5	18.0	34
					TOTAL	108.8	5.12	248.6	24.5		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	19.54	21.26
Time	36.0	44.76
Block Speed	32.6	28.5
Station Dwell	30.0	18.1
Station Space	1.15	1.25

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
"P" Wire Distribution

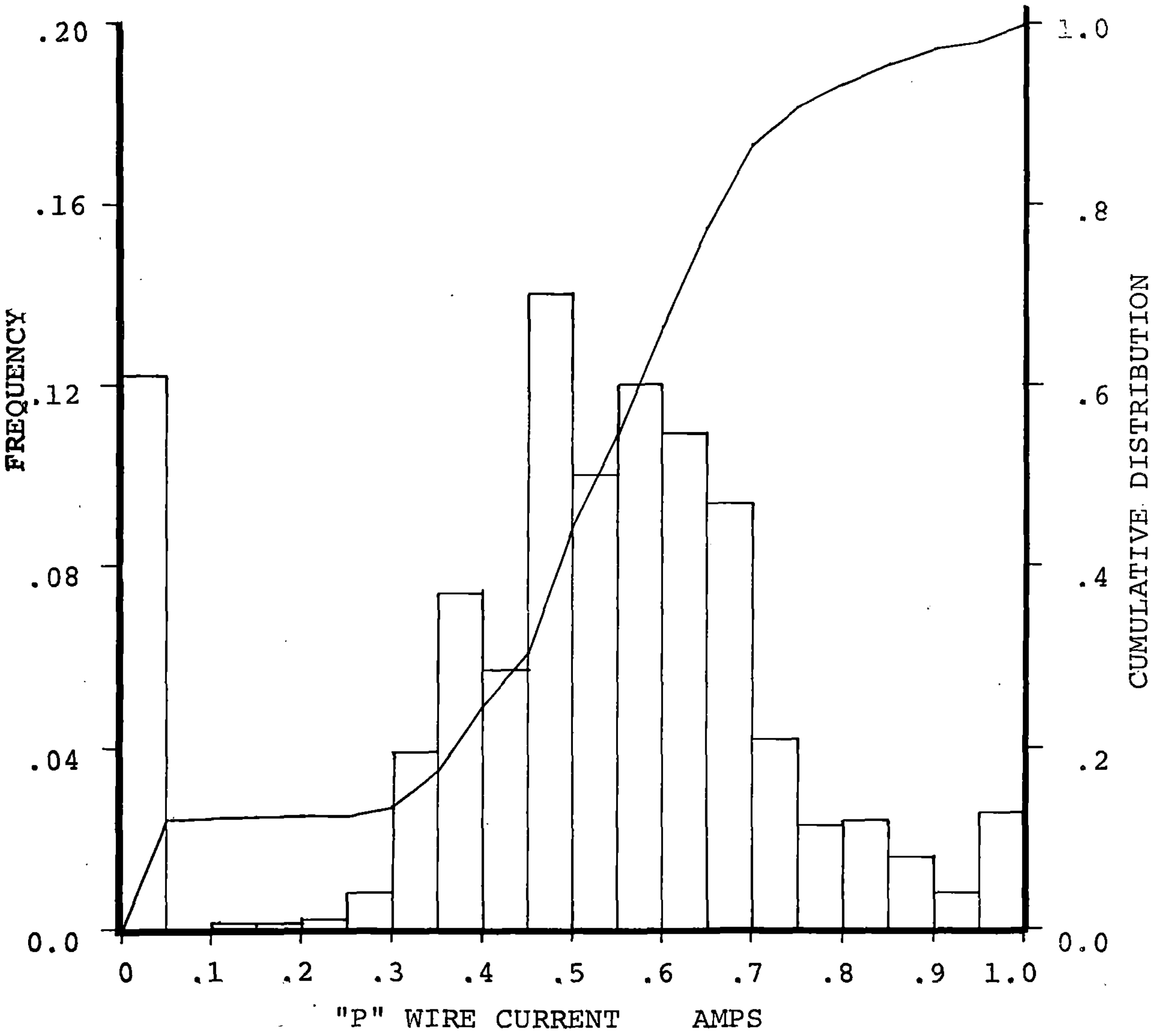


Figure 5–1. 'P-Wire' Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport
Vehicle Speed Distribution

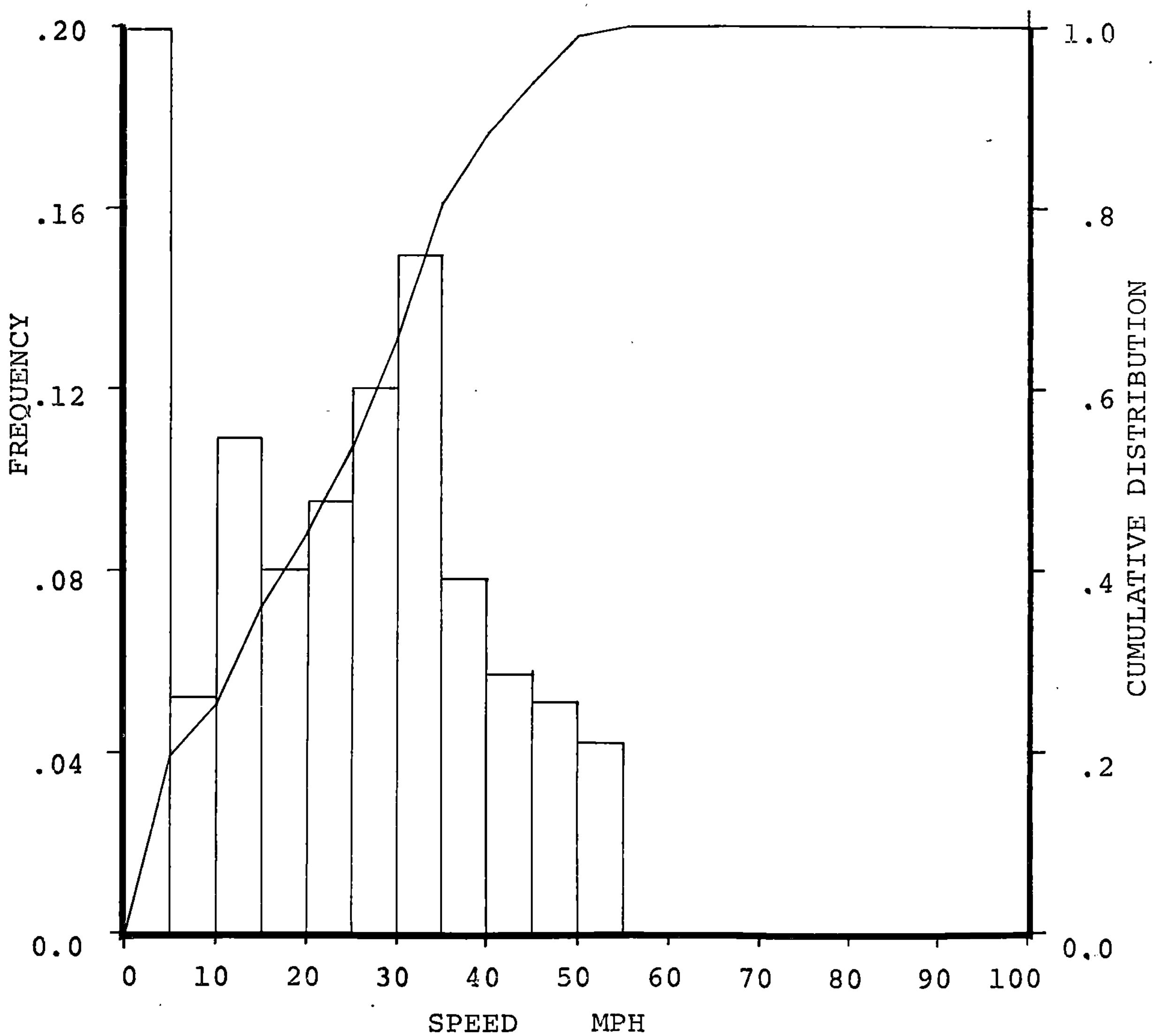


Figure 5–2. Vehicle Speed Distribution

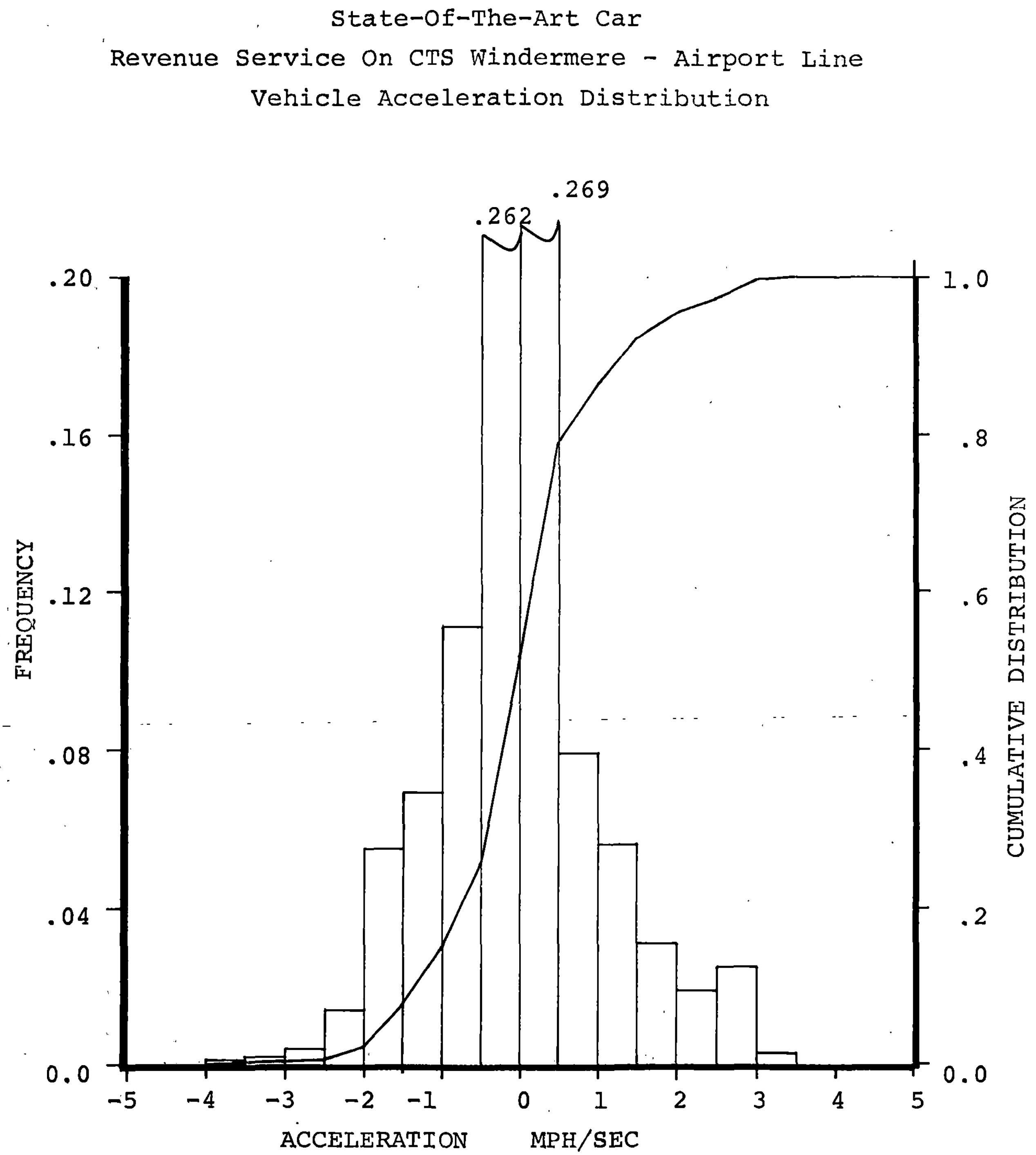


Figure 5–3. Vehicle Acceleration Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Journal Box Vertical Acceleration Distribution

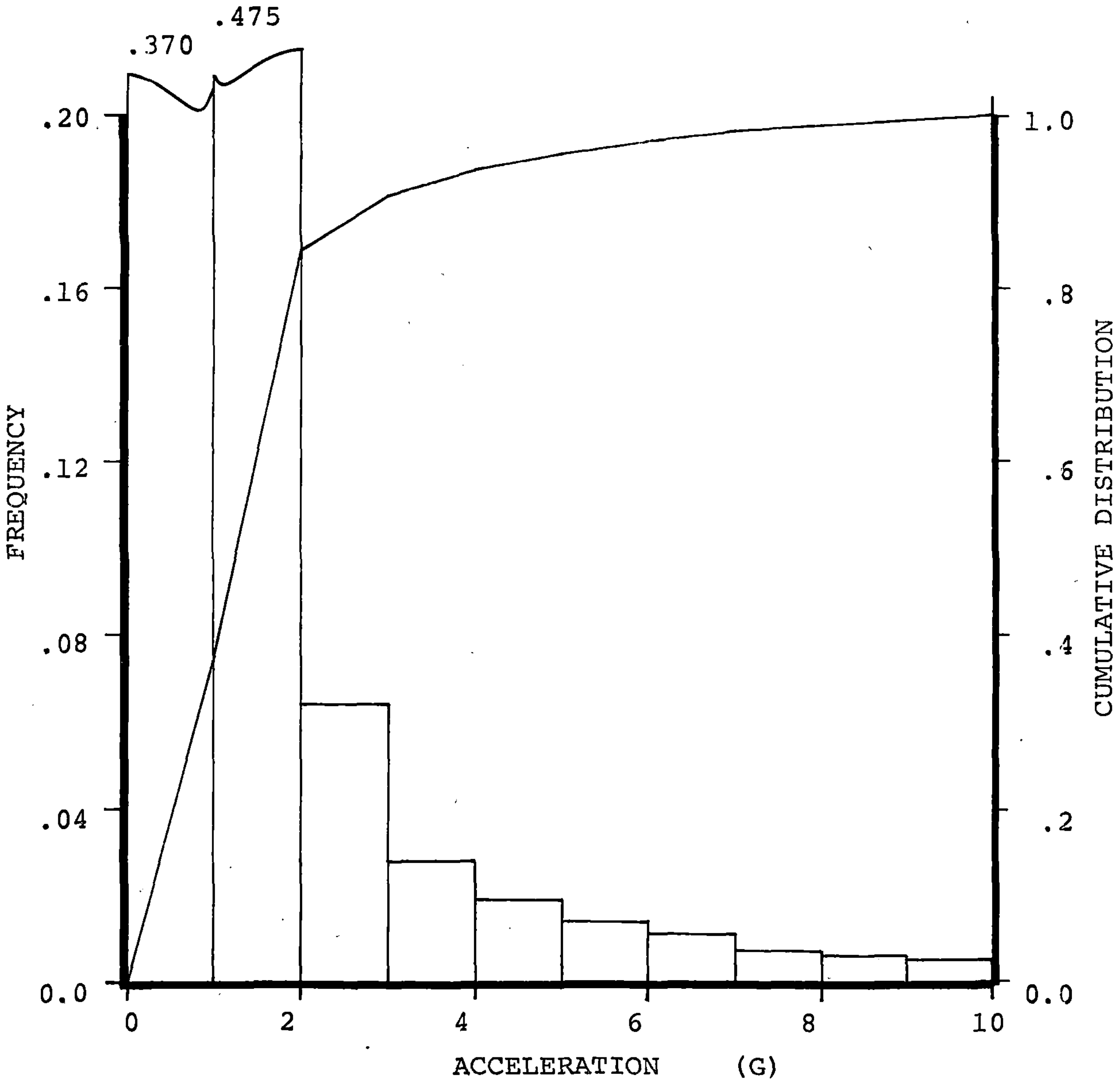


Figure 5–4. Journal Box Vertical Acceleration Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Journal Box Lateral Acceleration Distribution

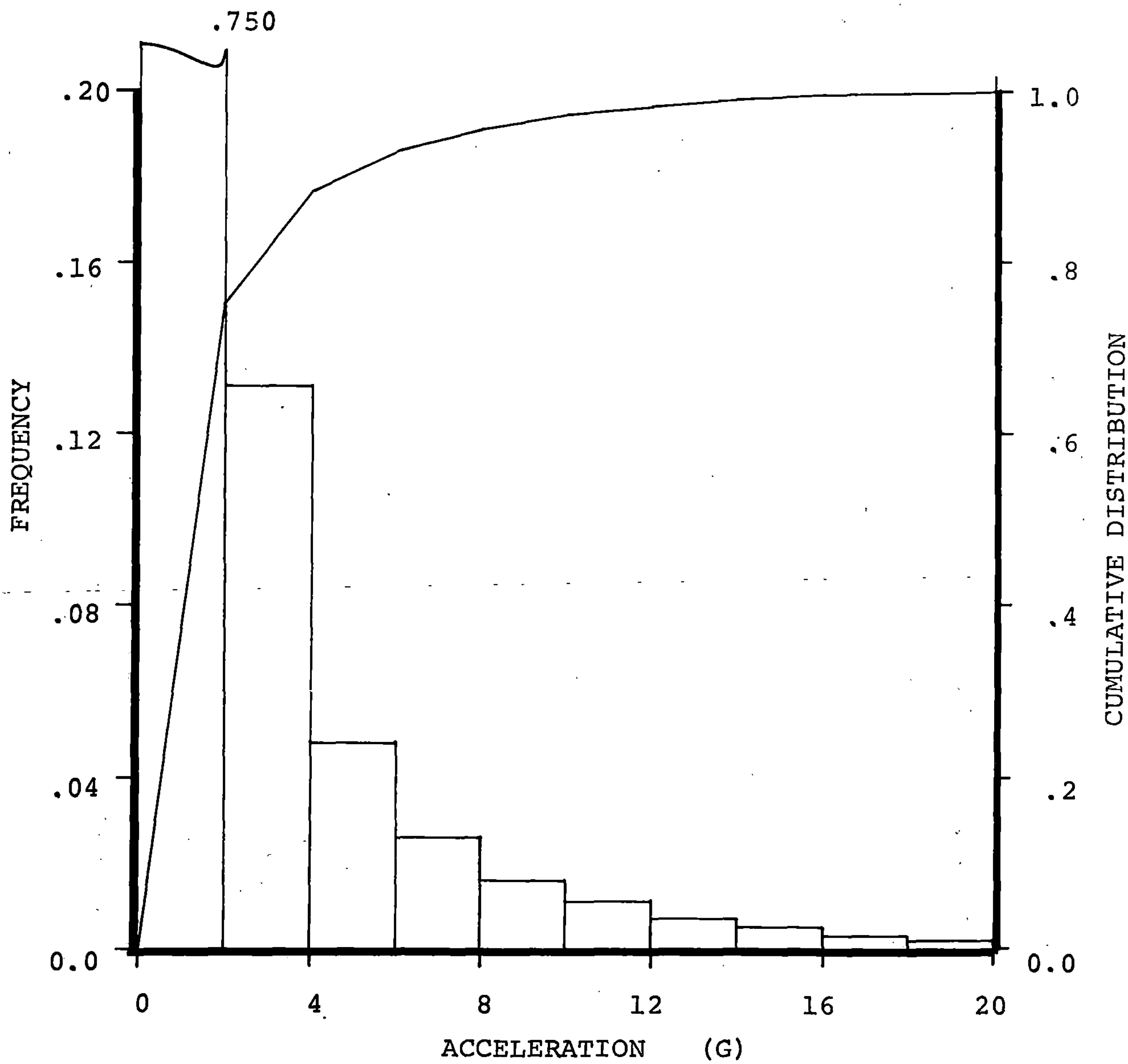


Figure 5—5. Journal Box Lateral Acceleration Distribution

State-Of-The-Art Car
Revenue Service On CTS Winderemere - Airport Line
Truck Frame Strain Level Distribution

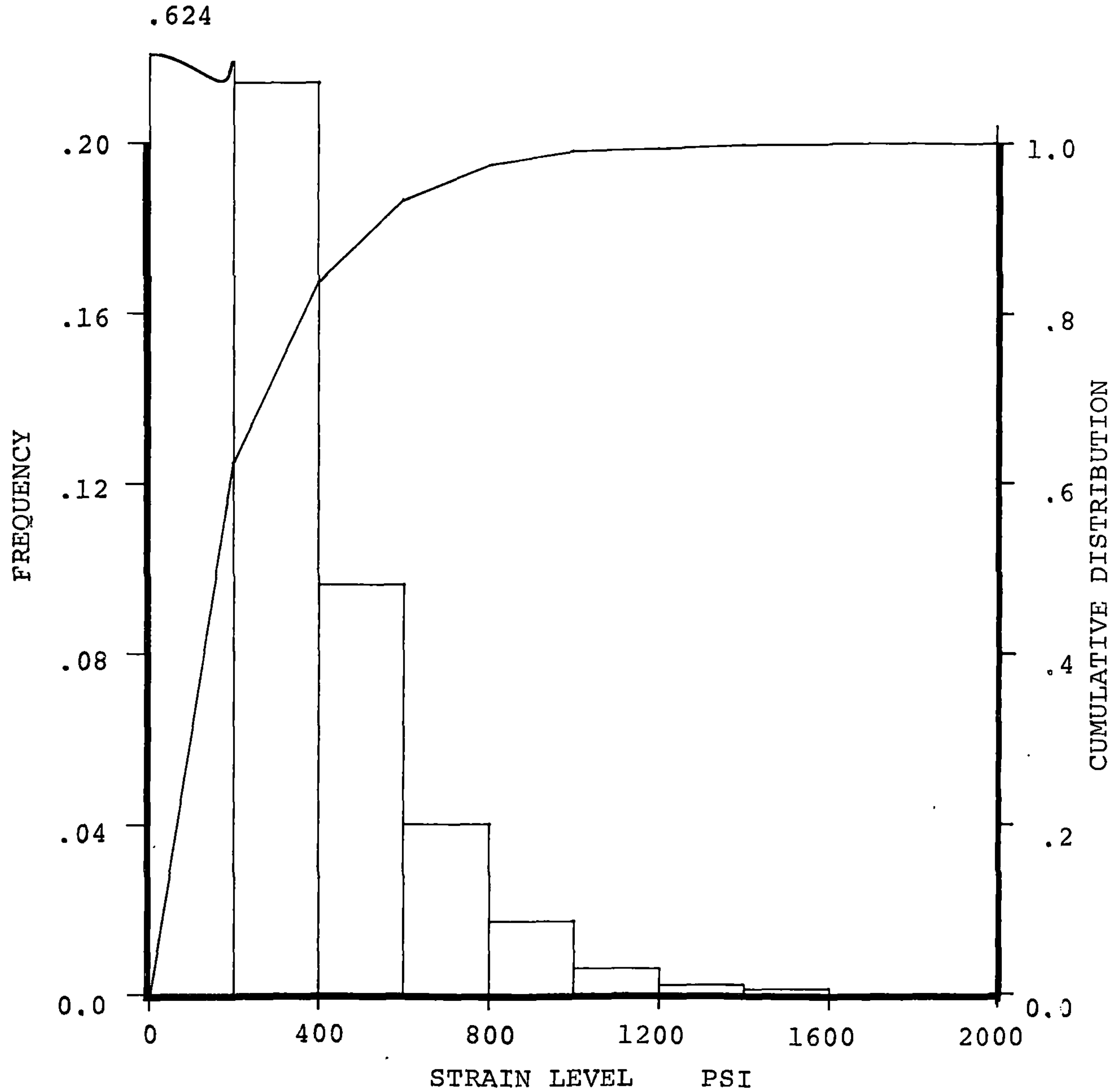


Figure 5–6. Truck Frame Strain Level Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Longitudinal Ride Roughness Distribution

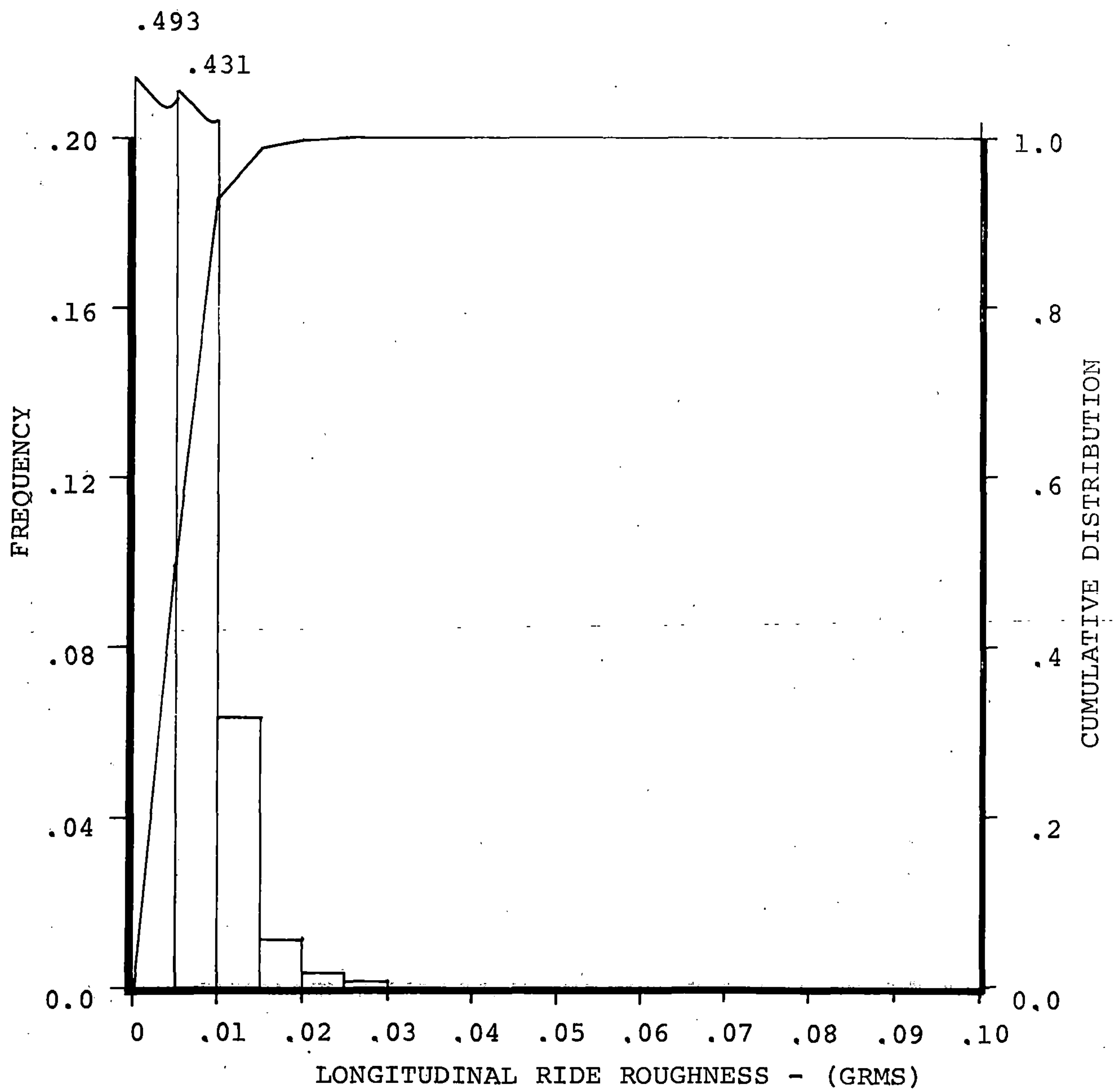


Figure 5–7. Longitudinal Ride Roughness Distribution

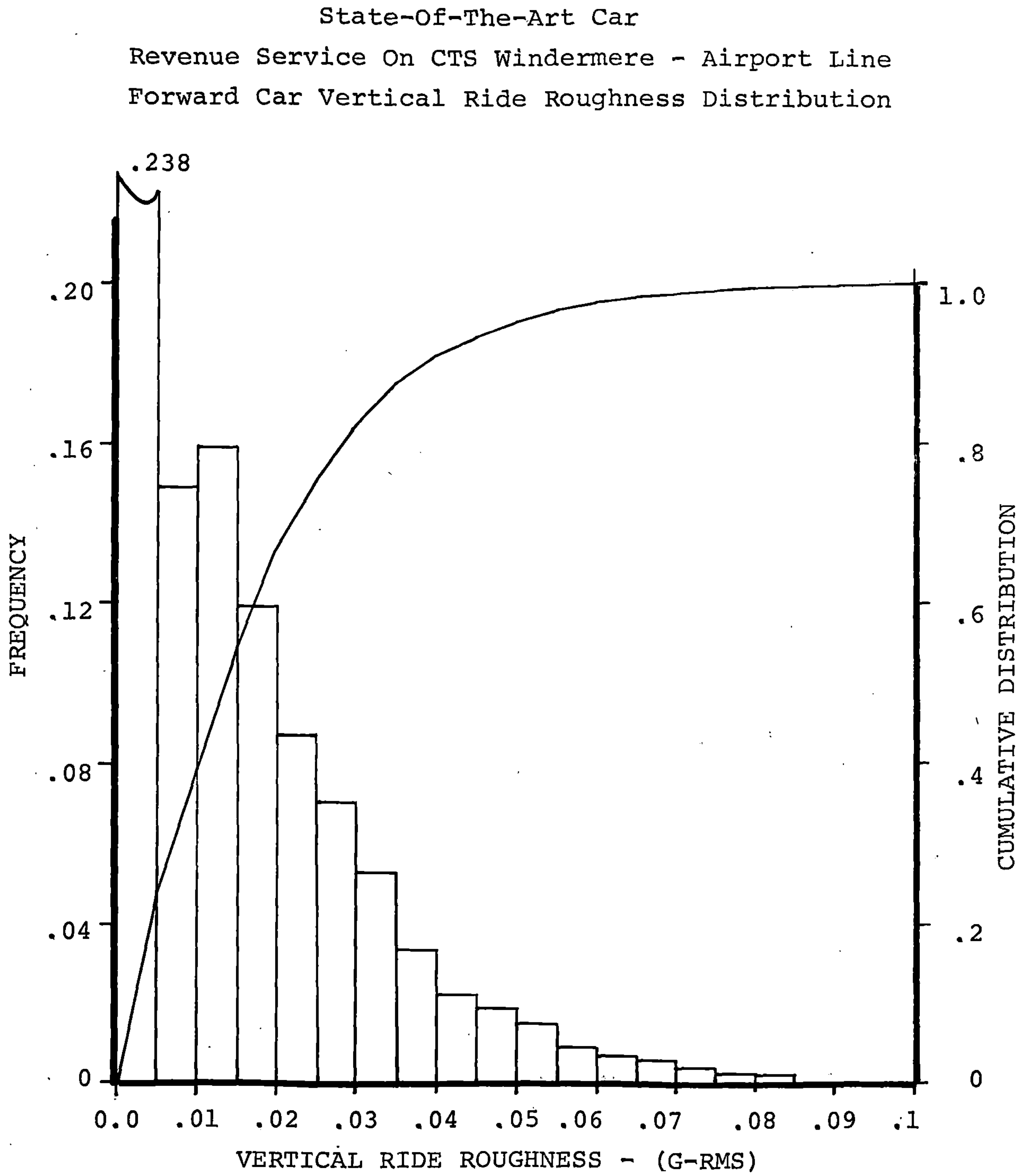


Figure 5–8. Forward Car Vertical Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Forward Car Lateral Ride Roughness Distribution

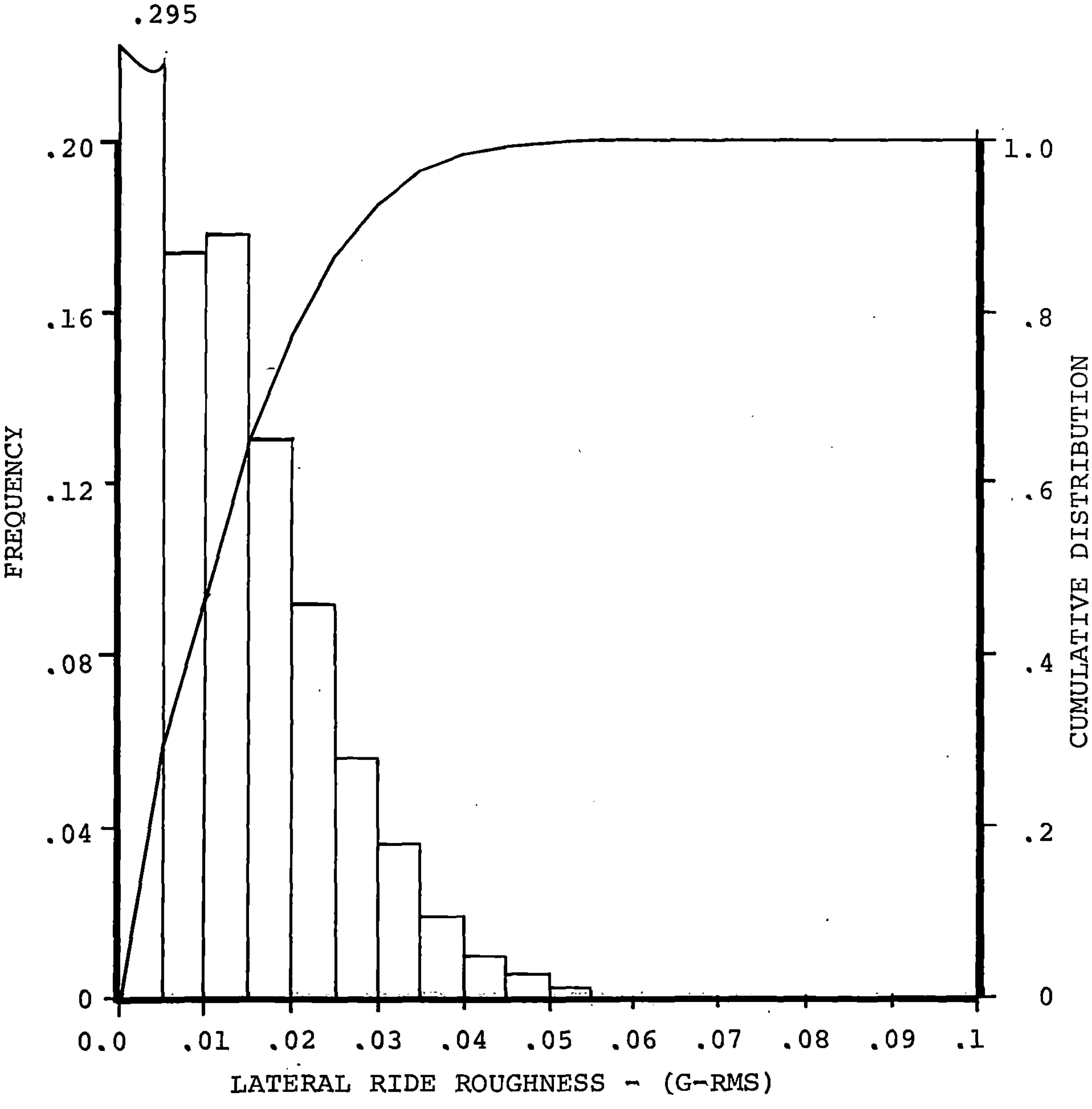


Figure 5–9. Forward Car Lateral Ride Roughness Distribution

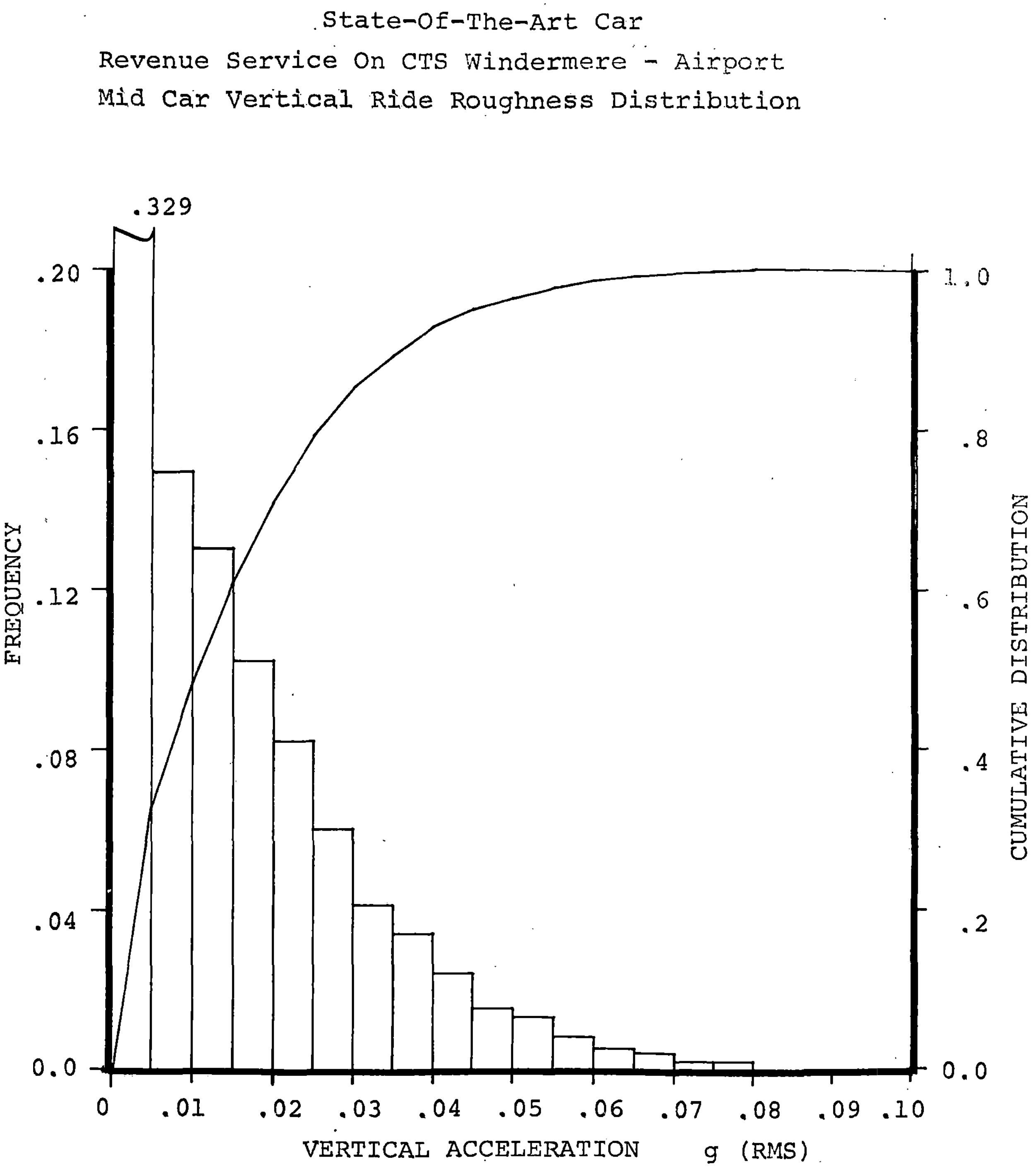


Figure 5–10. Mid-Car Vertical Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Mid Car Lateral Ride Roughness Distribution

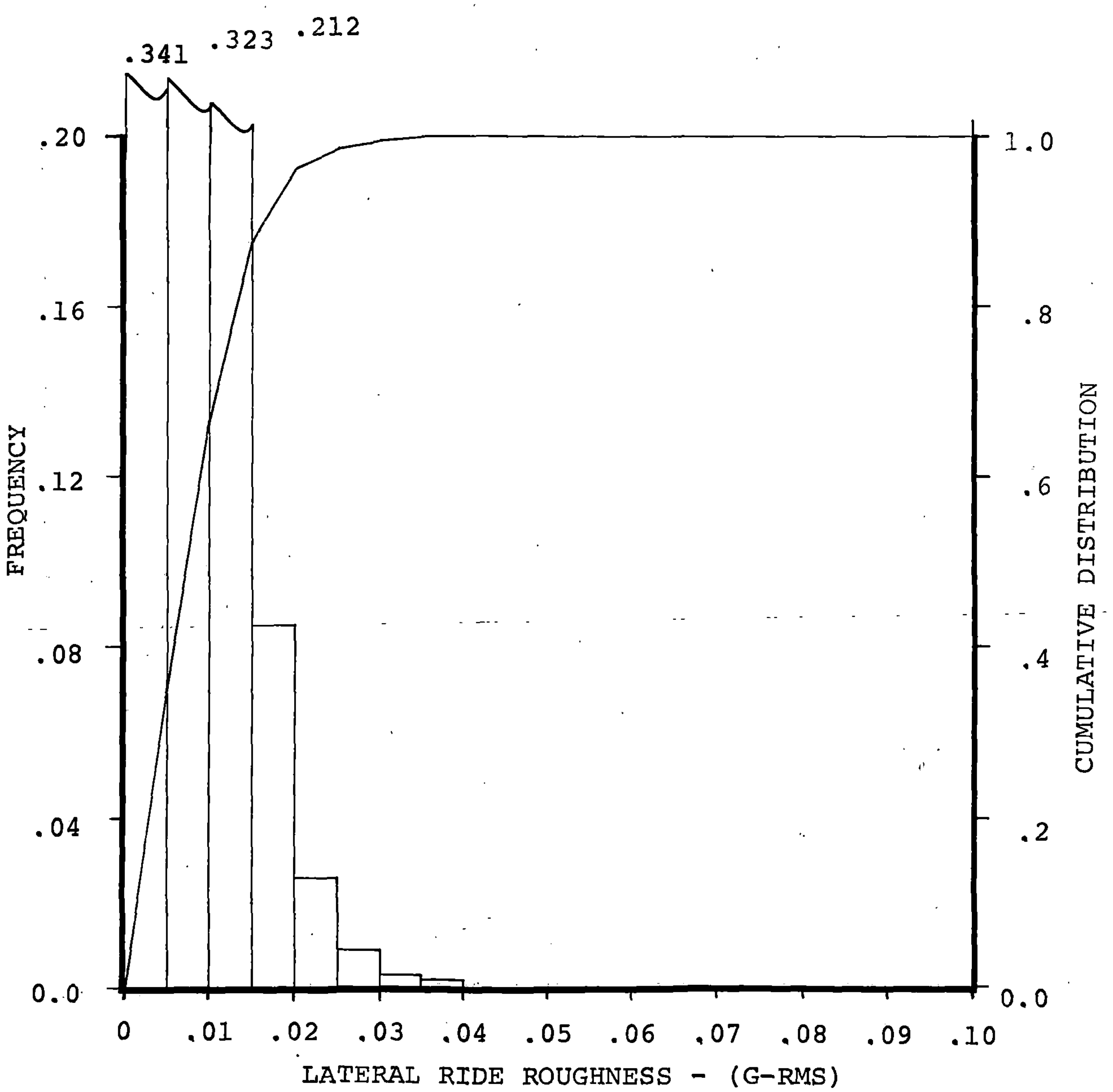


Figure 5—11. Mid-Car Lateral Ride Roughness Distribution

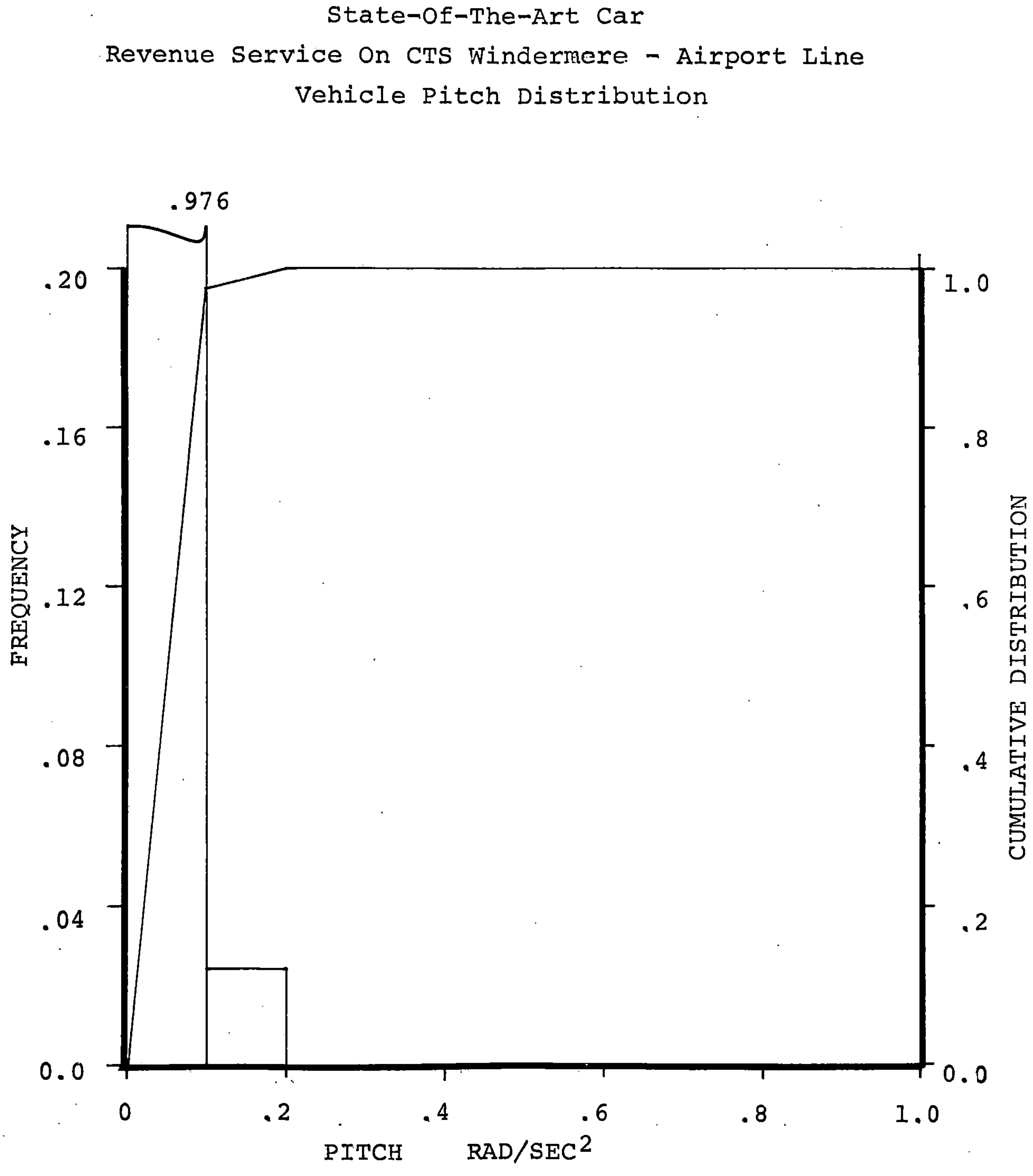


Figure 5–12. Vehicle Pitch Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Vehicle Roll Distribution

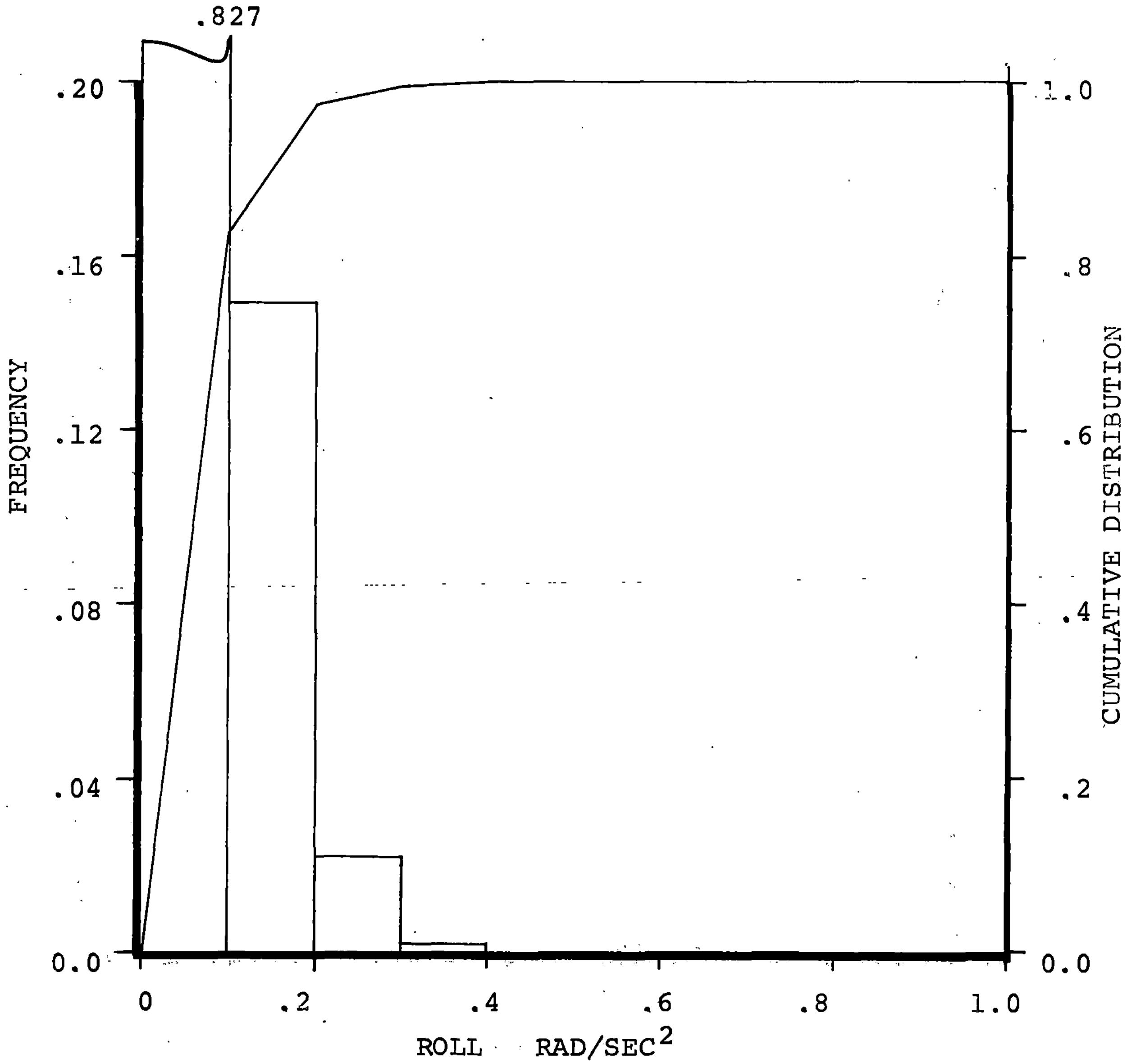


Figure 5—13. Vehicle Roll Distribution

State-Of-The-Art Car
Revenue Service On CTS Windermere - Airport Line
Vehicle Yaw Distribution

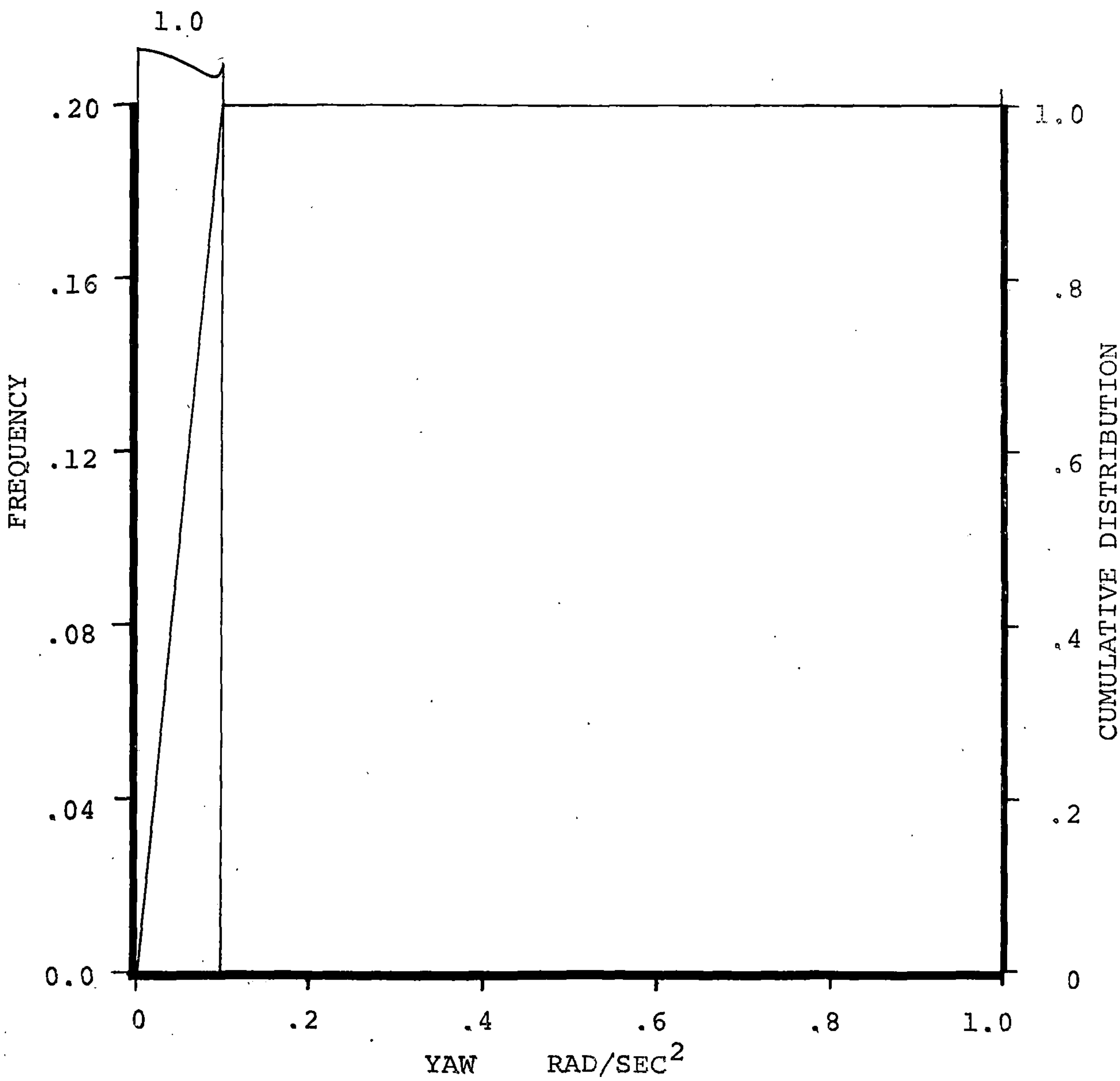


Figure 5–14. Vehicle Yaw Distribution

State-Of-The-Art Car
Revenue Service On The CTS Line
Interior Noise Level Distribution

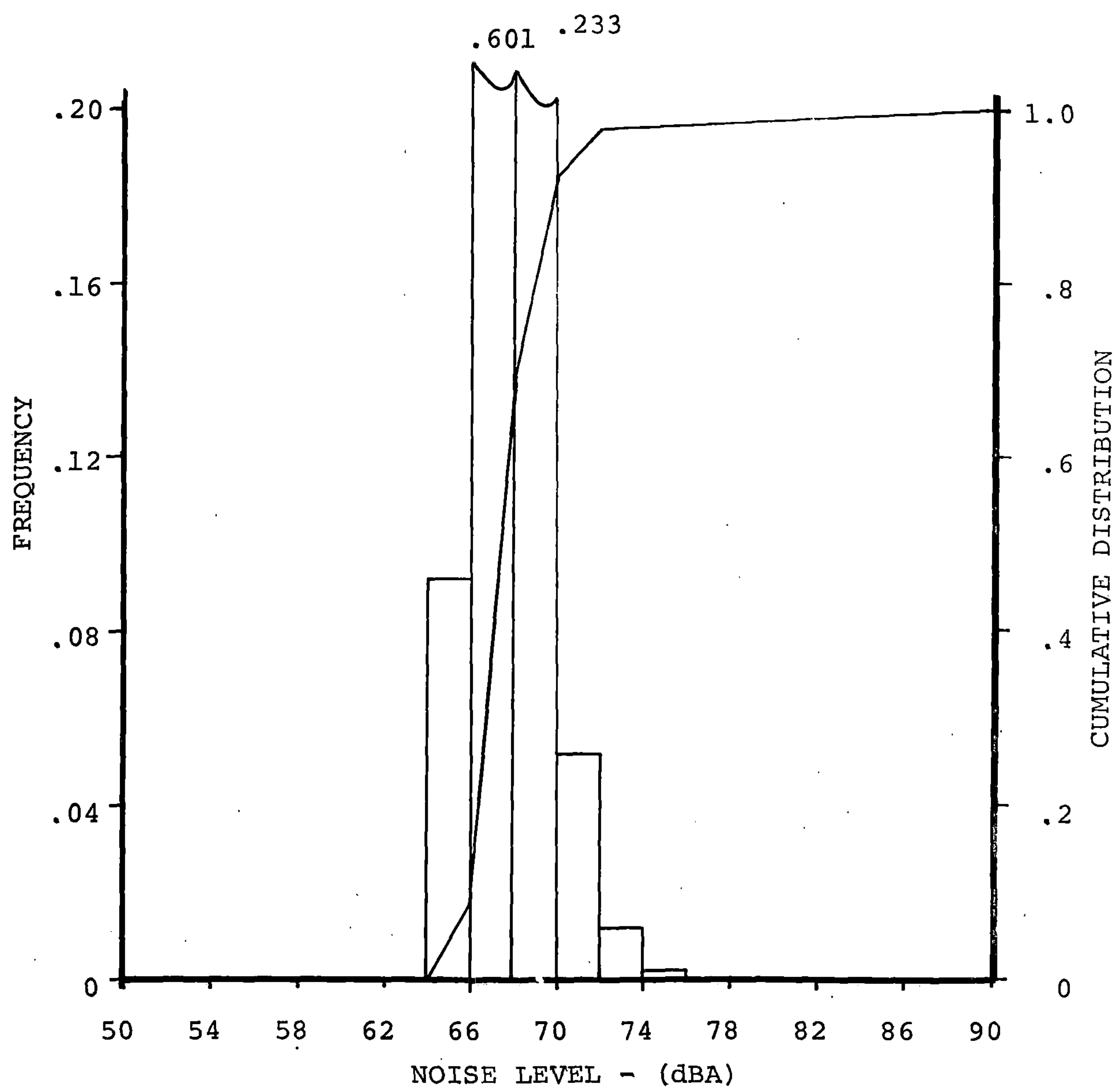


Figure 5–15. Interior Noise Level Distribution

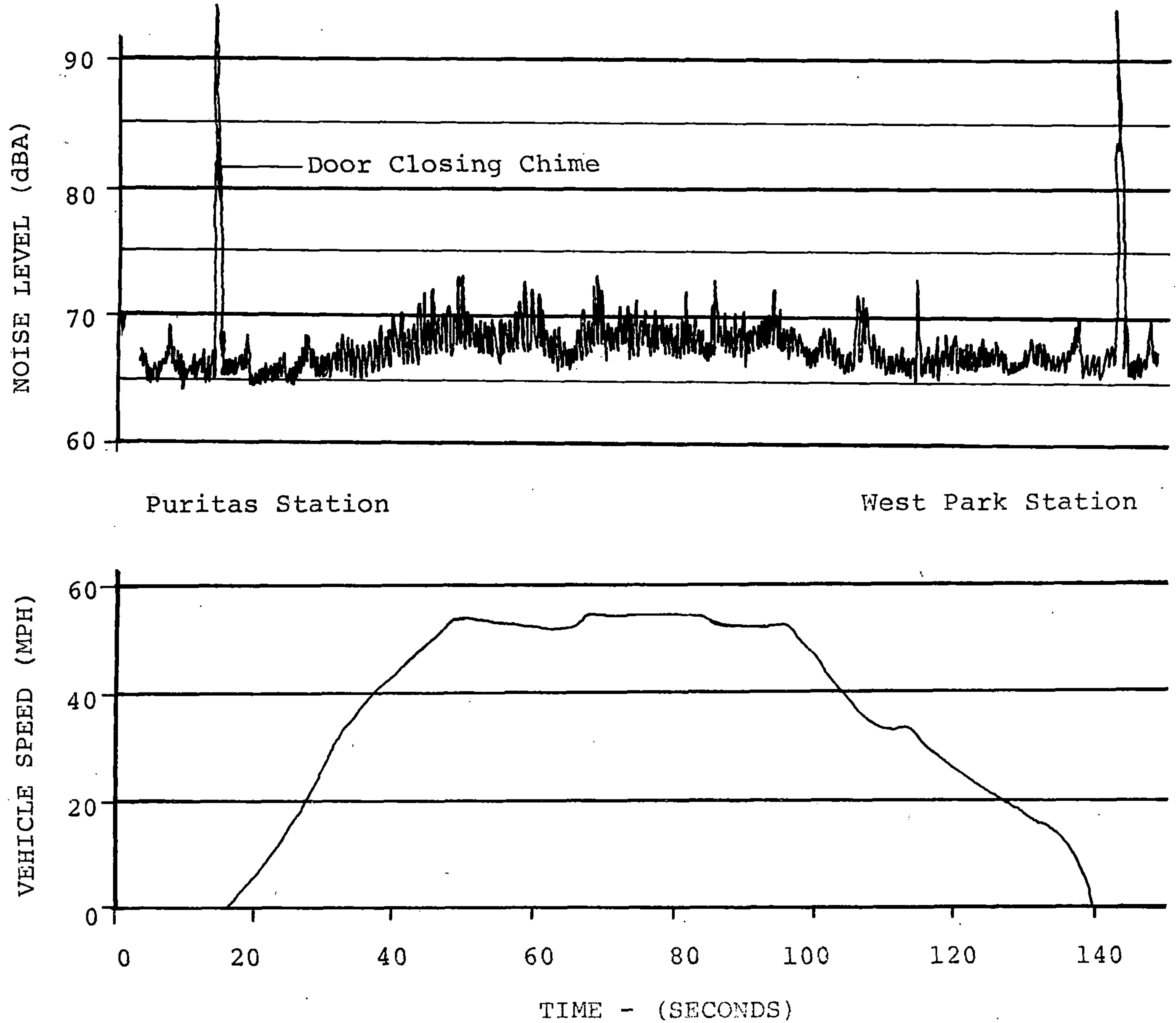


Figure 5–16. SOAC Interior Noise Level Sample

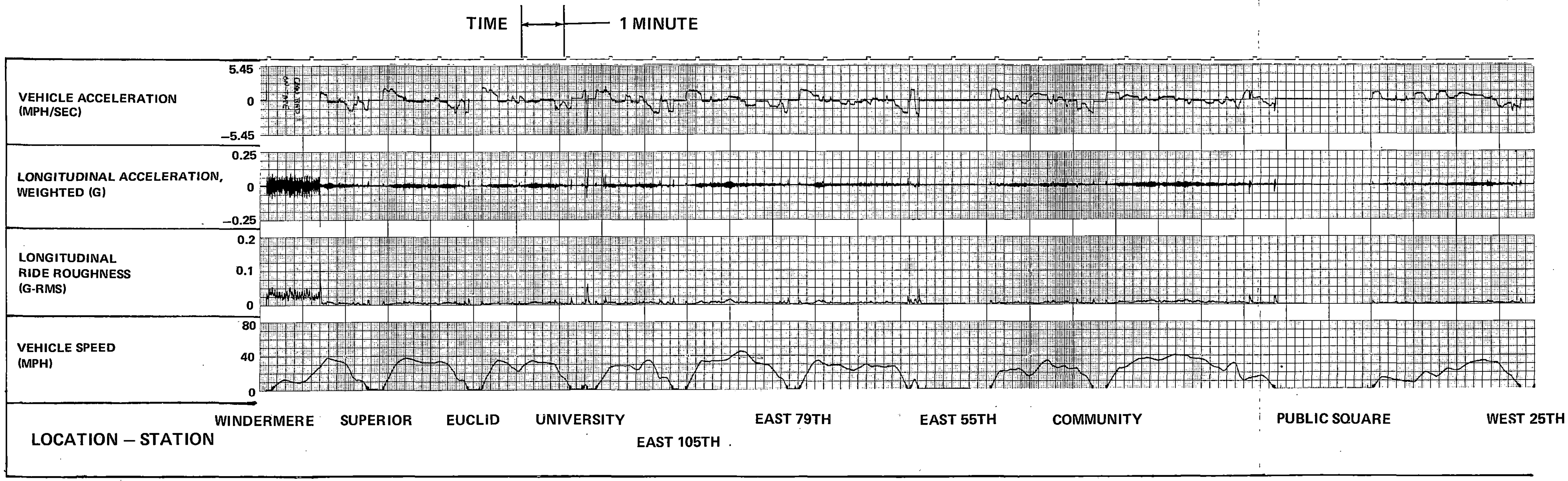


Figure 5–17. Vehicle Acceleration and Speed Time History Chart (WA) (Sheet 1 of 2)

