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MBTA RAPID TRANSIT SYSTEM (RED LINE)
WAYSIDE AND IN-CAR
NOISE AND VIBRATION LEVEL MEASUREMENTS

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FINAL REPORT

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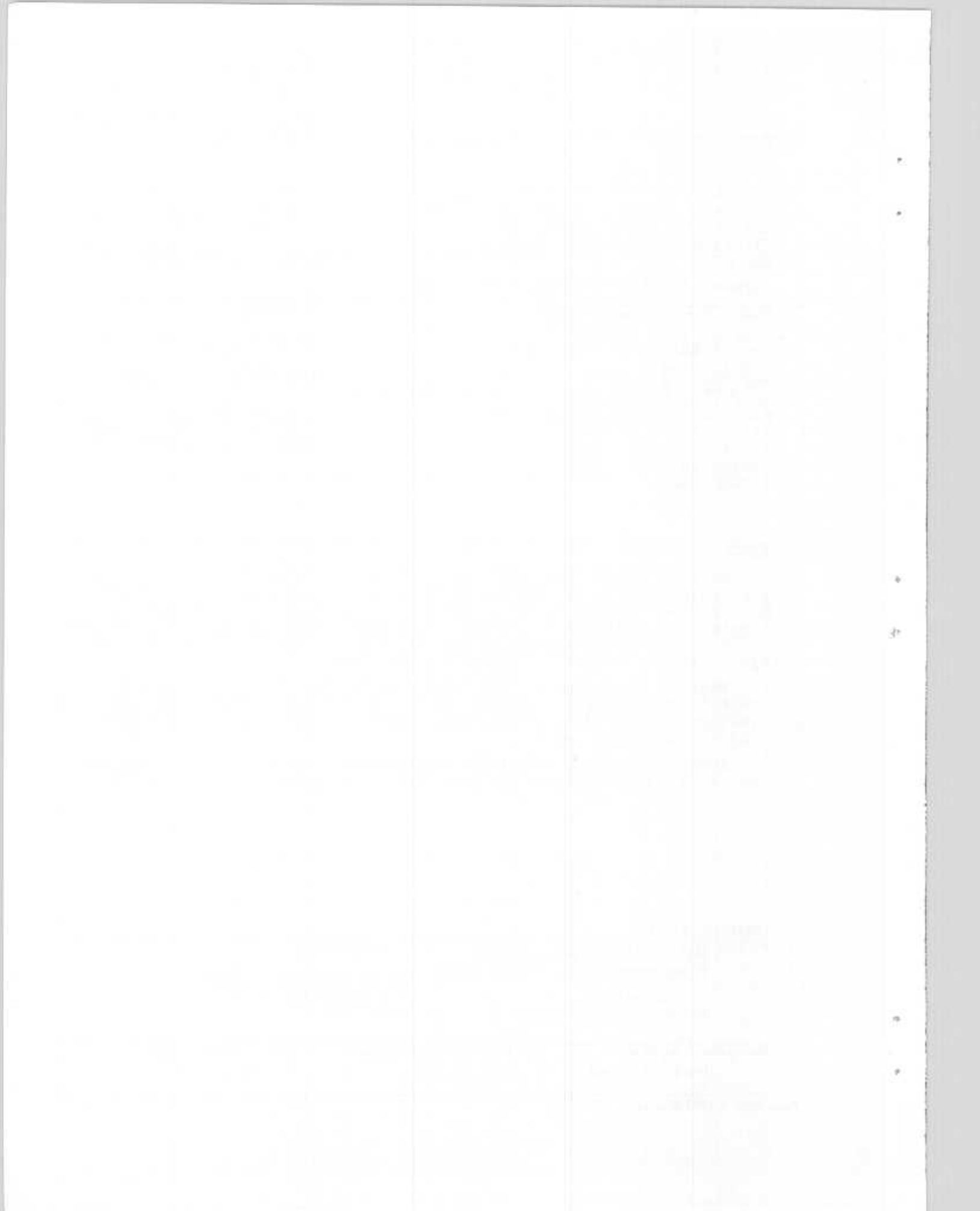
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16. Abstract <p>Wayside and in-car noise and vibration characteristics of a late-model mass transit car making up 2-car and 4-car trains are tabulated and analyzed in this report. The MBTA Type 1 South Shore Rapid Transit Car, designed and built by Pullman Standard, Chicago, Illinois and currently in operation on the Red Line of the Massachusetts Bay Transportation Authority (MBTA) was measured.</p> <p>Wayside measurements had been made by the tracks of the South Shore Extension of the Red Line 58 days after the official September 1, 1971 opening of this extension. These wayside measurements were repeated six months later.</p> <p>In-car noise and vibration measurements are made in a selected 2-car train on a typical run over various sections of the Red Line.</p> <p>February 1973</p>			
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PREFACE

Wayside and in-car noise and vibration characteristics of a late-model mass-transit car, making up four-car and two-car trains, are tabulated and analyzed in this report. The MBTA Type 1, So. Shore Rapid Transit Car designed and built by Pullman Standard, Chicago, Illinois and currently in operation on the Red line of the Massachusetts Bay Transportation Authority (MBTA) was measured.

Wayside measurements were made by the tracks of the So. Shore Extension of the Red line 58 days after the official September 1, 1971 opening of this extension. These noise and vibration measurements were repeated six months later. The average peak value of the wayside noise and vibration levels measured for 2-car and 4-car trains are as follows:

Date	Avg Speed mph	Avg Peak Noise Level dBA re 20 μ N/m ² *			Avg Peak Vibration Level dB re 10 ⁻⁶ g					
		at 25 ft	at 50 ft	at 100 ft	at 25 ft	at 38 ft				
Trains Measured					z-axis	x-axis	y-axis	z-axis	x-axis	y-axis
Oct 28, 1971 4-Car Trains	50.4	95.1	90.4	85.7	-	-	93.8	-	-	85.9
April 29, 1972 4-Car Trains	50.1	95.2	88.4	83.6	79.4	87.4	91.0	73.1	80.5	83.7
April 29, 1972 2-Car Trains	49.9	89.5	86.5	79.8	79.5	85.0	90.3	72.2	79.4	80.5

*dBA - "A" weighted sound pressure levels
- no data

In-car noise measurements were made at three locations in a selected 2-car train on a typical run over various sections of the Red Line. In addition three-axis vibration measurements were made at a point on the floor tiles over the rear wheel truck on the lead car. Typical coincident noise and vibration levels are tabulated in this report for the many varied conditions of the Red Line.

Note: Three-axis vibration measurements: z-axis vertical, x-axis longitudinal, y-axis lateral, respectively.

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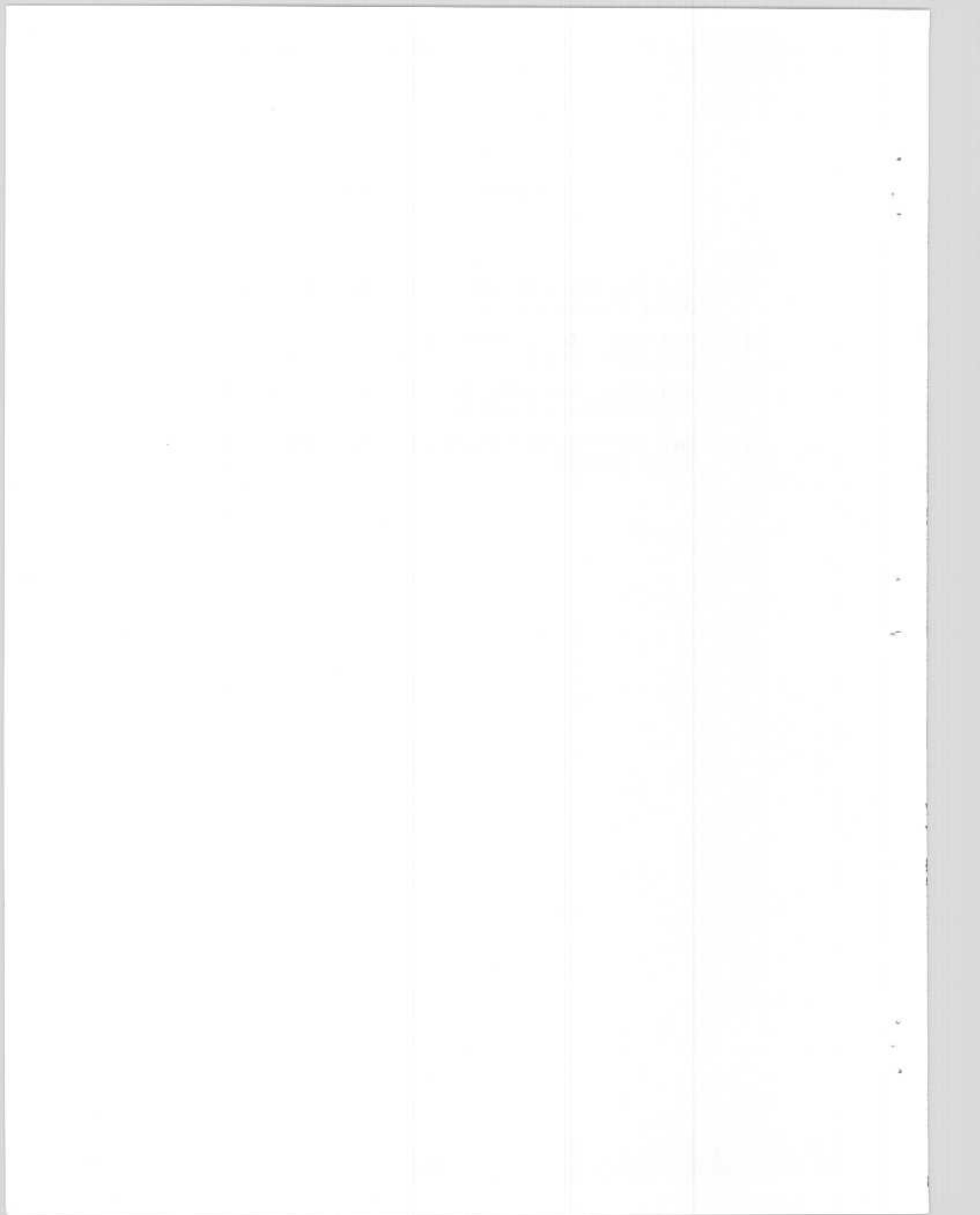
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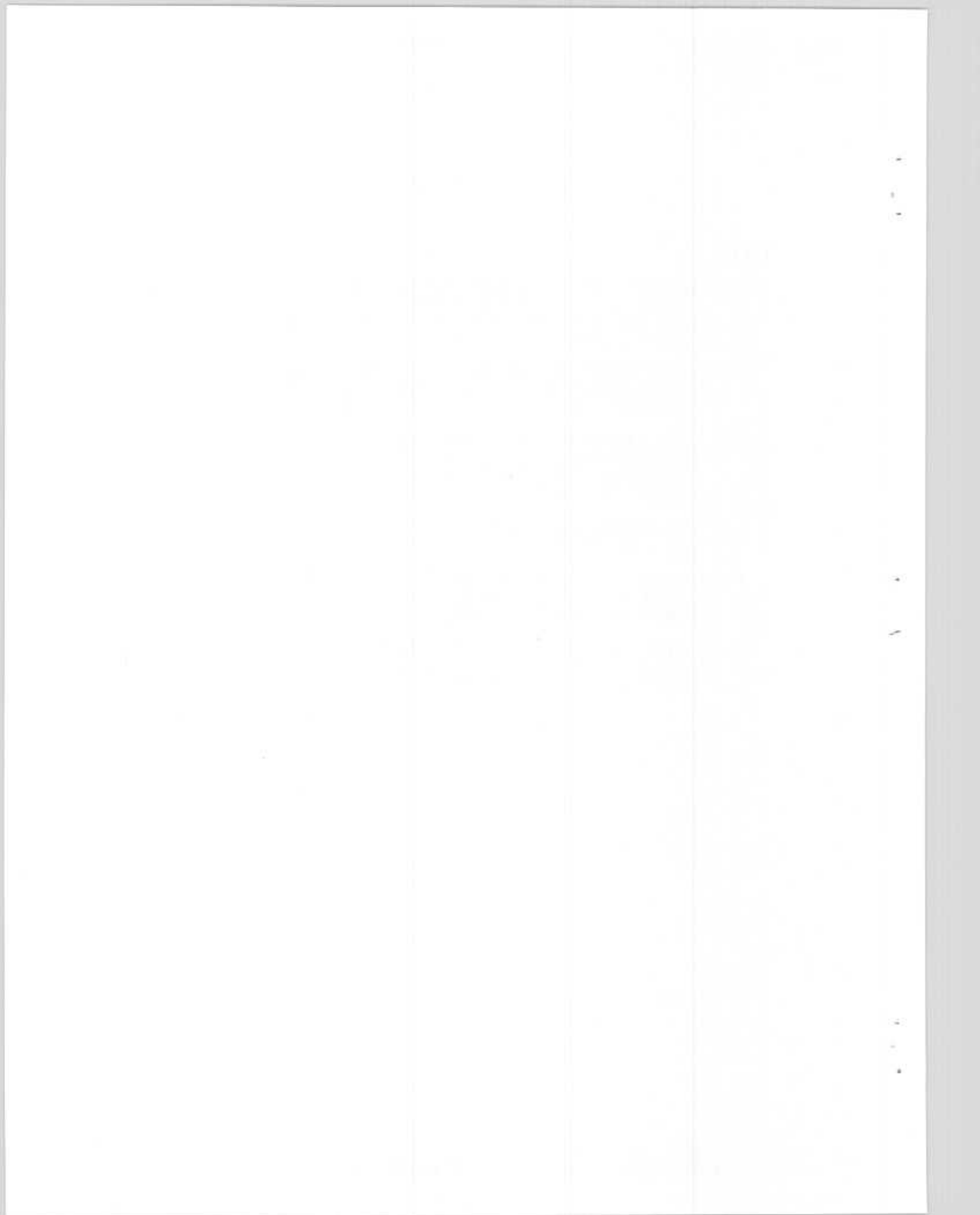
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1. INTRODUCTION

The U.S. Department of Transportation, Transportation Systems Center (TSC), Cambridge, MA undertook a project to measure and document the noise and vibration levels produced by rapid-transit cars operating on the Red Line of the Massachusetts Bay Transportation Authority (MBTA) Rapid Transit System.

The Red Line proper and the Ashmont Extension of the Red Line which run between Harvard Square in Cambridge, MA to Ashmont Station in Dorchester, MA is a relatively old line with wooden ties and a non-welded rail system. The So. Shore Extension of the Red Line which runs between Quincy Center in Quincy, MA and joins the Red Line at a point between Columbia and Andrew Stations in Dorchester, MA is a new line and was put into operation on September 1, 1971. This extension was constructed with a high-quality road bed with concrete ties and a welded rail system. New transit cars, designed and built by Pullman Standard, Chicago, Illinois, to MBTA developed specifications, were purchased by the MBTA for use on this new extension and on the Red Line from Harvard to Andrew Station. These cars have been designated No. 1 So. Shore Rapid Transit Cars by the MBTA.

Wayside noise and vibration measurements were made next to the So. Shore Extension tracks in Dorchester, MA on October 28, 1971 and repeated again on April 27, 1972 to obtain a comparison of measurement levels after the first six-months operational period.

In addition on April 29, 1972, the lead car of a two-car train was instrumented for the measurement of noise at two locations inside the car and at one location on the outside platform between cars. It was also instrumented for the measurement of floor vibrations in three axes at a point inside the car centered over the rear wheel trucks.

The above in-car measurements were made during typical runs over the Red Line proper, and on the Asmont, and So. Shore Extensions of the Red Line.

2. DISCUSSION

Noise-and-vibration level measurements were made on the Red Line and on the Ashmont and So. Shore Extensions of the Red Line of the Massachusetts Bay Transportation Authority (MBTA) Rapid Transit System.

Wayside measurements were made on October 28, 1971 next to the tracks of the So. Shore Extension. This was 58 days after the official September 1, 1971 opening of this extension. These same measurements were repeated six months later on April 27, 1971 to obtain a measure of the condition of the track and/or equipment during the first six months of operation. In addition in-car noise and vibration measurements were made in the lead car of a two-car train on a typical run on April 29, 1972.

This report documents the noise and vibration measurements made. Appendixes A through D contain the analyses of the wayside noise and ground vibration data. Appendixes E and F contain the analyses of the in-car noise and floor vibration data.

Microphone and vibration transducer locations and procedures used in obtaining and reducing measurement data are detailed. (See appendixes G and H.)

Appendixes I through L contain: the description of the transit car in use on the So. Shore Extension; the tunnel configuration at various points on the Red Line; definition of terms and calculation; and environmental data, respectively.

As an aid in reducing and analyzing the recorded data, time-history chart recordings were prepared for each microphone output (Noise level in dBA re $20\mu\text{N}/\text{m}^2$ vs Time) and for the three vibration axes (root mean square Acceleration dB re 10^{-6}g vs Time).

Specific occurrences identified from the time histories were selected for one-third-octave frequency spectral analyses for both noise at the three microphone locations and vibration in three axes.

Statistical analysis of noise data obtained have been prepared showing noise levels (dBA) vs. frequency of occurrence together with calculated noise indexes to form a basis for comparison.

Note that during the in-car measurements, the air conditioning equipment in the test train was turned off.

3. WAYSIDE NOISE MEASUREMENTS-MBTA RED LINE (SO. SHORE EXTENSION)
OCTOBER 28, 1971 (1500 TO 1650 HOURS)

Appendix A contains time-histories, statistical analyses, and 1/3-octave frequency spectra of wayside noise-level measurements made at the three wayside locations in an MBTA storage yard on Tenean Street, Dorchester, MA, next to the tracks of the MBTA South Shore Extension of the Red Line.

These measurements were made on October 28, 1971, 58 days after the official opening of the So. Shore Extension of the Red Line.

Figure A-1 contains a short representative coincident time history of wayside noise level measurements. Microphones were set up at perpendicular distances of 25, 50, and 100 ft. respectively from the centerline of the northbound track. The centerline of the southbound track was effectively 38, 63, and 113 ft., from these microphones. Noise levels are plotted in dBA re $20\mu\text{N}/\text{m}^2$ vs Time with the events of interest identified.

Table 3-1 shows the coincident wayside noise and ground vibration levels measured. The peak RMS noise level measured at the three microphones is tabulated for both north and southbound trains. As shown, measurements were made on individual 4-car trains each time they passed the measurement location in both the north- and southbound directions. Noise data obtained from trains traveling southbound were converted to equivalent levels at 25, 50 and 100 ft. for this tabulation by simple addition of 3.0, 1.8, and 0.9 dB, respectively. (See appendix K for conversion calculation.)

A comparison of the data on individual trains indicates that northbound trains generated noise approximately 3 dBA greater than southbound trains. The reason was not apparent at this point, but the larger noise levels measured on the northbound track are

TABLE 3-1
 COINCIDENT WAYSIDE NOISE AND GROUND VIBRATION LEVELS
 MBTA RED LINE (SOUTH SHORE EXTENSION)
 PULLMAN STANDARD, MBTA TYPE 1 SOUTH SHORE RAPID TRANSIT CARS

4-Car Trains - October 28, 1971

Car Serial Nos.	Time of Day hours	Speed mph	Direction	Peak RMS Noise Level * dBA re 20µN/m ²			Peak RMS Acceleration Level dB re 10 ⁻⁶ g	
				at 25 ft	at 50 ft	at 100 ft	y-axis at 25 ft	y-axis at 38 ft
1639,1638,1651,1650	15 03	51.5	N	91	87	81	90	
1639,1638,1651,1650	15 47	51.8	S	89	84	80		83
1639,1638,1651,1650	16 03	51.0	N	92	87	82	91	
1522,1515,1645,1644	15 08	44.5	S	85	81	-		-
1522,1515,1645,1644	15 23	50.0	N	88	84	-	86	
1502,1509,1607,1606	15 11	49.0	N	100	95	-	92	
1502,1509,1607,1606	15 54	50.5	S	97	92	86		87
1502,1509,1607,1606	16 12	50.2	N	100	95	89	95	
1633,1632,1648,1649	15 14	51.0	S	98	93	-		88
1633,1632,1648,1649	15 29	51.0	N	101	96	-	99	
1633,1632,1648,1649	16 13	51.0	S	98	94	88		87
1633,1632,1648,1649	16 28	51.0	N	102	97	93	98	
1505,1510,1618,1619	15 18	50.5	S	92	87	-		85
1505,1510,1618,1619	15 37	49.6	N	95	90	87	93	
1505,1510,1618,1619	16 24	50.5	S	92	87	81		85
1505,1510,1618,1619	16 43	49.5	N	96	91	85	93	
1623,1622,1513,1523	15 29	50.5	S	92	88	-		84
1623,1622,1513,1523	15 43	50.5	N	96	91	86	93	
1623,1622,1513,1523	16 30	50.5	S	92	87	82		84
1626,1627,1613,1612	15 33	51.0	S	91	87	-		86
1626,1627,1613,1612	15 47	49.5	N	94	89	84	91	
1626,1627,1613,1612	16 39	51.0	S	92	88	82		83
1503,1508,1641,1640	15 40	50.4	S	99	94	87		89
1503,1508,1641,1640	15 56	51.0	N	102	97	92	99	
1504,1506,1507,1514	16 08	49.7	S	99	95	88		90
1504,1506,1507,1514	16 22	51.0	N	102	96	91	99	
1637,1636,1517,1518	16 18	51.0	S	93	88	83		86
1637,1636,1517,1518	16 36	51.0	N	96	91	86	94	
Average (All Trains)		50.4	N-S	95.1	90.4	85.7		
Average (Northbound)		50.4	N	96.8	91.9	86.9	93.8	
Average (Southbound)		50.3	S	93.5	89.0	84.1		85.9

* Noise data from southbound trains converted to equivalent levels at 25, 50 and 100 ft from 38, 63 and 113 ft.

- No data measured

consistent with the larger vibration levels also measured on the northbound track. Ground vibration data from section 4 is also included in table 3-1.

To describe the overall temporal characteristic of the wayside noise at the measurement site, statistical analyses (see appendix K) were performed for the data from the three wayside microphones for a consecutive one-hour period between 1546 and 1646. During this one-hour period, 12 (4-car) trains passed the measurement site, six northbound and six southbound. These analyses are shown in figures A-10, A-11, and A-12.

At the three locations, the dynamic range of the noise measured was 39, 35, 31 dBA; the median noise levels were 69.4, 68.1, 68.3, dBA; and the noise-pollution levels were 89.8, 87.0 and 85.3 dBA for the 25, 50, and 100 ft. microphone locations, respectively. Other pertinent noise indexes are also included.

Figures A-2 and A-9 contain expanded coincident time histories and the associated 1/3-octave noise spectra of a representative selective few of the events measured at the three wayside locations. The integration period chosen for the spectral analysis is located on the time history at the proper point in time.

4. WAYSIDE GROUND VIBRATION MEASUREMENTS-MBTA RED LINE (SO. SHORE EXTENSION) - OCTOBER 28, 1971 (15 00 TO 16 51 HOURS)

Appendix B contains time histories and 1/3-octave frequency spectra of wayside ground vibration level measurements made on October 28, 1971, simultaneously with the noise measurements discussed in section 3.

A brass rod 2 ft. long and 7/8 inch in diameter was driven into the ground and located as shown in figure G-1 in an MBTA storage yard on Tenean Street, Dorchester, MA next to the tracks of the MBTA So. Shore Extension of the Red Line.

An insulated vibration transducer was mounted on the rod and the y-axis acceleration levels (lateral motion relative to track) measured and recorded on an F-M magnetic-tape recorder.

Figure B-1 contains a short representative time history of the wayside ground-vibration levels in the y-axis (lateral) at a point 25 ft. from the centerline of the northbound track. The centerline of the southbound track was effectively 38 ft. from the measurement point. The graphic history, plotted in dB re 10^{-6} g vs. Time, is in time coincidence with the wayside noise-level time history plotted in figure A-1.

Table 3-1 is a tabulation of the coincident wayside noise and ground vibration levels. The peak RMS acceleration levels measured in the y-axis (lateral) are tabulated for both north-and southbound trains. As shown, measurements were made on individual 4-car trains each time they passed the measurement location.

It is noted that the y-axis vibration levels measured for northbound trains were on the average 8 dB greater than those measured for southbound trains. Approximately 4 dB can be attributed to the relative distance that the two tracks are from the measurement point (by the inverse distance law, converting from 38 to 25 ft.). The remaining 4 dB could have been caused by the configuration of the northbound track and/or rail bed at

the measurement location. It was noted in discussion (section 3) that northbound trains also generated excess noise when compared with converted equivalent levels measured from southbound trains.

Figures B-2 through B-5 contain expanded time histories of the ground-vibration levels and the associated 1/3-octave vibration spectra of a representative selected few of the events measured. For the purpose of comparison, the same events selected in section 3 are presented. The integration periods chosen for the spectral analyses are located on the time histories at the proper point in time and are in time coincidence with the integration periods chosen for the noise spectral analyses of section 3.

5. WAYSIDE NOISE MEASUREMENTS-MBTA RED LINE (SO. SHORE EXTENSION)
APRIL 27, 1972 (13 15 TO 16 05 HOURS)

Appendix C contains time-histories, statistical analysis, and 1/3-octave frequency spectra of wayside noise level measurements made at the same three locations (figure G-1). Measurements were made on April 27, 1972, six months after similar measurements were made at this location. These measurements, made on October 28, 1971, are discussed in section 3. The wayside microphones were set up in the exact location for both tests. The April measurements were begun earlier in the afternoon than the October measurements to include measurements on 2-car trains as well as 4-car trains.

Figure C-1 contains a short representative coincident time history of the wayside noise-level measurements. Microphones were set up at a perpendicular distance of 25, 50 and 100 ft. from the centerline of the northbound track. The centerline of the southbound track was effectively 38, 63, and 113 ft. from the three microphones. Noise levels are plotted in dBA re $20\mu\text{N}/\text{m}^2$ vs Time with events of interest identified.

Tables 5-1 and 5-2 are tabulations of the coincident wayside noise and ground vibration levels measured for 2-car and 4-car trains, respectively. The peak RMS noise level measured at the three microphone locations is tabulated for both north-and southbound trains. As shown, measurements were made on individual trains each time they passed the measurement location in both the north and southbound directions. Noise data obtained for southbound trains were converted to equivalent levels at 25, 50 and 100 ft. for the purpose of these tabulations.

Note from tables 5-1 and 5-2 that the eight individual 2-car trains measured and tabulated were later paired into four different 4-car trains and each of these trains was also measured as the car passed by the measurement location.

TABLE 5-1. COINCIDENT WAYSIDE NOISE AND GROUND VIBRATION LEVELS META RED LINE (SO. SHORE EXTENSION) PULLMAN STANDARD, META TYPE 1 SO. SHORE RAPID TRANSIT CARS

2-Car Trains - April 27, 1972

Serial Nos	Time of Day hour	Speed mph	Direction	Peak RMS Noise Level* dBA re 20µN/m ²			Peak RMS Acceleration Level dB re 10 ⁻⁶ g							
				at 100 ft			at 25 ft		at 38 ft		at 38 ft		at 38 ft	
				at 25 ft	at 50 ft	at 100 ft	z-axis	x-axis	y-axis	z-axis	x-axis	y-axis	z-axis	x-axis
1628,1629	1318	51.3	N	97	91	85	80	-	90	73	81	83		
1628,1629	1400	50.3	S	83	87	80				71	72	75		
1514,1515	1323	51.3	S	74	79	73								
1611,1610	1327	50.6	N	100	96	90	82	-	95	75	84	88		
1611,1610	1413	50.3	S	99	94	88				72	78	81		
1519,1502	1329	47.4	S	90	85	78								
1503,1506	1334	49.5	N	90	86	80	76	85	86	72	79	80		
1503,1506	1419	47.9	S	89	84	77				71	78	80		
1618,1619	1341	49.9	S	87	83	78				72	79	81		
1637,1636	1354	50.5	S	90	85	78				72	74	76		
1604,1605	1407	50.4	S	86	81	76				72	74	76		
Average (All Trains)		49.9		89.5	86.5	79.8	79.3	85.0	90.3	72.2	79.4	80.5		

*Noise data from southbound trains converted to equivalent levels at 25, 50, and 100 ft. from 38, 63 and 113 ft, respectively.

- No data measured

TABLE 5-2. COINCIDENT WAYSIDE-NOISE AND GROUND-VIBRATION LEVELS MBTA RED LINE (SOUTH SHORE LINE) PULLMAN STANDARD, MBTA TYPE 1 SOUTH SHORE RAPID TRANSIT CARS

4-Car Trains - April 27, 1972

Car Serial Nos.	Time of Day hours	Speed mph	Direction	Peak RMS Noise Level* dBA re 20µN/m ²				Peak RMS Acceleration Level dB re 10 ⁻⁶ g					
				at 25 ft	at 50 ft	at 100 ft	at 25 ft		at 38 ft		at 38 ft		y-axis
							z-axis	x-axis	z-axis	x-axis	z-axis	y-axis	
1616,1617,1634,1635	1342	49.3	N	98	94	88	81	-	93	74	83	85	85
1616,1617,1634,1635	1429	50.7	S	95	90	82	81	92	95	75	83	86	86
1616,1617,1634,1635	1447	49.5	N	100	95	88	81	90	95	75	83	86	86
1616,1617,1634,1635	1529	50.7	S	94	90	-	82	91	95	-	-	-	-
1616,1617,1634,1635	1551	50.0	N	99	94	-	82	91	95	-	-	-	-
1502,1519,1515,1514	1349	49.5	N	94	88	83	77	85	88	72	79	80	80
1502,1519,1515,1514	1435	50.2	S	91	86	80	83	86	88	71	78	80	80
1502,1519,1515,1514	1456	50.2	N	94	88	83	78	86	88	71	78	80	80
1502,1519,1515,1514	1537	48.8	S	90	85	-	78	85	89	73	79	82	82
1502,1519,1515,1514	1556	50.8	N	93	88	-	78	85	89	73	79	82	82
1513,1523,1500,1518	1359	48.8	N	98	93	86	78	-	90	73	80	82	82
1513,1523,1500,1518	1442	49.8	S	95	90	83	81	88	90	72	76	79	79
1513,1523,1500,1518	1504	36.5 [†]	N	94	88	81	78	88	90	72	77	80	80
1513,1523,1500,1518	1544	50.2	S	94	89	-	78	85	87	72	77	80	80
1604,1605,1619,1618	1406	49.9	N	93	87	80	78	85	87	74	79	83	83
1604,1605,1619,1618	1449	48.9	S	87	82	77	77	85	87	72	76	79	79
1604,1605,1619,1618	1506	50.7	N	93	88	81	78	85	87	72	77	80	80
1604,1605,1619,1618	1553	48.6	S	88	83	-	81	90	95	74	79	83	83
1629,1628,1636,1637	1417	51.0	N	100	94	88	81	90	95	74	79	83	83
1629,1628,1636,1637	1505	49.5	S	93	88	81	79	88	90	74	79	83	83
1629,1628,1636,1637	1527	50.5	N	97	91	84	80	88	90	74	79	83	83
1623,1622,1505,1507	1422	49.9	N	97	91	84	80	88	90	74	79	83	83
1623,1622,1505,1507	1458	50.5	S	97	92	85	80	88	90	74	79	83	83
1623,1622,1505,1507	1517	49.4	N	99	95	-	81	89	94	73	78	81	81
1623,1622,1505,1507	1600	49.8	S	96	91	-	80	88	90	73	78	81	81
1612,1613,1602,1603	1431	50.7	N	98	92	85	80	91	93	73	78	81	81
1612,1613,1602,1603	1514	49.5	S	93	89	-	80	88	90	73	78	81	81
1612,1613,1602,1603	1532	51.1	N	97	91	-	80	88	90	73	78	81	81
1503,1506,1611,1610	1441	49.7	N	101	96	90	82	90	93	74	79	83	83
1510,1520,1509,1508	1527	56.4	S	102	97	-	78	85	88	-	-	-	-
1643,1642,1505,1507	1557	48.0	N	92	86	-	78	85	88	-	-	-	-
Average (All Trains)		50.1	N-S	95.2	88.4	83.6	79.4	87.4	91.0	73.1	80.5	83.7	83.7
Average (Northbound)		50.0	N	96.5	91.1	84.8	-	-	-	-	-	-	-
Average (Southbound)		50.3	S	93.5	88.6	81.3	-	-	-	-	-	-	-

*Noise data from southbound trains converted to equivalent levels at 25, 50 and 100 ft from 38, 63 and 113 ft.

[†]Not included in average speed calculation

A comparison of the noise levels for north- and southbound trains indicates (as in section 3 of this report) that northbound trains generate noise, approximately 3 dbA greater than southbound trains, which again suggests a configuration condition of the northbound track and/or rail bed. Ground vibration data from section 6 are included in tables 5-1 and 5-2.

To describe the overall temporal characteristics of the noise at the measurement site, statistical analyses (see appendix K) were performed for data from the three wayside microphones for a one hour period from 13 46 to 14 46. During the one hour period seventeen trains passed the measurement site; 5(2-car) trains southbound; 8(4-car) trains northbound; and 4(4-car) trains southbound. These analyses are shown in figures C-20, C-21 and C-22.

Table 5-3 is a summary of the statistical noise indexes calculated for both the October 28, 1971 and the April 27, 1972 measurements at the 50 ft. microphone station. A comparison shows decreases in each of the calculated noise indexes from October 1971 to April 1972 measurements even though more trains passed the measurement location during the April period (17 vs. 12 trains). These decreases noted cannot be accounted for by proximity of the measurement site to the heavily traveled Southeast Expressway and by the fact that the October analysis period was closer in time to the rush hour traffic period. It is noted that the southbound lane which would be the more heavily traveled at this period in time was acoustically shielded from the microphones because of the raised highway.

As will be shown in section 6 similar decreases were noted in the y-axis wayside vibration data. As theorized in section 6 the decrease in noise and vibration is probably due to the settling of the new rail bed during first six-month operation.

Figures C-2 through C-19 contain expanded coincident time histories at the three wayside microphone locations together with the associated 1/3-octave noise spectra of a representative few of the events measured for comparison with the October 28, 1971

TABLE 5-3. STATISTICAL SUMMARY OF WAYSIDE NOISE LEVELS, MBTA RED LINE (SO. SHORE EXTENSION)

Noise data 50 ft from centerline of near northbound track

	October 28, 1971 ¹ 1546 to 1646 hours	April 27, 1972 ² 1346 to 1446 hours
Max Noise Level	97.0 dBA	96.0 dBA
1% Percentile	87.4 dBA	84.8 dBA
10% Decile	75.1 dBA	70.0 dBA
Median	68.1 dBA	64.6 dBA
90% Decile	65.5 dBA	61.3 dBA
99% Percentile	64.1 dBA	59.4 dBA
Noise Pollution Level	87.0	82.7

¹Twelve, 4-car trains passed measurement site, 6-northbound, 6-southbound

²Seventeen trains passed measurement site; five, 2-car trains, southbound; eight, 4-car trains northbound; and four, 4-car trains southbound

data (figures A-2 through A-9). The integration period chosen for the spectral analysis is located on the time history at the proper point in time.

Figures C-2 through C-5 contain the data and analysis of two (2-car) trains northbound Serial Nos 1611,1610 and Serial Nos 1503,1506. Figures C-6 and C-7 contain the analysis of these 2-car trains paired up as a four car train northbound, with car Serial Nos 1503,1506 as the lead pair. (Note: 2-car train serial nos 1503 and 1506 was selected for in-car measurements during a typical run on April 29, 1972, see sections 7 and 8.) It is interesting to note that the noise generated by the 4-car train was dominated by the more noisy 2-car train Serial Nos 1611 and 1610. The expanded time histories (Figure C-2, C-4, and C-6) of data

at the 25-ft. microphone location exemplified this since the double peak in the noise-level history figure C-6a is caused by the passing of 2-car trains (Serial Nos 1503 and 1506 followed by the noisy pair Serial Nos 1611 and 1610. This is less obvious at the other two microphone locations but nevertheless also true.

Figures C-8 through C-11 contain the data and analysis of two 2-car trains southbound Serial Nos 1618 and 1619 and Serial Nos 1604 and 1605. Figures C-12 through C-15 contain the analysis of these 2-car trains paired up as a 4-car train traveling both north-and southbound. In this case, the noise generated by the individual 2-car trains was essentially at the same level and lower than the average, table 5-20. When paired as a 4-car train, the overall maximum level changed little if any; however, the noise level was extended over a longer period of time. The double peak in the noise-level history of the passing of each 2-car pair is again obvious in figures C-12a and C-14a where 2-car Serial Nos 1618 and 1619 were the lead pair southbound and the trailing pair northbound.

Figures C-16 through C-19 contain data and analysis of a 4-car train (Serial Nos 1616,1617,1634, and 1635). Although no measurements were made on the individual 2-car pairs, it is obvious, from the double peak in the noise-level history, (figures C-18a and C-19a), that both pair were essentially at the same level and higher than the average level for 2-car trains (table 5-2).

6. WAYSIDE GROUND VIBRATION MEASUREMENTS - MBTA RED LINE (SO. SHORE EXTENSION) APRIL 27, 1972 (13 15 TO 16 05 HOURS).

Appendix D contains time-histories and 1/3-octave frequency spectra of wayside ground-vibration level measurements made simultaneously with the noise measurements discussed in section 5.

Measurements were made on April 27, 1972, six months after similar measurements were made at this location. These measurements were made on October 28, 1971 and are discussed in section 4. For the October 1971 ground-vibration measurements, a brass rod 2 ft. long and 7/8 inch in diameter was driven into the ground and located as shown in figure G-1. The brass rod was purposely left in the ground at the conclusion of the October 1971 tests for the purpose of repeat measurements at a later time. This rod was used in the measurements to be discussed in this section.

Unlike the October 1971 measurements when only the y-axis (lateral) accelerations were measured, an insulated triaxial arrangement of vibration transducers were mounted on the above driven rod and three axes of acceleration measured and recorded on an F-M magnetic-tape recorder. Because the measurements were started earlier in the day, both 2-car and 4-car trains were available for measurement.

Figure D-1 contains a short representative history of the wayside ground vibration levels in three axes (x-axis - longitudinal motion; y-axis - lateral motion; z-axis - vertical motion; motion relative to all tracks) at 25 ft. from the centerline of the northbound track. The centerline of the southbound track was effectively 38 ft. from the measurement point. This graphic history, plotted in dB re 10^{-6} g vs. Time, is in time coincidence with the wayside noise levels plotted in figure C-1.

Tables 5-1 and 5-2 in section 5 are tabulations of the coincident wayside noise and ground vibration levels measured for 2-car and 4-car trains, respectively. The peak rms acceleration levels measured in three axes are tabulated for both north-and

southbound trains. As shown, measurements were made on individual trains each time they passed the measurement location in both the north-and southbound directions.

As in the October 1971 measurements, the y-axis accelerations measured for northbound trains was approximately 8 db greater than for those measured for southbound trains. Considering the relative distance the two tracks are from the measurement point, by the inverse distance law, as in section 4, approximately 4 db difference in level is not accounted for and suggests, together with noise measurement of sections 3 and 5, that a configuration condition exists in the northbound track and/or rail bed. It is also noted that the vibration levels for the x-and z-axes were also greater for northbound trains in excess of that which could be accounted for by the relative distance from the measurement point of the two tracks.

A comparison of the average maximum rms acceleration level in the y-axis measured for both north and southbound trains on April 27, 1971 (91.4 and 83.3 dB re 10^{-6} g in table 5-2) with the y-axis levels measured on October 19, 1971 (93.7 and 85.9 dB re 10^{-6} g in Table 3-1) shows a decrease of 2.5 dB in the vibration level for both north-and southbound trains. As shown in table 5-3, the statistical-noise indexes tabulated also decreased between the October 1971 and April 1972 measurements. It is theorized that these decreases are due to the initial settling of the rail bed during the first six-month's operational period.

Figures D-2 through D-19 contain expanded coincident time histories of the ground-vibration levels in three axes and the associated 1/3-octave vibration spectra of a representative few of the events measured. For the purpose of comparison, the same events selected in section 5 are presented (figures C-2 through C-19). The integration periods chosen for the spectral analyses are located on the time histories at the proper point in time and are in time coincidence with the integration periods chosen for the noise spectral analysis of section 5.

Figures D-2 through D-5 contain data and analysis of two, 2-car trains northbound Serial Nos 1611 and 1610 and Serial Nos 1503 and 1506. Figures D-6 and D-7 contain the analyses of these two-car trains paired up as a four-car train northbound with Serial Nos 1503 and 1506 as the lead pair (Note: 2-car train Serial Nos 1503, 1506 was selected for in-car measurements during a typical run on April 29, 1972 (sections 7 and 8). A close analysis of the expanded time histories of the vibration data, figures D-2, D-4, and D-6 reveals 3 and 5 peaks on the time history during the passing of a 2-car and a 4-car train, respectively. These peaks are a result of the "point source" vibrations from the sets of wheel trucks as they pass the measurement point. Because of the close proximity of the trucks of adjacent cars, a single broader peak is obtained from this pairing. The y-axis data in figure D-2 for Serial Nos 1611 and 1610 show three peaks of varying amplitudes, with the first peak resulting from the passby of the front truck on the lead car. This caused the lowest vibration level. The second broader peak is the combination of the rear truck of the lead car with the front truck of the second car. Finally, the third peak is the rear wheel truck of the second car passing the measurement point. The same thing is true of the peaks shown in the y-axis data in figure D-6 showing the 4-car train made up of the 2-car trains. The five peaks can be easily seen. The first two peaks are identical with the first two shown in figure D-4; the last two peaks are identical with the last two shown in figure D-2; the middle of third peak is a combination of the last peak shown in figure D-4 and the first peak of figure D-2 since the train was joined at this point. Figure D-6 shows a definite difference exists in the vibration levels from the sets of wheel trucks as they passed the measurement point. It appears the condition of the wheels is the main factor causing the differences. It is noted that car Serial Nos 1611 and 1610 generated more noise than car Serial Nos 1503, 1506 (figures C-2 and C-4). Figures D-2 and D-4 show Serial Nos 1611 and 1610 also generated a higher ground-vibration level than Serial Nos 1503 and 1506.

It is more difficult to distinguish the peaks on the vibration time history for the two 2-car trains shown in figures D-8 and D-10 (Serial Nos 1618 and 1619 and Serial Nos 1604 and 1605, respectively) since the levels are lower and the train is farther from the measurement point when traveling on the southbound track;

However, when these trains are combined into a 4-car train traveling on the northbound track, the levels are higher and the peaks more distinguishable (figure D-14). It is obvious that the vibration level of the peaks are lower and more uniform in figure D-14 than those in figure D-6 suggesting all wheels on these 4-car trains were more uniform and in good condition. The noise level measured for these 2-car trains and their combination as a four-car train, (figures C-8, C-10, C-12 and C-14) confirms the uniformity between trains and the less-than-average noise generated.

Figures D-16 through D-19 contain data and analysis of a 4-car train with car Serial Nos 1616, 1617, 1634 and 1635 traveling north-and southbound. No measurements were made on these individual 2-car trains: however, the vibration-level peaks suggest a mix of wheels both in good and questionable condition. It appears that the front-wheel trucks on the lead car, and perhaps, the rear wheels on the third car were all in good condition with the remaining trucks containing wheels in questionable condition.

7. IN-CAR NOISE-LEVEL MEASUREMENTS - MBTA RED LINE APRIL 29, 1972
(01 00 TO 04 00 HOURS)

Appendix E contains time-histories, statistical analysis and 1/3-octave frequency spectra of noise-level measurements made on and in, a 2-car train made up of MBTA type 1 So. Shore Rapid Transit Cars designed and built by Pullman Standard, Chicago, Illinois for the MBTA.

A 2-car train with car Serial Nos 1503 and 1506 was selected for this test since wayside noise-and-vibration measurements were made on this pair during revenue service on April 27, 1972 (sections 5 and 6). The lead car of this 2-car train, Serial No. 1503, was instrumented for noise and vibration measurements. Figure G-2 shows microphone and vibration transducer locations; figure G-8 shows the car's interior. Measurements were made in the subways and on the surface lines of the MBTA Red Line proper and the Ashmont and So. Shore Extension of the Red Line during a typical run in the early morning hours of April 29, 1972 when no revenue service was provided on these lines.