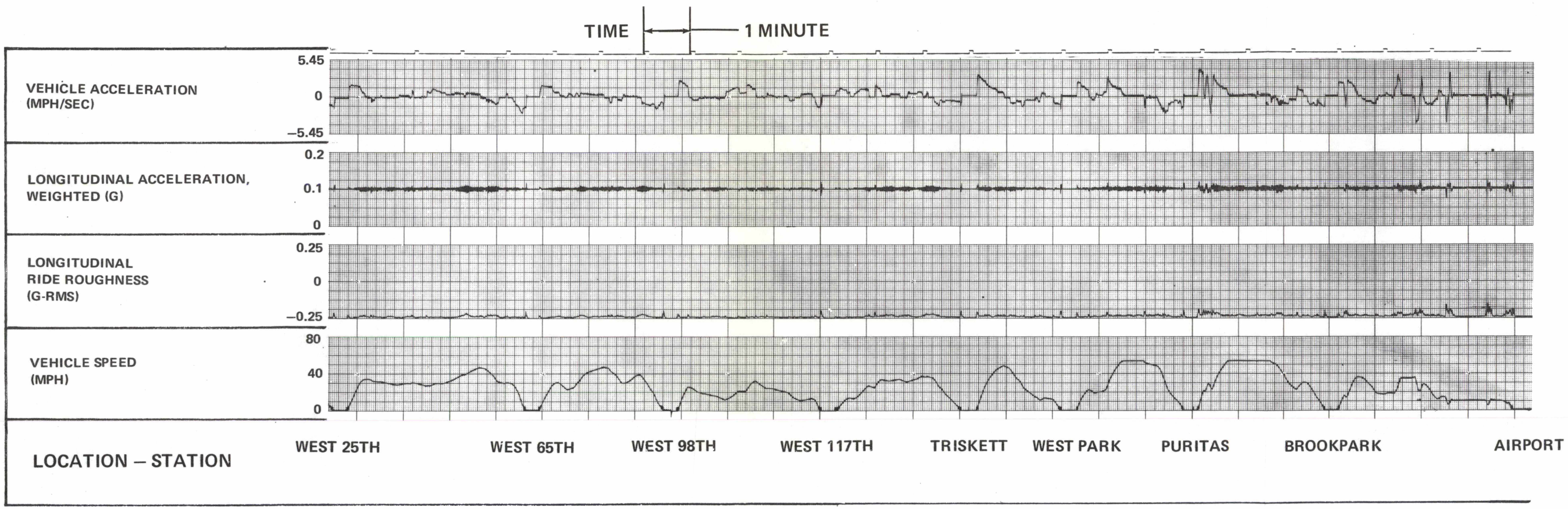


Figure 5–17. Vehicle Acceleration and Speed Time History Chart (WA) (Sheet 2 of 2)

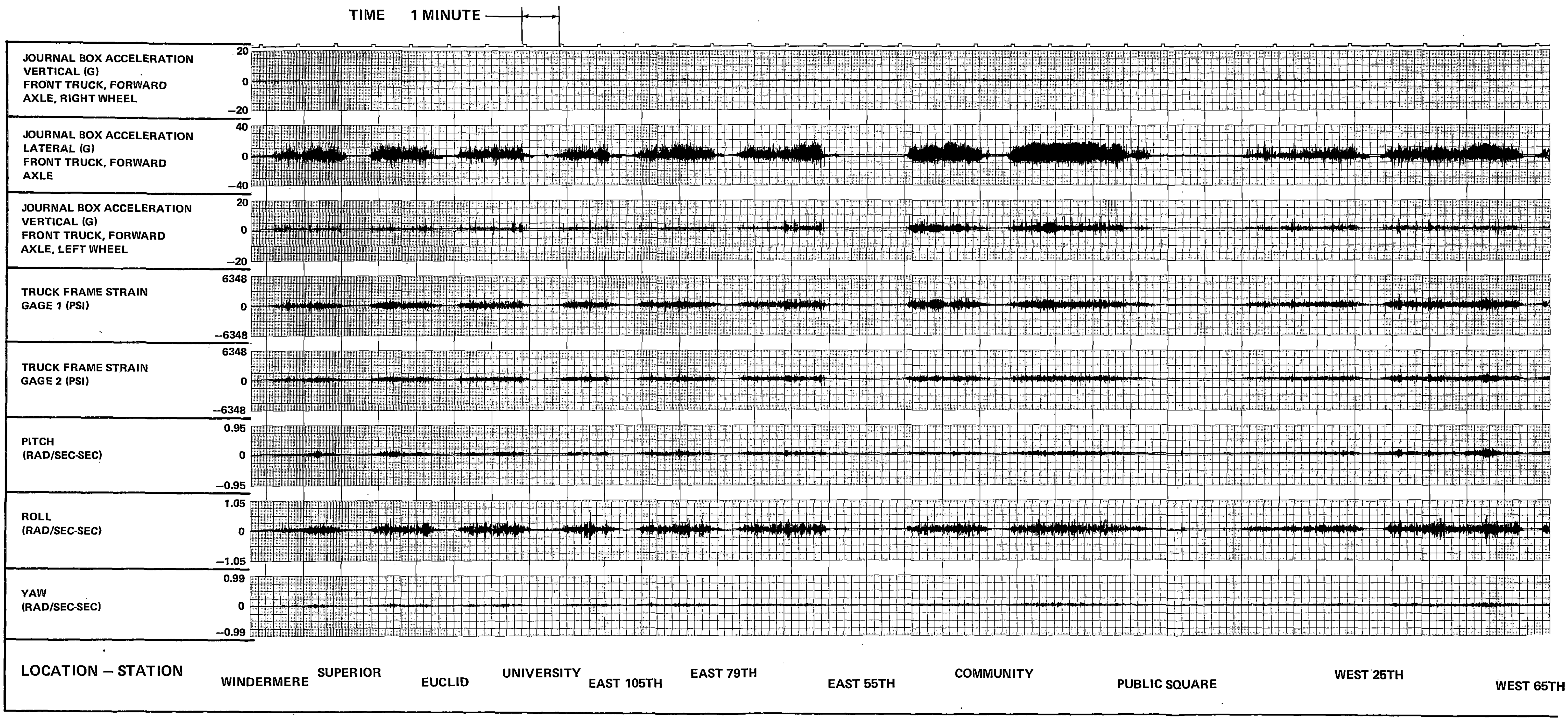


Figure 5–18. Journals, Truck Frame, and Angular Acceleration Time History Chart (WA) (Sheet 1 of 2)

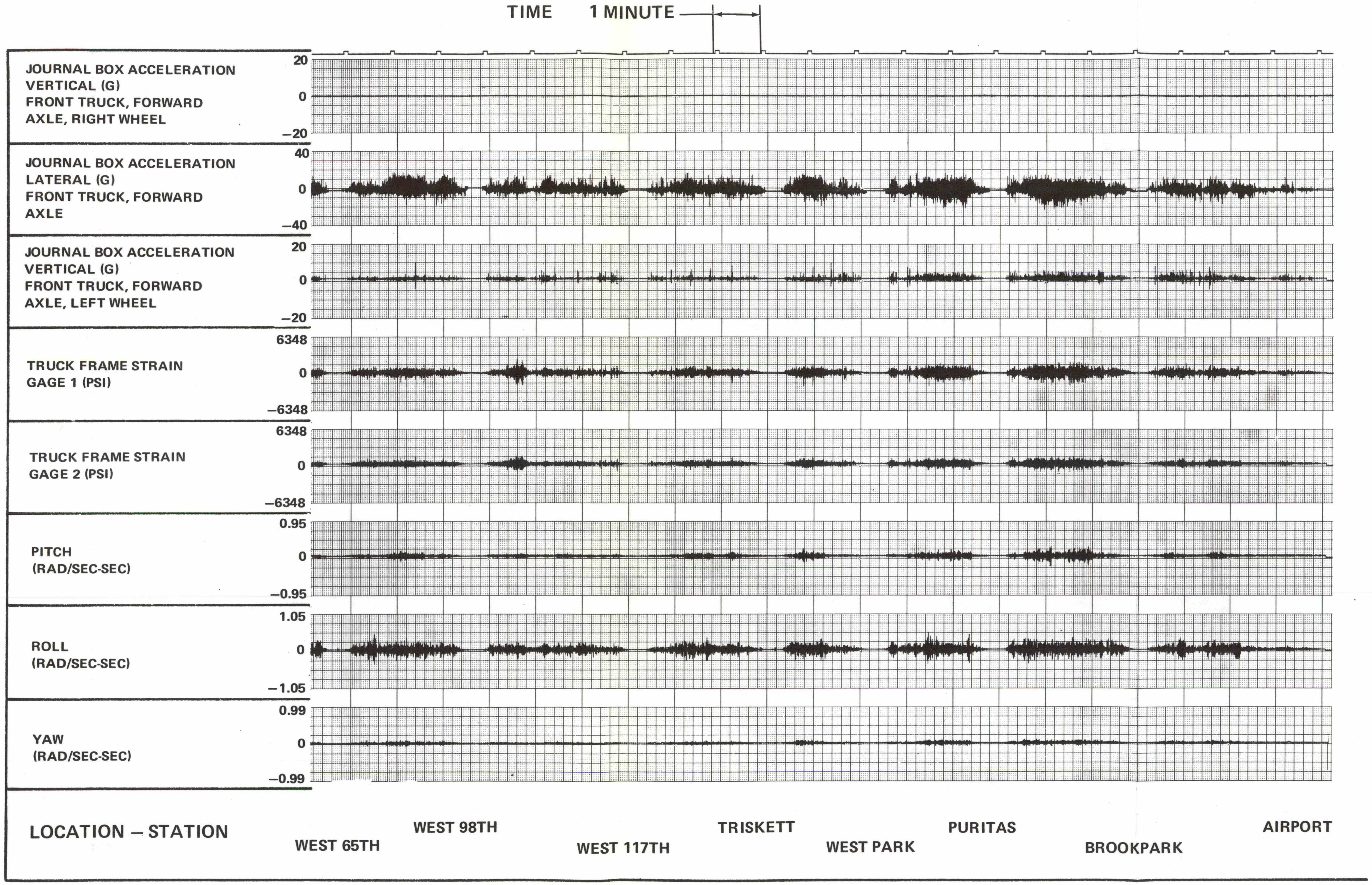


Figure 5–18. Journals, Truck Frame, and Angular Acceleration Time History Chart (WA) (Sheet 2 of 2)

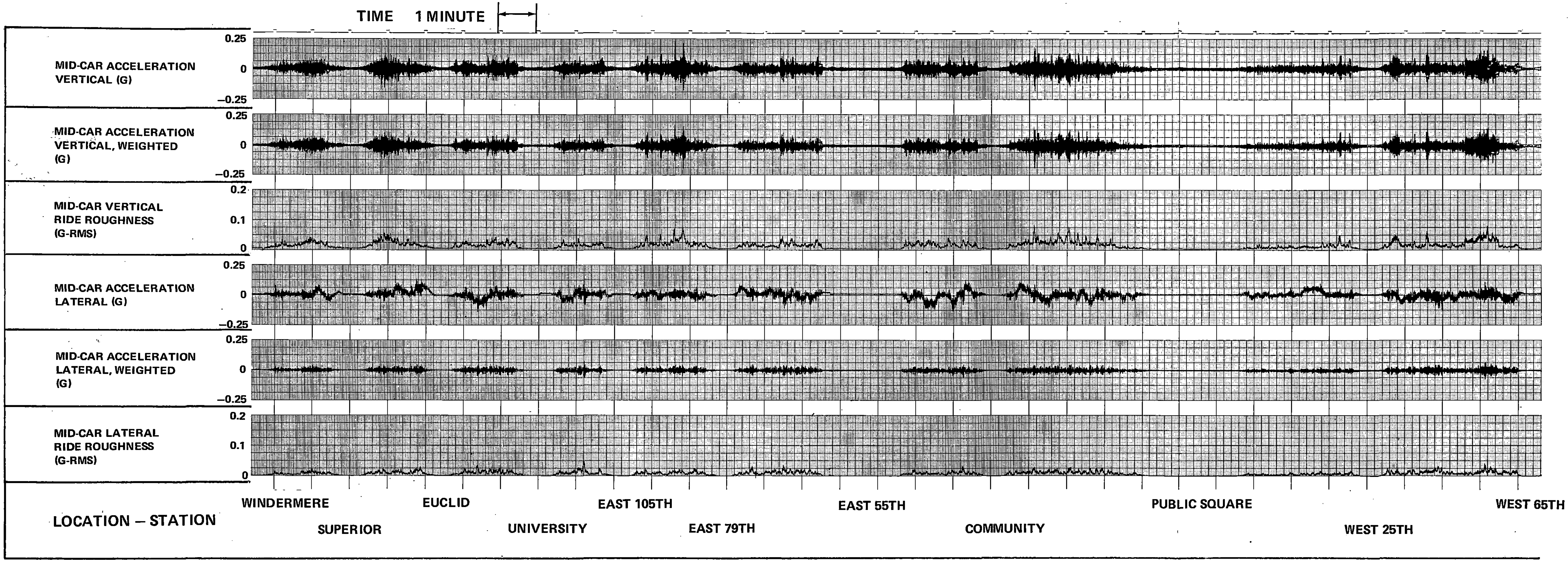


Figure 5–19. Mid-Car Acceleration Time History Chart (WA) (Sheet 1 of 2)

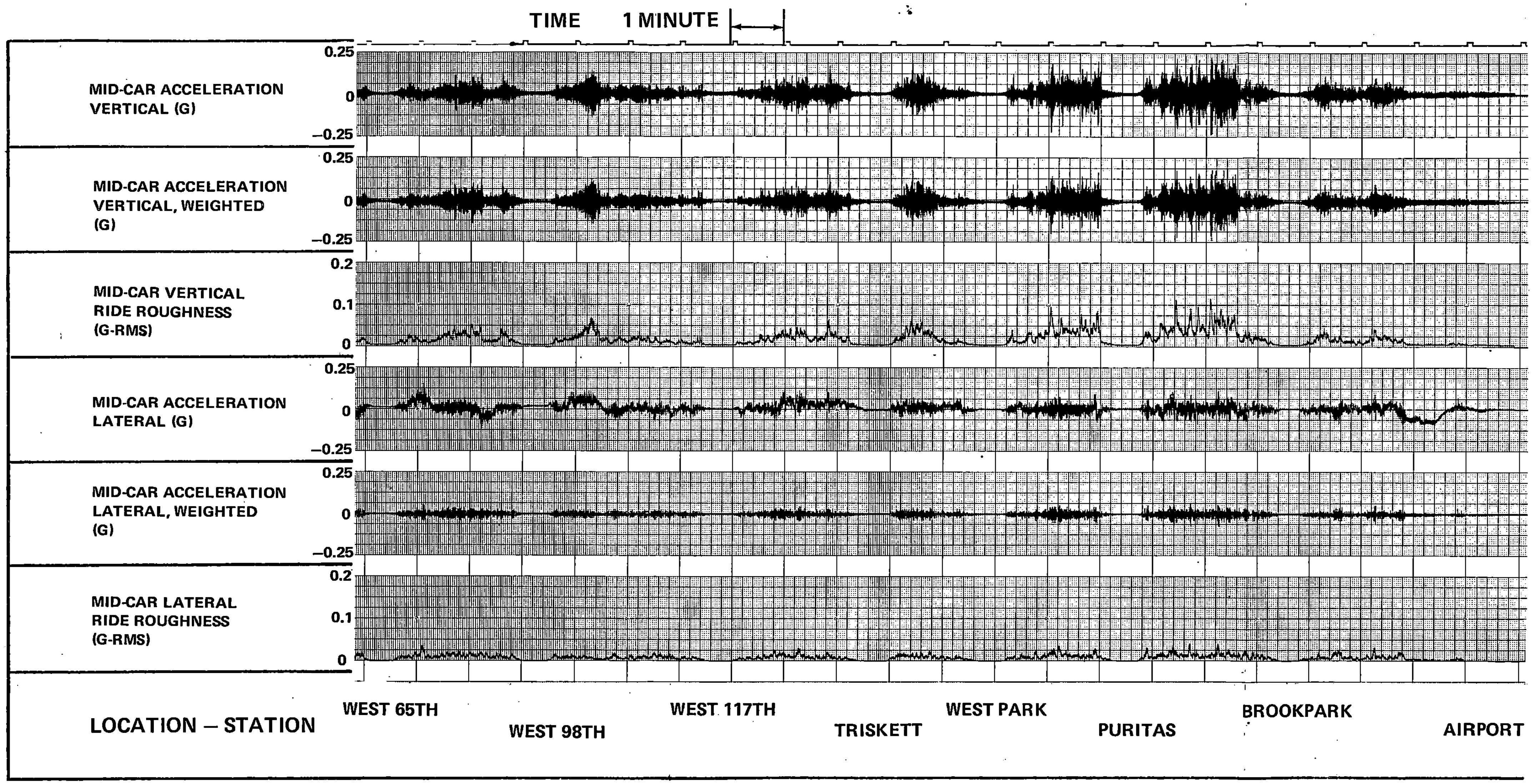


Figure 5–19. Mid-Car Acceleration Time History Chart (WA) (Sheet 2 of 2)

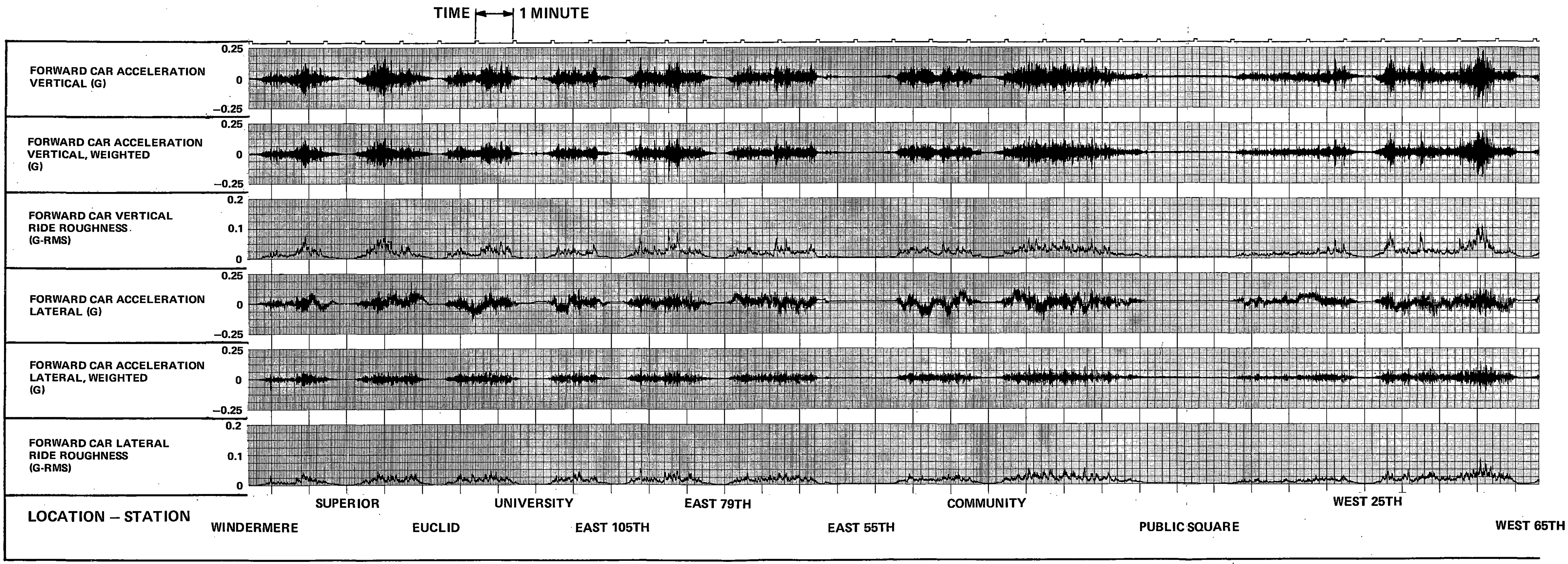


Figure 5–20. Forward Car Acceleration Time History Chart (WA) (Sheet 1 of 2)

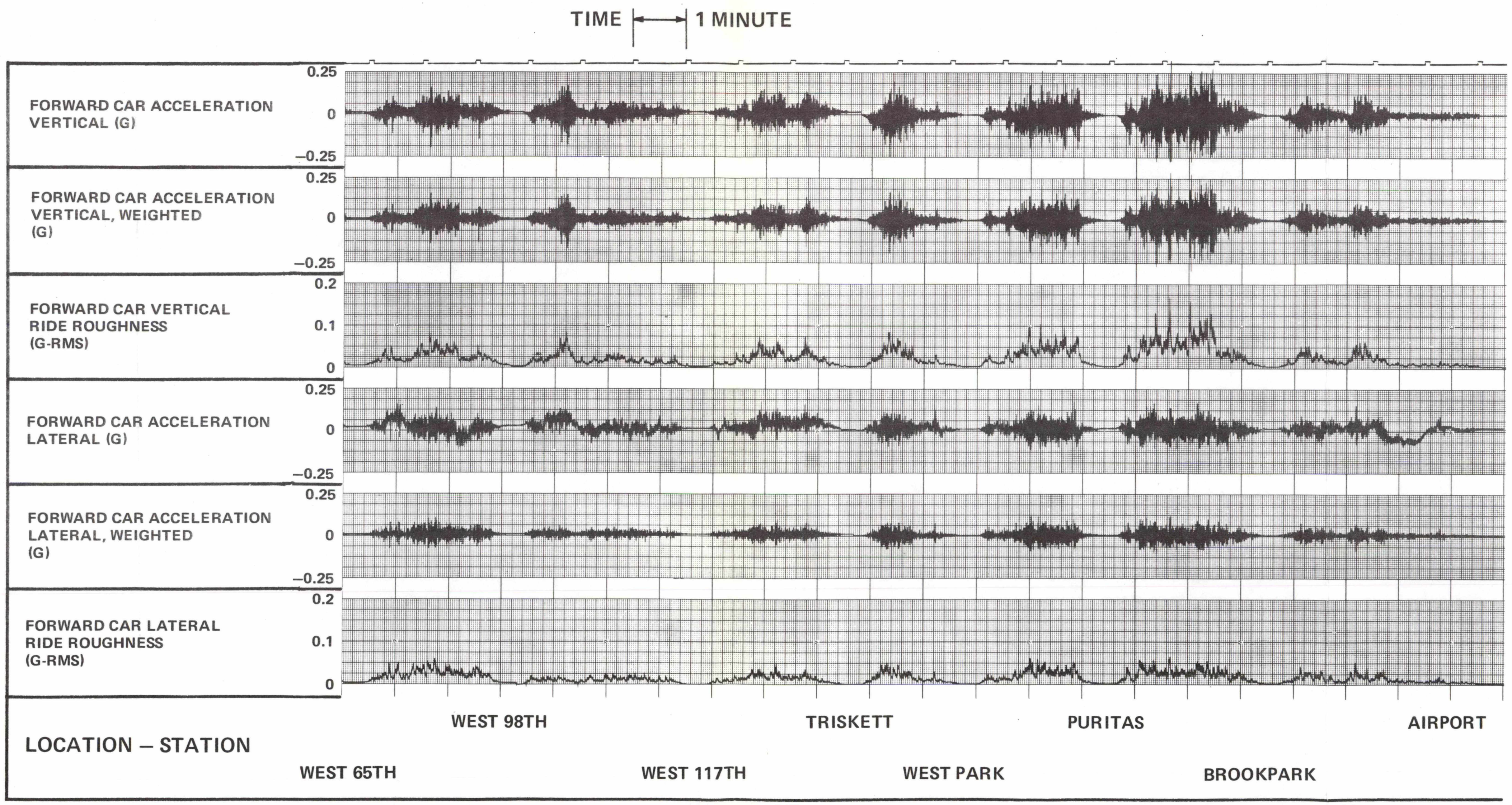


Figure 5–20. Forward Car Acceleration Time History Chart (WA) (Sheet 2 of 2)

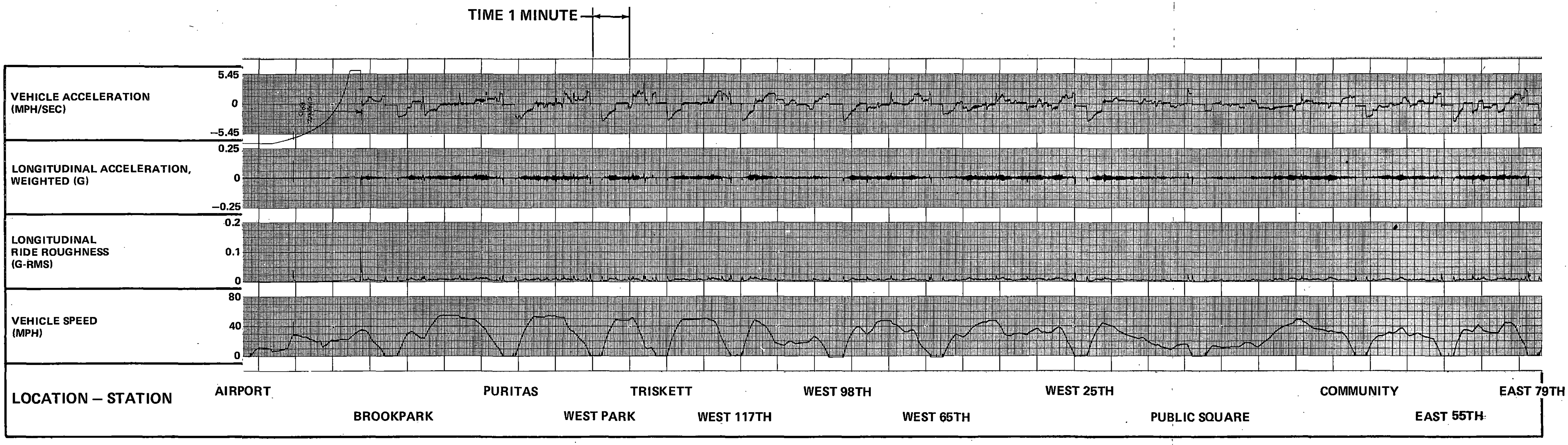


Figure 5–21. Vehicle Acceleration and Speed Time History Chart (AW) (Sheet 1 of 2)

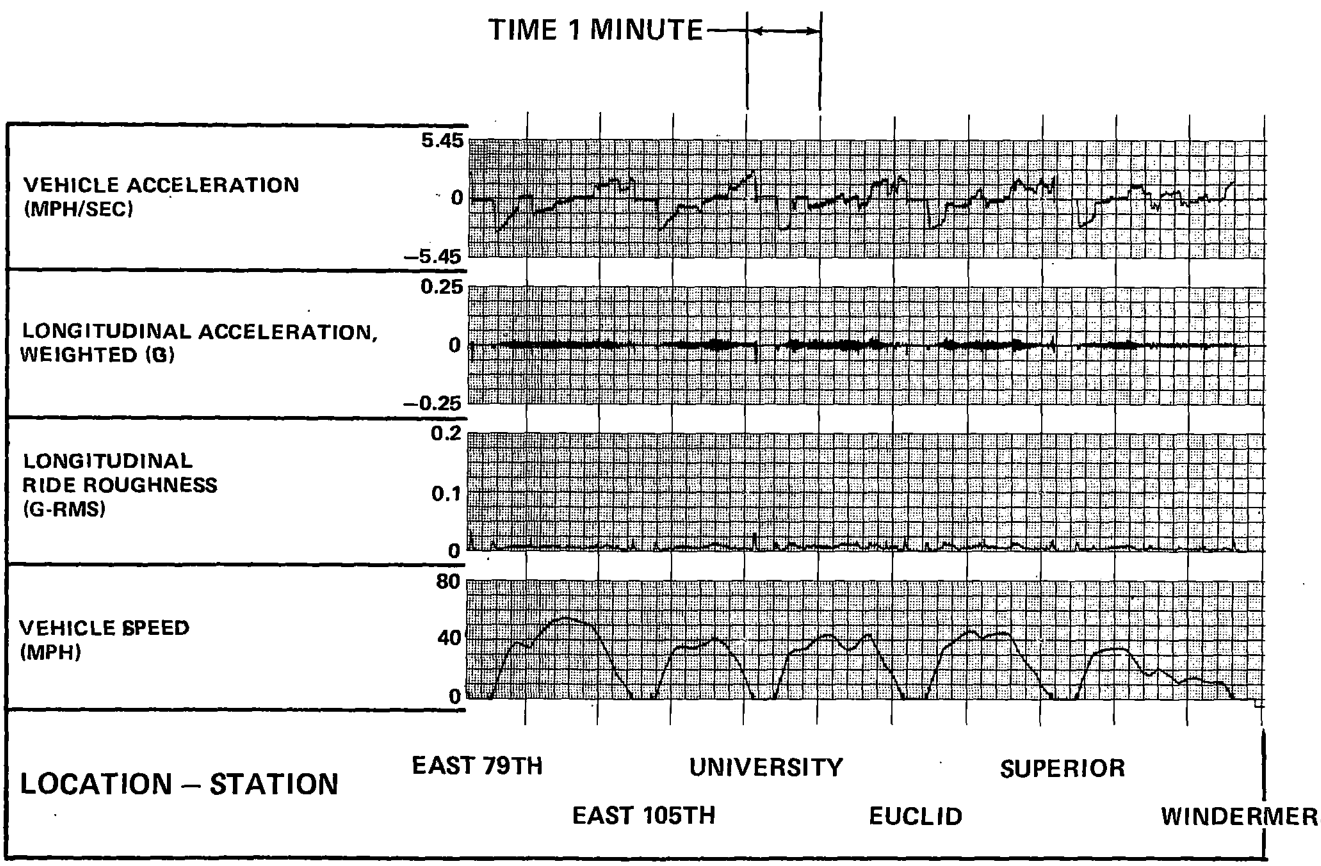


Figure 5–21. Vehicle Acceleration and Speed Time History Chart (AW) (Sheet 2 of 2)

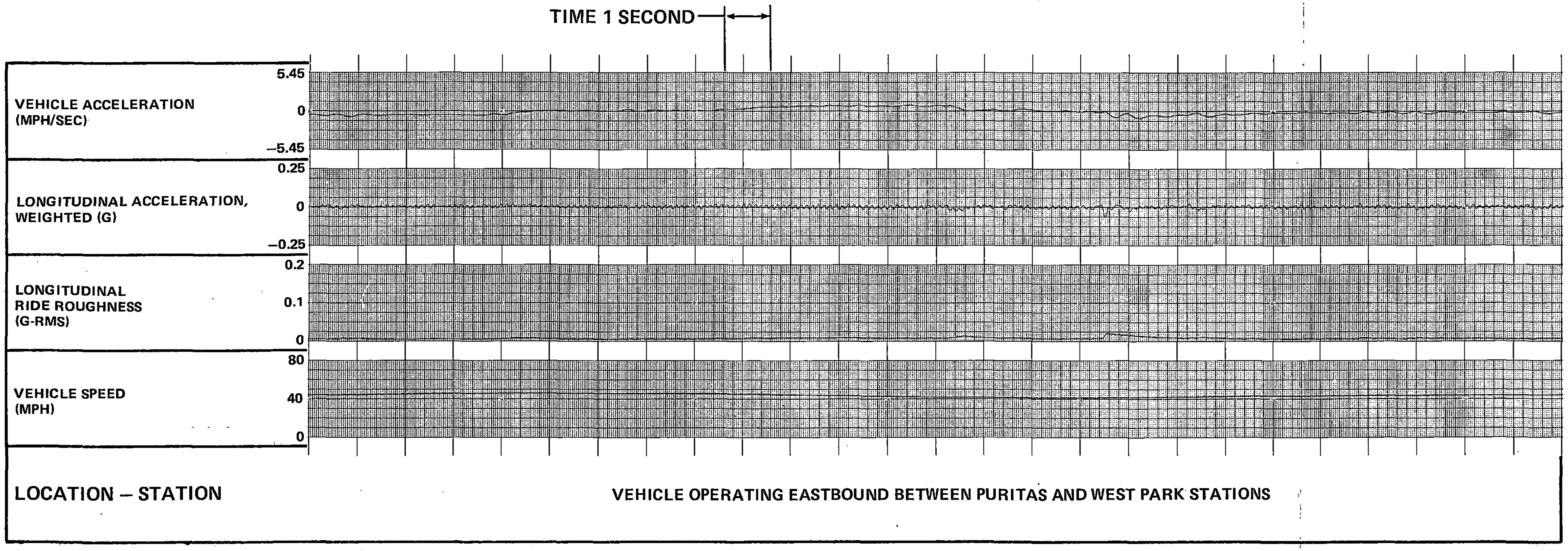


Figure 5–22. Vehicle Acceleration and Speed Time History Chart (~)

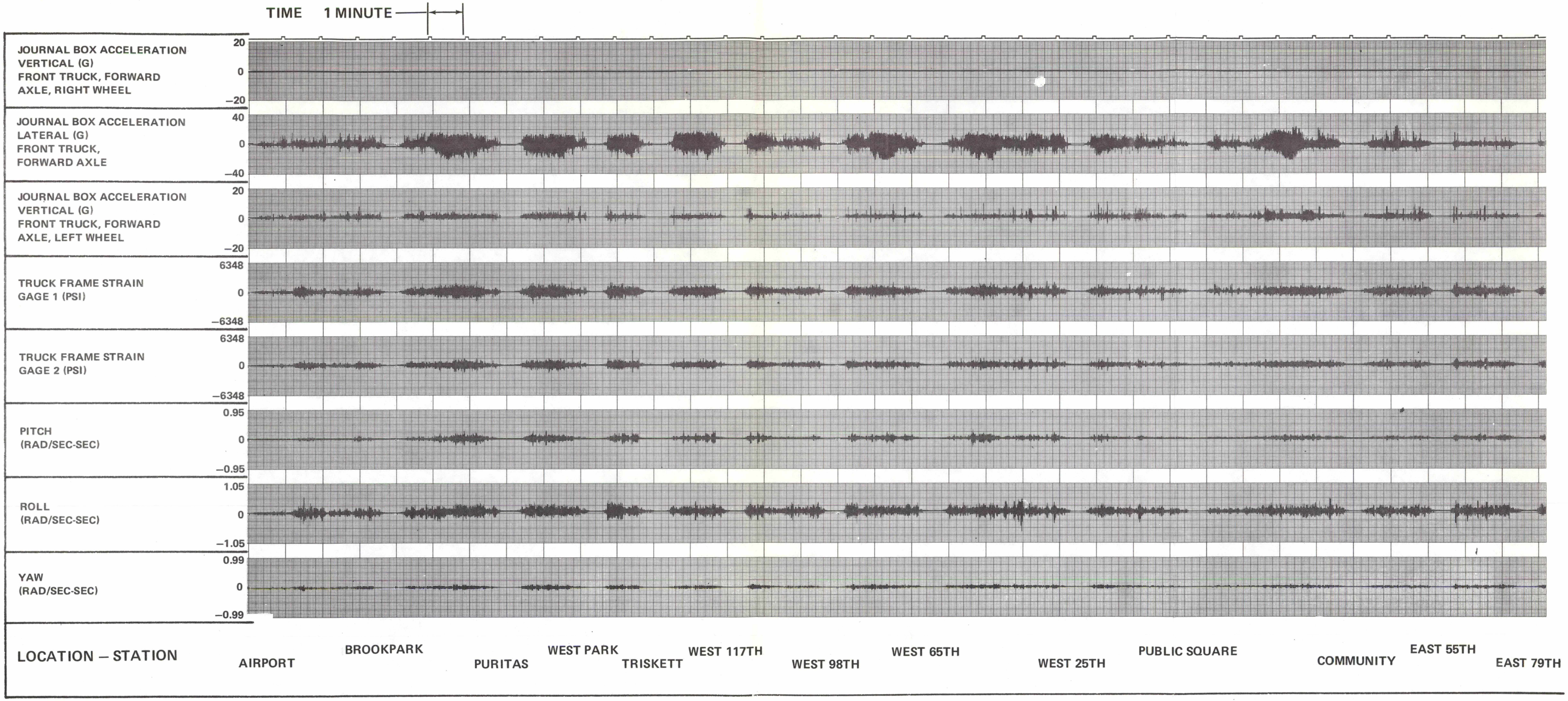


Figure 5–23. Journals, Truck Frame, and Angular Acceleration Time History Chart (AW) (Sheet 1 of 2)

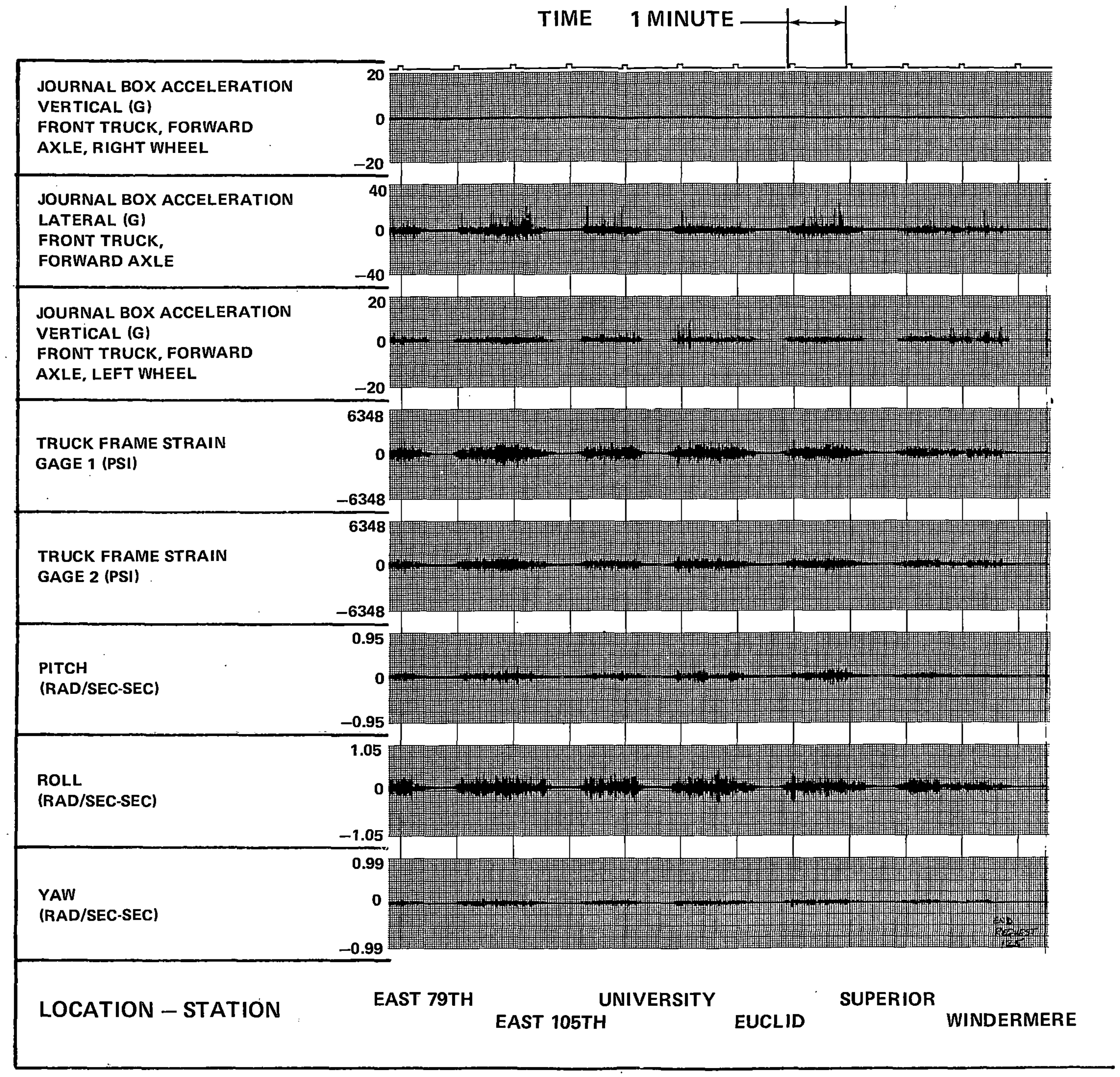


Figure 5–23. Journals, Truck Frame, and Angular Acceleration Time History Chart (AW) (Sheet 2 of 2)

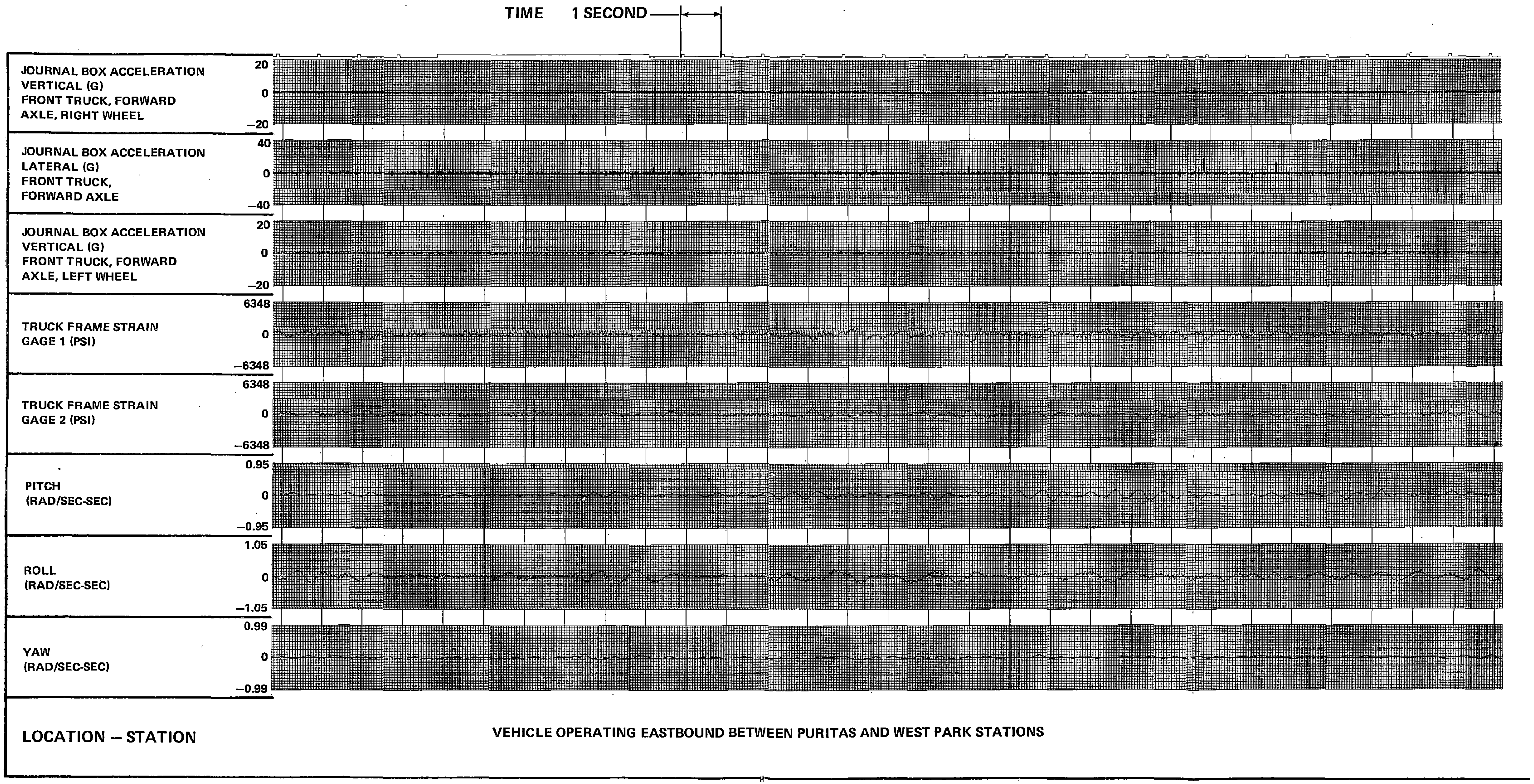


Figure 5–24. Journals, Truck Frame, and Angular Acceleration Time History Chart (~)

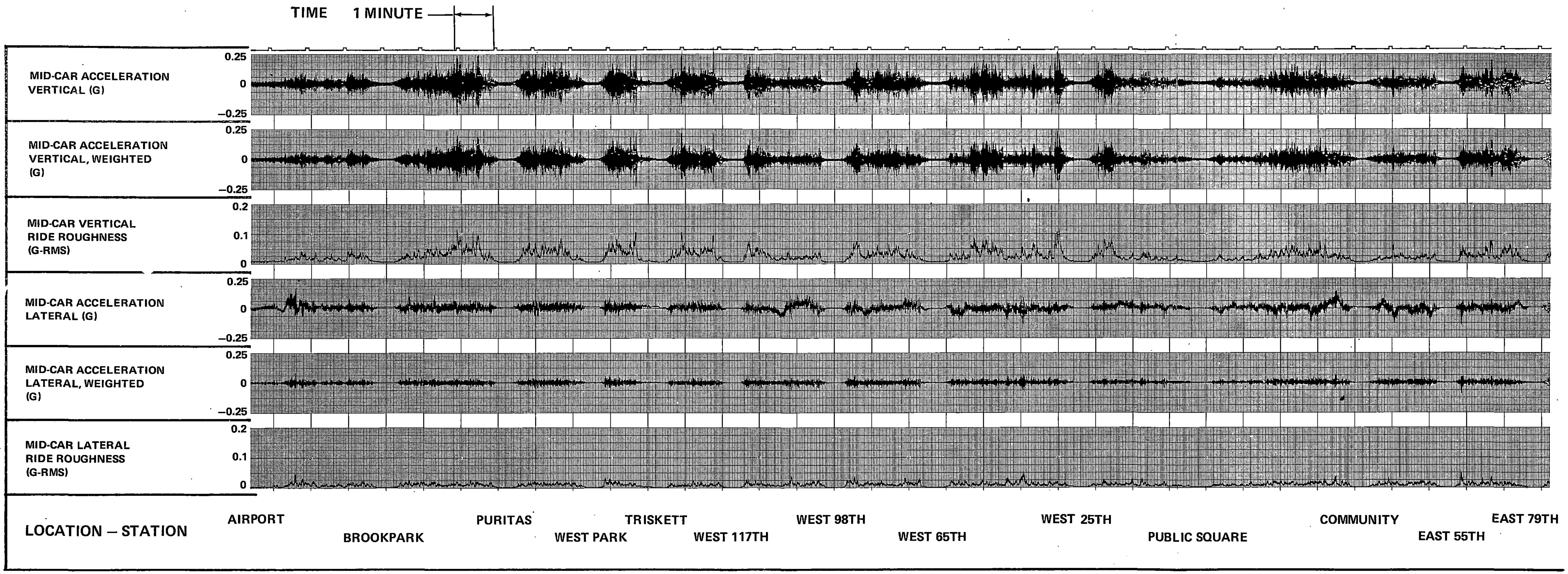


Figure 5–25. Mid-Car Acceleration Time History Chart (AW) (Sheet 1 of 2)

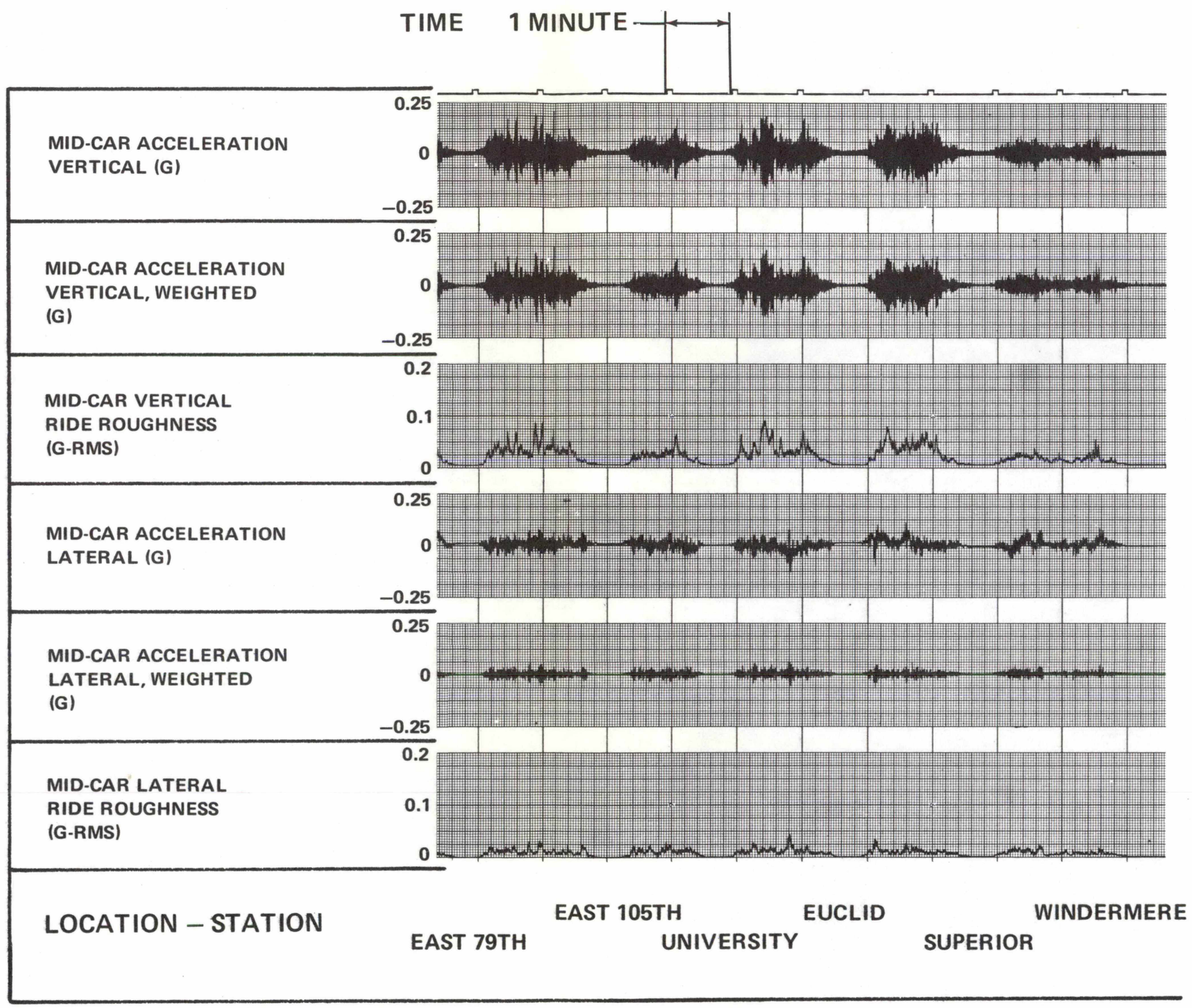


Figure 5–25. Mid-Car Acceleration Time History Chart (AW) (Sheet 2of 2)

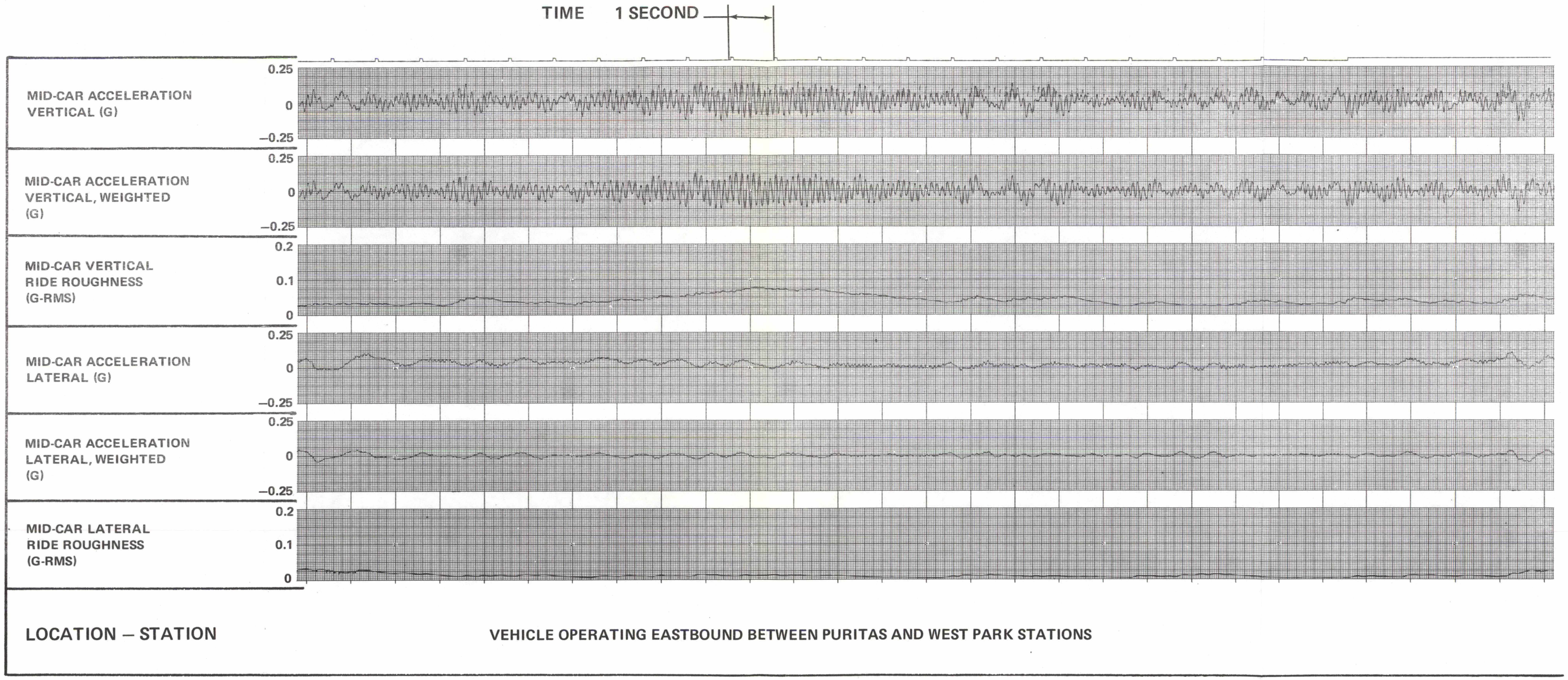


Figure 5–26. Mid-Car Acceleration Time History Chart (~)