Figures E-1, E-15, and E-19 contain coincident time histories of noise measurement levels at three locations on the test car over various sections of the MBTA Red Line. Noise levels are plotted in dBA re $20\mu\text{N}/\text{m}^2$ vs. Time with points of interest identified. Coincident values of train speed have been superimposed on the time history charts.

Figure E-1 contains noise data obtained northbound from the Quincy Center Station, Quincy, MA on the So. Shore Extension of the Red Line to the end of the Red Line at Harvard Station, Cambridge, MA. This is the normal route for the Type 1 cars and includes many varied rail-and-road bed conditions including travel on surface lines, in subways of various cross sections, on elevated structures and travel on both welded and non-welded rails. The Tenean St. wayside measurement site is identified on the time history between No. Quincy and Andrew Stations.

Figure E-15 contains noise data obtained from Ashmont to Columbia Stations Dorchester, MA, on the Ashmont Extension of the Red Line. Although the measurements were made on the Type 1 Transit Car; these cars are not normally used on this extension which is relatively old and contains both surface and subway travel on an old rail bed, with non-welded rails and wooden ties. Measurements were made on this extension to compare the effects caused by new and old road beds, and welded and non-welded rails on surface lines.

Figure E-19 contains data obtained southbound on the So. Shore Extension of the Red Line, between the Columbia Station Area and Quincy Center Stations. During this run the instrumented car (Serial No. 1503) was the rear car of the 2-car train. The Tenean St. wayside measurement site has been located on the history.

To describe the overall temporal characteristics of the noise levels measured, statistical analyses (Appendix K) were performed for the three microphone locations for the following three sections of the Red Line:

- a. So. Shore Extension (figure E-1) - Quincy Center Station to Columbia: New rail bed, welded rail construction, concrete ties with neoprene pads under rails, surface line (figures E-22, E-23 and E-24).
- b. Red Line proper (figure E-1) - Columbia to Harvard Stations: Old rail bed, non-welded rails, wood ties on on ballast, 95% subway travel (figures E-25, E-26 and E-27).
- c. Ashmont Extension (figure E-15) - Ashmont to Columbia Stations: Old rail bed, non-welded rails, wood ties ballast, 25 percent subway travel (figures E-28, E-29 and E-30).

Table 7-1 is a summary tabulation of several of the calculated statistical noise indexes at the three microphone locations in the 2-car trains for the three sections of the Red Line. The results show in general that operation on the So. Shore extension is

TABLE 7-1 STATISTICAL SUMMARY IN-CAR NOISE-LEVEL MEASUREMENTS - MBTA RED LINE
PULLMAN STANDARD, MBTA TYPE 1 SO. SHORE RAPID TRANSIT CARS

2-Car Train Serial Nos 1503, 1506 - April 29, 1972

Line Traversed	Noise Range dBA at Location*			Median Noise Level dBA at Location*	Max Noise Lev dBA at Location*			10% Decile dBA at Location*			Noise Pollution Level at Location*				
	1	2	3		1	2	3	1	2	3	1	2	3		
So. Shore Extension-Red Line Quincy Center to Columbia Sta.	20	28	41	70.3	82	85	98	73.9	77.4	87.7	78.4	86.1	105.7		
Ashmont Extension-Red Line Ashmont to Columbia Sta.	25	36	38	70.2	72.7	79.7	85	90	99	77.9	81.3	92.6	85.4	96.6	118
Red Line (Proper) Columbia to Harvard Sta.	25	31	42	71.9	72.3	82.7	86	88	102	80.9	82.9	95.2	91.0	99.7	121

*Location 1 - Microphone located mid-car inside
 Location 2 - Microphone located over rear wheel truck inside
 Location 3 - Microphone located on outside platform between cars

quieter than operation on the Red Line proper or the Ashmont Extension. The main reason for this being that operation on the So. Shore Extension included travel on high quality rail bed, welded rail construction and 100% surface line travel. The highest noise levels were measured when the train negotiated the Neponset River Bridge and the Savin Hill Flyover both elevated concrete structures.

Table 7-2 is a tabulation of typical coincident noise and vibration levels recorded on the MBTA Red Line to compare the many varied line conditions. Points selected were chosen where the speed of the train was essentially constant to obtain a representative level unaffected by acceleration and deceleration.

TABLE 7-2 TYPICAL COINCIDENT IN-CAR NOISE AND FLOOR VIBRATION LEVELS-MBTA RED LINE, PULLMAN STANDARD, MBTA TYPE 1 SO. SHORE RAPID TRANSIT CARS

2-Car Train Serial Nos 1503,1506 - April 29, 1972

Operating Situation	Track Condition ⁺	Speed mph	Peak rms Noise Level dBA at Location*			Peak rms Acceleration Level** dB re 10 ⁻⁶ g		
			1	2	3	z-axis	x-axis	y-axis
Cruising	A,G	51	69	72	90	83	74	72
Cruising	A,G,F	46	75	78	100	80	70	69
Cruising	B,G,E	44	78	81	105	89	80	79
Cruising	C,G	52	74	80	100	86	76	76
Cruising	C,G,E	36	74	78	100	86	76	74
Cruising	C,D	48	81	86	108	86	78	78
Cruising	C,D,H	30	79	84	108	89	79	77

*Location 1 - Microphone located mid-car inside

Location 2 - Microphone located over rear wheel trucks inside

Location 3 - Microphone located on outside platform between cars

**Triaxial accelerometer mounted on floor tiles over rear wheel trucks.

- A) Welded rail, new rail bed, concrete ties
- B) Welded rail fastened to concrete bridge deck
- C) Non-welded rail, old rail bed, wood ties
- D) Subway
- E) Elevated Structure
- F) Under 8 Lane Highway
- G) Surface Line
- H) Sharp Curve "Wheel Squeal"

Figures E-2 through E-5 contain the expanded coincident time histories at the three in-car microphone locations along with the associated 1/3-octave frequency spectra of events on the northbound track of the So. Shore Extension of the Red Line which was selected for analysis. Figures E-16 through E-18 contain analyses of selected events northbound on the Ashmont Extension of the Red Line. Figures E-20 and E-21 contain analyses of selected events southbound on the So. Shore Extension of the Red Line. (See time histories, figures E-1, E-15 and E-19, to locate events on each line with relation to one another.) Where applicable, the integration periods chosen for spectral analysis have been located on the expanded history at the proper point in time.

Figures E-2 and E-3 contain data analysis northbound at the Tenean St. wayside measurement site. Shown on the expanded history also are the increases in noise level due to tunnel effects as the train went under the Redfield St. Bridge and under the 8-lane Southeast Expressway. Figures C-4 and C-5 show wayside measurements made on April 27, 1972 as the test train Serial Nos 1503 and 1506 passed this measurement point on a revenue run northbound.

Figures E-4 and E-5 contain analyses and data as the test train negotiated the Neponset River Bridge northbound. The 12 dB increase in noise level is due to the drastic change in the rail bed from high-quality ballast (which tends to absorb sound and vibration) to a highly resonant bridge deck constructed of concrete over rolled steel girders, with rails fastened into the concrete on 1/2-inch neoprene pads. The Savin Hill Flyover (figure E-1) is of a similar construction and shows a similar increase in noise level.

Figures E-6 and E-7 contain data and analysis as the test train entered the subway just before Andrew Station on the Red Line and negotiated a sharp right hand curve. Figure E-7 is the spectral analysis of the "wheel squeal".

No expanded time histories are included for figures E-8 through E-14; figure E-1 shows complete noise history.

Figure E-8 is the spectral analysis at the crest of the Long-fellow Bridge. Figure E-9 is the spectral analysis at the Cambridge end of the bridge at a point where the tracks are below grade level, essentially a two-track tunnel with no roof.

The MBTA Red Line subway system is made up of various tunnels with different cross-sections. Figures E-10 through E-14 are the noise spectral analyses at points in the subway system with different tunnel configurations. The cross-sectional data for these locations are included in appendix J; figures J-2 through J-7, respectively. A comparison of the frequency spectra of the noise data recorded at the microphone on the outside platform between cars at each of the six locations shows resonant peaks due to tunnel acoustics associated with the configuration of the tunnel. Note that the analysis of the two-section tunnel (figure E-11) with the smallest dimensions has a peak at 400 Hz, while the larger two-track tunnels peak at higher frequencies.

Figure E-16 is the noise-frequency spectra in the subway tunnel between Ashmont and Shawmut Stations on the Ashmont Extension of the Red Line (figure J-8 shows tunnel cross section).

Figure E-17 is the noise-frequency spectra on a straight section of surface track between Fields Corner and Savin Hill stations. Note that noise levels of 74, 80, and 100 dbA were generated by the test train at a speed of 52 mph at the three microphone locations on this section of non-welded track with wood ties.

Figure E-18 is the noise spectra recorded at the Savin Hill Station with the train stopped and the train door open. Levels of 68, 64, and 73 dbA were measured. Each car in the test train was equipped with a motor generator. The major noise source is the operation of the motor generator at a mid-car location under the cars.

Figures E-20 and E-21 contain expanded time histories and noise spectra at the three in-car microphone locations southbound on the straight section of surface track by the Tenean St. wayside measurement site area. A comparison of levels measured at a train speed of 50 mph, 69, 77 and 90 dBA on this track, with levels measured of 71-, 75-, and 92-dBA at 51 mph measured on the northbound track at Tenean St. measurement site (figure E-3) again confirms a configuration condition with the northbound track and/or rail bed. (See discussion in sections 3, 4, 5, and 6.) In addition, a comparison of the above data measured on welded track with the data measured on a non-welded section of track shows the marked effect that track condition has on the noise level generated.

8. IN-CAR FLOOR-VIBRATION LEVEL MEASUREMENT-MBTA RED LINE
APRIL 29, 1972 (0100 TO 0400 HOURS)

Appendix F contains time-histories, and 1/3-octave frequency spectra of the in-car floor-vibration level measurements in a 2-car train made up of MBTA Type 1 So. Shore Rapid Transit Cars.

These vibration measurements made on April 29, 1972 were recorded simultaneously with the noise measurements recorded at three locations in the cars and discussed in section 7.

A 2-car train with Serial Nos 1503 and 1506 was selected for this test since wayside noise and ground vibration data were recorded on this pair during revenue service on April 27, 1972 (sections 5 and 6). The lead car of this 2-car train (Serial No. 1503) was instrumented for noise and vibration measurements (figure G-2 shows microphone and vibration transducer locations). A triaxial accelerometer was mounted on the floor tiles centered over the rear wheel trucks with a thin layer of bee's wax. Measurements were made in the subways and on the surface lines of the MBTA Red Line Proper and the Ashmont and So. Shore Extension of the Red Line on a typical run during the early morning hours of April 29, 1972 when no revenue service was being provided on these lines.

Figures F-1, F-15 and F-19 contain coincident time histories of the rms acceleration levels in these three axes (x-axis longitudinal motion; y-axis, lateral motion; z-axis, vertical motion) of floor vibrations at a point centered over the rear wheel trucks of the test car on various sections of the Red Line. These graphic histories plotted in dB re 10^{-6} g vs Time, is in time coincidence with the noise level histories plotted in figures E-1, E-15 and E-19 respectively. Coincident values of speed data have been superimposed only on the noise time-history charts (figures E-1, E-15, and E-19.)

Figure F-1 contains vibration data obtained northbound from the Quincy Center Station, Quincy, MA, on the So. Shore Extension of the Red Line to the end of the Red Line at Harvard Station,

Cambridge, MA. This is the normal route for the Type 1 transit cars and includes many varied rail and road bed conditions including travel on surface lines, in subways of various cross sections, on elevated structures, and on both welded and non-welded rails. The Tenean St. wayside measurement site is identified on history between the No. Quincy and Andrew Stations.

Figure F-15 contains vibration data obtained between Ashmont and Columbia Stations, Dorchester, MA on the Ashmont Extension of the Red Line. The Type 1 transit cars are not normally run on this extension of the Red Line which contains both surface and subway travel on an old rail bed, wood ties, and non-welded rails.

Figure F-19 contains vibration data obtained southbound on the So. Shore Extension of the Red Line between Columbia and the Quincy Center Station. Only during this run was the instrumented car (Serial No. 1503) the rear car of the 2-car train. The Tenean St. wayside-measurement site has been located on the time history.

Table 7-1 is a tabulation of typical coincident noise and vibration levels recorded on the Red Line to compare the many varied line conditions. Points selected from figures F-1, F-15, and F-19 were chosen where the speed of the train was essentially constant to obtain a representative level unaffected by acceleration and deceleration. The three sections of the Red Line can be physically described on the whole as follows:

- a. So. Shore Extension (figures F-1 and F-19) - Quincy Center Station to Columbia Area, Dorchester, MA (new rail Bed; welded rail construction, concrete ties with neoprene pads under rails, surface line).
- b. Red Line (figure E-1) - Columbia Station Dorchester, MA to Harvard Station, Cambridge, MA (old rail bed, non-welded rails, wood ties on ballast, 95 percent subway travel).
- c. Ashmont Extension (figure F-15) - Ashmont to Columbia Stations, Dorchester, MA (old rail bed, non-welded rails, wood ties on ballast, 25 percent subway travel).

Figures F-2 through F-5 contain the expanded coincident time histories of the rms acceleration level in three axes along with the associated 1/3-octave vibration spectra of events selected

for analysis on the northbound track for the So. Shore Extension of the Red Line. Figures F-6 through F-14 contain analysis of selected events northbound on the Ashmont Extension of the Red Line. Figures F-20 and F-21 contain analysis of selected events southbound on the So. Shore Extension of the Red Line. See time-histories figures F-1, F-15 and F-19 to locate events on each line with relation to one another.

For the purpose of comparison the same events selected for analysis in section 7 are presented (figures F-1, F-15 and F-19).

Where applicable the integration period chosen for vibration spectral analysis has been located on the expanded time history at the proper point in time and are in time coincidence with the integration period chosen for the noise spectral analysis of section 7.

Figures F-2 and F-3 contain data and analyses northbound at the Tenean St. wayside measurement site. Also shown on the expanded time history are points corresponding to where the test train crossed the Walnut and Taylor St. Bridges and where the train went under Redfield St. and the 8 lane Southeast Expressway. Note the absence of a vibration peak (figure F-2) corresponding to the point at which the train went under the SE Expressway and Redfield St.. This confirms the increase in noise levels noted in figure E-2 at these points is a result of tunnel effects. Note also approximately a 2 db increase in the vibration level in the vicinity of the wayside measurement site. This increase is not noted on the data recorded on the southbound track (figure F-20). Figures E-2 and E-3 show the in-car noise level measurements at this point. Figures C-4, C-5 and D-4, D-5 show wayside noise-and-ground-vibration level measurements which were made on April 27, 1972 as the test train (Serial Nos 1503 and 1506) passed the measurement point on a northbound revenue run.

Figures F-4 and F-5 contain vibration data and analyses as the test train negotiated the Neponset River Bridge northbound. Note the increase in vibration level due to the drastic change

in rail bed from high-quality concrete ties in ballast to a bridge deck constructed of concrete over rolled steel girders with the rails on 1/2-inch neoprene pads fastened directly into the concrete. The Savin Hill Flyover (figure F-1) is of a similar construction and shows a similar increase in vibration levels. Figures E-4 and E-5 show the coincident noise-level measurements.

Figures F-6 and F-7 contain vibration data and analyses as the train entered the subway and negotiated a sharp right-hand curve just before Andrew Station on the Red Line. Corresponding noise data are included in figures E-6 and E-7.

Figures F-8 through F-14 contain analyses at points at the crest and end of the Longfellow Bridge and at various points of different tunnel configuration. These points are in time coincidence with noise data present in figures E-8 through E-14. It is interesting to note that little difference is seen in the three-axes vibration spectra between points although the noise spectra show differences as a result of tunnel acoustics.

Figure F-16 is the frequency analyses of vibration data in the subway tunnel between Ashmont and Shawmut stations on the Ashmont Extension of the Red Line. As above in the main tunnel of the Red Line, little difference is noted in the vibration spectra.

Figure F-17 is the frequency spectra of vibration levels measured on a straight section of surface track between Fields Corner and Savin Hill stations. Note that 86-, 76-, and 76-dB levels were generated in the z-, x-, and y-axes, respectively, at a speed of 52 mph on this section of non-welded track with wood ties.

Figure F-18 is the vibration spectra recorded at the Savin Hill station with the train stopped and the doors open (55-, 55-, and 53-dB re 10^{-6} g levels were measured, respectively). The major contributor to the acceleration levels recorded was the operation of the motor generator at a mid-car location under the cars.

Figures F-20 and F-21 contain expanded time histories and floor-vibration spectra in the z-, x-, and y-axes southbound on the straight section of surface track by the Tenean St. wayside measurement site. A comparison of levels, measured at train speeds of: 50 mph, 82-, 73-, and 72-dB in the z-, x-, and y-axes, respectively, on this section of welded track (concrete ties), with those at 52 mph, 87-, 78-, and 76-dB on non-welded track (wood ties) (Figure F-17), illustrates the effect of track condition on the floor accelerations generated.

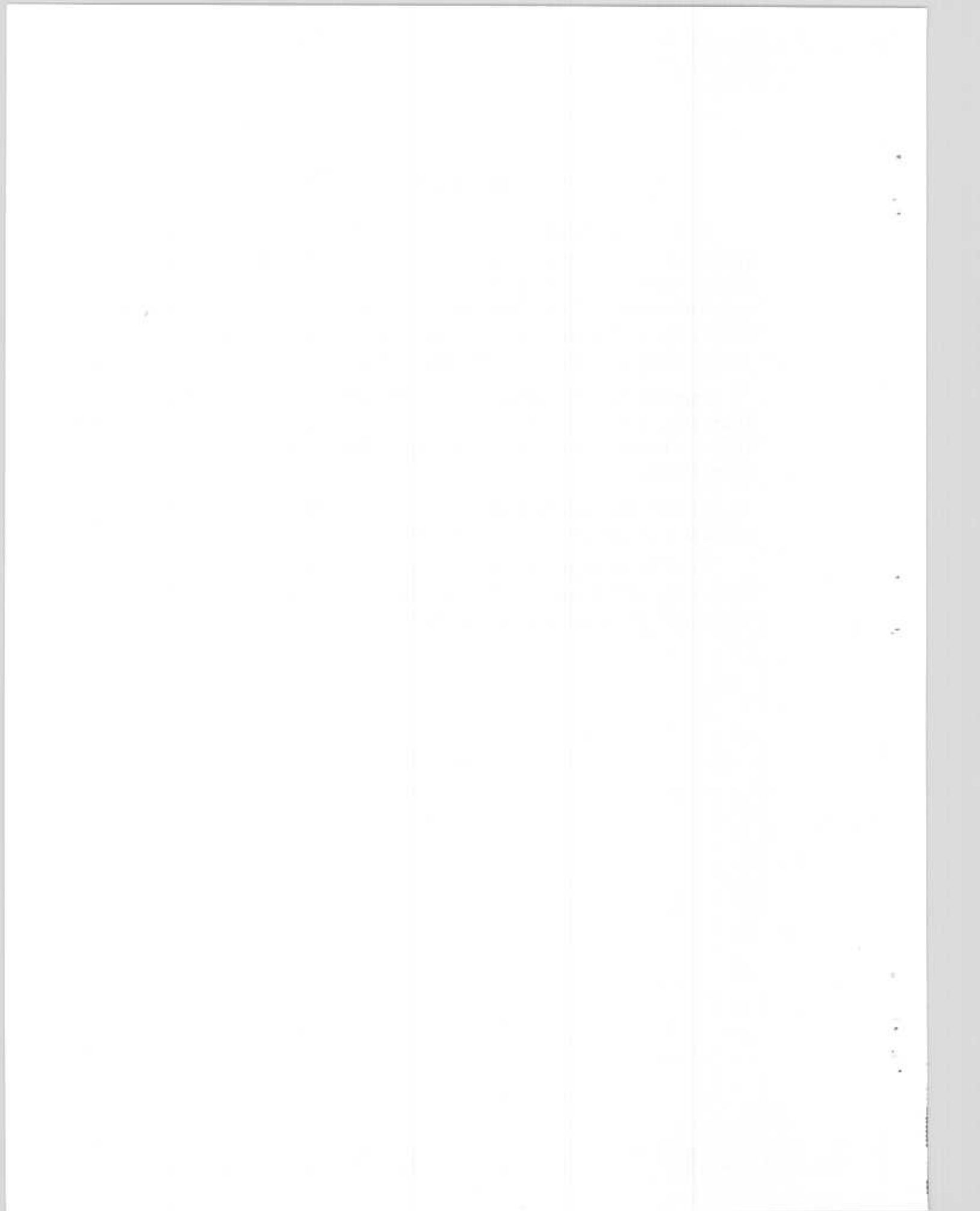
9. OBSERVATIONS AND COMMENTS

A review and comparison of in-car noise and vibration measurements made over various sections of the Red Line indicate that the South Shore Extension represents a significant improvement over the older sections of the Red Line with respect to the generation of noise and vibration. This improvement stems from the high-quality track bed with concrete ties and welded rail construction (table 7-2).

Wayside measurements made at six-month intervals indicate an improvement of the noise and vibration characteristics of the South Shore Extension resulting from track bed settling by normal line operations.

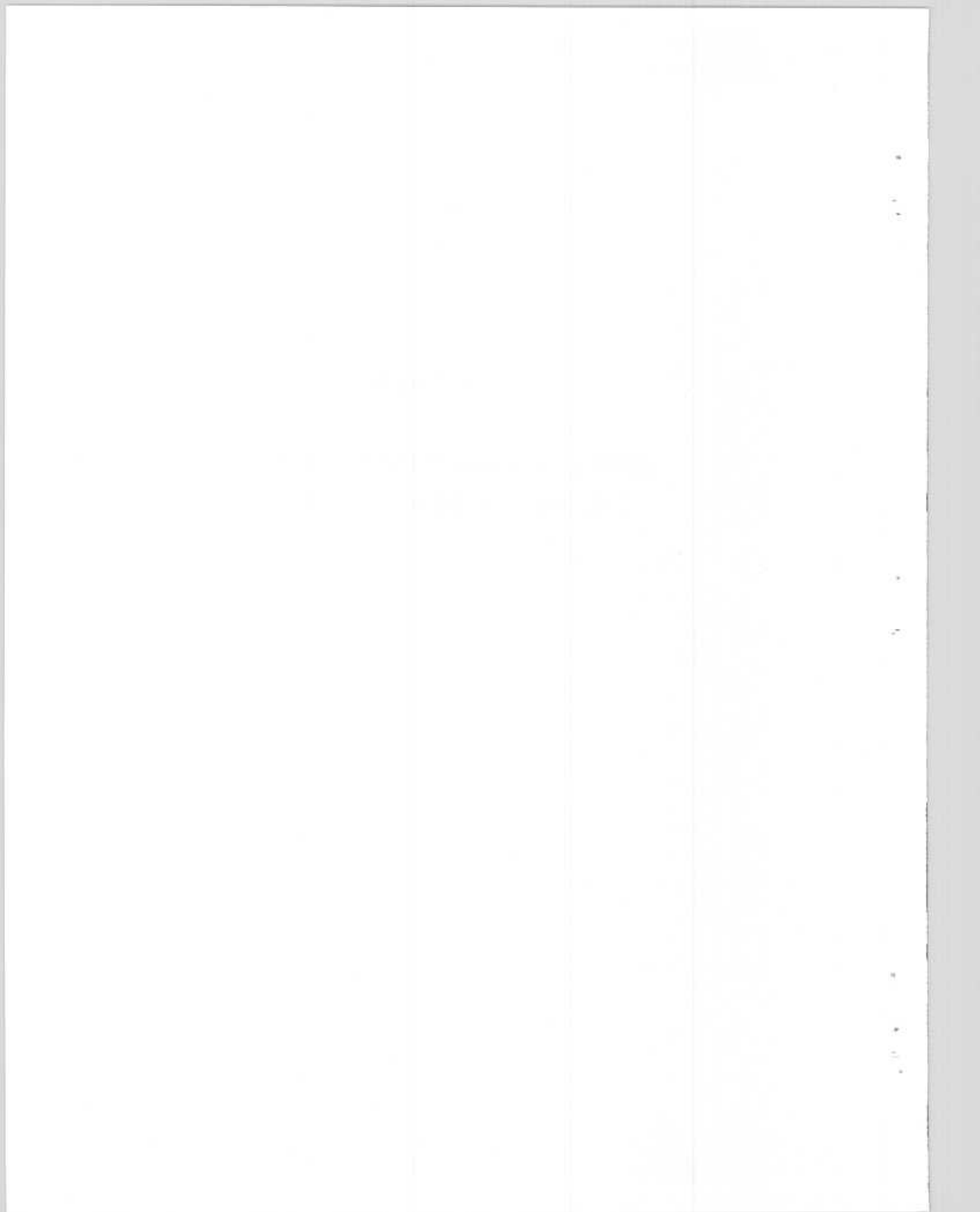
In-car measurements were made with no passengers in the cars and all air-conditioning equipment off.

Wayside measurements were made during revenue service. Trains traveling southbound by the Tenean Street measurement site were more heavily laden with passengers than were the northbound trains.



APPENDIX A

WAYSIDE NOISE MEASUREMENTS - MBTA RED LINE
(SO. SHORE EXTENSION) - OCTOBER 28, 1971



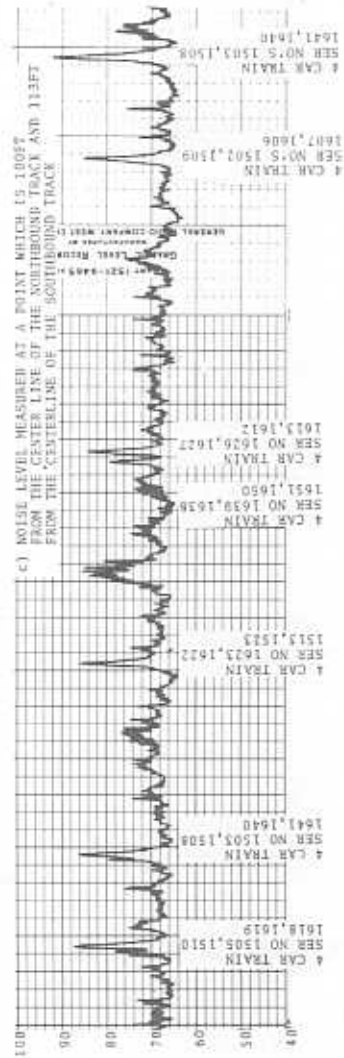
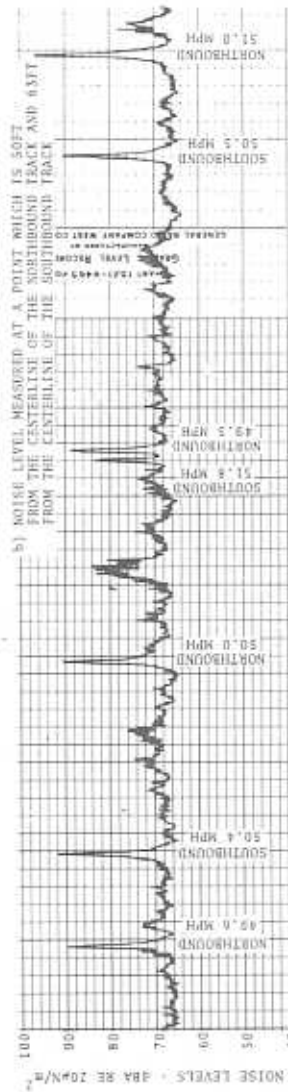
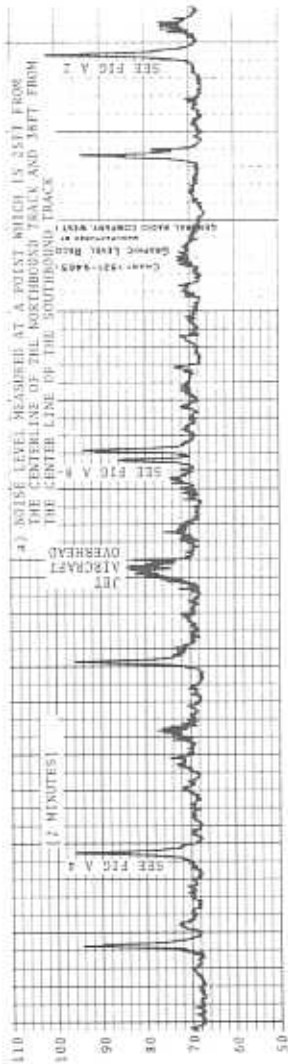


Figure A-1. Coincident Time Histories - Wayside Noise Levels. MBTA Red Line (South Shore Extension) October 28, 1971. Microphones placed 6.1 ft above level grade and 3 ft above rail tops. See figure G-1 for microphone locations.

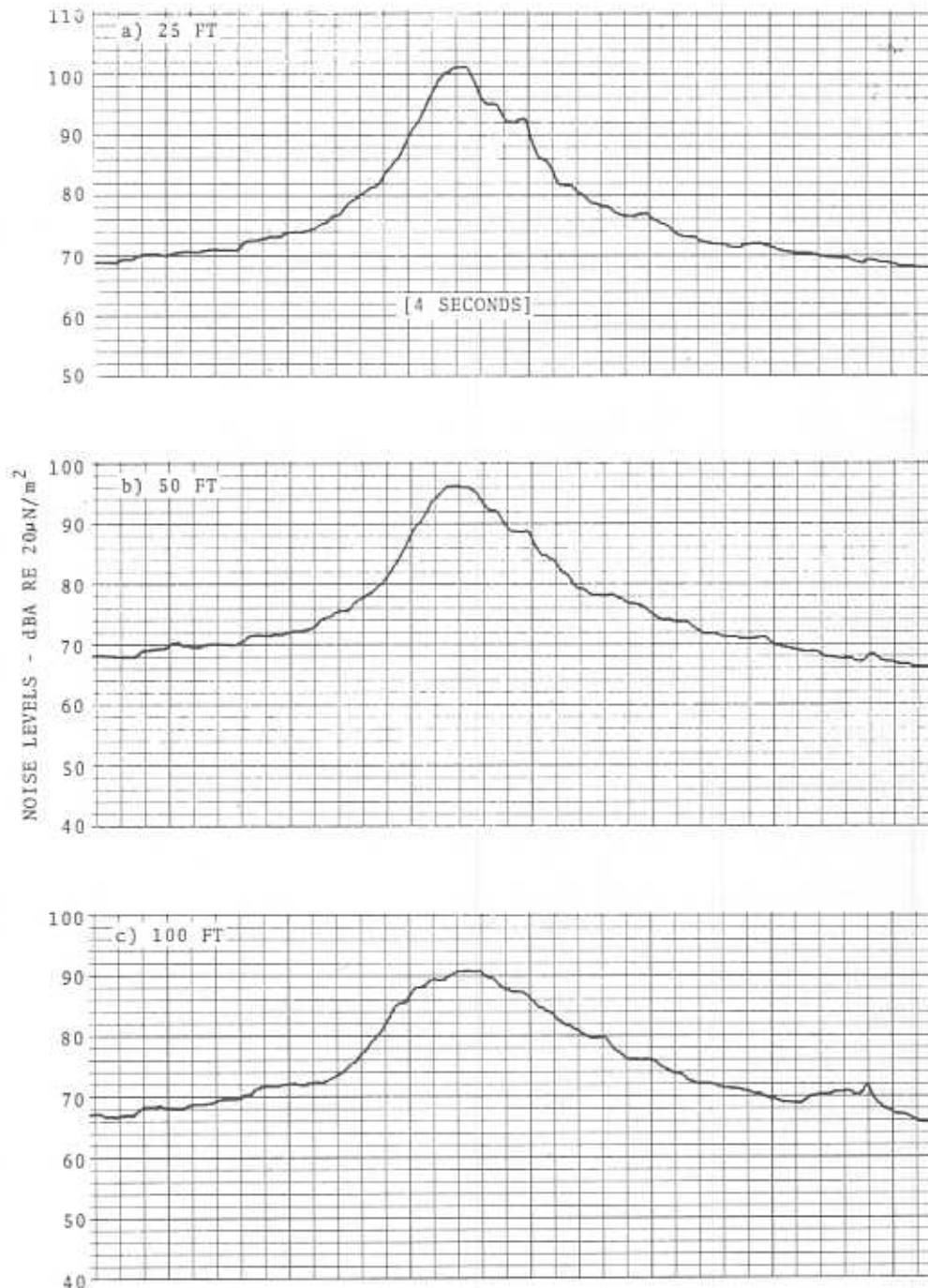


Figure A-2. Coincident Time Histories - Wayside Noise Levels at 25, 50, and 100 ft from centerline at northbound track. MBTA Redline (So Shore Extension) Oct. 28, 1971. Four-Car Train northbound Ser. Nos 1503, 1508, 1641, 1640 at 51.0 mph. See figure A-1.

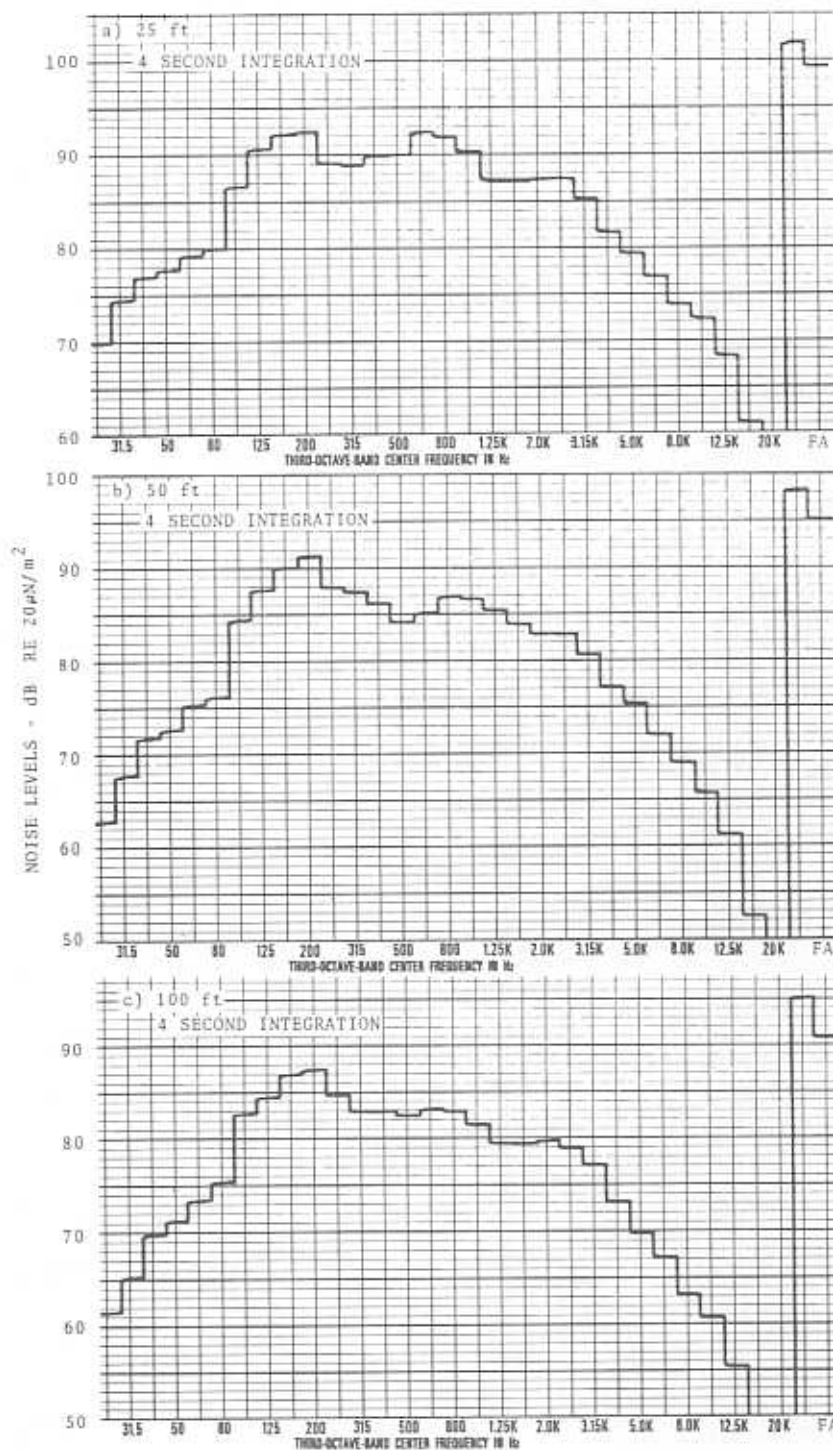


Figure A-3. Wayside Noise Spectra at 25, 50, and 100 ft from center line of northbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four-Car Train northbound Ser. Nos 1503, 1508, 1641, 1640 at 51.0 mph. See figure A-2.

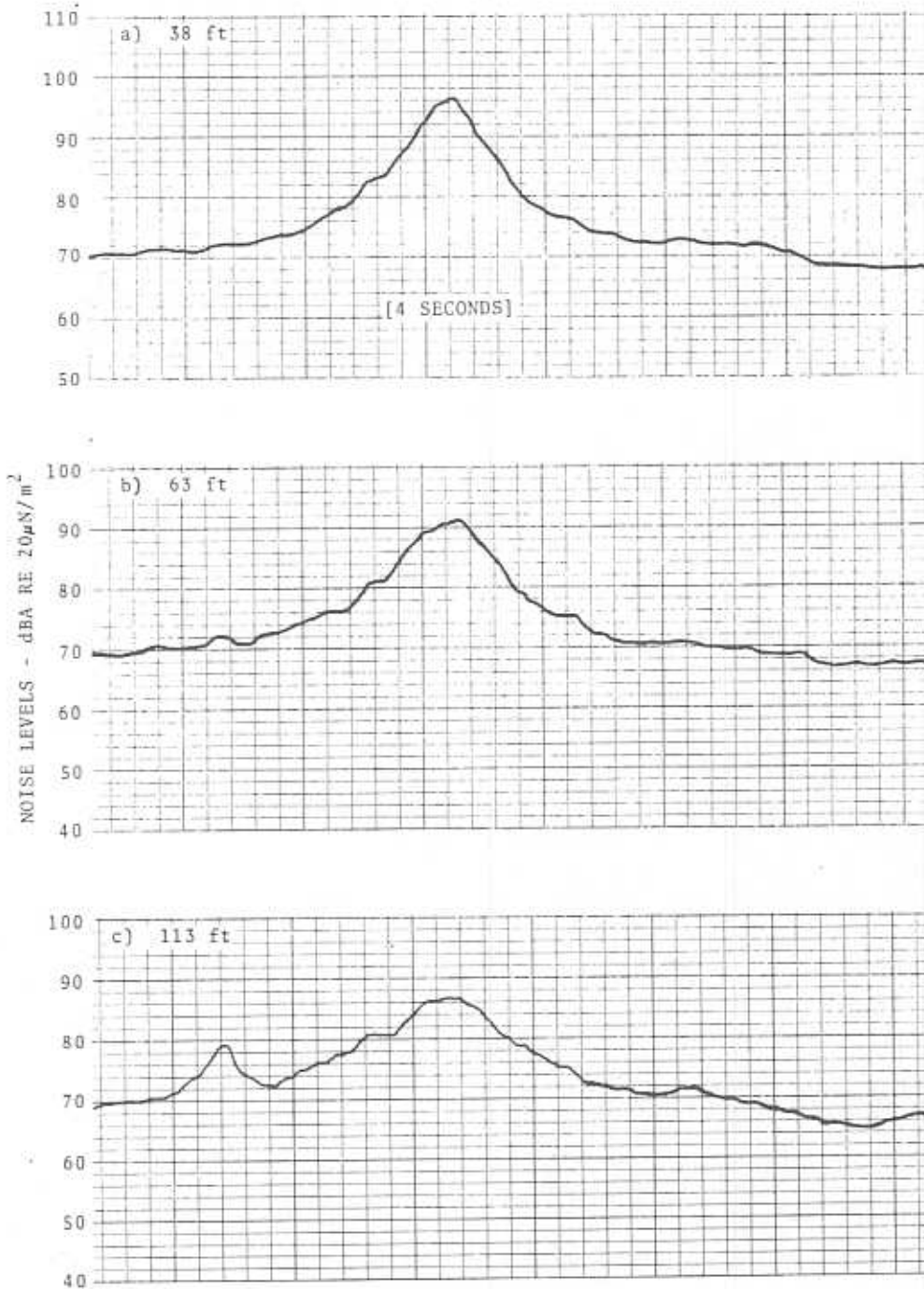


Figure A-4. Coincident Time Histories - Wayside Noise Levels at 38, 63, and 113 ft. from centerline of southbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four-Car Train southbound. Ser. Nos 1503, 1508, 1641, 1640 at 50.4 mph. See figure A-1.

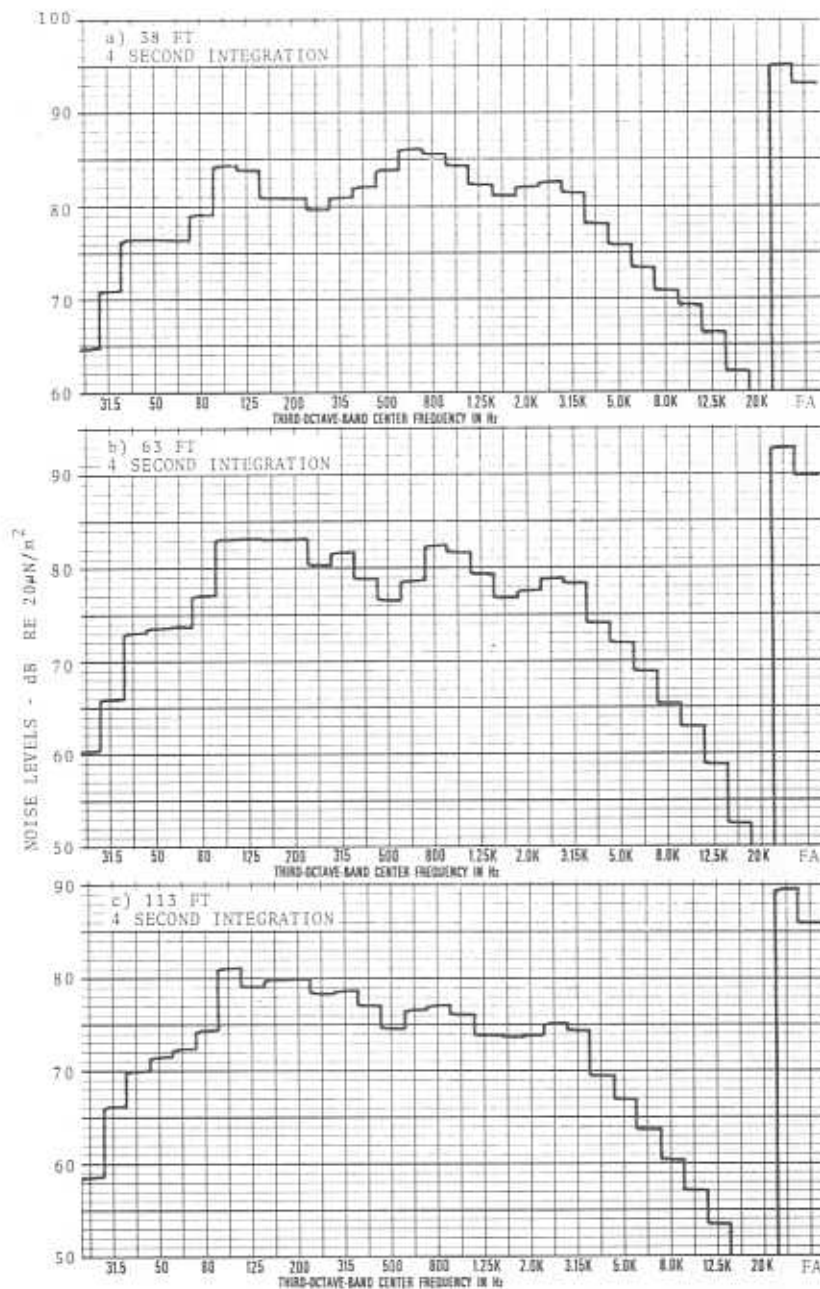


Figure A-5. Wayside Noise Spectra at 38, 63, and 113 ft from centerline of southbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four Car Train southbound, Ser. Nos 1503, 1508, 1641, 1640 at 50.4 mph. See figure A-4.