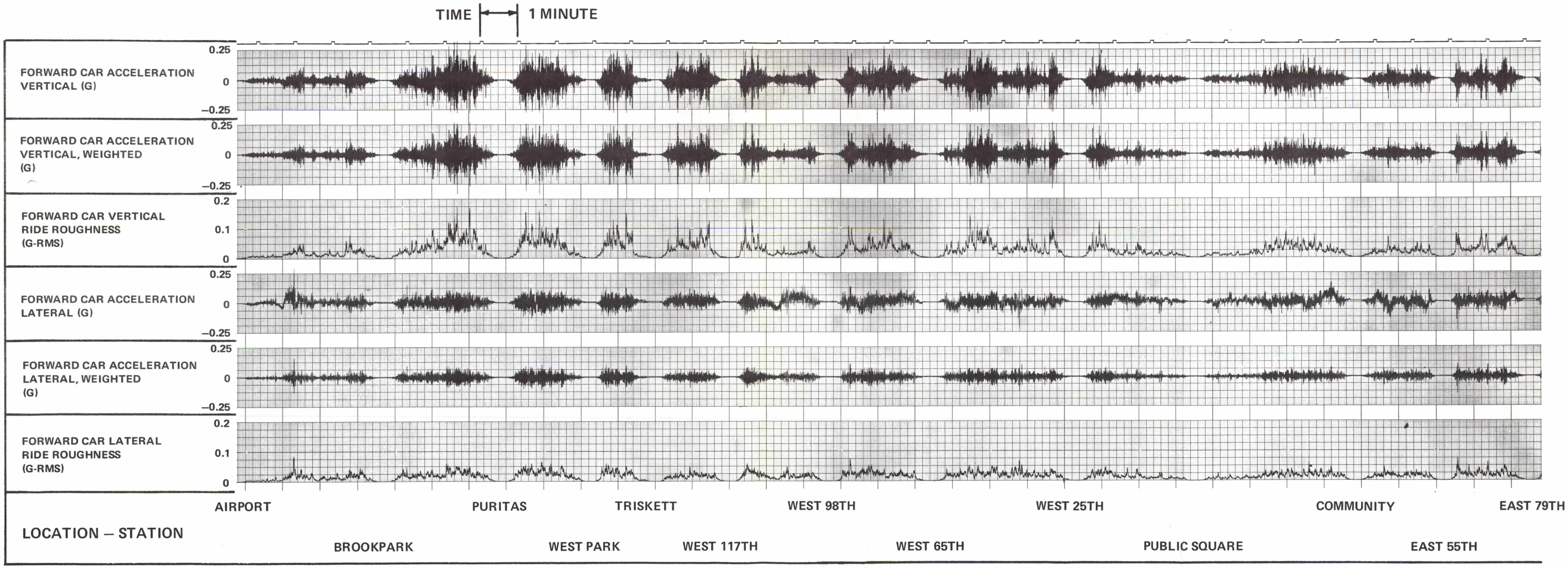


Figure 5–27. Forward Car Acceleration Time History Chart (AW) (Sheet 1 of 2)

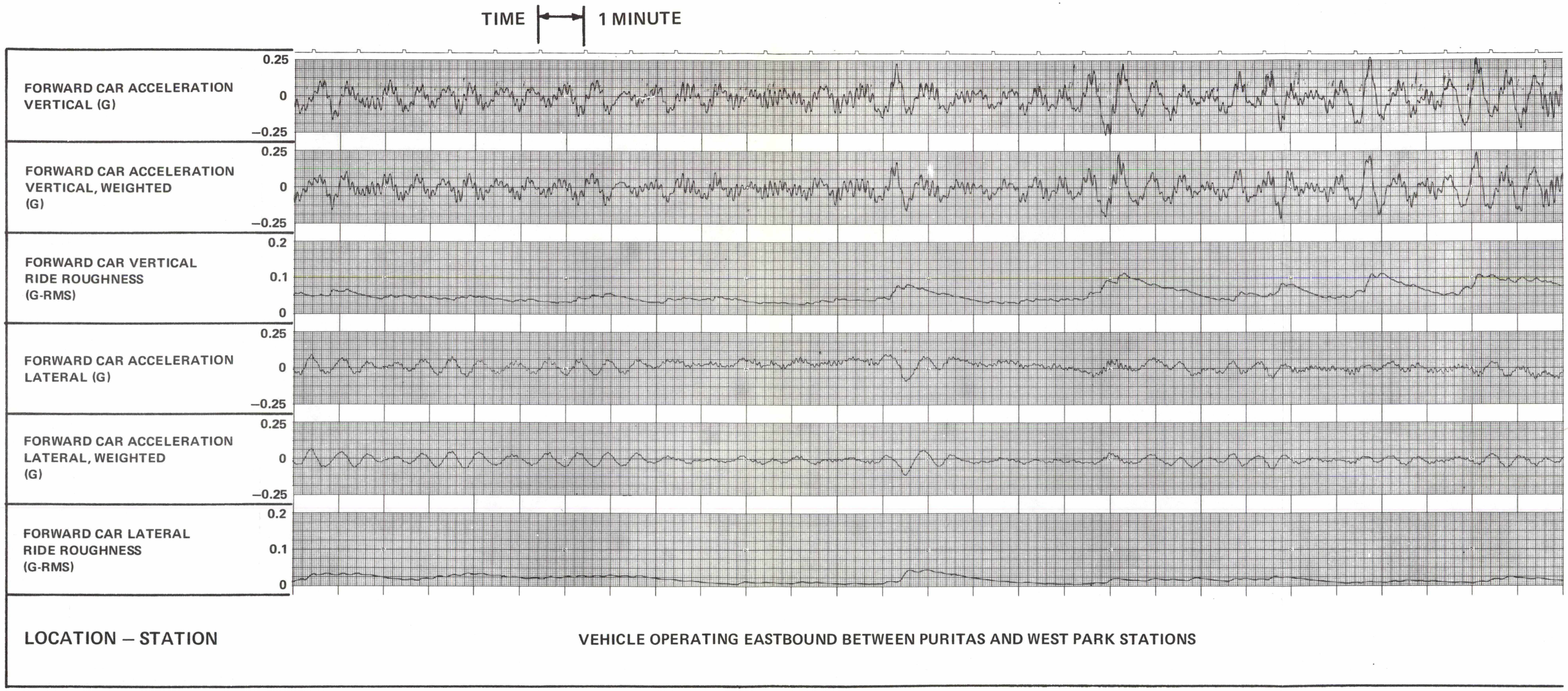


Figure 5–28. Forward Car Acceleration Time History Chart (~)

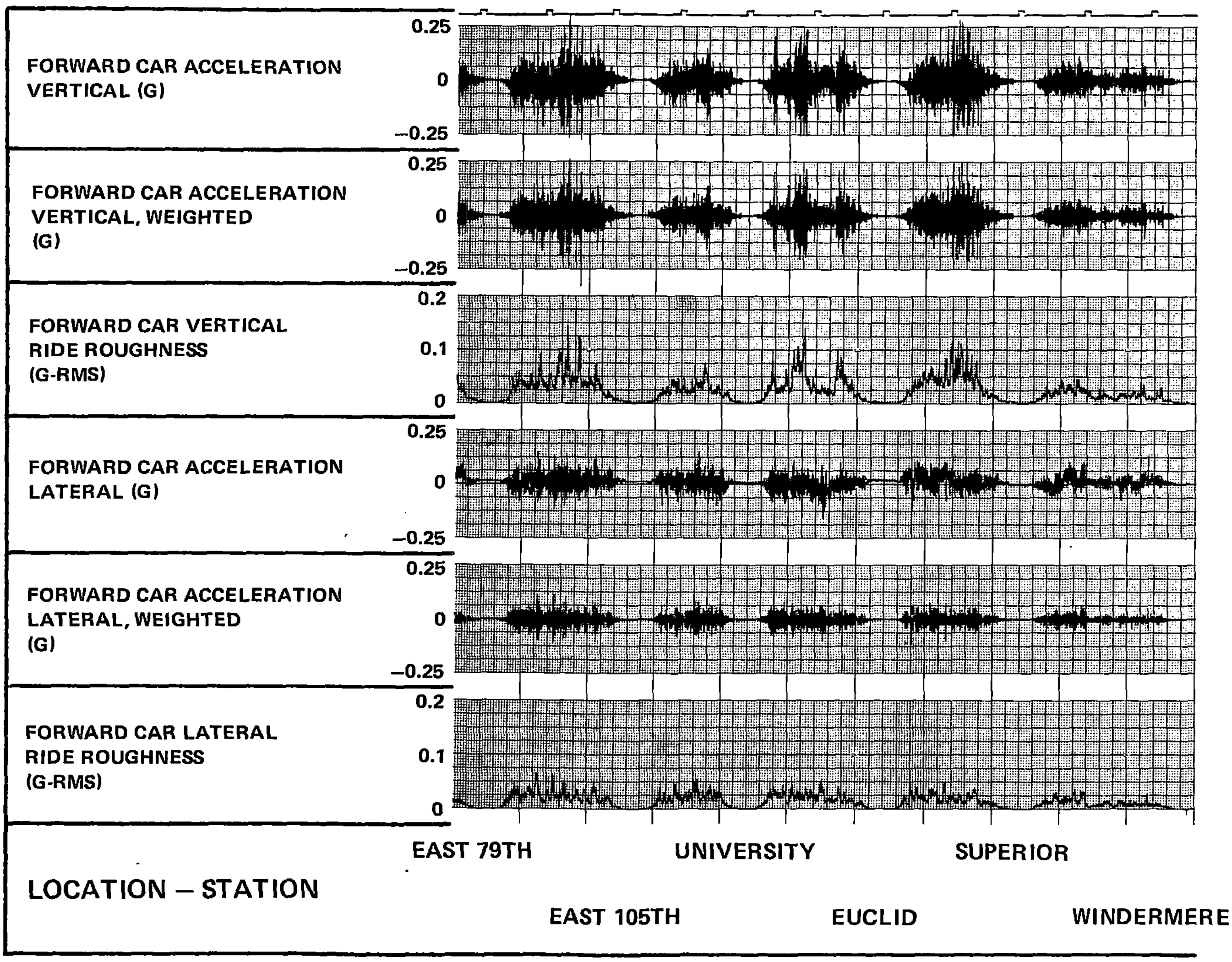


Figure 5–27. Forward Car Acceleration Time History Chart (AW) (Sheet 2 of 2)

APPENDIX C
TESTING AT CHICAGO

1.0 TEST DESCRIPTION

As part of the Operational Test and Evaluation Program, the State-of-the-Art Cars were in Chicago from December 19, 1974 to February 10, 1975. The period during vehicle set-up and checkout was used to install the engineering instrumentation system and to perform the Simulated Revenue Service Tests.

1.1 Test Site

The SOACs were operated on the Skokie Swift Line (Figure 1-1). This line originates at the Dempster Avenue Station in the village of Skokie and terminates at the Howard Street Station on the CTA Evanston Line. Only the two stations are on the route which is 4.9 miles long. The scheduled trip time was 6.5 minutes. The line is at grade level with seven gate controlled grade crossings. Both third rail and catenary systems are used for vehicle power collection.

1.2 Test Operations

The test plan was to operate the SOAC in simulated revenue service over the test route. For safety and operational reasons, vehicle operation was entirely under the control of CTA personnel during the tests. The only requirement imposed by the test was to maintain the normal scheduled service as close as possible.

The test run was scheduled for and accomplished on the late evening on January 15, 1975. Due to the lack of work crews and other operations, there were no incidents which would reflect on the test data.

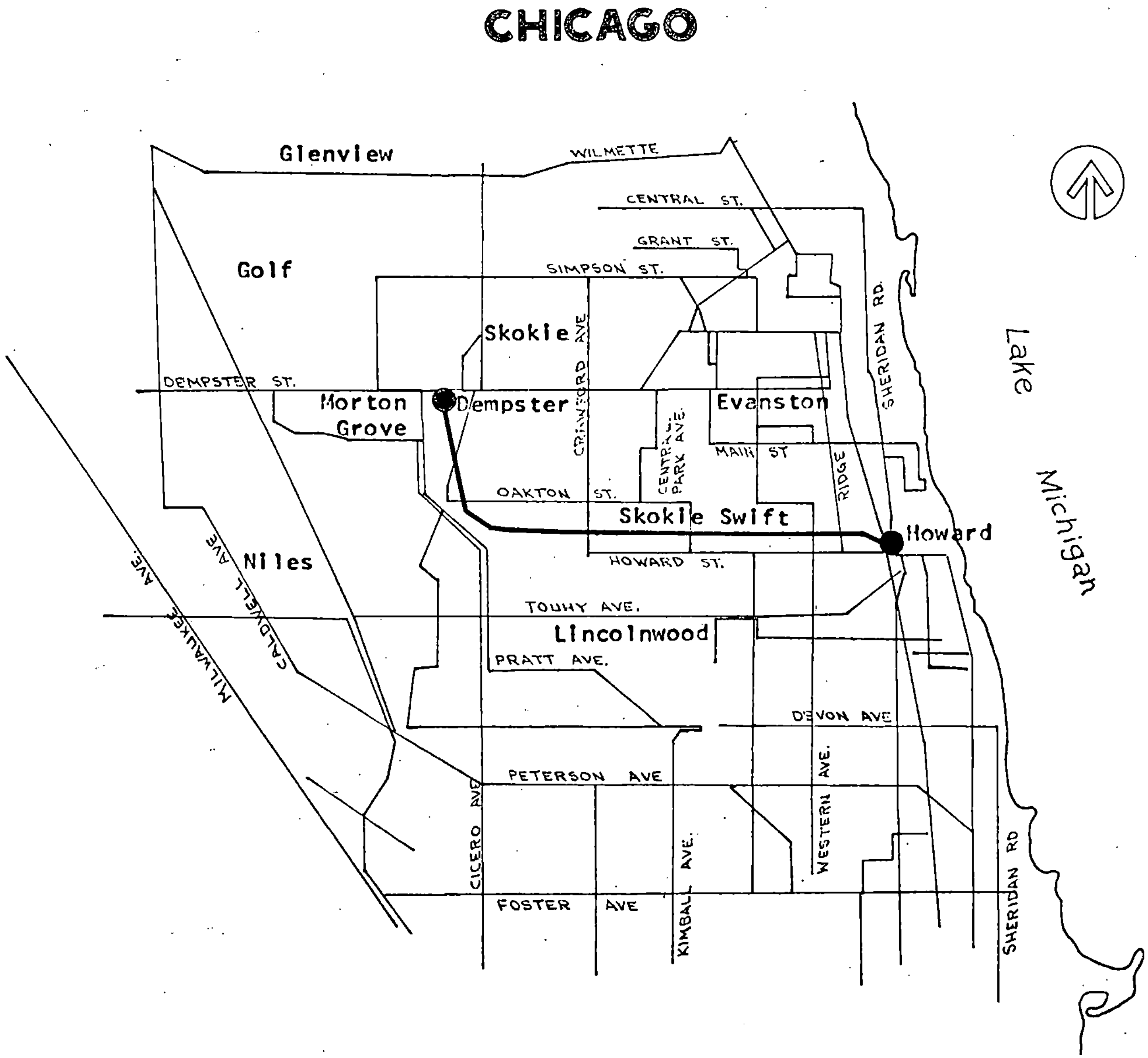


Figure 1–1. CTA Skokie Swift Line

2.0 TEST PROCEDURES

Pretest

1. Mount all required sensors
2. Calibrate Instrumentation System
3. Brief Test Crew on Test Operations

   NOTE:

   One vehicle is instrumented for noise measurements, avoid other than normal conversation.

Test

1. Operate the vehicles in a simulated revenue service, i.e. maintain the given schedule.
2. Provide a nominal 10 second door opening at each scheduled stop.
3. Provide voice commentary on instrumentation recording during progress of test.
4. Maintain a manual log of events during the test run, correlated to the instrumentation system records.
5. Monitor various preselected data channels to ascertain validity of test run.
6. The Test Controller will terminate the test if:
   (a) An extended delay or train shutdown occurs
   (b) One or more required data channels malfunction
   (c) The test vehicle is not operating properly

   Advise Test Controller of any abnormal operations or events that occur during the test run.

3.0 INSTRUMENTATION

The SOAC Instrumentation System was used for this series of tests. This system is described in detail in Volume VI of State-of-the-Art Car (SOAC) Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Test Report, UMTA-MA-06-0025-75-6, January 1975. A synopsis is included below.

3.1 Ride Qualities, Structural and Performance Tests

Electrical signals from the vehicle mounted transducers are conducted by cables to an interface panel which is connected to an instrumentation console containing two magnetic tape recorders, two light beam oscillographs, a time code generator, a temperature recorder and signal conditioners. Any 28 selected test parameters can be recorded on tape and displayed on the oscillographs. In addition, wheel speeds may be recorded directly on the oscillographs; total power is recorded on tape and displayed on a mechanical counter. The time code generator provides signals that are recorded on both tape and the oscillograph. The oscillographs provide quick-look data to evaluate test progress and results during testing (See Figure 3-1).

3.2 Noise Tests

The instrumentation used for noise measurement consisted of a 1" condenser microphone with battery operated cathode follower and a 1/4" single channel tape recorder.

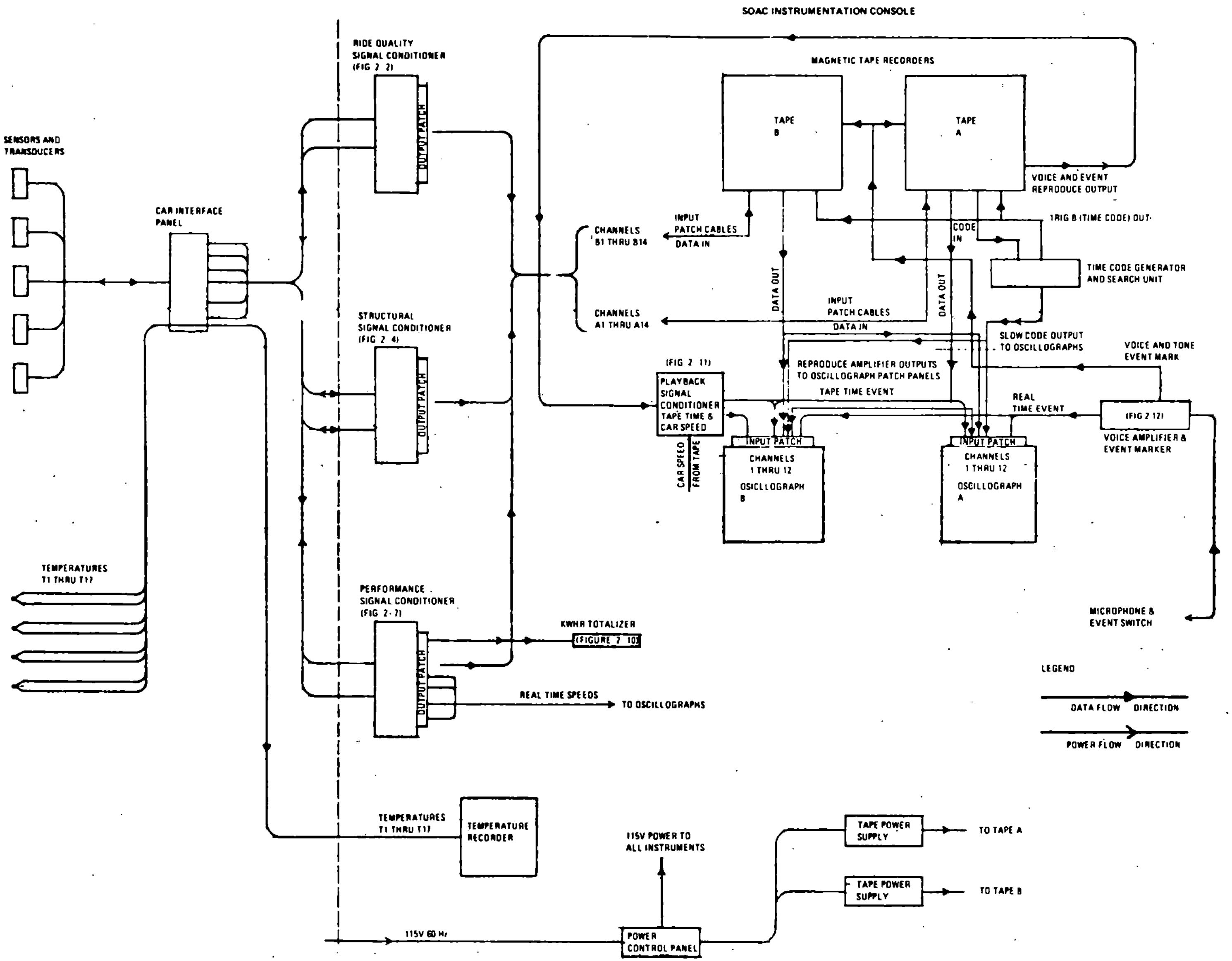


Figure 3—1. SOAC Instrumentation System Block Diagram

4.0 DATA

The parameters recorded during the property tests are described in Tables 4-1 and 4-2. The definition of the parameter measurements is contained in Appendix A, Standard Outputs for SOAC Property Tests.

Data was recorded for the roundtrip routes noted in the Test Description Section. All of the data was recorded on analog tapes and processed to provide three types of outputs.

Time History Charts

Station Summary Tables

Frequency Histograms

4.1 Time History Charts

A slow chart speed strip-out of certain parameters is included in this report. The purpose of these charts is to provide an indication of the maximum levels of parameters during various phases of the run. The complete run is described on the charts including station stops and any particularities that occurred. A series of time histories at a high chart speed is included to illustrate the cyclical nature of the data. These charts are a single time frame for all parameters and are representative of the worst case conditions exhibited for a particular test run.

Intermediate parameters, such as a weighted (filtered) car body acceleration are shown on some charts.

4.2 Station Summary

A summation or summary of specific parameters is made by each station stop. These include test running time and distance for comparison to the property's schedule. Power consumption, motor duty cycle parameters are also summarized by station to indicate the relative sizing of the SOAC propulsion with respect to operations on the property. Station stops and maximum speeds are also shown as another indicator of vehicle operation in a scheduled service environment.

Table 4–1. SOAC Revenue Service Data List A

PARAMETER			STANDARD OUTPUTS		
DESIGNATION NO.	DESCRIPTION	RANGE	RECORDED	PRESENTED	PRELIMINARY ANALYSIS
301	Longitudinal Acceleration	± 0.25 g's	AP/A	Format(3)	Format(4)
302	Line Voltage	0 to 1000 VDC	LVD/A	None	-
303	Line Current	0 to 2000 ADC	LCD/A	None	-
304	No. 1 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
305	No. 1 Truck Armature Current	0 to 1000 ADC	MACD/A	None	RMS-MAC/A
306	No. 1 Truck Field Current	± 50 ADC	MFCD/A	None	RMS-MFC/A
307	No. 2 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
308	No. 2 Truck Armature Current	0 to 1000 ADC	MACD/A	None	-
309	No. 2 Truck Field Current	± 50 ADC	MFCD/A	None	-
310	"P" Wire Current	0 to 1.00 ADC	CS/A	None	Format(3)
317	Total Power Consumption	1 Pulse/0.1 KWHR	PCC/A	Format(2)	Format(2)
315	Speed	0 to 80 MPH	VS/A	Format(3)	Format(4)
318	Brake Cylinder Pressure	0 to 100 psig	BCP/A	None	-

Table 4–2. SOAC

PARAMETER DESIGNATION NO.	DESCRIPTION
101	Front Truck, Forward Axle, Righthand Wheel Journal Box Vertical Acceleration
102	Front Track, Forward Axle, Righthand Wheel Journal Box Lateral Acceleration
103	Front Truck, Forward Axle Lefthand Wheel Journal Box Vertical Acceleration
115	Mid Car Centerline Vertical Acceleration
116	Mid Car Centerline Lateral Acceleration
120	Forward Car Centerline Vertical Acceleration
121	Forward Car Centerline Lateral Acceleration
219	Truck Frame Upper Strain Gage
220	Truck Frame Lower Strain Gage
221	Pitch Angular Acceleration
222	Roll, Angular Acceleration
223	Yaw, Angular Acceleration
--	Interior Sound Pressure

Revenue Service Data List B

STANDARD OUTPUTS

RANGE	RECORDED	PRESENTED	PRELIMINARY ANALYSIS
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	-
± 0.25 g's	AC/A	Format(3)	RRV/A(1), (3)
± 0.25 g's	AC/A	Format(3)	RRH/A(1), (3)
± 0.25 g's	AC/A	Format(3)	RRV/A(1)
± 0.25 g's	AC/A	Format(3)	RRH/A(1)
± 6348 psi	STP	Format(3)	Fromat(4)
± 6348 psi	STP	Format(3)	-
± 1.5 Rad/sec/sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
40 to 120 dB(re 2 x 10^{-5} N/M^2)	SP/A	NL/A(1)	NL/A(2)

4.3 Frequency Histograms

These distributions are an indication of the ratio of time that a parameter is at a particular level with respect to the time to complete a roundtrip scheduled service run. These parameters may be used to describe how the vehicle was driven, the track conditions, and how the vehicle responded to these conditions.

5.0 DATA DISCUSSION

Vehicle operation was such that while operating northbound from Howard to Dempster, the SOAC No. 2 was leading. A positive value on the time history chart is vehicle start-up. For the southbound run, vehicle start-up is a negative trace on the time history.

As defined in Section 4, there are three forms of data. These forms are discussed below with respect to three categories:

(1) Operation

How the vehicle was operated and maintained schedule.

(2) Environment

Track and truck conditions.

(3) Response

How the vehicle responded to the operational environment.

Figures 5-1 to 14 present the frequency histogram for the CTA tests. Figure 5-15 is a sample of the Interior Noise Level time history. The remaining time history charts are shown in Figures 5-16 through 5-23. Table 5-1 presents a summary of some of the test parameters and is taken from the histograms and time history charts. Tables 5-2 and 5-3 are the Station Summaries with power consumption.

5.1 Operation

As mentioned above, the Skokie Swift route is 5.0 miles with one station stop. The SOAC was not pushed to its rated limits in acceleration or braking. As seen in the "P-Wire" histogram, most of the trip time was spent in cruising. The speed histogram shows that most of the cruising was accomplished at 50 and 35 mph.

From the Station Summaries, it can be seen that SOAC took 8.7 minutes to complete the scheduled 6.5 minute trip. No reason can be forwarded for this.

The propulsion system was run at 50% of its continuous rating of 460 amps (RMS).

5.2 Environment

The journal accelerations and the truck frame stress levels are indications of track conditions. A summary of these parameters is shown in Table 5-1. The 50th percentile is a statistical quantity and is read as 50% of the time the journal box vertical acceleration is between plus and minus .55 gs. This quantity is dependent upon the distribution of the test parameter, which for this data, is assumed to be linear within a class interval (i.e. 1 to 2 gs, etc.). The 95th percentile is read similarly. The nominal value is the 50th percentile for the test parameter considering only the time the vehicle is moving.

The journal box lateral acceleration 50th percentile is $\pm$ 1.0 gs. Unfortunately during a de-trucking operation, the strain gages were wiped off and truck stress data was not recorded.

5.3 Response

The car body Ride Roughness and Noise Level parameters are the indicators of how the vehicle responded to the operation and environment. Ride Roughness is a vibration parameter which is weighted according to human response characteristics in riding comfort. This technique is similar to using the "A" weighing on sound pressure to yield Noise Level. Noise Level and Ride Roughness are related to "human responses". Both of these parameters are described in the Standard Outputs section of this report. Summaries of these values are shown in Table 5-1.

Noise Level data was taken in the middle of the non-instrumented car at a seat passenger ear level. The original engineering tests at TTC indicate that this is the quietest location in the car. The statistical quantities derived from the data are:

L(99)	L(90)	L(50)	L(10)	L(1)	L(EQ)
59	64	65	66	69	66

A sample of the Noise Level Time History is shown in Figure 5-15.

Table 5—1.

Journal Box Vertical Acceleration (G)

Journal Box Lateral Acceleration (G)

Truck Frame Stress (PSI)

Forward Car Vertical Acceleration (G)

Mid Car Vertical Acceleration (G)

Forward Car Lateral Acceleration (G)

Mid Car Lateral Acceleration (G)

Longitudinal Ride Roughness (GRMS)

Forward Car Vertical Ride Roughness (GRMS)

Mid Car Vertical Ride Roughness (GRMS)

Forward Car Lateral Ride Roughness (GRMS)

Mid Car Lateral Ride Roughness (GRMS)

Pitch (RAD/Sec-Sec)
Roll (RAD/Sec-Sec)
Yaw (Rad/Sec-Sec)

Summary

50TH PERCENTILE	"NOMINAL"	95TH PERCENTILE	MAXIMUM
± .55	± .60	± 1.7	±13.5
± 1.0	± 1.0	± 1.9	±20.0
(DATA CHANNEL MALFUNCTION)			
± .022	± .022	± .084	± .250
± .022	± .023	± .078	± .250
± .023	± .024	± .101	± .150
± .045	± .047	± .088	± .100
.007	.007	.013	.030
.024	.025	.049	.095
.020	.020	.045	.100
.015	.015	.032	.060
.007	.007	.040	.040
± .050	± .052	± .095	± .100
± .058	± .060	± .160	± .263
± .050	± .052	± .095	± .100

Table 5–2. Station Summary I

STATION		SCHEDULE		TEST		POWER CONSUMPTION					
NO.	NAME	DISTANCE (MILES)	TIME (MINUTES)	DISTANCE (MILES)	TIME (MINUTES)	KWHR	KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Howard Street	0	0	0	0	0	0	0	0	0	0
2	Dempster	4.93	6.5	5.45	8.60	23.85	4.38	234.2	19.1	15.0	54
					T O T A L	23.85	4.38	234.2	19.1		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	4.93	5.45
Time	6.50	8.60
Block Speed	45.5	38.0
Station Dwell	30.0	15.0
Station Space	4.93	5.45

Table 5–3. Station Summary II

STATION		SCHEDULE		TEST		POWER CONSUMPTION					
NO.	NAME	DISTANCE (MILES)	TIME (MINUTES)	DISTANCE (MILES)	TIME (MINUTES)	KWHR	KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Dempster Street	0	0	0	0	0	0	0	0	0	0
2	Howard Street	4.93	6.5	5.47	8.97	21.53	3.94	238.2	20.0	21.6	54
					T O T A L	21.53	3.94	238.2	20.0		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	4.93	5.47
Time	6.50	8.97
Block Speed	45.5	36.6
Station Dwell	30.0	21.6
Station Spacing	4.93	5.47

State-Of-The-Art Car
Revenue Service On CTA Skokie Swift Line
"P-Wire" Current Distribution

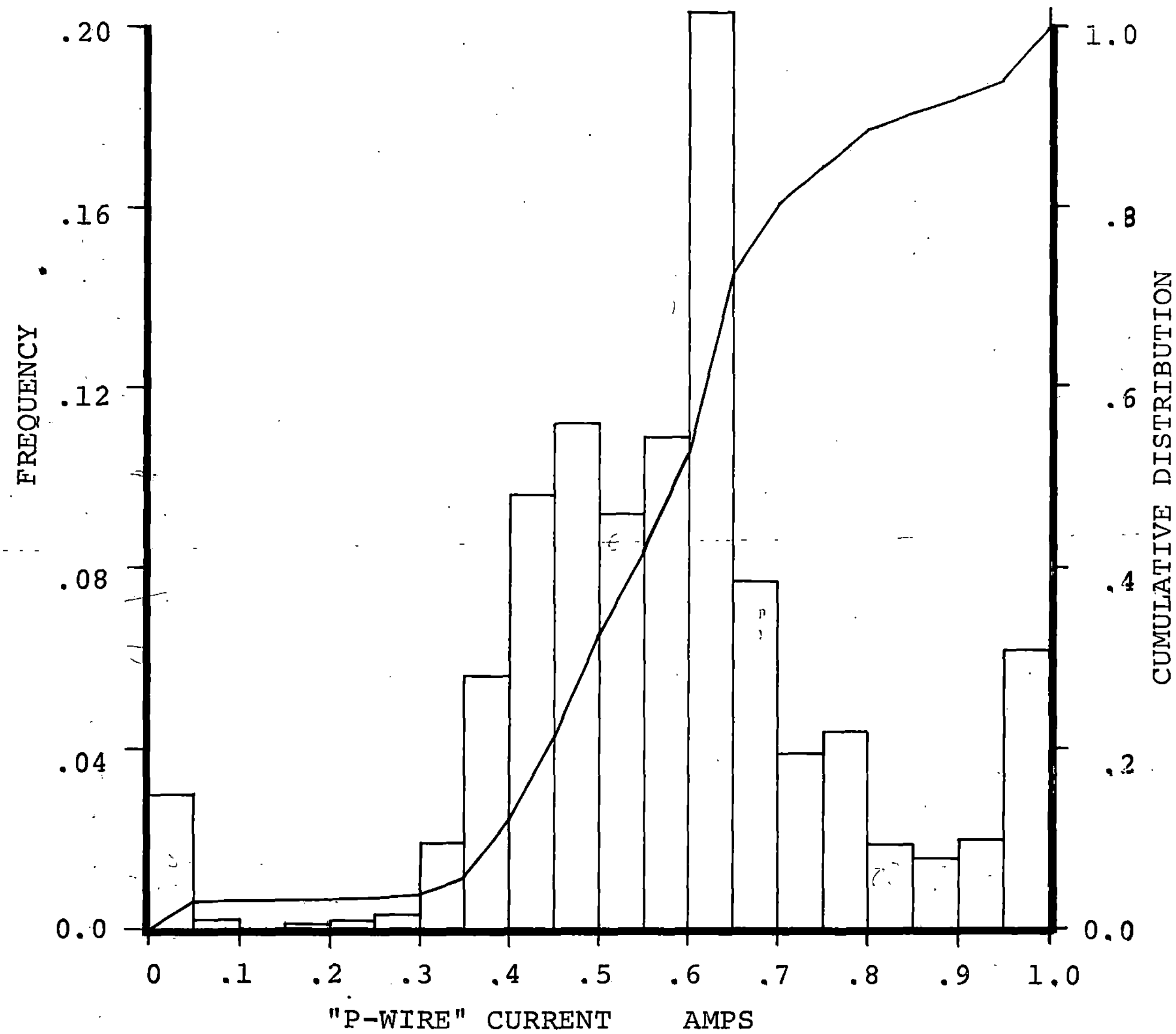


Figure 5–1. 'P-Wire' Current Distribution

State-Of-The-Art Car

Revenue Service On CTA Skokie Swift Line

Vehicle Speed Distribution

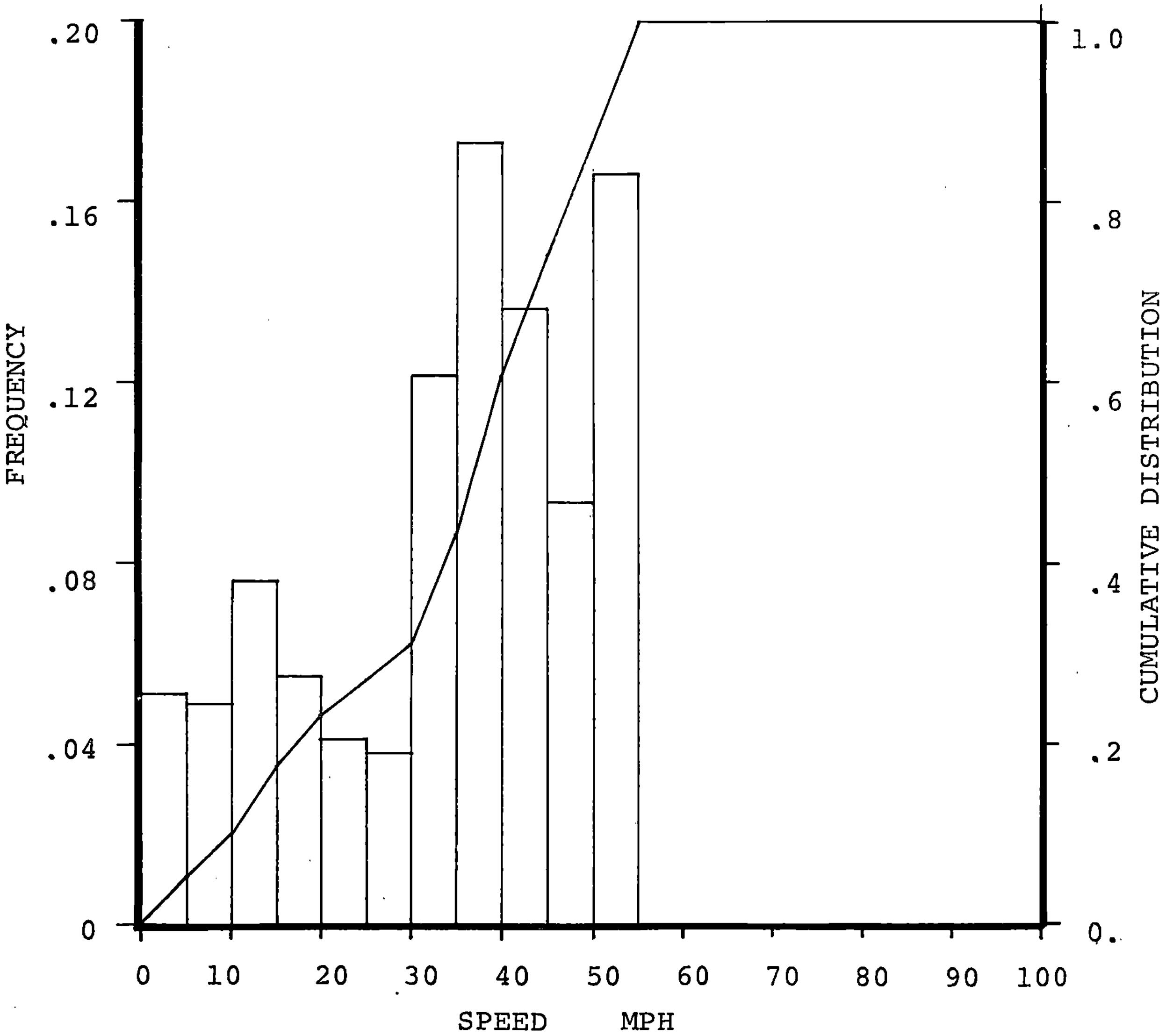


Figure 5–2. Vehicle Speed Distribution

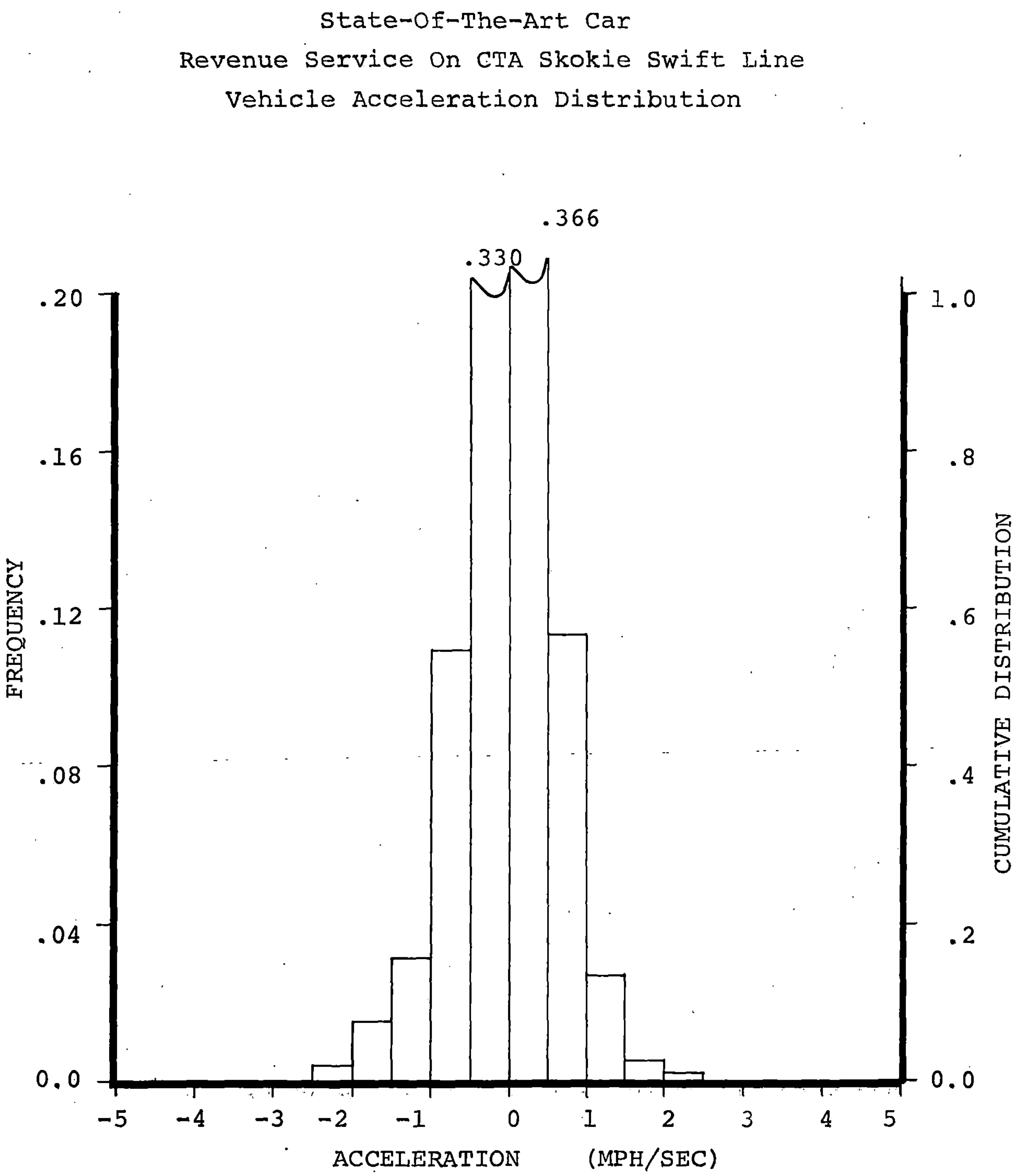


Figure 5–3. Vehicle Acceleration Distribution

State-Of-The-Art Car
Revenue Service on CTA Skokie Swift Line
Journal Box Vertical Acceleration Distribution

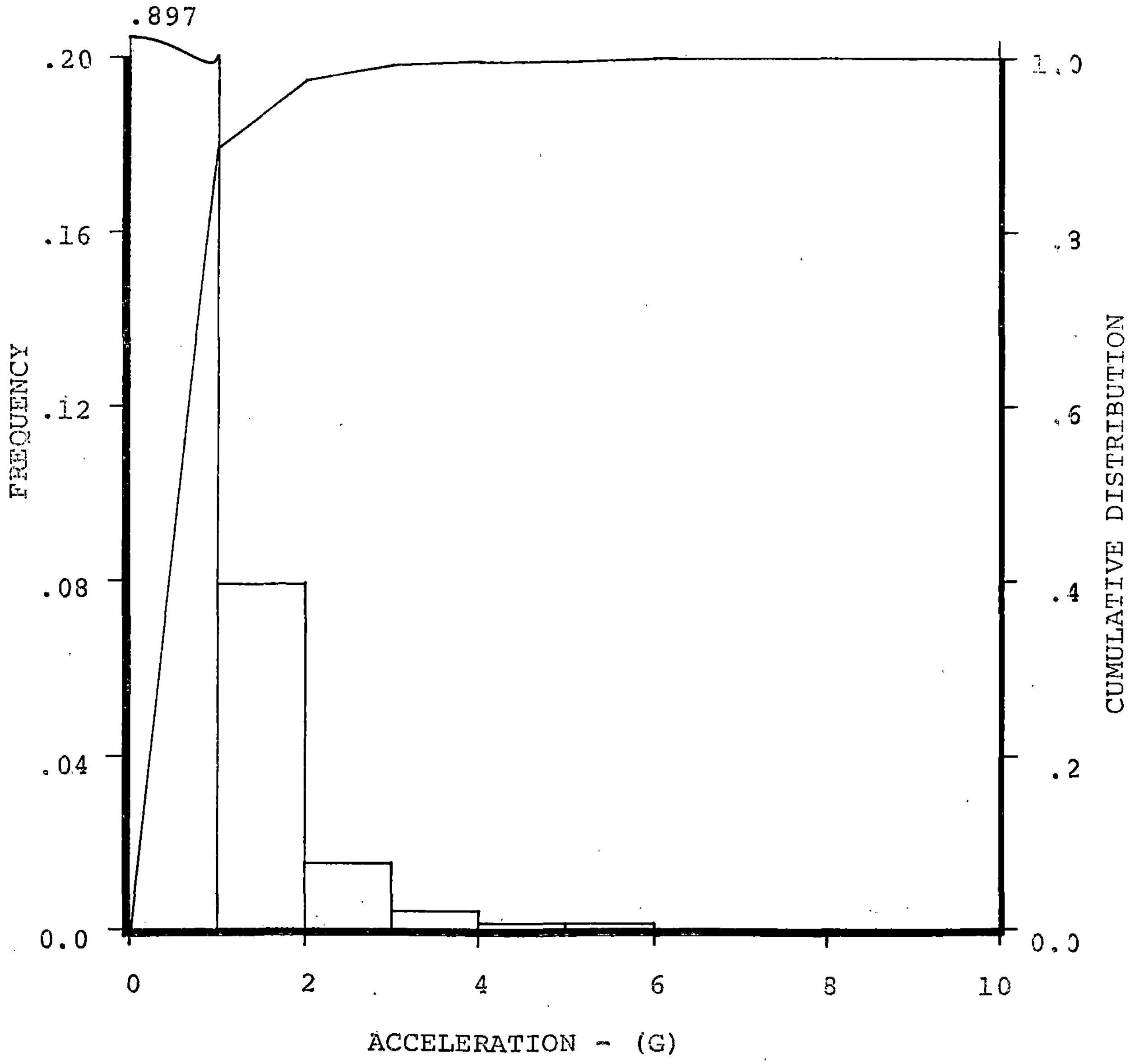


Figure 5–4. Journal Box Vertical Acceleration Distribution

State-Of-The-Art Car
Revenue Service On CTA Skokie Swift Line
Journal Box Lateral Acceleration Distribution

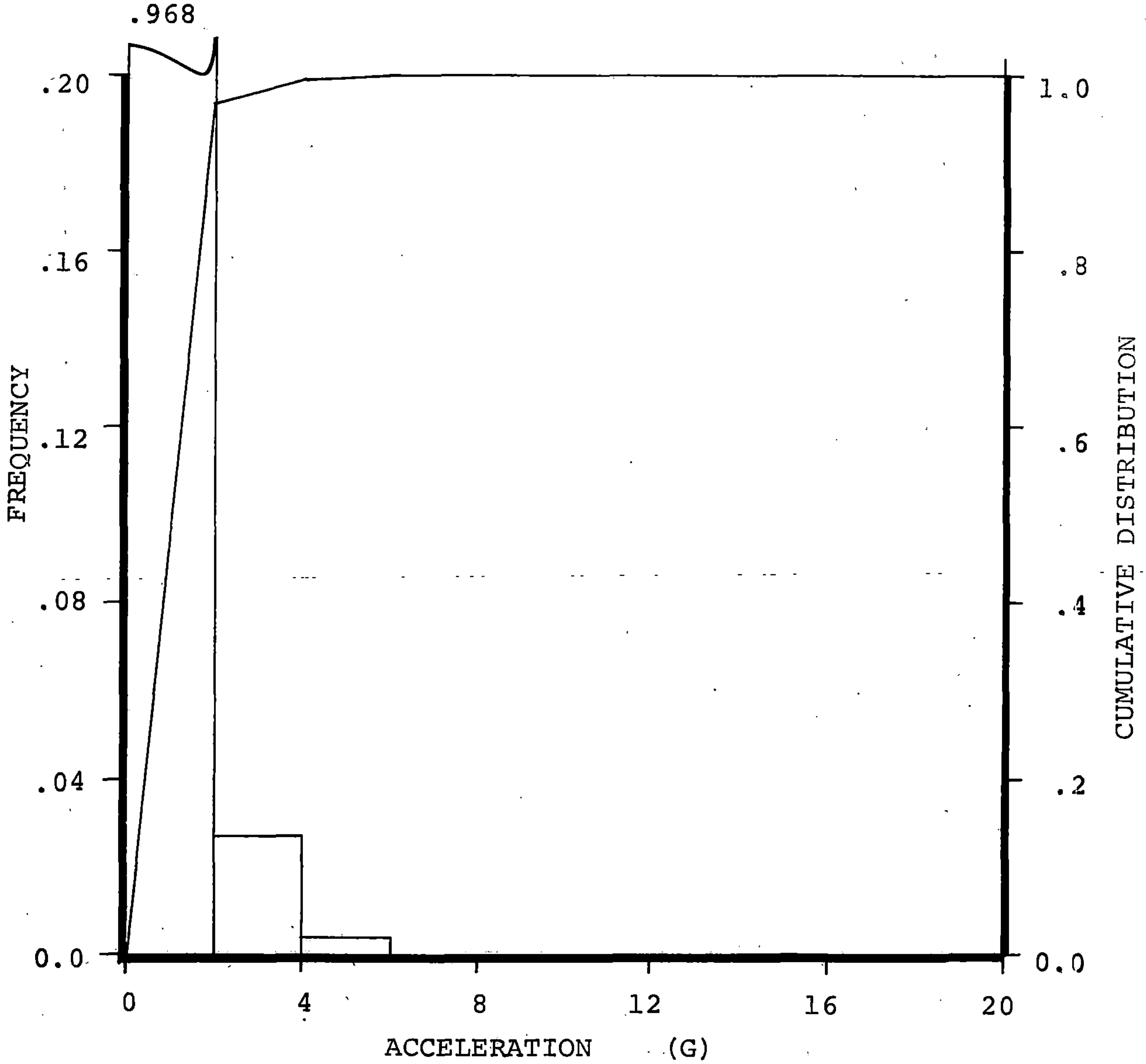


Figure 5—5. Journal Box Lateral Acceleration Distribution

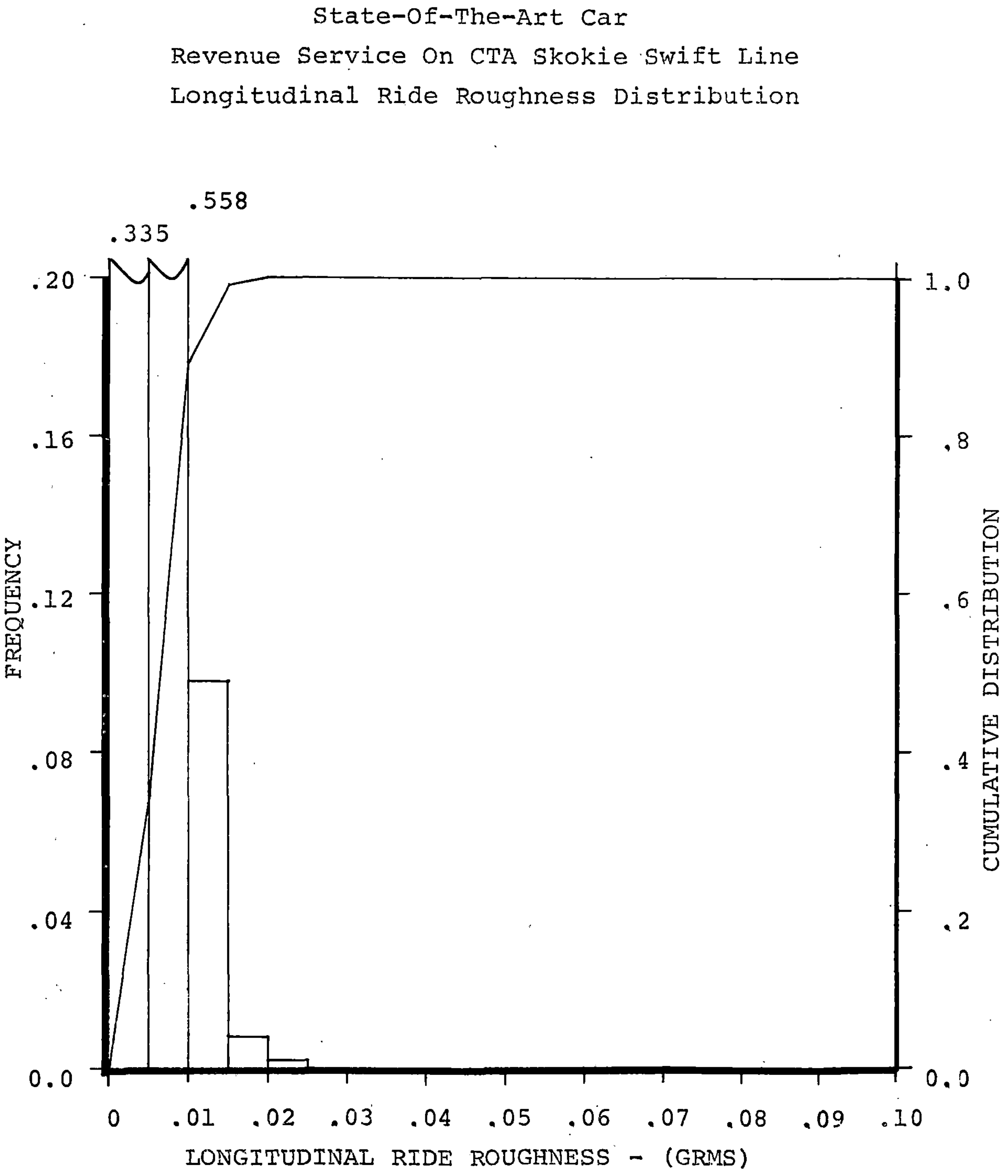


Figure 5–6. Longitudinal Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On CTA Skokie Swift Line
Forward Car Vertical Ride Roughness Distribution

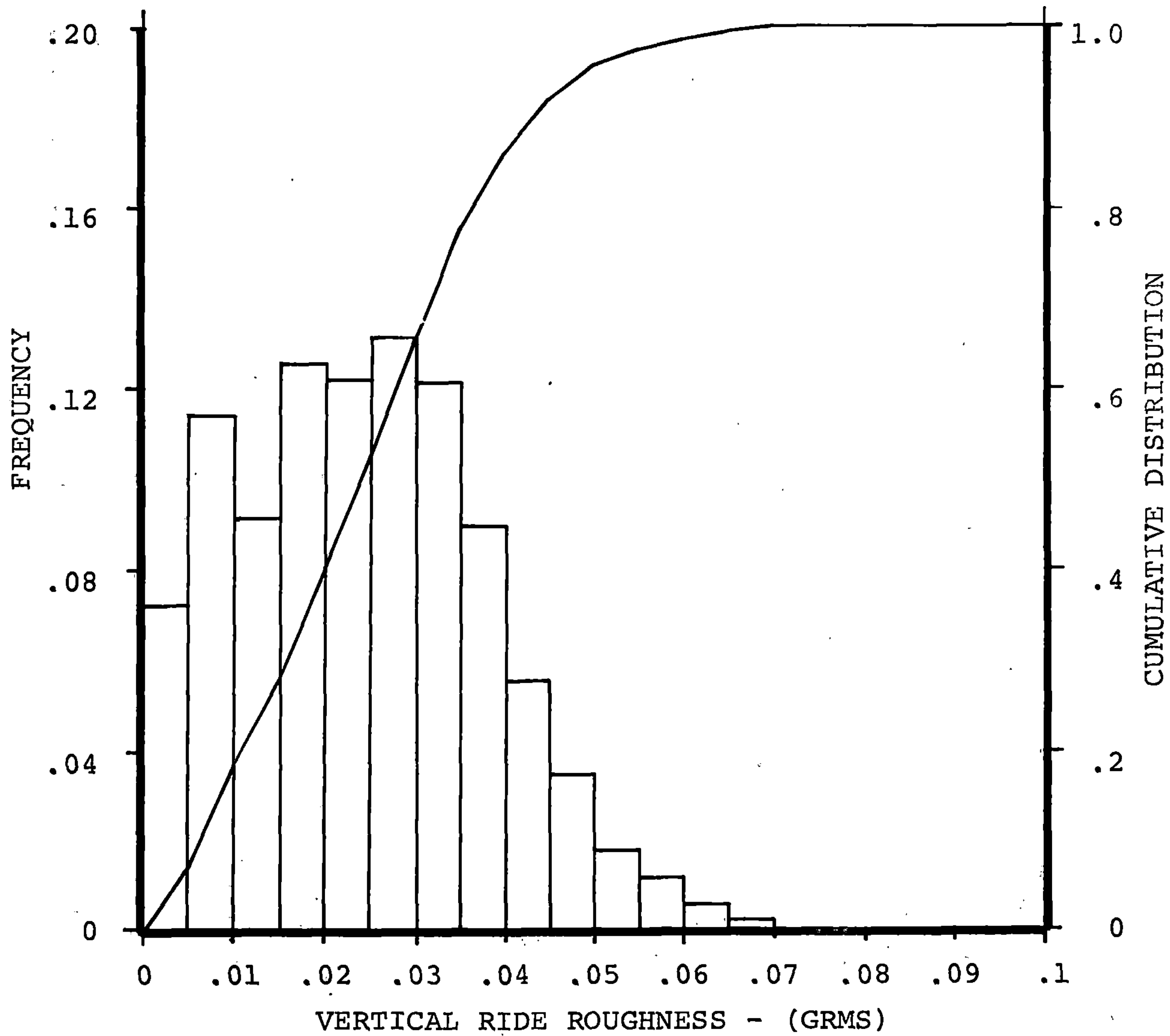


Figure 5–7. Forward Car Vertical Ride Roughness Distribution

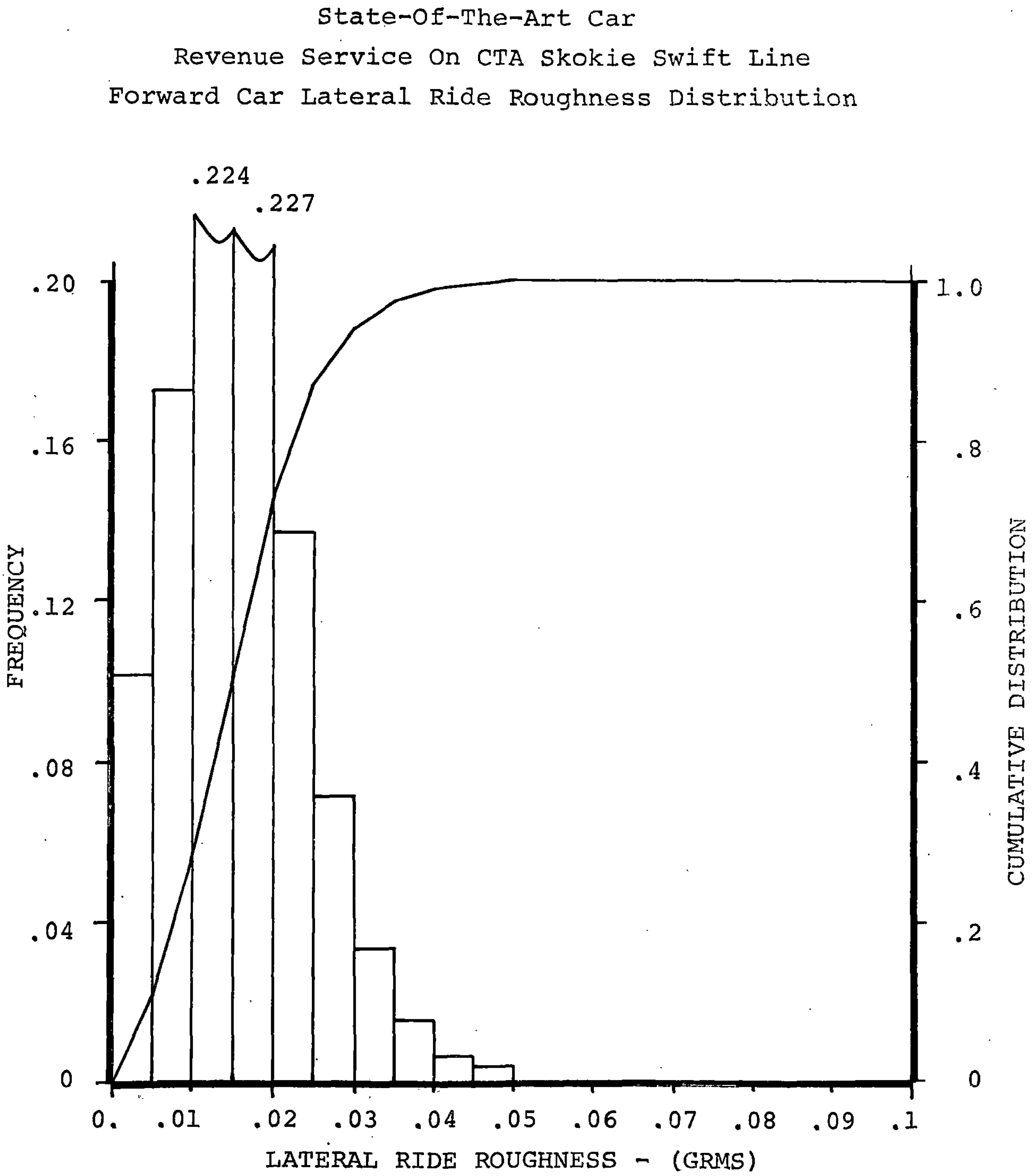


Figure 5–8. Foward Car Lateral Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service on CTA Skokie Swift Line
Mid Car Vertical Ride Roughness Distribution