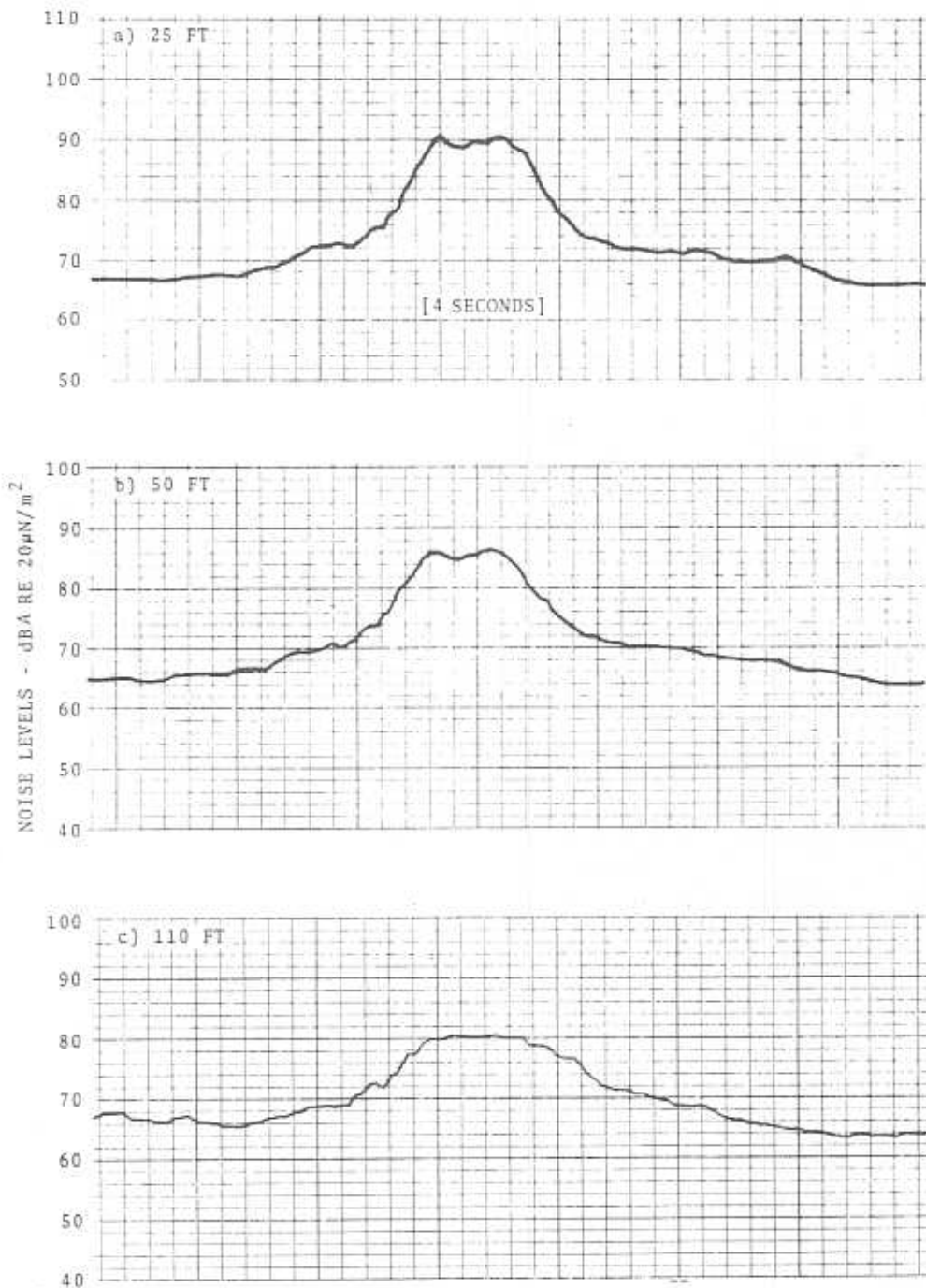


Figure A-6. Coincident Time Histories - Wayside Noise Levels at 25, 50, and 100 ft from centerline of northbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four Car Train northbound Ser. Nos 1639, 1638, 1650, 1651 at 51.0 mph. See figure A-1.

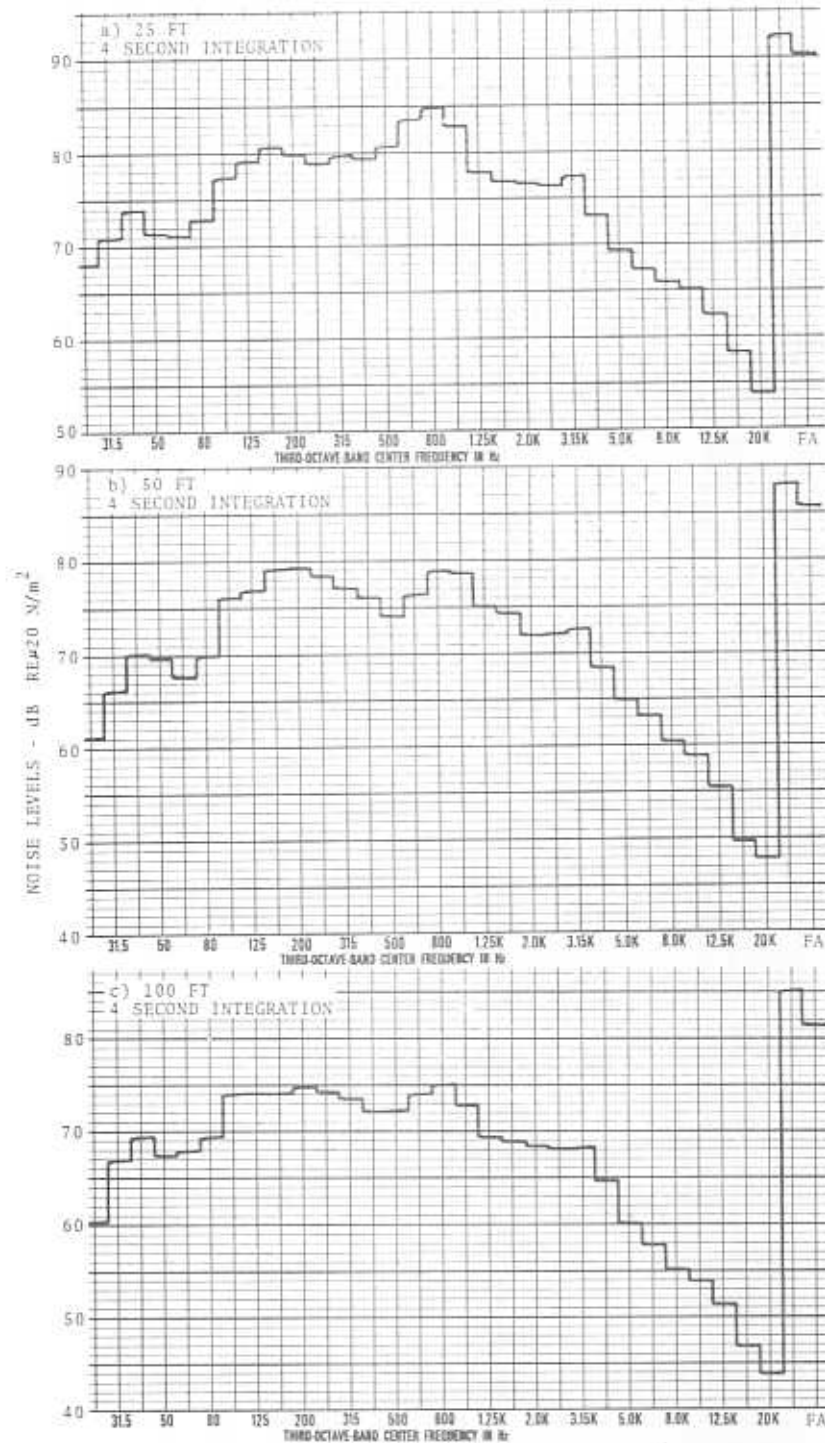


Figure A-7 Wayside Noise Spectra at 25, 50, and 100 ft from centerline of northbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four-Car Train northbound Ser. Nos 1639, 1638, 1650, 1651 at 51.0 mph. See figure A-6.

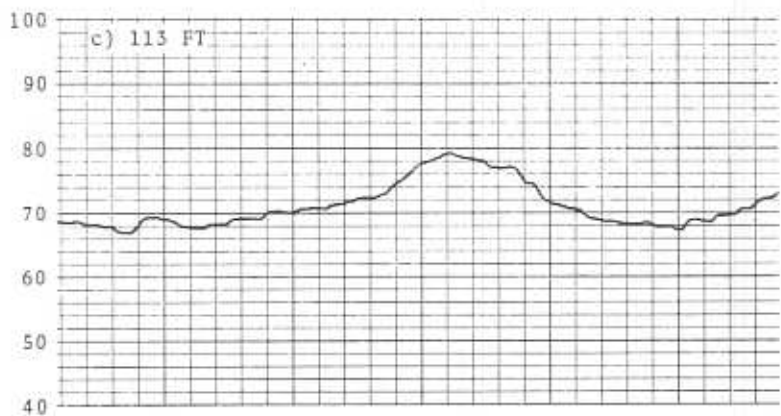
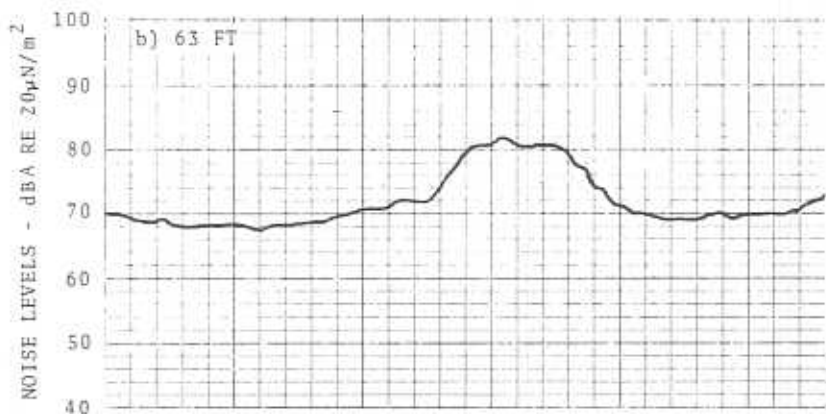
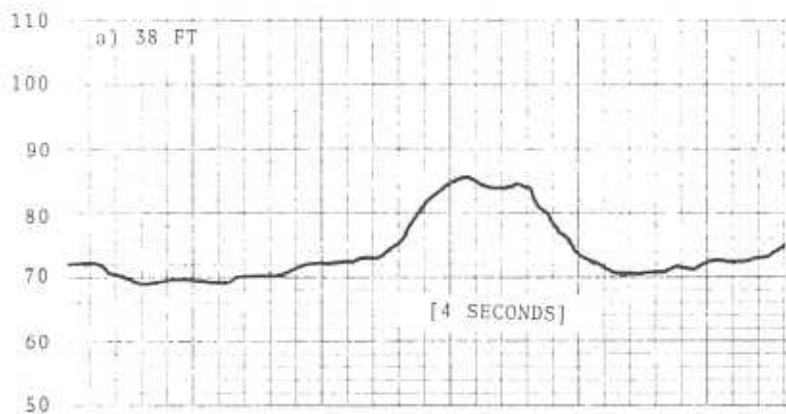


Figure A-8. Coincident Time Histories - Wayside Noise Levels at 38, 63, and 113 ft from centerline of southbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four-Car Train southbound Ser. Nos 1639, 1650, 1651 at 51.8 mph. See figure A-1.

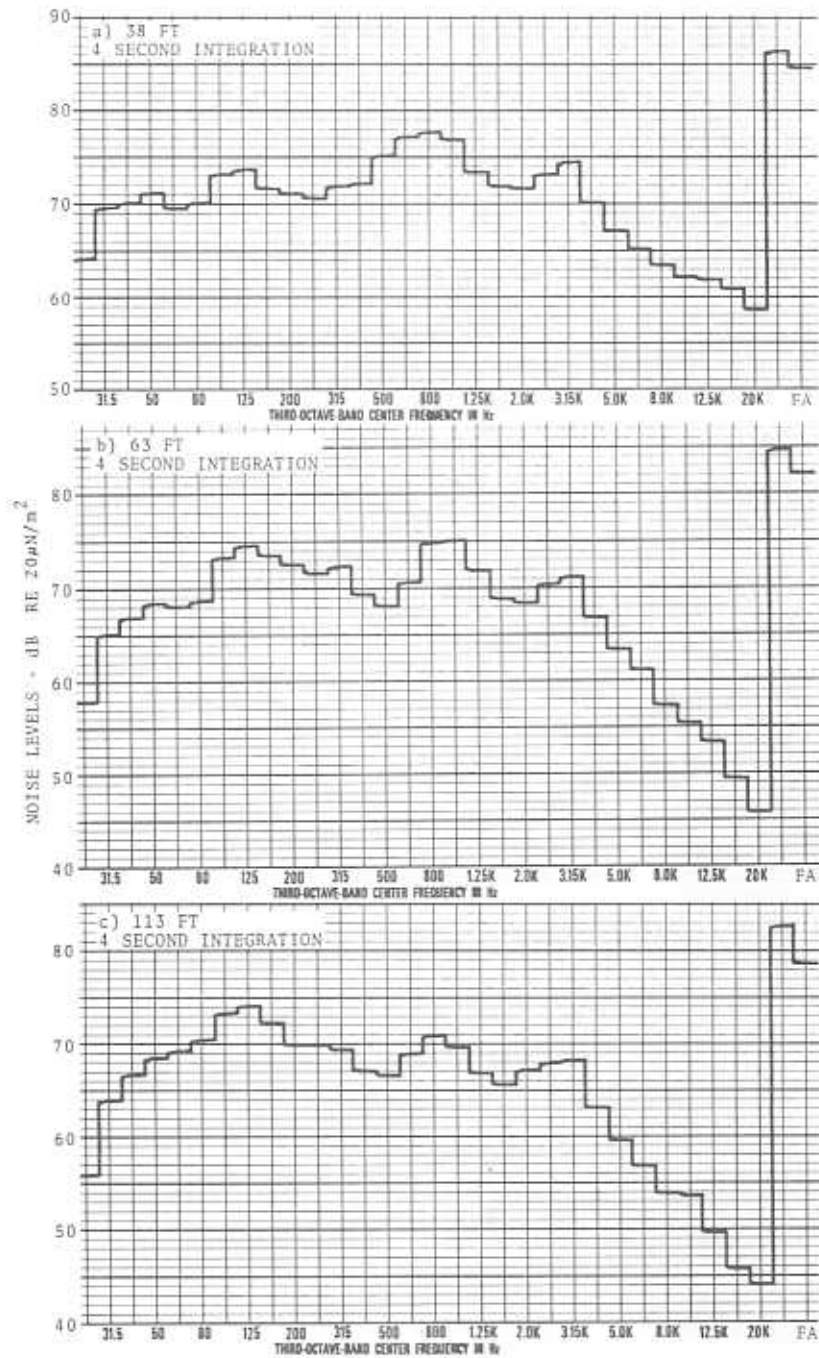


Figure A-9. Wayside Noise Spectra at 38, 63, and 113 ft from the centerline of southbound track. MBTA Red Line (So Shore Extension) Oct 28, 1971. Four-car train southbound, Ser. Nos 1639, 1638, 1650, 1651 at 51.8 mph. See figure A-8.

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

TUE 07/25/72
 15:16

NOISE DATA FROM RUN NO. RT-20-72-3A OF THE MOBILE NOISE LABORATORY ON
 OCT. 28 1971 FROM 15:46 TO 16:46 ON TENEAN ST. DORCHESTER, MASS.
 (ZONE 19 UNIVERSAL GRID LOCATION 331.61 - 4683.68 .)
 MICROPHONE LOCATED 25FT. FROM CENTERLINE NEAR TRACK (NORTHBOND)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

DISTRI
 BUTION DBA*

2 103 +
 13 102 +
 9 101 +
 9 100 +
 14 99 +
 8 98 +
 19 97 +
 25 96 +
 27 95 +
 34 94 +
 33 93 +
 32 92 +
 43 91 +
 39 90 +
 56 89 +
 77 88 +
 70 87 +
 92 86 +
 108 85 +
 130 84 +
 126 83 +
 165 82 +
 172 81 +
 203 80 +
 274 79 +
 295 78 +
 309 77 +
 373 76 +
 518 75 +
 624 74 +
 802 73 +
 1314 72 +
 1911 71 +
 3045 70 +
 5301 69 +
 6163 68 +
 4807 67 +
 1455 66 +
 101 65 +
 2 64 +
 0 63

SAMPLES= 28800
 AVERAGE= 70.2 DBA*
 STANDARD DEVIATION= 4.6 DBA*
 ENERGY MEAN= 78 DE**
 NOISE POLLUTION LEVEL= 89.8
 1% PERCENTILE= 90.5 DBA*
 10% DECILE= 75.8 DBA*
 MEDIAN= 69.4 DBA*
 90% DECILE= 67.3 DBA*
 99% PERCENTILE= 66.1 DBA*
 WALSH HEALEY EXP.= 2.9 %
 RANGE= 39 DB

LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure A-10. Statistical Analysis - Wayside Noise Data - MBTA Red Line-25 ft.
 (So. Shore Extension), October 28, 1971

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

TUE 07/25/72
 15:02

NOISE DATA FROM RUN NO. RT-20-72-2A OF THE MOBILE NOISE LABORATORY ON
 OCT. 28 1971 FROM 15:46 TO 16:46 ON TENEAN ST. DORCHESTER, MASS.
 (ZONE 19 UNIVERSAL GRID LOCATION 331.61 - 4683.68 .)
 MICROPHONE LOCATED 50 FT. FROM CENTERLINE NEAR TRACK (NORTHBOUND)
 (1/8 SECOND INTEGRATIONS, 3 PER SECOND)

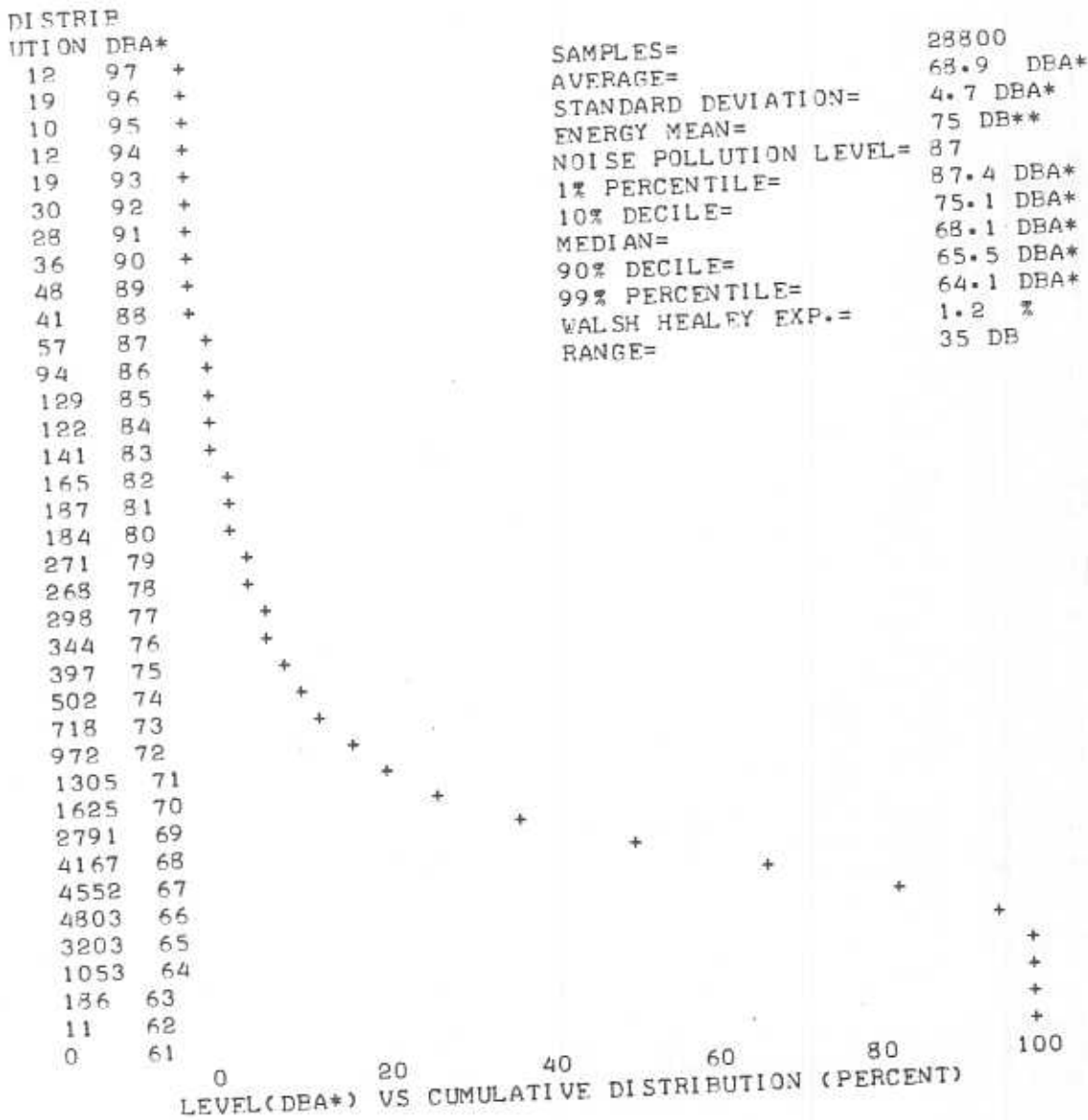


Figure A-11. Statistical Analysis - Wayside Noise Data - MBTA Red Line-50 ft.
 (So. Shore Extension), October 28, 1971

12	97	0			
19	96	0			
10	95	0			
12	94	0			
19	93	0			
30	92	0			
28	91	0			
36	90	0			
48	89	0			
41	88	0			
57	87	0			
94	86	00			
129	85	00			
122	84	00			
141	83	00			
165	82	00			
187	81	00			
184	80	00			
271	79	000			
268	78	00			
298	77	000			
344	76	000			
397	75	000			
502	74	0000			
718	73	00000			
972	72	000000			
1305	71	00000000			
1625	70	0000000000			
2791	69	0000000000000000			
4167	68	000000000000000000000000			
4552	67	000000000000000000000000			
4803	66	000000000000000000000000			
3203	65	00000000000000000000			
1053	64	0000000			
186	63	00			
11	62	0			
DIST.	DBA*	0	10	20	30
LEVEL(DBA*) VS DISTRIBUTION (PERCENT)					

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure A-11 (Continued). Statistical Analysis - Wayside Noise Data - MBTA
 Red Line (So. Shore Extension), October 28, 1971
 50 ft

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

TUE 07/25/72
 14:05

NOISE DATA FROM RUN NO. RT-20-72-1A OF THE MOBILE NOISE LABORATORY ON
 OCT. 28 1971 FROM 15:46 TO 16:46 ON TENEAN ST. DORCHESTER, MASS.
 (ZONE 19 UNIVERSAL GRID LOCATION 331.61 - 4683.68 .)
 MICROPHONE LOCATED 100FT. FROM CENTERLINE NEAR TRACK (NORTHBOUND)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

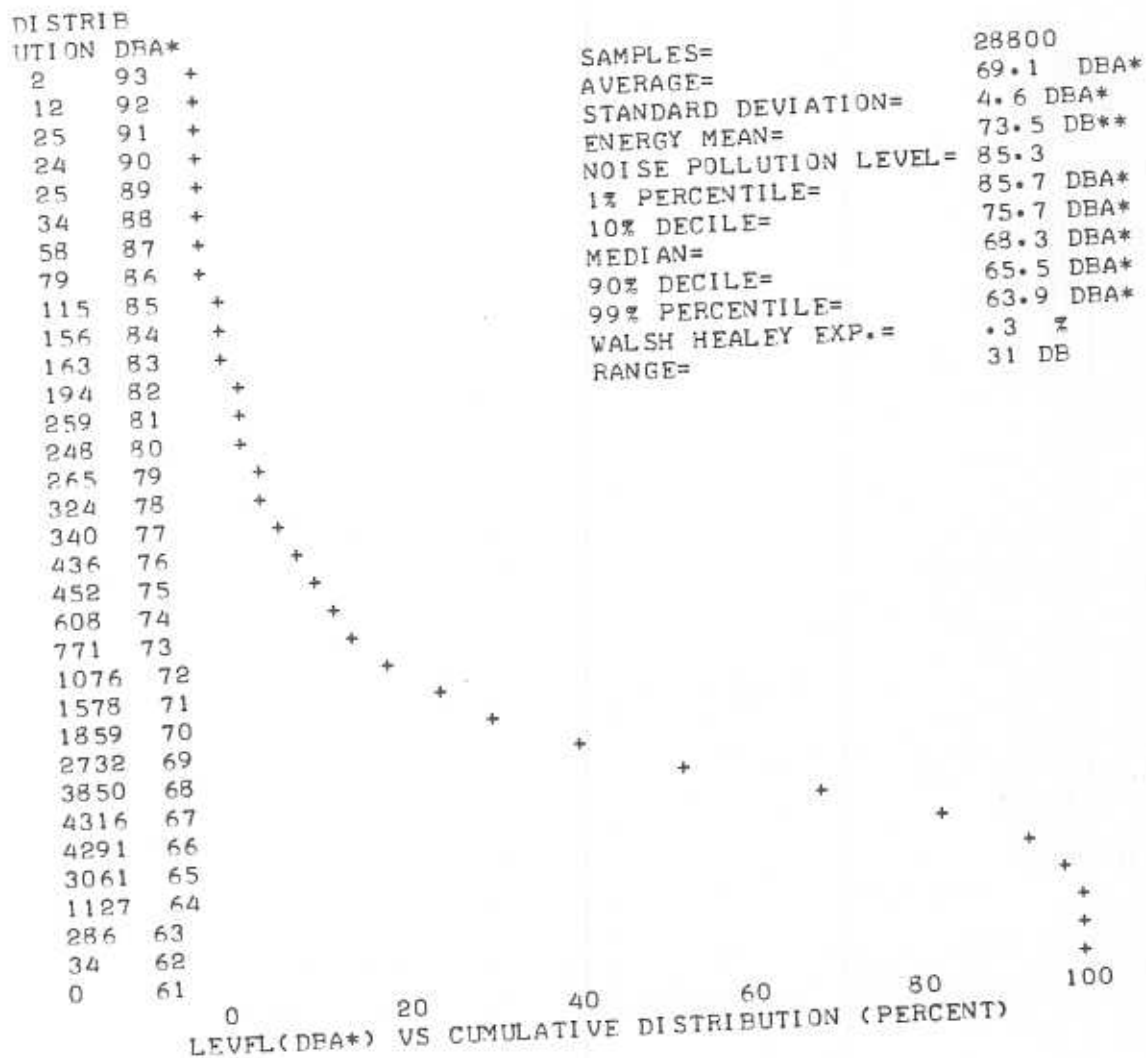


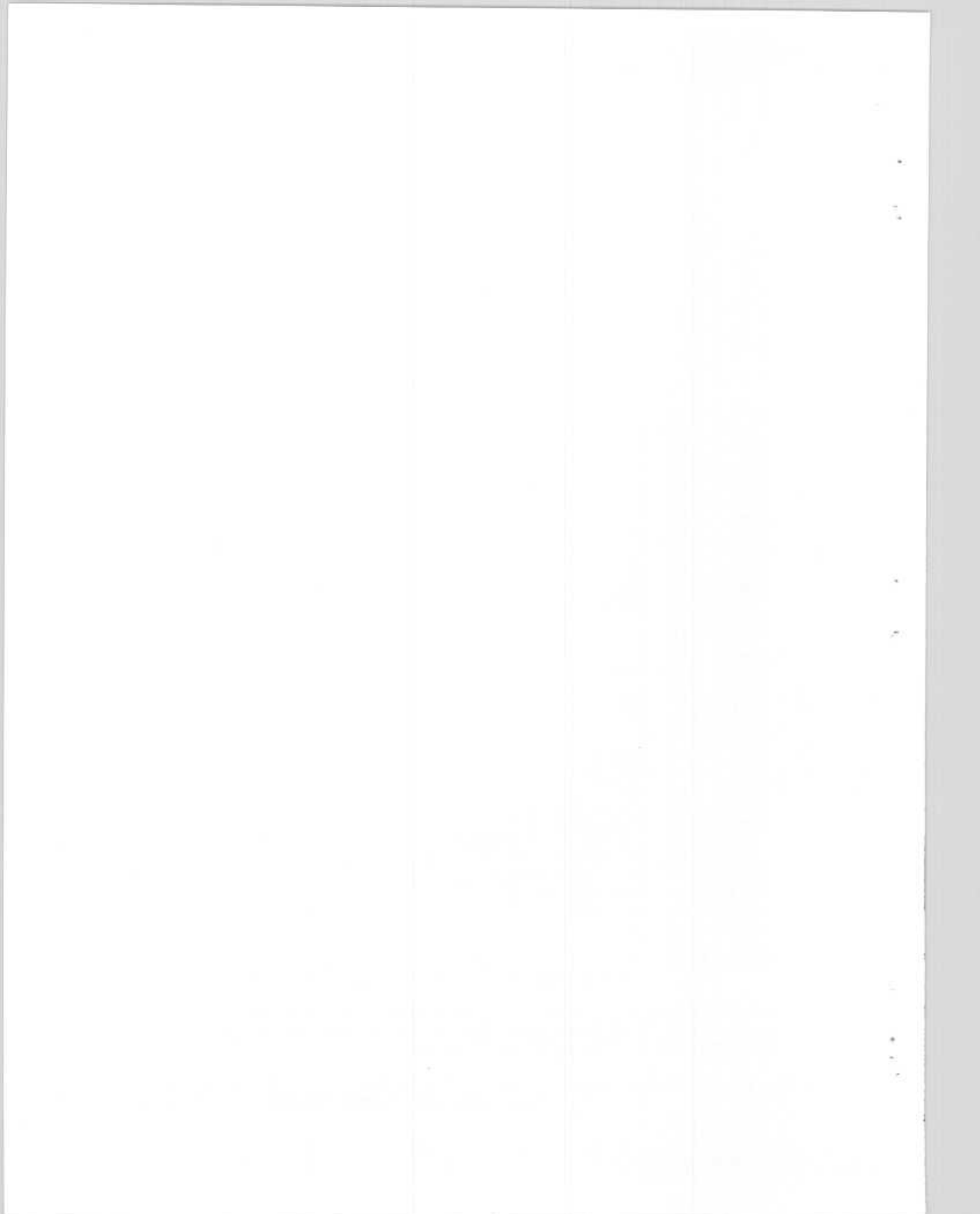
Figure A-12. Statistical Analysis - Wayside Noise Data - MBTA Red Line-100 ft.
 (So. Shore Extension), October 28, 1971

DIST.	DBA*	0	10	20	30
2	93	0			
12	92	0			
25	91	0			
24	90	0			
25	89	0			
34	88	0			
58	87	0			
79	86	00			
115	85	00			
156	84	00			
163	83	00			
194	82	00			
259	81	00			
248	80	00			
265	79	00			
324	78	000			
340	77	000			
436	76	000			
452	75	000			
608	74	0000			
771	73	00000			
1076	72	0000000			
1578	71	000000000			
1859	70	00000000000			
2732	69	000000000000000			
3850	68	0000000000000000000			
4316	67	000000000000000000000			
4291	66	000000000000000000000			
3061	65	00000000000000000			
1127	64	0000000			
286	63	000			
34	62	0			

LEVEL(DBA*) VS DISTRIBUTION (PERCENT)

*-A WRIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RF. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF THE SQUARES OF THE SOUND PRESSURES.

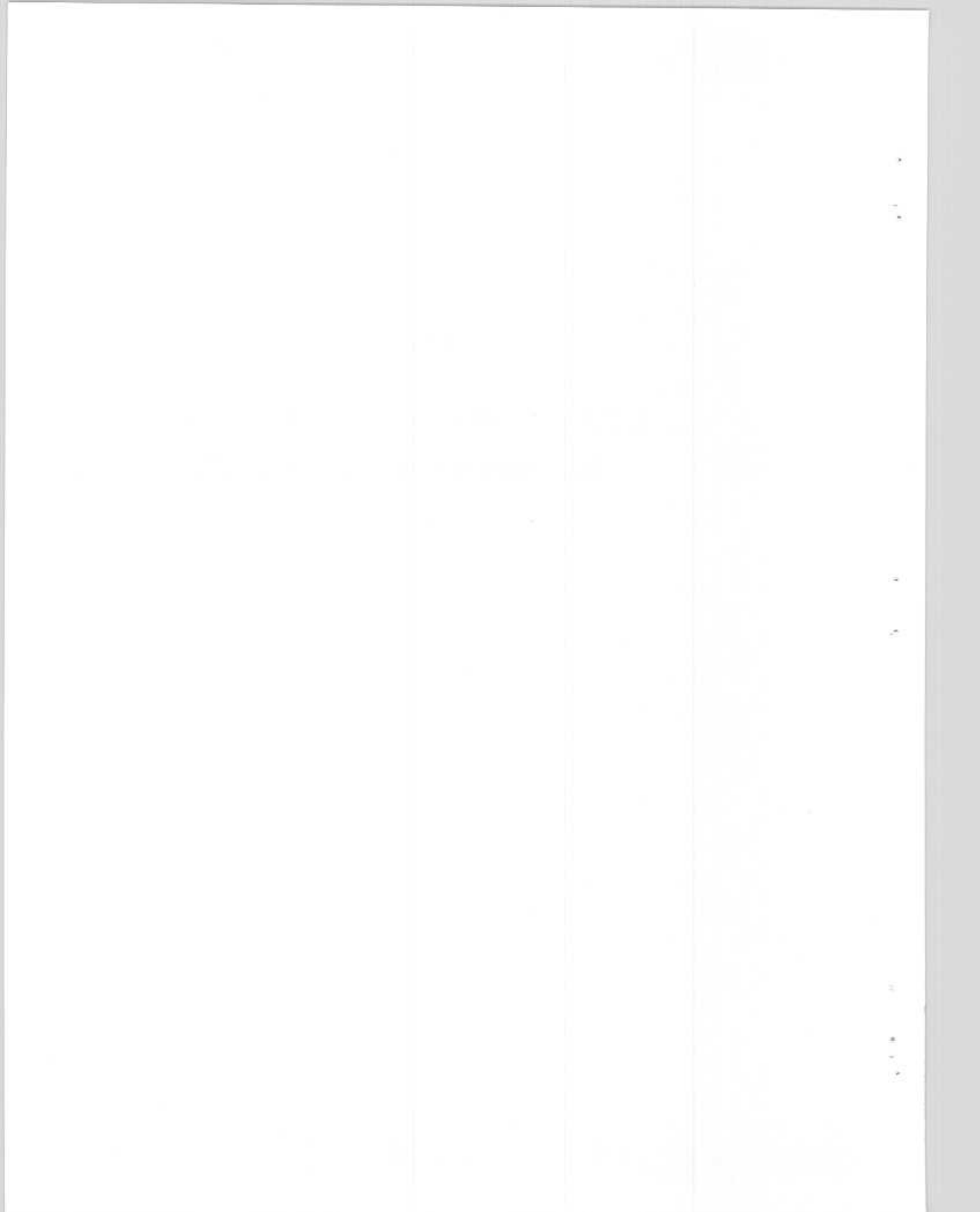
Figure A-12 (Continued). Statistical Analysis - Wayside Noise Data - META Red Line (So. Shore Extension), October 28, 1971
 100 ft.



APPENDIX B

WAYSIDE VIBRATION MEASUREMENTS - MBTA RED LINE

(SO. SHORE EXTENSION) - OCTOBER 28, 1971



RMS Acceleration Level - dB re $10^{-6}g$

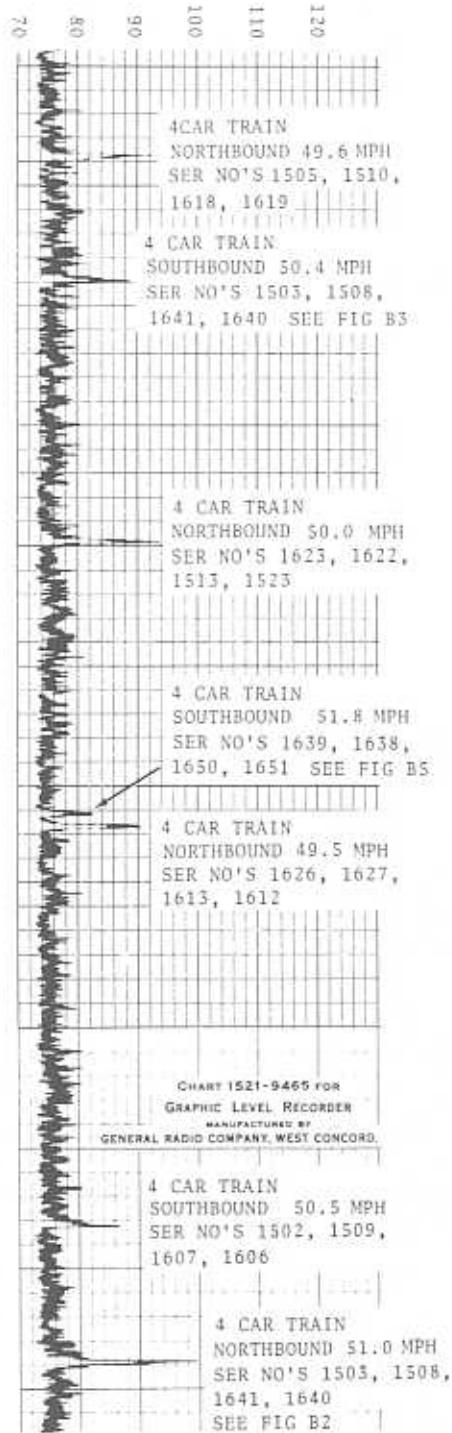


Figure B-1. Time History - Wayside Ground Vibration Levels Lateral (y) Axis at a point which is 25 ft. from the center line of the northbound track and 38 feet from the centerline of the southbound track. MBTA Red Line (So. Shore Extension) Oct. 28, 1971. See Figure G4 for accelerometer location and mounting.

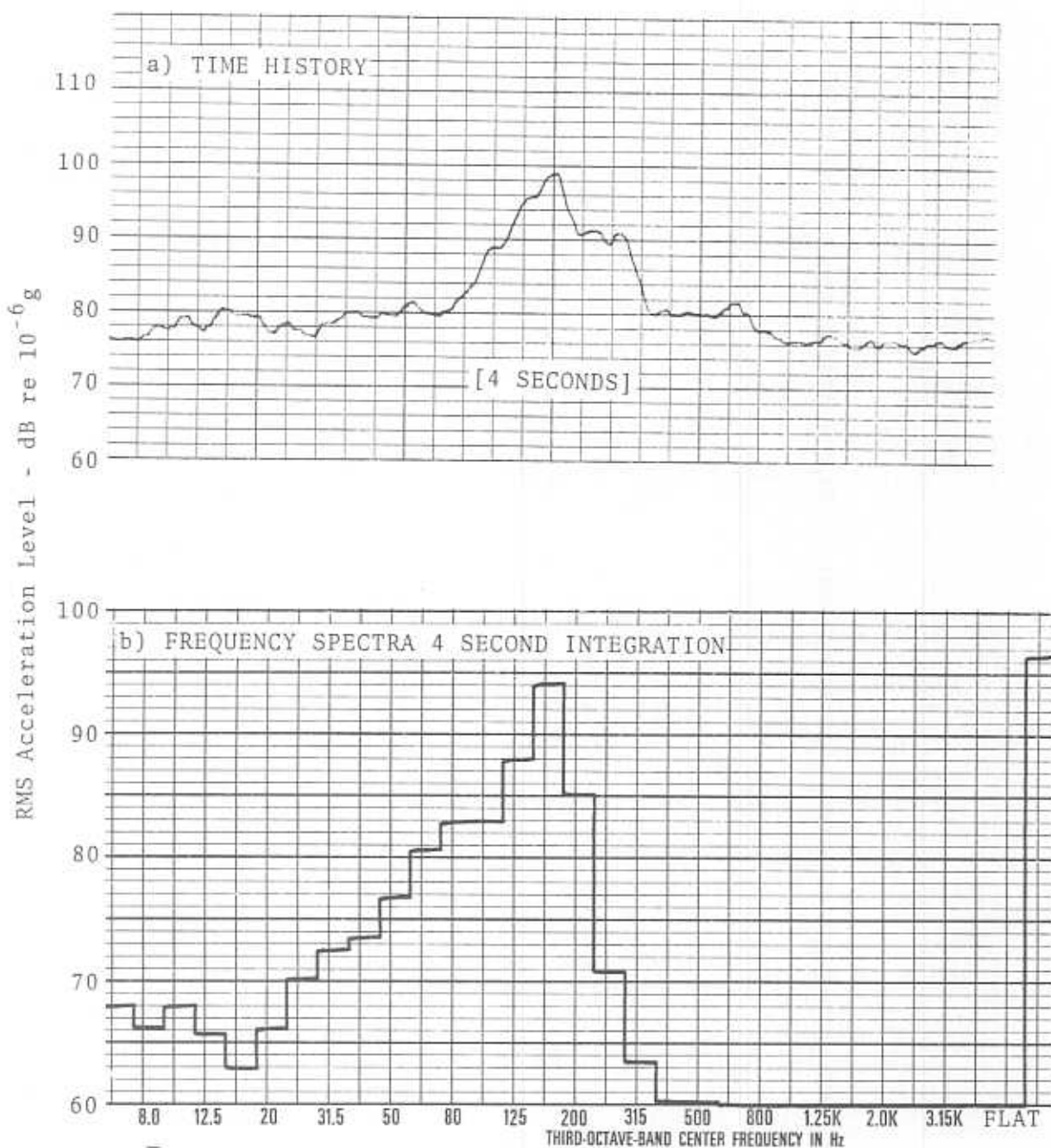


Figure B-2. Ground Vibration - Lateral (y) Axis 25 feet from the centerline of the northbound track. MBTA Red Line (So. Shore Extension) Oct. 28, 1971. Four-Car Train Ser. Nos 1503, 1508, 1641, 1640 at 51.0 mph. See Figure B1.

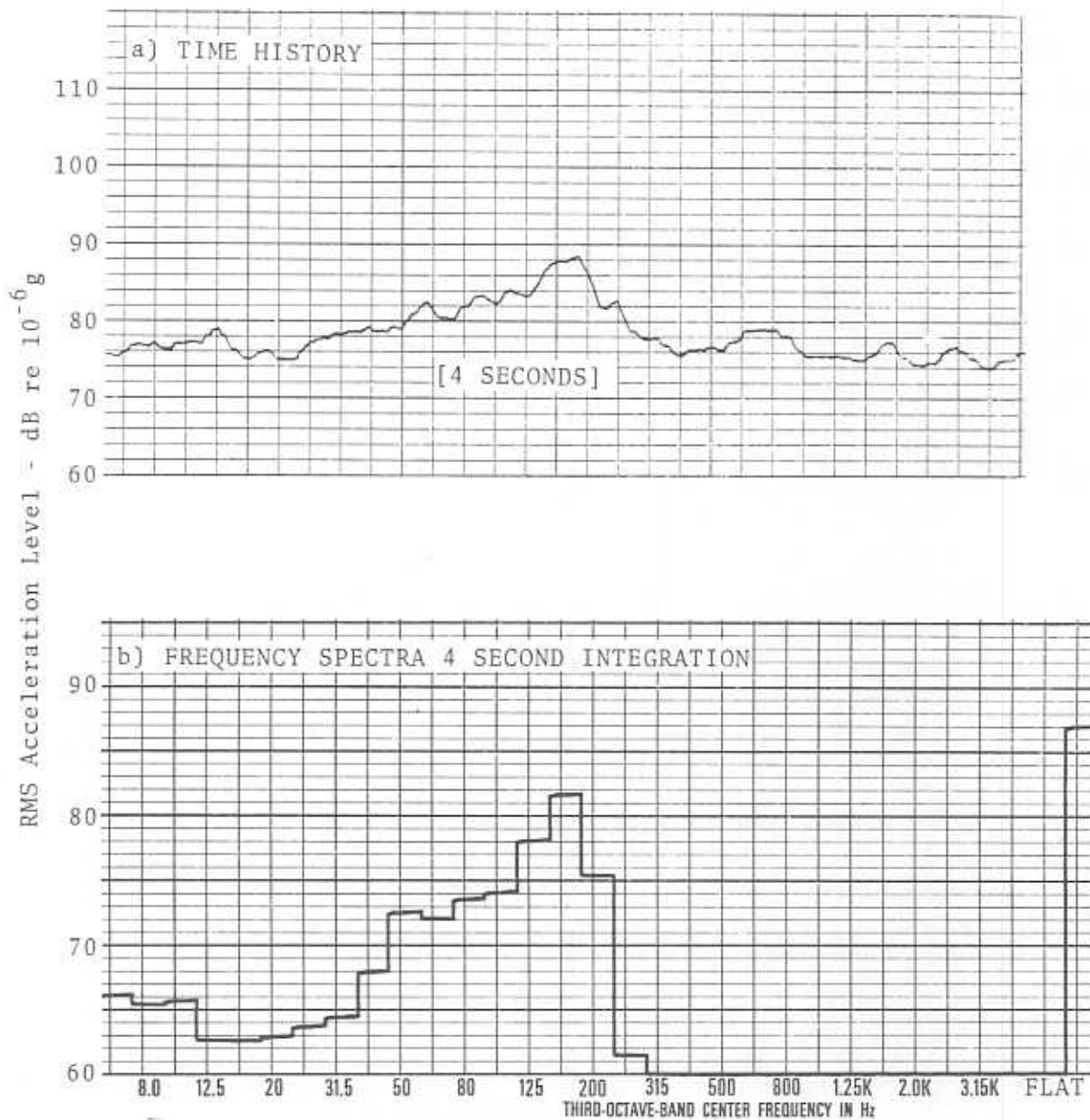


Figure B-3. Ground Vibration-Lateral (y) Axis 38 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension). Four-Car Train Ser. Nos 1503, 1508, 1641, 1640 at 50.4 mph. Oct. 28, 1971. See Figure B1.

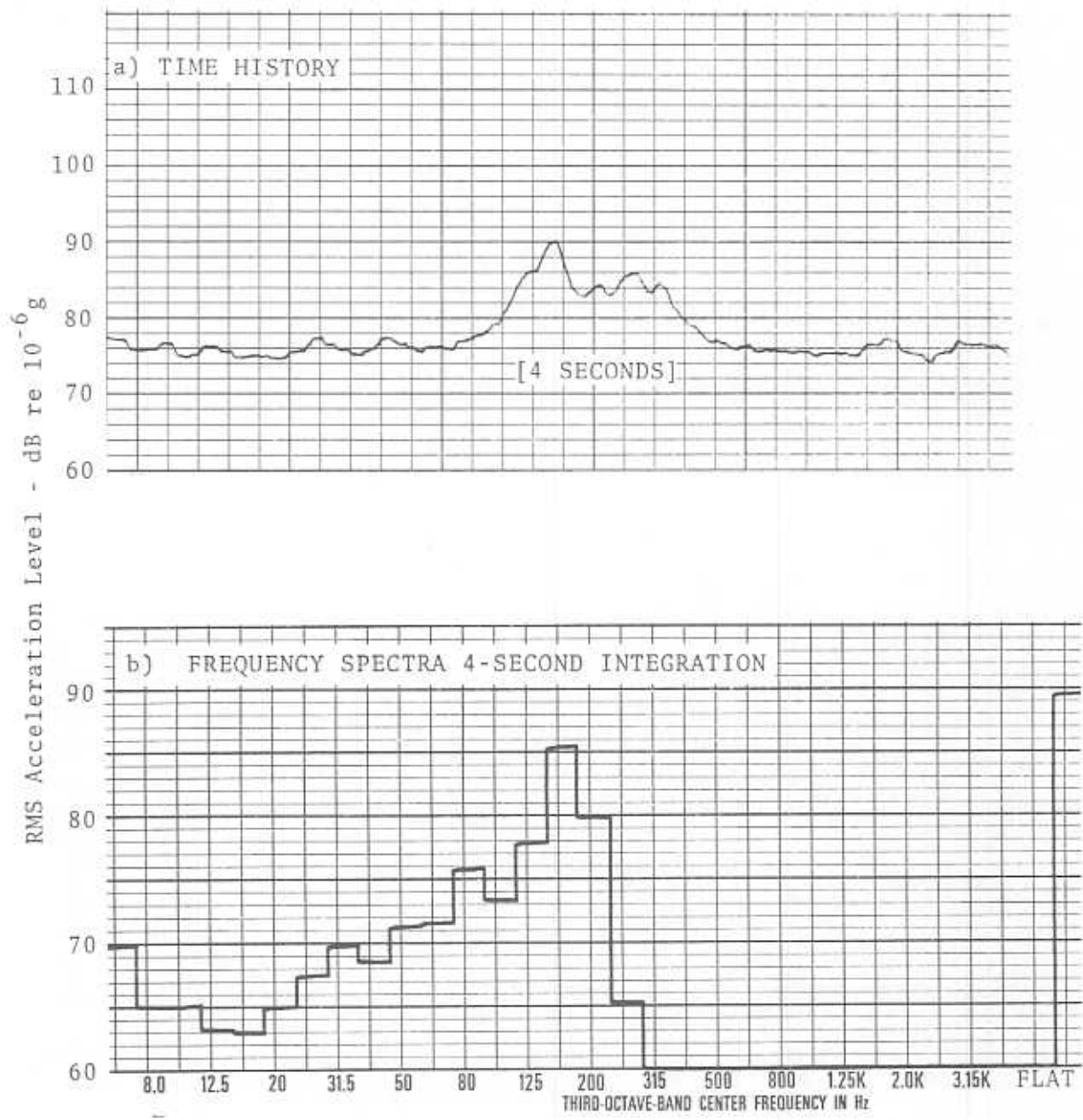


Figure B-4. Ground Vibration - Lateral (y) Axis 25 feet from the center line of the northbound track. MBTA Red Line (So. Shore Extension) Oct. 28, 1971. Four-Car Train Ser. Nos 1639, 1638, 1651, 1650 at 51.0 mph See Figure B1.

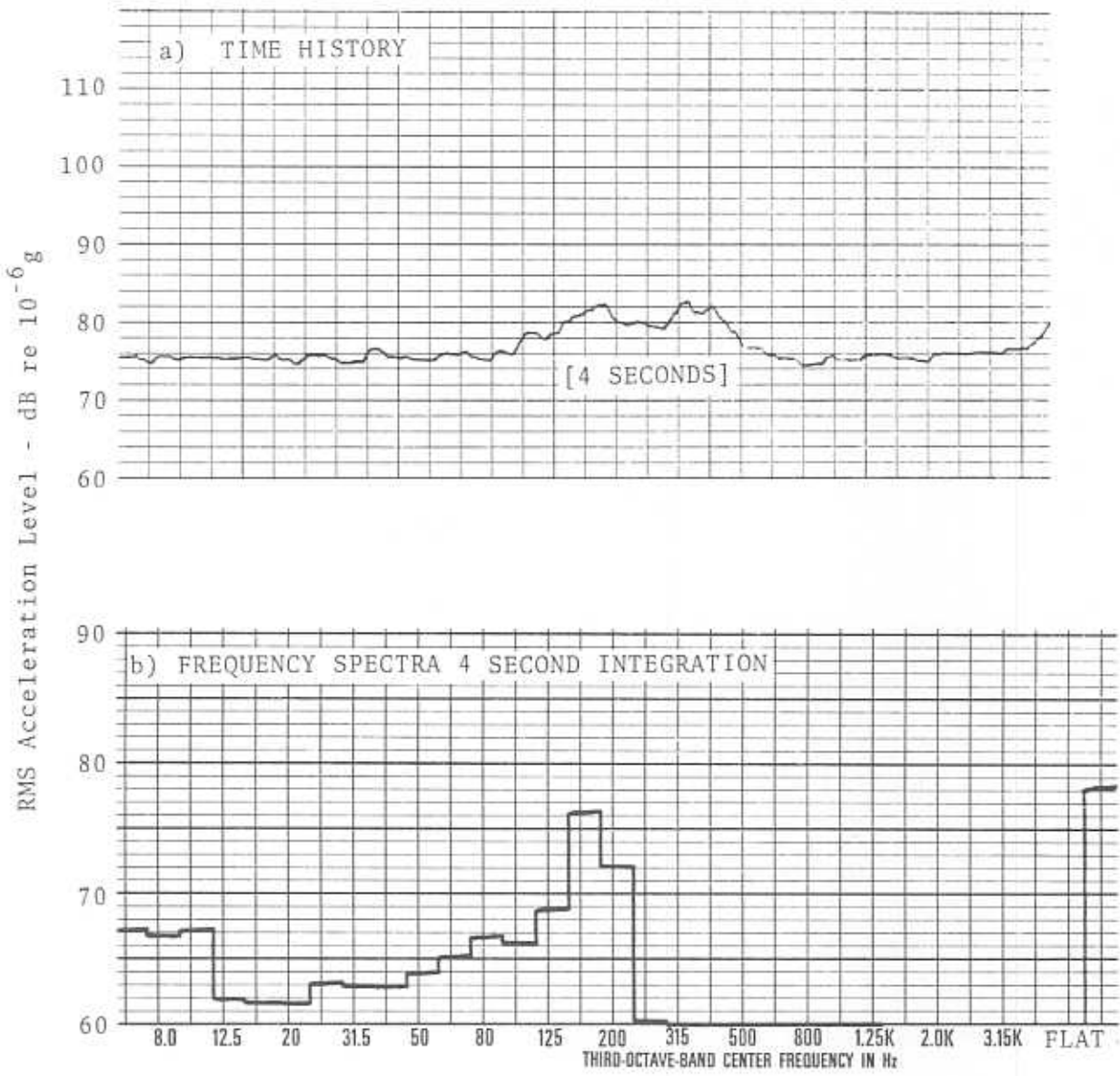


Figure B-5. Ground Vibration - Lateral (y) Axis 38 feet from centerline of southbound track. MBTA Red Line (So. Shore Extension) Oct. 28, 1971. Four-Car Train southbound Ser. Nos 1639, 1638, 1650, 1651 at 51.8 mph. See Figure B-1.

APPENDIX C

WAYSIDE NOISE MEASUREMENTS - MBTA RED LINE
(SO. SHORE EXTENSION)-APRIL 27, 1972

100

100

100

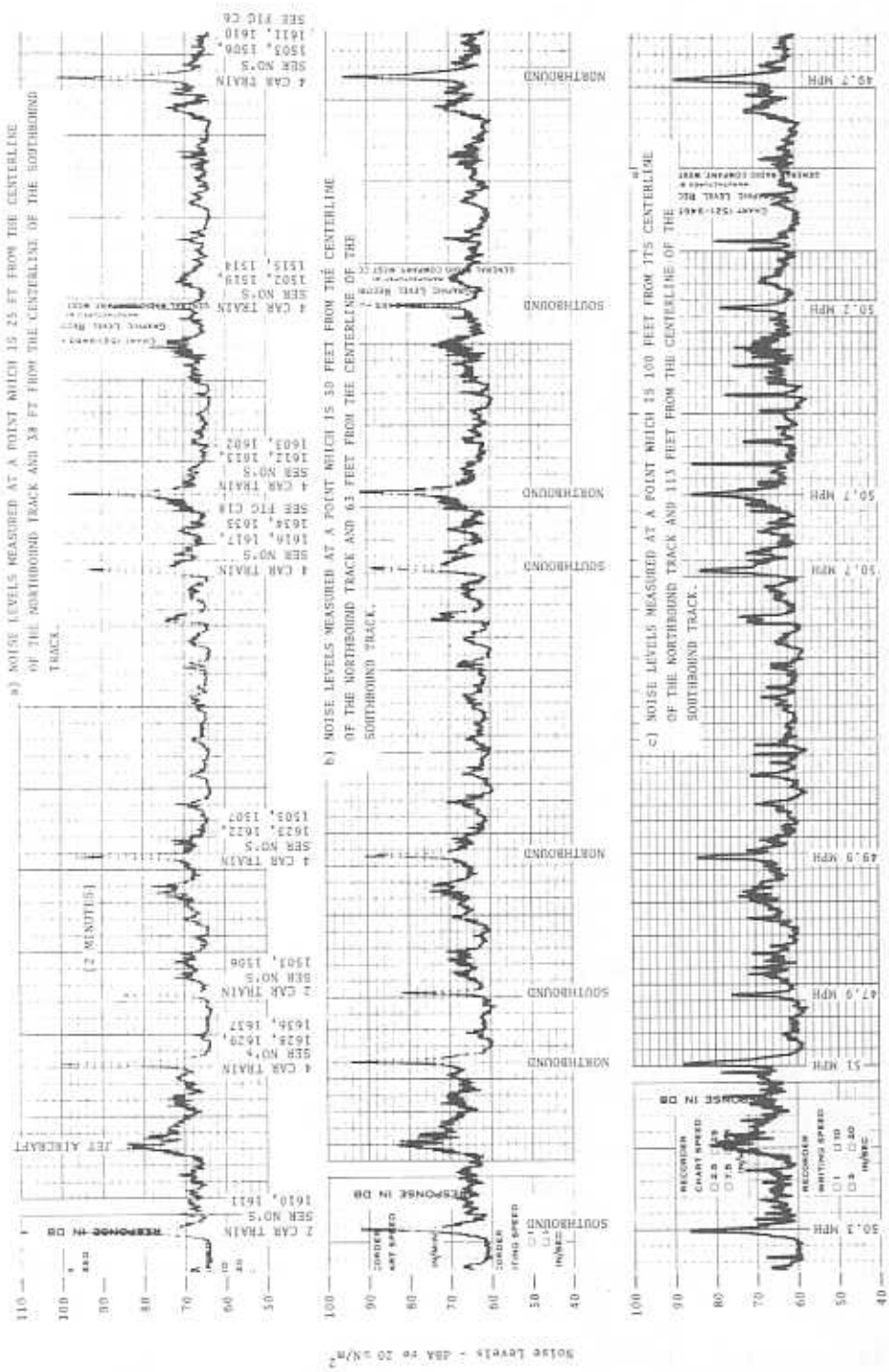


Figure C-1. Coincident Time Histories - Wayside Noise Levels. MBTA Red Line (So. Shore Extension) April 27, 1972. Microphones placed 6.1 ft above level grade and 3 ft above rail tops. See C-1 for microphone locations.

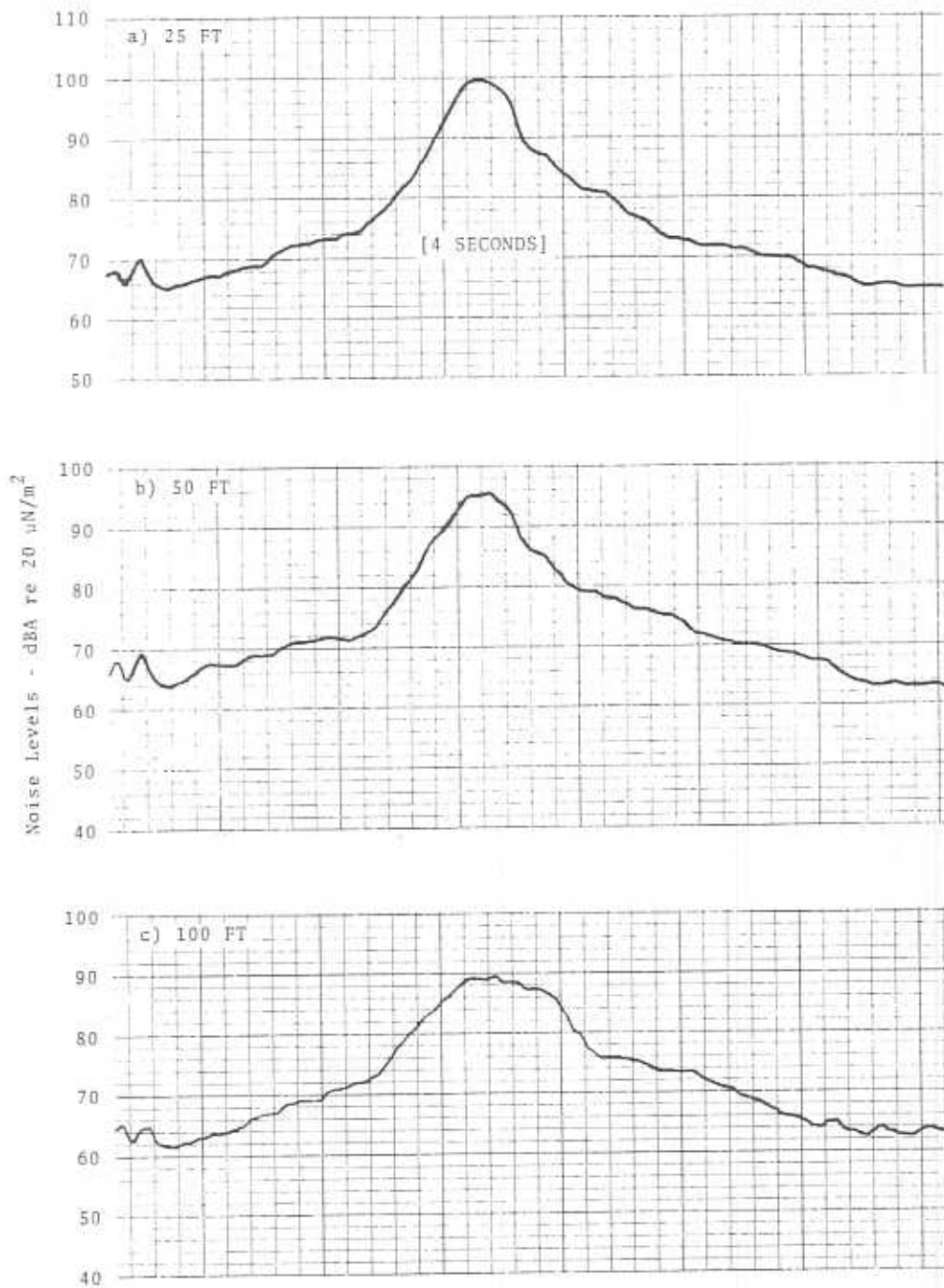


Figure C-2 Coincident Time Histories - Wayside Noise Levels at 25, 50 and 100 ft. from the centerline of the northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound Ser. No s 1611, 1610 at 50.6 mph.

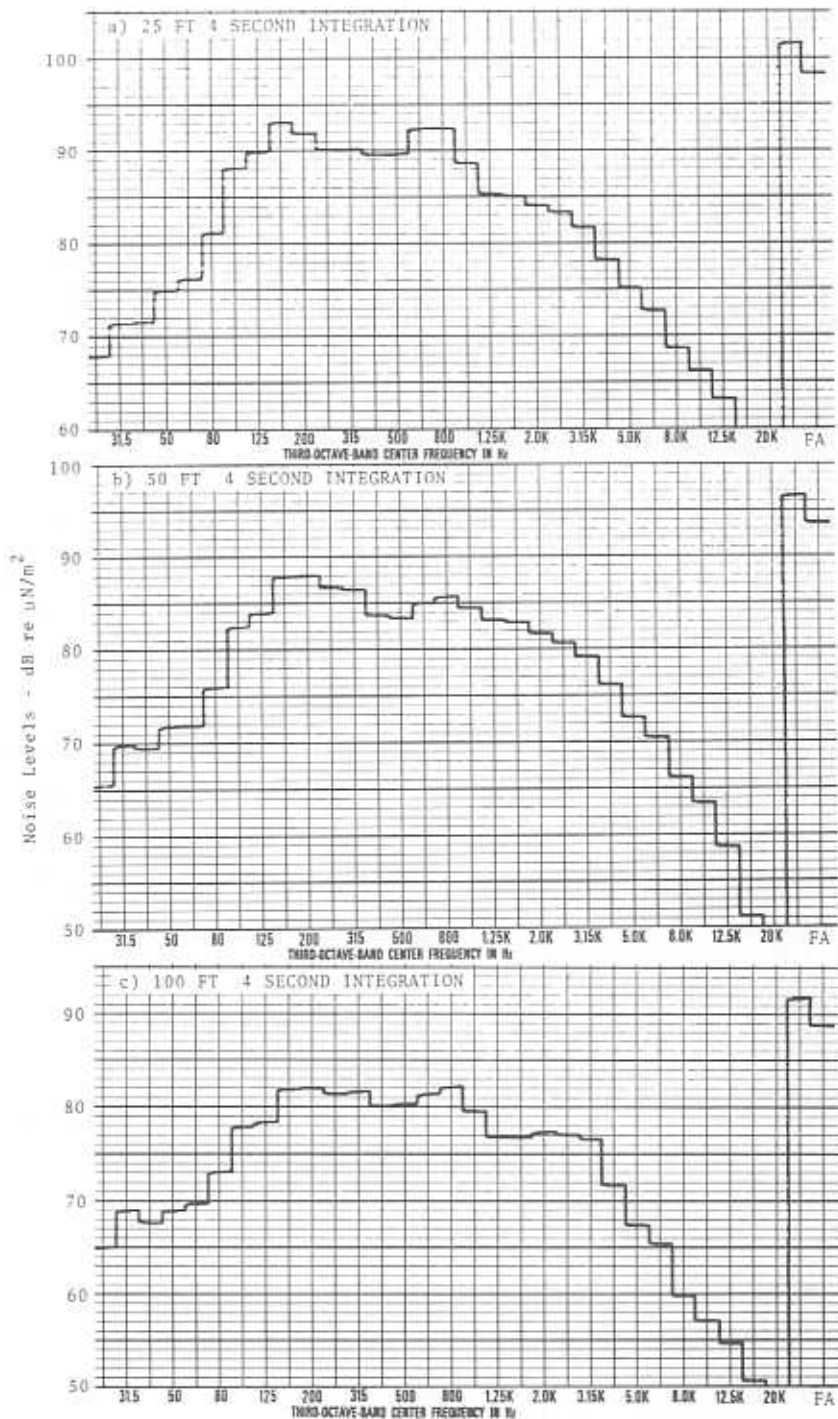


Figure C-3 Wayside Noise Spectra at 25,50 and 100 ft. from the centerline of the northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound Ser. No s 1611, 1610 at 50.0 mph. See Figure G2.

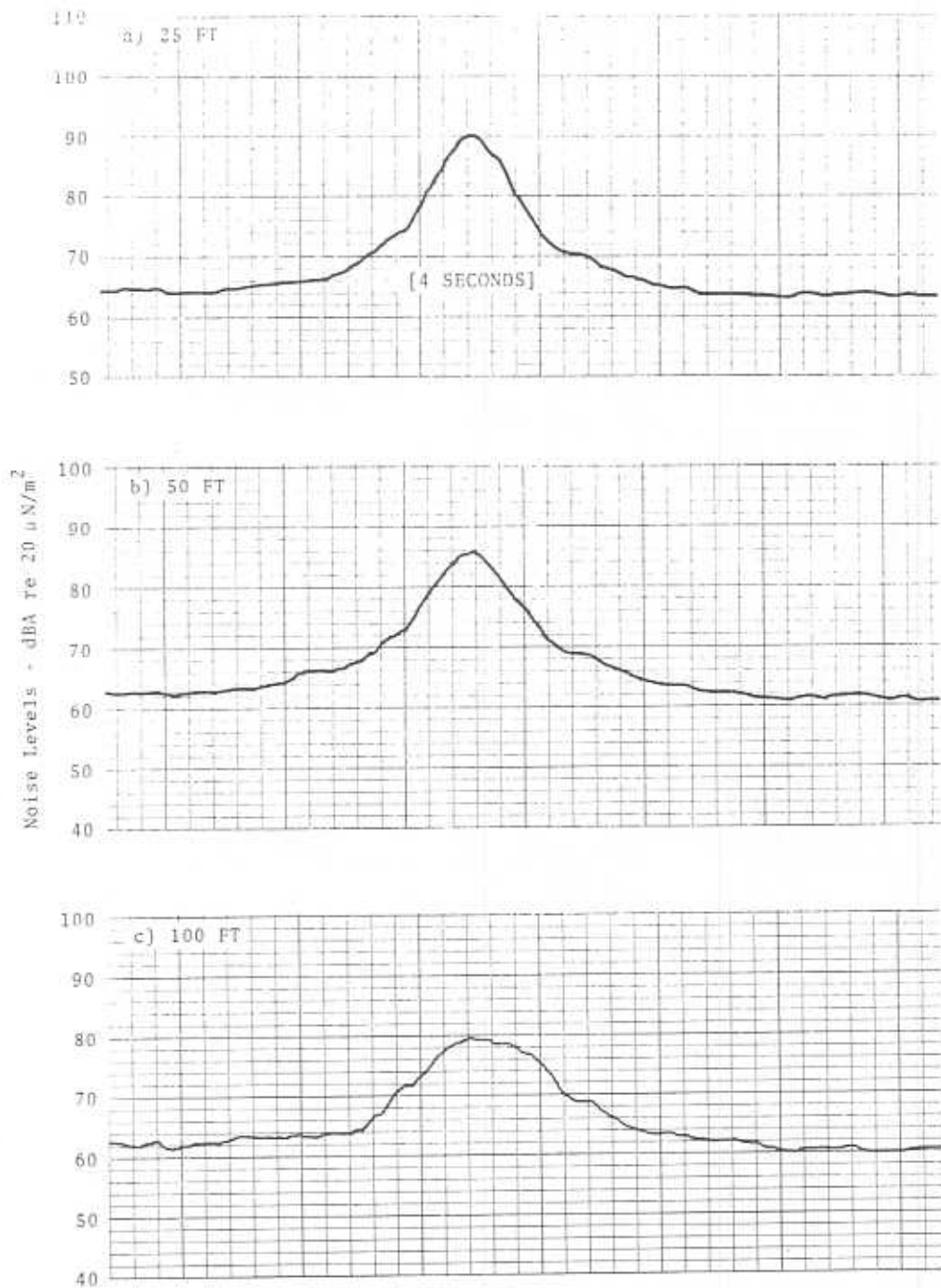


Figure C-4 Coincident Time Histories - Wayside Noise Levels at 25,50 and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound, Ser. Nos 1503, 1506, at 49.5 mph.

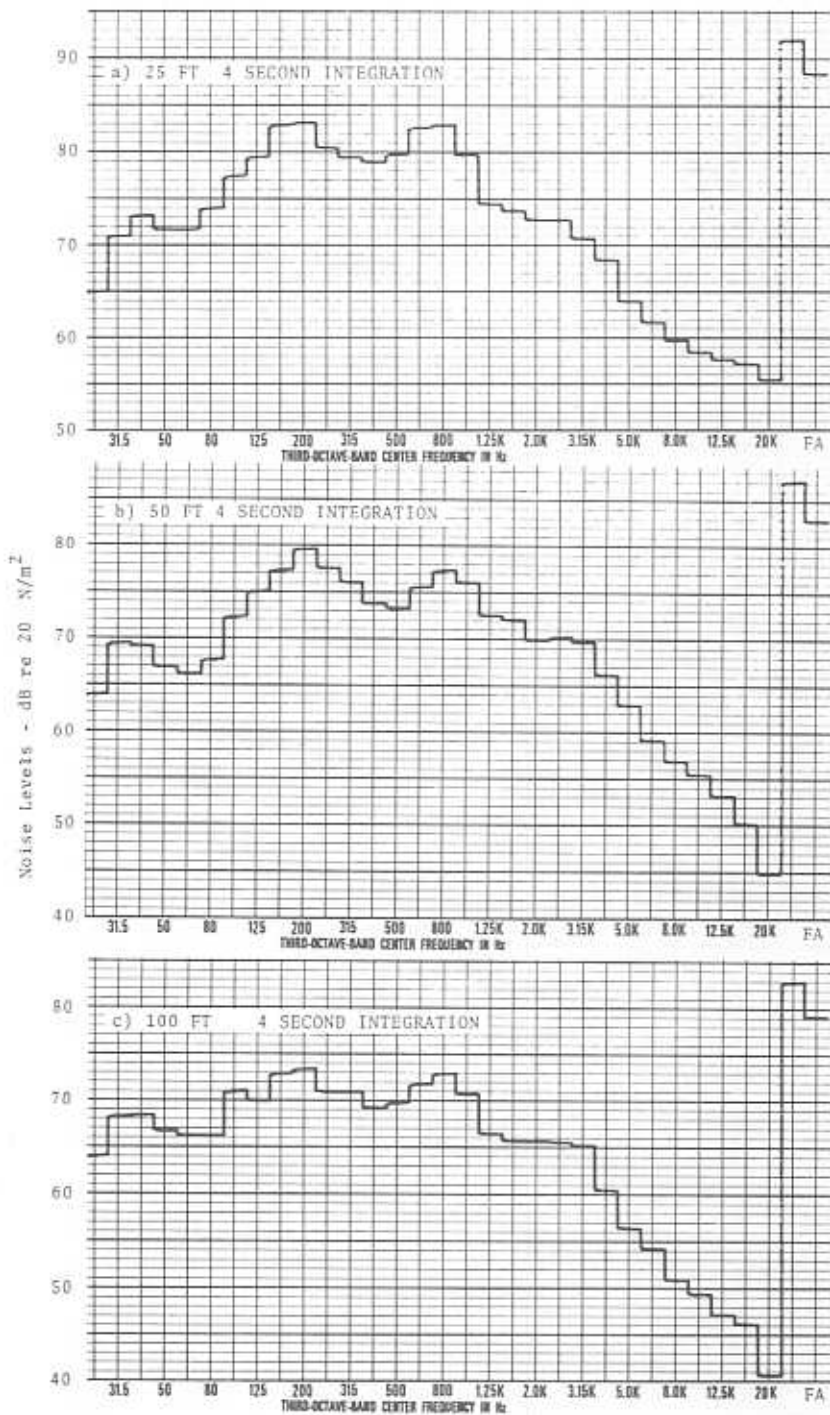


Figure C-5 Wayside Noise Spectra at 25, 50, and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound, Ser. Nos 1503, 1506 at 49.5 mph. See Figure G-4.

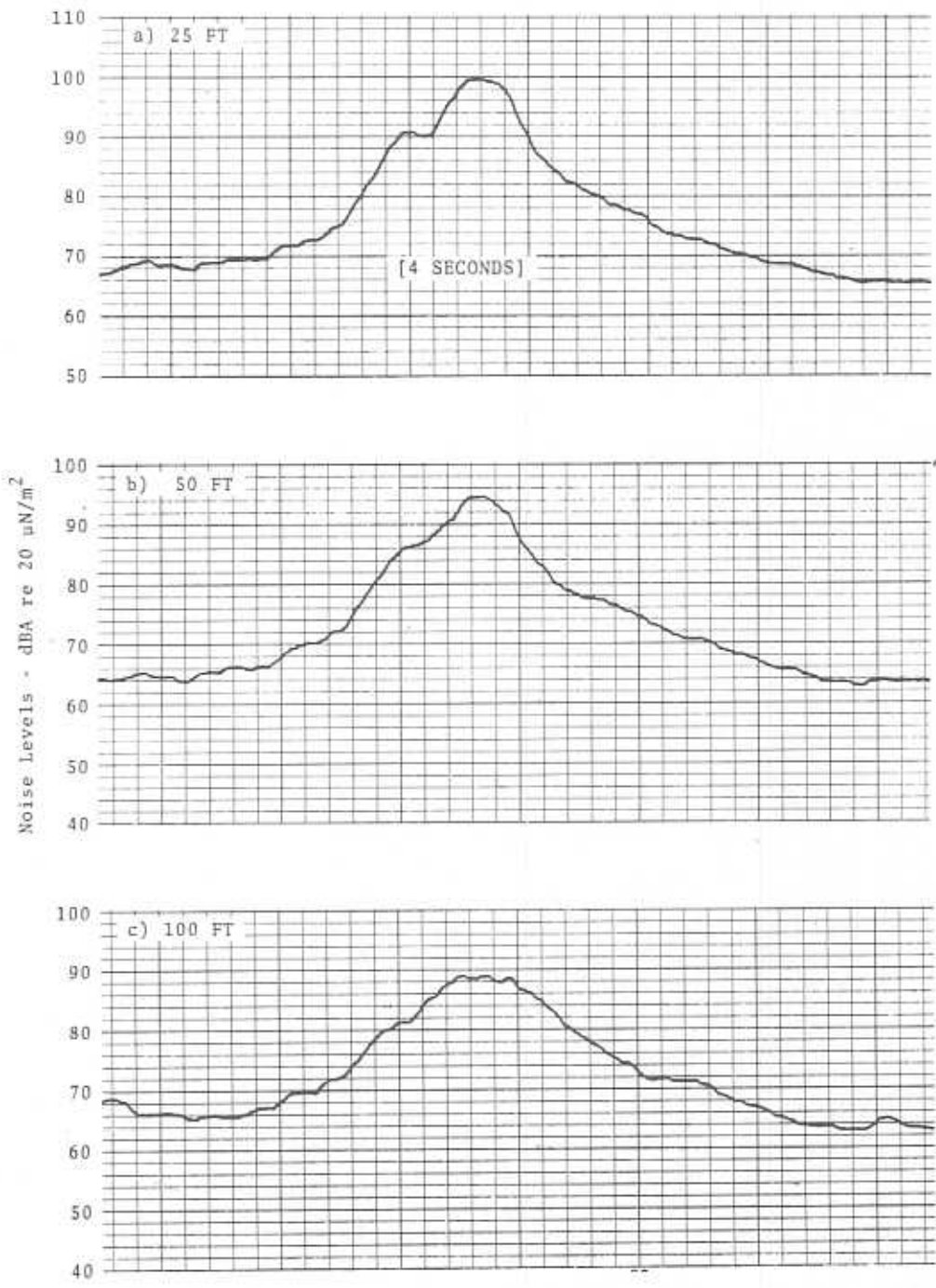


Figure C-6 Coincident Time Histories - Wayside Noise Levels at 25,50 and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension). April 27, 1972. 4-Car Train northbound - Ser. Nos 1503, 1506, 1611, 1610 at 49.7 mph. See Figure G1.

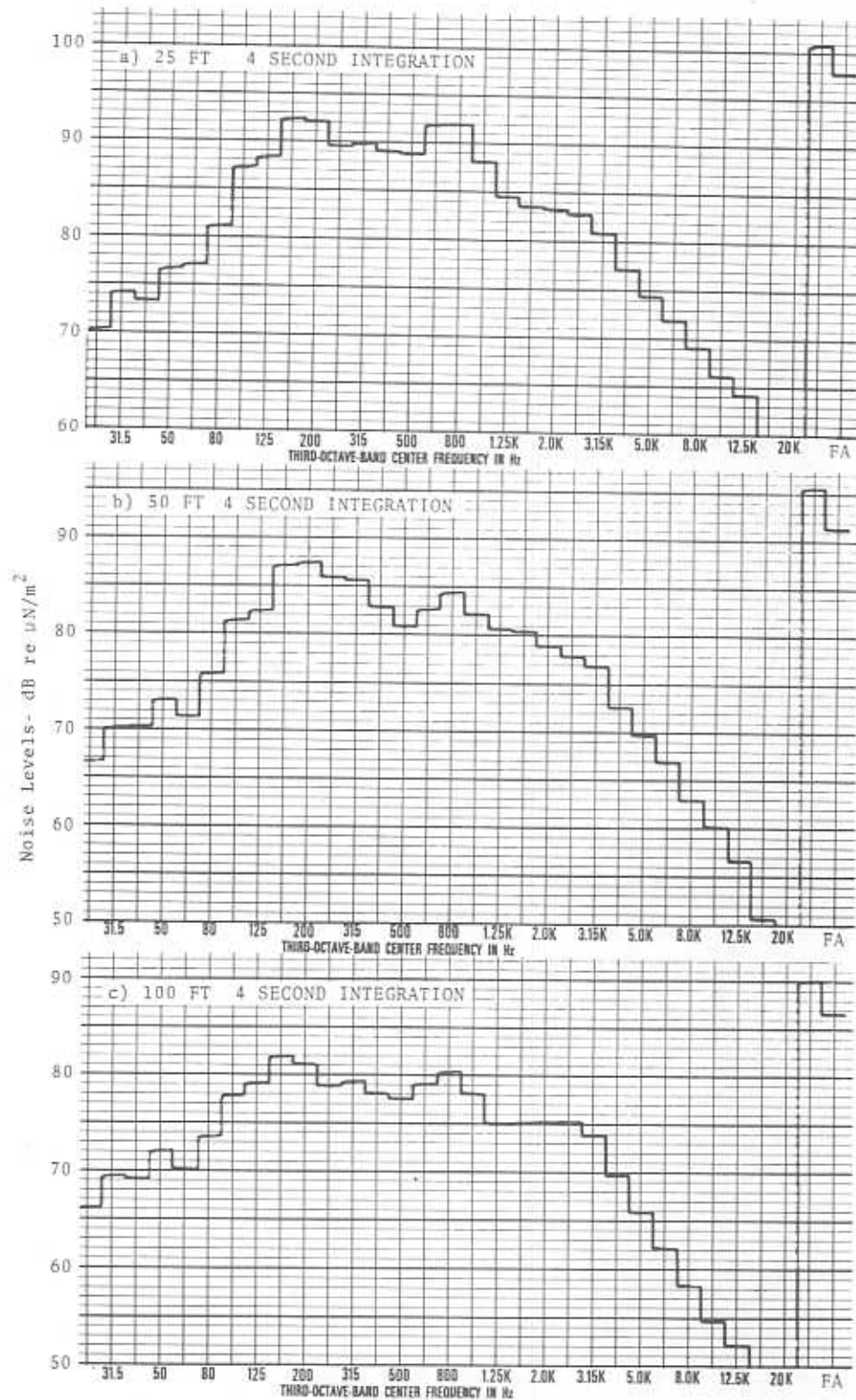


Figure C-7 Wayside Noise Spectra at 25, 50, and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound - Ser. Nos 1503, 1506, 1611, 1610 at 49.7 mph. See Figure G6.

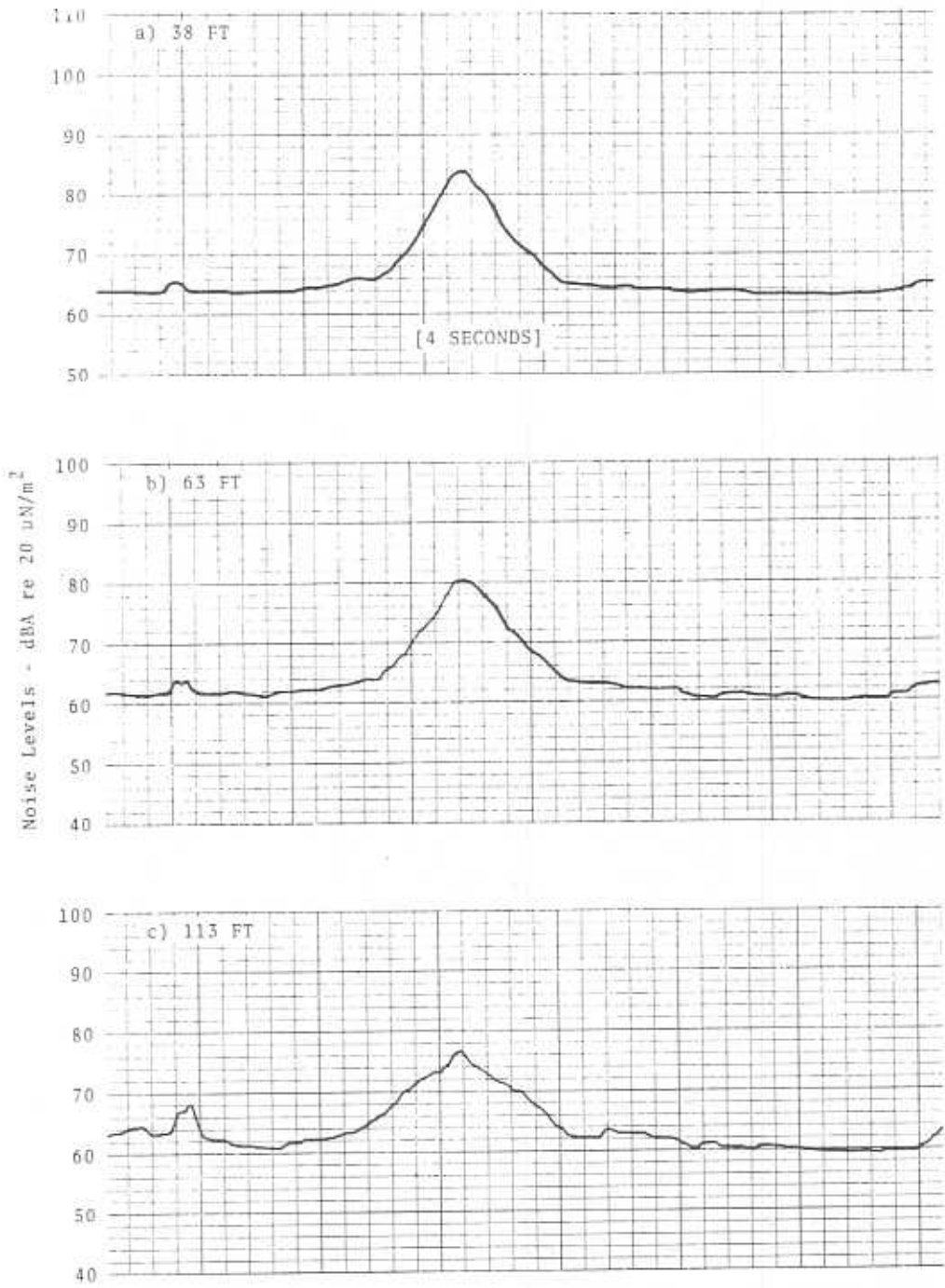


Figure C-8 Coincident Time Histories - Wayside Noise Levels at 38, 63, and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound - Ser. Nos 1618, 1619 at 49.9 mph.

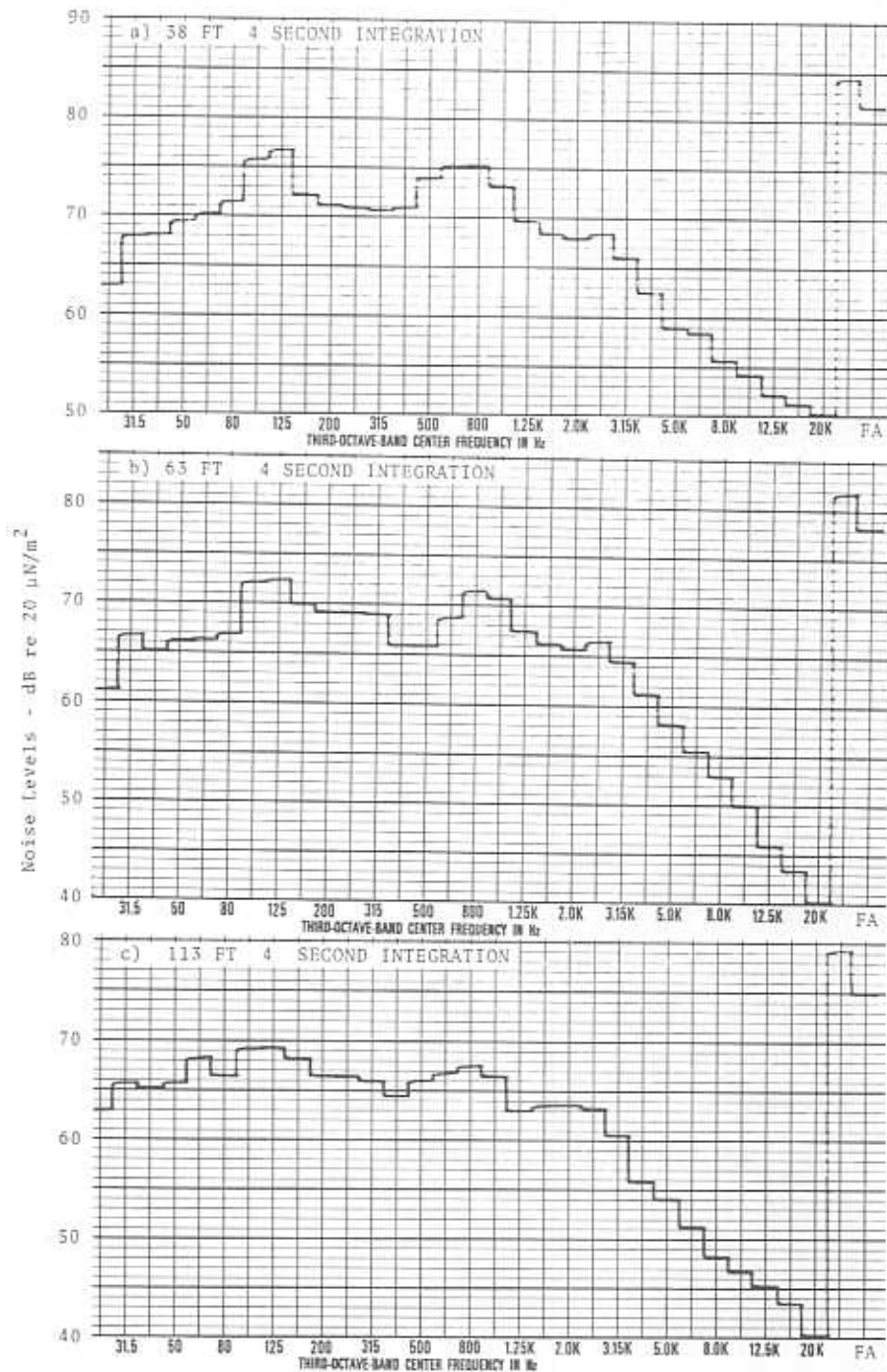


Figure C-9 Wayside Noise Spectra at 38,63, and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound - Ser. Nos 1618, 1619 at 49.9 mph. See Figure G8.