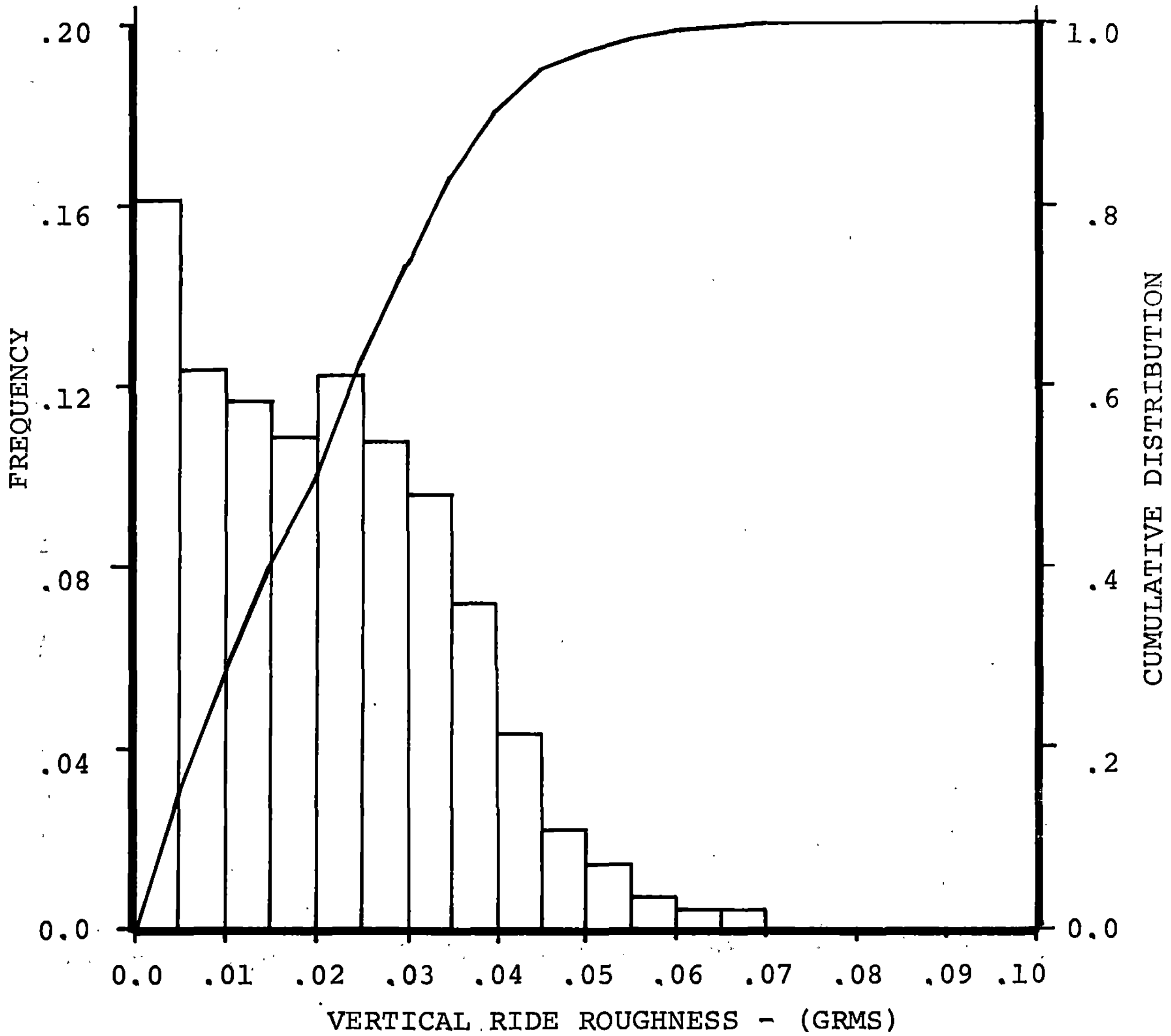


Figure 5–9. Mid-Car Vertical Ride Roughness Distribution

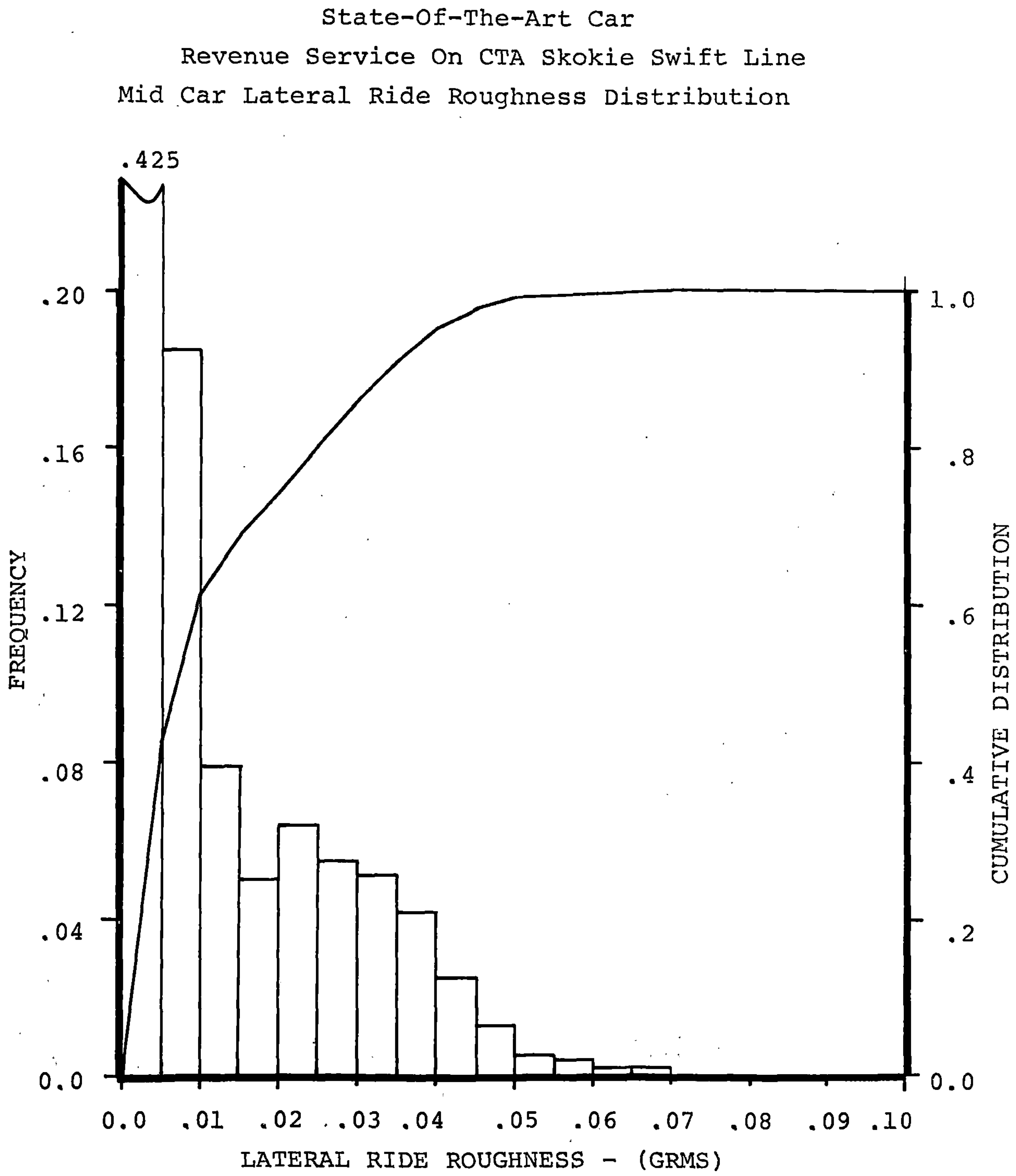


Figure 5–10. Mid-Car Lateral Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On CTA Skokie Swift Line
Vehicle Pitch Distribution

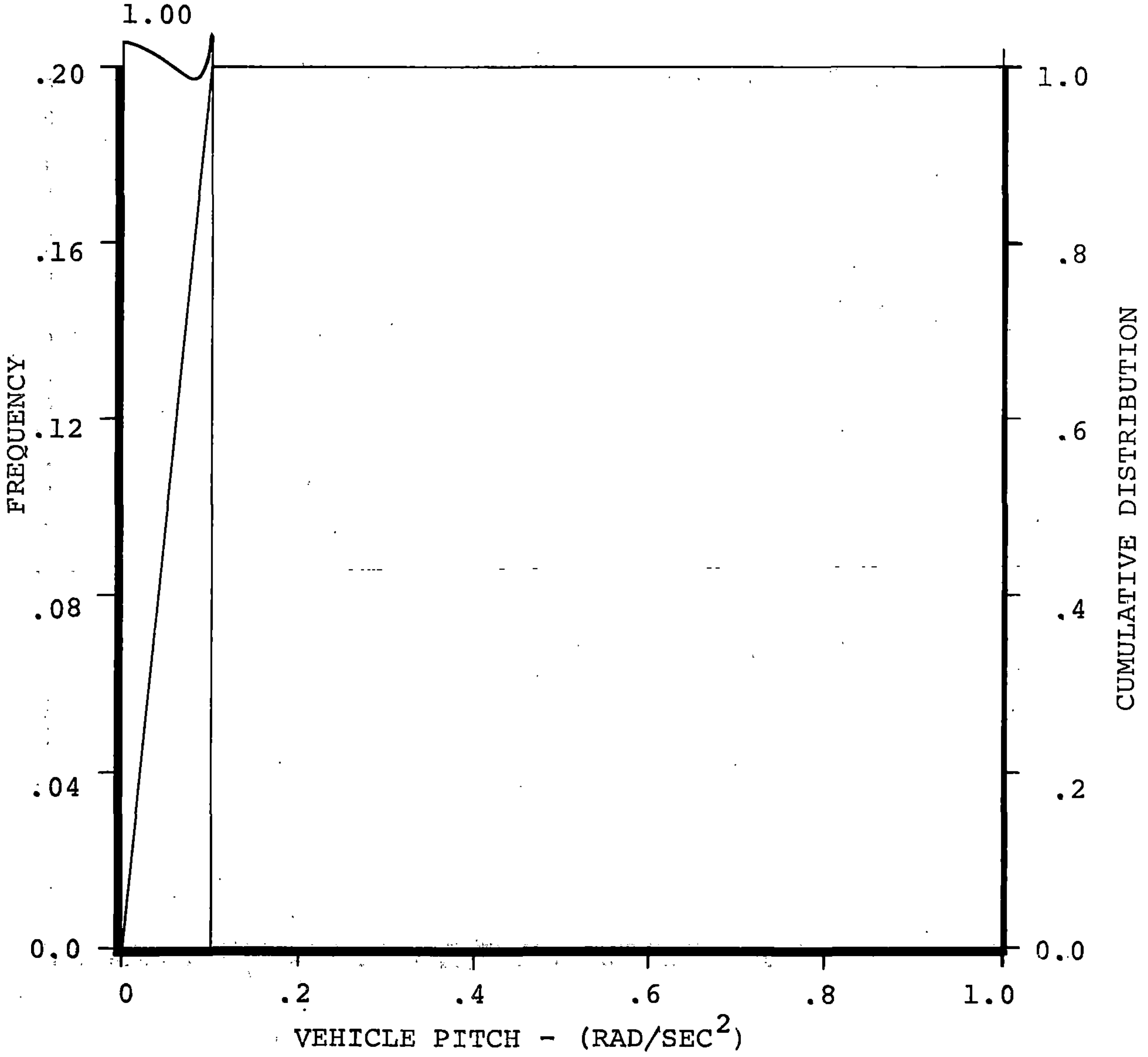


Figure 5—11. Vehicle Pitch Distribution

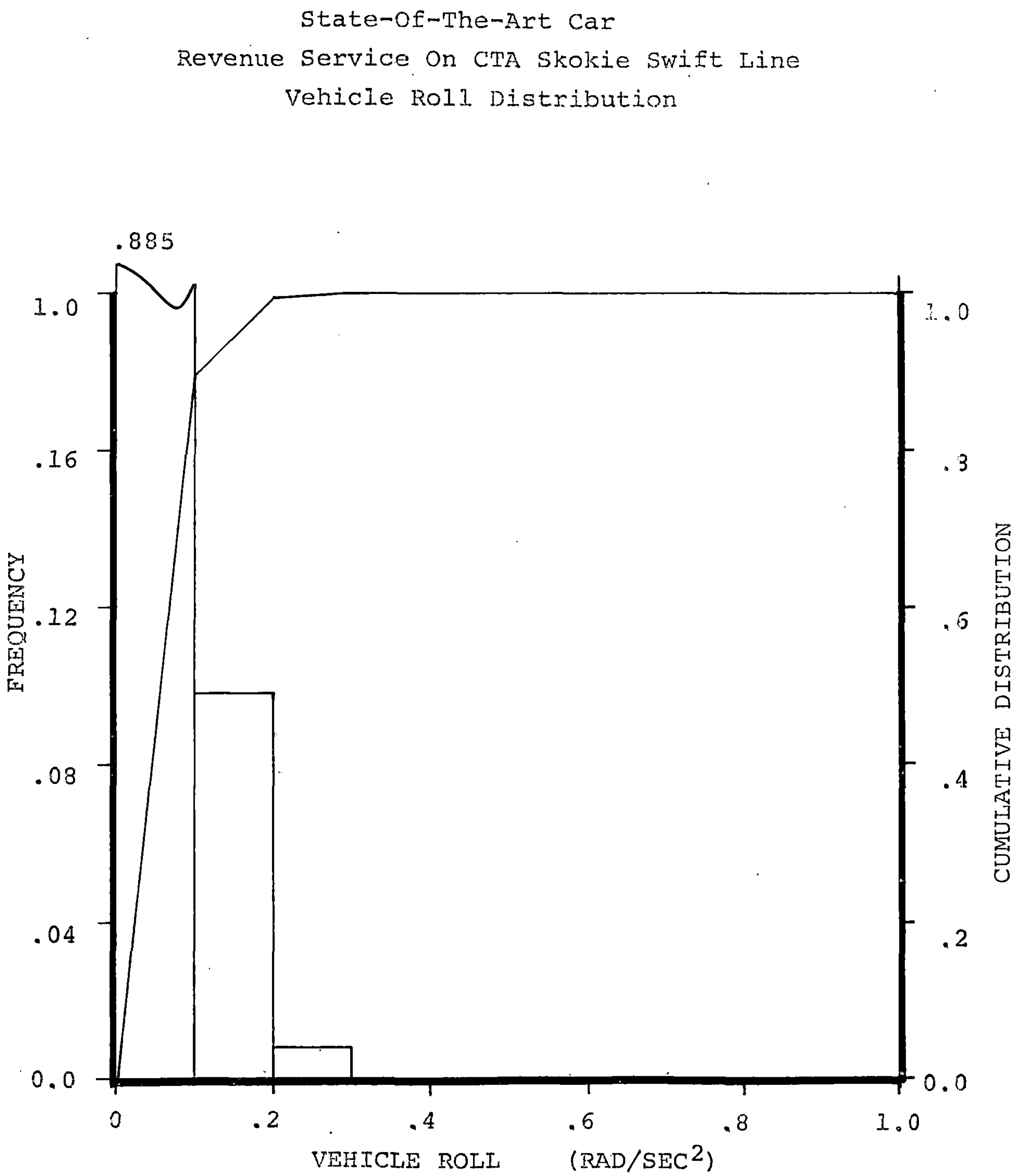


Figure 5–12. Vehicle Roll Distribution

State-Of-The-Art Car
Revenue Service On CTA Skokie Swift Line
Vehicle Yaw Distribution

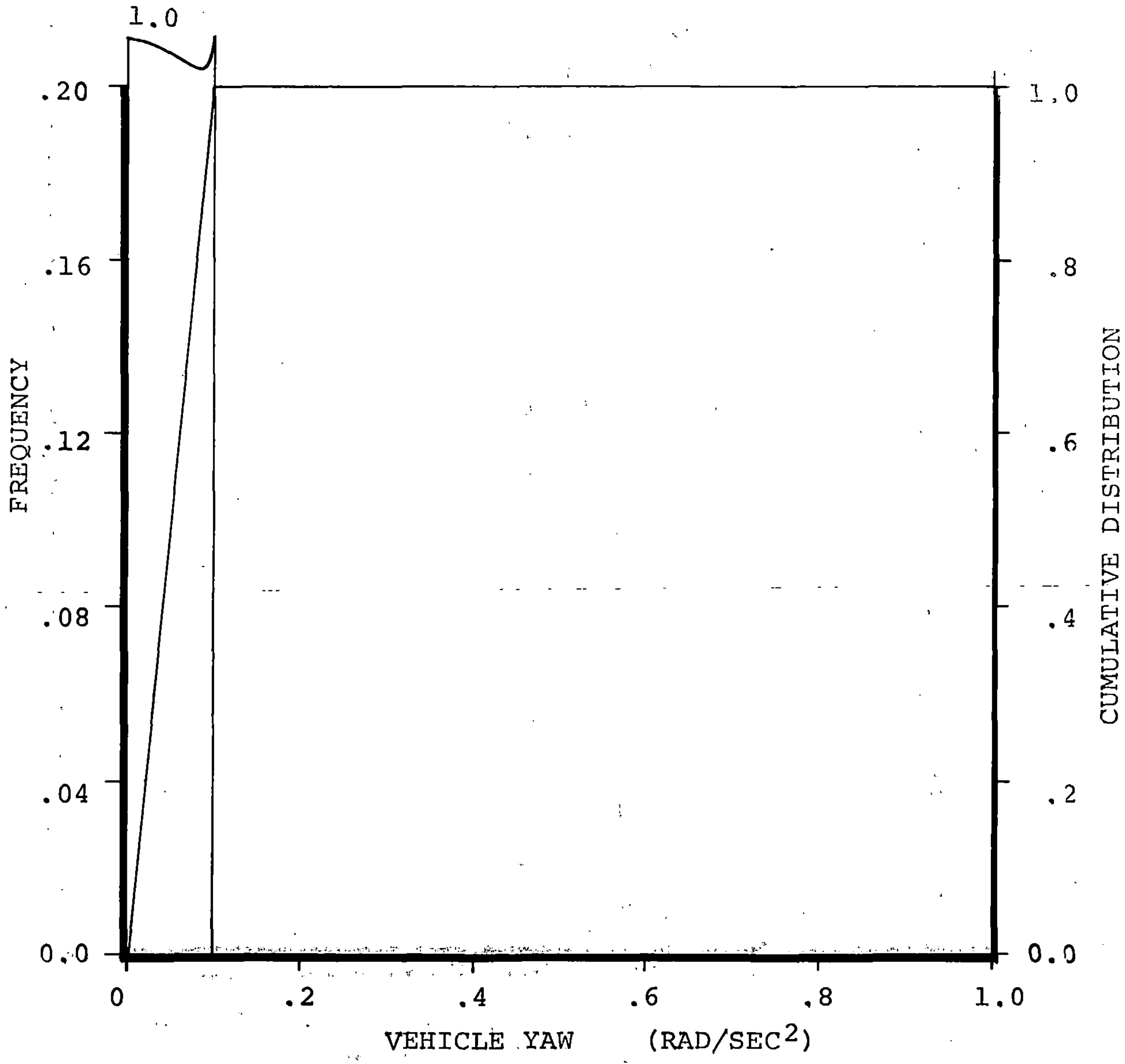


Figure 5–13. Vehicle Yaw Distribution

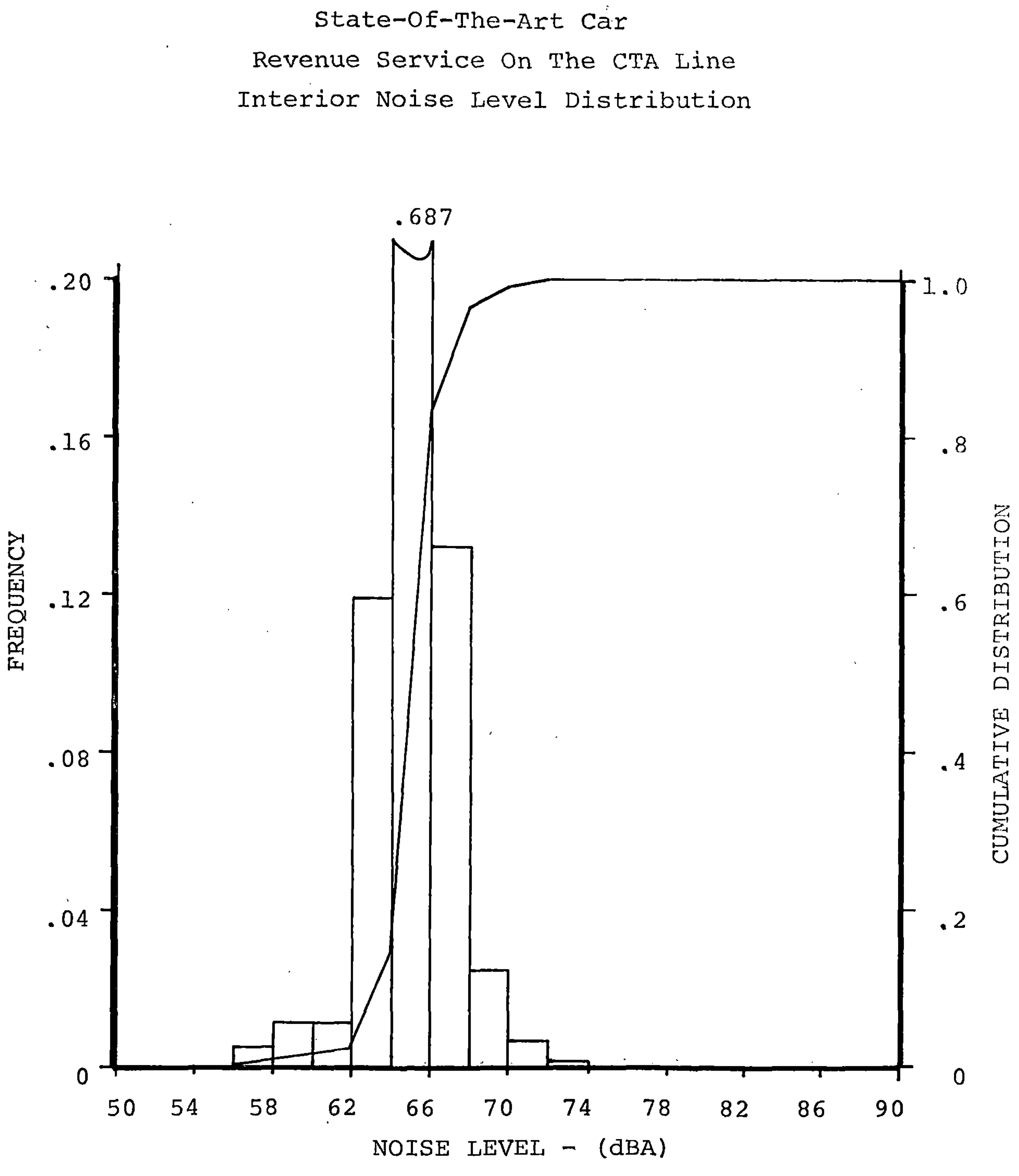


Figure 5–14. Interior Noise Level Distribution

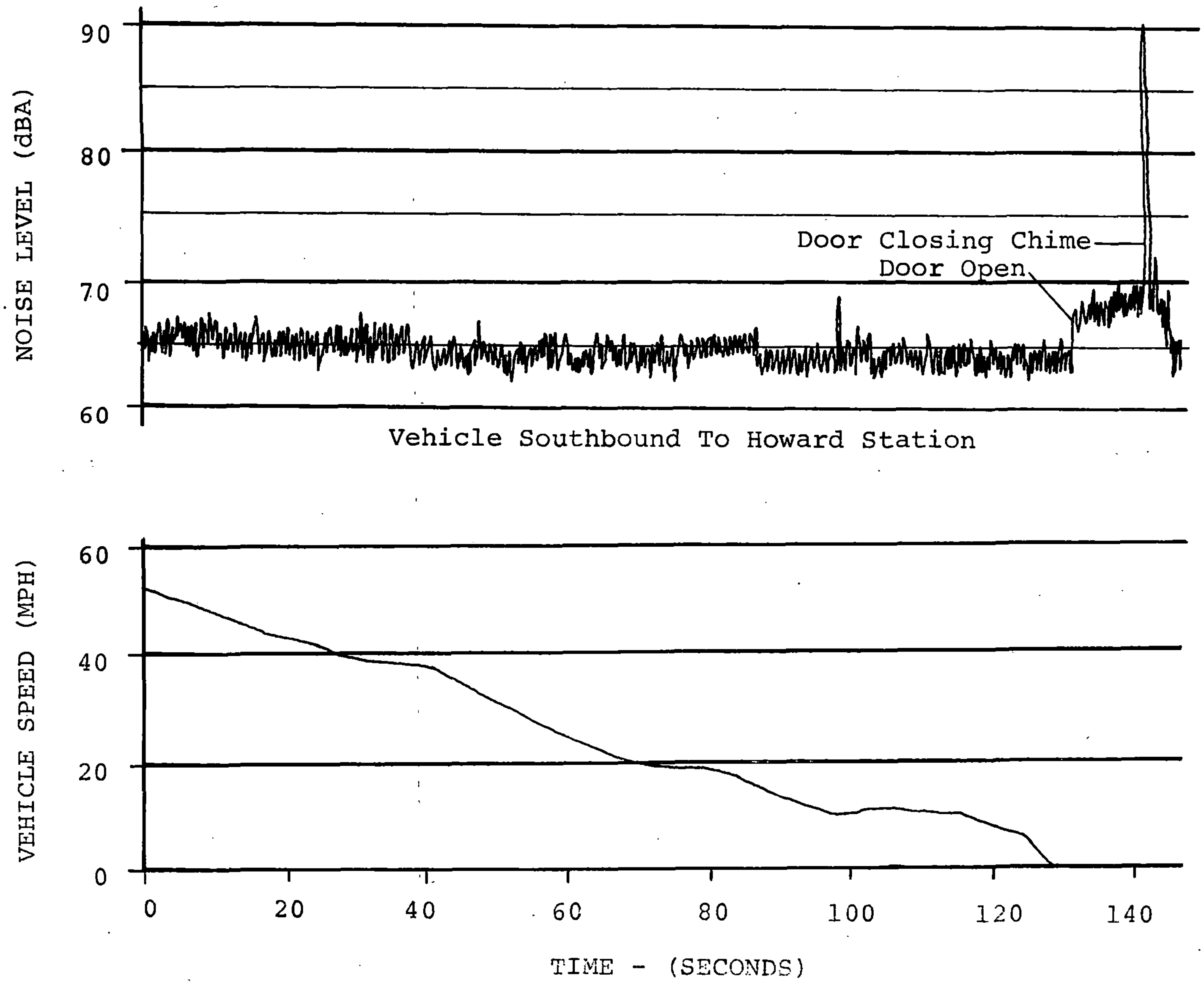


Figure 5–15. SOAC Interior Noise Level Time History Sample

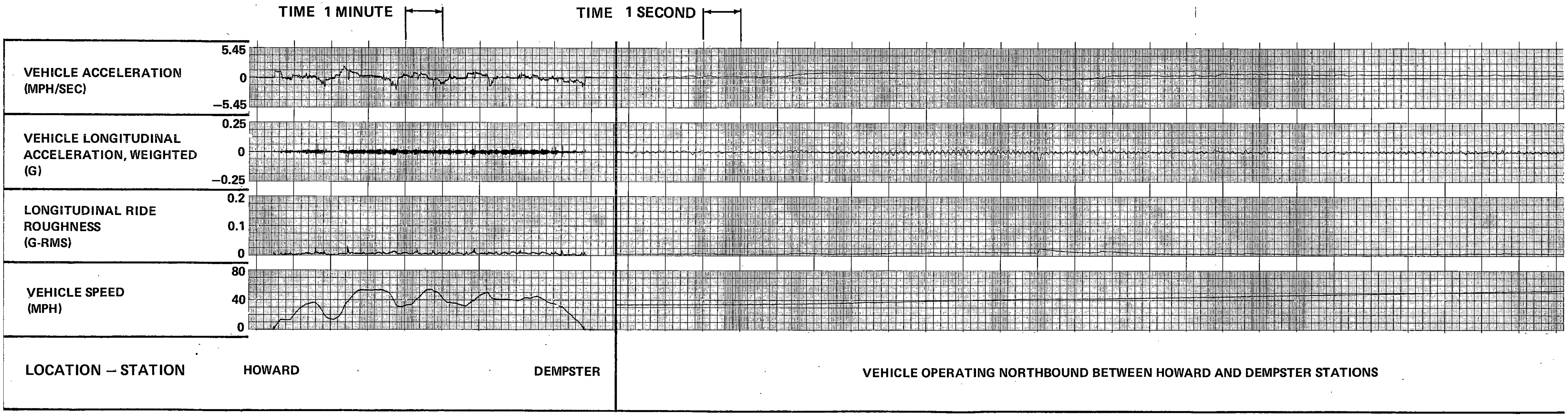


Figure 5–16. Vehicle Acceleration and Speed Time History Chart (H–D)

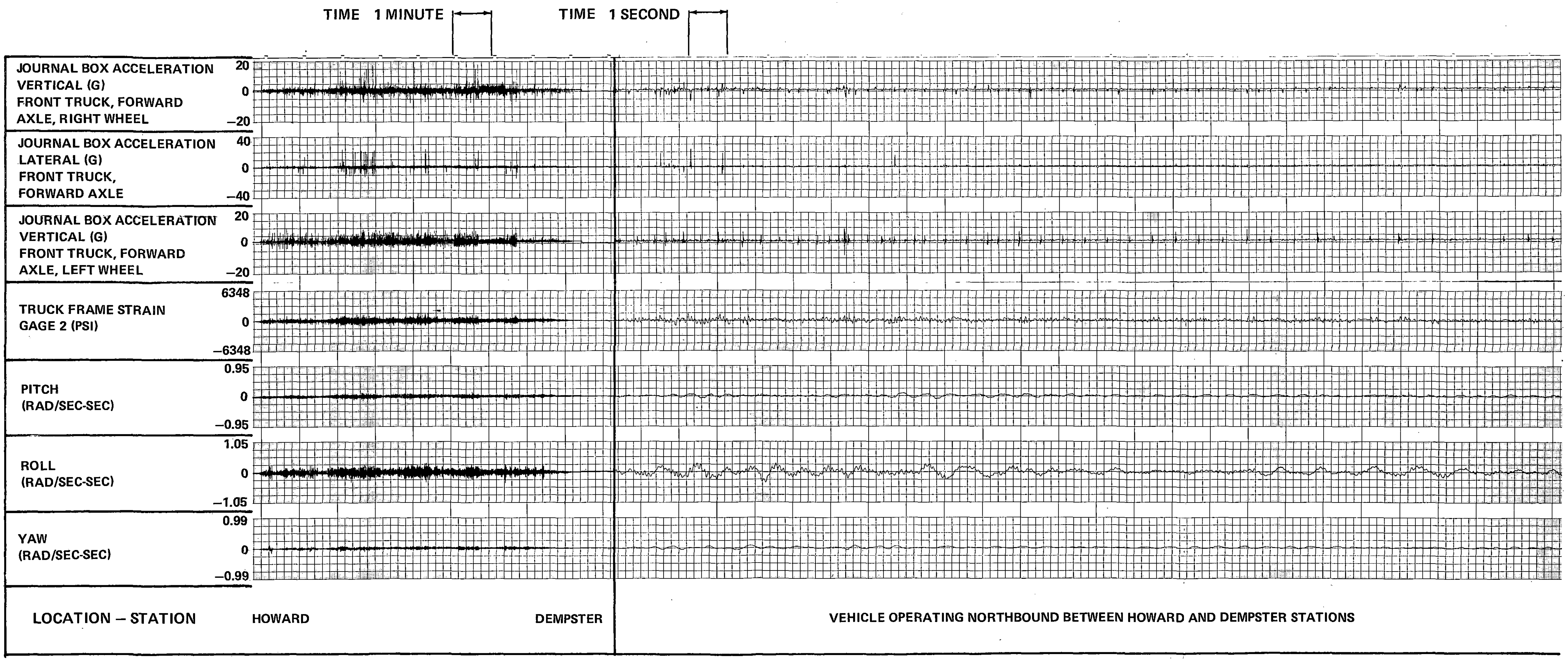


Figure 5–17. Journals, Truck Frame, and Angular Accelerations Time History Charts (H–D)

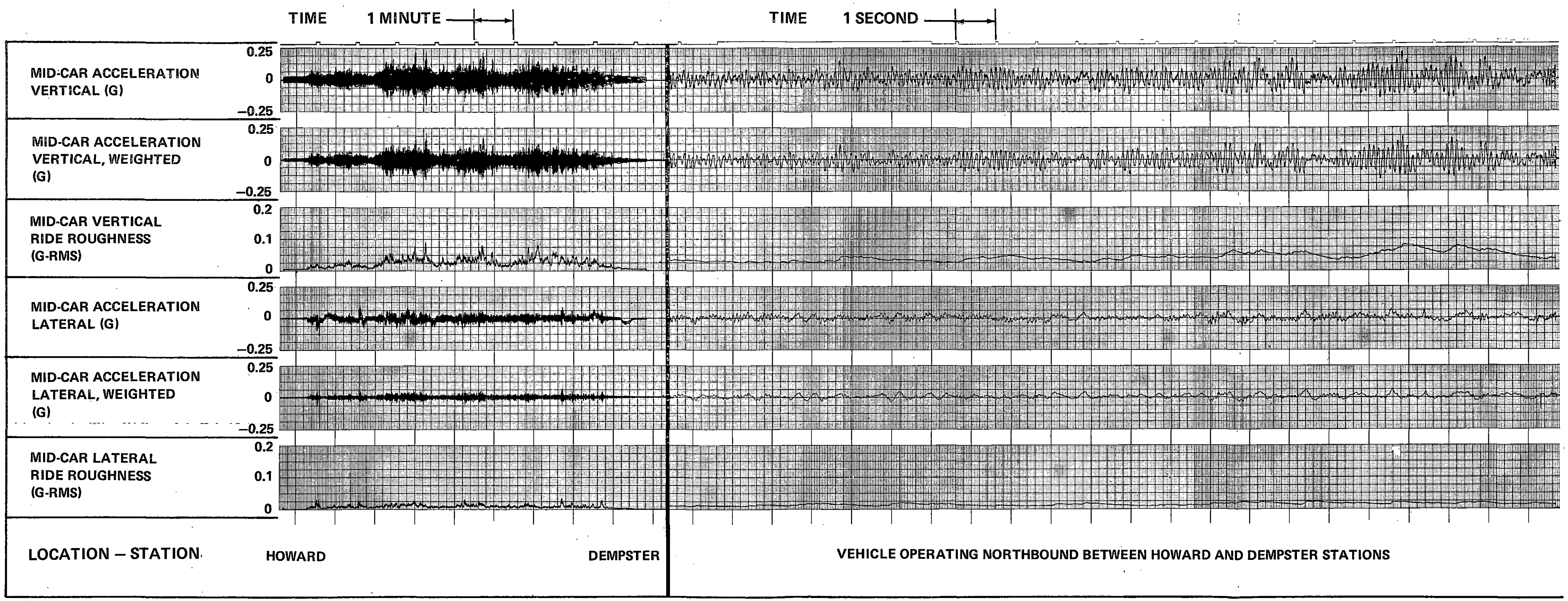


Figure 5–18. Mid-Car Acceleration Time History Chart (H–D)

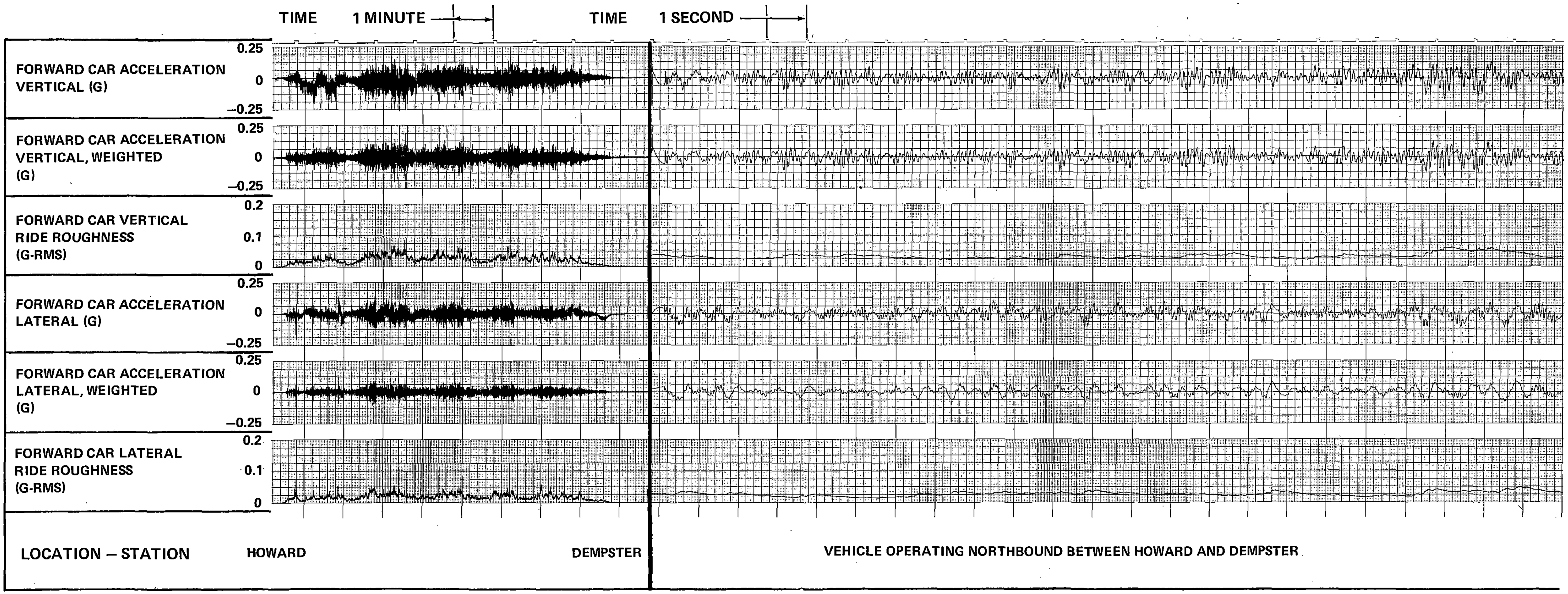


Figure 5–19. Forward Car Acceleration Time History Chart (A–D)

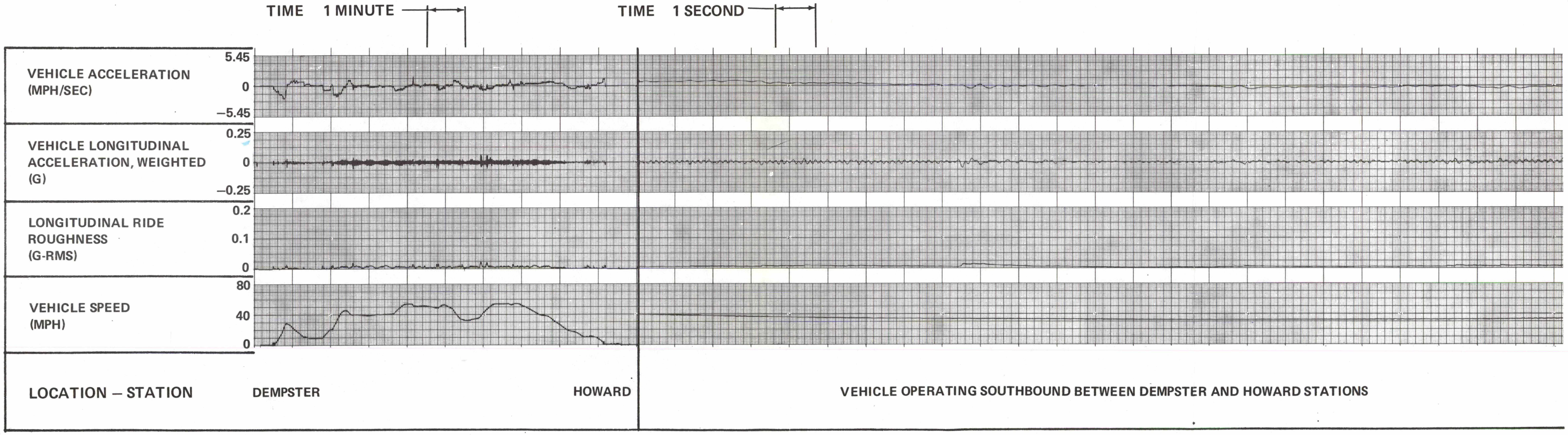


Figure 5–20. Vehicle Acceleration and Speed Time History Chart (D–H)

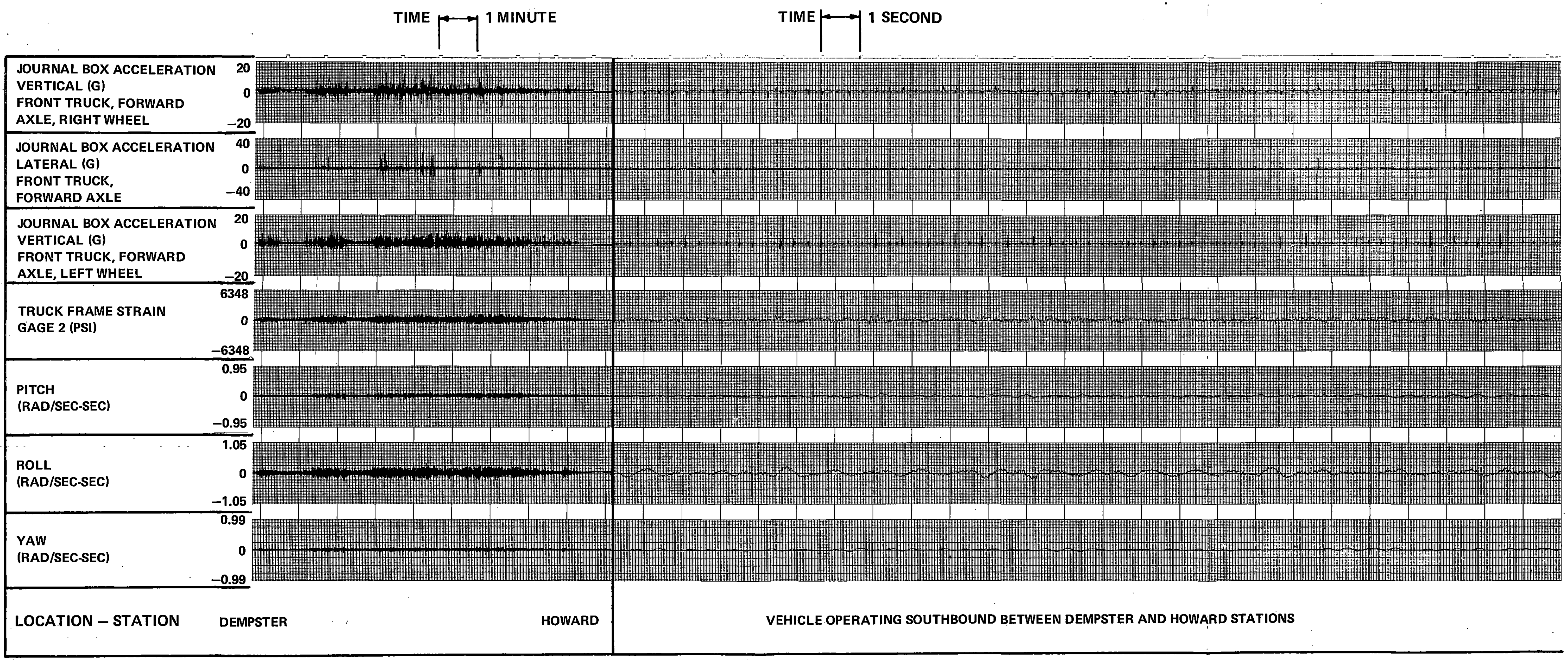


Figure 5–21. Journals, Truck Frame, and Angular Accelerations Time History Chart (D–H)

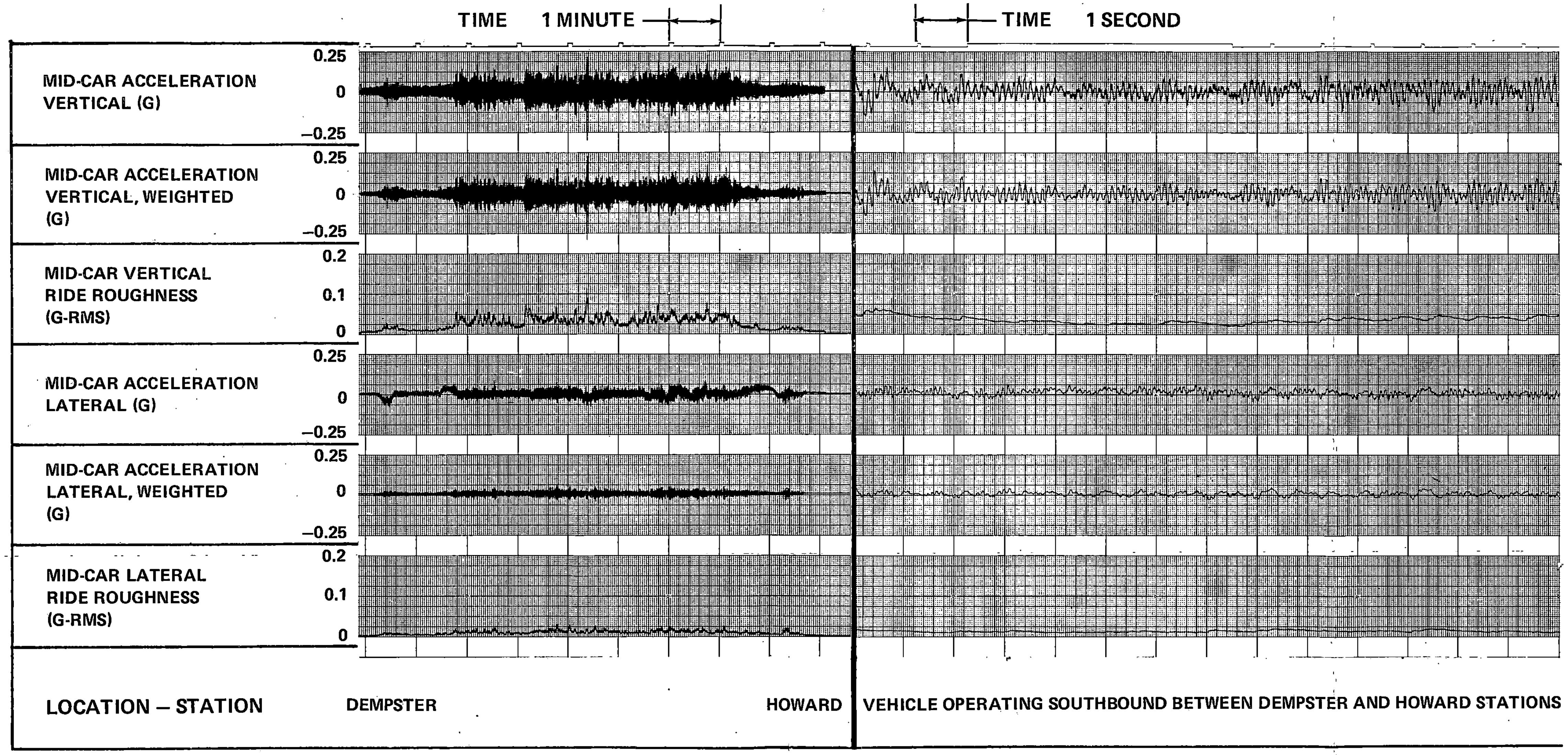


Figure 5–22. Mid-Car Acceleration Time History Chart (D–H)

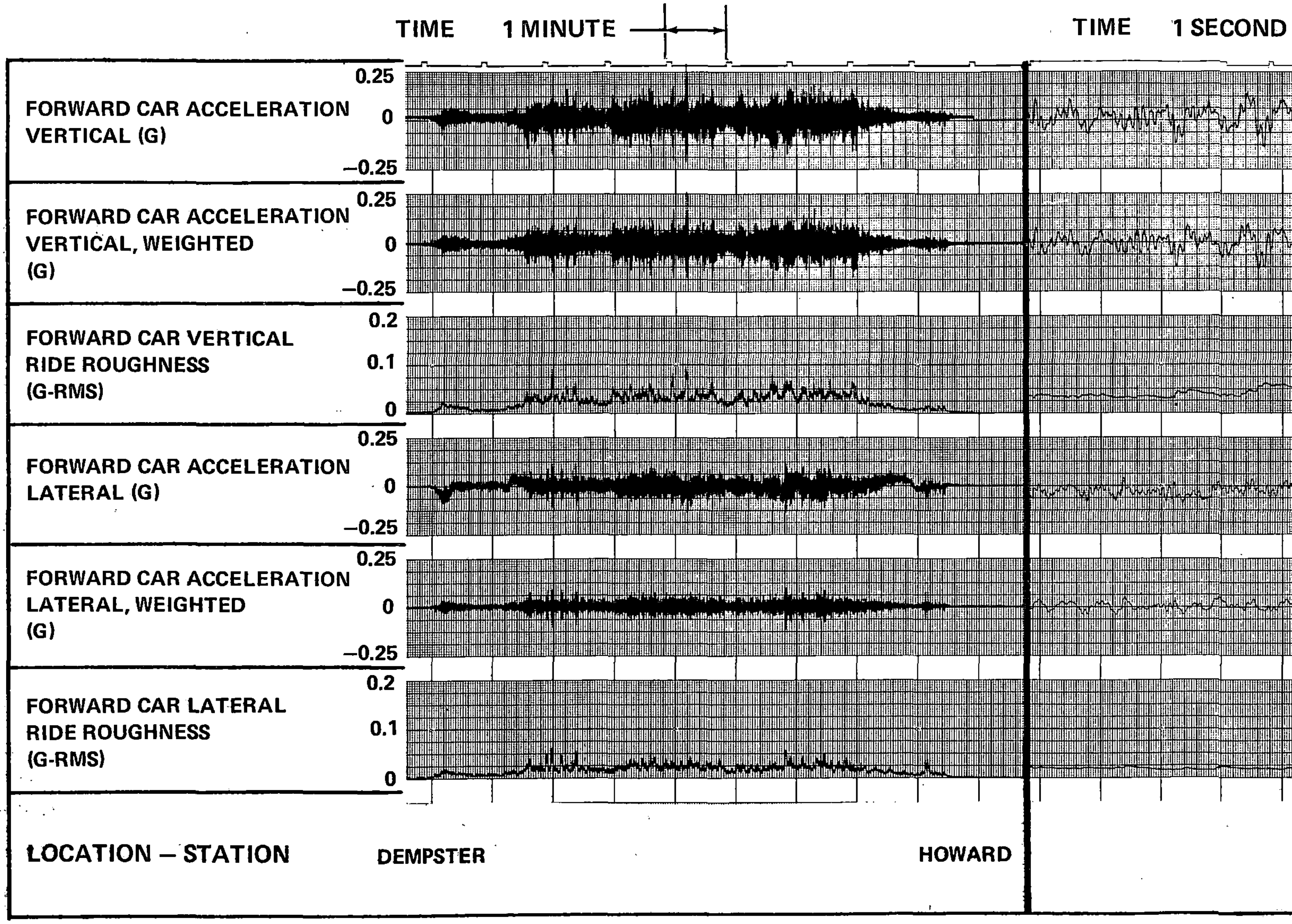
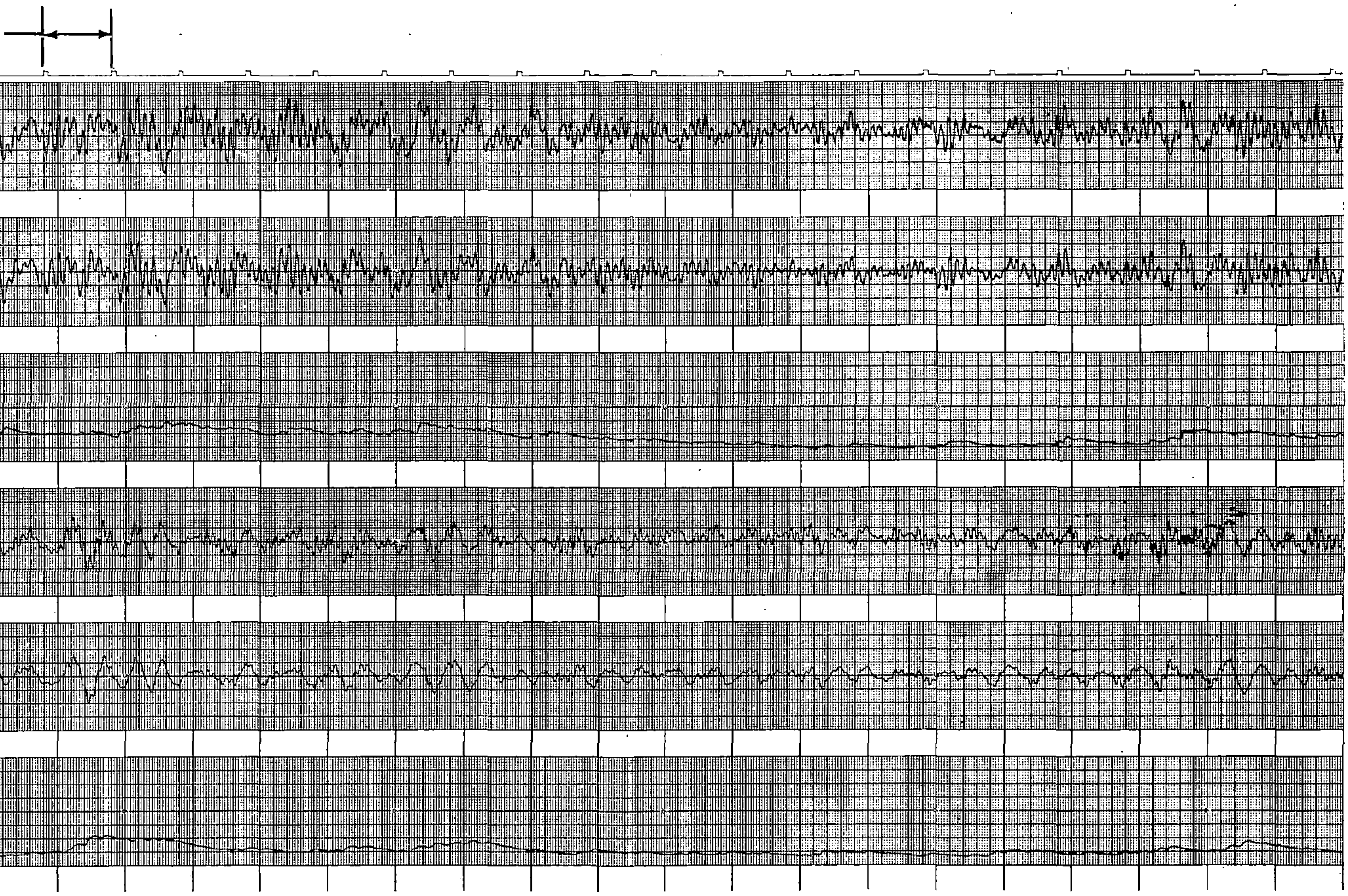


Figure 5–23. Forward Car Acceleration Time History Chart (D–H)



VEHICLE OPERATING SOUTHBOUND BETWEEN DEMPSTER AND HOWARD STATIONS

APPENDIX D
TESTING AT PHILADELPHIA

1.0 TEST DESCRIPTION

As part of the Operational Test and Evaluation Program, the State-of-the-Art Cars were in Philadelphia from February 20th to May 1, 1975. The period following the completed operational demonstration phase was used to perform the Simulated Revenue Service Tests.

1.1 Test Site

The SOACs were operated on the SEPTA Broad Street Subway. This line is entirely underground with the exception of the northern terminal Fern Rock. From Fern Rock the line runs southward through the central business district and terminates at Pattison Avenue, a distance of 10 miles. There are 22 stations with a scheduled service time of 34 minutes.

1.2 Test Operations

The test plan was to operate the SOAC in simulated revenue service over the test route. For safety and operational reasons, vehicle operation was entirely under the control of SEPTA personnel during the tests. The only requirement imposed by the test was to maintain the normal scheduled service as close as possible and to simulate the normal station stop by opening the car doors on the side opposite the station platform.

The tests were scheduled for and completed on the evening of April 23, 1975. No significant events occurred which detract from the validity of the test data.

Subsequent to the engineering tests, an exploratory type test on gearbox resonance was accomplished on the SOAC. These tests showed a car body vibration at 74 to 84 mph induced by wheels and gearboxes. This speed range was far above the speeds for the SEPTA tests and no influence on the SEPTA test data was expected or found.

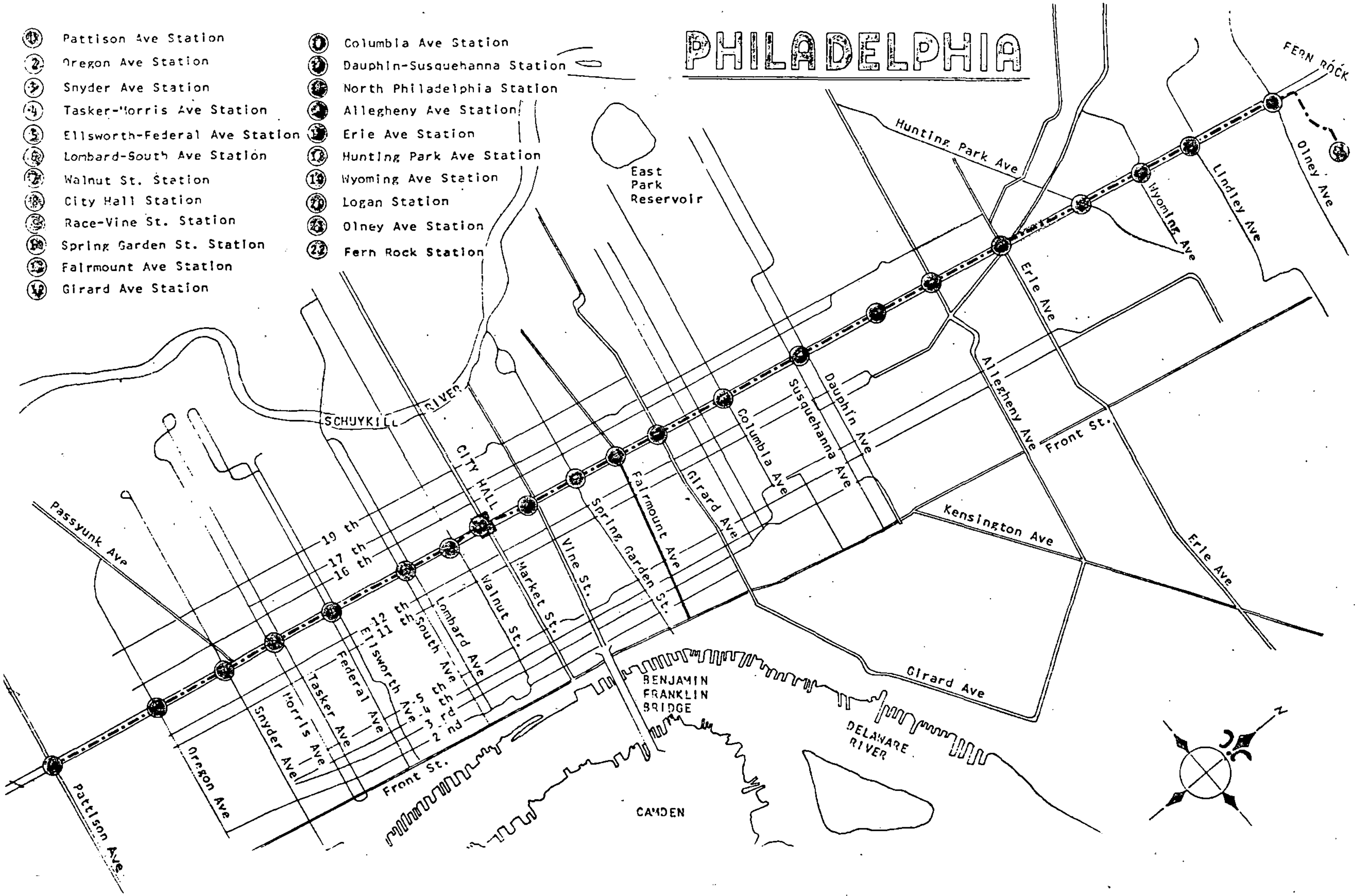


Figure 1—1. The SEPTA Broad Street Subway System

2.0 TEST PROCEDURES

Pretest

1. Mount all required sensors
2. Calibrate Instrumentation System
3. Brief Test Crew on Test Operations

   NOTE:

   One vehicle is instrumented for noise measurements, avoid other than normal conversation.