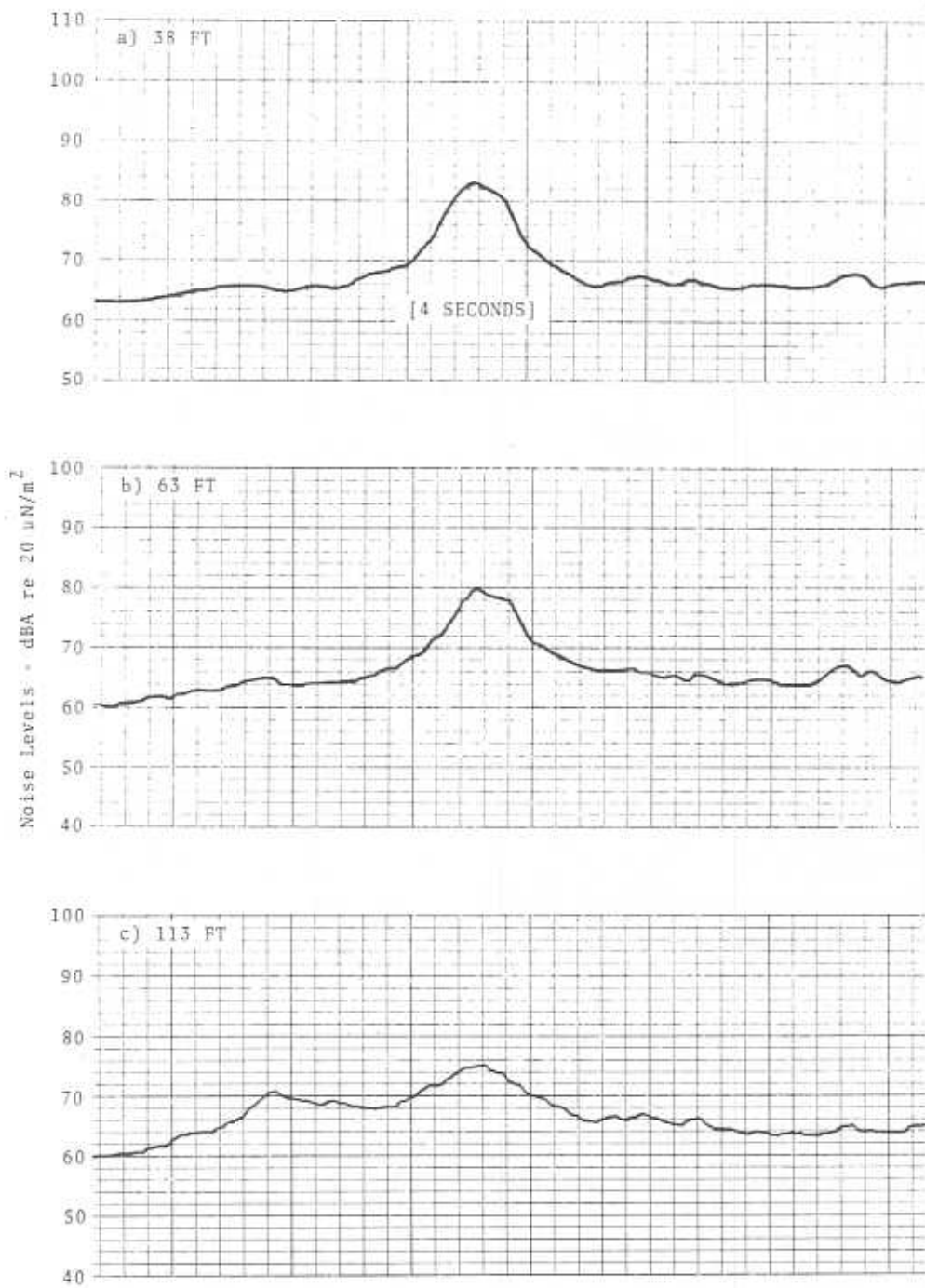


Figure C-10 Coincident Time Histories - Wayside Noise Levels at 38,63 and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound - Ser. Nos 1604, 1605 at 50.4 mph.

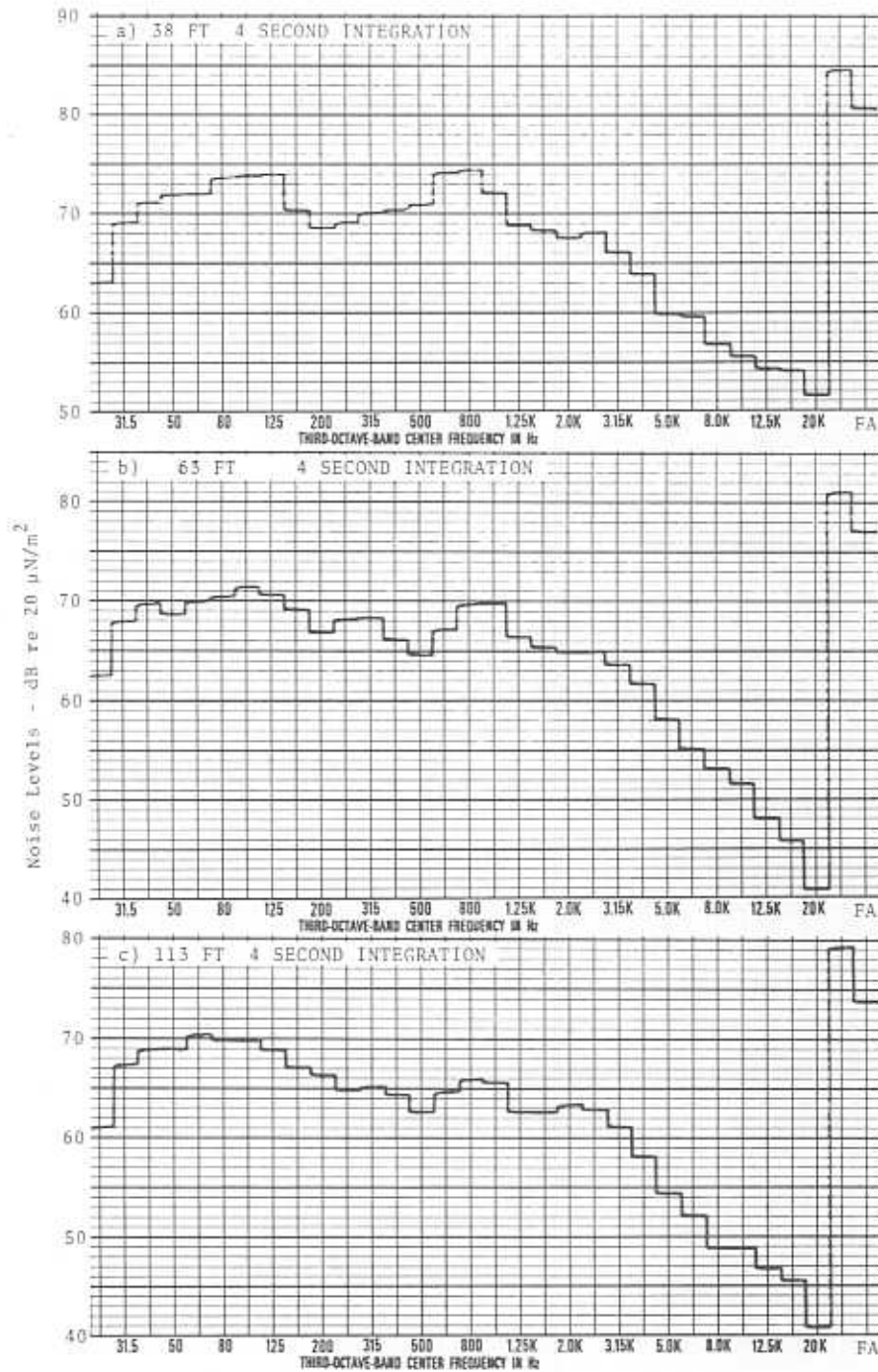


Figure C-11 Wayside Noise Spectra at 38,63 and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound - Ser. Nos 1604, 1605 at 50.4 mph See Figure G10.

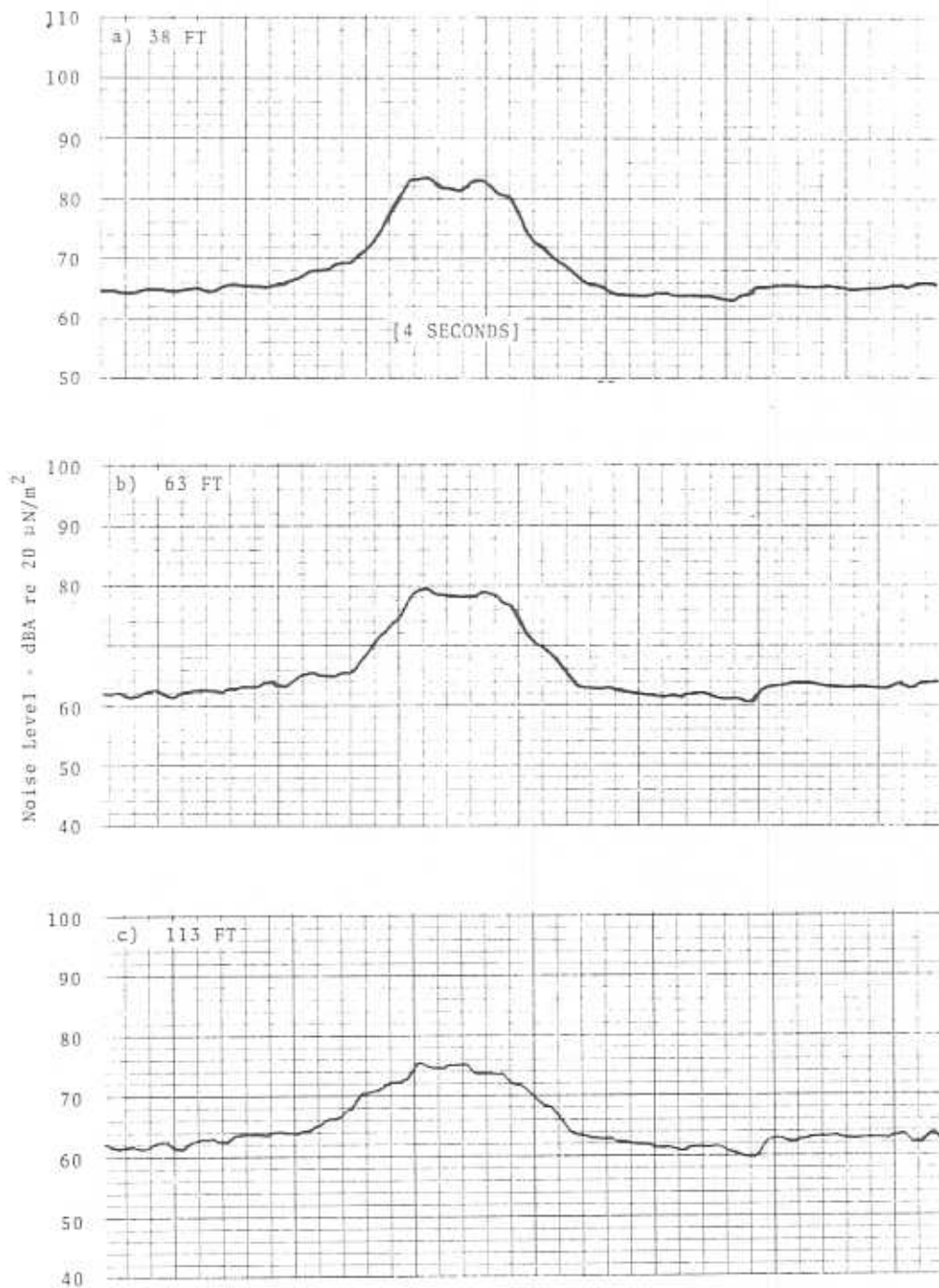


Figure C-12 Coincident Time Histories - Wayside Noise Levels at 38,63, and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension). April 27, 1972. 4-Car Train southbound - Ser. Nos 1604, 1605, 1618, 1619 at 48.9 mph.

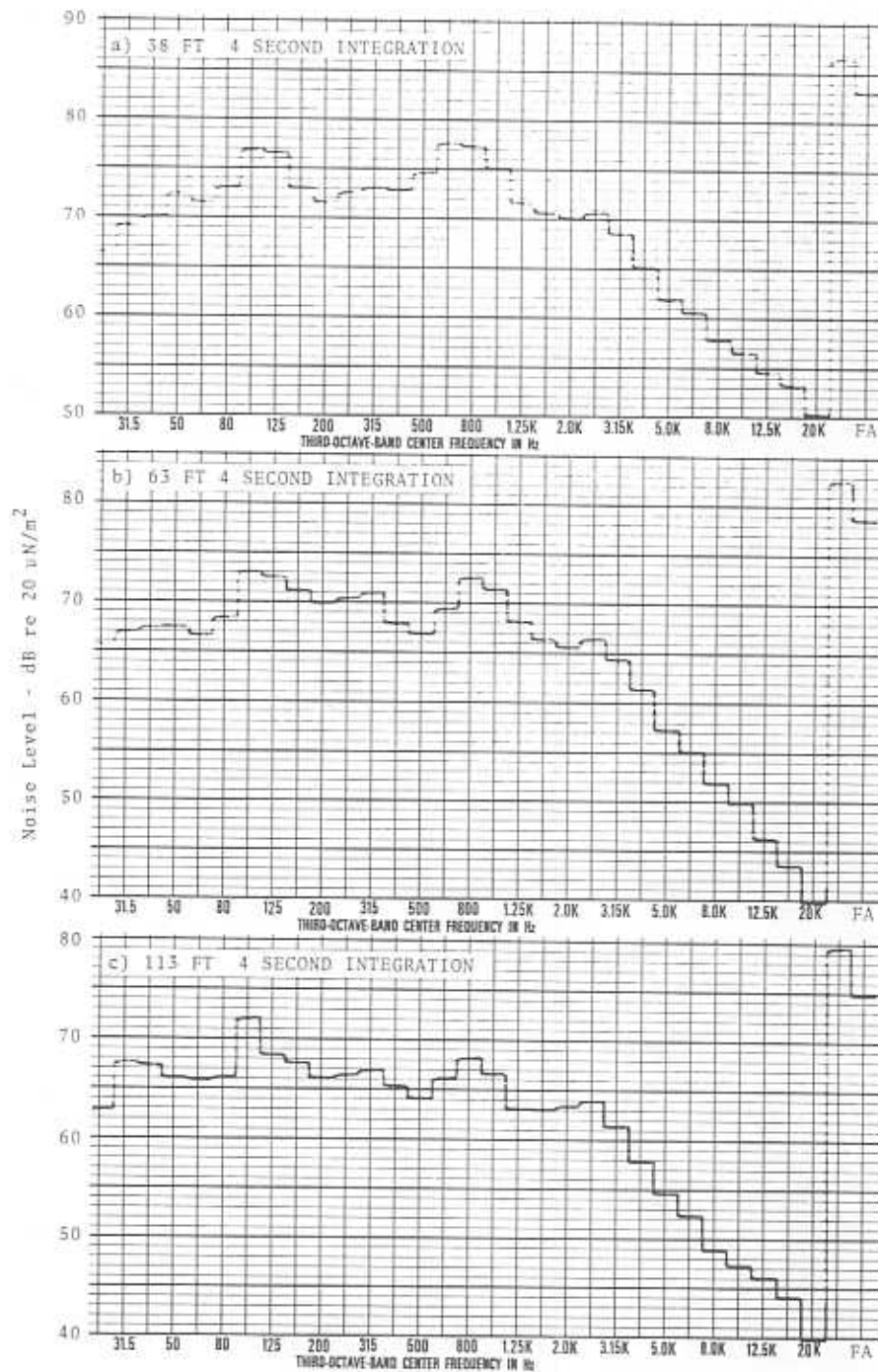


Figure C-13 Wayside Noise Spectra 38,63 and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train southbound - Ser. Nos 1604, 1605, 1619, 1618 at 48.9 mph.

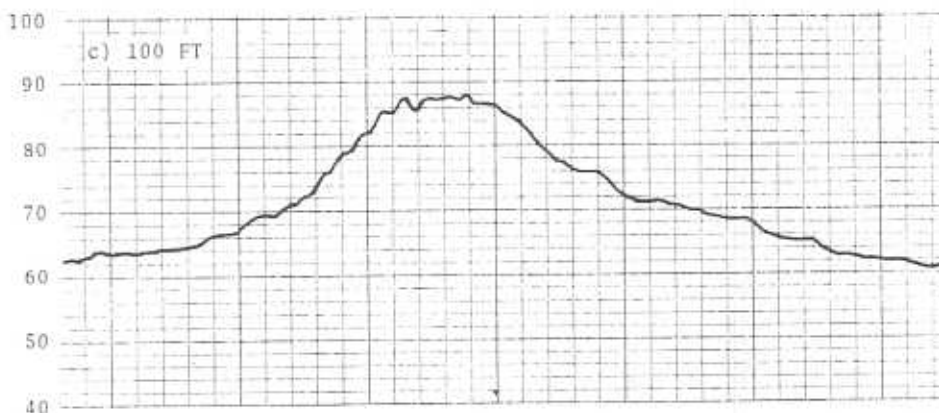
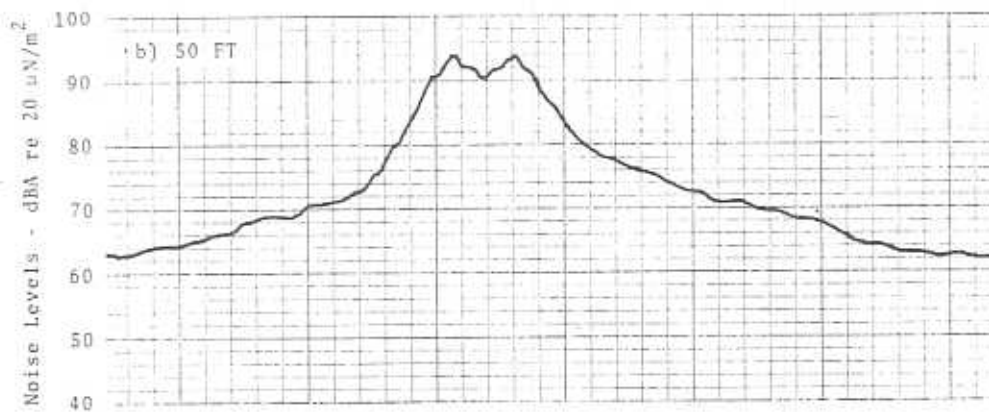
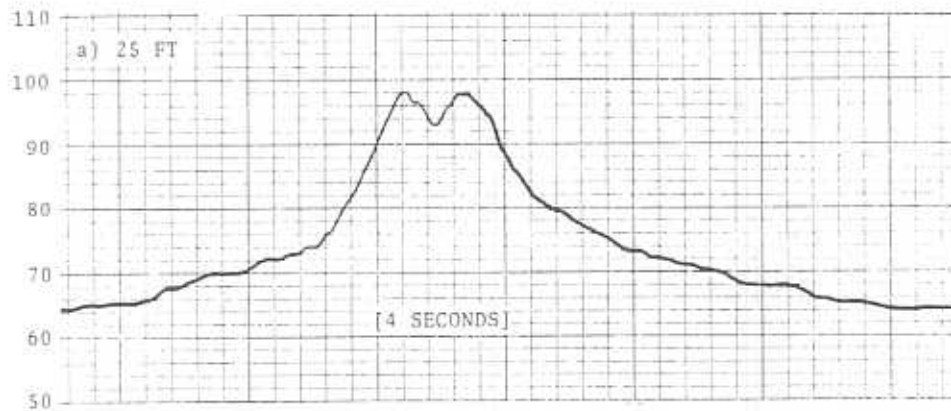


Figure C-14. Coincident Time Histories - Wayside Noise Levels at 25, 50, and 100 ft. from center line of northbound track. MBTA Red Line (So. Shore Extension). April 27, 1972. 4-Car Train northbound - Ser. Nos 1604, 1605, 1619, 1618 at 49.9 mph

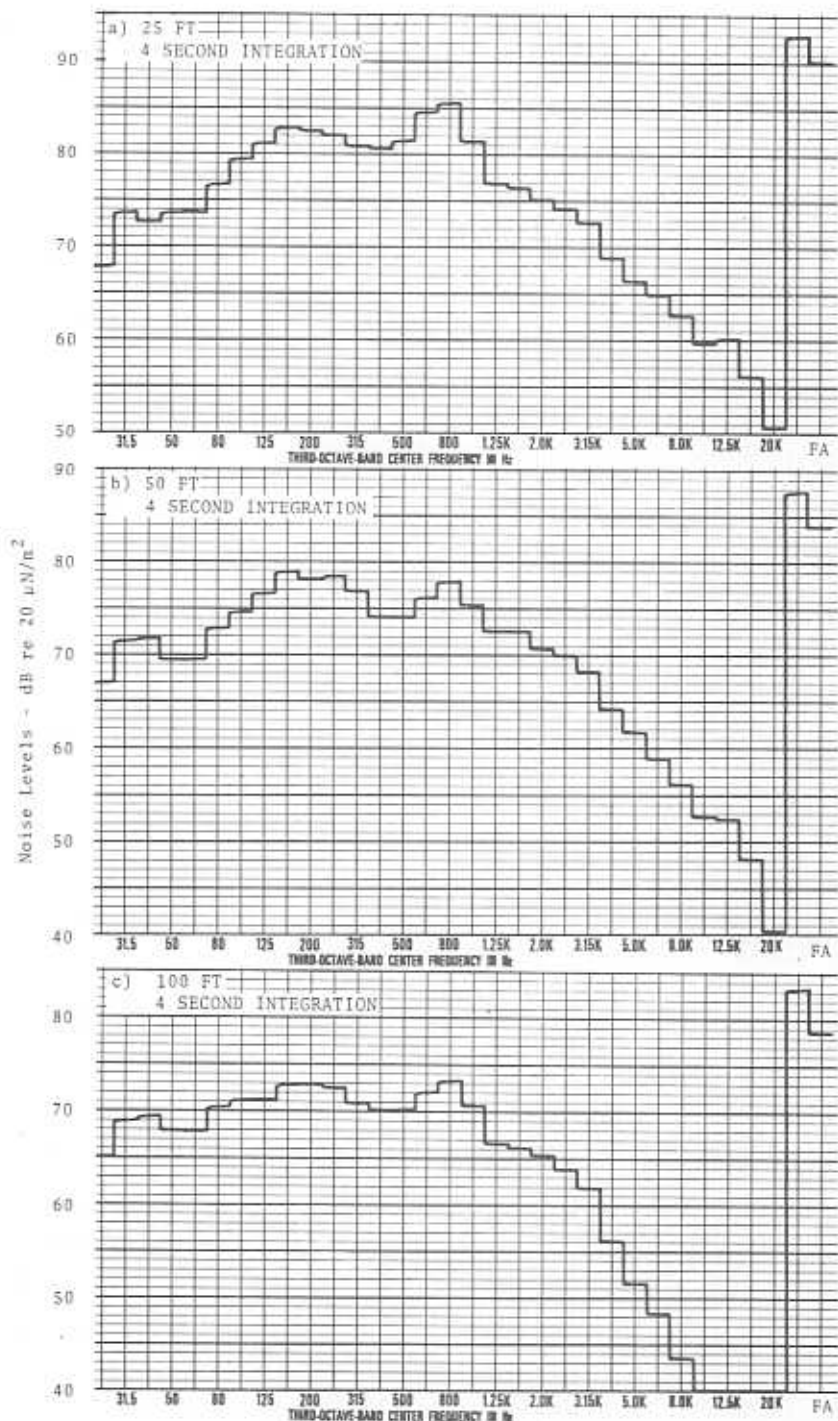


Figure C-15 Wayside Noise Spectra at 25, 50, and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound - Ser. Nos 1604, 1605, 1619, 1618 at 49.9 mph. See Figure G14.

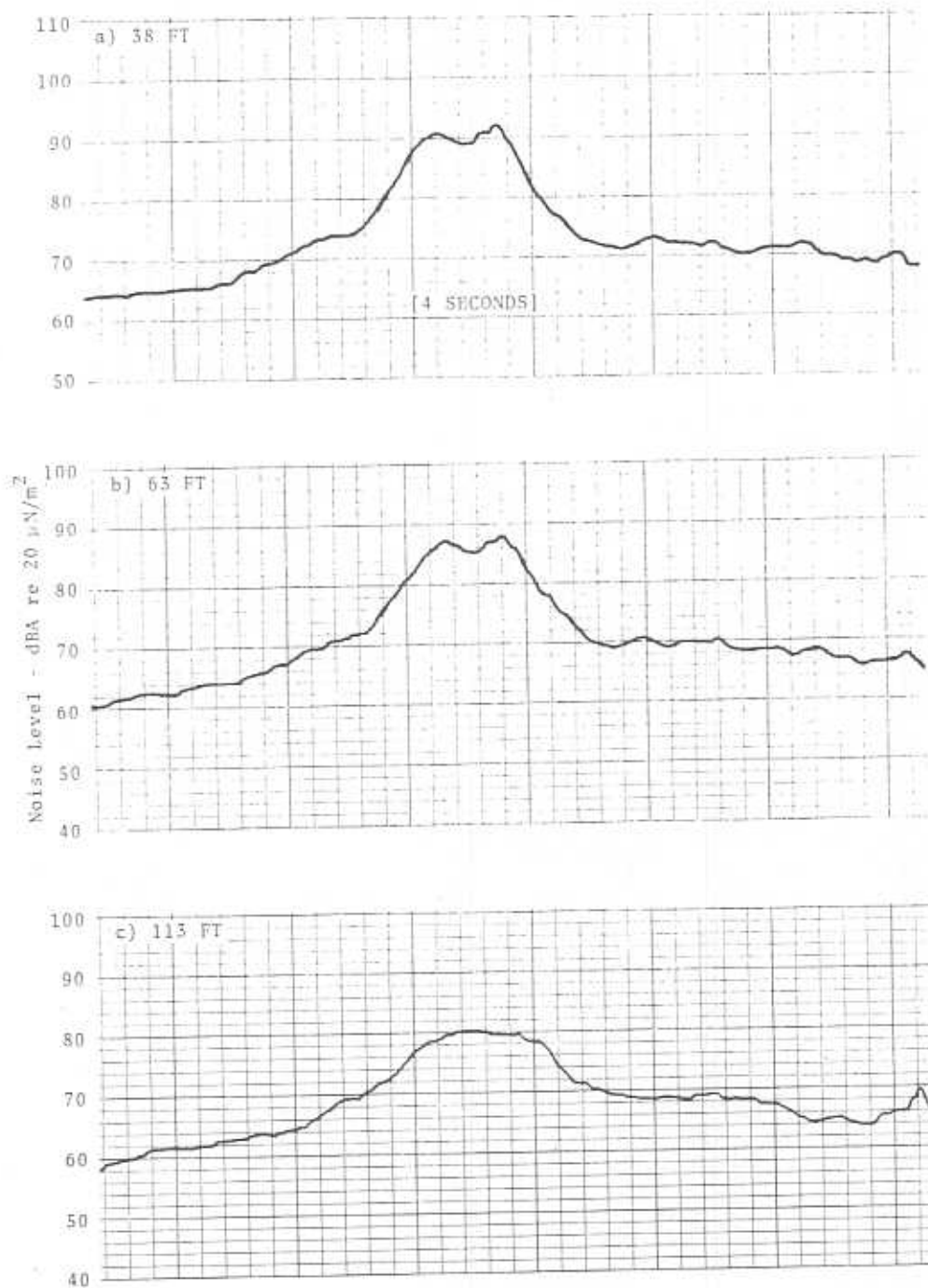


Figure C-16 Coincident Time Histories - Wayside Noise Levels at 38, 63, and 113 ft. from centerline of southbound track. MBTA Red Line (So. Shore Extension). April 27, 1972. 4-Car Train southbound - Ser. Nos 1616, 1617, 1634, 1635 at 50.7 mph. See Figure G1.

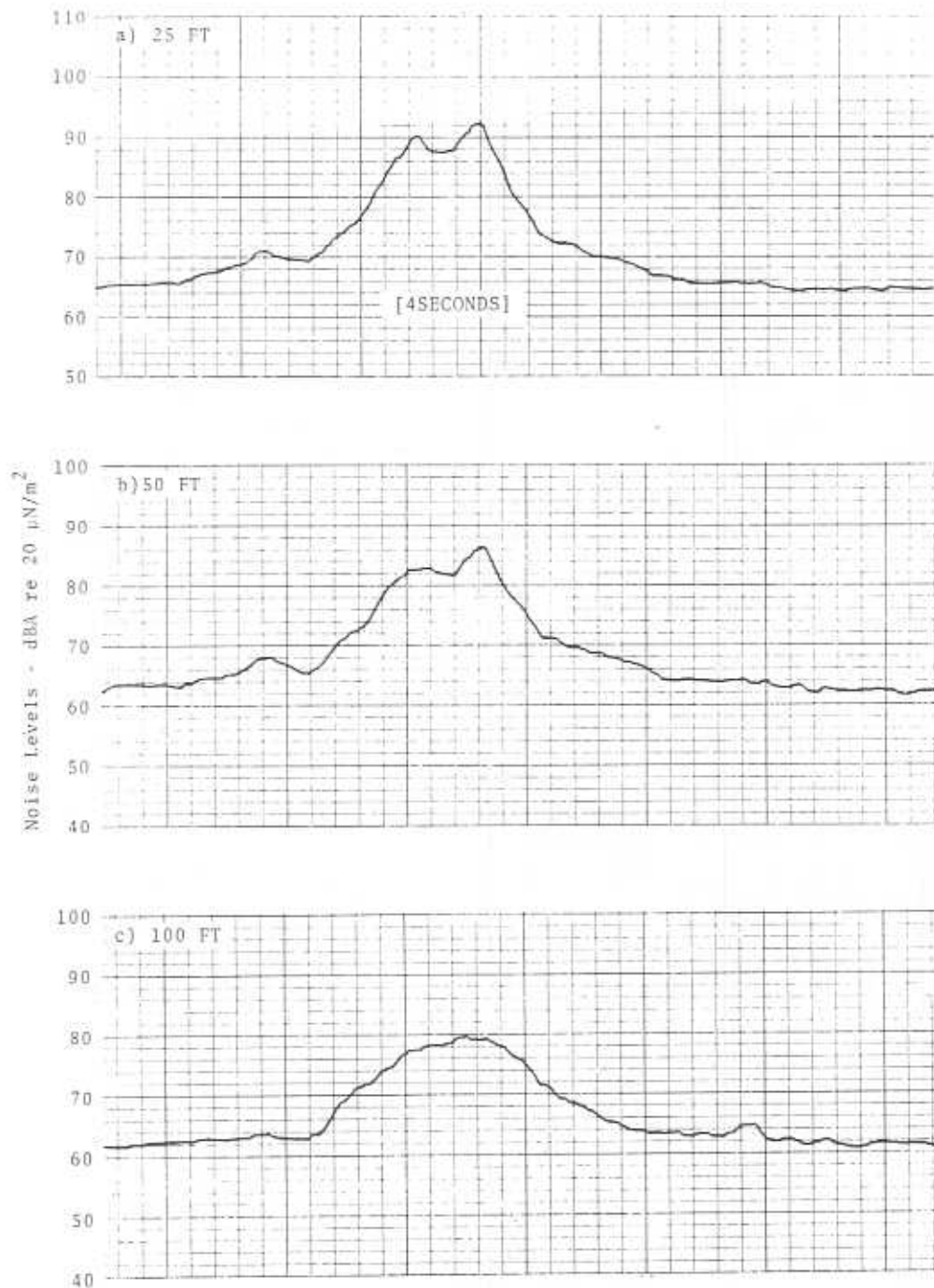


Figure C-18 Coincident Time Histories - Wayside Noise Levels at 25, 50 and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension). April 27, 1972. 4-Car Train northbound - Ser. Nos 1616, 1617, 1634, 1635 at 49.3 mph.

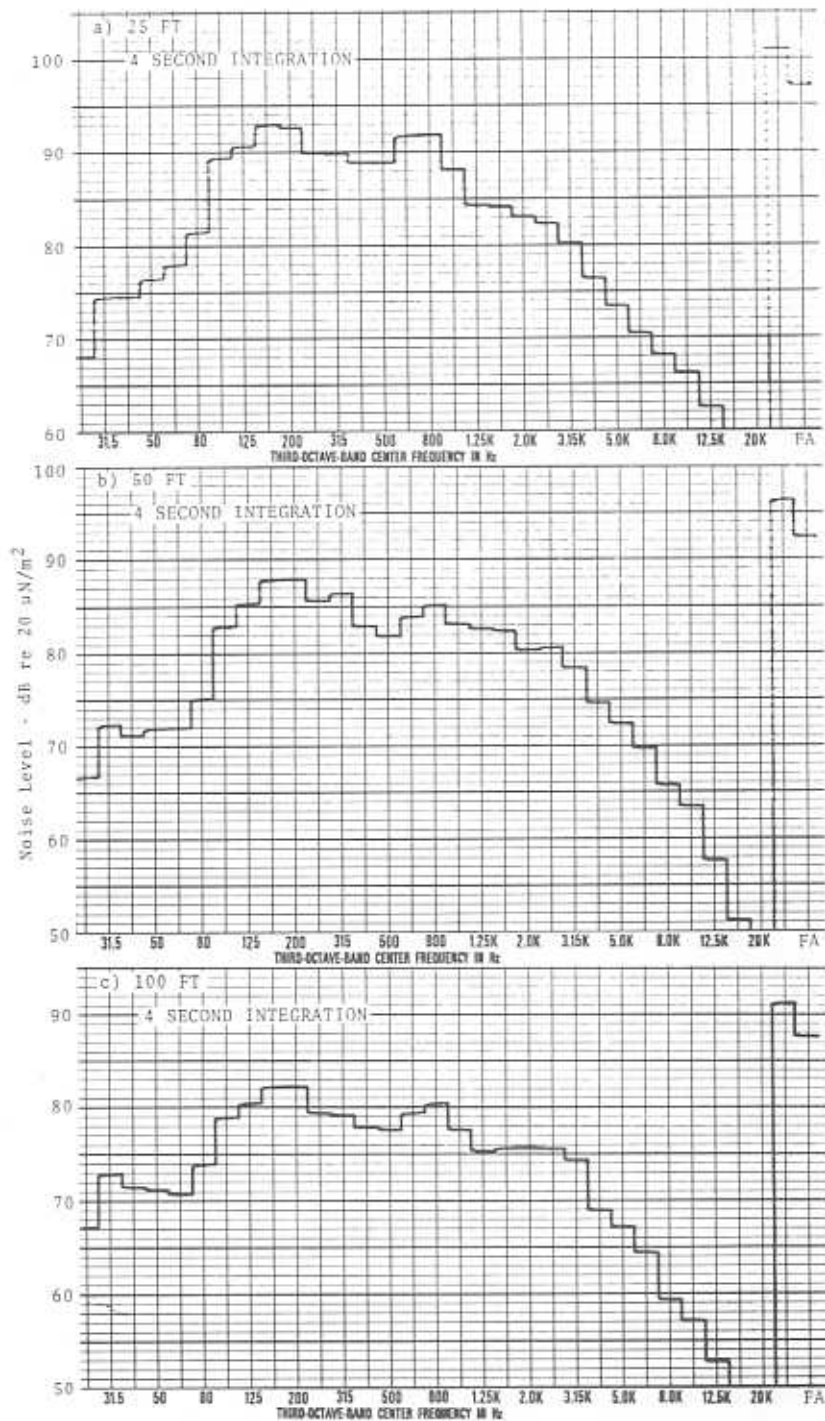


Figure C-19 Wayside Noise Spectra at 25, 50, and 100 ft. from centerline of northbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound - Ser. Nos. 1616, 1617, 1634, 1635 at 49.3 mph. See figure C-18.

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

WED 07/26/72
 13:25

NOISE DATA FROM RUN NO. RT-46-72-1A OF THE MOBILE NOISE LABORATORY ON
 APRIL 27 1972 FROM 13:46 TO 14:46 ON TENEAN ST. DORCHESTER, MASS.
 (ZONE 19 UNIVERSAL GRID LOCATION 331.61 - 4683.68 .)
 MICROPHONE LOCATED 25FT. FROM CENTERLINE NEAR TRACK(NORTHBOUND)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

DISTRIB

UTION DBA*

1	103	+
0	102	+
5	101	+
8	100	+
7	99	+
10	98	+
12	97	+
7	96	+
16	95	+
24	94	+
29	93	+
43	92	+
40	91	+
30	90	+
29	89	+
32	88	+
33	87	+
35	86	+
43	85	+
47	84	+
43	83	+
50	82	+
64	81	+
49	80	+
73	79	+
91	78	+
156	77	+
179	76	+
290	75	+
360	74	+
426	73	+
605	72	+
821	71	+
1142	70	+
2076	69	+
2708	68	+
3687	67	+
4729	66	+
4621	65	+
3995	64	+
1952	63	+
222	62	+
10	61	+
0	60	+

SAMPLES=	28800
AVERAGE=	67.3 DBA*
STANDARD DEVIATION=	4.3 DBA*
ENERGY MEAN=	75.4 DB**
NOISE POLLUTION LEVEL=	86.4
1% PERCENTILE=	88.2 DBA*
10% DECILE=	71.9 DBA*
MEDIAN=	66.8 DBA*
90% DECILE=	64.2 DBA*
99% PERCENTILE=	63 DBA*
WALSH HEALEY EXP.=	1.9 %
RANGE=	42 DB

LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure C-20. Statistical Analysis - Wayside Noise Data - MBTA Red Line-25 ft
 (So. Shore Extension), April 27, 1972

1	103	0			
0	102	0			
5	101	0			
8	100	0			
7	99	0			
10	98	0			
12	97	0			
7	96	0			
16	95	0			
24	94	0			
29	93	0			
43	92	0			
40	91	0			
30	90	0			
29	89	0			
32	88	0			
33	87	0			
35	86	0			
43	85	0			
47	84	0			
43	83	0			
50	82	0			
64	81	0			
49	80	0			
73	79	0			
91	78	00			
156	77	00			
179	76	00			
290	75	000			
360	74	000			
426	73	000			
605	72	0000			
821	71	00000			
1142	70	0000000			
2076	69	000000000000			
2708	68	00000000000000			
3687	67	000000000000000000			
4729	66	0000000000000000000000			
4621	65	0000000000000000000000			
3995	64	0000000000000000000000			
1952	63	00000000000			
222	62	00			
10	61	0			
DIST. DBA*	0		10	20	30
			LEVEL(DBA*) VS DISTRIBUTION (PERCENT)		

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure C-20 (Continued). Statistical Analysis - Wayside Noise Data - MBTA
 Red Line (So. Shore Extension), April 27, 1972 25 ft

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

WED 07/26/72
 14:04

NOISE DATA FROM RUN NO. RT-46-72-3A OF THE MOBILE NOISE LABORATORY ON
 APRIL 27 1972 FROM 13:46 TO 14:46 ON TENEAN ST. DORCHESTER, MASS.
 (ZONE 19 UNIVERSAL GRID LOCATION 331.61 - 4683.68 .)
 MICROPHONE LOCATED 50 FT. FROM CENTERLINE NEAR TRACK(NORTHBOUND)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

DISTRIB
 UTION DBA*

5	96	+
5	95	+
3	94	+
13	93	+
13	92	+
18	91	+
21	90	+
23	89	+
38	88	+
55	87	+
41	86	+
45	85	+
34	84	+
38	83	+
49	82	+
48	81	+
53	80	+
65	79	+
87	78	+
87	77	+
109	76	+
128	75	+
193	74	+
296	73	+
403	72	+
489	71	+
530	70	+
846	69	+
1431	68	+
1878	67	+
2618	66	+
3404	65	+
3512	64	+
3895	63	+
3508	62	+
2699	61	+
1504	60	+
562	59	+
52	58	+
2	57	+
0	56	+

SAMPLES=	28800
AVERAGE=	64.9 DBA*
STANDARD DEVIATION=	4.4 DBA*
ENERGY MEAN=	71.4 DB**
NOISE POLLUTION LEVEL=	82.7
1% PERCENTILE=	84.8 DBA*
10% DECILE=	70 DBA*
MEDIAN=	64.6 DBA*
90% DECILE=	61.3 DBA*
99% PERCENTILE=	59.4 DBA*
WALSH HEALEY EXP.=	.5 %
RANGE=	39 DB

LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure C-21. Statistical Analysis - Wayside Noise Data - MBTA Red Line -50 ft (So. Shore Extension), April 27, 1972

5	96	0			
5	95	0			
3	94	0			
13	93	0			
13	92	0			
18	91	0			
21	90	0			
23	89	0			
38	88	0			
55	87	0			
41	86	0			
45	85	0			
34	84	0			
38	83	0			
49	82	0			
48	81	0			
53	80	0			
65	79	0			
87	78	00			
87	77	00			
109	76	00			
128	75	00			
193	74	00			
296	73	000			
403	72	000			
489	71	0000			
530	70	0000			
846	69	000000			
1431	68	000000000			
1878	67	00000000000			
2618	66	000000000000000			
3404	65	0000000000000000000			
3512	64	0000000000000000000			
3895	63	000000000000000000000			
3508	62	000000000000000000000			
2699	61	0000000000000000000			
1504	60	000000000			
562	59	0000			
52	58	0			
2	57	0			
DIST. DBA*	0		10	20	30

LEVEL(DBA*) VS DISTRIBUTION (PERCENT)

*--A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF THE SQUARES OF THE SOUND PRESSURES.