Test

1. Operate the vehicles in a simulated revenue service, i.e. maintain the given schedule.
2. Provide a nominal 10 second door opening at each scheduled stop.
3. Provide voice commentary on instrumentation recording during progress of test.
4. Maintain a manual log of events during the test run, correlated to the instrumentation system records.
5. Monitor various preselected data channels to ascertain validity of test run.
6. The Test Controller will terminate the test if:
   (a) An extended delay or train shutdown occurs
   (b) One or more required data channels malfunction
   (c) The test vehicle is not operating properly

   Advise Test Controller of any abnormal operations or events that occur during the test run.

3.0 INSTRUMENTATION

The SOAC Instrumentation System was used for this series of tests. This system is described in detail in Volume VI of State-of-the-Art Car (SOAC) Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Test Report, UMTA-MA-06-0025-75-6, January 1975. A synopsis is included below.

3.1 Ride Qualities, Structural and Performance Tests

Electrical signals from the vehicle mounted transducers are conducted by cables to an interface panel which is connected to an instrumentation console containing two magnetic tape recorders, two light beam oscillographs, a time code generator, a temperature recorder and signal conditioners. Any 28 selected test parameters can be recorded on tape and displayed on the oscillographs. In addition, wheel speeds may be recorded directly on the oscillographs; total power is recorded on tape and displayed on a mechanical counter. The time code generator provides signals that are recorded on both tape and the oscillograph. The oscillographs provide quick-look data to evaluate test progress and results during testing (See Figure 3-1).

3.2 Noise Tests

The instrumentation used for noise measurement consisted of a 1" condenser microphone with battery operated cathode follower and a 1/4" single channel tape recorder.

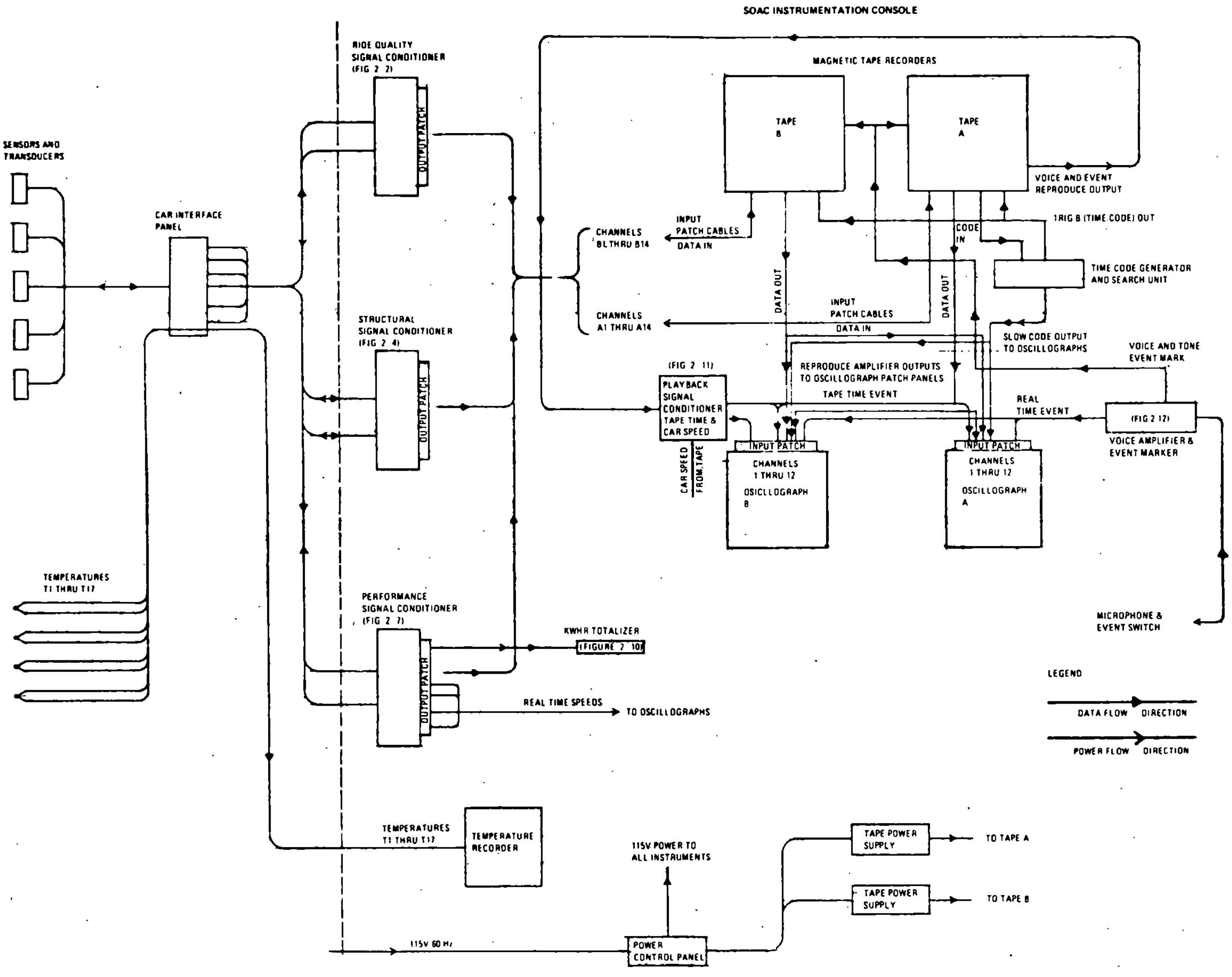


Figure 3—1. SOAC Instrumentation System Block Diagram

4.0 DATA

The parameters recorded during the property tests are described in Tables 4-1 and 4-2. The definition of the parameter measurements is contained in Appendix A, Standard Outputs for SOAC Property Tests.

Data was recorded for the roundtrip routes noted in the Test Description Section. All of the data was recorded on analog tapes and processed to provide three types of outputs.

Time History Charts

Station Summary Tables

Frequency Histograms

4.1 Time History Charts

A slow chart speed strip-out of certain parameters is included in this report. The purpose of these charts is to provide an indication of the maximum levels of parameters during various phases of the run. The complete run is described on the charts including station stops and any particularities that occurred. A series of time histories at a high chart speed is included to illustrate the cyclical nature of the data. These charts are a single time frame for all parameters and are representative of the worst case conditions exhibited for a particular test run.

Intermediate parameters, such as a weighted (filtered) car body acceleration are shown on some charts.

4.2 Station Summary

A summation or summary of specific parameters is made by each station stop. These include test running time and distance for comparison to the property's schedule. Power consumption, motor duty cycle parameters are also summarized by station to indicate the relative sizing of the SOAC propulsion with respect to operations on the property. Station stops and maximum speeds are also shown as another indicator of vehicle operation in a scheduled service environment.

Table 4–1. SOAC Revenue Service Data List A

PARAMETER			STANDARD OUTPUTS		
DESIGNATION NO.	DESCRIPTION	RANGE	RECORDED	PRESENTED	PRELIMINARY ANALYSIS
301	Longitudinal Acceleration	± 0.25 g's	AP/A	Format(3)	Format(4)
302	Line Voltage	0 to 1000 VDC	LVD/A	None	-
303	Line Current	0 to 2000 ADC	LCD/A	None	-
304	No. 1 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
305	No. 1 Truck Armature Current	0 to 1000 ADC	MACD/A	None	RMS-MAC/A
306	No. 1 Truck Field Current	± 50 ADC	MFCD/A	None	RMS-MFC/A
307	No. 2 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
308	No. 2 Truck Armature Current	0 to 1000 ADC	MACD/A	None	-
309	No. 2 Truck Field Current	± 50 ADC	MFCD/A	None	-
310	"P" Wire Current	0 to 1.00 ADC	CS/A	None	Format(3)
317	Total Power Consumption	1 Pulse/0.1 KWHR	PCC/A	Format(2)	Format(2)
315	Speed	0 to 80 MPH	VS/A	Format(3)	Format(4)
318	Brake Cylinder Pressure	0 to 100 psig	BCP/A	None	-

Table 4–2. SOAC Revenue Service Data List B

PARAMETER DESIGNATION NO.	PARAMETER DESCRIPTION	RANGE	STANDARD OUTPUTS RECORDED	STANDARD OUTPUTS PRESENTED	STANDARD OUTPUTS PRELIMINARY ANALYSIS
101	Front Truck, Forward Axle, Righthand Wheel Journal Box Vertical Acceleration	± 20 g's	AJ/A	Format(3)	Format(4)
102	Front Track, Forward Axle, Righthand Wheel Journal Box Lateral Acceleration	± 20 g's	AJ/A	Format(3)	Format(4)
103	Front Truck, Forward Axle Lefthand Wheel Journal Box Vertical Acceleration	± 20 g's	AJ/A	Format(3)	-
115	Mid Car Centerline Vertical Acceleration	± 0.25 g's	AC/A	Format(3)	RRV/A(1), (3)
116	Mid Car Centerline Lateral Acceleration	± 0.25 g's	AC/A	Format(3)	RRH/A(1), (3)
120	Forward Car Centerline Vertical Acceleration	± 0.25 g's	AC/A	Format(3)	RRV/A(1)
121	Forward Car Centerline Lateral Acceleration	± 0.25 g's	AC/A	Format(3)	RRH/A(1)
219	Truck Frame Upper Strain Gage	± 6348 psi	STP	Format(3)	Fromat(4)
220	Truck Frame Lower Strain Gage	± 6348 psi	STP	Format(3)	-
221	Pitch Angular Acceleration	± 1.5 Rad/sec/sec.	ACA/A	Format(3)	Format(4)
222	Roll, Angular Acceleration	± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
223	Yaw, Angular Acceleration	± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
-	Interior Sound Pressure	40 to 120 dB(re 2 x $10^{-5}N/M^2$)	SP/A	NL/A(1)	NL/A(2)

4.3 Frequency Histograms

These distributions are an indication of the ratio of time that a parameter is at a particular level with respect to the time to complete a roundtrip scheduled service run. These parameters may be used to describe how the vehicle was driven, the track conditions, and how the vehicle responded to these conditions.

5.0 DATA DISCUSSION

Vehicle operation was such that while operating southbound from the Fern Rock Station, the instrumented car, SOAC No. 2, was leading. A positive longitudinal acceleration value on the time history chart is start-up. For the northbound run vehicle start-up is a negative value on the longitudinal acceleration time history.

As defined in Section 4, there are three forms of data. These forms are discussed below with respect to three categories:

(1) Operation

How the vehicle was operated and maintained schedule.

(2) Environment

Track and truck conditions

(3) Response

How the vehicle responded to the operational environment.

Figures 5-1 to 5-13 present the frequency histograms for the SEPTA tests. Figure 5-14 is a sample of the Interior Noise Level time history. The remaining time history charts are shown in Figures 5-15 through 5-25. Table 5-1 is a summary of some of the test parameters and is taken from the histograms and time history charts. Tables 5-2 and 5-3 are the Station Summaries with power consumption.

5.1 Operation

The Station Summaries show that the SOAC maintained the SEPTA schedule and even ran early. As noted on the Summaries, station stop times were too short, and possibly influenced the early run time.

The maximum acceleration rate for the SOAC at SEPTA is shown on the time histories to be 2.73 mph/sec. This value is within the SOAC specification.

The Station Summaries show 14 percent of the trip time was spent in a station. This is comparable to the speed frequency histogram which shows 22 percent of the trip time in the 0 to 5 mph band. The 8 percent difference would be the time spent with the vehicle moving at 5 mph or less. This is a high ratio of low speed running.

The Station Summaries show the power consumption for the SOAC to be 136 KWHR for the roundtrip. For the scheduled distance of 20 miles this is 6.8 KWHR/mile. For the measured distance of 22.5 miles, it is 6.1 KWHR/mile.

The RMS armature current indicates the relative sizing of the SOAC propulsion system with respect to the test route. The SOAC motors have a continuous rating of 175 hp (460 amps), and a one hour rating of 230 hp (600 amps). The roundtrip required 281.5 amp (RMS) or 61 percent of the continuous rating. Consistently the most severe cycle is the Logan to Wyoming Street run which required around 370 amps.

5.2 Environment

The journal accelerations and truck frame stress were to be used as an indicator of track conditions. Unfortunately, the vertical journal box accelerometer failed prior to the test and this data was not obtained. In addition, the truck frame stress gage was destroyed prior to this test and this data is also missing.

The summary values for the journal lateral acceleration are shown in Table 5-1. The 50th percentile is a statistical quantity and is read as 50 percent of the time the journal lateral acceleration is between $\pm$ 3.4 gs. The 95th percentile is read similarly. The "nominal" value is the 50th percentile for vehicle moving time.

5.3 Response

Ride Roughness and Noise Levels are parameters which are related to "human responses". Ride Roughness is a ride comfort rating of vibration levels, and Noise Level is a hearing comfort rating of sound pressure levels. The parameters are described in the Standard Output Section of this report. A summary of the values for the SEPTA tests is shown in Table 5-1.

A summary of the car body acceleration levels is also shown in Table 5-1. From the time history charts it can be seen that the 7.5 hertz is the dominant vertical vibration frequency.

Interior Noise Level data was taken in the middle of the non-instrumented car at a seated person's ear level. The original engineering tests at TTC indicated that this is the quietest point in the car. The statistical quantities derived from the data are:

L(99)	L(90)	L(50)	L(10)	L(1)	L(EQ)
64 dBA	66	68	75	82	72

Table 5—1. Summary Values for SOAC Operating on the ~~CTS Airport~~ SEPTA Line

	50TH %	"NOMINAL"	95TH %	MAXIMUM
Journal Box Vertical Acceleration (G)	(DATA CHANNEL MALFUNCTION)			-
Journal Box Lateral Acceleration (G)	± 3.4	± 3.8	± 9.25	-
Truck Frame Stress (PSI)	(DATA CHANNEL MALFUNCTION)			-
Forward Car Vertical Acceleration (G)	± .022	± .026	± .071	± .197
Mid Car Vertical Acceleration (G)	± .019	± .022	± .068	± .209
Forward Car Lateral Acceleration (G)	± .015	± .018	± .047	± .222
Mid Car Lateral Acceleration (G)	± .015	± .018	± .038	± .163
Longitudinal Ride Roughness (GRMS)	.004	.005	.014	.080
Forward Car Vertical Ride Roughness (GRMS)	.011	.013	.043	.100
Mid Car Vertical Ride Roughness (GRMS)	.012	.014	.050	.115
Forward Car Lateral Ride Roughness (GRMS)	.007	.009	.029	.118
Mid Car Lateral Ride Roughness (GRMS)	.004	.005	.017	.090
Pitch (RAD/Sec-Sec)	± .140	± .150	± .190	± .119
Roll (RAD/Sec-Sec)	± .125	± .140	± .230	± .932
Yaw (RAD/Sec-Sec)	± .138	± .146	± .190	± .173

Table 5–2. Station Summary I

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	POWER CONSUMPTION KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Fern Rock	0	0	0	0	0	0	0	0	0	0
2	Olney Avenue	.68	3.0	.74	3.25	3.09	4.15	104.6	27.8	19.2	20
3	Logan Street	.62 1.3	2.0	.69	2.12	1.47	2.14	185.4	22.7	15.6	30
4	Wyoming Avenue	.38 1.68	2.0	.40	1.08	2.84	7.07	368.0	28.5	12.0	39
5	Hunting Park Ave.	.45 2.13	1.0	.55	1.18	4.10	7.44	377.6	27.5	10.0	43
6	Erie Avenue	.60 2.73	2.0	.72	2.18	3.59	5.02	257.2	28.0	18.0	38
7	Allegheny Avenue	.53 3.26	2.0	.58	1.45	3.05	5.24	277.2	29.7	10.8	42
8	North Philadelphia	.41 3.67	1.0	.52	1.32	3.62	7.03	328.7	29.1	9.6	40
9	Dauphin Street	.58 4.25	2.0	.66	1.46	3.43	5.18	314.9	25.1	14.4	42
10	Columbia Avenue	.58 4.83	1.0	.67	1.41	4.29	6.45	359.2	26.9	12.0	44
11	Girard Avenue	.51 5.34	2.0	.59	1.53	2.11	3.58	257.0	23.6	9.6	32
12	Fairmount Ave.	.33 5.67	1.0	.37	1.19	1.98	5.43	286.8	28.6	9.6	28
13	Spring Garden St.	.28 5.95	1.0	.35	1.07	2.00	5.66	331.3	28.3	9.6	34
14	Race - Vine Street	.38 6.33	1.0	.43	1.33	1.81	4.24	270.9	24.1	20.4	34
15	City Hall	.35 6.68	2.0	.41	1.57	1.98	4.80	197.2	28.9	13.2	22
16	Walnut Street	.25 6.93	1.0	.30	1.15	2.00	6.77	256.7	30.8	13.2	28
17	Lombard Street	.33 7.26	2.0	.38	1.46	1.81	4.75	217.7	28.9	10.8	22
18	Ellsworth Avenue	.56 7.82	1.0	.62	1.32	3.71	5.98	351.4	27.2	10.8	43
19	Tasker Avenue	.44 8.26	1.0	.51	1.31	3.70	7.29	351.2	28.3	12.0	43
20	Snyder Avenue	.39 8.65	2.0	.45	1.58	2.59	5.79	266.8	25.8	12.0	34
21	Oregon Avenue	.51 9.16	2.0	.60	1.32	3.62	6.07	339.3	27.3	12.0	44
22	Pattison Avenue	.86 10.02	2.0	.81	2.95	5.16	6.33	275.4	28.2	12.0	40
				TOTALS		61.95	5.46	278.7	27.4		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	10.02	11.35
Time	34.0	33.23
Block Speed	17.7	20.5
Station Dwell	30.0	12.7
Station Spacing	.48	.54

Table 5–3. Station Summary II

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	POWER CONSUMPTION KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	Pattison Avenue	0	0	0	0	0	0	0	0	0	0
2	Oregon Avenue	.86	1.0	.85	1.80	4.13	4.85	280.0	28.0	14.4	44
3	Snyder Avenue	.51	2.0	.63	1.42	3.39	5.39	291.1	28.5	10.8	44
4	Tasker Avenue	.39	2.0	.42	1.34	2.47	5.88	248.4	31.0	12.0	36
5	Ellsworth Avenue	.44	1.0	.53	1.26	3.77	7.14	342.1	29.0	12.0	45
6	Lombard Street	.56	1.0	.62	1.42	4.08	6.55	324.9	27.4	13.2	46
7	Walnut Street	.33	2.0	.39	1.44	2.18	5.53	197.0	32.5	14.4	28
8	City Hall	.25	1.0	.10	1.37	1.53	5.16	207.1	26.8	19.2	24
9	Race Vine Street	.35	2.0	.40	1.26	2.76	6.96	269.4	31.9	12.0	34
10	Spring Garden Street	.38	1.0	.41	1.14	3.32	8.20	312.8	30.2	12.0	34
11	Fairmount Avenue	.28	1.0	.35	1.13	3.32	9.59	318.7	32.0	13.2	38
12	Girard Avenue	.33	1.0	.38	1.24	2.56	6.65	281.2	29.0	13.2	33
13	Columbia Avenue	.51	2.0	.57	1.41	3.83	6.74	305.8	27.7	15.6	44
14	Dauphin Street	.58	1.0	.67	1.45	4.44	6.69	347.8	27.7	12.0	45
15	North Philadelphia	.58	2.0	.69	1.83	4.22	6.15	284.1	23.2	12.0	45
16	Alleghany Avenue	.41	1.0	.51	1.42	3.90	7.66	328.5	30.1	15.6	46
17	Erie Avenue	.53	2.0	.59	1.59	4.42	7.48	307.4	29.7	13.2	46
18	Hunting Park Ave.	.60	2.0	.70	1.67	5.12	7.32	309.6	29.6	14.4	46
19	Wyoming Avenue	.45	2.0	.51	1.41	3.01	5.93	299.4	27.3	14.4	45
20	Logan Avenue	.38	1.0	.43	1.19	3.70	8.52	369.0	29.0	15.6	42
21	Olney Avenue	.62	2.0	.71	1.72	5.49	7.69	291.0	26.1	15.6	45
22	Fern Rock	.68	3.0	.64	3.07	2.59	4.06	100.0	27.5	16.8	15
					TOTALS	74.23	6.69	284.4	28.6		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	10.02	11.10
Time	33.0	31.58
Block Speed	18.2	21.1
Station Dwell	30.	13.9
Station Spacing	.48	.53

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
"P-Wire" Current Distribution

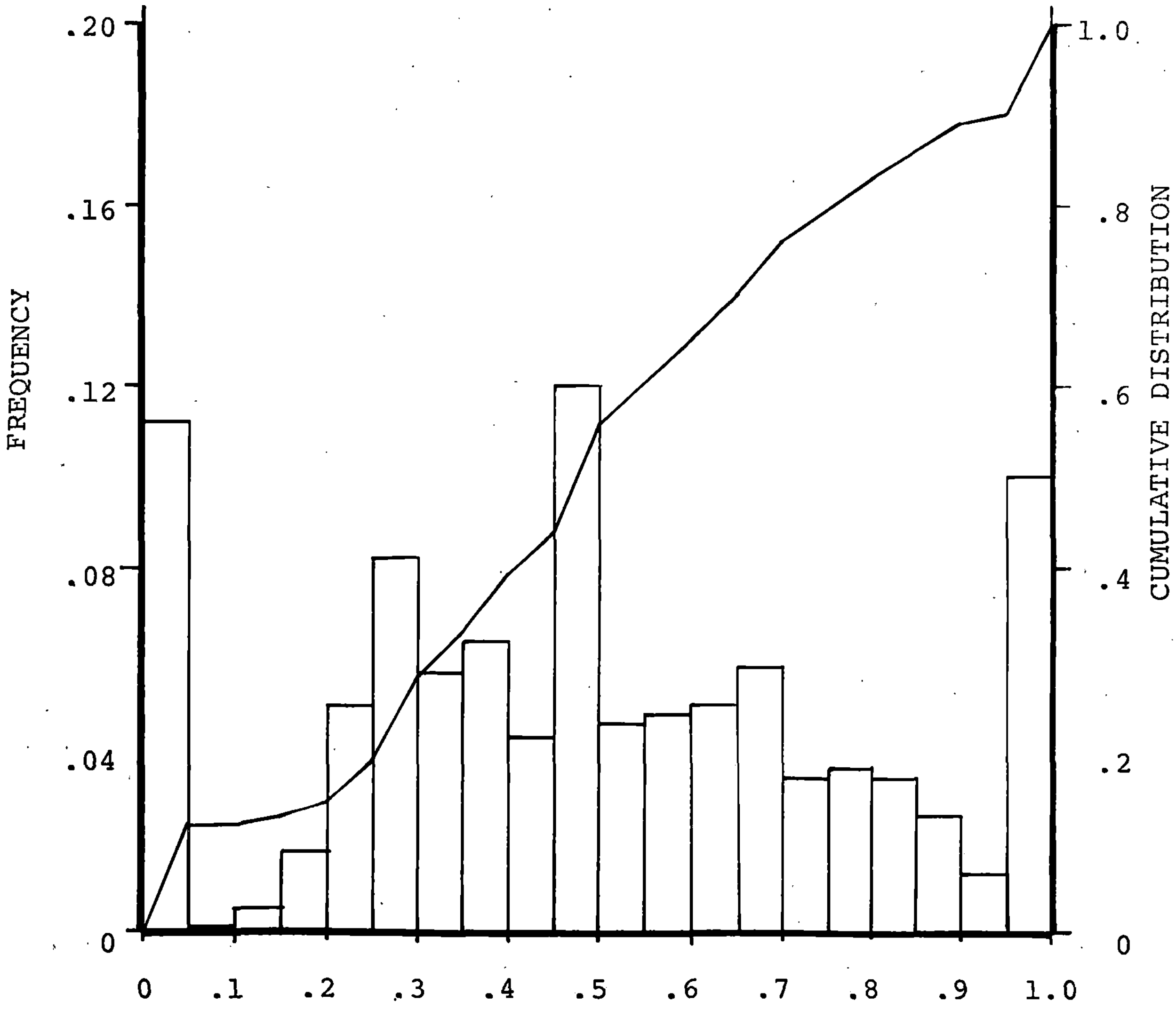


Figure 5–1. 'P-Wire' Current Distribution

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
Vehicle Speed Distribution

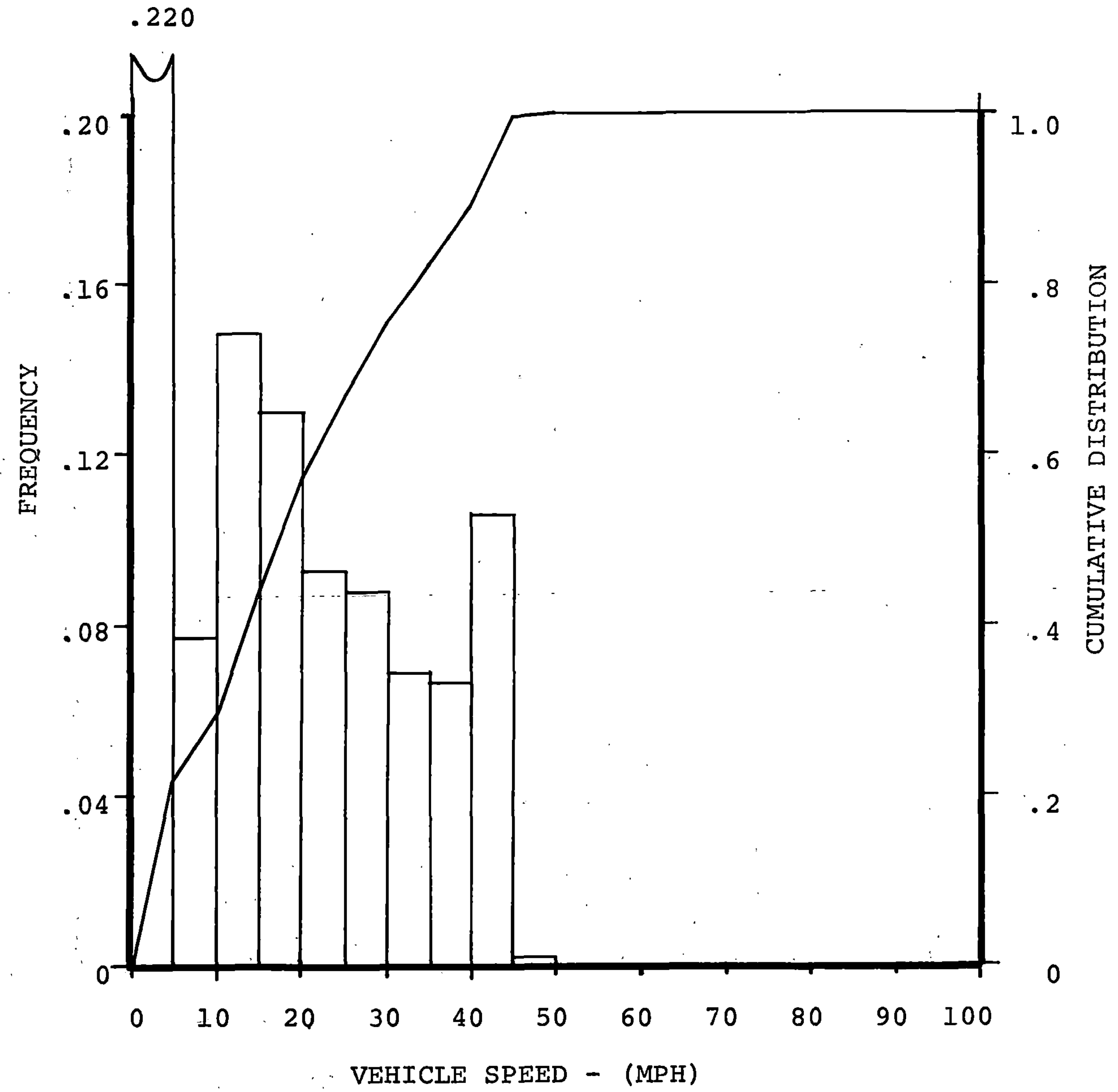


Figure 5–2. Vehicle Speed Distribution

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
Vehicle Acceleration Distribution

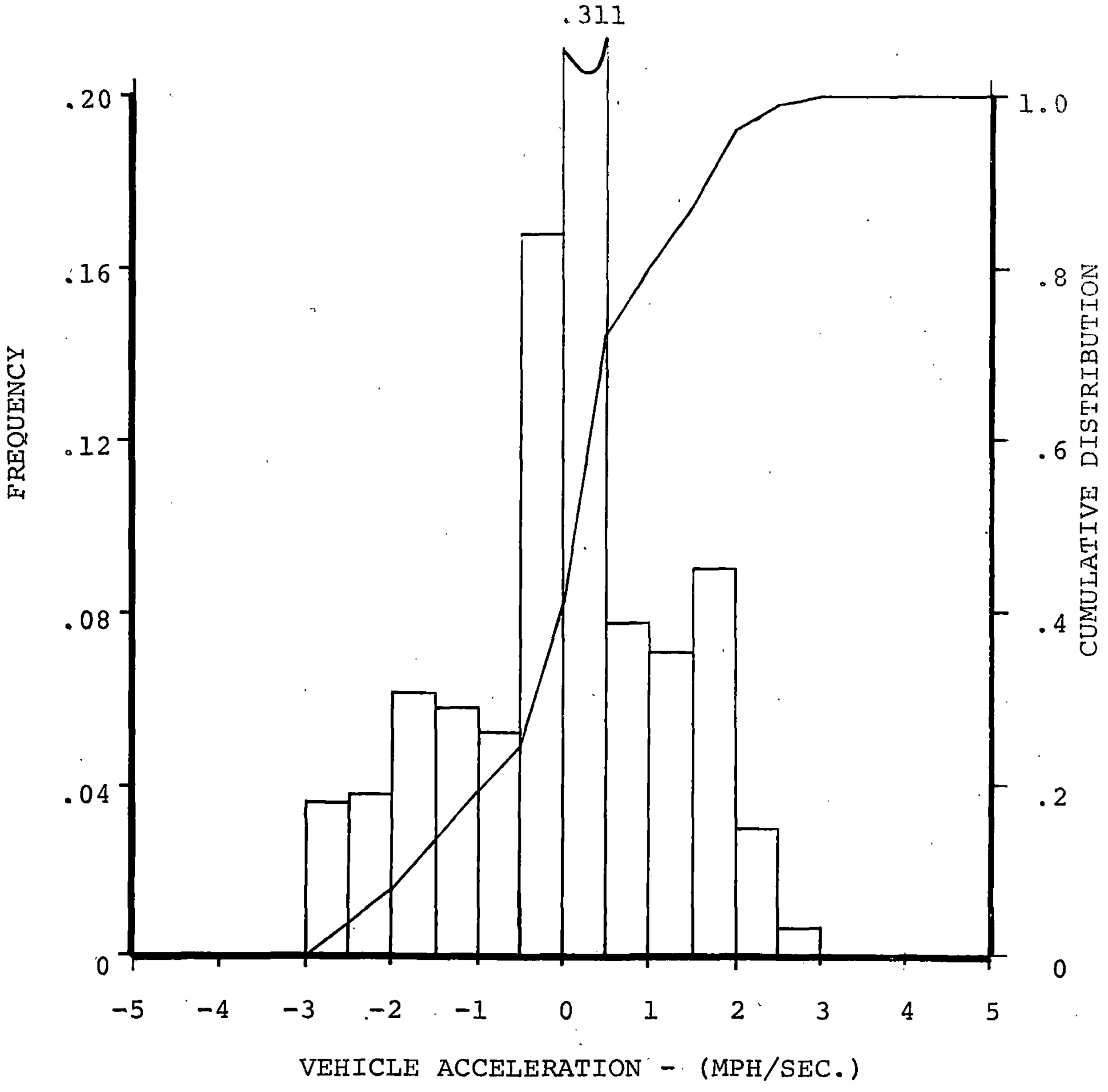


Figure 5—3. Vehicle Acceleration Distribution

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
Journal Box Lateral Acceleration Distribution

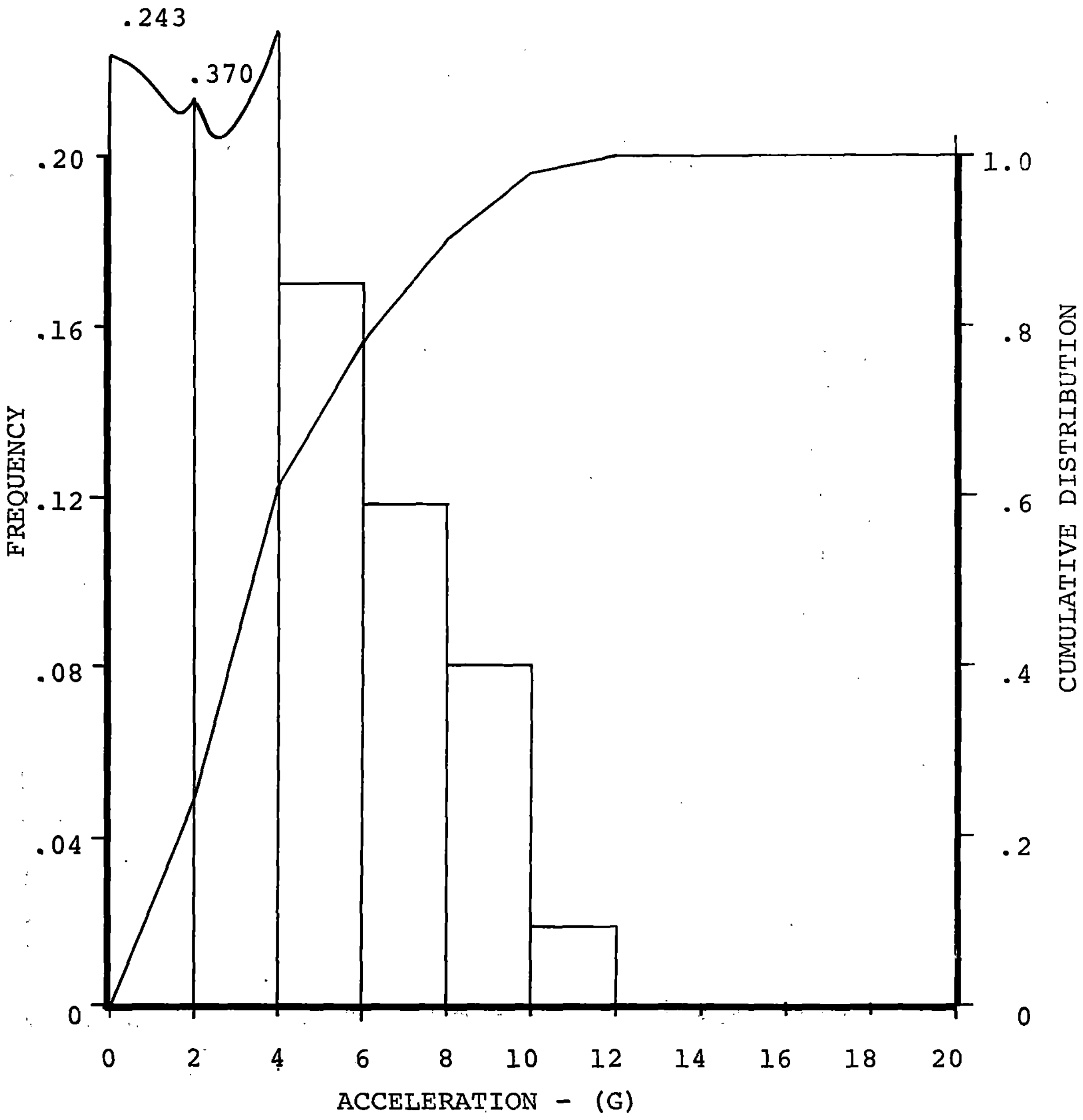


Figure 5–4. Journal Box Lateral Acceleration Distribution

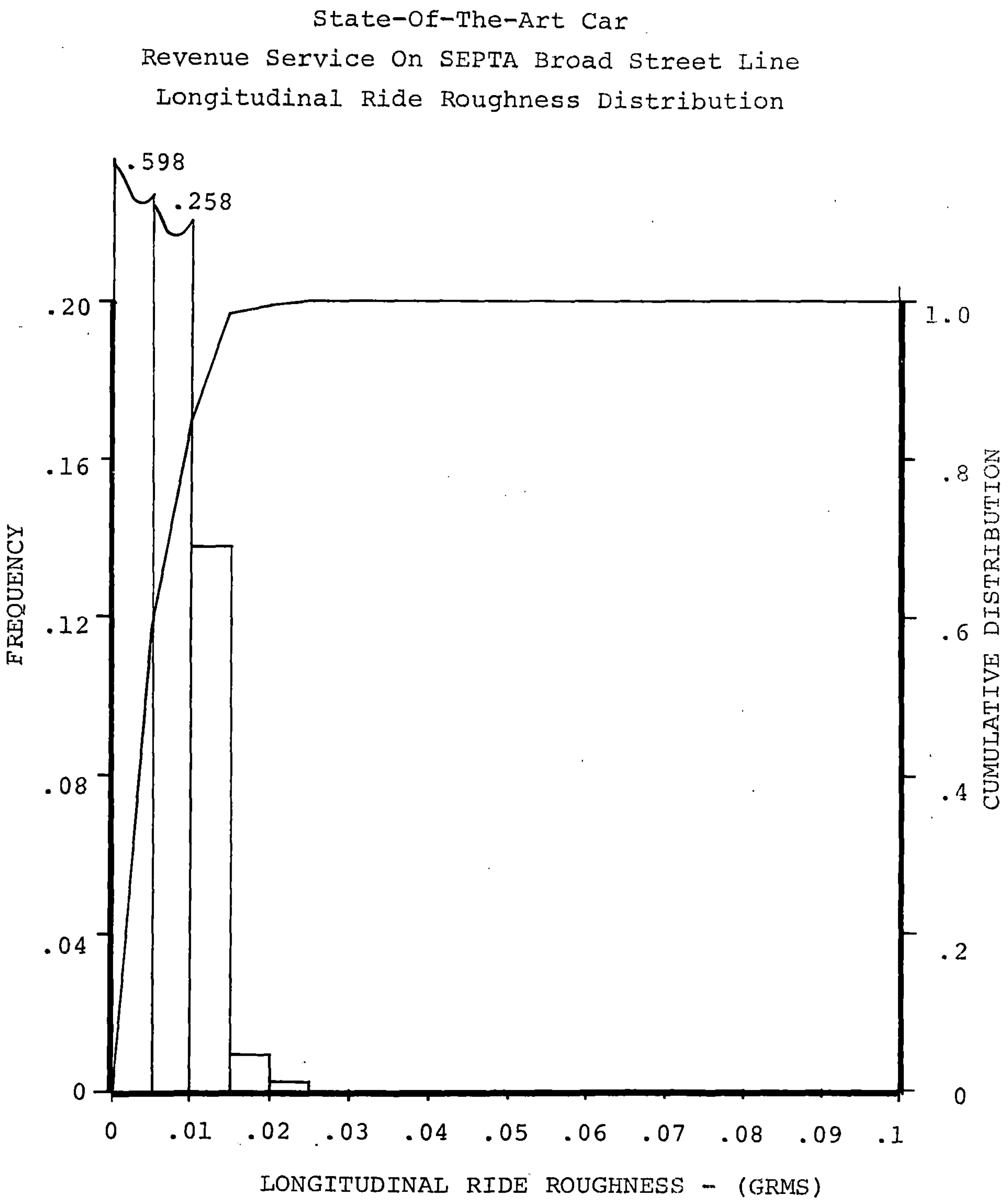


Figure 5—5. Longitudinal Ride Roughness Distribution

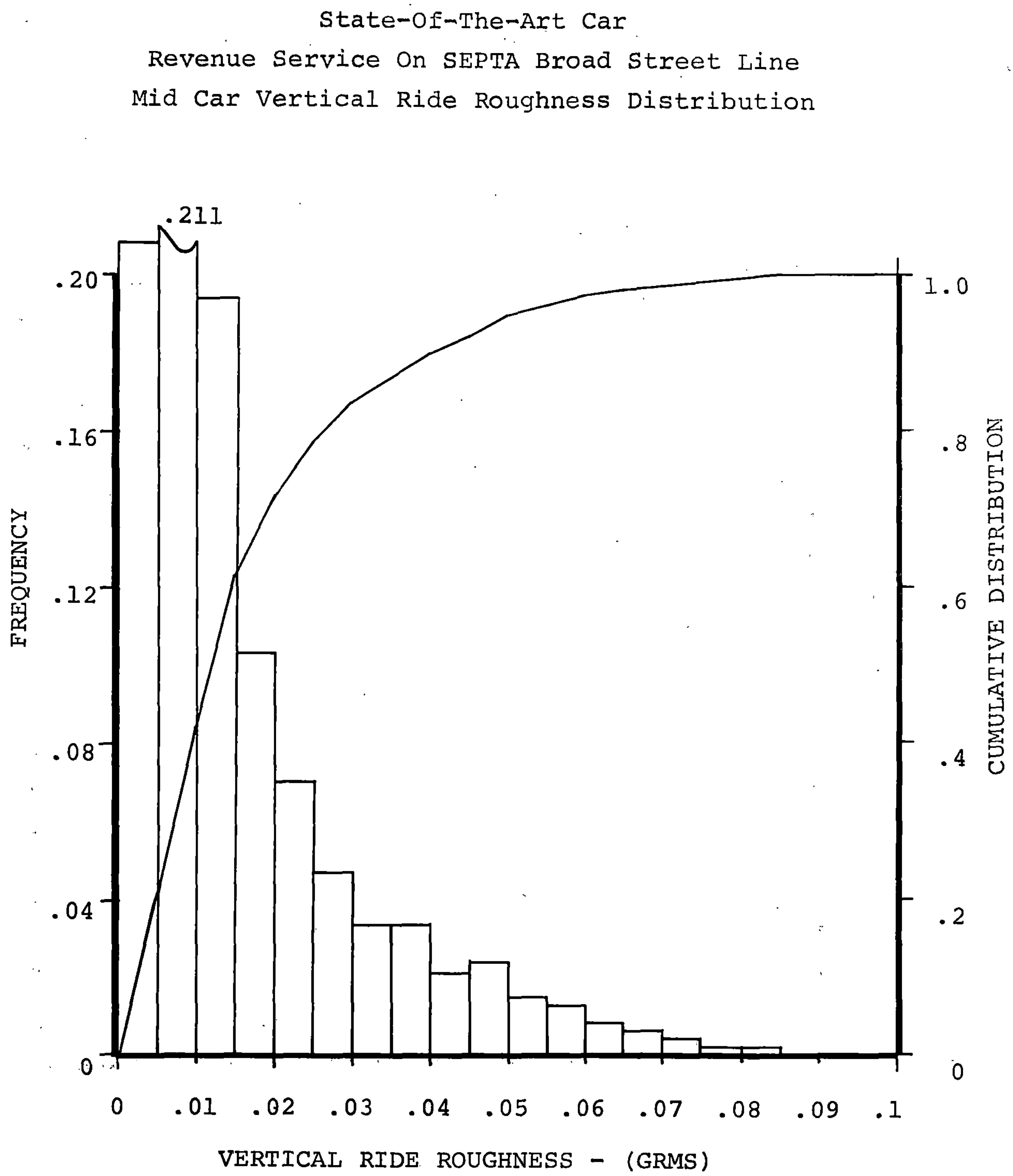


Figure 5–6. Mid-Car Vertical Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
Mid Car Lateral Ride Roughness Distribution

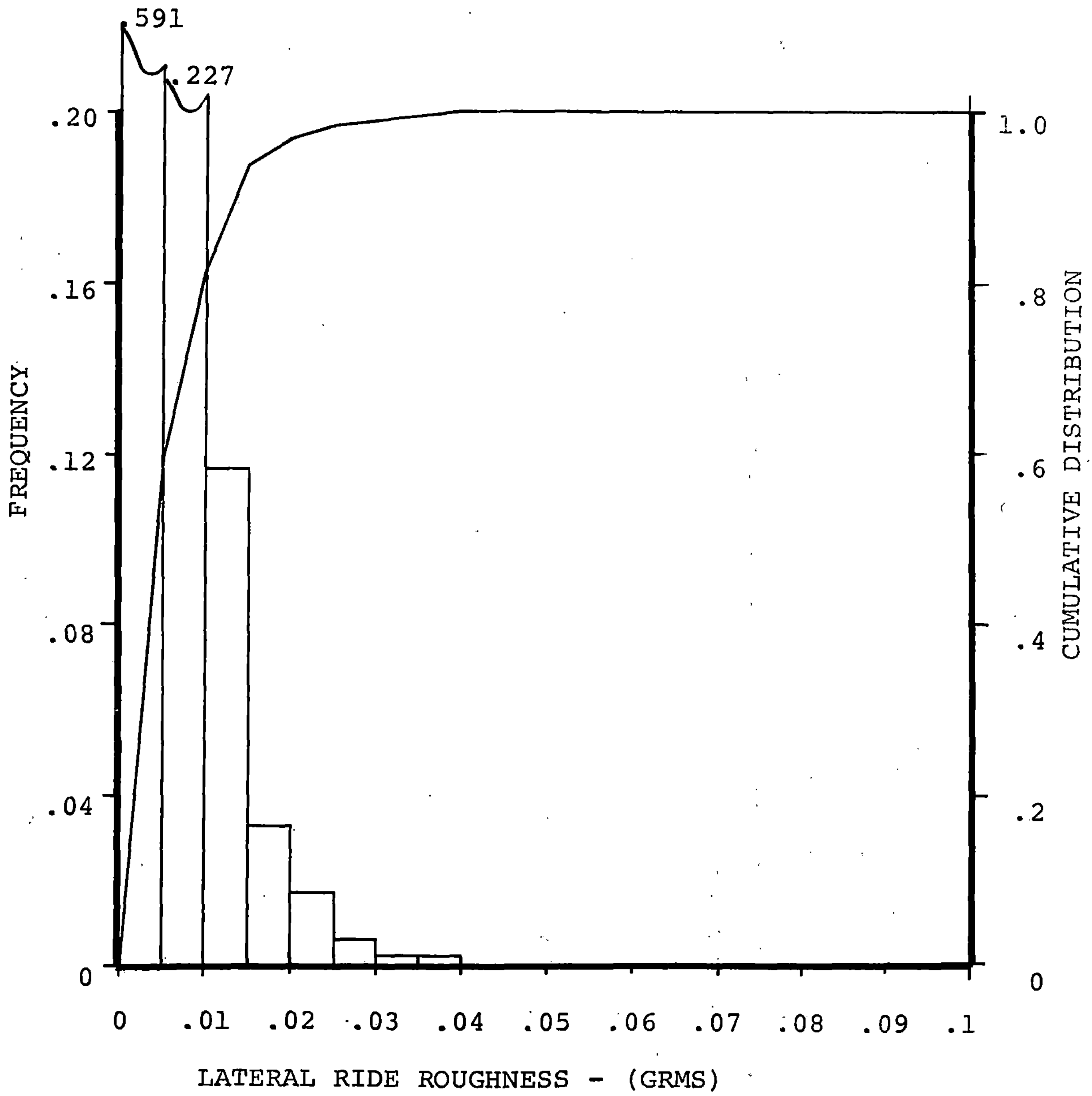


Figure 5–7. Mid-Car Lateral Ride Roughness Distribution

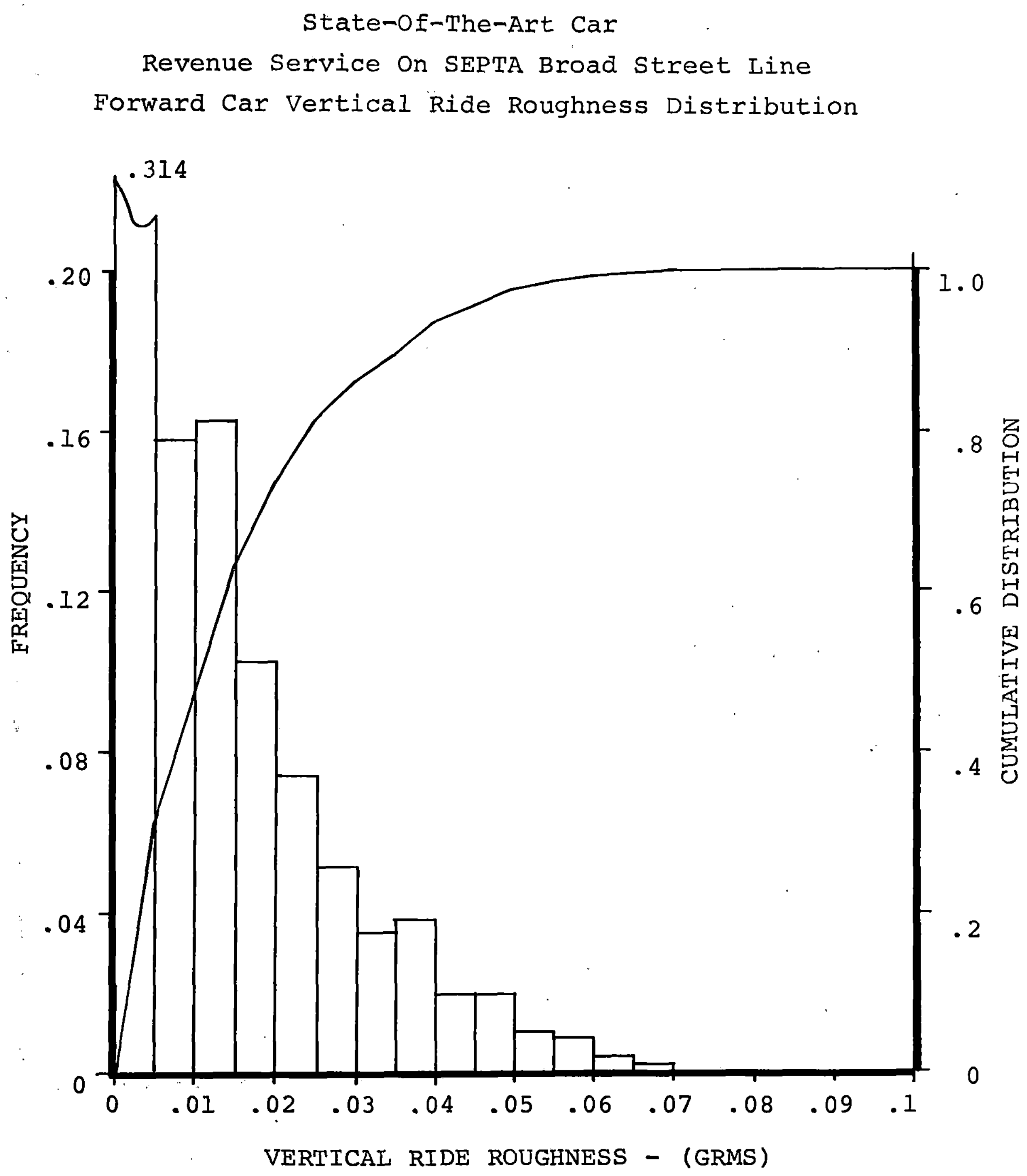


Figure 5–8. Forward Car Vertical Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
Forward Car Lateral Ride Roughness Distribution

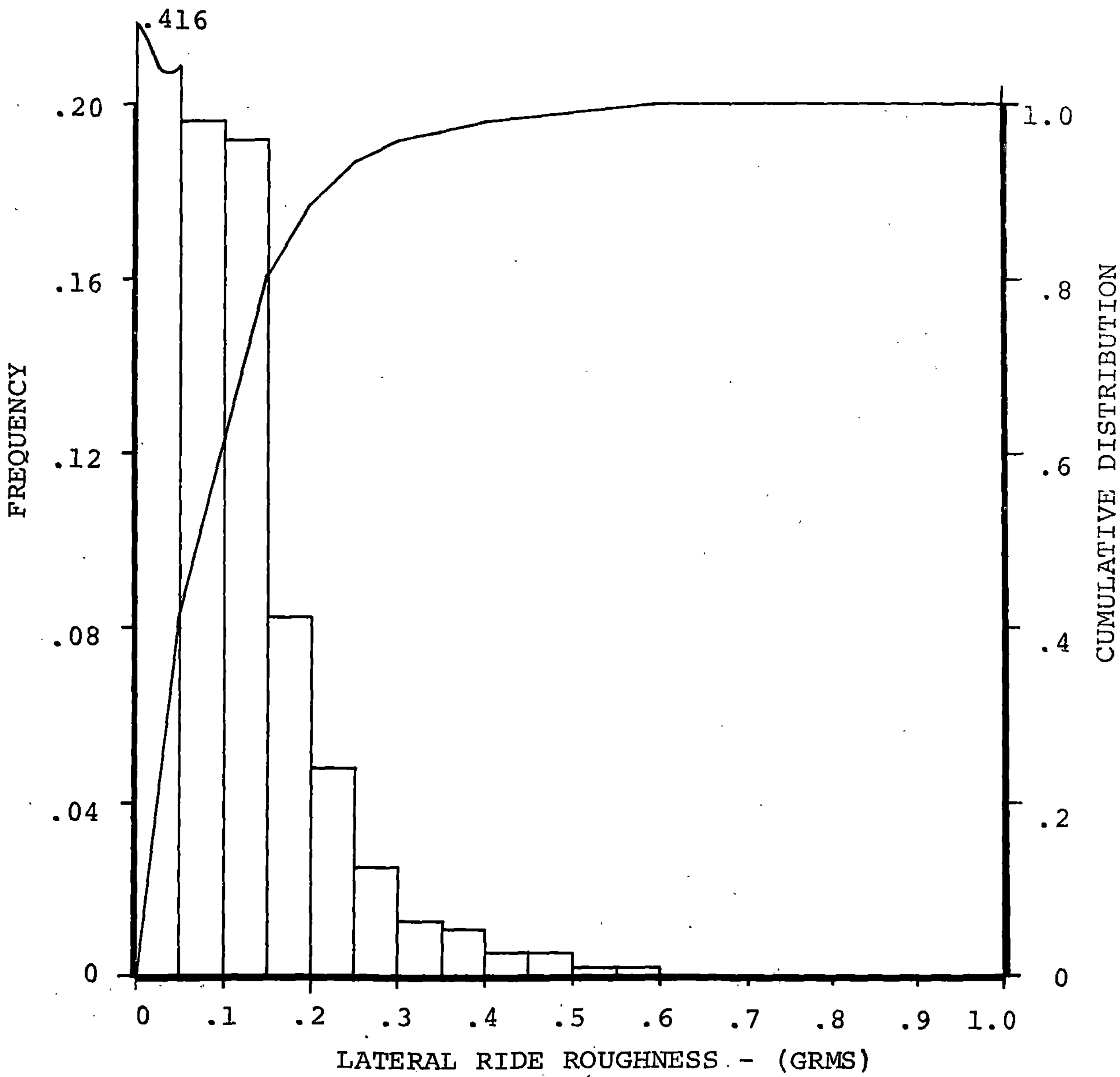


Figure 5–9. Forward Car Lateral Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On SEPTA Broad Street Line
Vehicle Pitch Distribution