Figure C-21 (Continued). Statistical Analysis - Wayside Noise Data - MBTA Red Line (So. Shore Extension), April 27, 1972 50 ft

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

WED 07/26/72
 14:26

NOISE DATA FROM RUN NO. RT-46-72-4A OF THE MOBILE NOISE LABORATORY ON
 APRIL 27 1972 FROM 13:46 TO 14:46 ON TENEAN ST. DORCHESTER, MASS.
 (ZONE 19 UNIVERSAL GRID LOCATION 331.61 - 4683.68 .)
 MICROPHONE LOCATED 100FT. FROM CENTERLINE NEAR TRACK(NORTHBOUND)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

DISTRIB
 UTION DBA*

8 90 +
 6 89 +
 11 88 +
 15 87 +
 26 86 +
 22 85 +
 50 84 +
 55 83 +
 62 82 +
 55 81 +
 62 80 +
 68 79 +
 91 78 +
 112 77 +
 128 76 +
 166 75 +
 183 74 +
 313 73 +
 450 72 +
 536 71 +
 567 70 +
 855 69 +
 1446 68
 1682 67
 2151 66
 2688 65
 2971 64
 3446 63
 3494 62
 2982 61
 2286 60
 1336 59
 392 58
 83 57
 2 56
 0 55

SAMPLES= 28800
 AVERAGE= 64.5 DBA*
 STANDARD DEVIATION= 4.3 DBA*
 ENERGY MEAN= 68.8 DB**
 NOISE POLLUTION LEVEL= 79.8
 1% PERCENTILE= 81.4 DBA*
 10% DECILE= 70.2 DBA*
 MEDIAN= 64.1 DBA*
 90% DECILE= 60.5 DBA*
 99% PERCENTILE= 58.5 DBA*
 WALSH HEALEY EXP.= 0 %
 RANGE= 34 DB

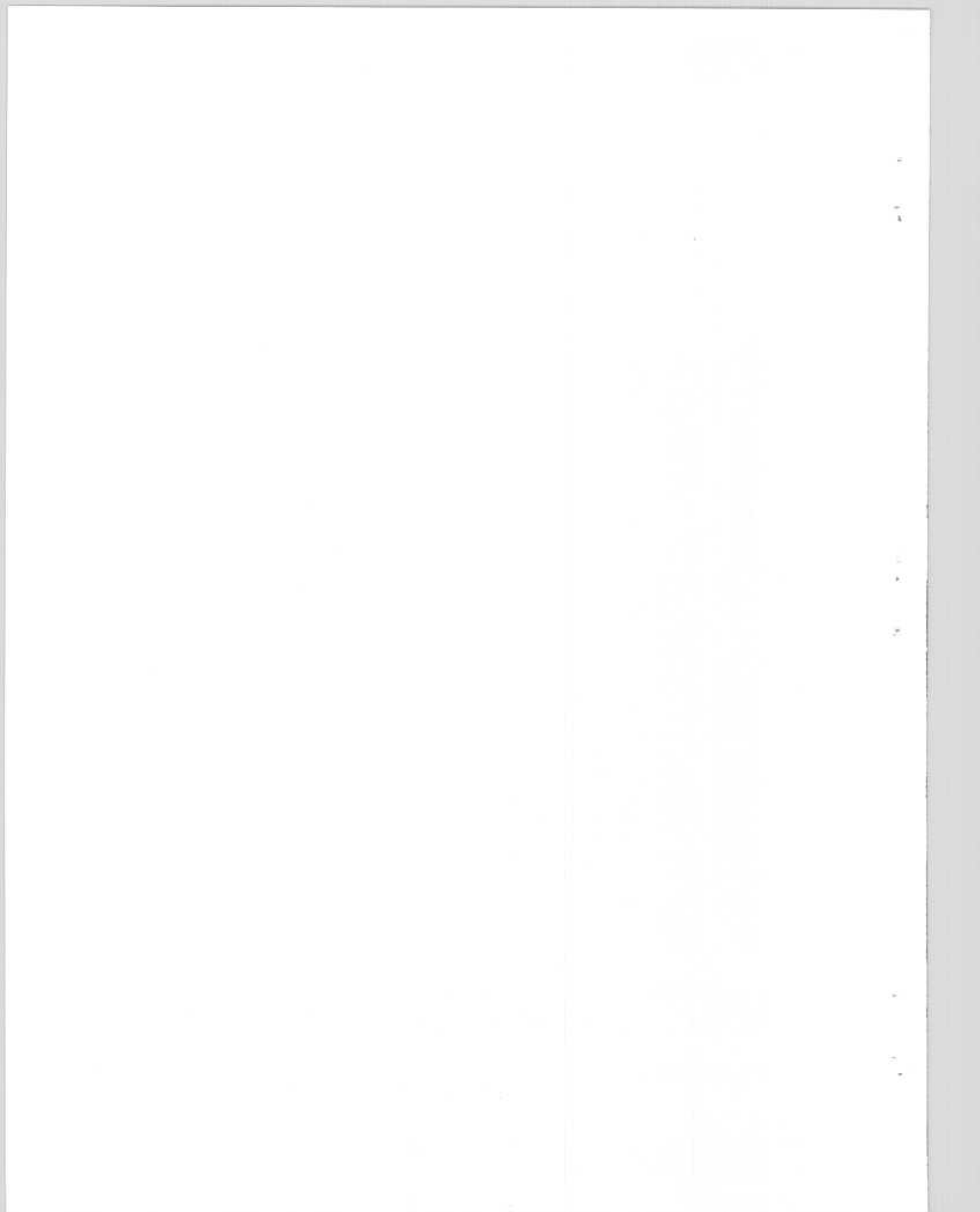
LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure C-22. Statistical Analysis - Wayside Noise Data - MBTA Red Line-100 ft
 (So. Shore Extension) April 27, 1972

8	90	0		
6	89	0		
11	88	0		
15	87	0		
26	86	0		
22	85	0		
50	84	0		
55	83	0		
62	82	0		
55	81	0		
62	80	0		
68	79	0		
91	78	00		
112	77	00		
128	76	00		
166	75	00		
183	74	00		
313	73	000		
450	72	000		
536	71	0000		
567	70	0000		
855	69	000000		
1446	68	000000000		
1682	67	0000000000		
2151	66	000000000000		
2688	65	00000000000000		
2971	64	0000000000000000		
3446	63	000000000000000000		
3494	62	000000000000000000		
2982	61	0000000000000000		
2286	60	000000000000		
1336	59	00000000		
392	58	000		
83	57	00		
2	56	0		
DIST. DBA*	0	10	20	30
	LEVEL(DBA*) VS DISTRIBUTION (PERCENT)			

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

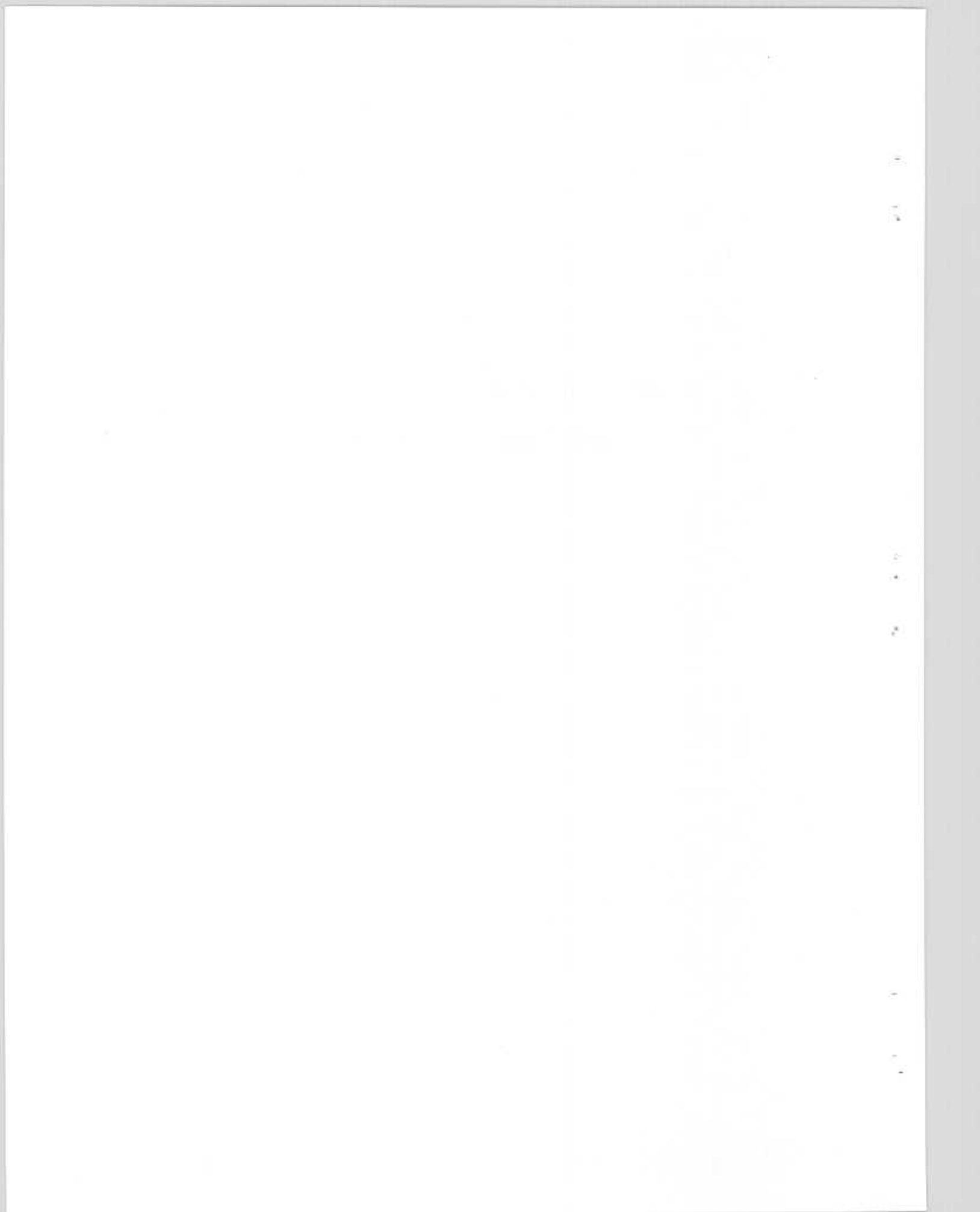
Figure C-22 (Continued). Statistical Analysis - Wayside Noise Data - MBTA
 Red Line (So. Shore Extension) April 27, 1972
 100 ft



APPENDIX D

WAYSIDE VIBRATION MEASUREMENTS - MBTA RED LINE

(SOUTH SHORE EXTENSION)-APRIL 27, 1972



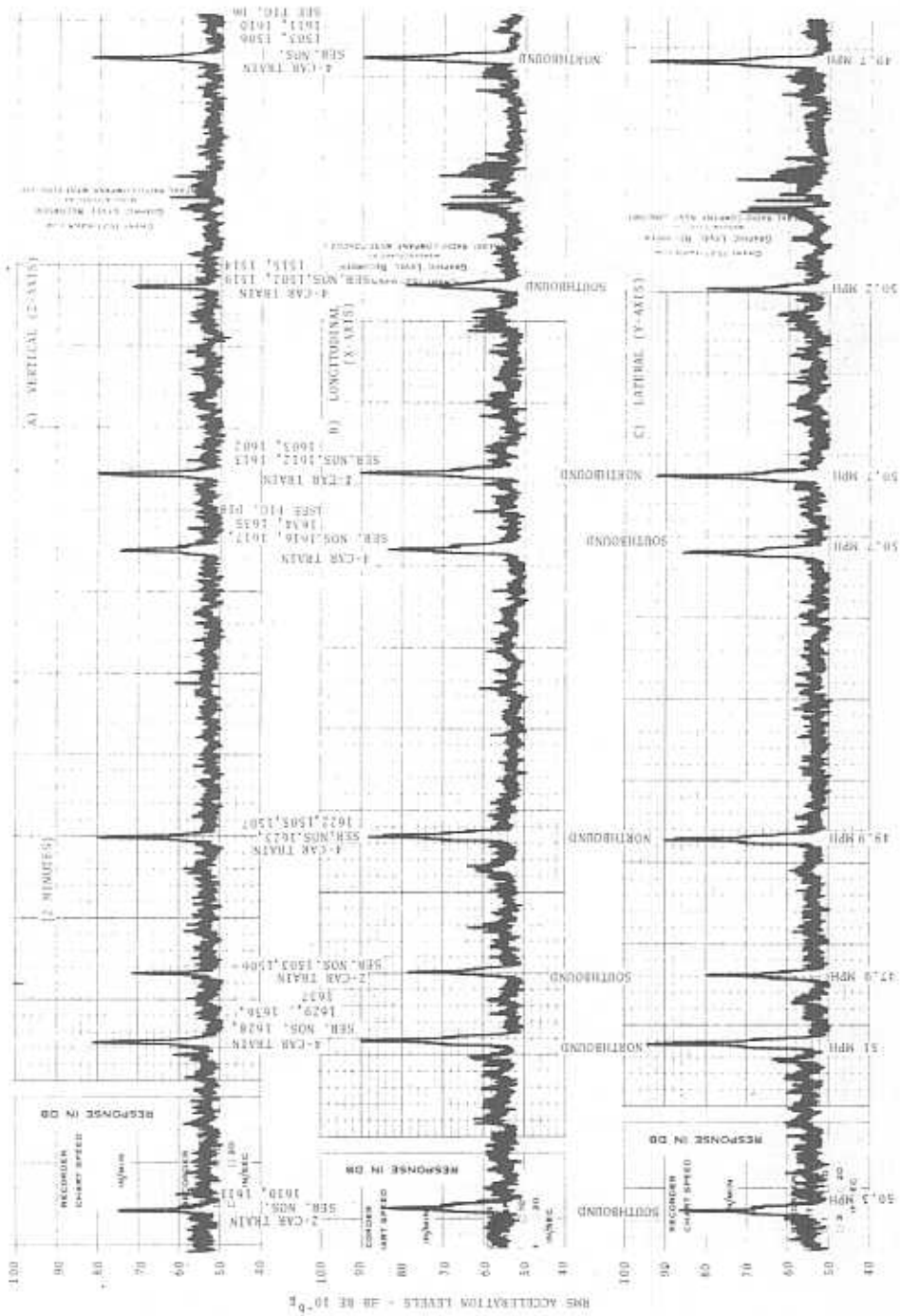
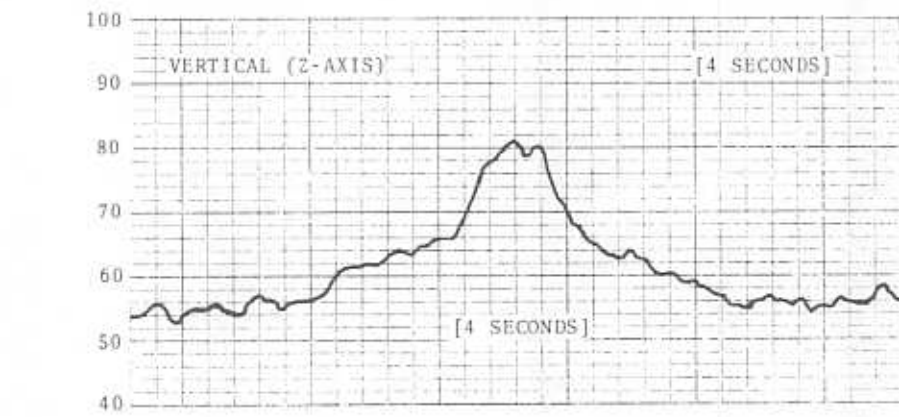


Figure D-1. Coincident Time Histories - Wayside Ground-Vibration Levels in 3 Axes at a point which is 25 ft from the centerline of the northbound track and 38 ft from the centerline of the southbound track. MBTA Red Line (So. Shore Extension) April 27, 1972. See Figure G-1 for accelerometer location and mounting.



LOGITUDINAL (X-AXIS)

NO DATA

RMS ACCELERATION LEVELS - dB RE 10^{-6} g

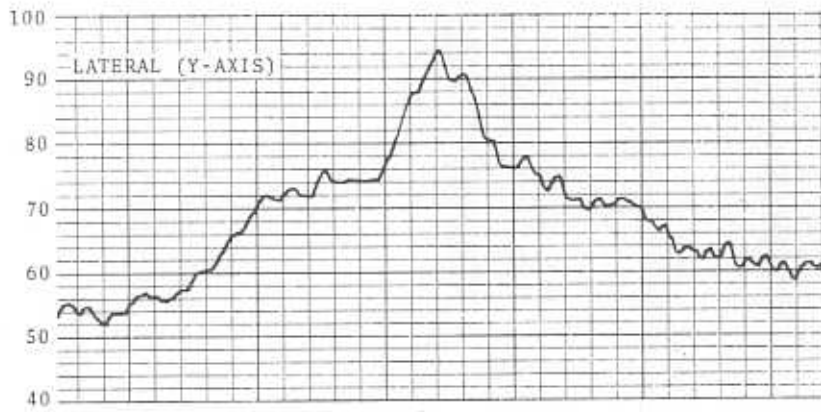


Figure D-2 Coincident Time Histories - Ground Vibration Levels in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound Ser. Nos 1611, 1610 at 50.6 mph.

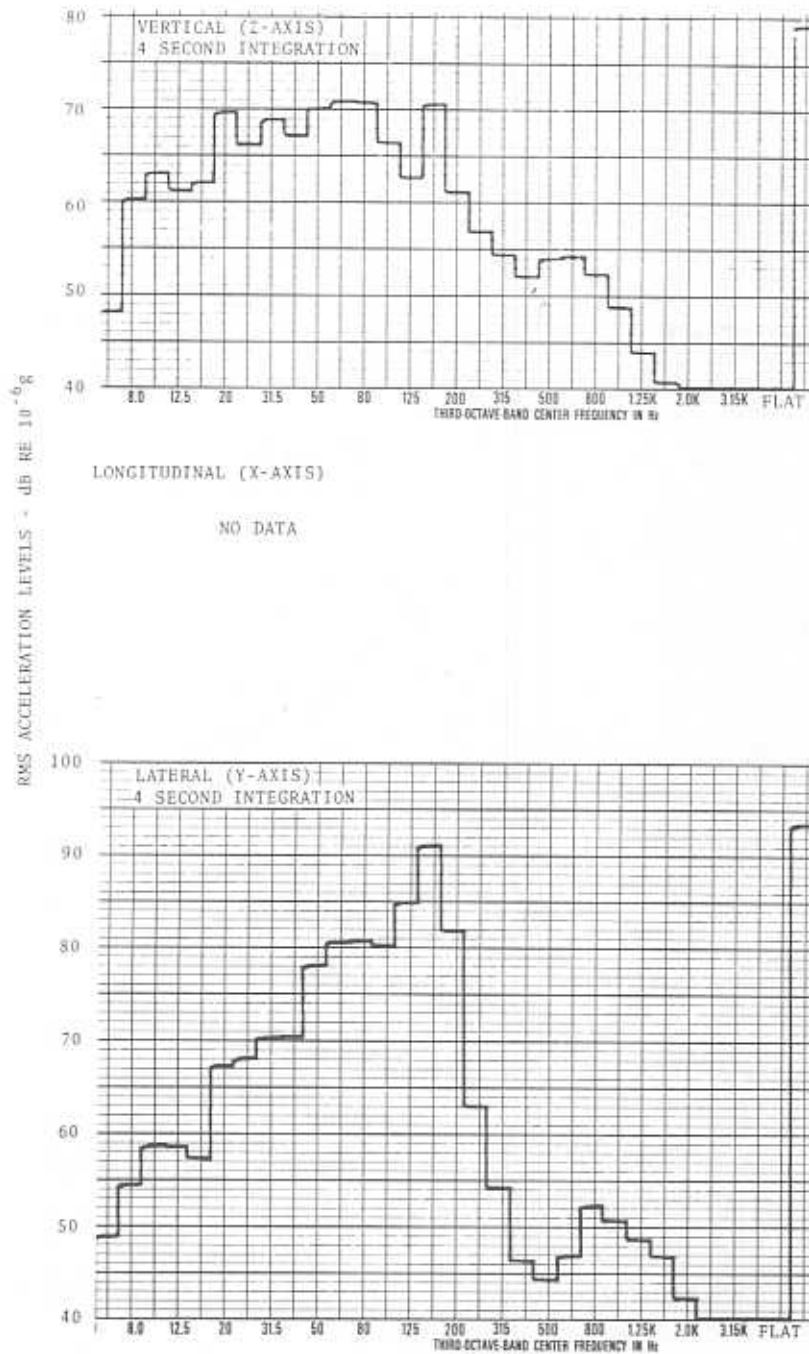


Figure D-3 Coincident Ground Vibration Spectra in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound Ser. Nos 1616, 1610 at 50.6 mph.

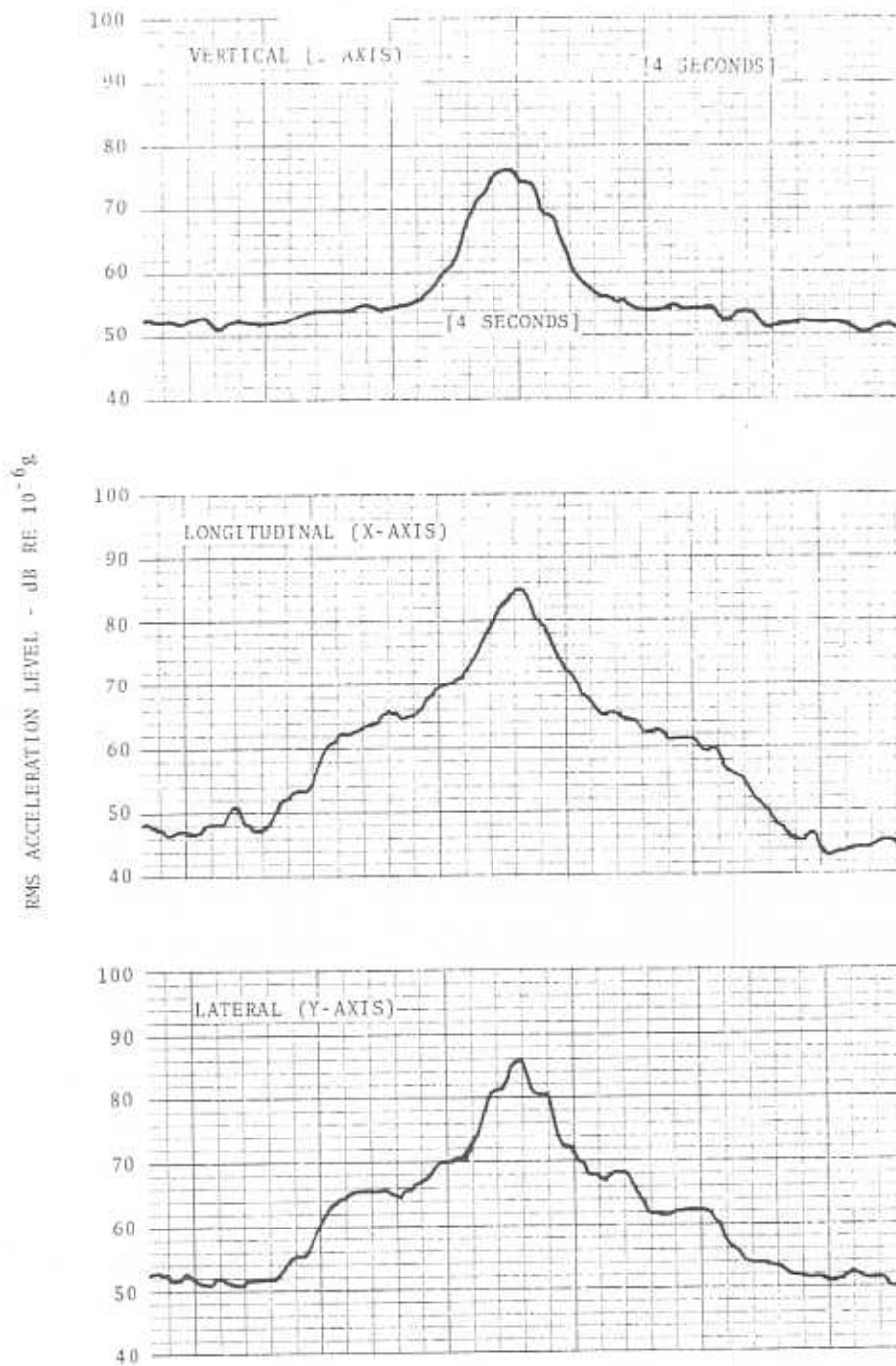


Figure D-4 Coincident Time Histories - Ground Vibration Levels in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound Ser. Nos 1503, 1506 at 49.5 mph.

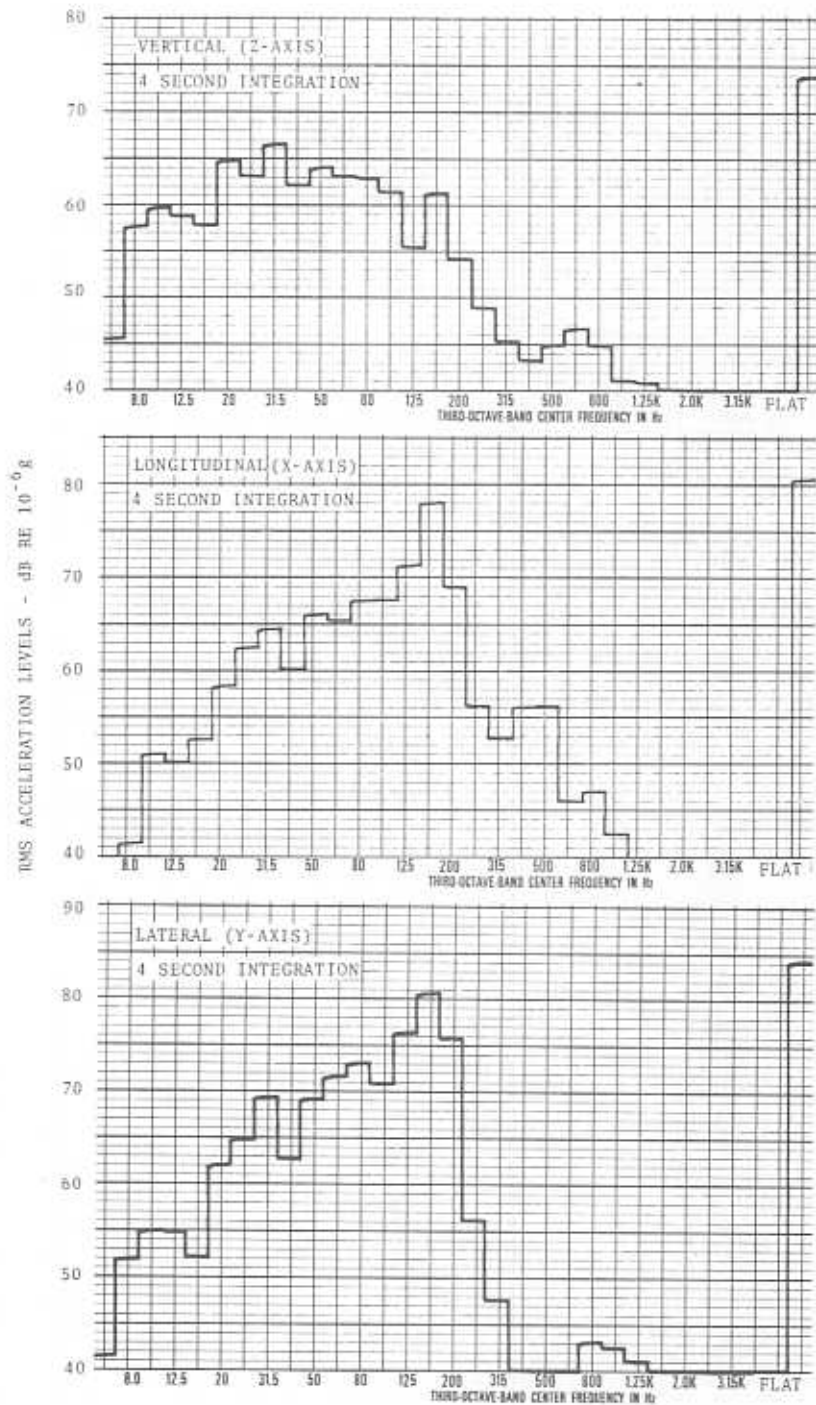


Figure D-5 Coincident Ground Vibration Spectra in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train northbound, Ser. Nos 1503, 1506 at 49.5 mph. See Figure D-4.

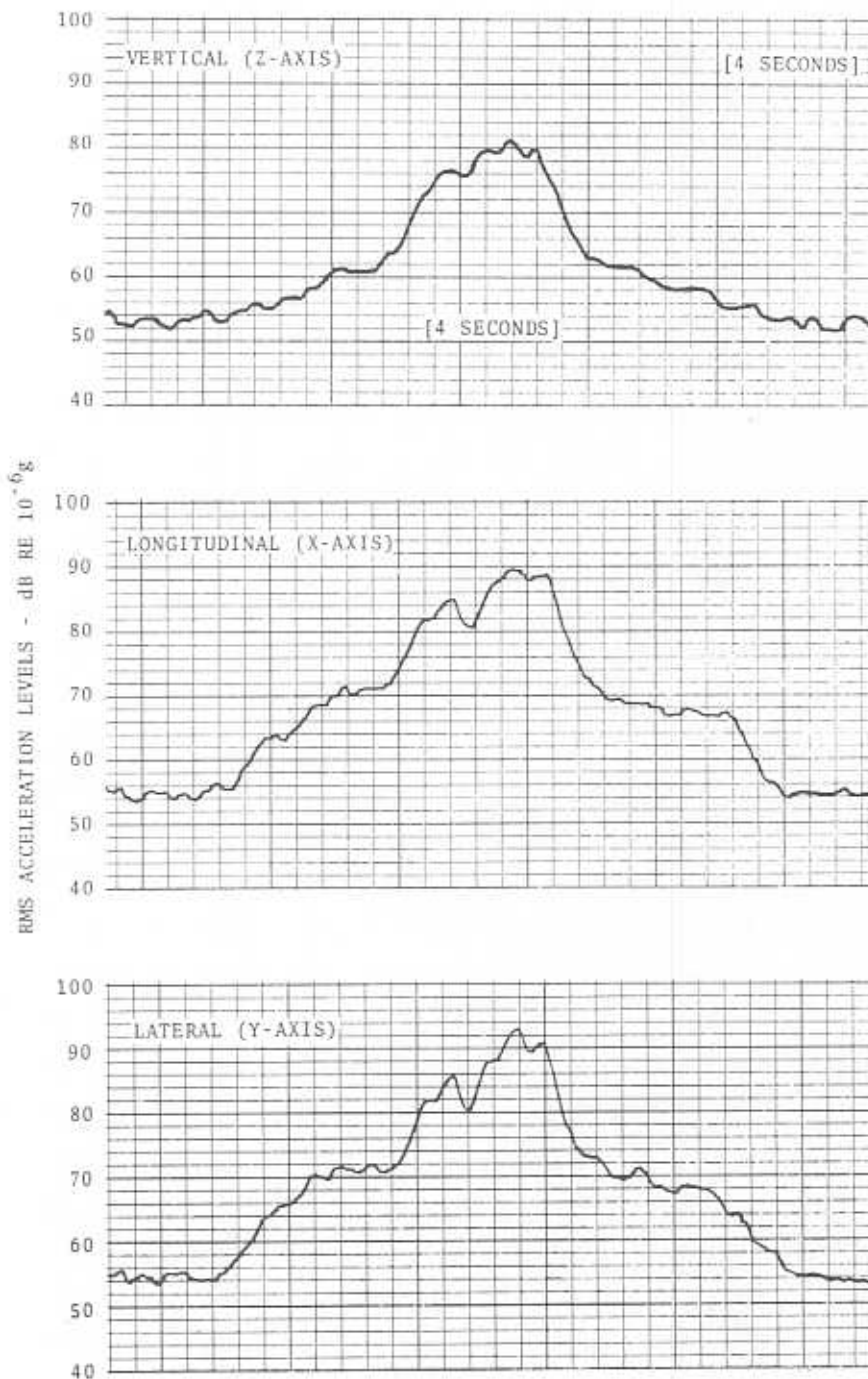


Figure D-6 Coincident Time Histories - Ground Vibration Levels in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound, Ser. Nos 1503, 1506, 1611, 1610 at 49.7 mph. See Figure D-1.

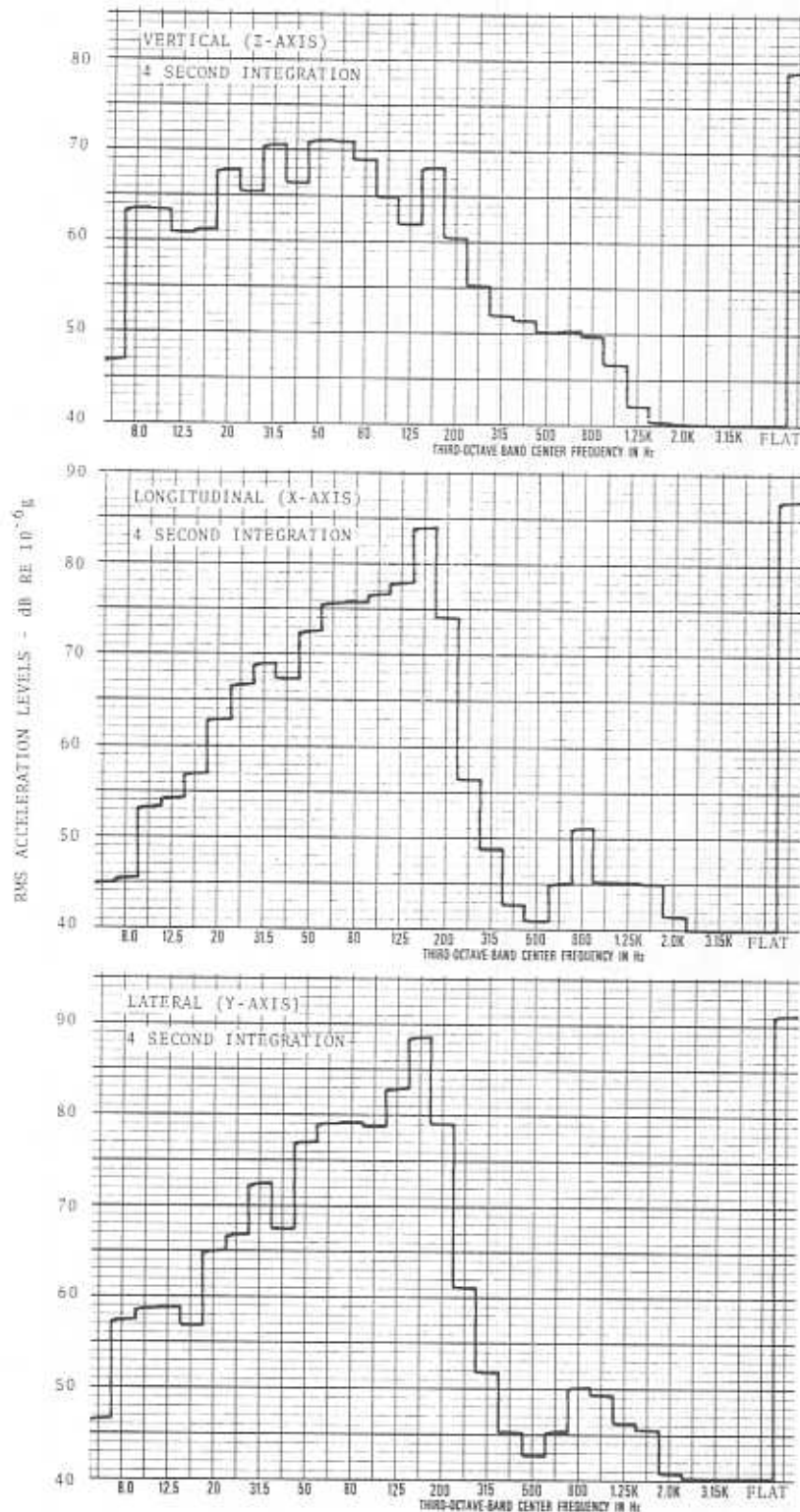


Figure D-7 Coincident Ground Vibration Spectra in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound, Ser. Nos 1503, 1506, 1611, 1610 at 49.7 mph.

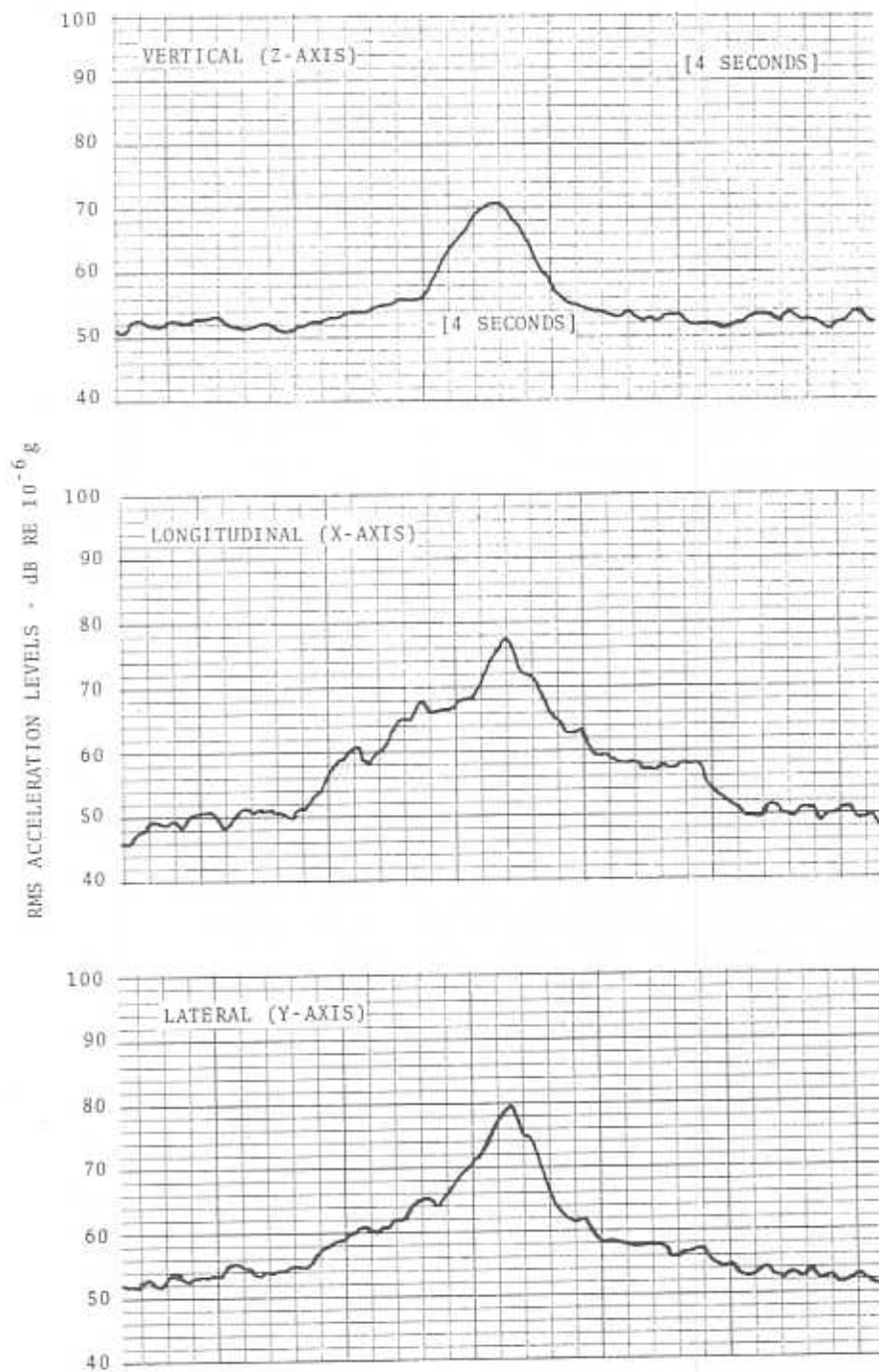


Figure D-8 Coincident Time Histories - Ground Vibration Levels in three axes 38 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound Ser. Nos 1618, 1619, at 49.9 mph.

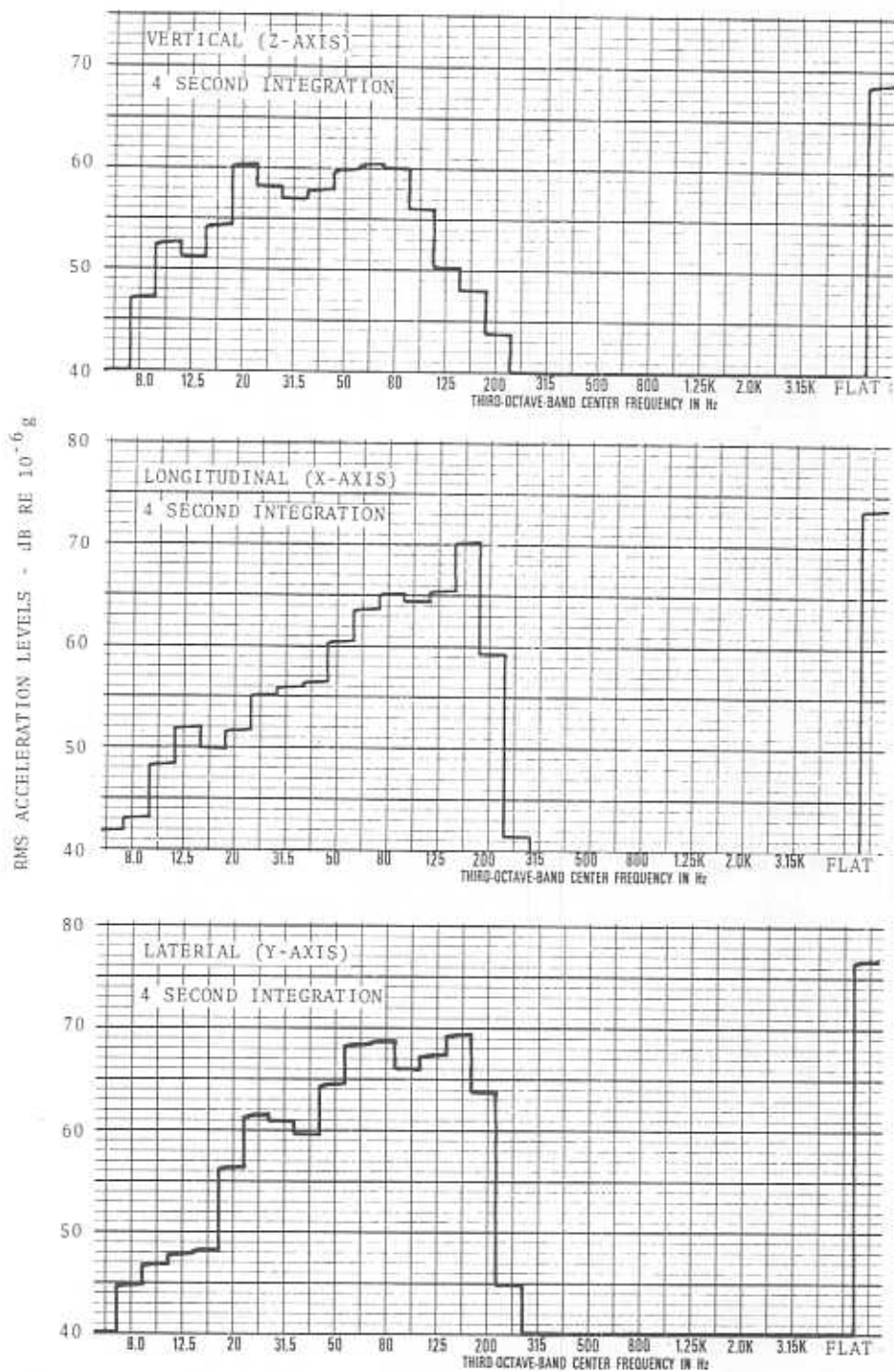


Figure D-9 Coincident Ground Vibration Spectra in three axes 38 feet from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound, Ser. Nos 1618, 1619 at 49.9 mph. See Figure D-8.