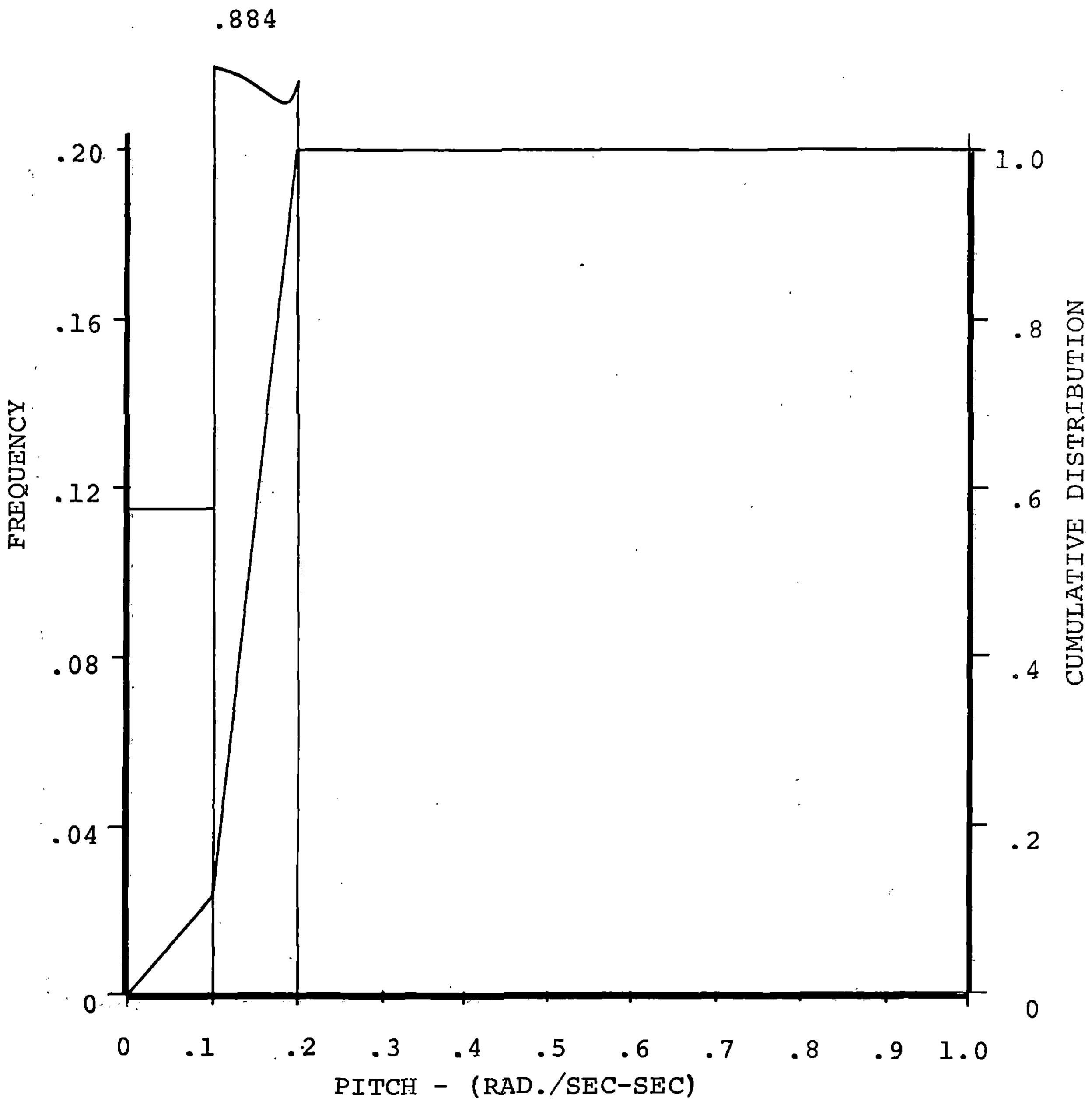


Figure 5–10. Vehicle Pitch Distribution

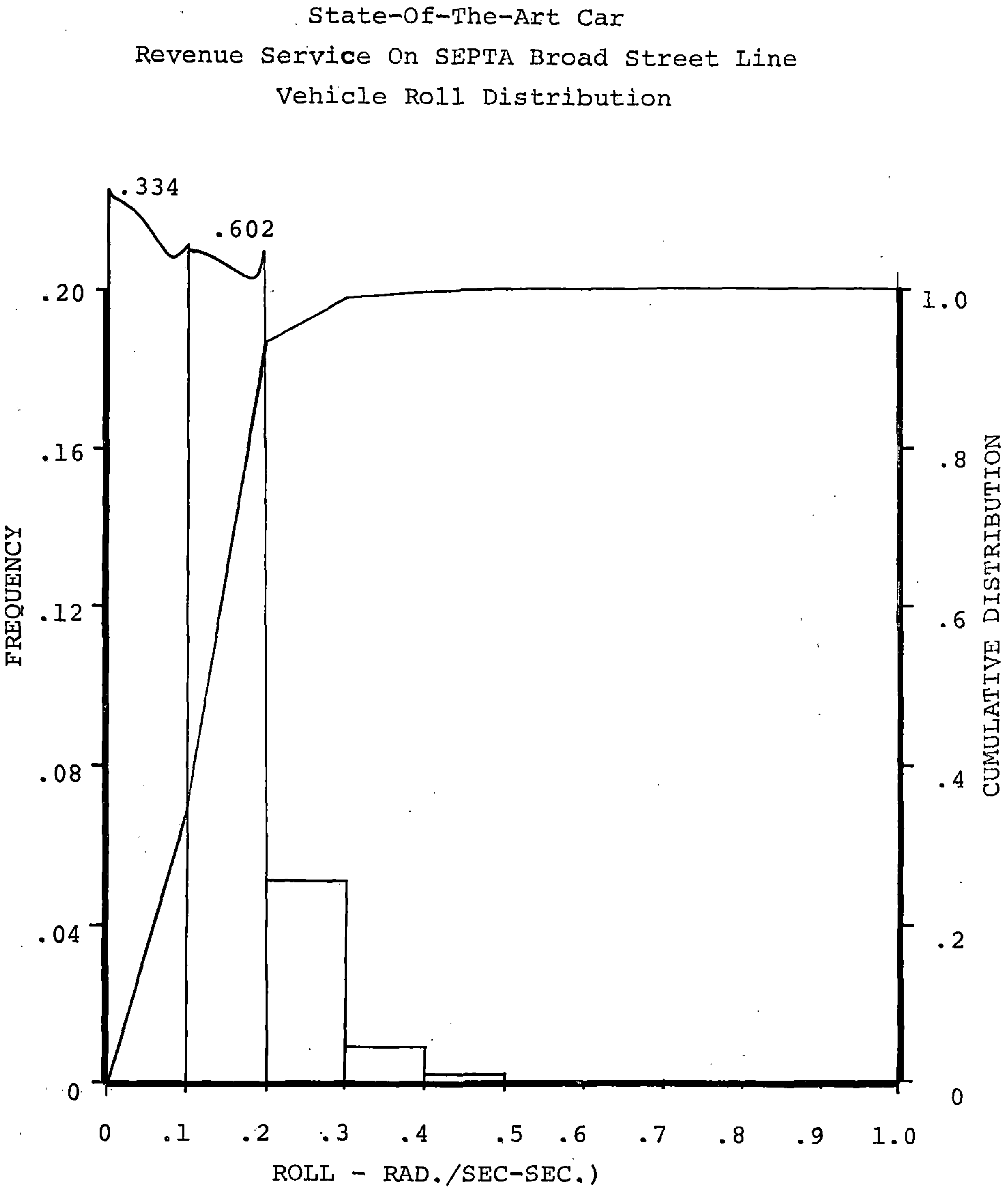


Figure 5—11. Vehicle Roll Distribution

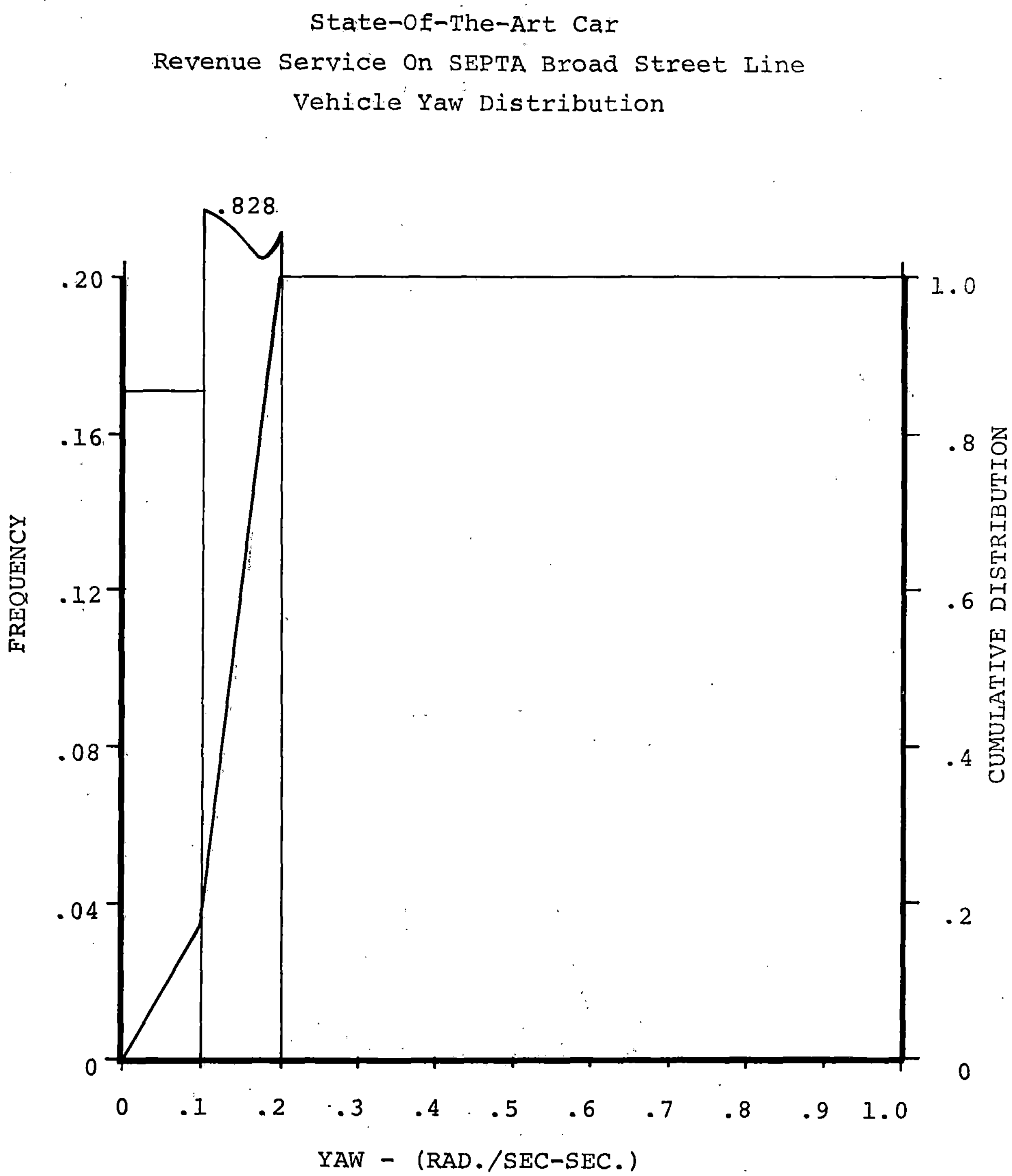


Figure 5–12. Vehicle Yaw Distribution

State-Of-The-Art Car
Revenue Service On The SEPTA Broad Street Line
Interior Noise Level Distribution

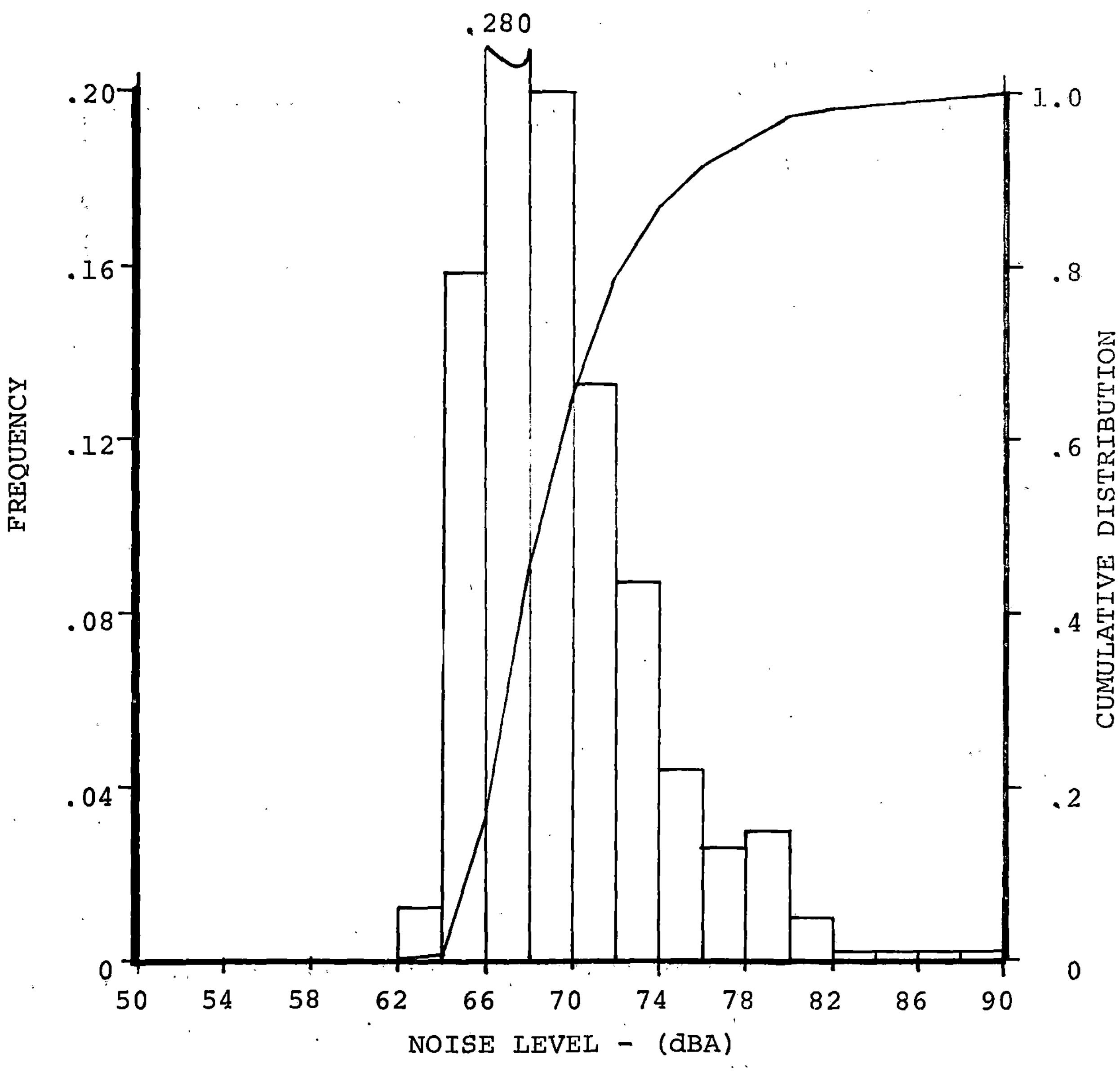


Figure 5—13. Interior Noise Level Distribution

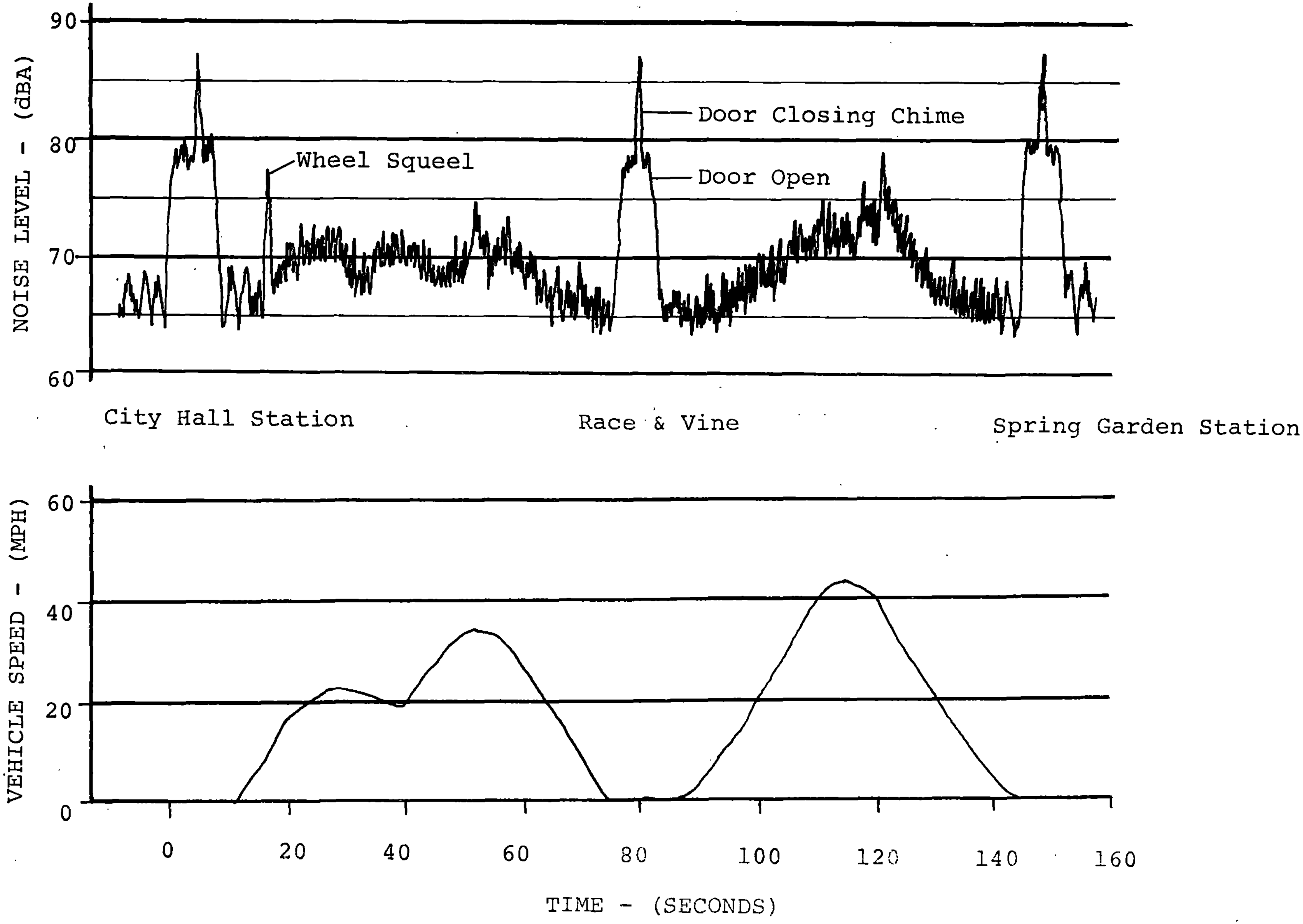


Figure 5–14. SOAC Interior Noise Level Sample

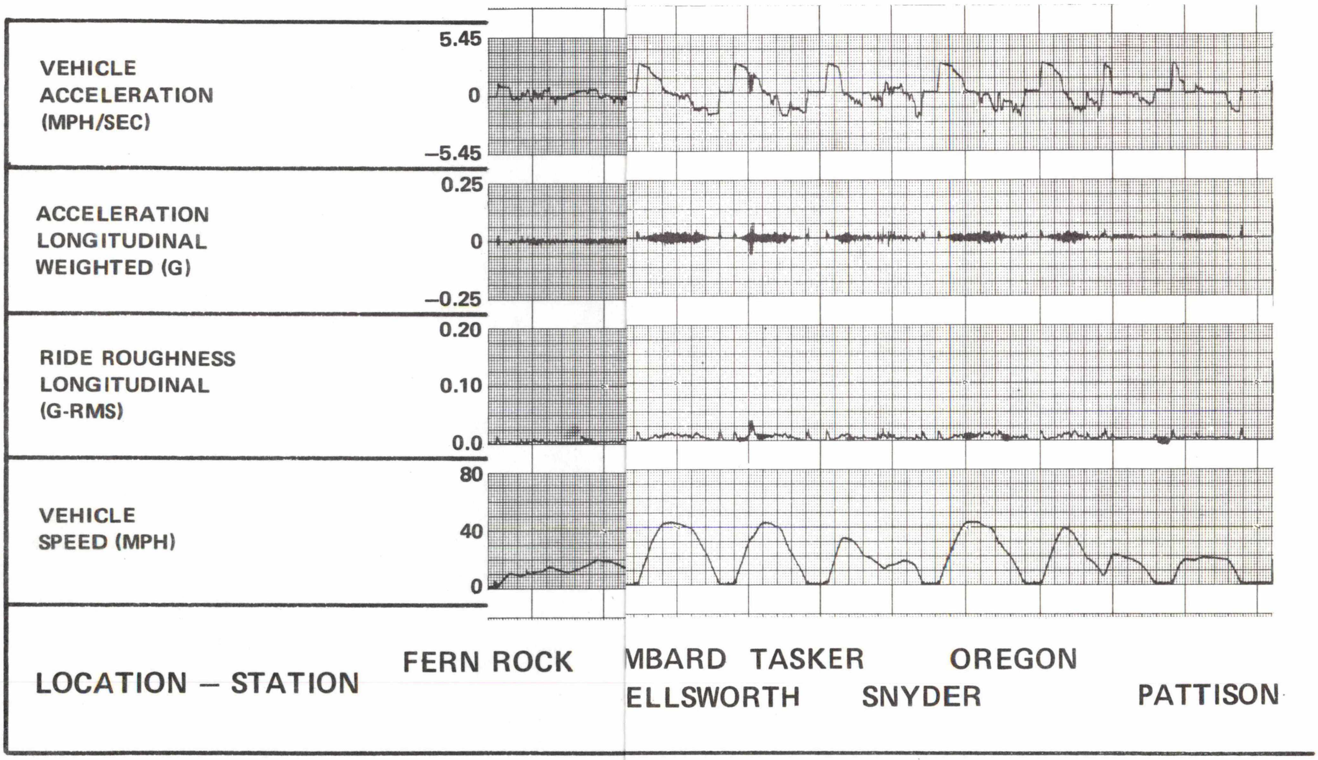


Figure 5–15. Vehicle Accele

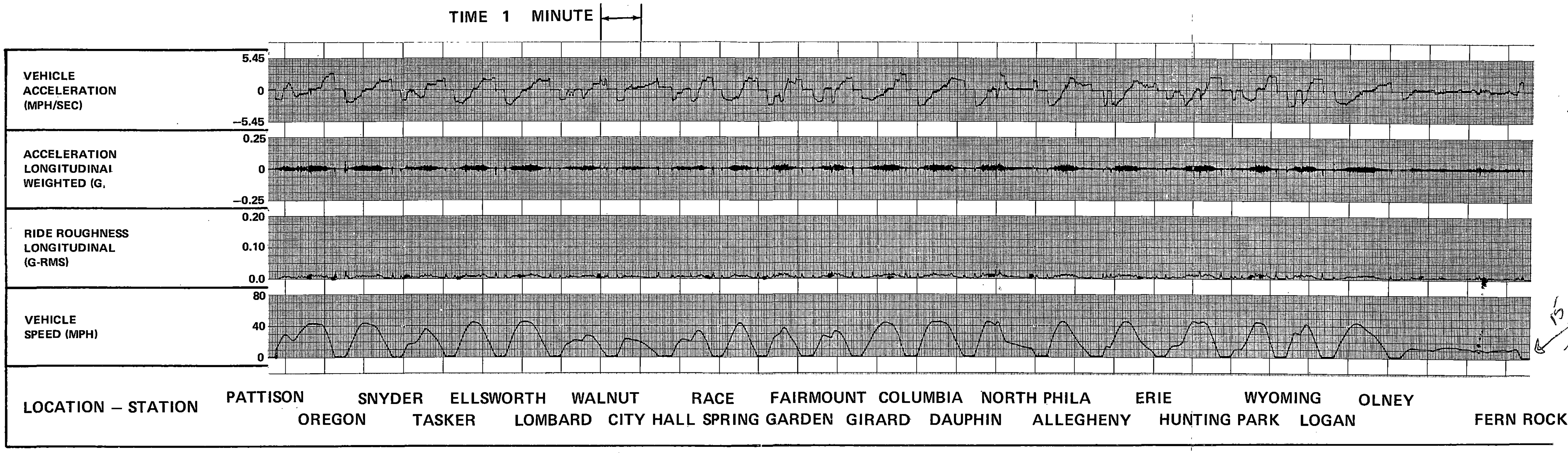


Figure 5–16. Vehicle Acceleration and Speed Time History Chart (P–F)

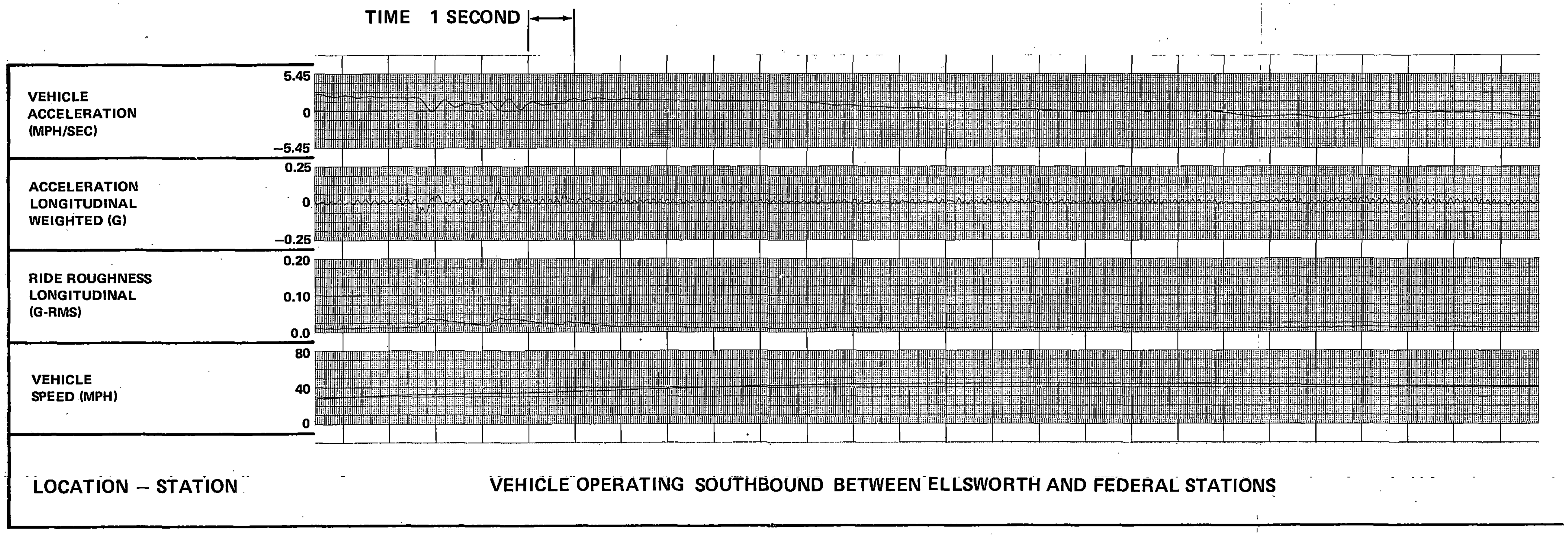


Figure 5–17. Vehicle Acceleration and Speed Time History Chart (~)

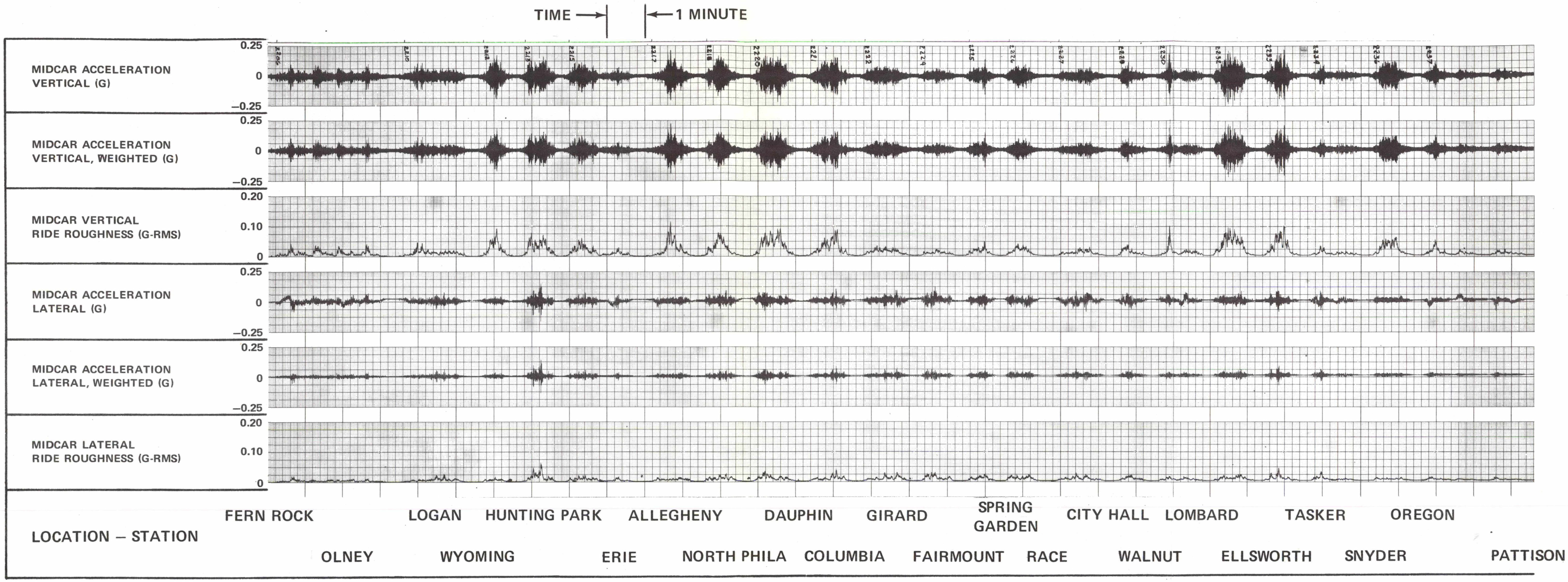


Figure 5–18. Mid-Car Acceleration Time History Chart (F–P)

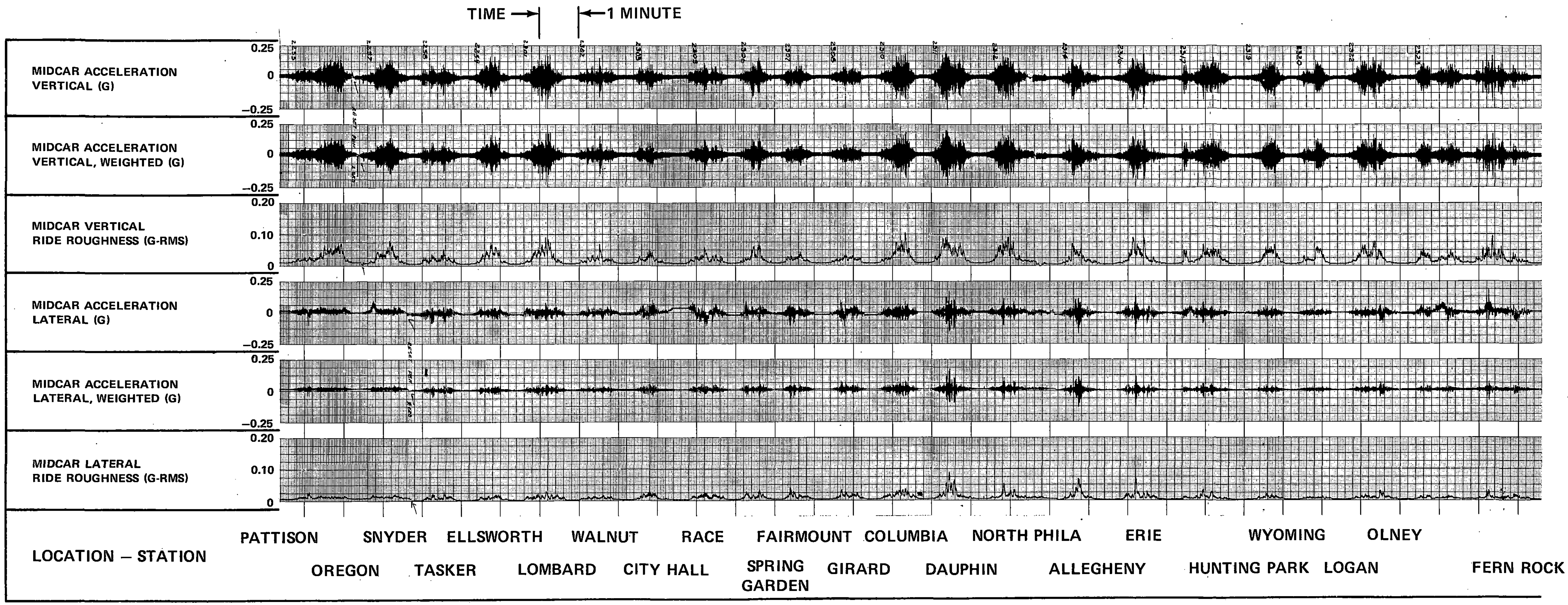


Figure 5–19. Mid-Car Acceleration Time History Chart (P–F)

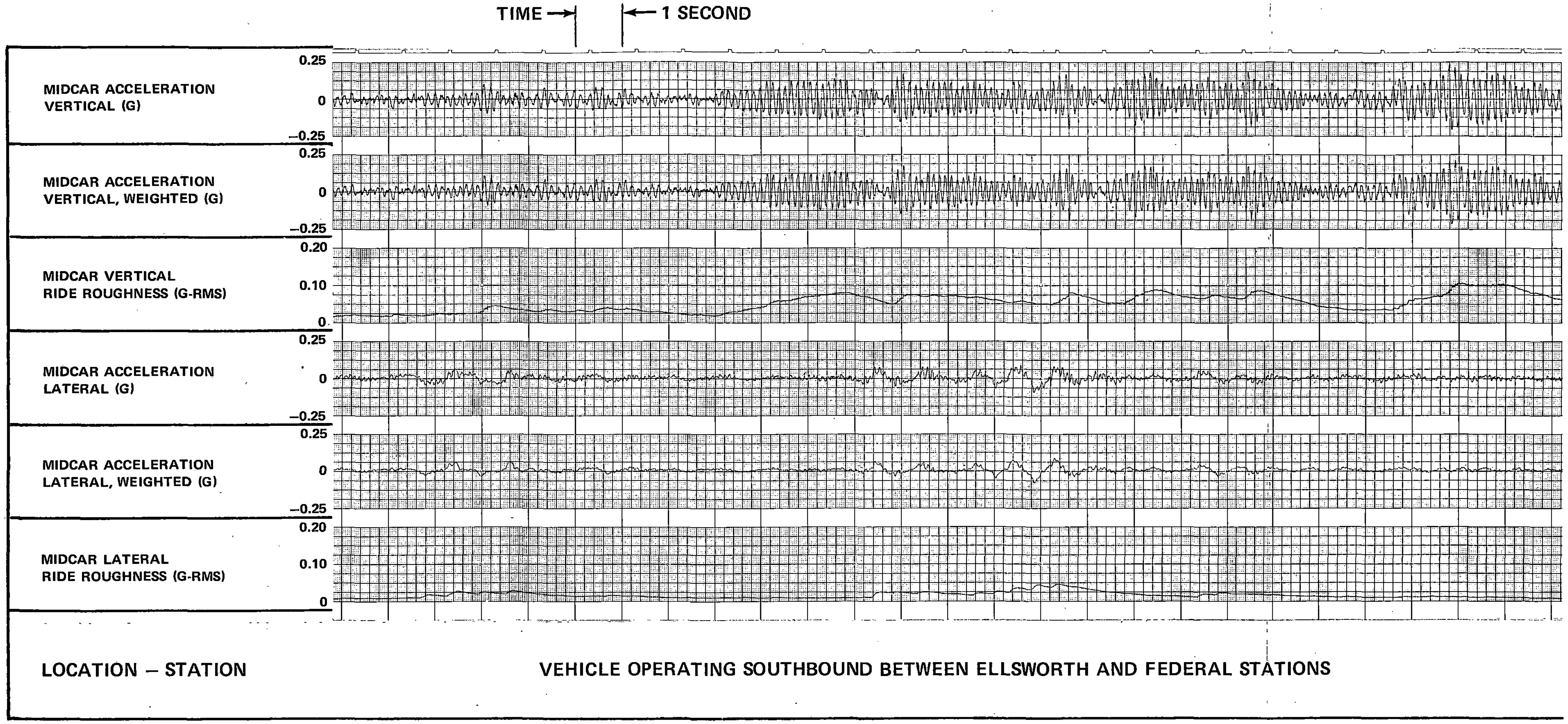


Figure 5–20. Mid-Car Acceleration Time History Chart (~)

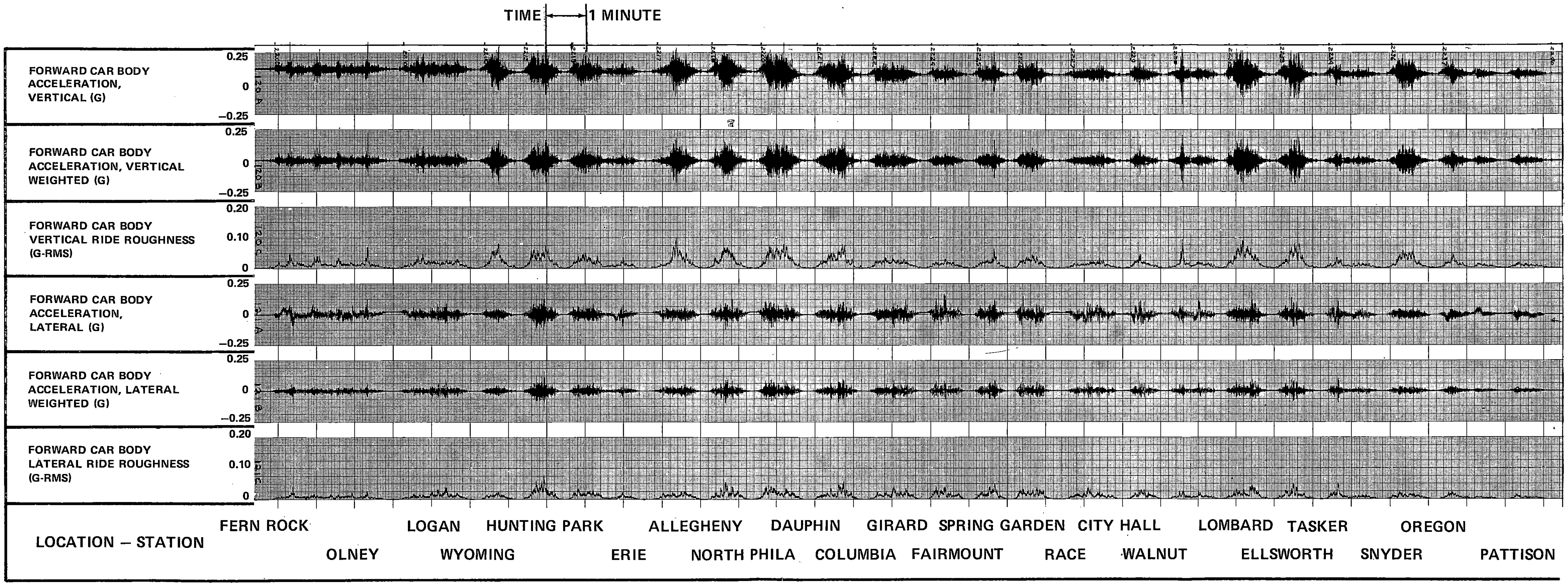


Figure 5–21. Forward Car Acceleration Time History Chart (F–P)

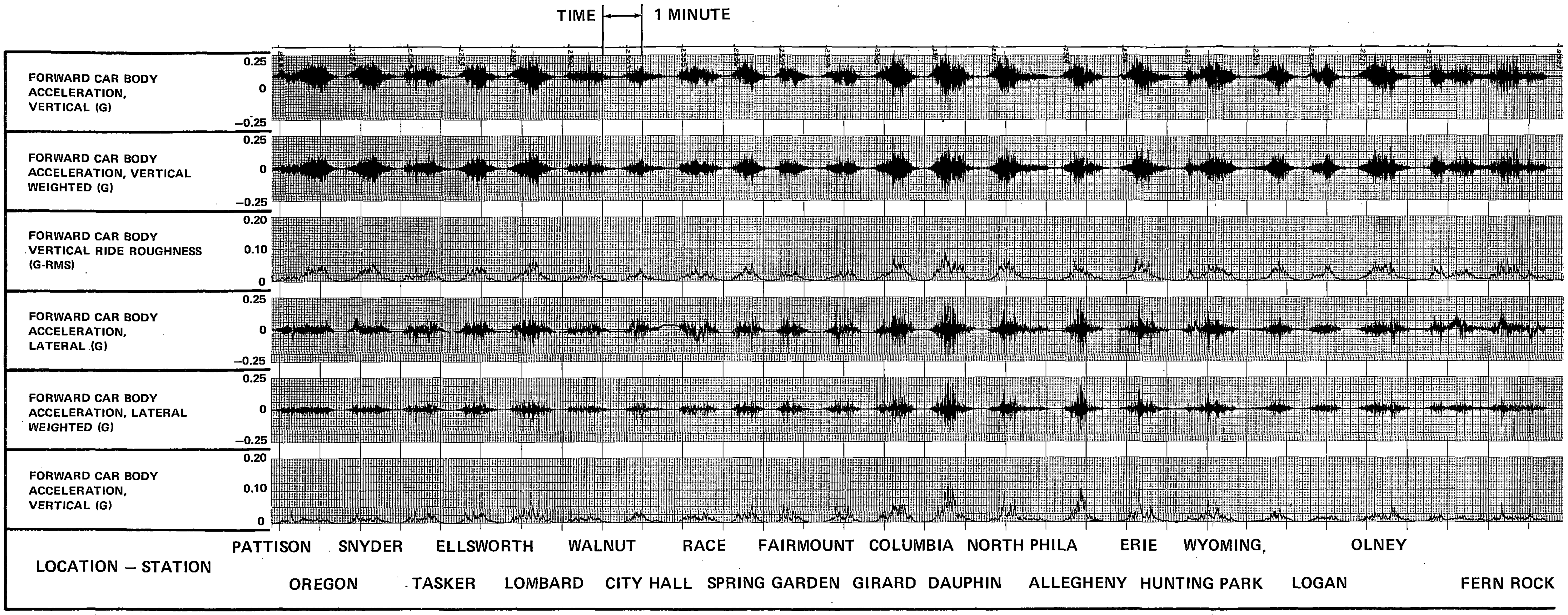


Figure 5–22. Forward Car Acceleration Time History Chart (P–F)

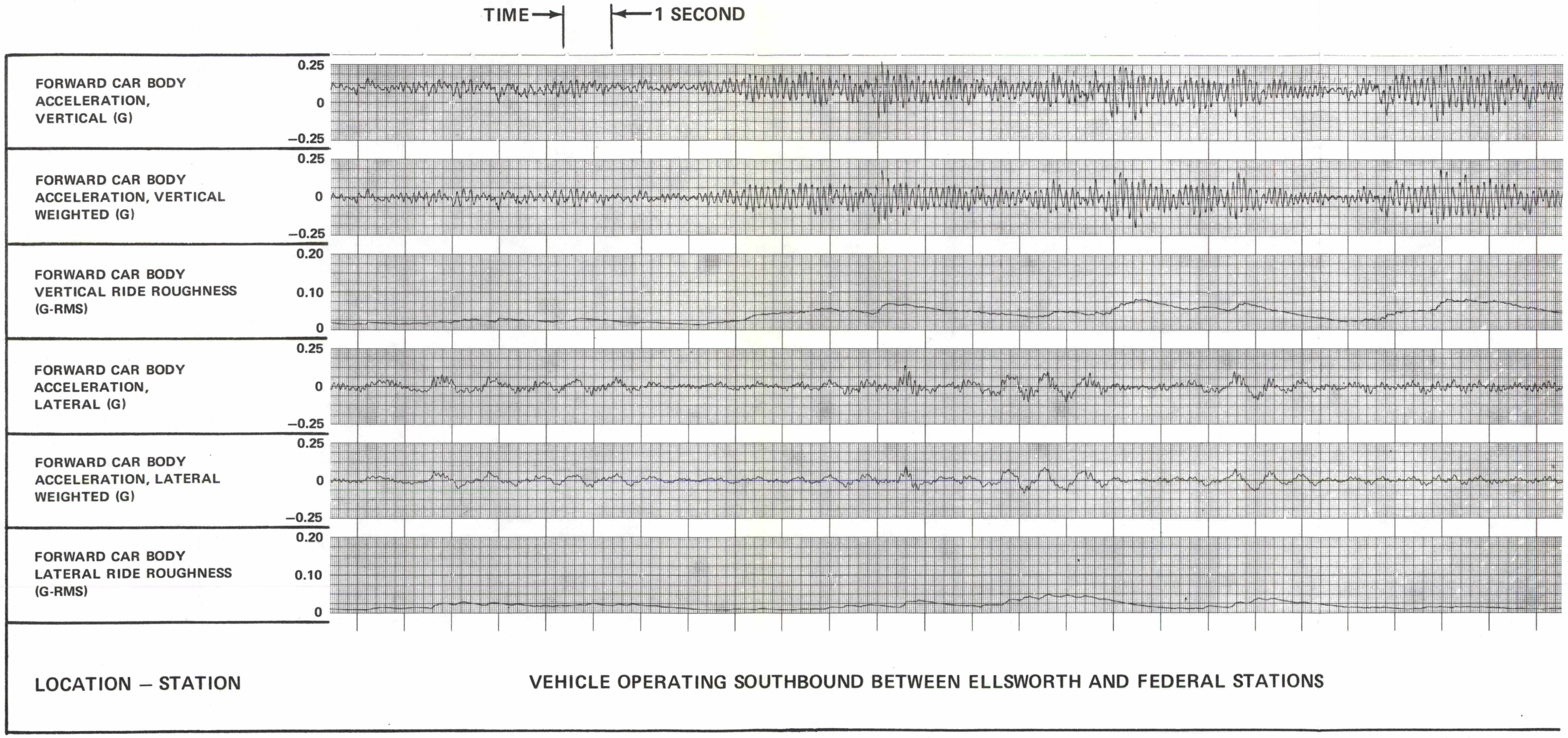


Figure 5–23. Forward Car Acceleration Time History Chart (~)

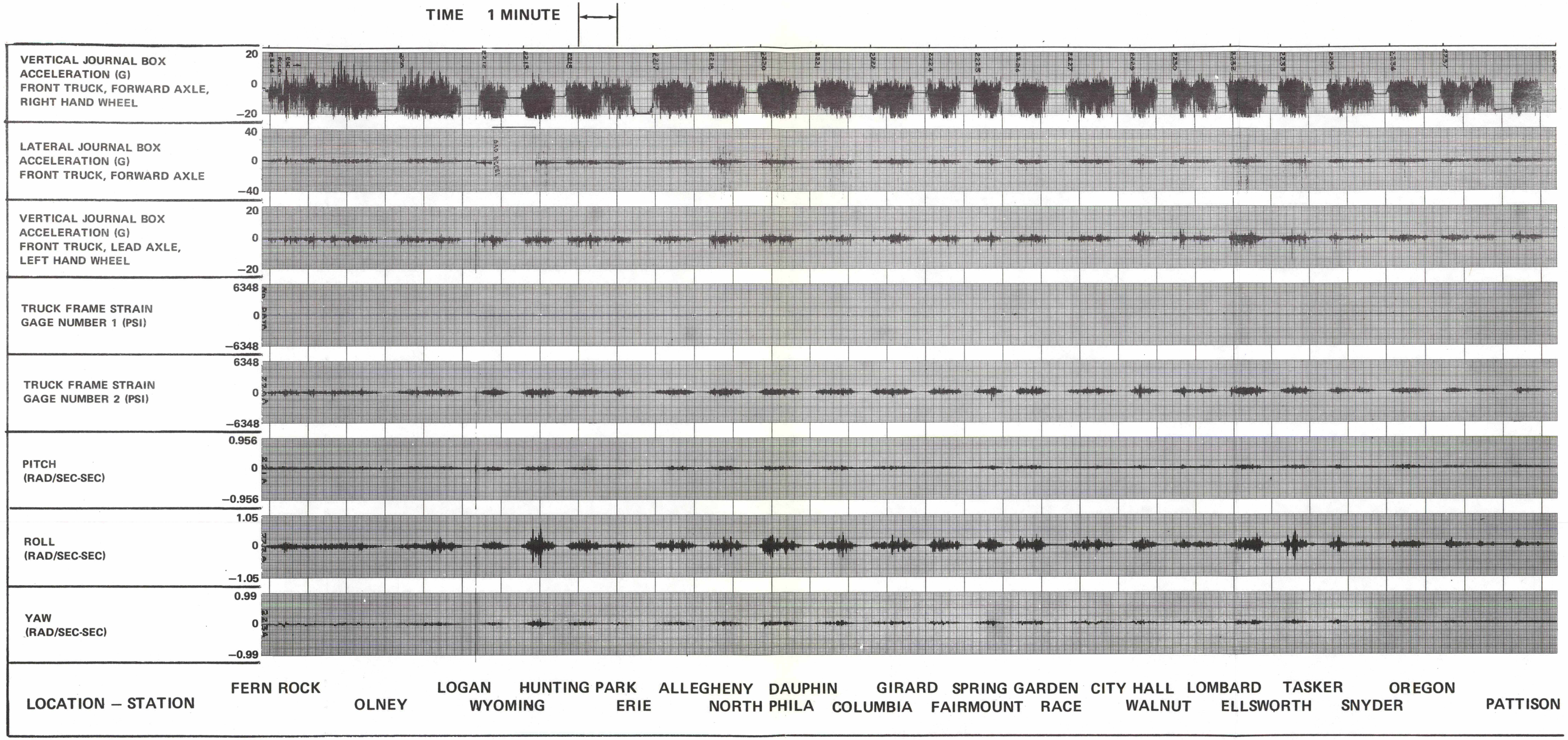


Figure 5–24. Journals, Truck Stress, and Angular Acceleration Time History Chart (F–P)

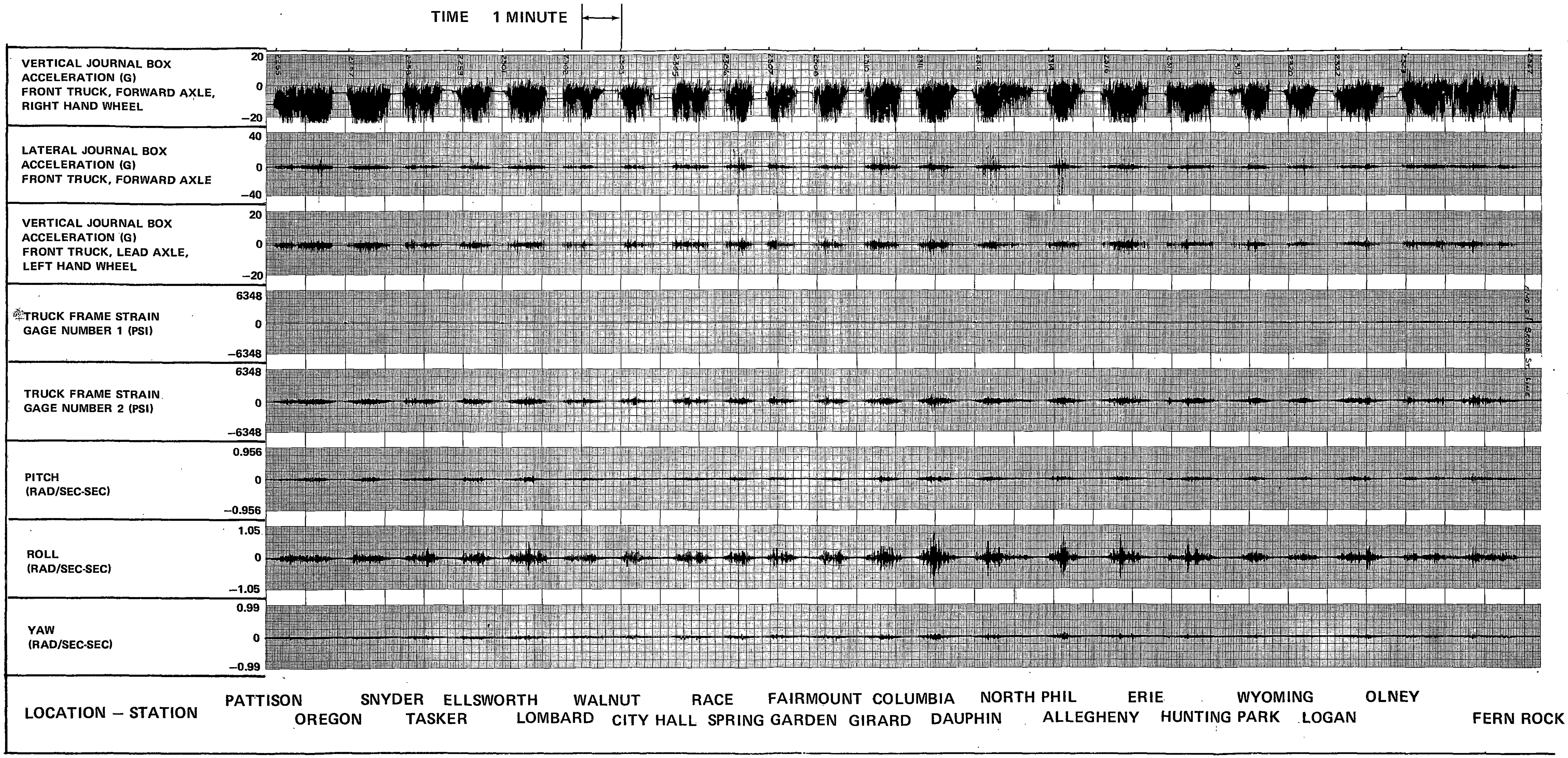


Figure 5–25. Journals, Truck Stress, and Angular Acceleration Time History Chart (P–F)

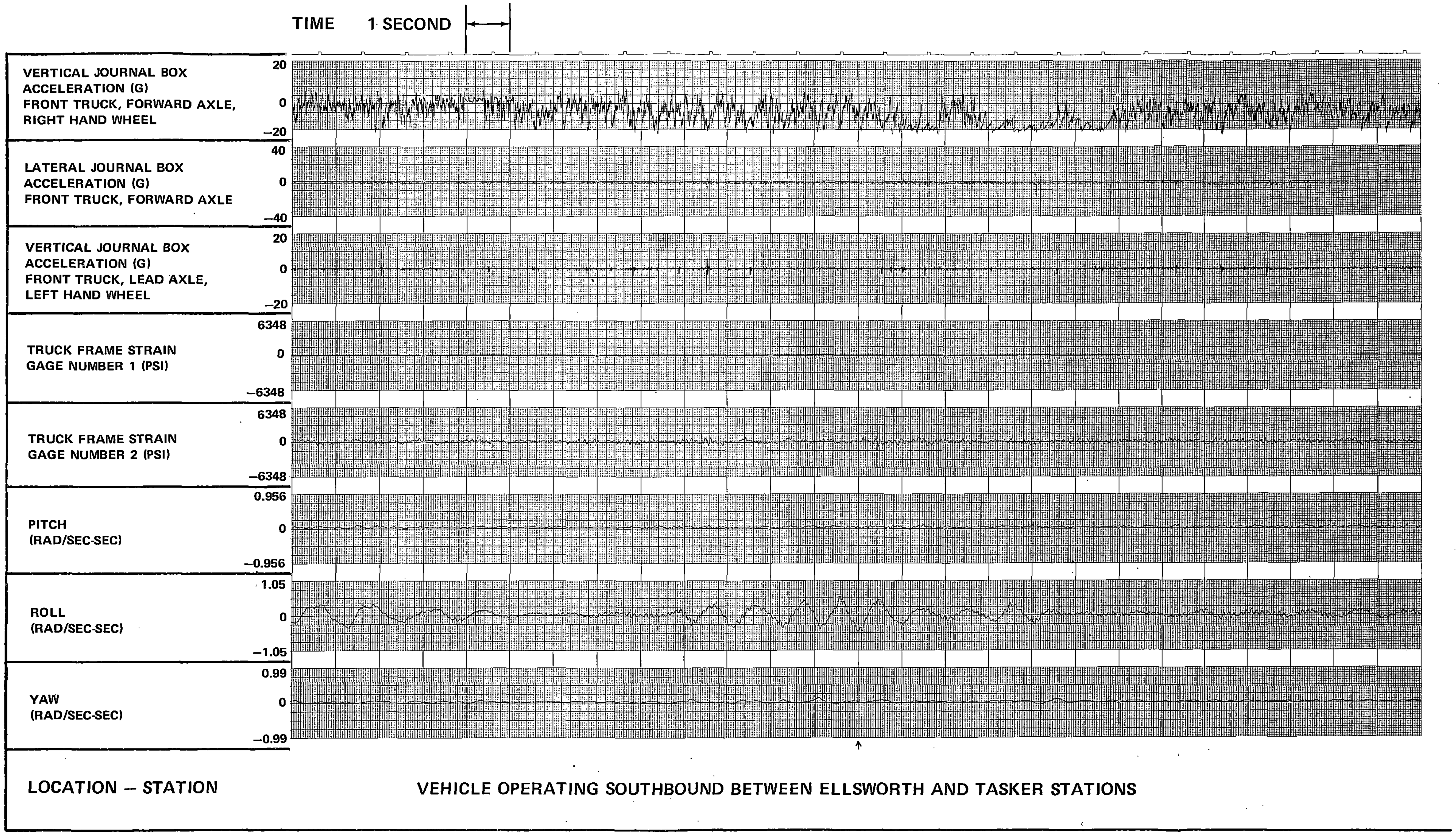


Figure 5–26. Journals, Truck Stress, and Angular Acceleration Time History Chart (~)

APPENDIX E
TESTING AT LINDENWOLD, N.J.

1.0 TEST DESCRIPTION

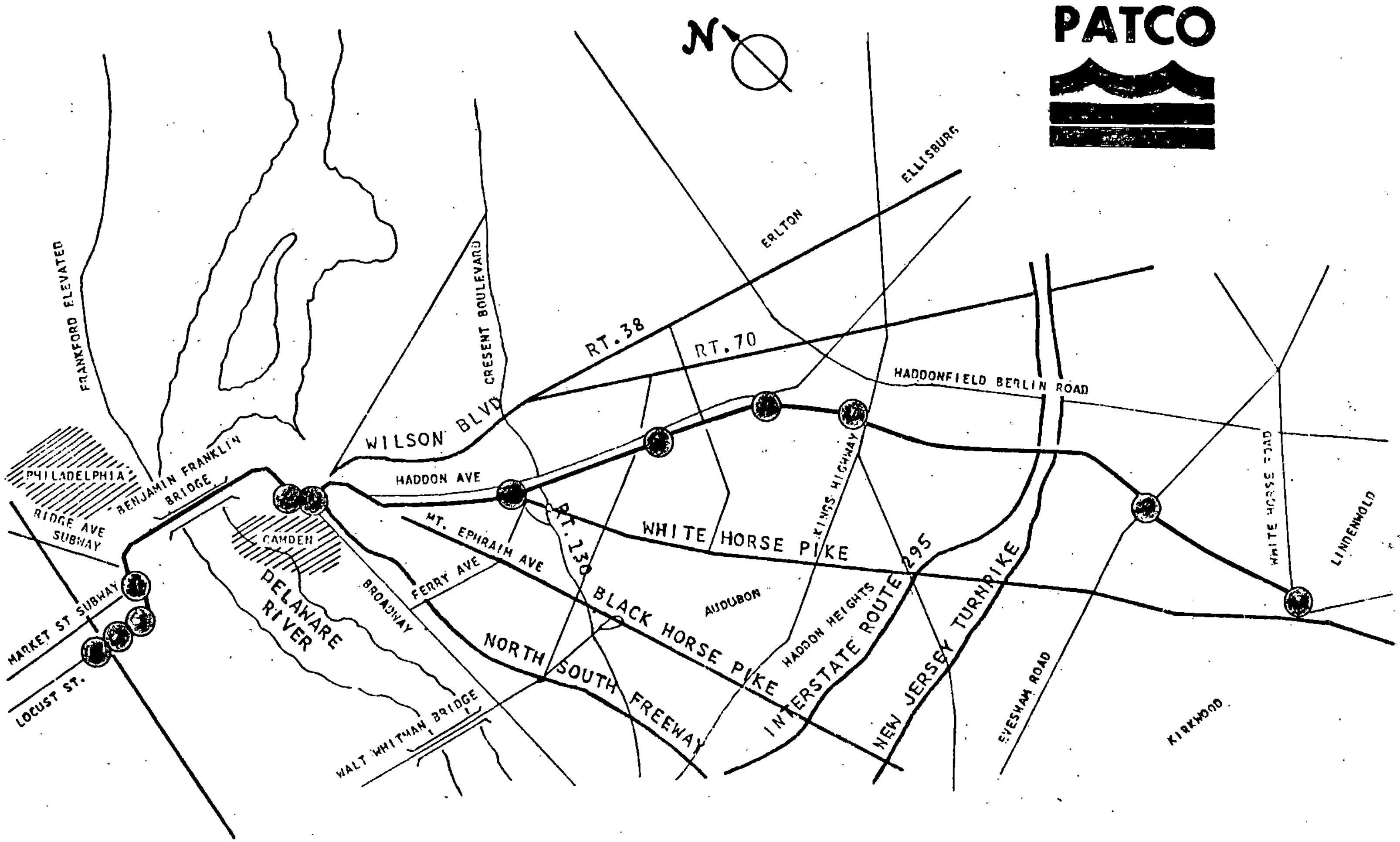
At the conclusion of the SOAC Operational Test and Evaluation Program, ending in Philadelphia on the SEPTA lines, a proposal was instituted to operate the SOAC on the PATCO Lindenwold Line for an extended period. The opportunity arose to perform the SOAC Simulated Revenue Service Tests on the PATCO lines as the details of the proposed extension were being firmed and prior to the removal of the instrumentation system from SOAC following the SEPTA tests.

1.1 Test Site

The PATCO Lindenwold line is 14.1 miles long with 11 stations. It has scheduled service time of 22.5 minutes. The route originates in Lindenwold, New Jersey and runs elevated and at grade level westward to Ferry Avenue. Beyond Ferry Avenue the line is subsurface through Camden, surfaces to cross the Delaware River via the Ben Franklin Bridge and becomes a subway again, terminating at 15th and Locust Streets in Philadelphia. The surface and elevated sections of the route in New Jersey have a 70 mph track speed limit.

1.2 Test Operations

The tests were scheduled for and accomplished during the early morning of May 1, 1975. The test plan was incorporated into a program to verify the SOAC car clearances on the Lindenwold Line and to move the vehicles from SEPTA property to the PATCO Lindenwold Shops. The tests were performed as soon as the clearance runs were completed. As with previous tests, the vehicle operation was entirely under the control of PATCO personnel during the tests. The requirements to provide normal schedule service and to provide a door opening on the car side opposite to a station platform were maintained. As noted below, the test time and operation were sufficient and no significant events occurred which would invalidate the tests.



15th-16th and LOCUST STS. PHILA
12th-13th and LOCUST STS. PHILA.
9th -10th and LOCUST STS. PHILA.
8th- and MARKET STS PHILA.
CITY HALL, CAMDEN
BROADWAY, CAMDEN
FERRY AVENUE, CAMDEN
COLLINGSWOOD
WESTMONT
HADDONFIELD
ASHLAND
LINDENWOLD

Figure 1–1. The PATCO Lindenwold Line

2.0 TEST PROCEDURES

Pretest

1. Mount all required sensors
2. Calibrate Instrumentation System
3. Brief Test Crew on Test Operations

   NOTE:

   One vehicle is instrumented for noise measurements, avoid other than normal conversation.

Test

1. Operate the vehicles in a simulated revenue service, i.e. maintain the given schedule.
2. Provide a nominal 10 second door opening at each scheduled stop.
3. Provide voice commentary on instrumentation recording during progress of test.
4. Maintain a manual log of events during the test run, correlated to the instrumentation system records.
5. Monitor various preselected data channels to ascertain validity of test run.
6. The Test Controller will terminate the test if:

   (a) An extended delay or train shutdown occurs

   (b) One or more required data channels malfunction

   (c) The test vehicle is not operating properly

   Advise Test Controller of any abnormal operations or events that occur during the test run.

3.0 INSTRUMENTATION

The SOAC Instrumentation System was used for this series of tests. This system is described in detail in Volume VI of State-of-the-Art Car (SOAC) Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Test Report, UMTA-MA-06-0025-75-6, January 1975. A synopsis is included below.

3.1 Ride Qualities, Structural and Performance Tests

Electrical signals from the vehicle mounted transducers are conducted by cables to an interface panel which is connected to an instrumentation console containing two magnetic tape recorders, two light beam oscillographs, a time code generator, a temperature recorder and signal conditioners. Any 28 selected test parameters can be recorded on tape and displayed on the oscillographs. In addition, wheel speeds may be recorded directly on the oscillographs; total power is recorded on tape and displayed on a mechanical counter. The time code generator provides signals that are recorded on both tape and the oscillograph. The oscillographs provide quick-look data to evaluate test progress and results during testing (See Figure 3-1).

3.2 Noise Tests

The instrumentation used for noise measurement consisted of a 1" condenser microphone with battery operated cathode follower and a 1/4" single channel tape recorder.

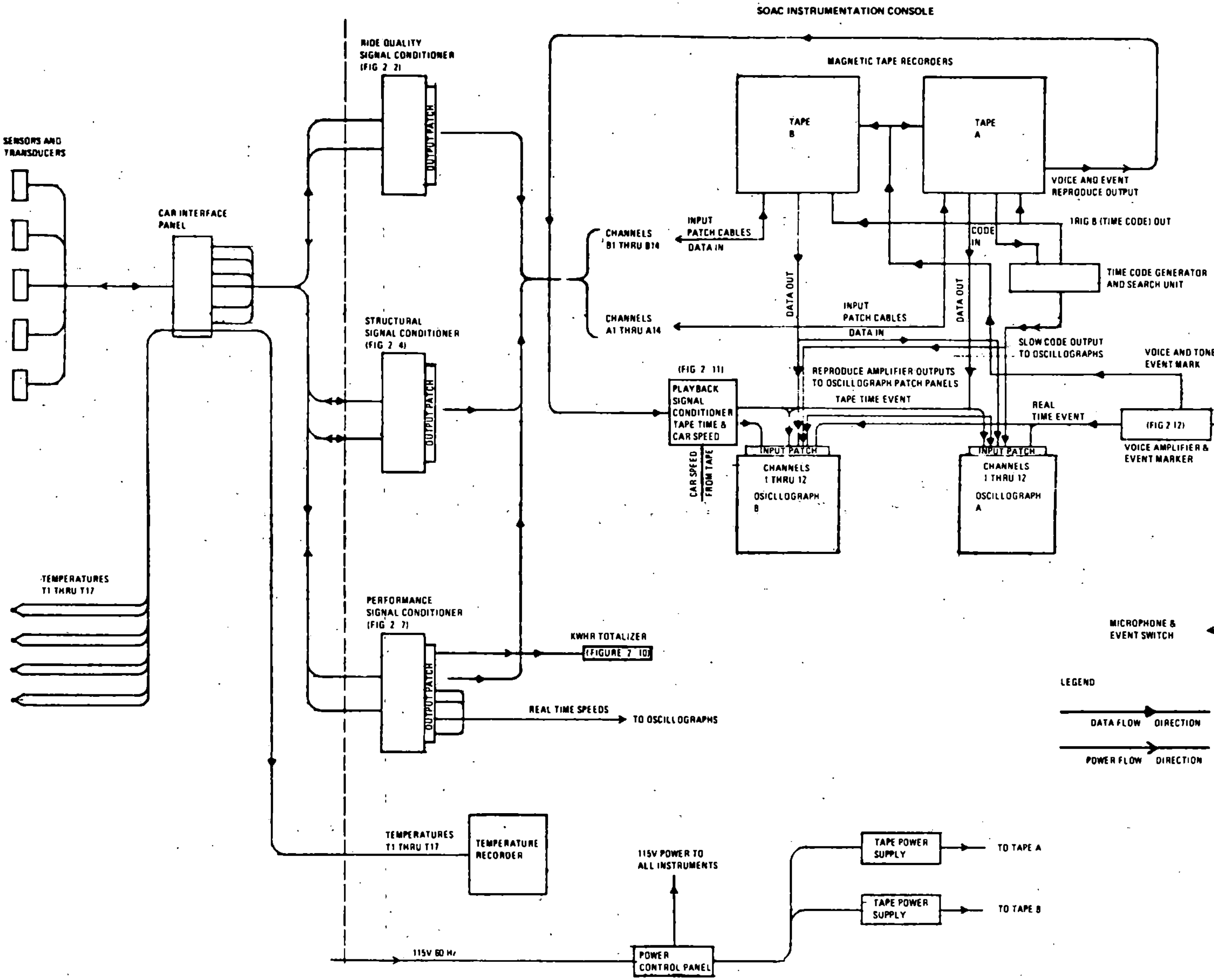


Figure 3–1. SOAC Instrumentation System Block Diagram

4.0 DATA

The parameters recorded during the property tests are described in Tables 4-1 and 4-2. The definition of the parameter measurements is contained in Appendix A, Standard Outputs for SOAC Property Tests.

Data was recorded for the roundtrip routes noted in the Test Description Section. All of the data was recorded on analog tapes and processed to provide three types of outputs.

Time History Charts

Station Summary Tables

Frequency Histograms

4.1 Time History Charts

A slow chart speed strip-out of certain parameters is included in this report. The purpose of these charts is to provide an indication of the maximum levels of parameters during various phases of the run. The complete run is described on the charts including station stops and any particularities that occurred. A series of time histories at a high chart speed is included to illustrate the cyclical nature of the data. These charts are a single time frame for all parameters and are representative of the worst case conditions exhibited for a particular test run.

Intermediate parameters, such as a weighted (filtered) car body acceleration are shown on some charts.

4.2 Station Summary

A summation or summary of specific parameters is made by each station stop. These include test running time and distance for comparison to the property's schedule. Power consumption, motor duty cycle parameters are also summarized by station to indicate the relative sizing of the SOAC propulsion with respect to operations on the property. Station stops and maximum speeds are also shown as another indicator of vehicle operation in a scheduled service environment.

Table 4–1. SOAC Revenue Service Data List A

PARAMETER DESIGNATION NO.	DESCRIPTION	RANGE	STANDARD OUTPUTS RECORDED	PRESENTED	PRELIMINARY ANALYSIS
301	Longitudinal Acceleration	± 0.25 g's	AP/A	Format(3)	Format(4)
302	Line Voltage	0 to 1000 VDC	LVD/A	None	-
303	Line Current	0 to 2000 ADC	LCD/A	None	-
304	No. 1 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
305	No. 1 Truck Armature Current	0 to 1000 ADC	MACD/A	None	RMS-MAC/A
306	No. 1 Truck Field Current	± 50 ADC	MFCD/A	None	RMS-MFC/A
307	No. 2 Truck Armature Voltage	0 to 1200 VDC	MAVD/A	None	-
308	No. 2 Truck Armature Current	0 to 1000 ADC	MACD/A	None	-
309	No. 2 Truck Field Current	± 50 ADC	MFCD/A	None	-
310	"P" Wire Current	0 to 1.00 ADC	CS/A	None	Format(3)
317	Total Power Consumption	1 Pulse/0.1 KWHR	PCC/A	Format(2)	Format(2)
315	Speed	0 to 80 MPH	VS/A	Format(3)	Format(4)
318	Brake Cylinder Pressure	0 to 100 psig	BCP/A	None	-

Table 4–2. SOAC

PARAMETER DESIGNATION NO.	DESCRIPTION
101	Front Truck, Forward Axle, Righthand Wheel Journal Box Vertical Acceleration
102	Front Track, Forward Axle, Righthand Wheel Journal Box Lateral Acceleration
103	Front Truck, Forward Axle Lefthand Wheel Journal Box Vertical Acceleration
115	Mid Car Centerline Vertical Acceleration
116	Mid Car Centerline Lateral Acceleration
120	Forward Car Centerline Vertical Acceleration
121	Forward Car Centerline Lateral Acceleration
219	Truck Frame Upper Strain Gage
220	Truck Frame Lower Strain Gage
221	Pitch Angular Acceleration
222	Roll, Angular Acceleration
223	Yaw, Angular Acceleration
-	Interior Sound Pressure

Revenue Service Data List B

RANGE	STANDARD OUTPUTS RECORDED	PRESENTED	PRELIMINARY ANALYSIS
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	Format(4)
± 20 g's	AJ/A	Format(3)	-
± 0.25 g's	AC/A	Format(3)	RRV/A(1), (3)
± 0.25 g's	AC/A	Format(3)	RRH/A(1), (3)
± 0.25 g's	AC/A	Format(3)	RRV/A(1)
± 0.25 g's	AC/A	Format(3)	RRH/A(1)
± 6348 psi	STP	Format(3)	Fromat(4)
± 6348 psi	STP	Format(3)	-
± 1.5 Rad/sec/sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
± 1.5 Rad/sec-sec.	ACA/A	Format(3)	Format(4)
40 to 120 dB(re 2 x 10^{-5} N/M^2)	SP/A	NL/A(1)	NL/A(2)

4.3 Frequency Histograms

These distributions are an indication of the ratio of time that a parameter is at a particular level with respect to the time to complete a roundtrip scheduled service run. These parameters may be used to describe how the vehicle was driven, the track conditions, and how the vehicle responded to these conditions.

5.0 DATA DISCUSSION

The instrumented car, SOAC No. 2, was operating in the forward direction when running westbound. A positive longitudinal acceleration on the westbound time history charts is vehicle start-up.

As defined in Section 4, there are three forms of data. These forms are discussed below with respect to three categories:

(1) Operation

How the vehicle is operated and maintained schedule.

(2) Environment

Track and truck conditions.

(3) Response

How the vehicle responded to operational environment.

Figures 5-1 through 5-14 present the frequency histograms for the PATCO tests. Figure 5-15 is a sample of Noise Level Time History. The remaining time histories are presented in Figures 5-16 through 5-27. Table 5-1 presents a summary of some of the test parameters taken from the histograms and time histories. Tables 5-2 and 5-3 are the Station Summaries with power consumption.

5.1 Operation

The Stations Summaries show that the SOAC was able to maintain the PATCO schedule reasonably well. The SOAC run was 10 percent longer than the schedule. It should be noted that the station stops were shorter than scheduled.

The maximum acceleration was 2.73 mph/sec. and the maximum braking rate was 3.3 mph/sec. A light rain wet the rails and induced a few wheel spin/slides on the open portion of the route.

The Station Summaries also show that 9 percent of the travel time was spent in a station. This compares to the speed frequency histogram which shows 13 percent in the 0 to 5 mph band. The differential 4 percent is the time ratio of vehicle moving below 5 mph. The rest of the speed histogram shows a substantial proportion of time in the 35-40 mph and in the 65-70 mph bands.

The "P-Wire" histogram provides some information on how the SOAC was driven. Twenty-four percent of the time was spent in requesting the maximum acceleration from the propulsion system. The 9 percent station time is reflected in the p = 0 distribution value. The relatively "flat" distribution of the braking request (p .45) is probably attributable to the drivers attempts to ease the vehicle slides.

The power consumption for the roundtrip route was 204.7 KWHR. For the scheduled distance of 28.2 miles, this is 7.3 KWHR/mile. For the measured distance of 31.3 miles, it is 6.5 KWHR/mile.

The RMS armature current indicates the relative sizing of the SOAC propulsion system with respect to the route. The SOAC has a continuous rating of 175 hp (460 amps) and a one hour rating of 230 hp (600 amps). The roundtrip armature current was 395.7 or 86 percent of the continuous rating. The most severe cycle occurred between Westmont and Collingswood stations (510 amps).

5.2 Environment

The journal accelerations and truck stresses are to be used as indication of track conditions. A summary of these values is shown in Table 5-1. The 50th percentile is a statistical quantity and is read as 50 percent of the trip time the journal box vertical level is between $\pm$ 0.6 gs. The 95th percentile is read similarly. The nominal value is the 50th percentile for the time that the vehicle is moving.

The truck frame strain gage was destroyed prior to the PATCO tests and this data was not available.

5.3 Response

Ride Roughness and Noise Levels are parameters which are related to "human responses". Ride Roughness is a ride comfort rating of vibration levels and Noise Level is a hearing comfort rating of sound pressure levels. These parameters are described in the Standard Outputs section of this report. A summary of the Ride Roughness values is presented in Table 5-1. Interior Noise Level data was taked in the middle of the non-instrumented car at a seated person's ear level. The original engineering tests at TTC indicate that this is the quietest point in the car. The statistical quantities derived from this data are:

L(99)	L(90)	L(50)	L(10)	L(1)	L(EQ)
62	64	66	77	89	74

Journal Box Vertical Acceleration (G)

Journal Box Lateral Acceleration (G)

Truck Frame Stress (PSI)

Forward Car Vertical Acceleration (G)

Mid Car Vertical Acceleration (G)

Forward Car Lateral Acceleration (G)

Mid Car Lateral Acceleration (G)

Longitudinal Ride Roughness (GRMS)

Forward Car Vertical Ride Roughness (GRMS)

Mid Car Vertical Ride Roughness (GRMS)

Forward Car Lateral Ride Roughness (GRMS)

Mid Car Lateral Ride Roughness (GRMS)

Pitch (RAD/Sec-Sec)
Roll (RAD/Sec-Sec)
Yaw (RAD/Sec-Sec)

50TH %	"NOMINAL"	95TH %	MAXIMUM
± .6	± .64	± 1.88	± 4.00
± 1.0	± 1.1	± 1.94	± 4.50
(DATA CHANNEL MALFUNCTION)			
± .018	± .020	± .070	± .250
± .021	± .022	± .072	± .225
± .019	± .021	± .075	± .141
± .017	± .019	± .054	± .084
.005	.005	.018	.058
.019	.021	.044	.140
.019	.021	.041	.090
.012	.013	.029	.083
.006	.006	.015	.035
± .140	± .145	± .190	± .285
± .108	± .116	± .199	± .315
± .103	± .112	± .190	± .141

Table 5–2. Station Summary I

STATION NO.	STATION NAME	SCHEDULE DISTANCE (MILES)	SCHEDULE TIME (MINUTES)	TEST DISTANCE (MILES)	TEST TIME (MINUTES)	POWER CONSUMPTION KWHR	POWER CONSUMPTION KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
1	15th & Locust St.	0	0	0	0	0	0	0	0	0	0
2	12th & Locust St.	.28	1.0	.25	.85	2.83	11.15	466.6	30.2	13.2	38
3	8th & Market St.	.65	2.5	.75	1.95	4.78	6.00	356.6	31.1	12.0	32
4	City Hall-Camden	2.35	5.0	2.66	5.37	15.82	6.01	316.3	29.6	12.0	38
5	Broadway	.15	1.0	.30	1.34	2.65	8.75	282.9	27.8	10.0	18
6	Ferry Avenue	2.16	3.0	2.35	2.82	13.86	5.90	373.9	21.8	10.0	72
7	Collingswood	1.61	2.0	1.76	2.13	11.93	6.77	451.9	23.5	12.0	72
8	Westmont	1.05	1.0	1.15	1.65	10.08	8.78	467.3	24.9	12.0	72
9	Haddonfield	.87	1.0	.96	1.51	8.70	9.10	510.2	27.9	12.0	70
10	Ashland	3.19	3.0	3.52	4.12	22.75	6.46	437.7	22.3	10.8	72
11	Lindenwold	1.79	3.0	1.95	2.60	12.45	6.38	393.9	22.4	12.0	72
					TOTALS	105.85	6.70	397.8	26.0		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	14.10	15.65
Time	22.5	24.34
Block Speed	37.6	38.6
Station Dwell	30.	11.6
Station Spacing	1.28	1.42

Table 5–3. Station Summary II

STATION	SCHEDULE		TEST		POWER CONSUMPTION					
NAME	DISTANCE (MILES)	TIME (MINUTES)	DISTANCE (MILES)	TIME (MINUTES)	KWHR	KWHR/MILE	I-ARM (AMP-RMS)	I-FLD (AMP-RMS)	STOP TIME SECONDS	MAX. SPEED (MPH)
Lindenwold	0	0	0	0	0	0	0	0	0	0
Ashland	1.79	3.0	1.97	2.40	12.39	6.29	441.1	23.3	14.4	70
Haddonfield	3.19	3.0	3.49	3.75	19.44	5.58	416.8	20.6	18.0	70
Westmont	.87	1.0	0.99	1.55	9.58	9.66	498.8	26.2	16.8	68
Collingswood	1.05	1.0	1.17	1.75	11.08	9.44	510.7	28.5	10.8	70
Ferry Avenue	1.61	2.0	1.69	1.87	8.92	5.27	406.9	21.1	10.8	70
Broadway	2.16	3.0	2.42	3.15	12.74	5.26	365.0	20.9	12.0	70
City Hall-Camden	.25	1.0	.25	1.24	1.68	6.72	248.6	27.7	14.4	20
8th & Market St.	2.35	5.0	2.61	4.95	15.17	5.80	311.4	27.9	12.0	40
12th & Locust St.	.65	2.5	.74	1.92	5.23	7.08	349.5	30.3	13.2	37
15th & Locust St.	.28	1.0	.31	.99	2.62	8.55	413.3	28.5	13.2	29
			TOTALS		98.85	6.32	393.5	25.1		

TEST RUN SUMMARY

	SCHEDULE	TEST
Distance	14.10	15.64
Time	22.5	23.57
Block Speed	37.6	39.8
Station Dwell	30.	13.6
Station Spacing	1.28	1.42

6.54
Avg. Both ways

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
"P-Wire" Current Distribution

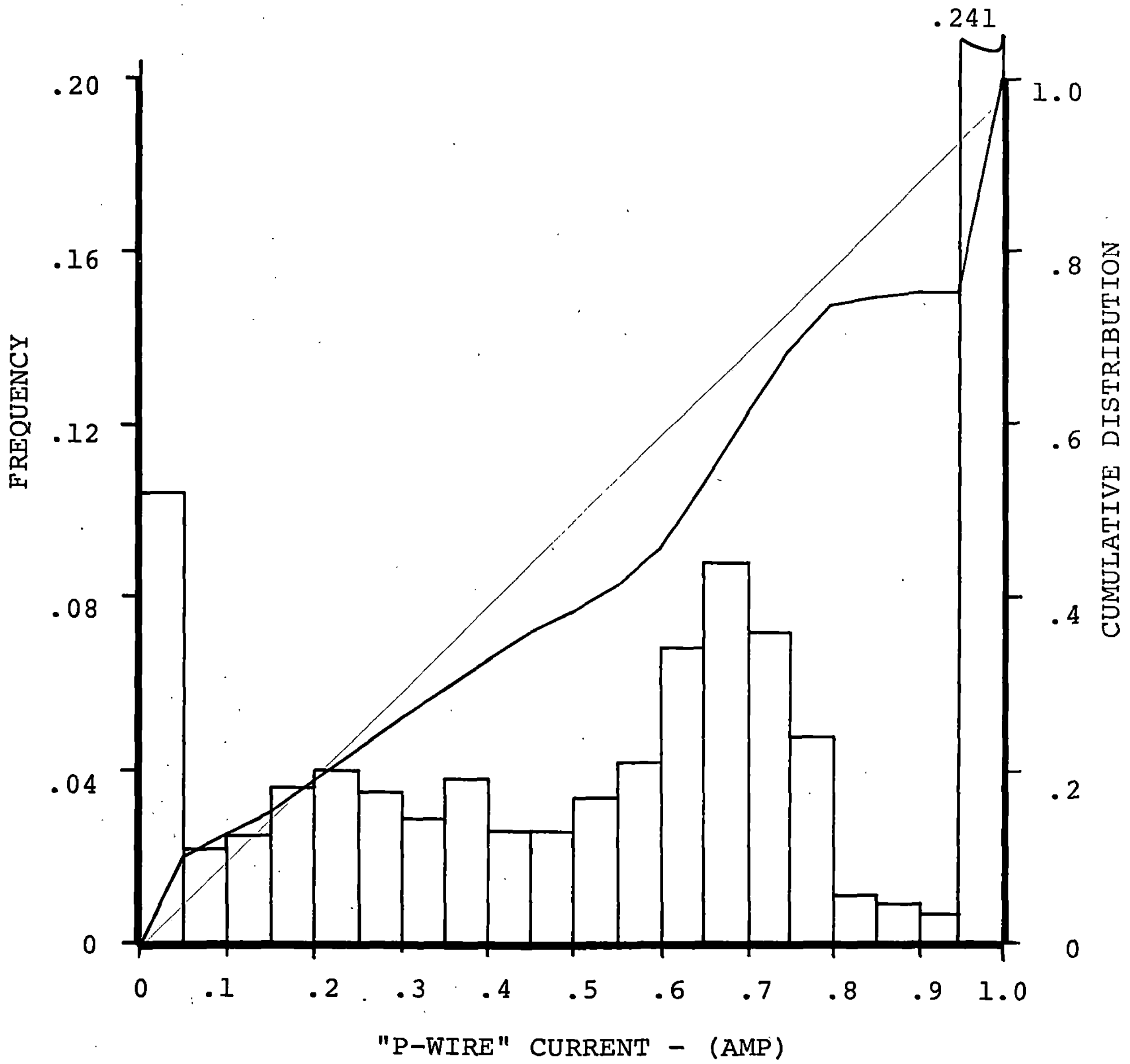


Figure 5–1. 'P-Wire' Current Distribution

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
Vehicle Speed Distribution

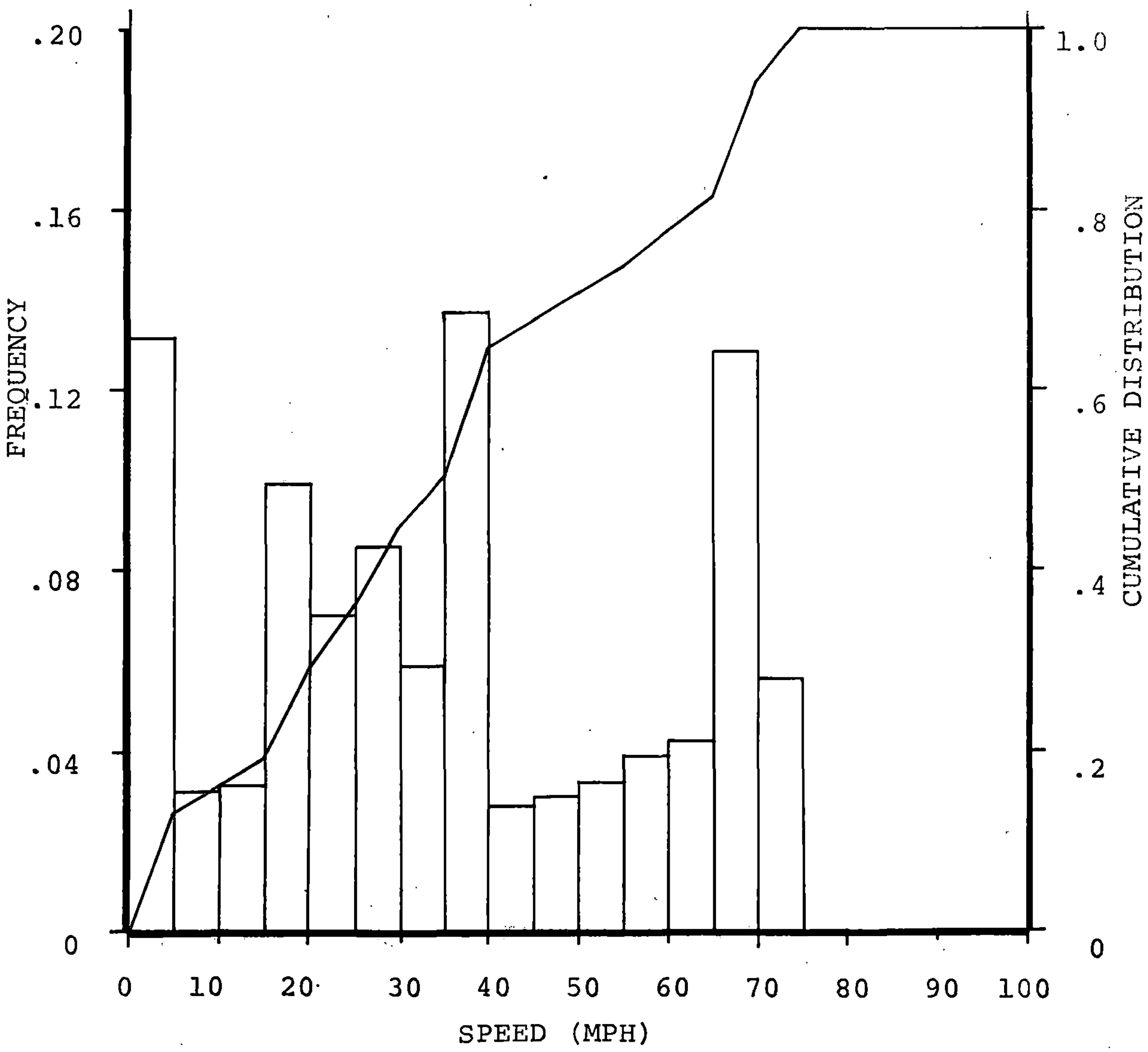


Figure 5–2. Vehicle Speed Distribution

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
Vehicle Acceleration Distribution

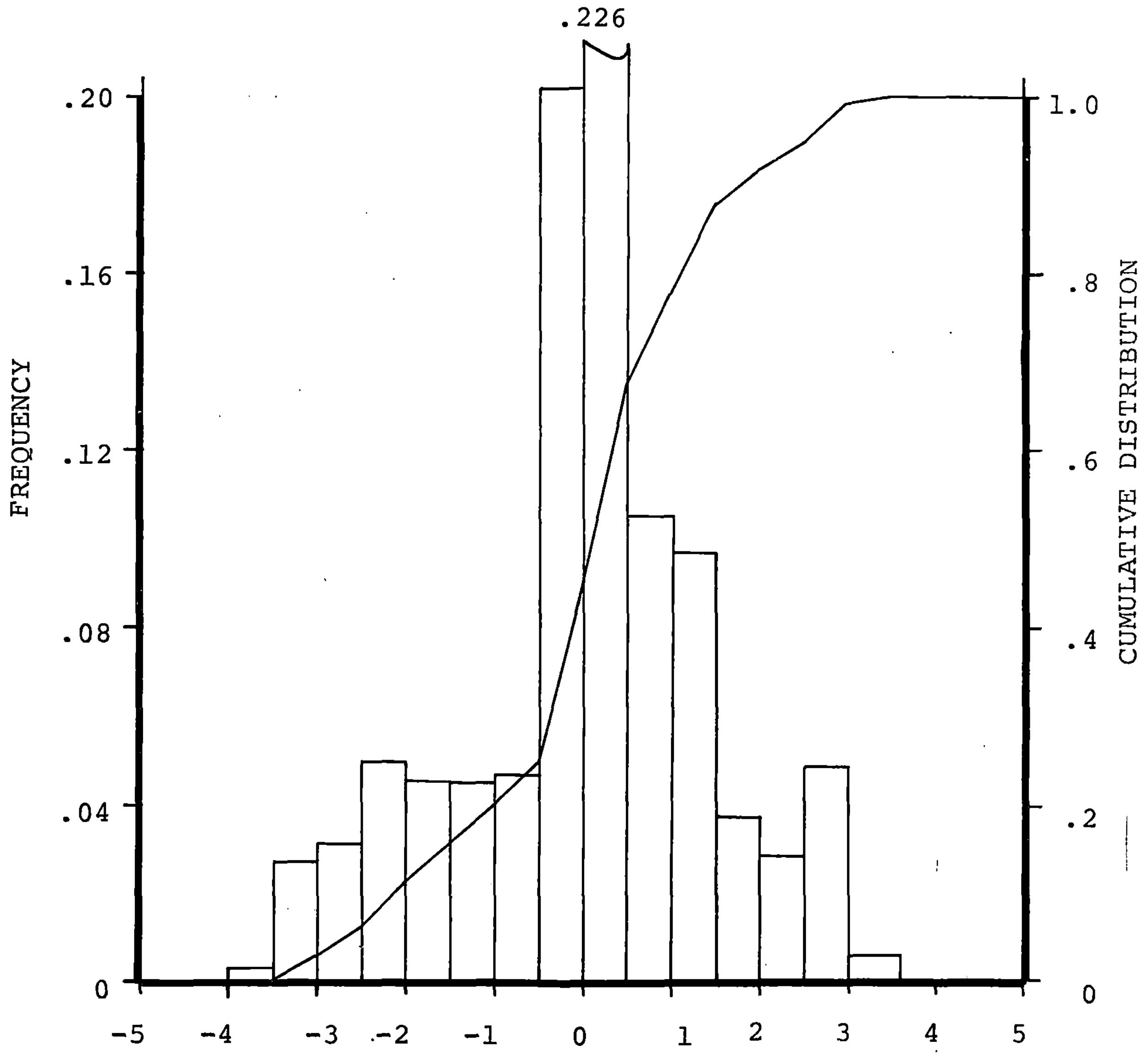


Figure 5–3. Vehicle Acceleration Distribution

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
Journal Box Vertical Acceleration Distribution

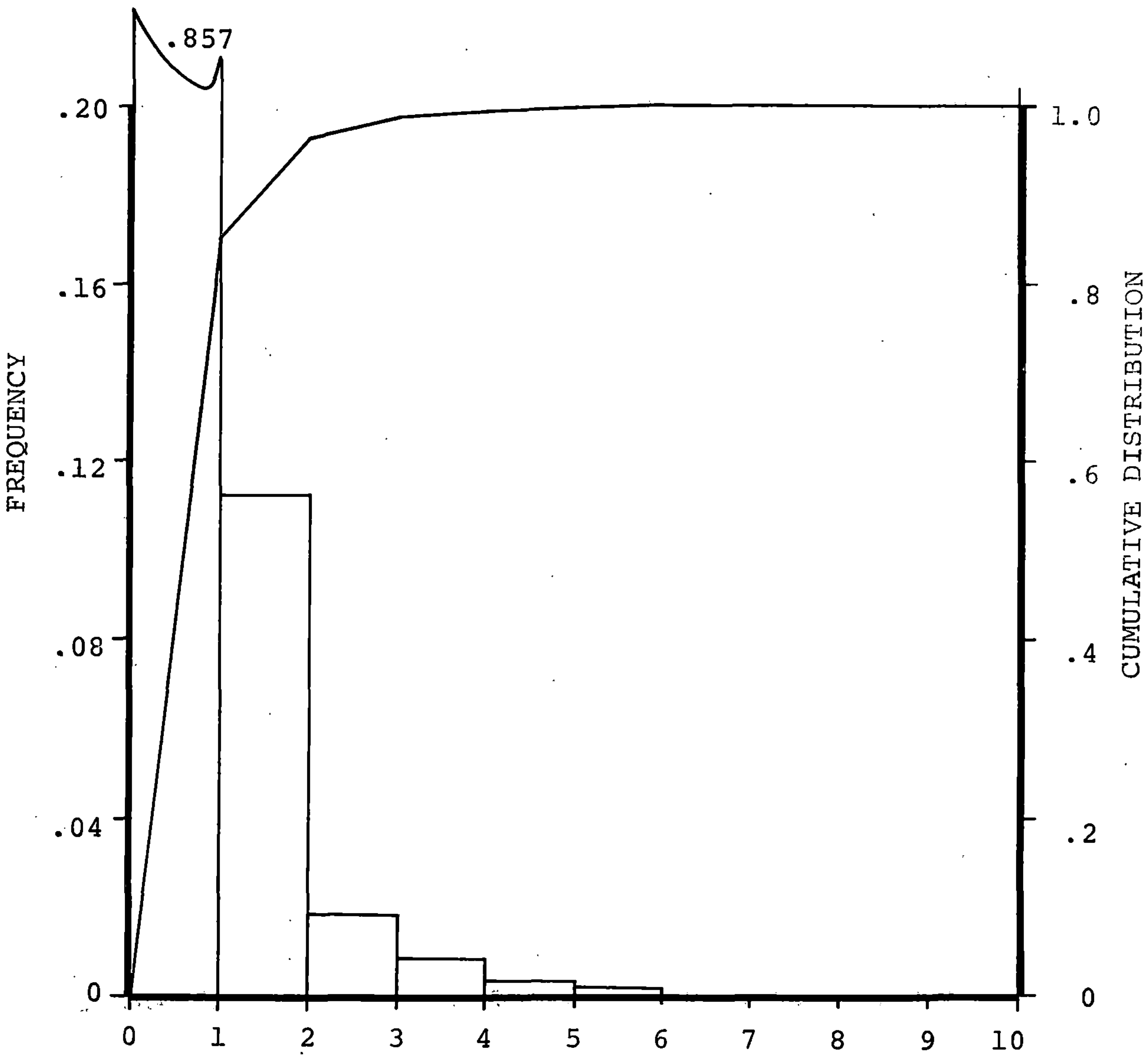


Figure 5–4. Journal Box Vertical Acceleration Distribution

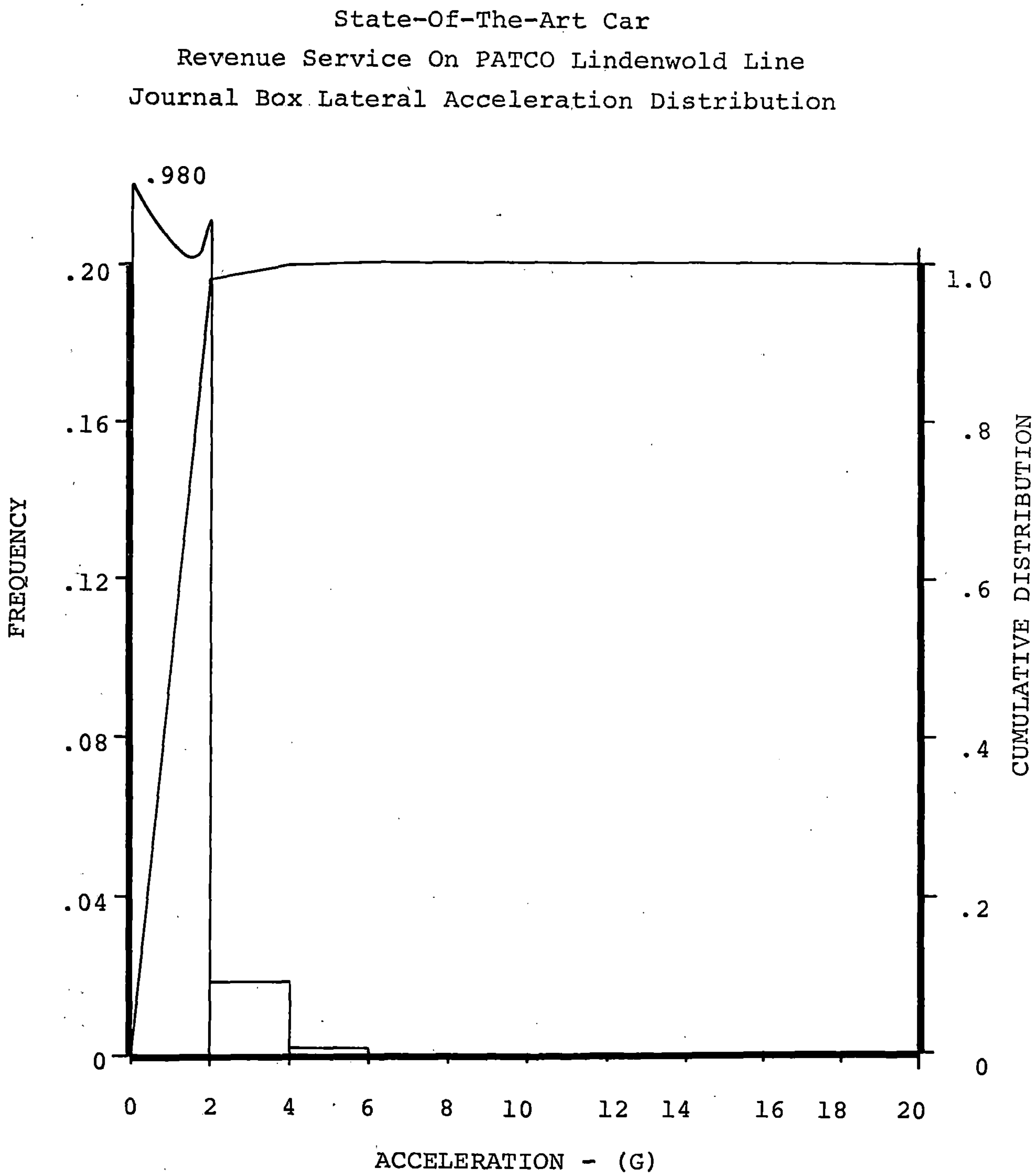


Figure 5—5. Journal Box Lateral Acceleration Distribution

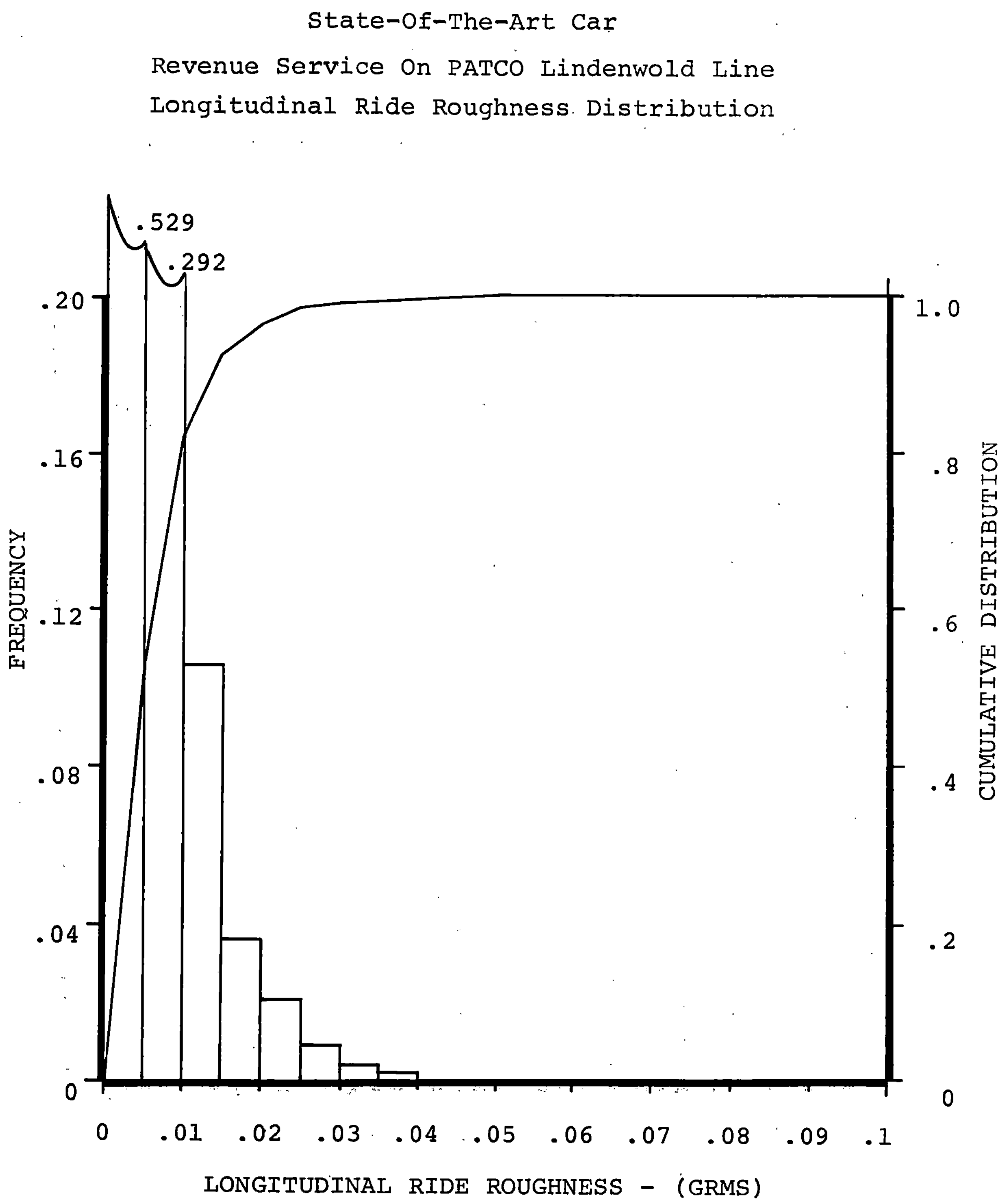


Figure 5–6. Longitudinal Ride Roughness Distribution

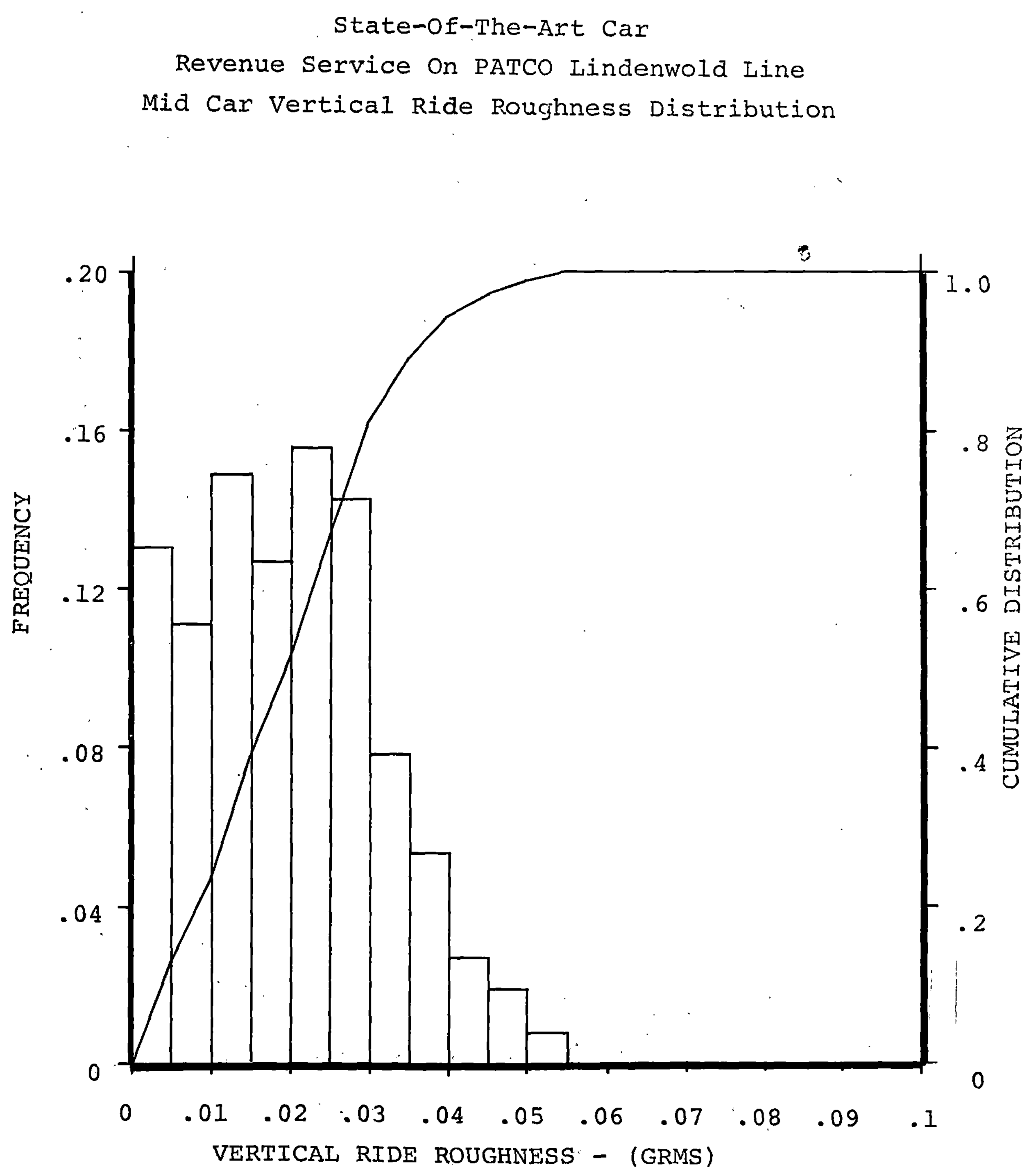


Figure 5–7. Mid-Car Vertical Ride Roughness Distribution

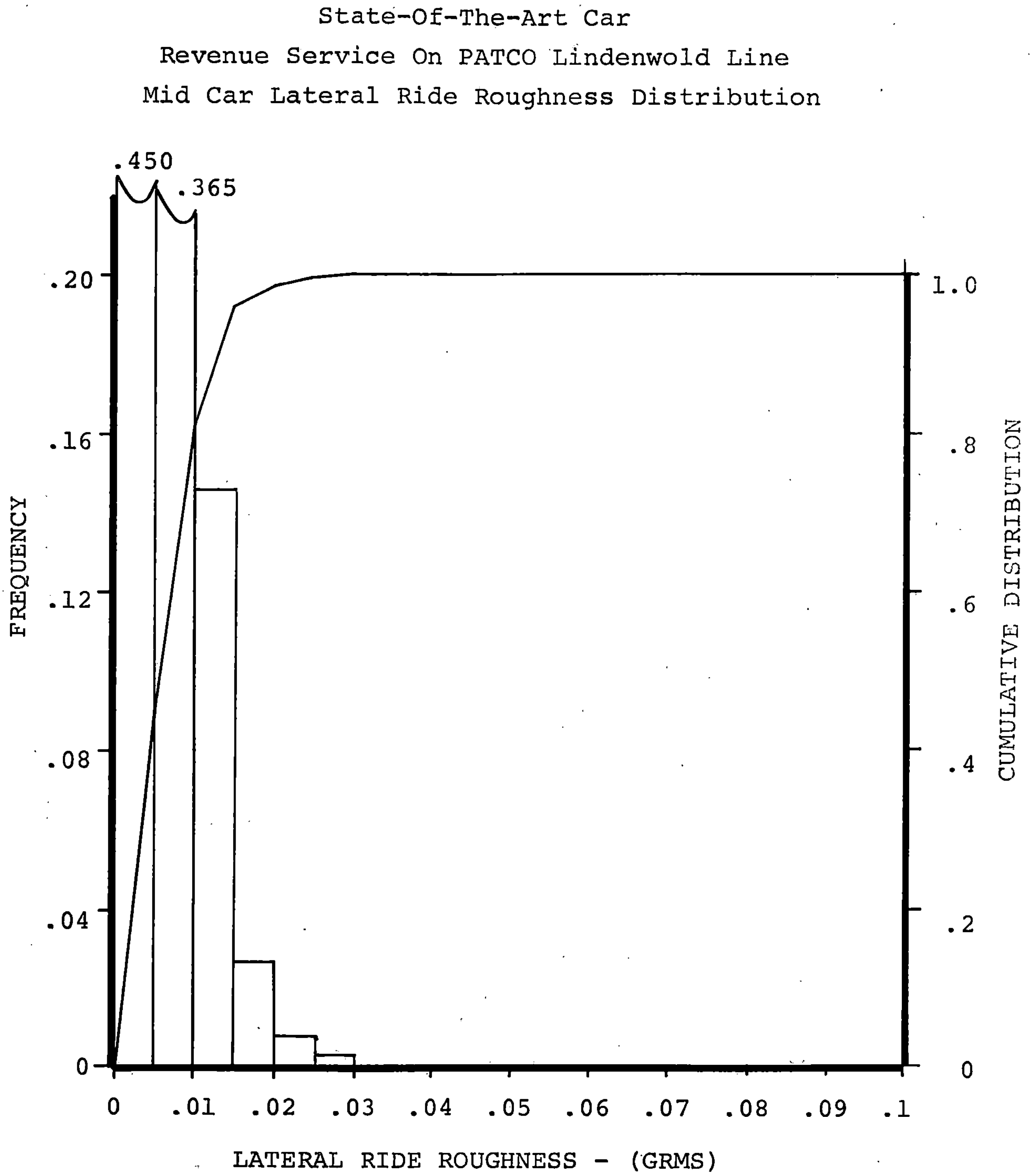


Figure 5–8. Mid-Car Lateral Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
Forward Car Vertical Ride Roughness Distribution

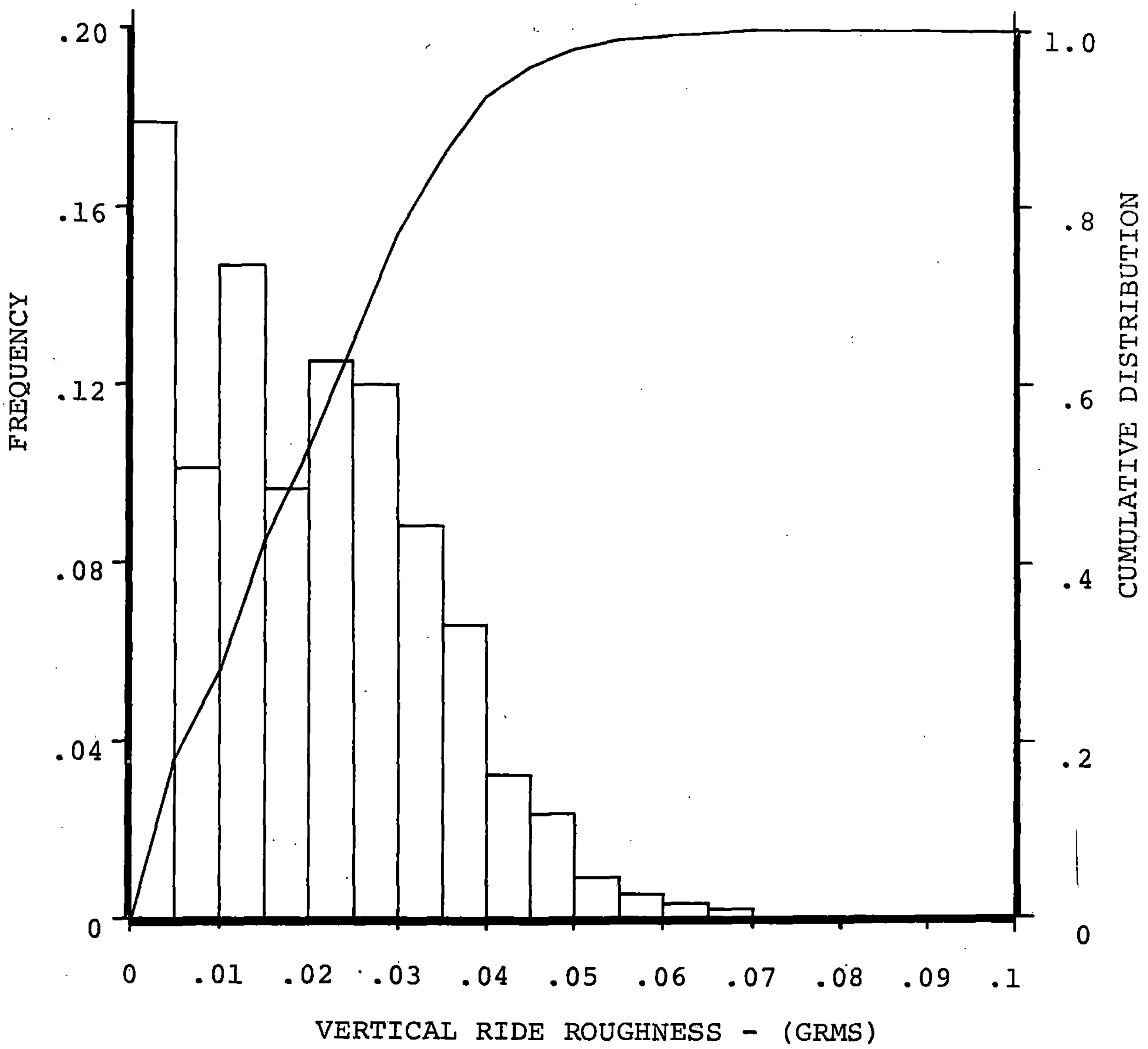


Figure 5–9. Forward Car Vertical Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
Forward Car Lateral Ride Roughness Distribution

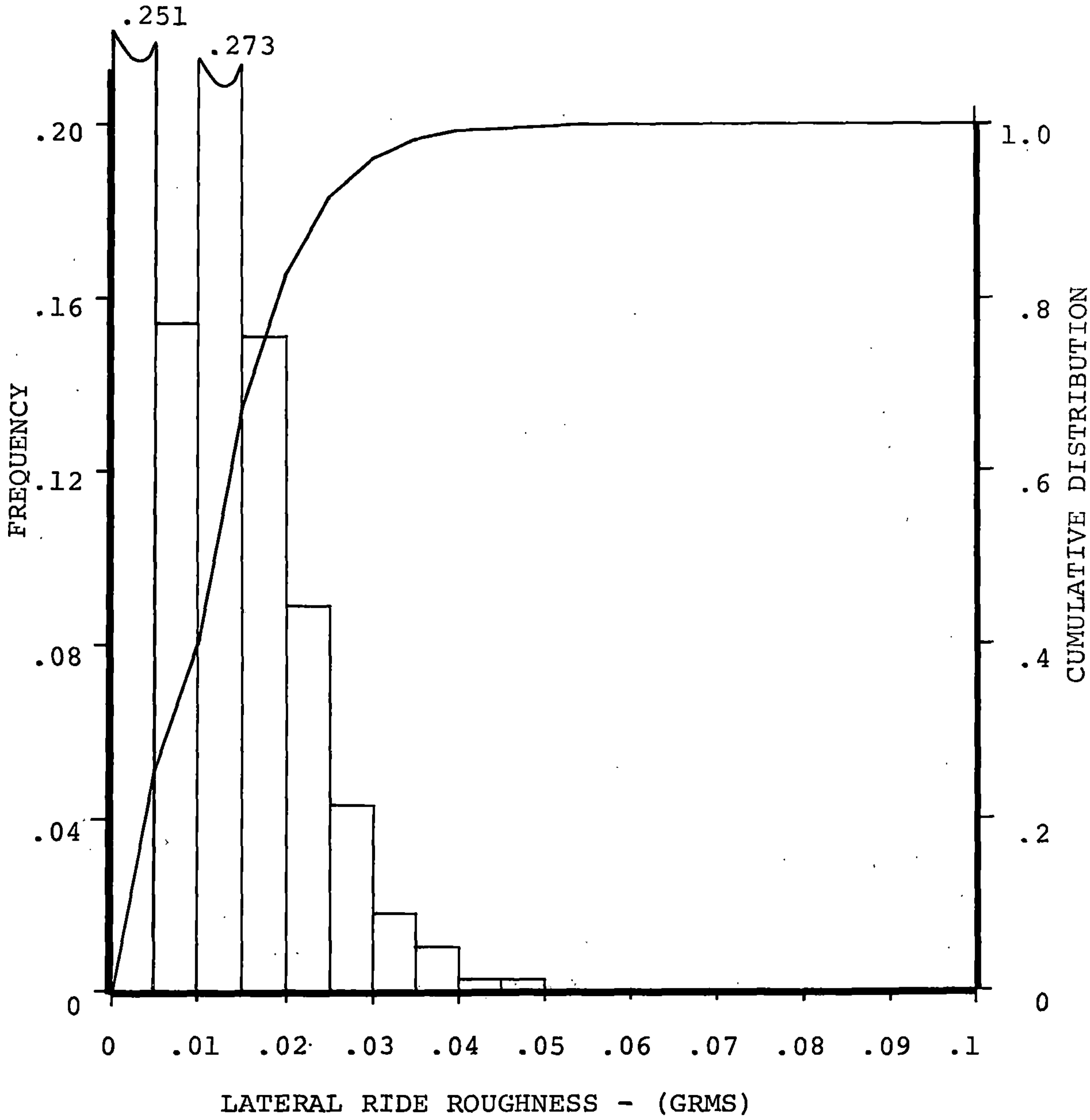


Figure 5–10. Forward Car Lateral Ride Roughness Distribution

State-Of-The-Art Car
Revenue Service On PATCO Lindenwold Line
Vehicle Pitch Distribution