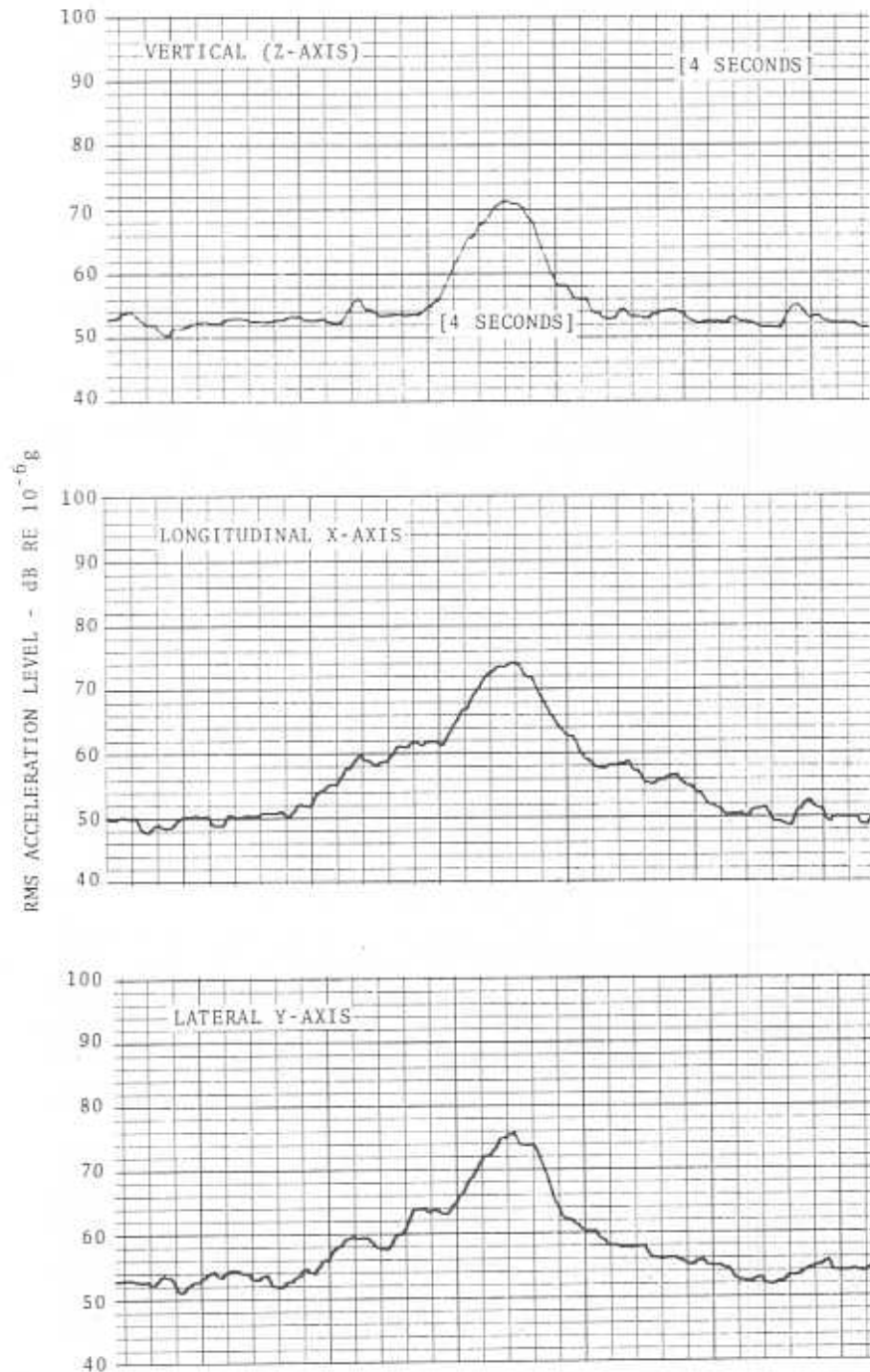


Figure D-10 Coincident Time Histories - Ground Vibration Levels in three axes 38 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound Ser. Nos 1604, 1605 at 50.4 mph.

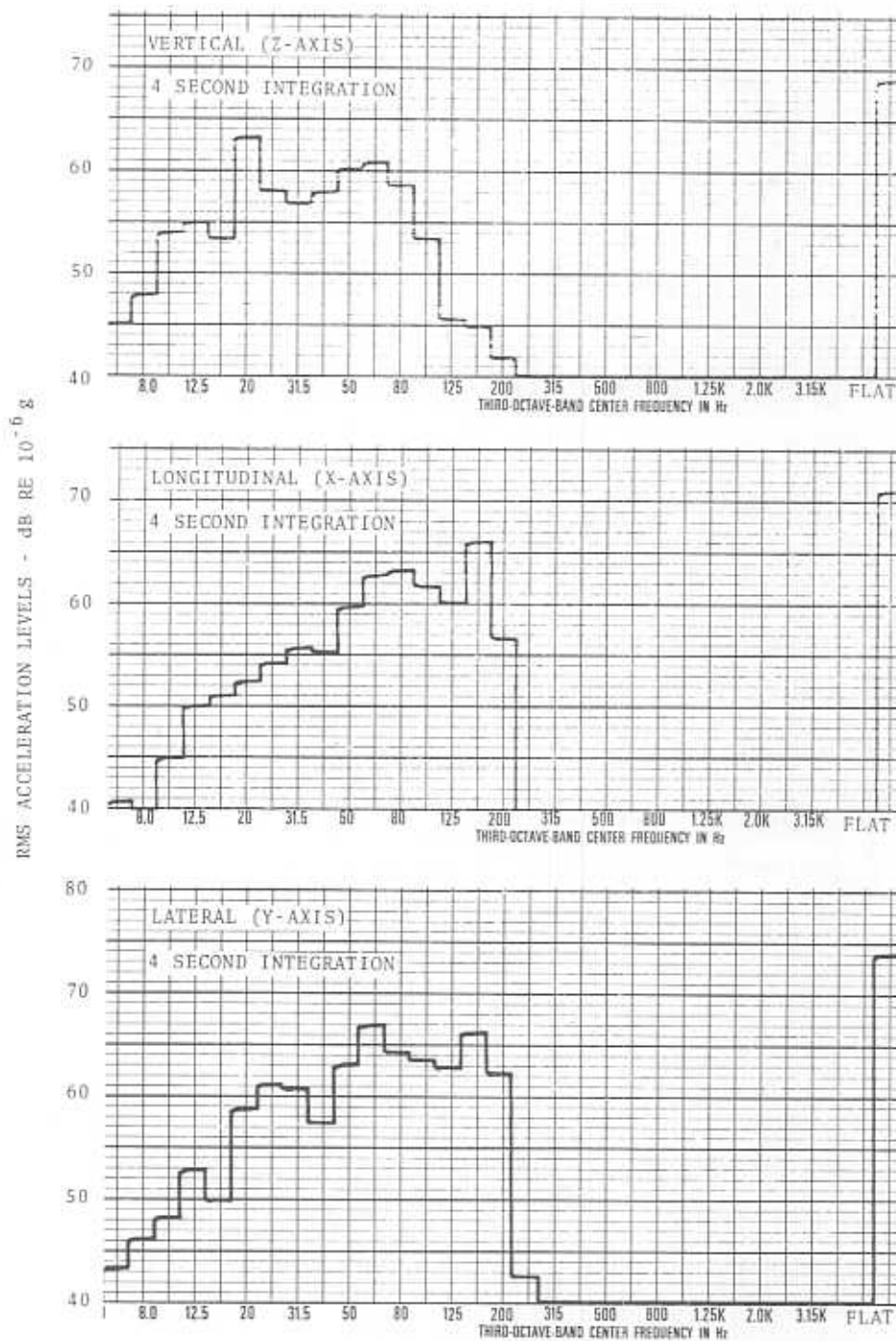


Figure D-11 Coincident Ground Vibration Spectra in three axes 38 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 2-Car Train southbound Ser. Nos 1604, 1605, at 50.4 mph. See figure D10.

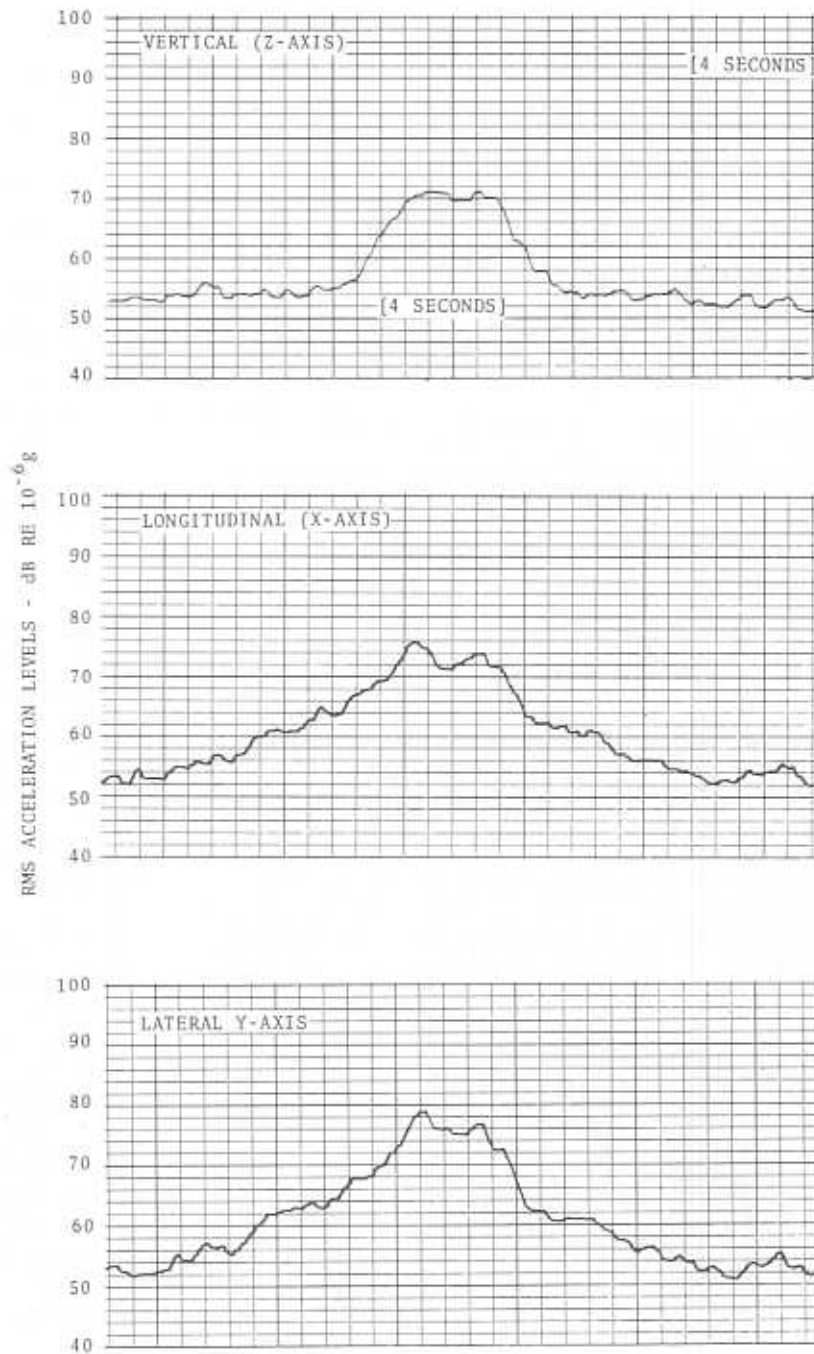


Figure D-12 Coincident Time Histories - Ground Vibration Levels in three axes 38 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train southbound, Ser. Nos 1604, 1605, 1619, 1618 at 48.9 mph.

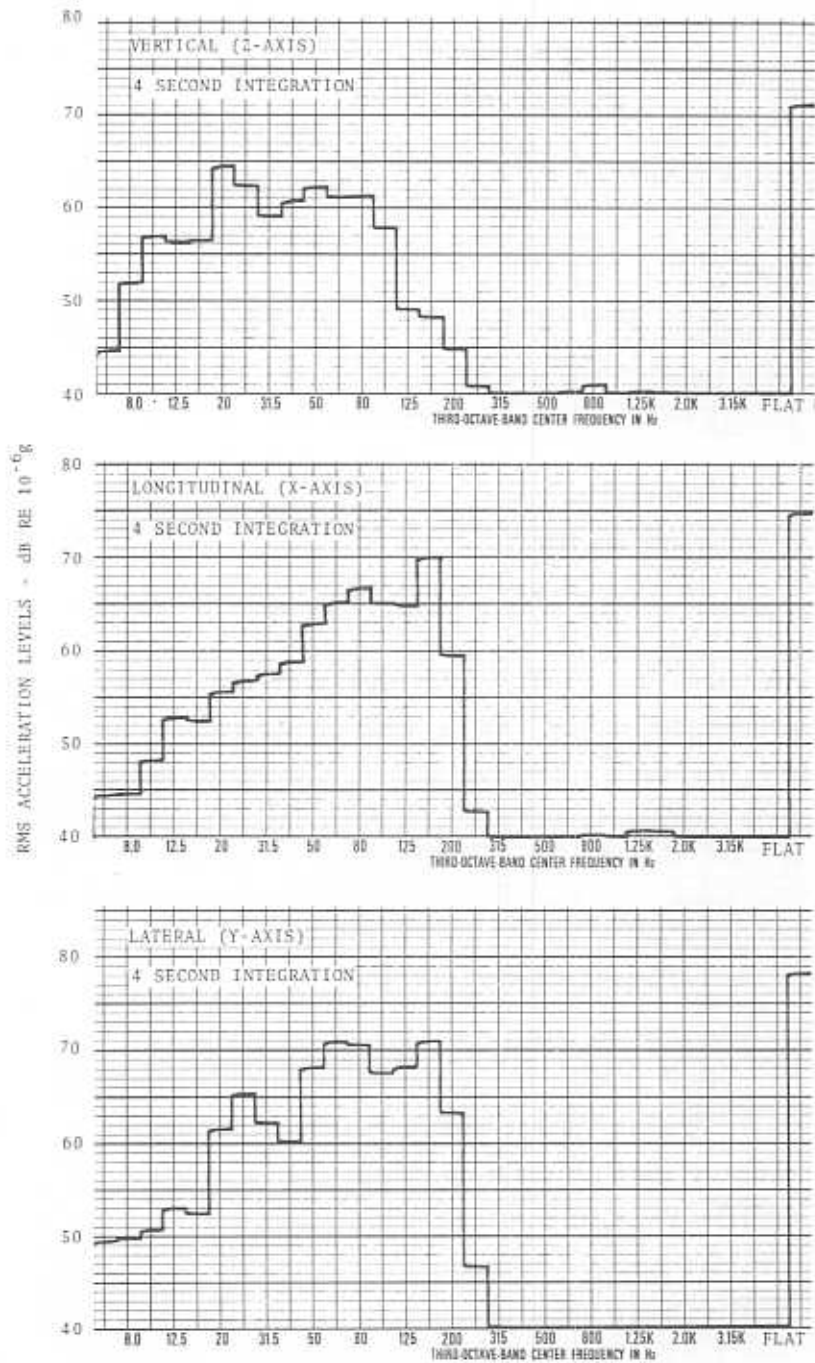


Figure D-13 Coincident Ground Vibration Spectra in three axes 38 feet from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train south-bound, Ser. Nos 1604, 1605, 1619, 1618 at 48.9 mph. See Figure D12.

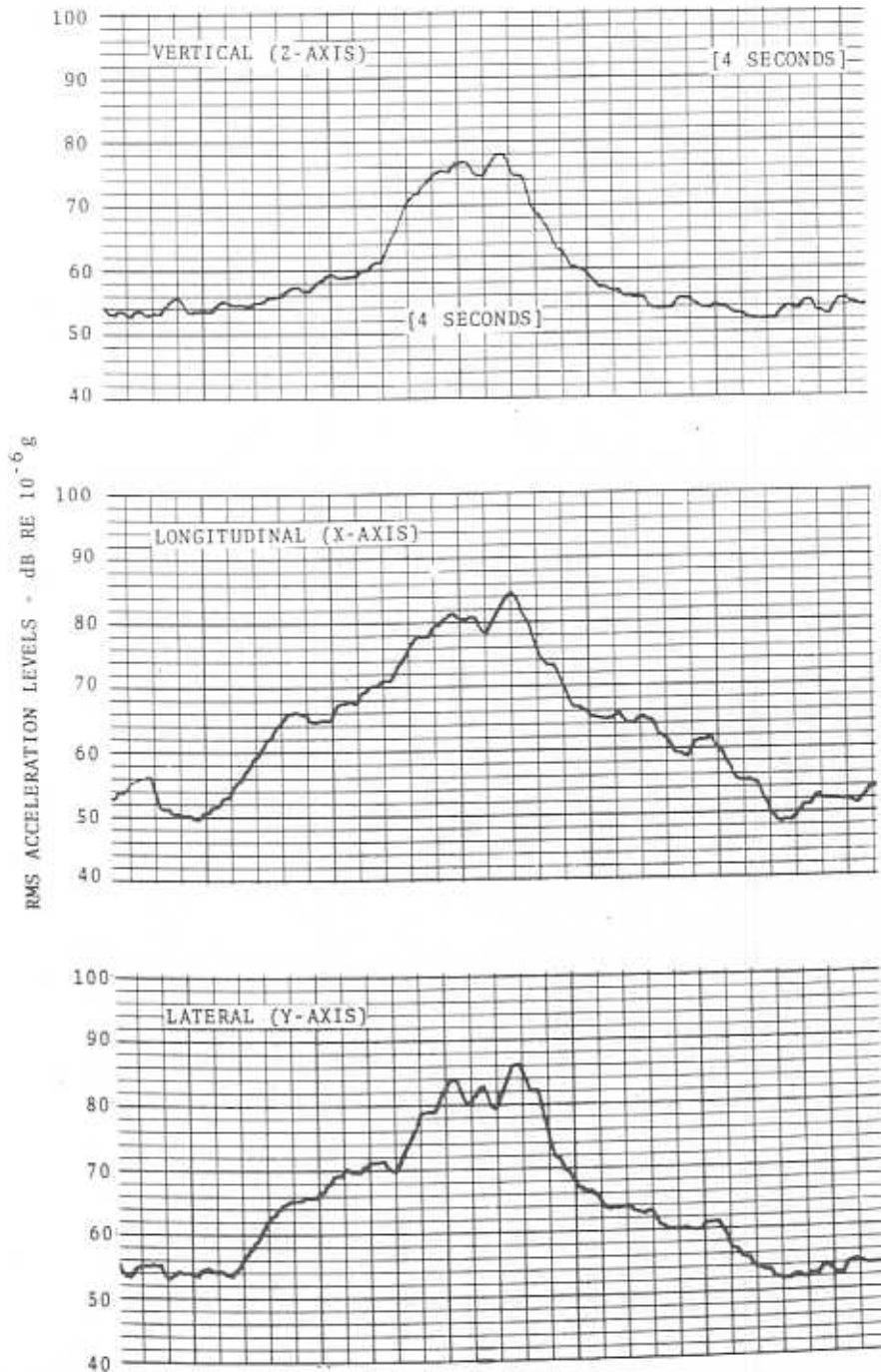


Figure D-14 Coincident Time Histories - Ground Vibration Levels in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound, Ser. Nos 1604, 1605, 1619, 1618 at 49.9 mph.

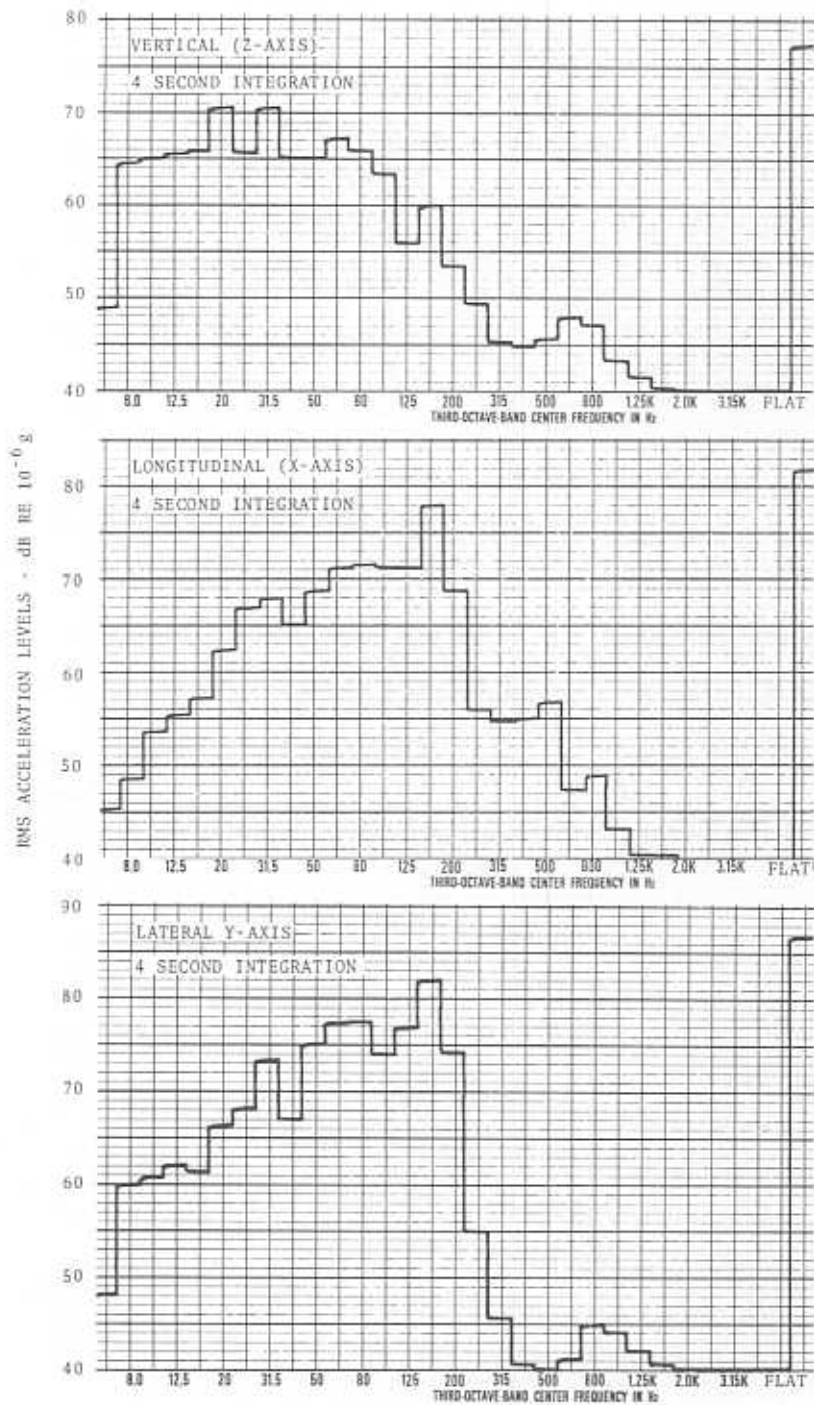


Figure D-15 Coincident Ground Vibration Spectra in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound Ser. Nos 1604, 1605, 1619, 1618 at 49.9 mph. See Figure D-14.

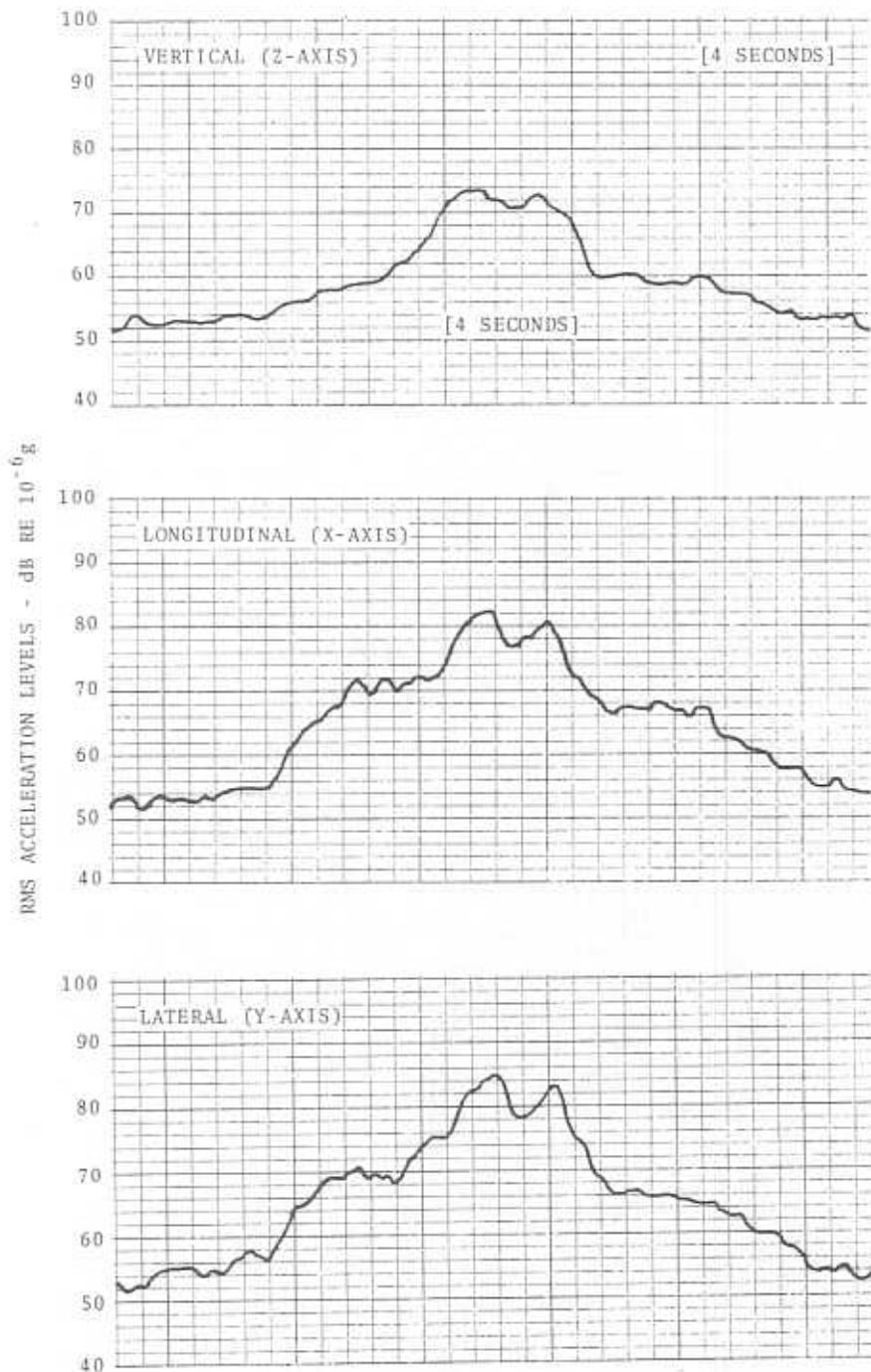


Figure D-16 Coincident Time Histories - Ground Vibration Levels in three axes 38 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train southbound Ser. Nos 1616, 1617, 1634, 1635 at 50.7 mph. See Figure D4.

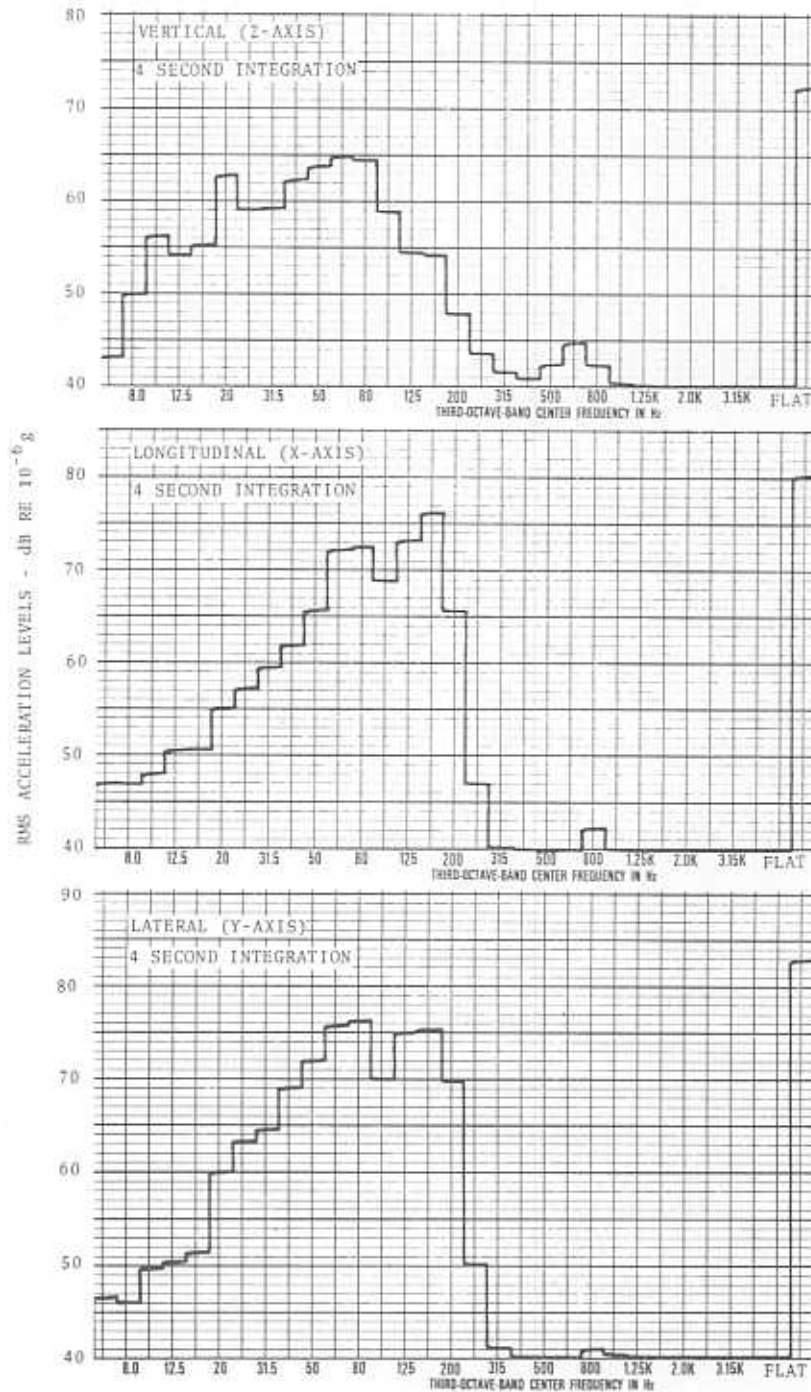


Figure D-17 Coincident Ground Vibration Spectra in three axes 38 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train south-bound Ser. Nos 1616, 1617, 1634, 1635 at 50.7 mph. See Figure D16.

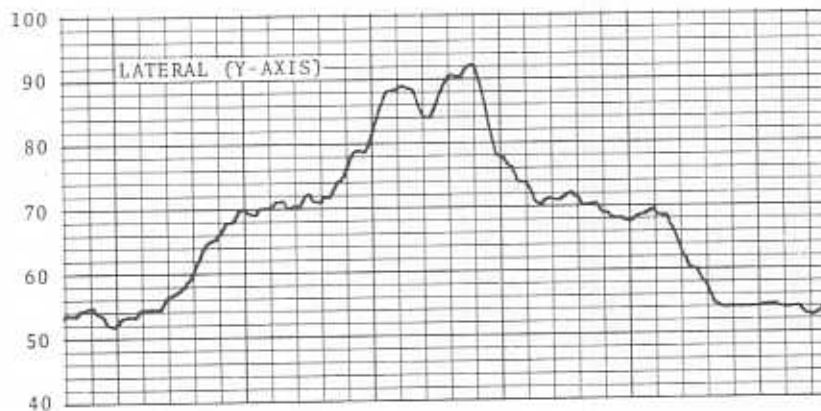
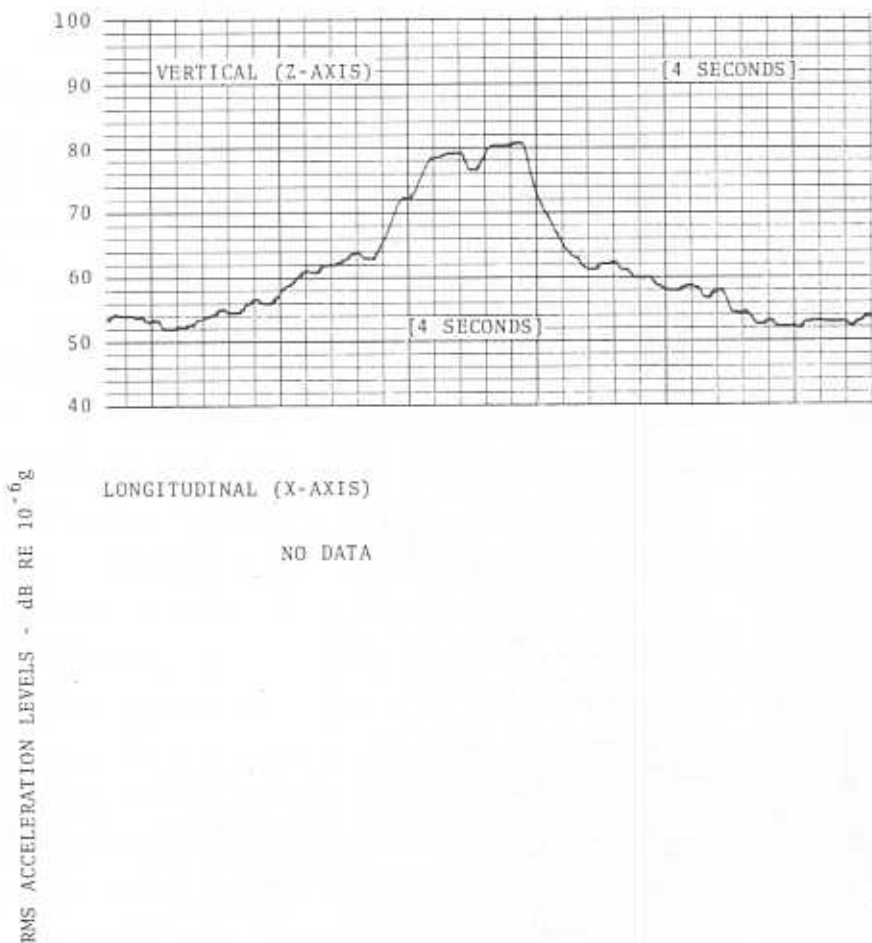


Figure D-18 Coincident Time Histories - Ground Vibration Levels in three axes 25 ft. from the track center line. MBTA Red Line (So, Shore Extension) April 27, 1972. 4-Car Train northbound Ser. Nos 1616, 1617, 1634, 1635 at 49.3 mph.

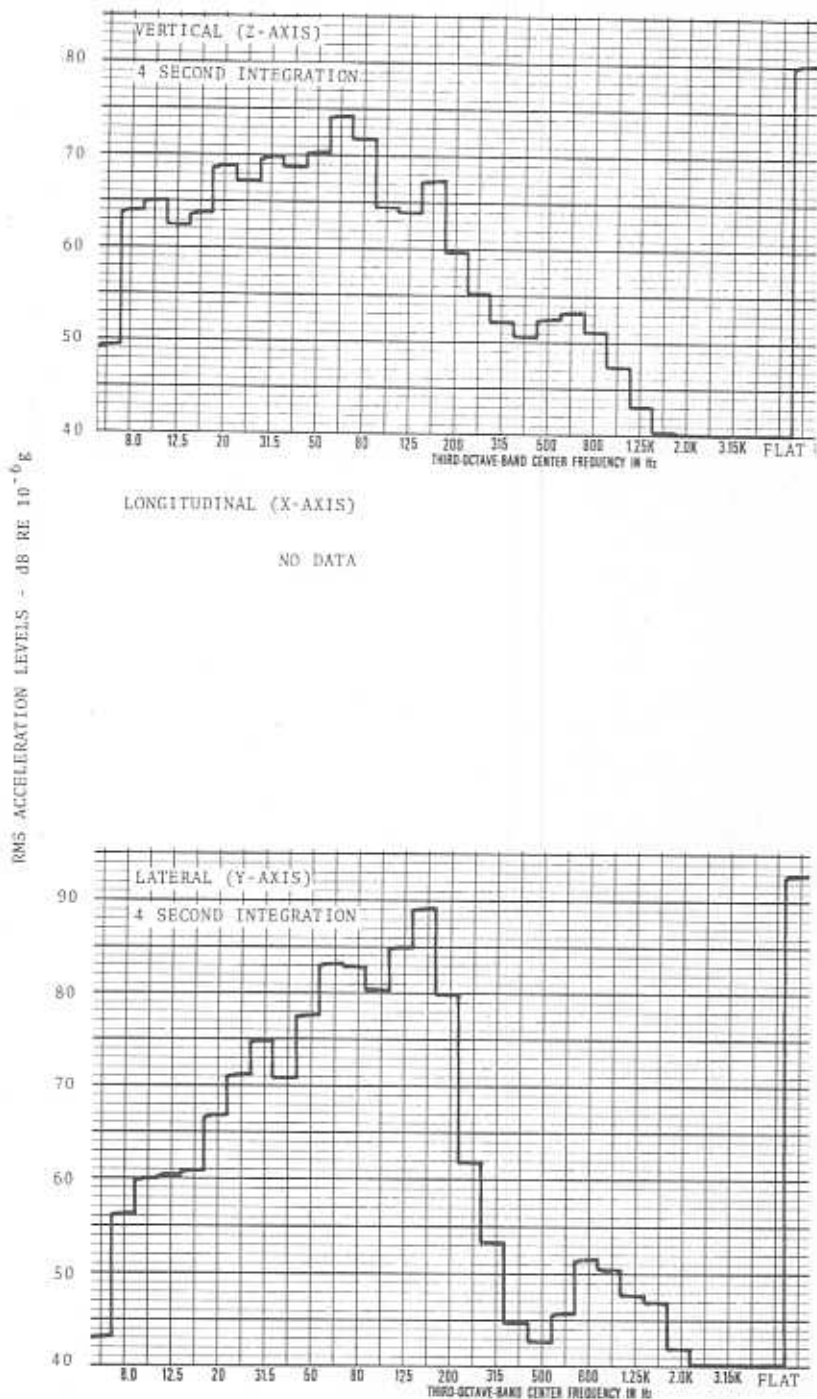


Figure D-19 Coincident Ground Vibration Spectra in three axes 25 ft. from track centerline. MBTA Red Line (So. Shore Extension) April 27, 1972. 4-Car Train northbound Ser. Nos' 1616, 1617, 1634, 1635 at 49.3 mph. See Figure D-18.

3

4

4

7

8

8

8

8

APPENDIX E

IN-CAR NOISE LEVEL MEASUREMENTS - MBTA RED LINE

APRIL 29, 1972

1
2
3

4
5

6
7

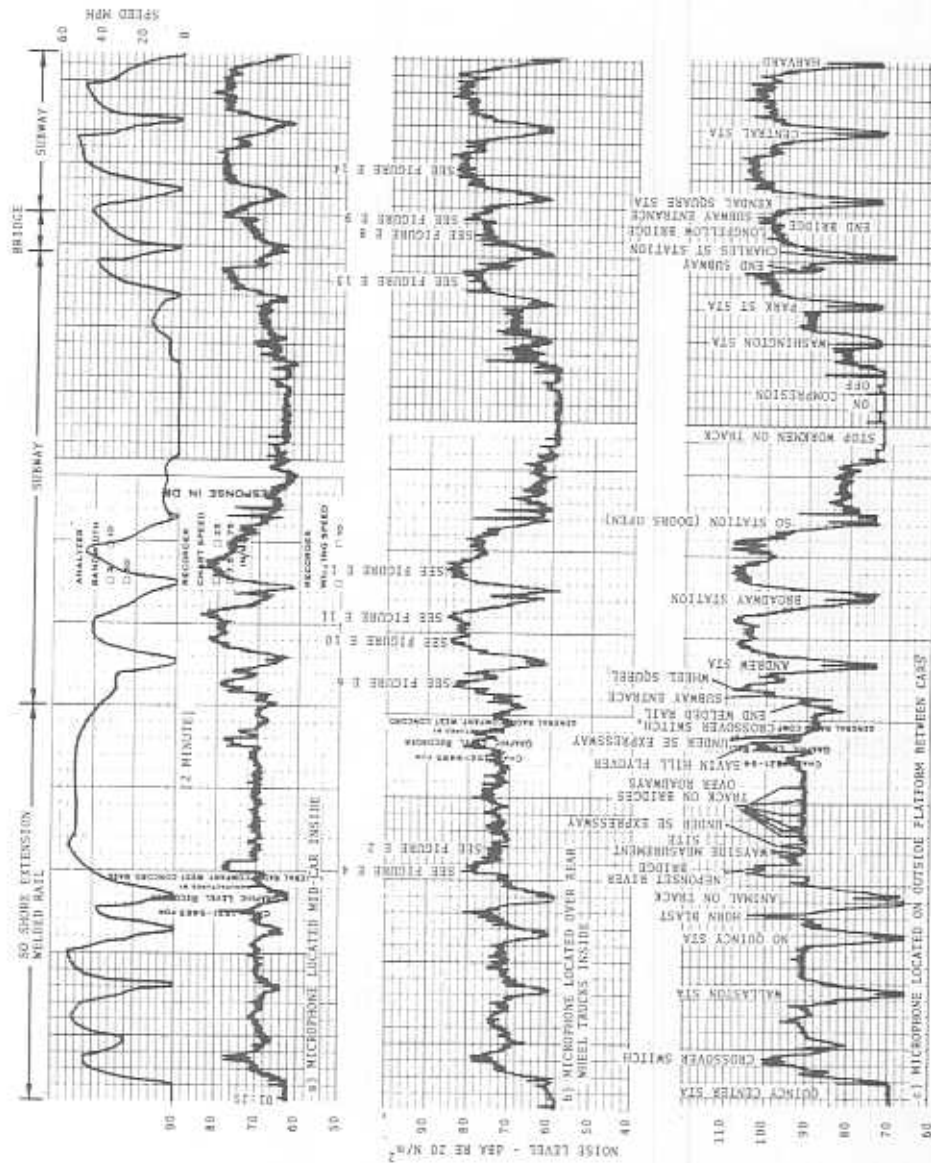


Figure E-1. Coincident Time Histories - Noise Levels Measured at Three Locations on MBTA Type 1 So. Shore Rapid Transit Cars Ser. Nos. 1503, 1506 on the MBTA Red Line (So. Shore Extension) northbound, April 29, 1972. (See Figure G-2 for Microphone Locations).

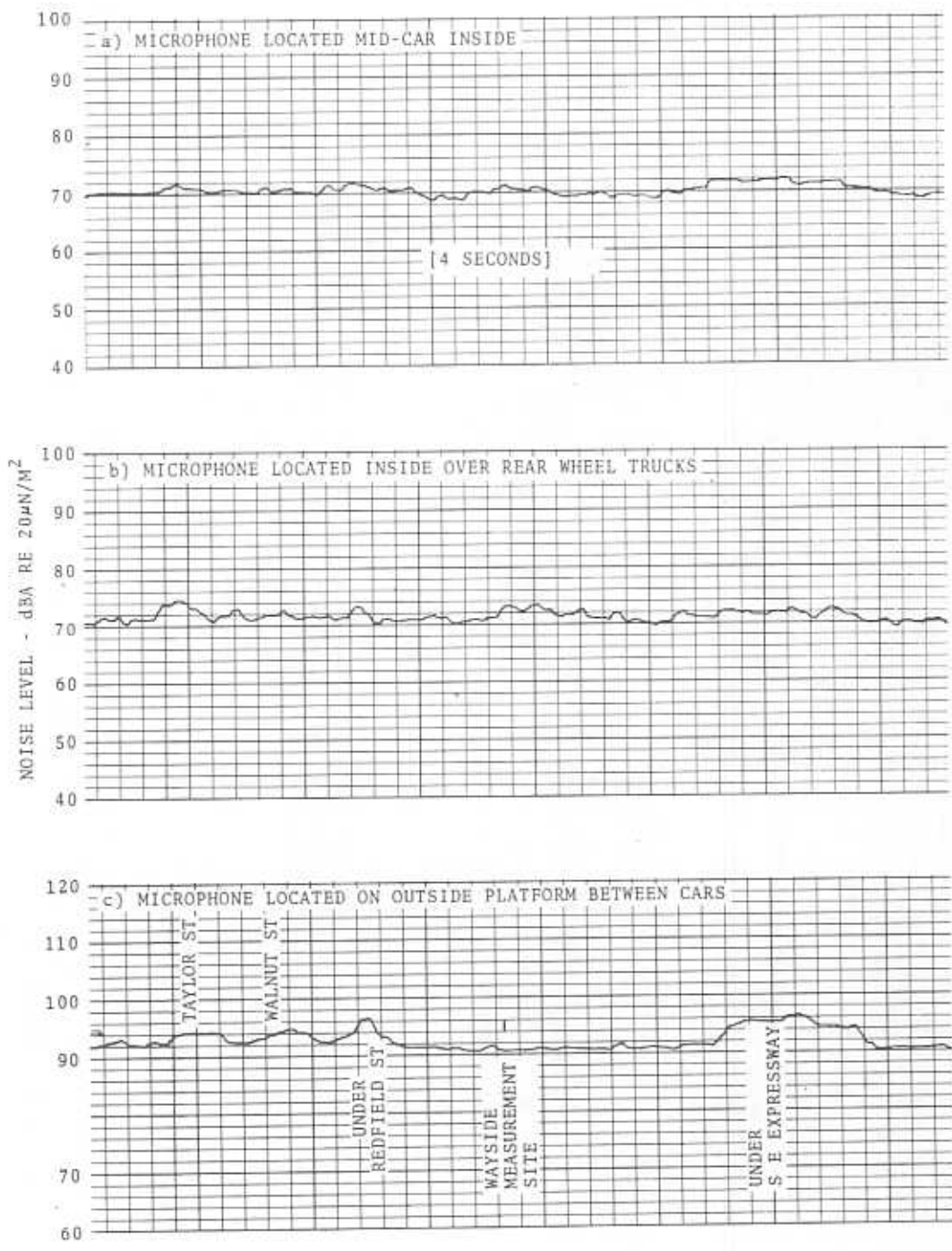


Figure E-2 Coincident Time Histories - Noise Levels at three locations. Tenean St. Wayside Measurements Site Area. MBTA Red Line (So. Shore Extension) April 29, 1972. (See Figure E1).