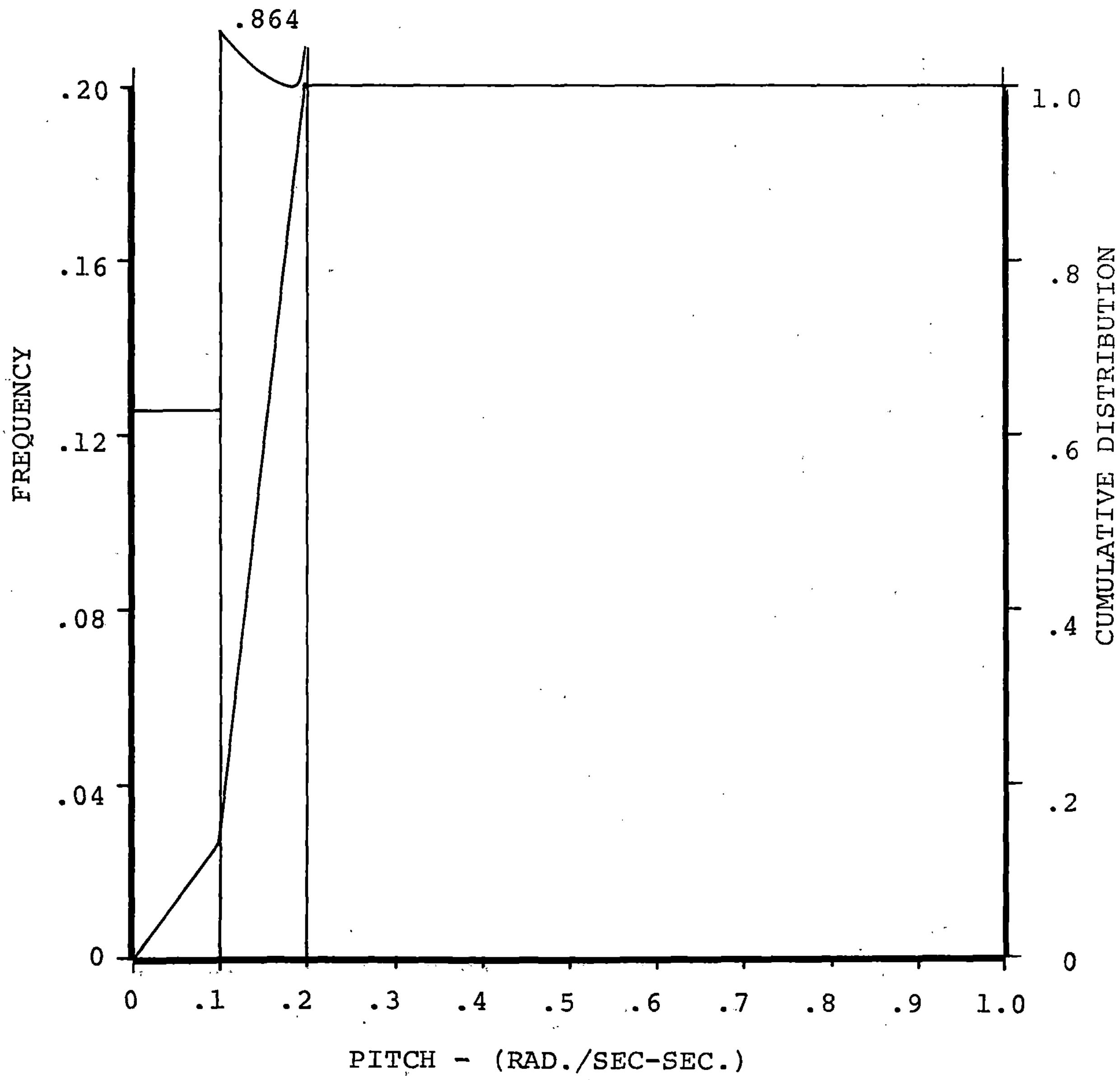


Figure 5–11. Vehicle Pitch Distribution

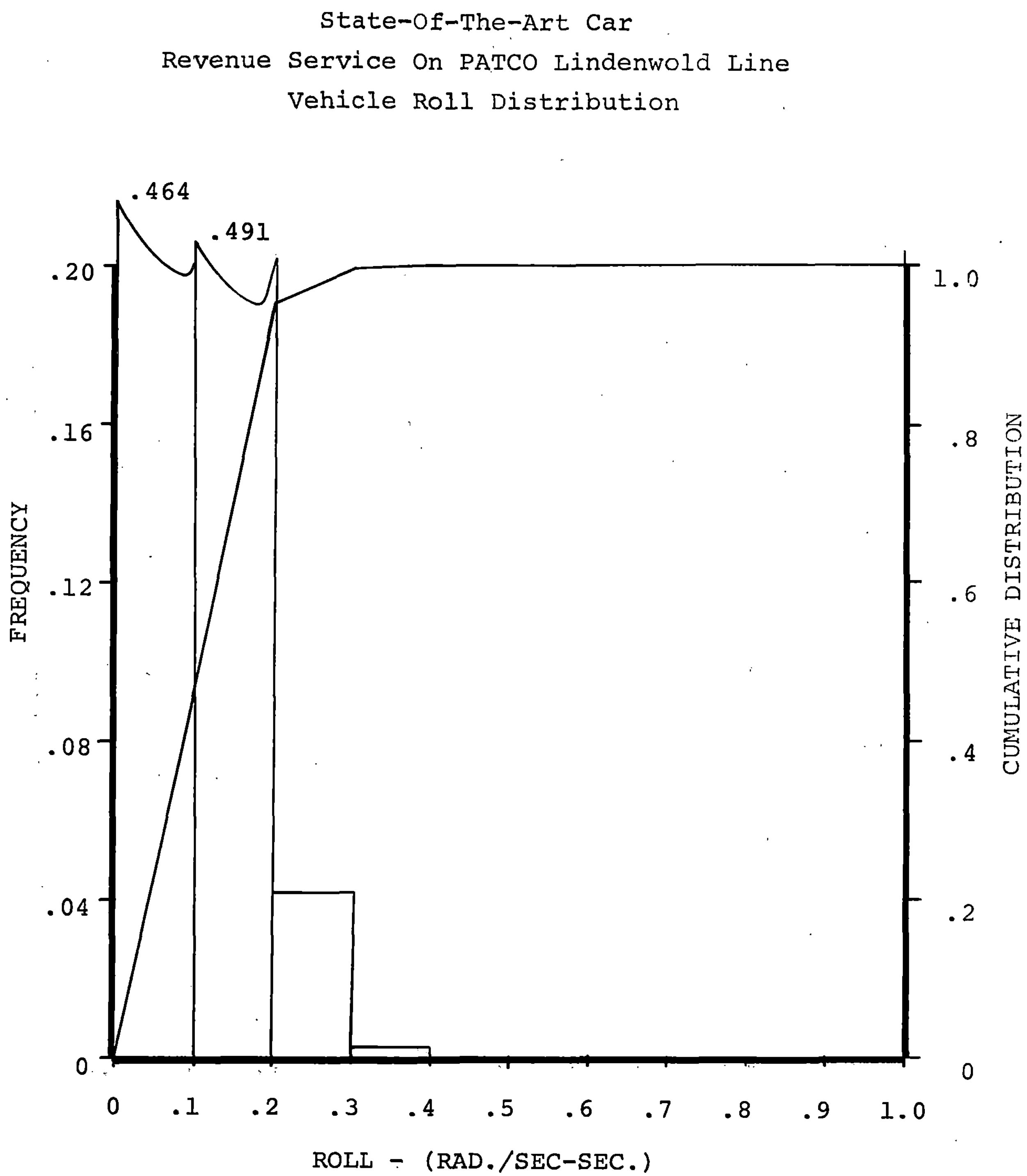


Figure 5–12. Vehicle Roll Distribution

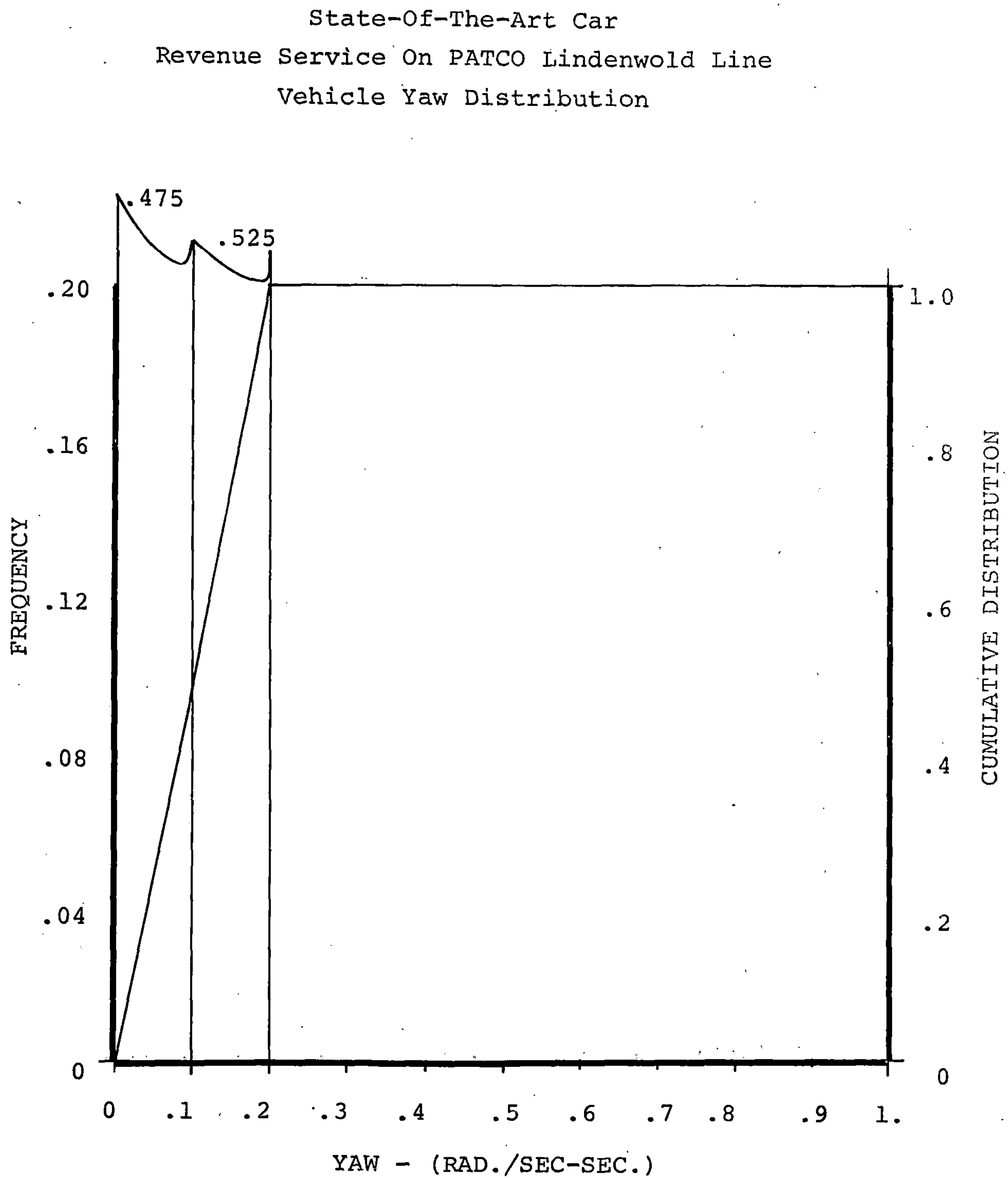


Figure 5—13. Vehicle Roll Distribution

State-Of-The-Art Car
Revenue Service On The PATCO Line
Interior Noise Level Distribution

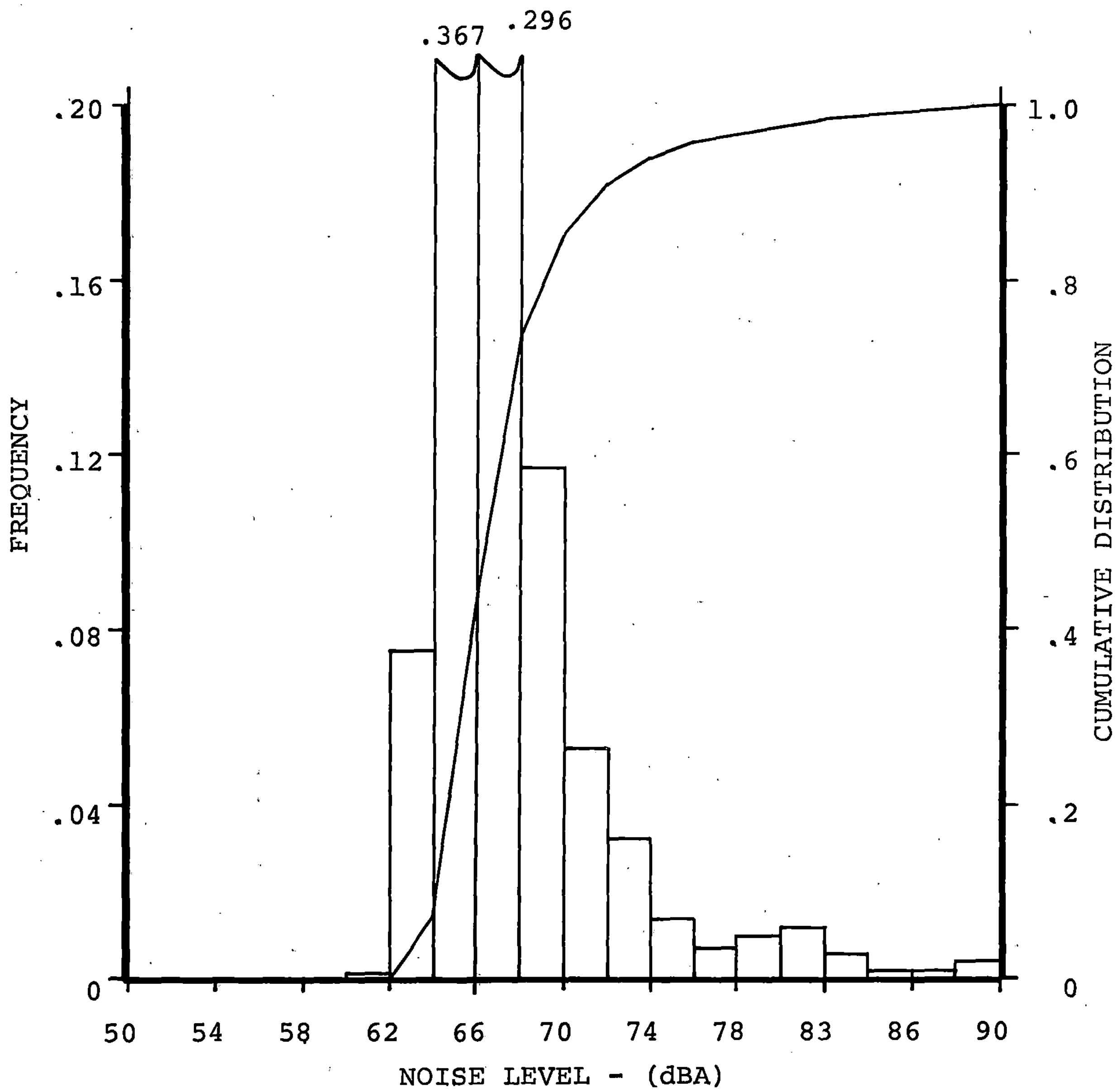


Figure 5–14. Interior Noise Level Distribution

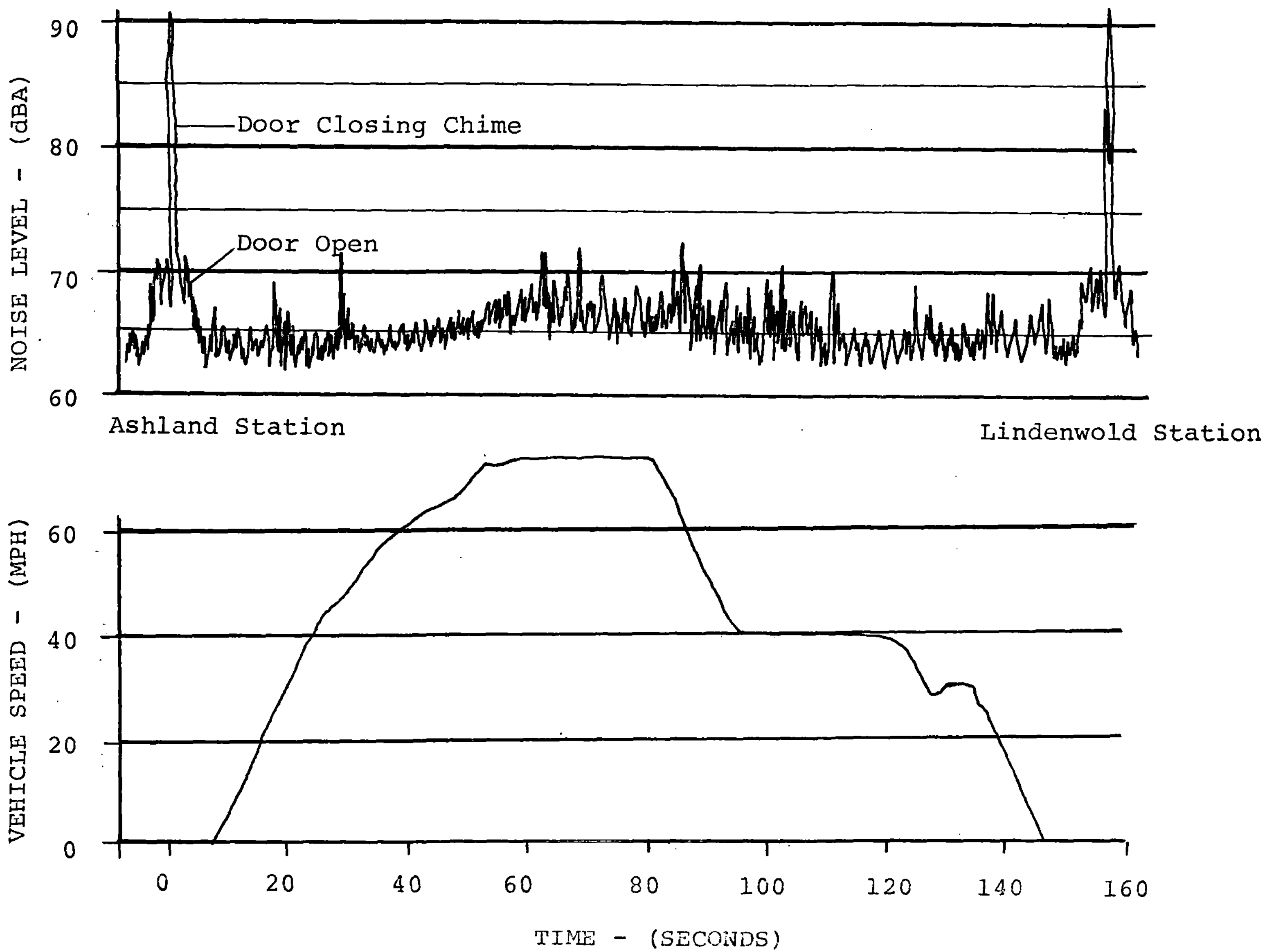


Figure 5—15. SOAC Interior Noise Level Sample

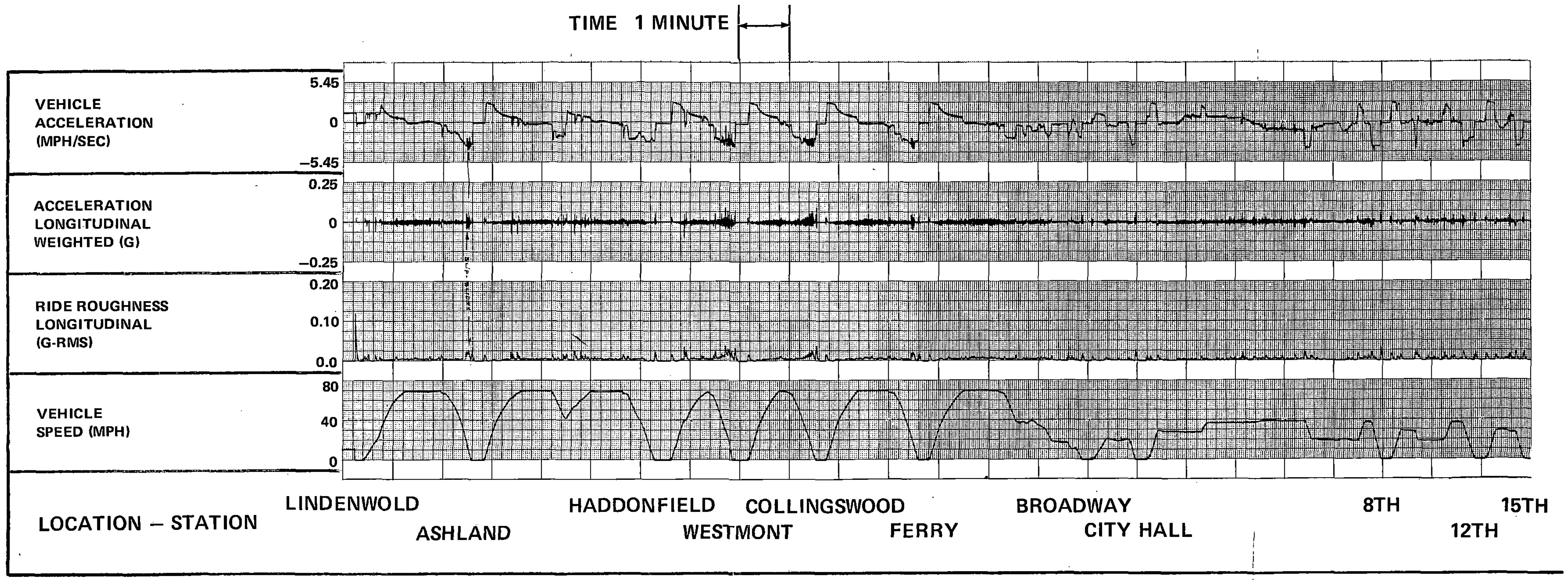


Figure 5–16. Vehicle Acceleration and Speed Time History Chart (L-15)

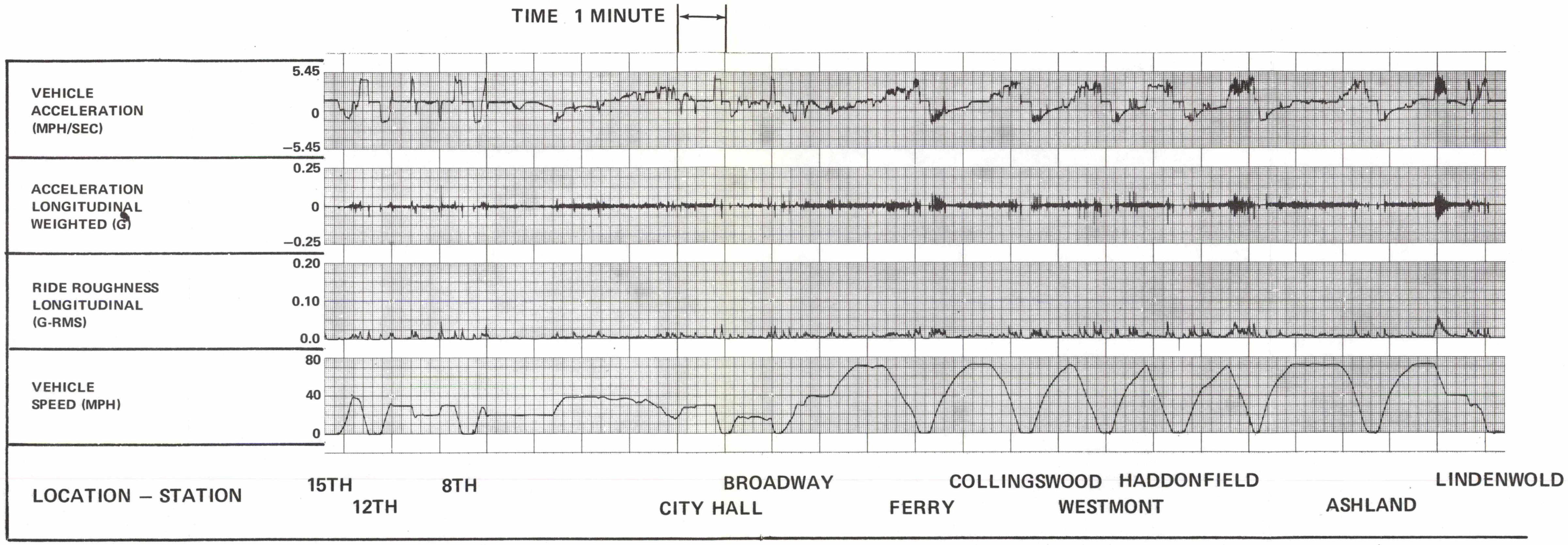


Figure 5–17. Vehicle Acceleration and Speed Time History Chart (15-L)

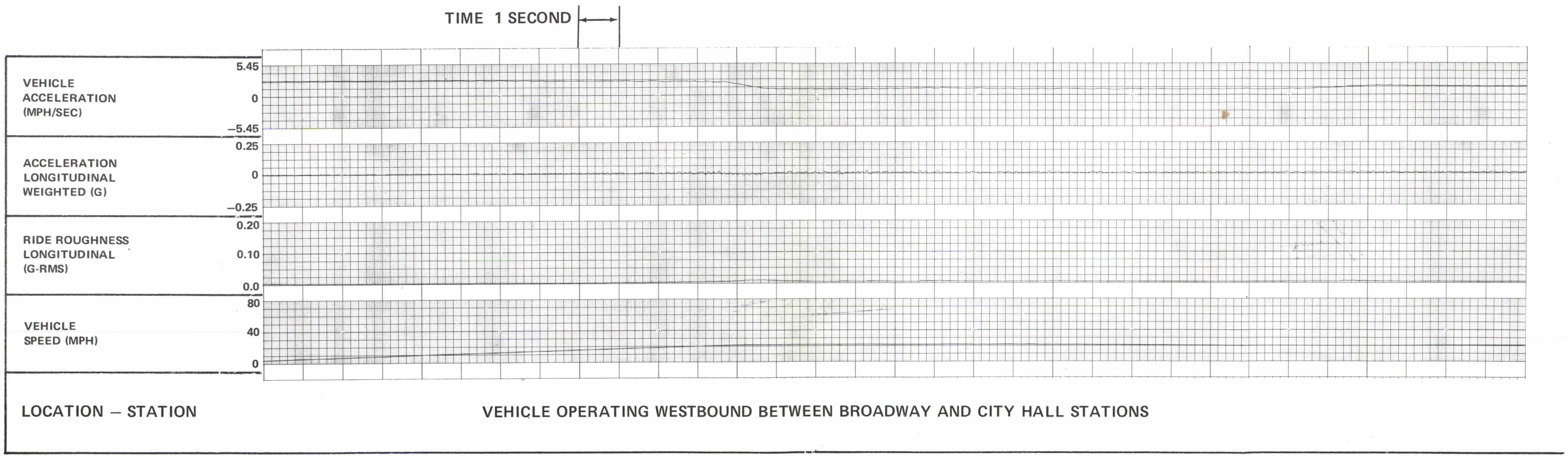


Figure 5–18. Vehicle Acceleration and Speed Time History Chart (~)

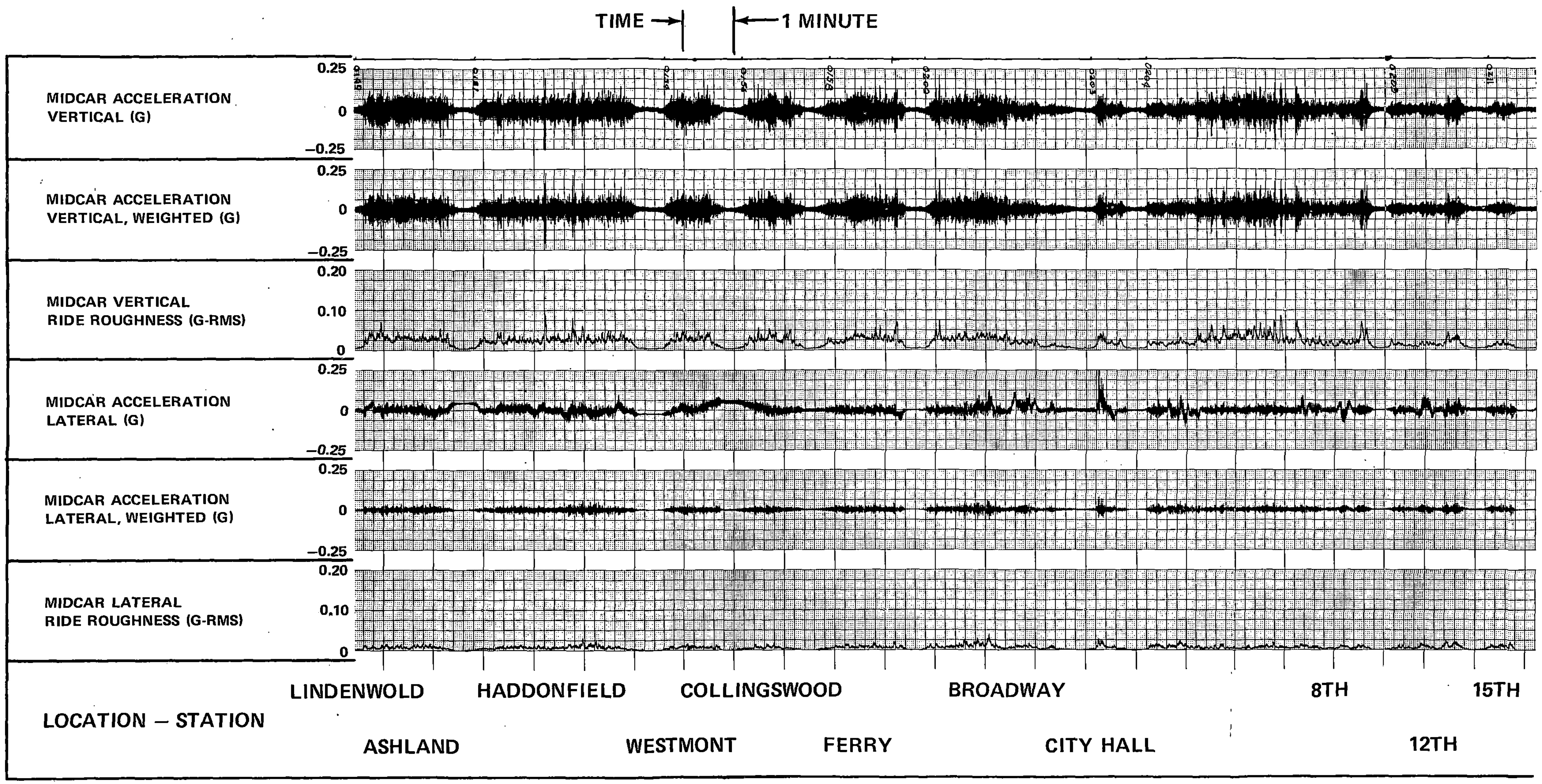


Figure 5–19. Mid-Car Acceleration Time History Chart (L-15)

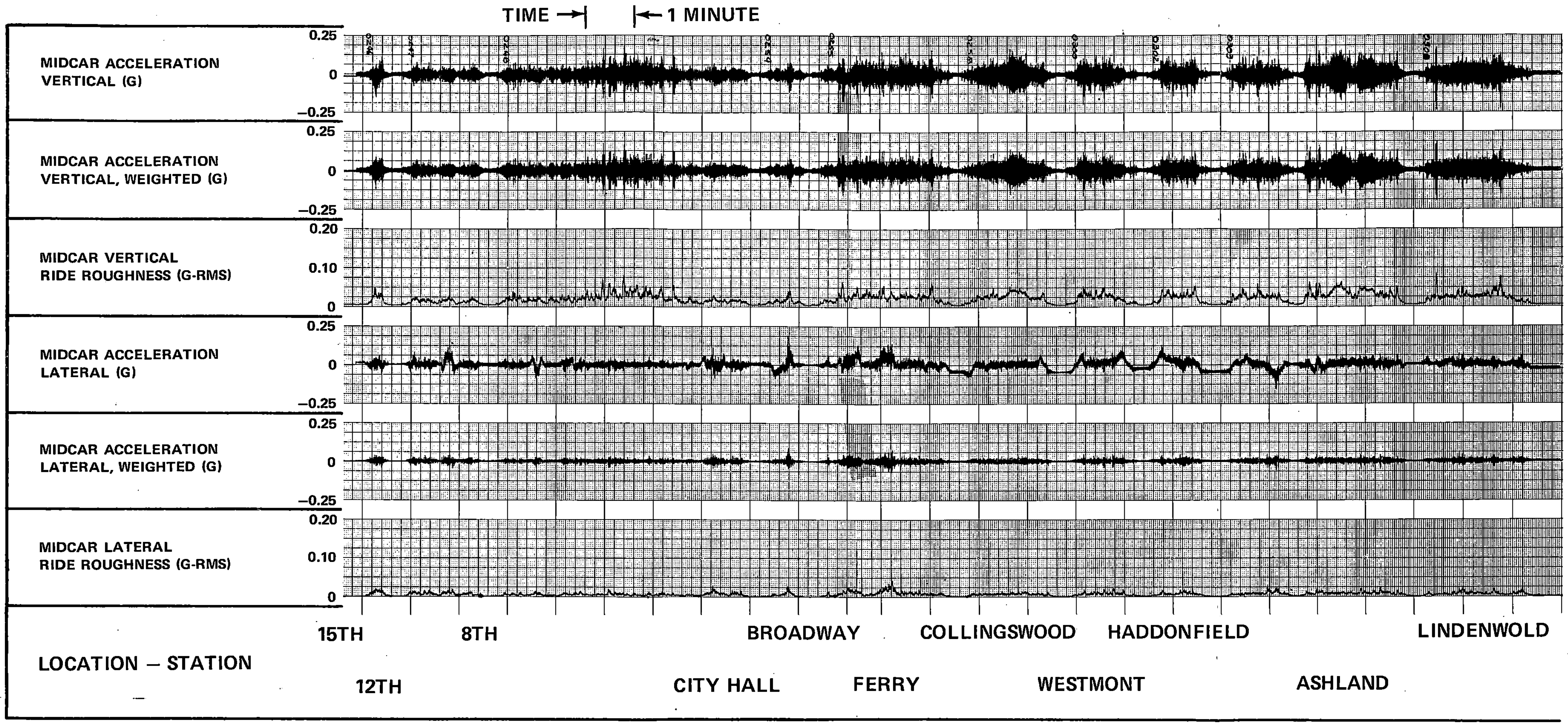


Figure 5–20. Mid-Car Acceleration Time History Chart (15-L)

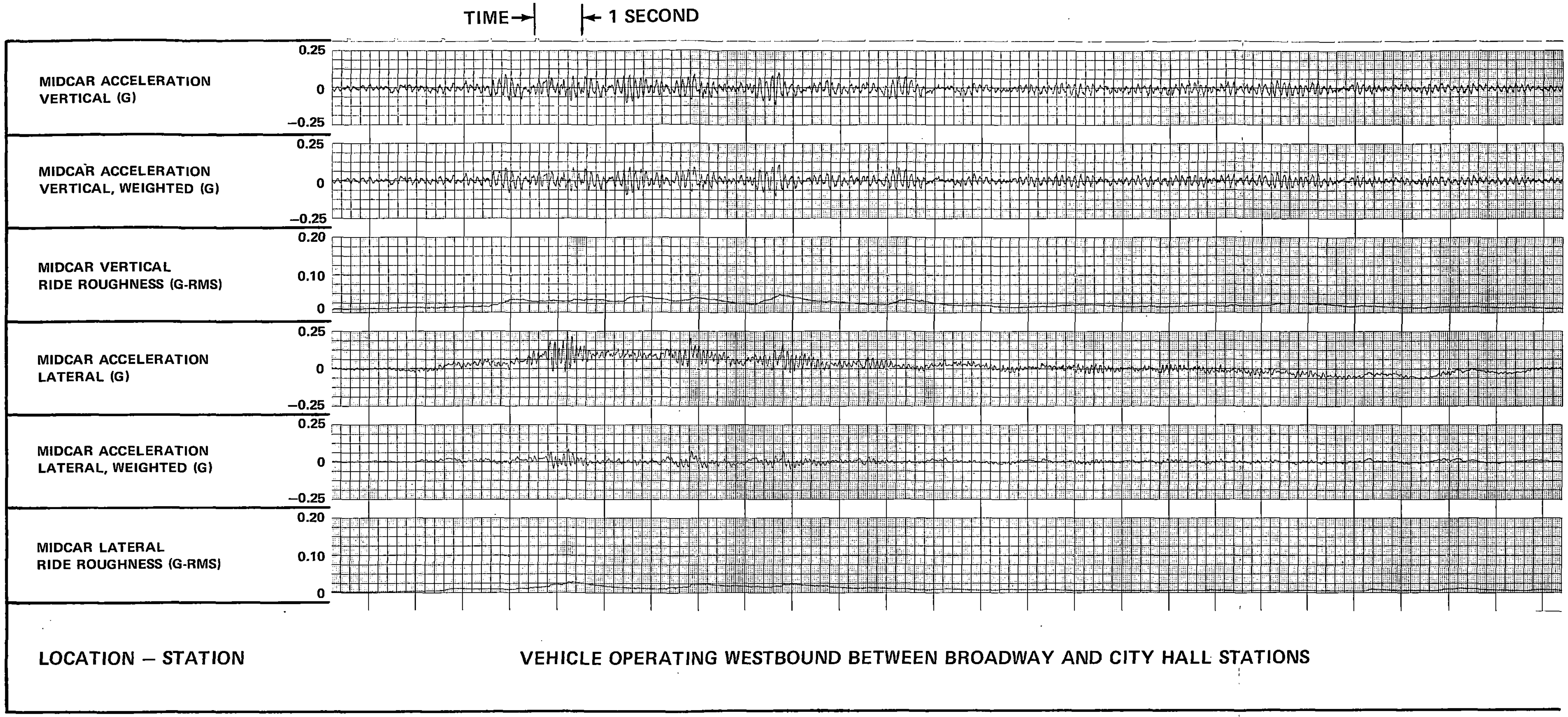


Figure 5–21. Mid-Car Acceleration Time History Chart (~)

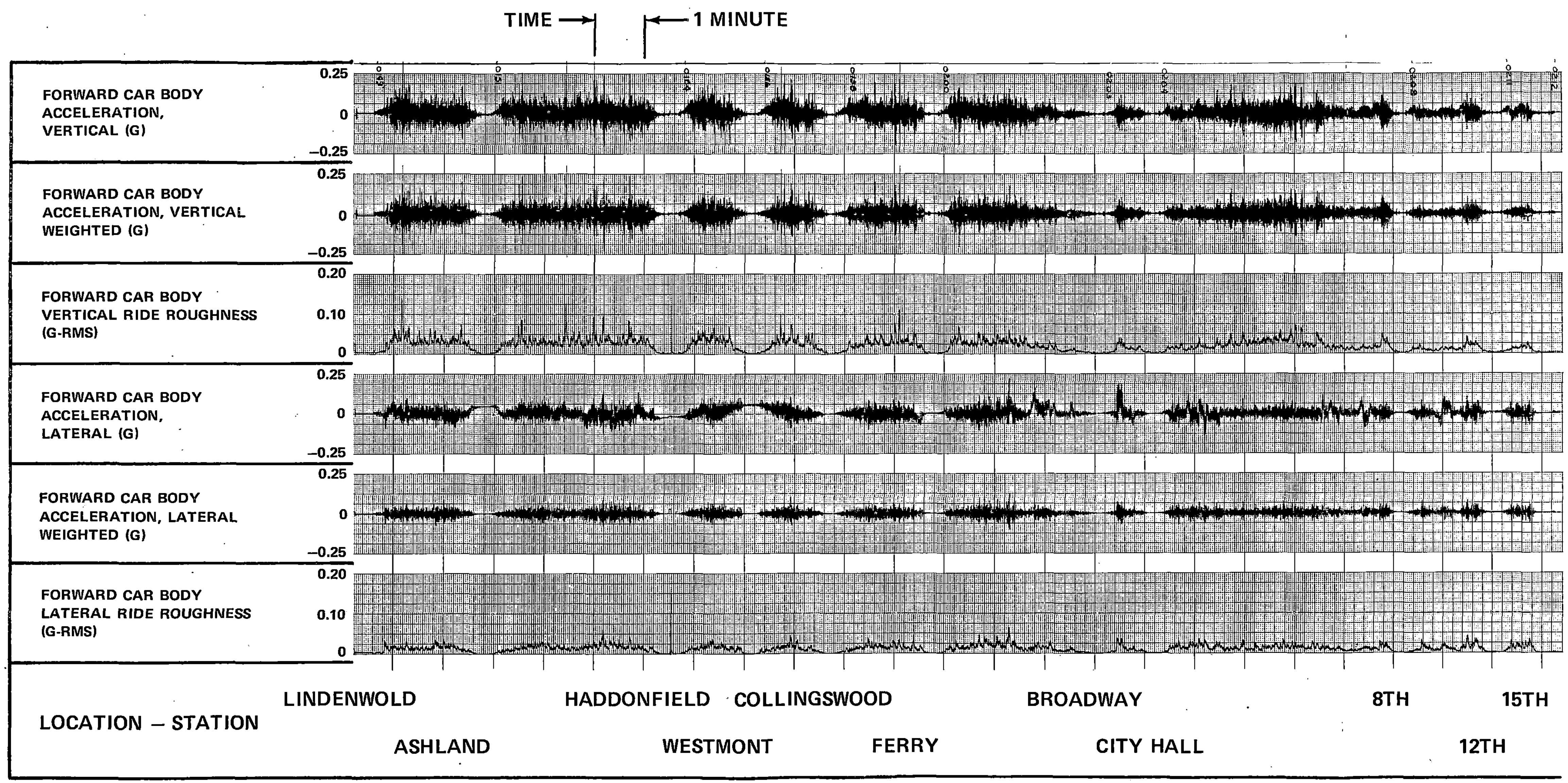


Figure 5–22. Forward Car Acceleration Time History Chart (L-15)

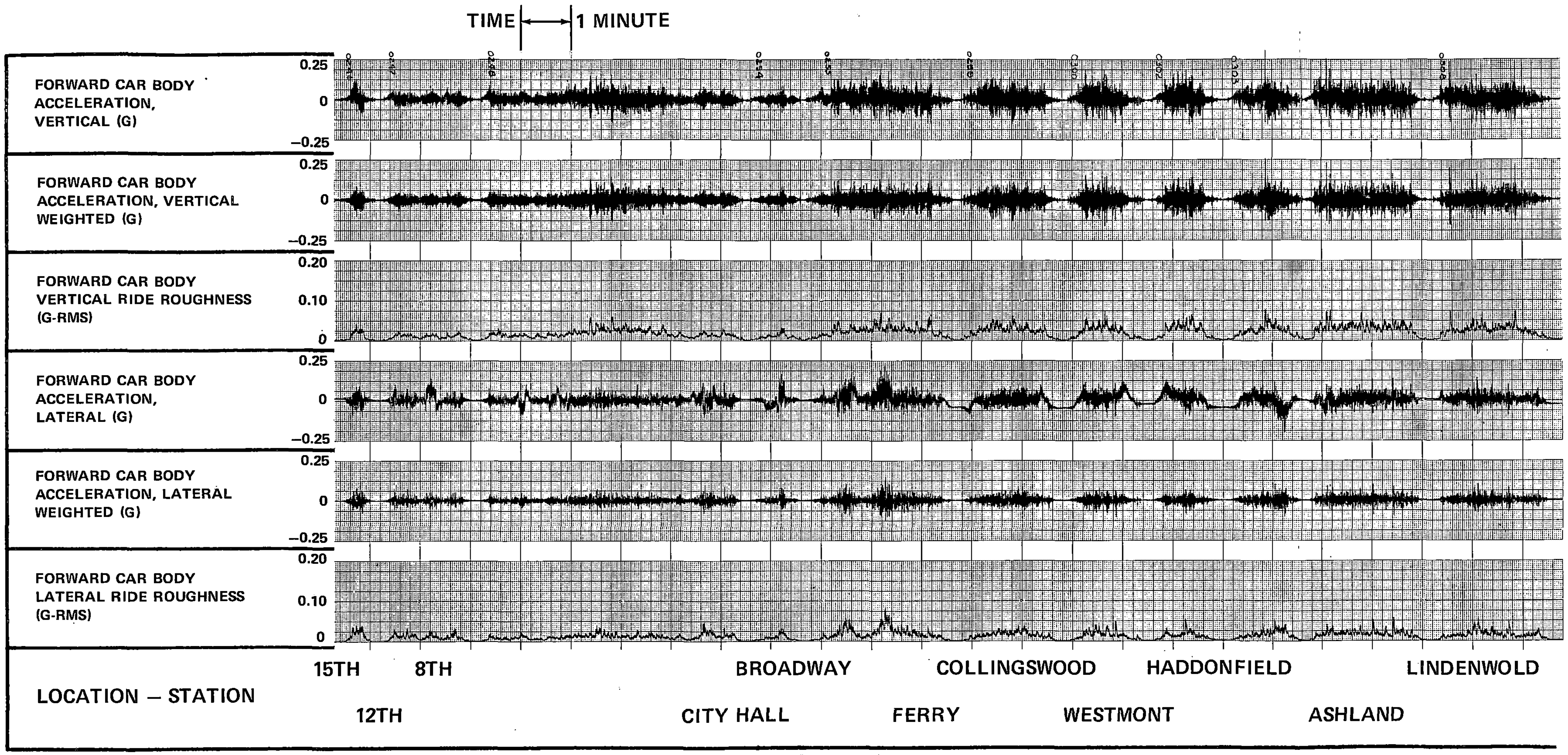


Figure 5–23. Forward Car Acceleration Time History Chart (15-L)

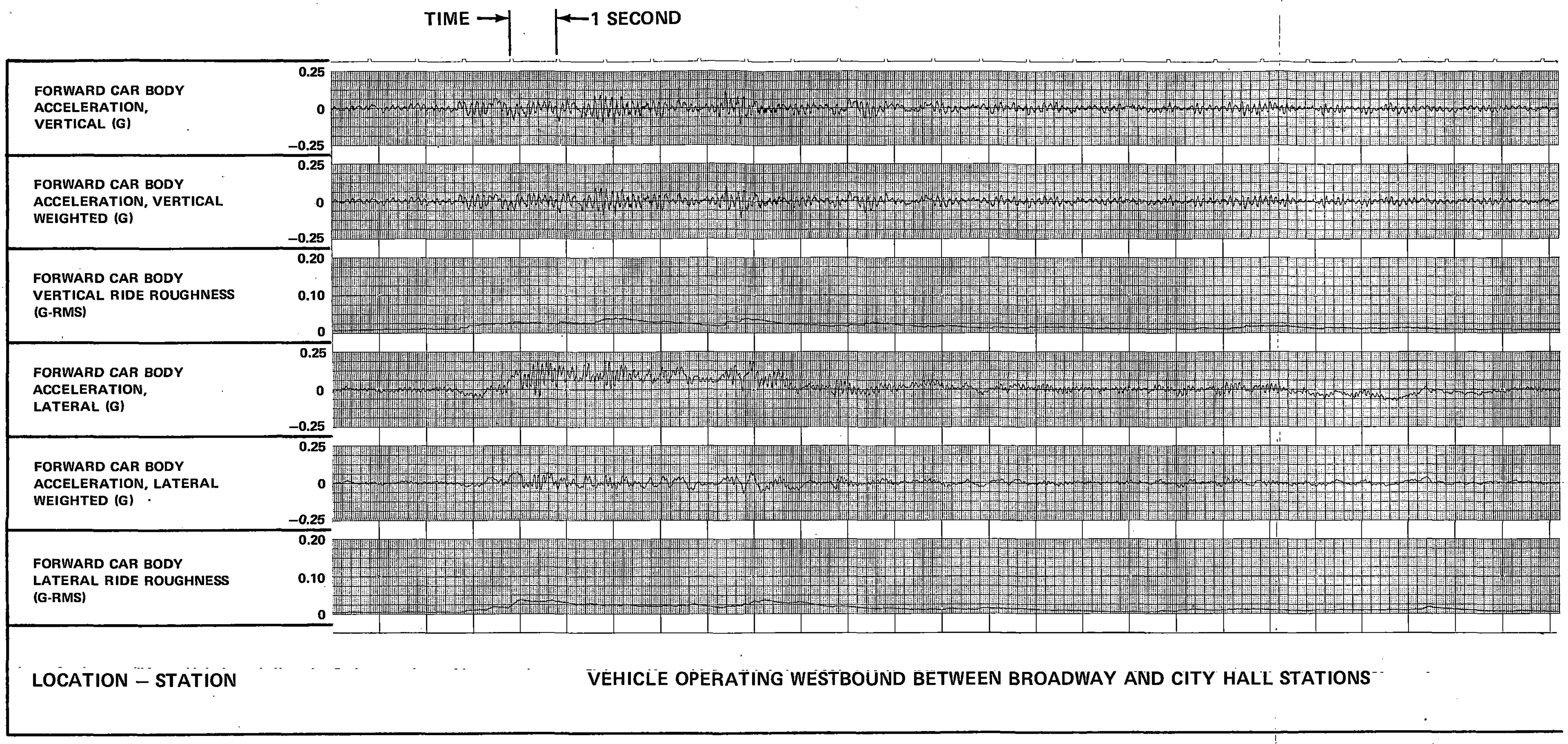


Figure 5–24. Forward Car Acceleration Time History Chart (~)

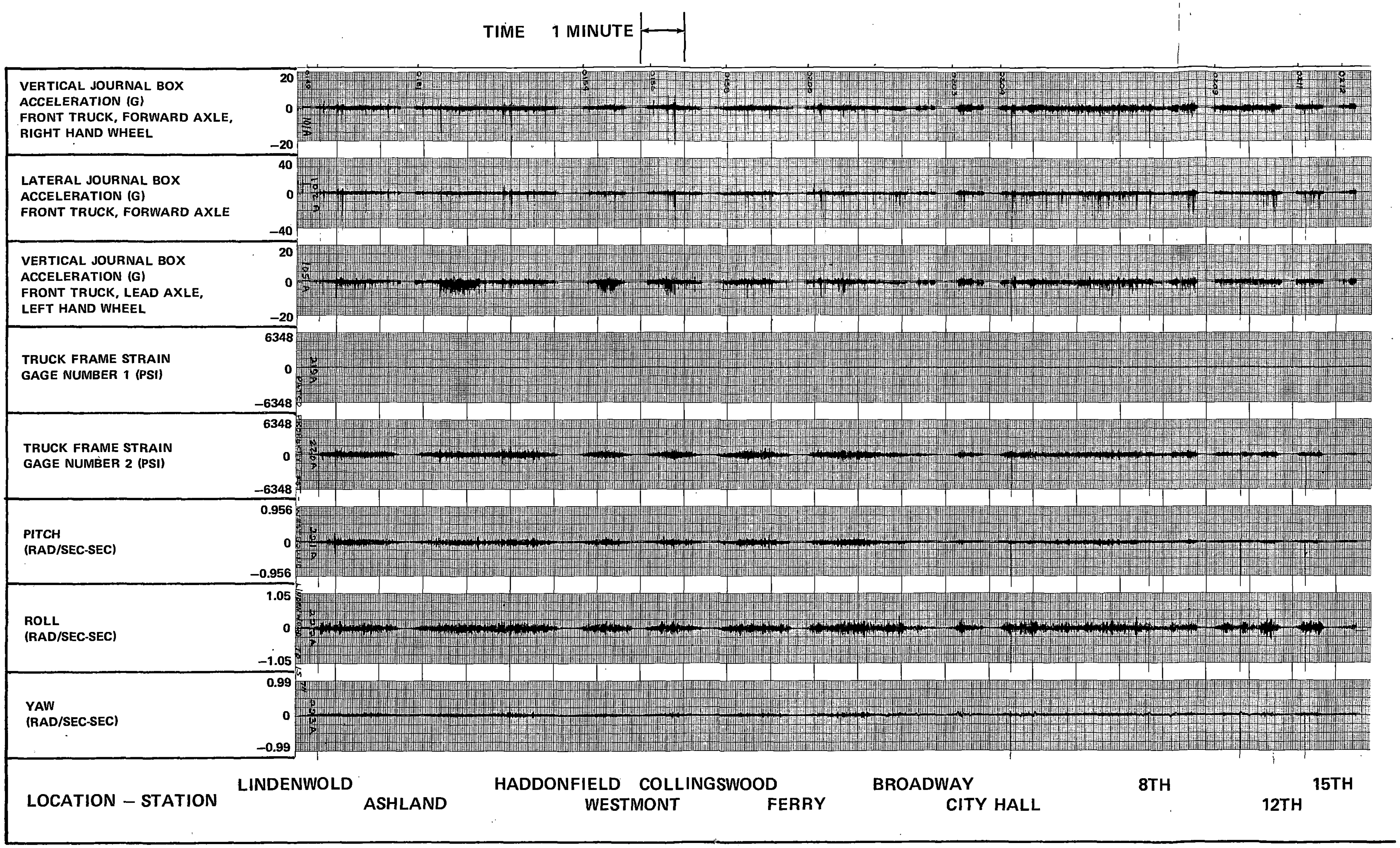


Figure 5–25. Journals, Truck Frame, and Angular Acceleration Time History Chart (L-15)

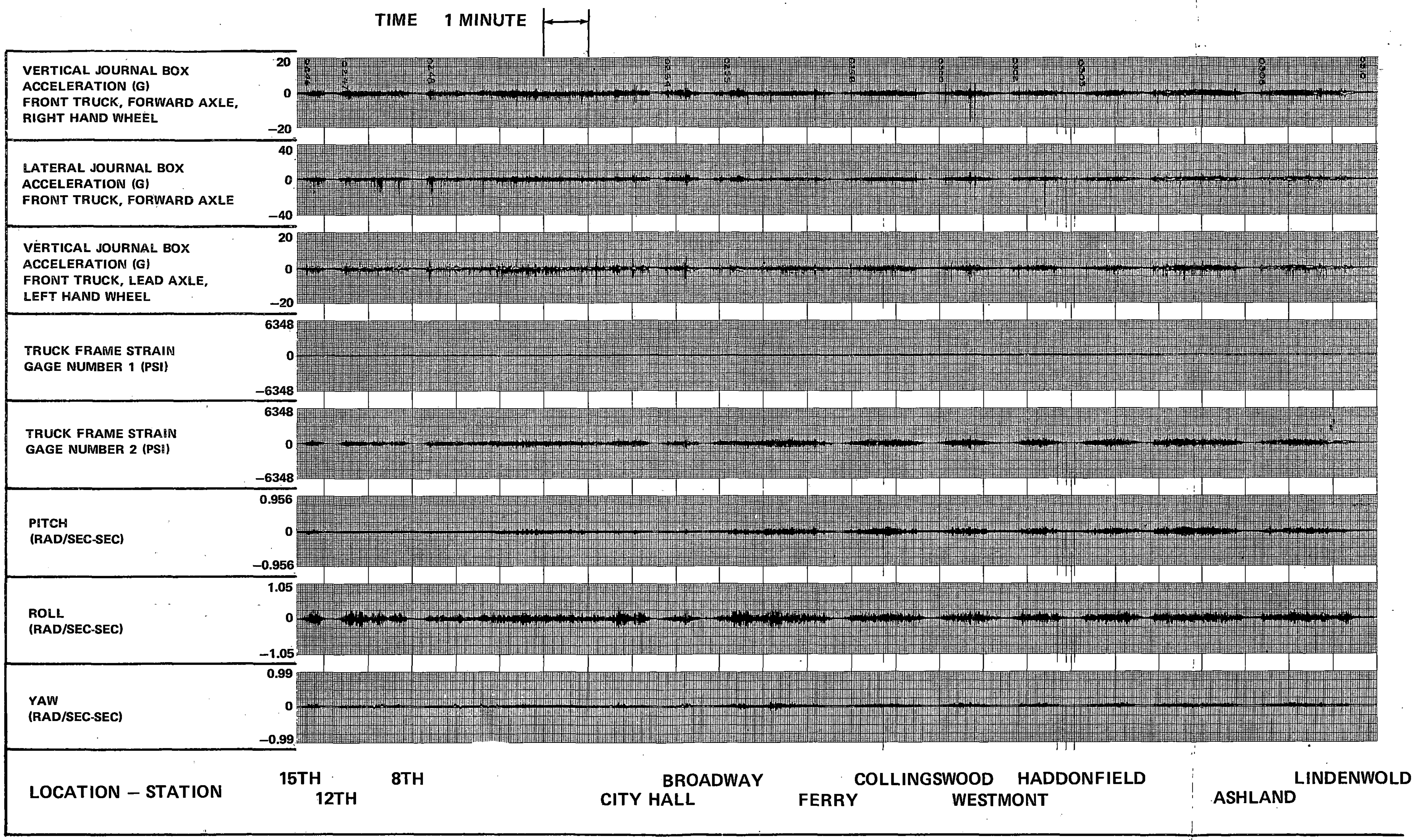


Figure 5–26. Journals, Truck Frame, and Angular Acceleration Time History Chart (15-L)

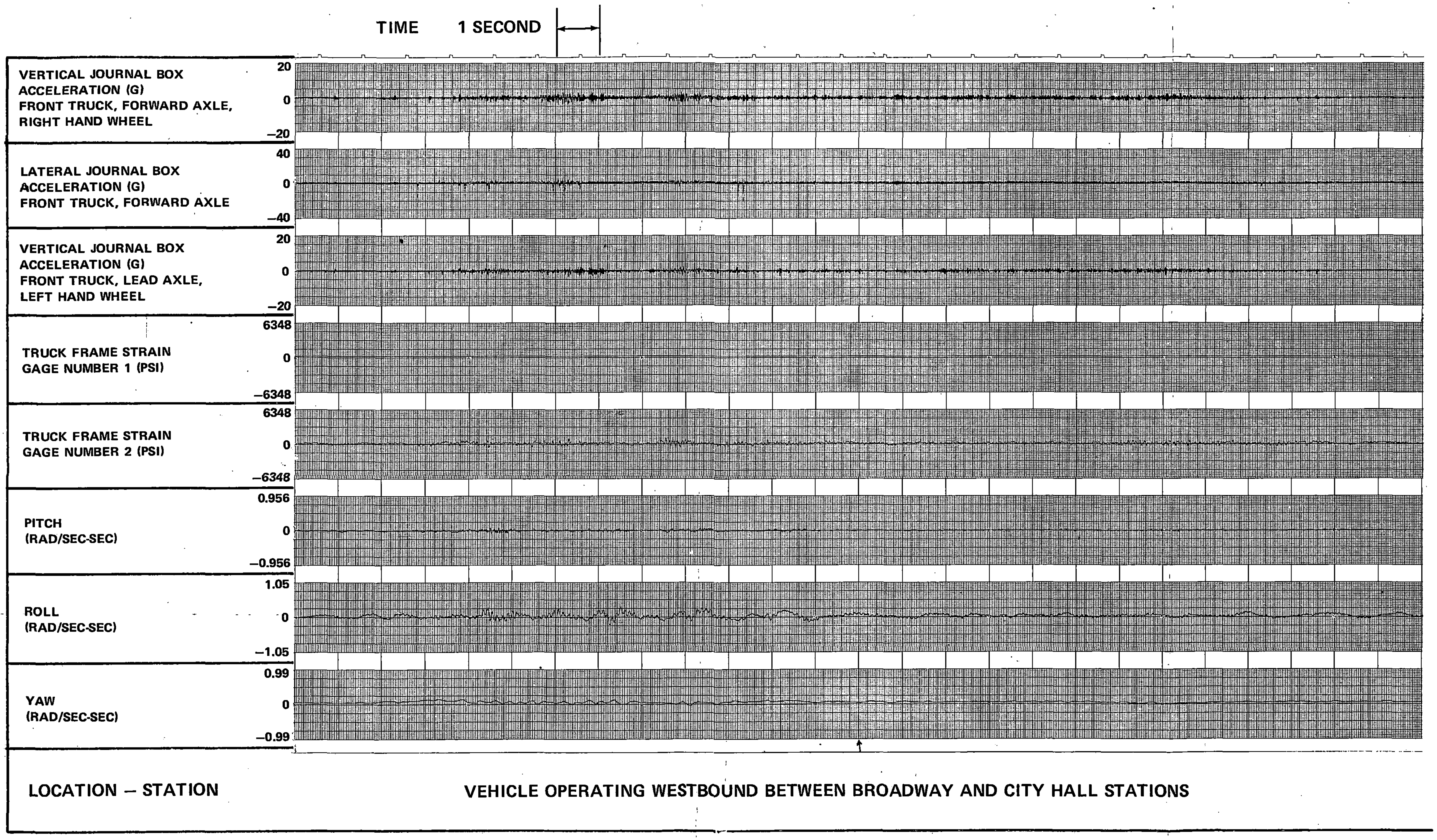


Figure 5–27. Journals, Truck Frame, and Angular Acceleration Time History Chart (~)