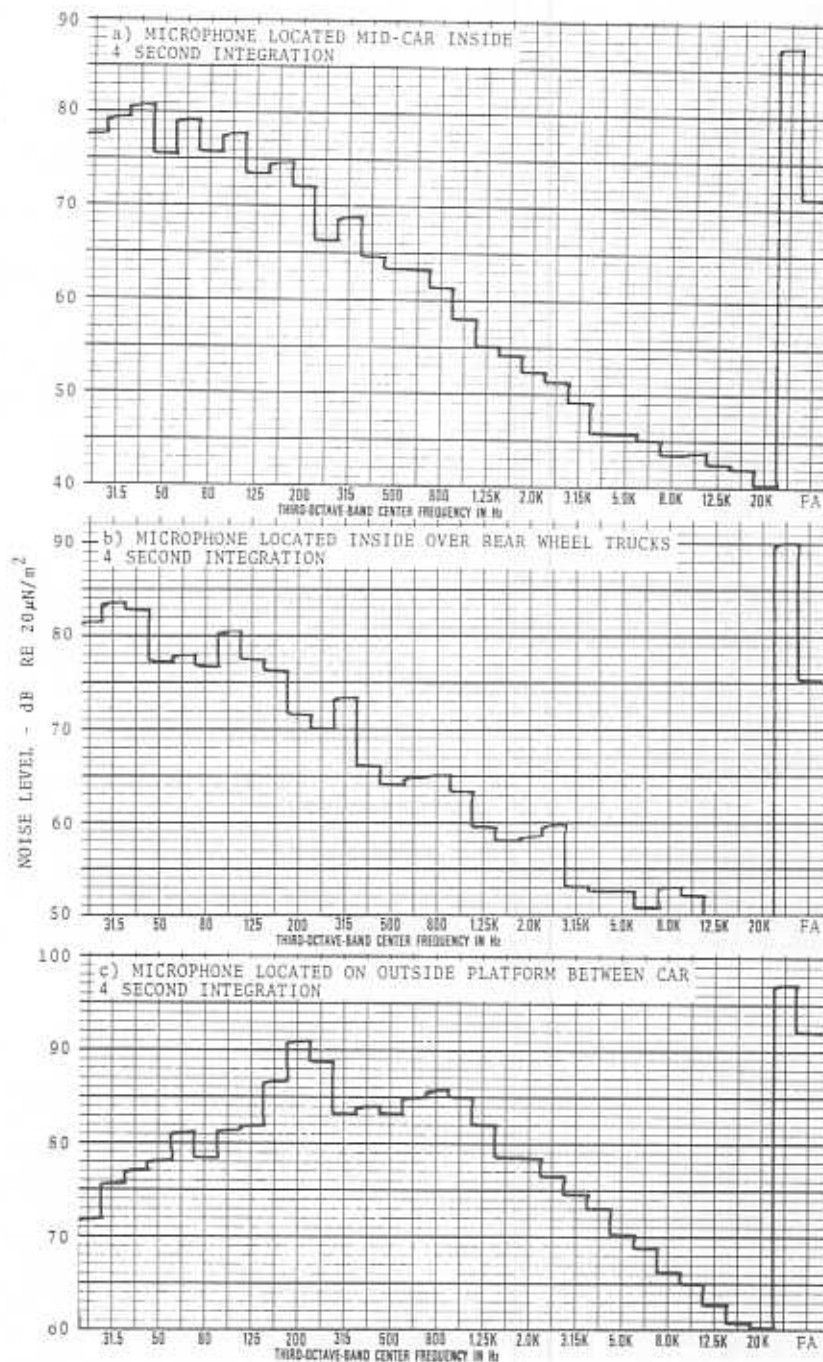


Figure E-3 Coincident Noise Spectra at three in-car locations. Tenean St. Wayside Measurement Site Area. MBTA Red Line (So. Shore Extension) April 29, 1972. (See Figure E2).

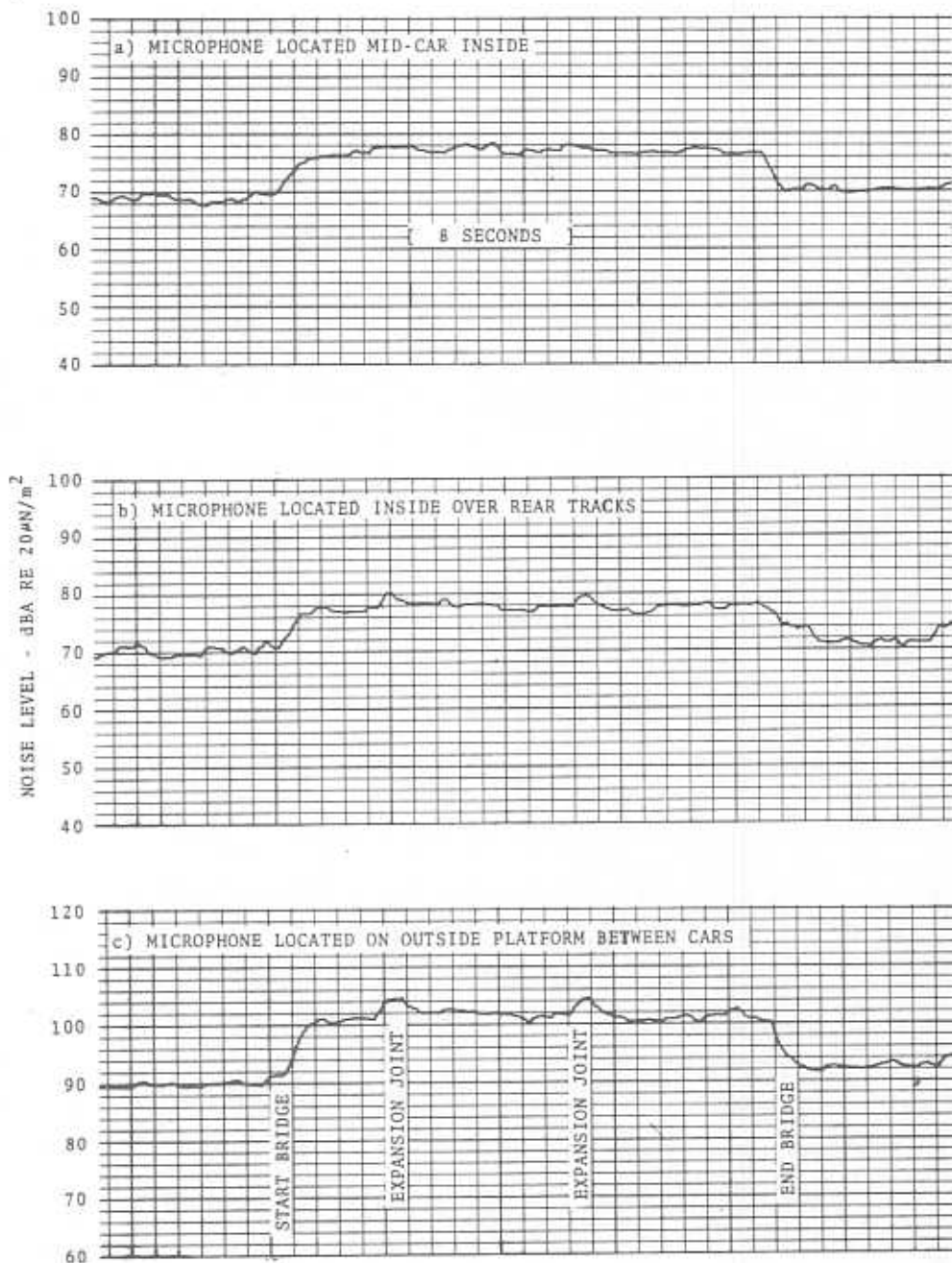


Figure E-4 Coincident Time Histories - Noise Levels at three locations. Neponset River Bridge. MBTA Red Line (So. Shore Extension). (See Figure B1.)

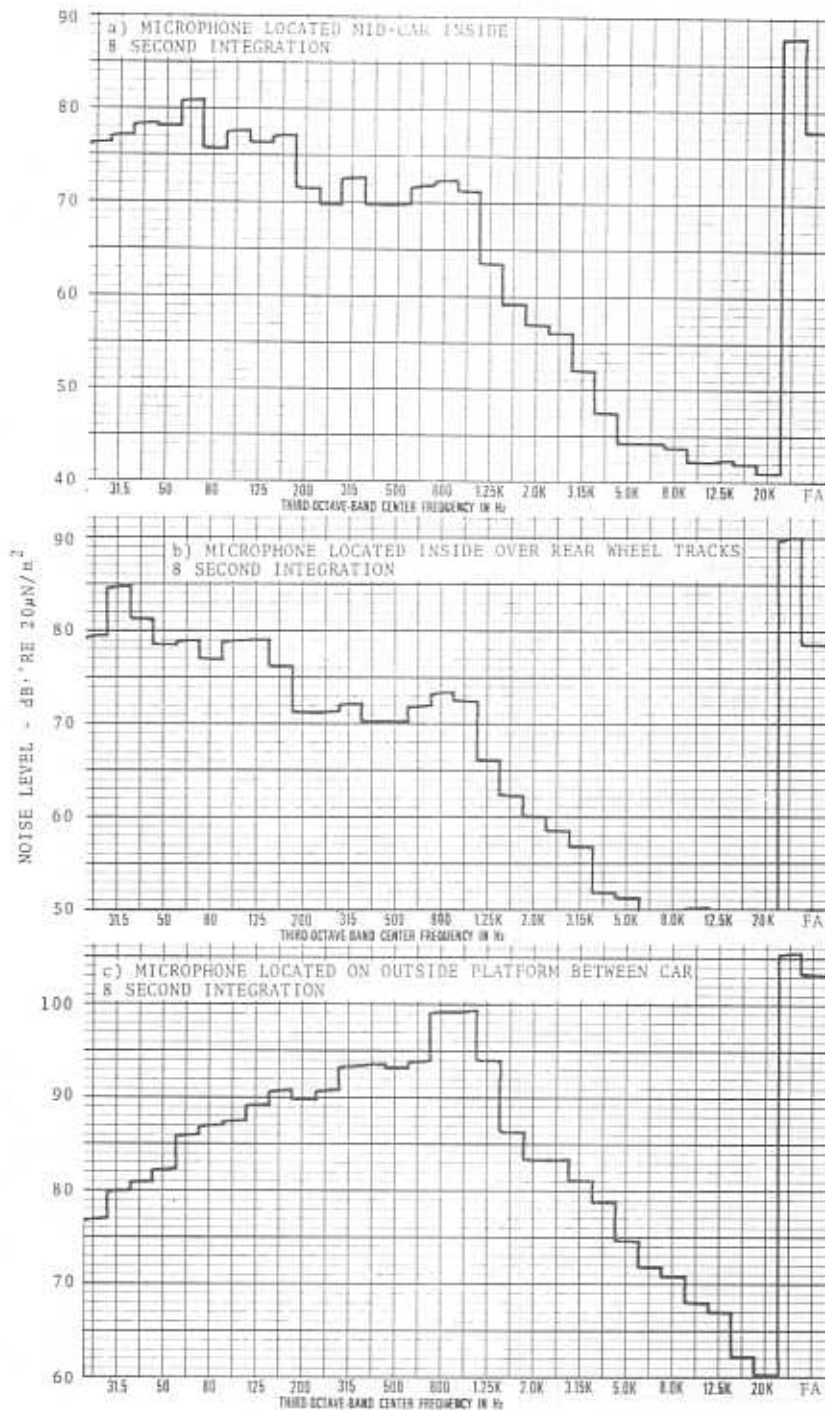


Figure E-5 Coincident Noise Spectra at three locations. Neponset River Bridge, MBTA Red Line (So. Shore Extension). April 29, 1972. (See Figure B4).

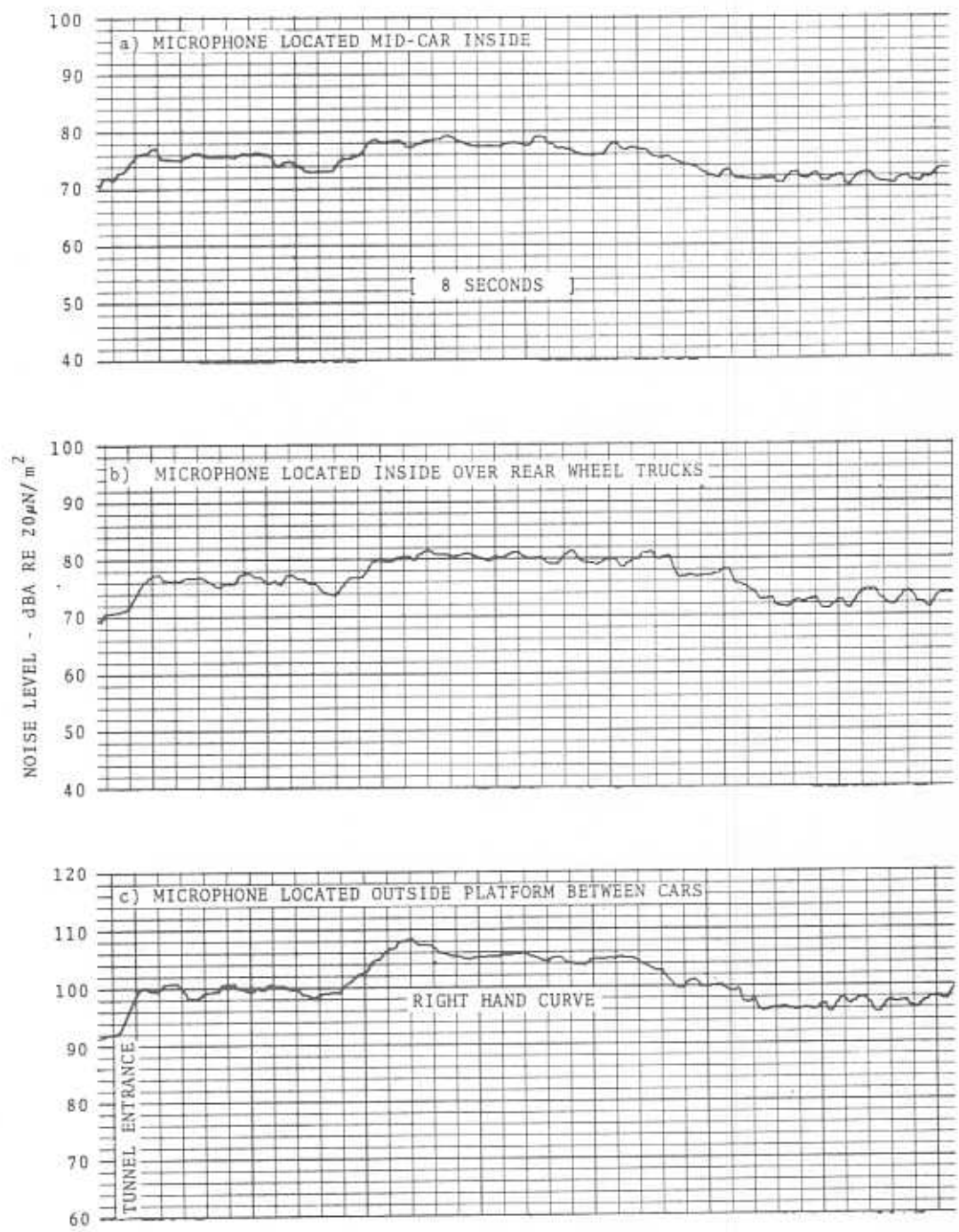


Figure E-6. Coincident Time Histories - Noise Levels at three locations. Sharp right-hand curve after entering tunnel before Andrew Station. MBTA Red Line April 29, 1972. See figure E-1.

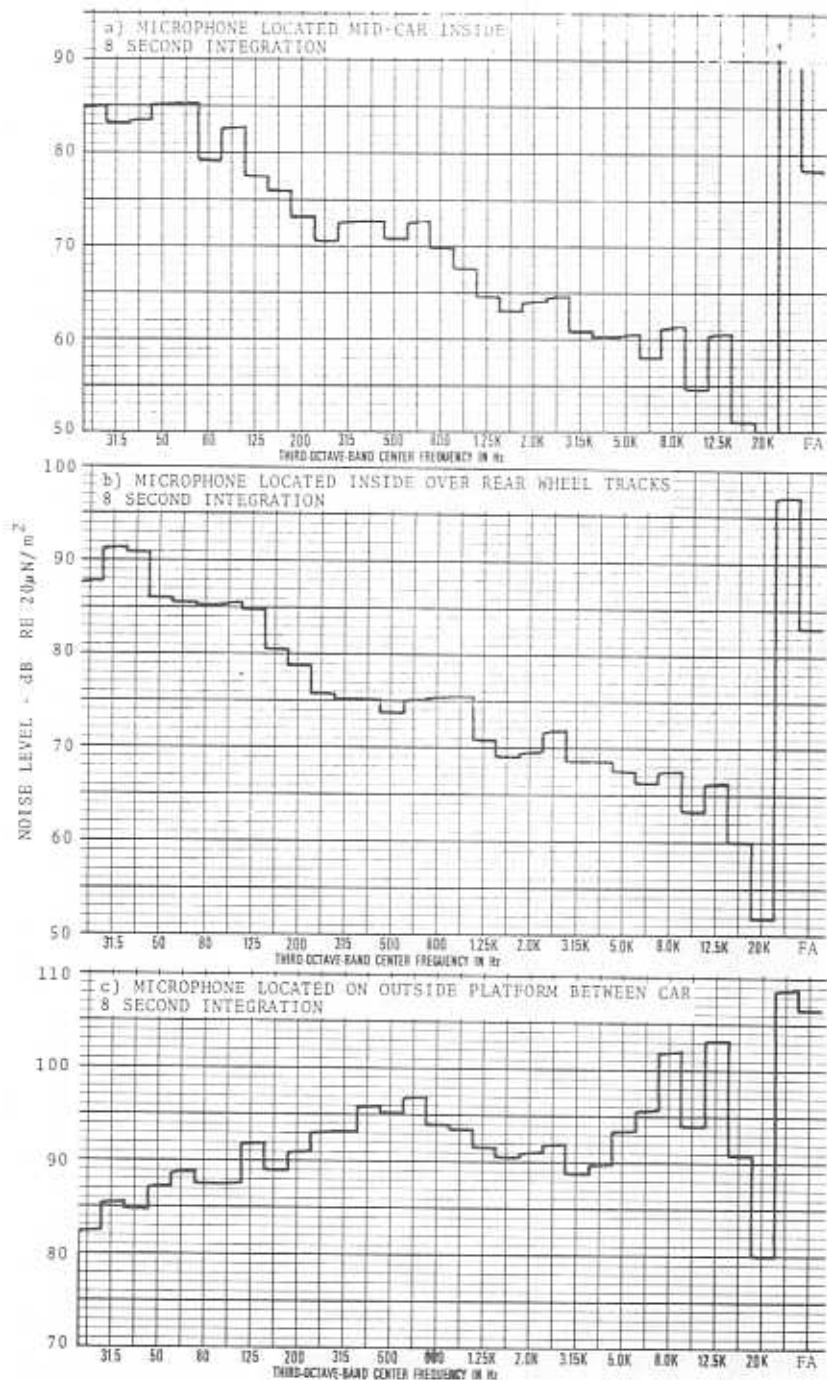


Figure E-7. Coincident Noise Spectra at three locations. Sharp right-hand curve after entering tunnel before Andrew Station. MBTA Red Line. April 29, 1972. See Figure E-6

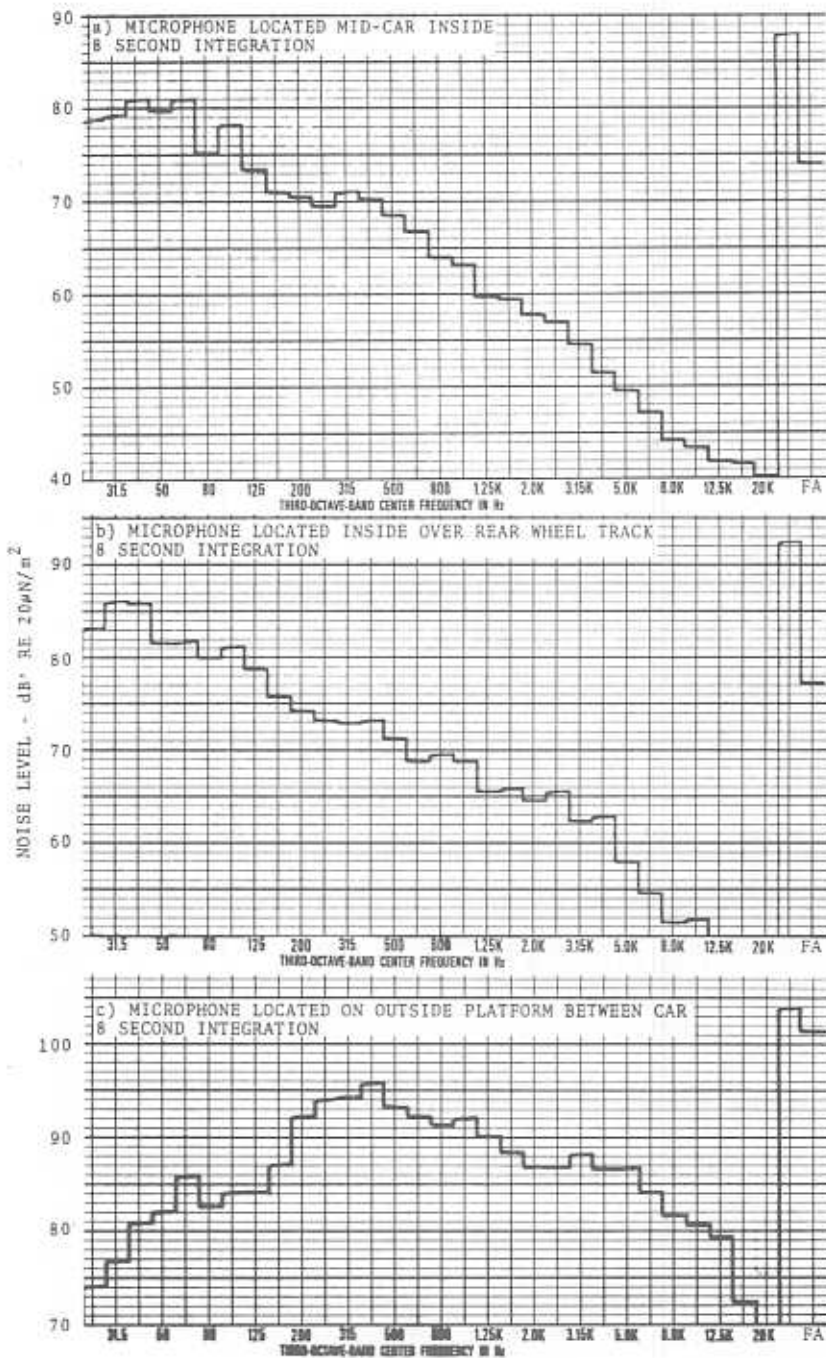


Figure B8. Coincident Noise Spectra at three locations. At Crest of Longfellow Bridge. MBTA Red Line. April 29, 1972. See Figure B1.

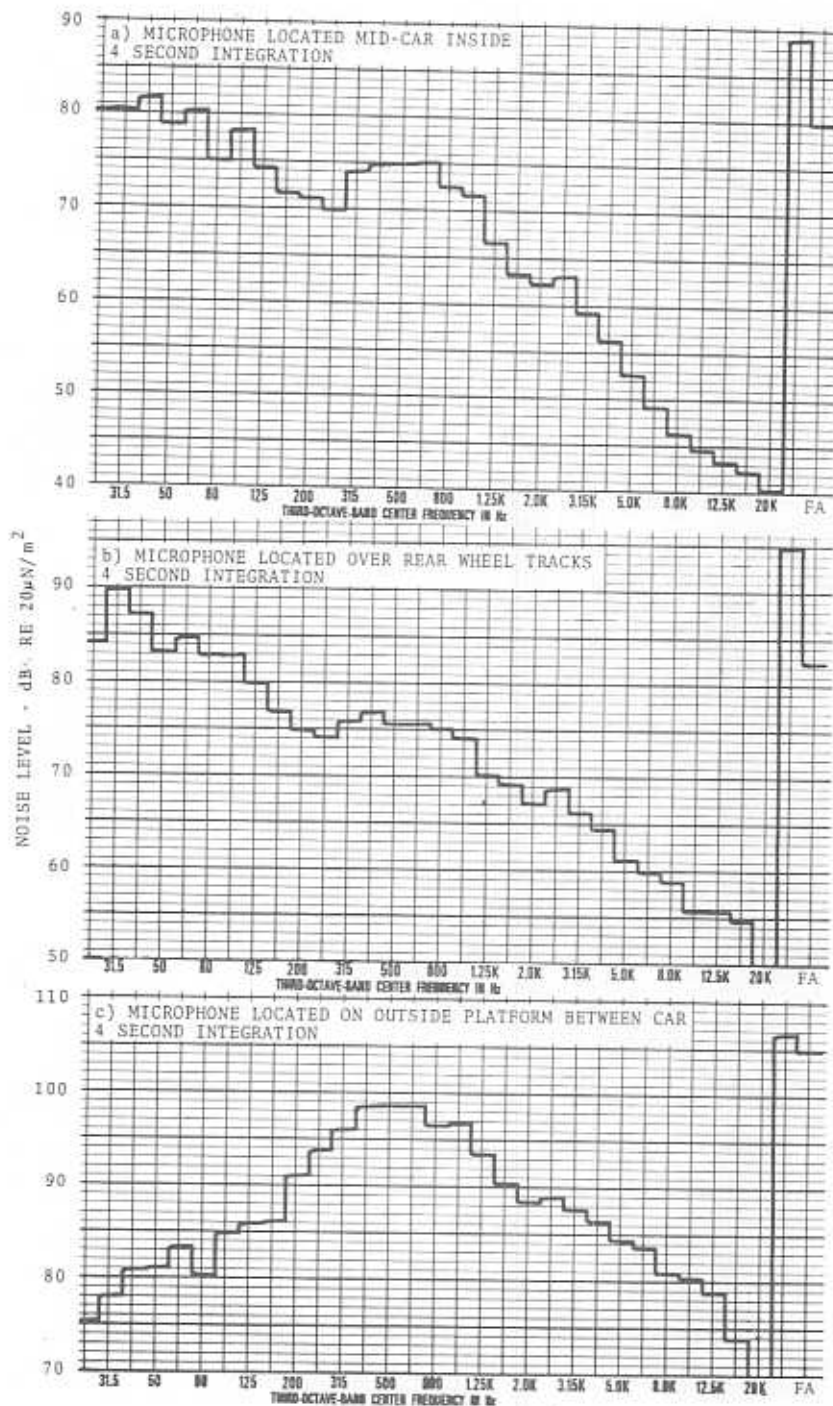


Figure E-9. Coincident Noise Spectra at three locations at Cambridge End of Longfellow Bridge. MBTA Red Line. April 29, 1972. See figure E-1.

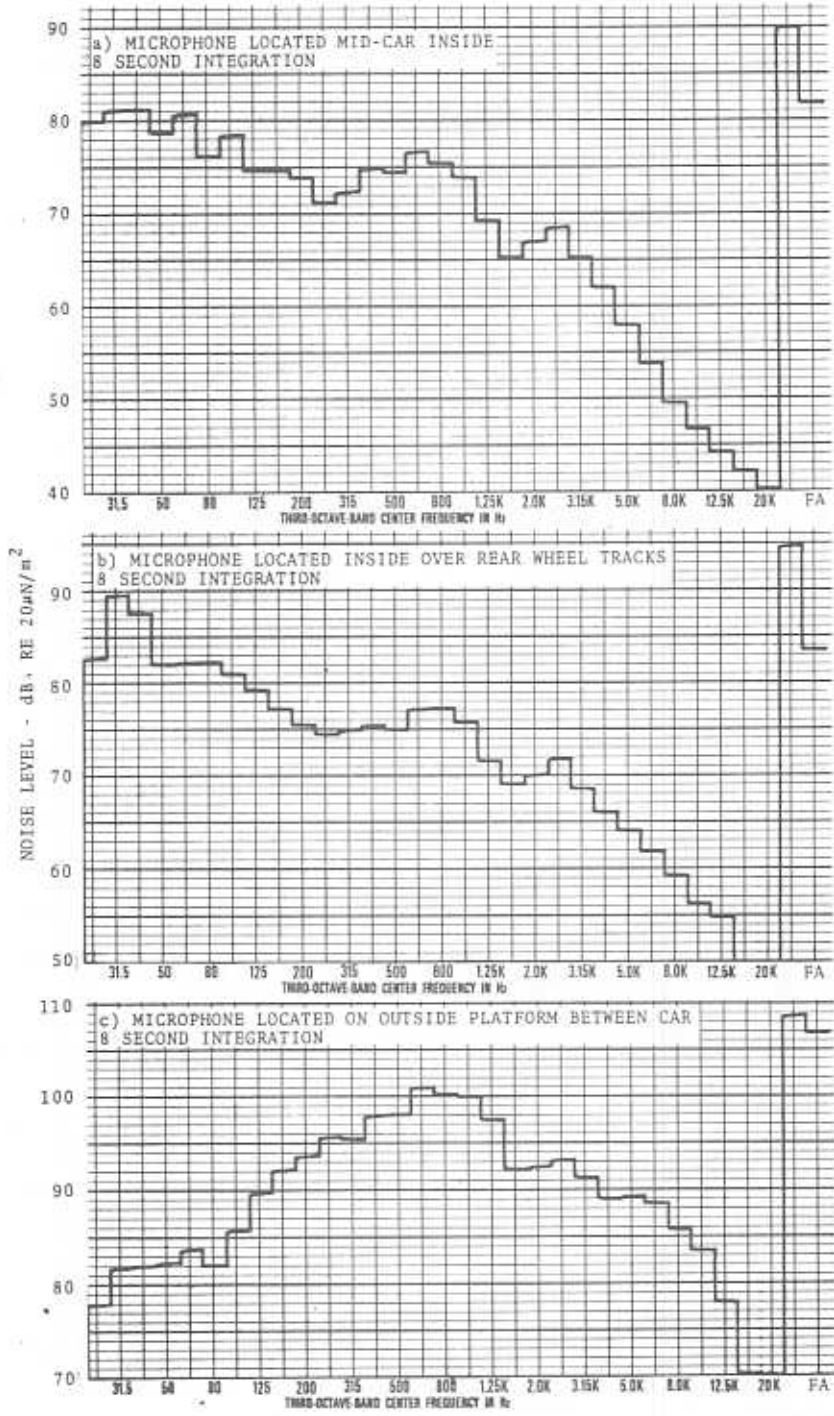


Figure E-10 Coincident Noise Spectra at three locations. Dorchester Tunnel between Andrew and Broadway Stations. MBTA Red Line. April 29, 1972. See Figure E-1. See Figure J-2 for tunnel cross section.

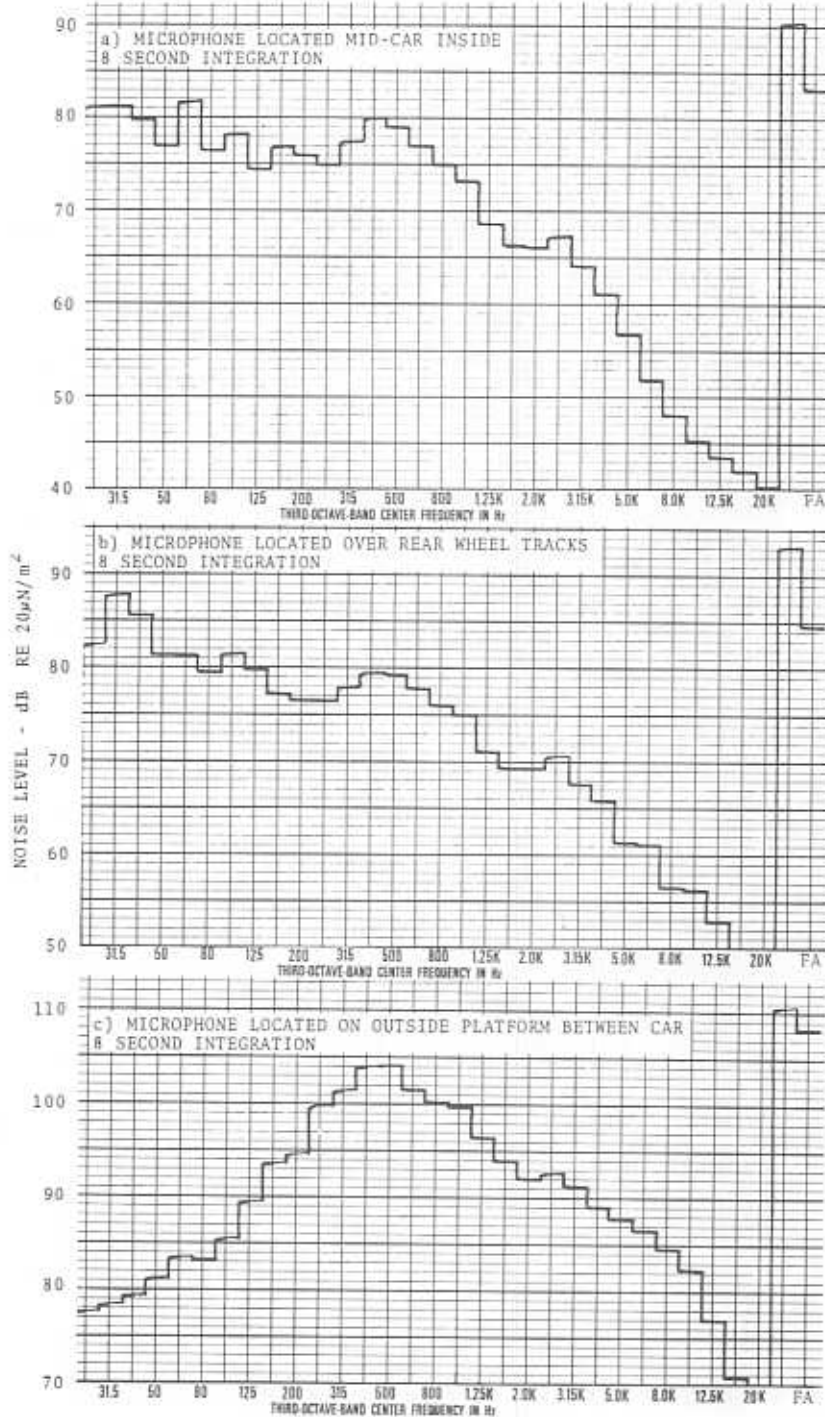


Figure E-11 Coincident Noise Spectra at three locations. Two section tunnel between Andrew and Broadway Stations. MBTA Red Line. April 29, 1972. See Figure E1. See Figure J-3 for tunnel cross section.

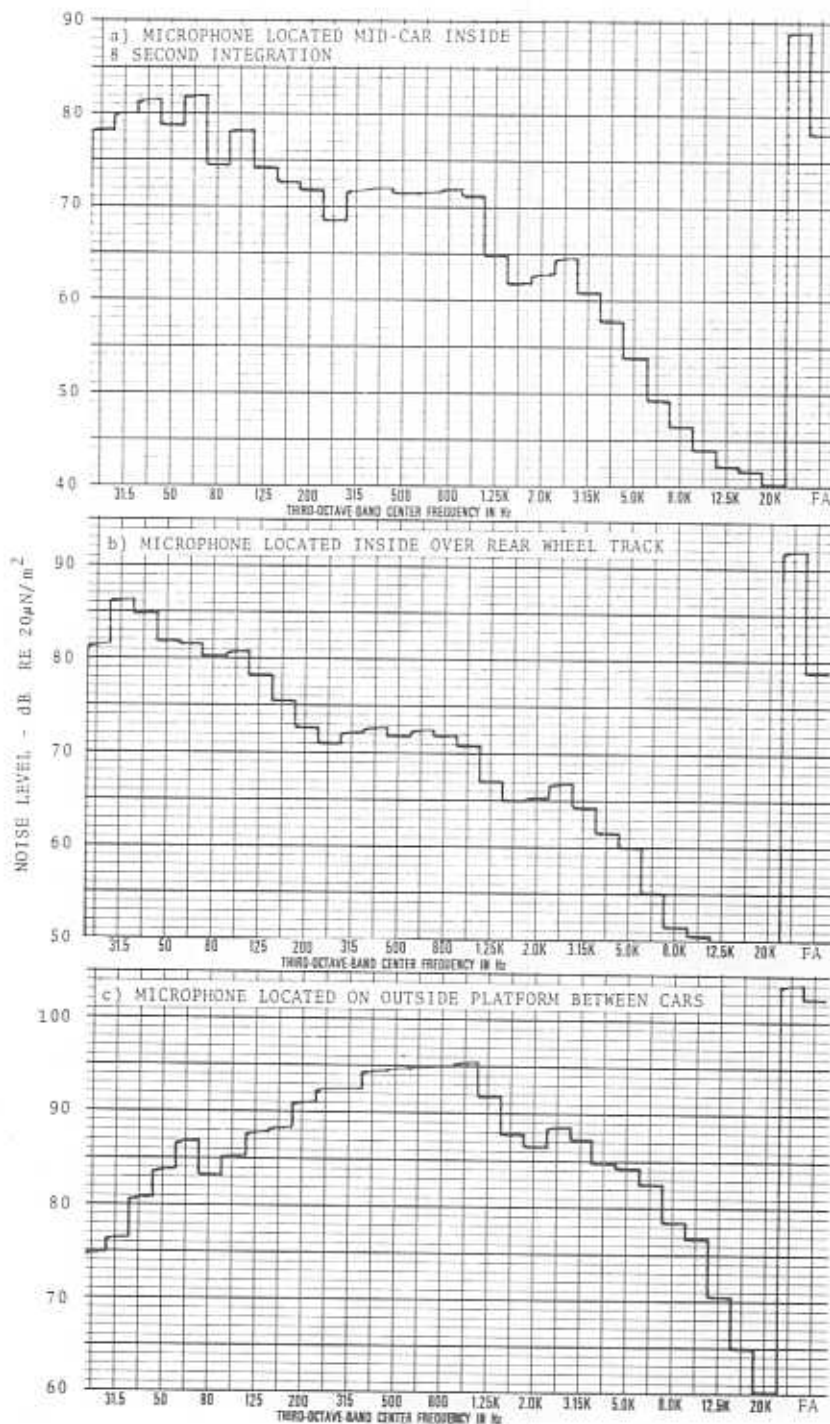


Figure E-13 Coincident Noise Spectra at three locations. Beacon Hill Tunnel between Park St and Charles St. Stations. MBTA Red Line. April 29, 1972. See Figure E4. See Figure J5 for tunnel cross section.

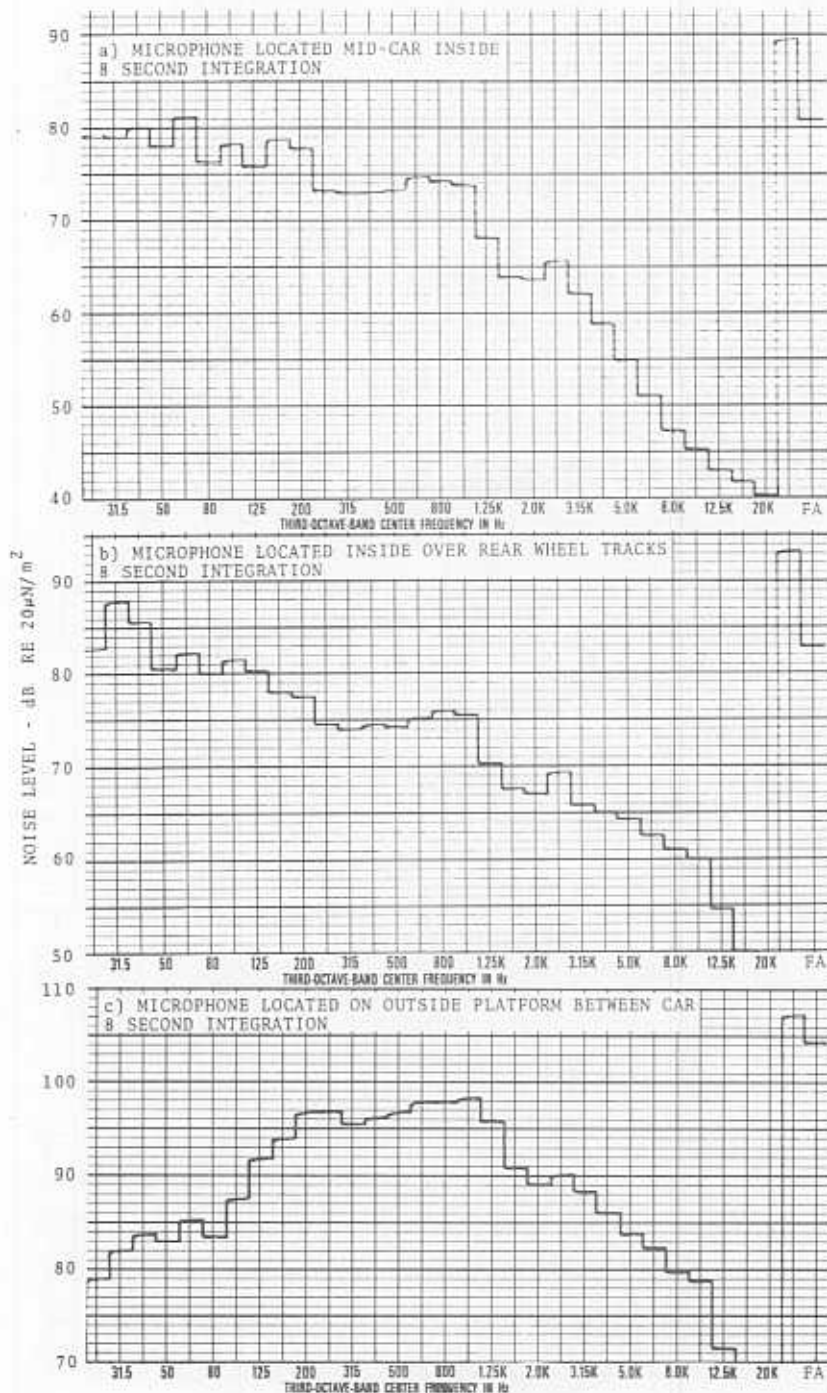


Figure E-14 Coincident Noise Spectra at three locations. Main St. Tunnel between Kendall and Central Stations. MBTA Red Line. April 29, 1972. See Figure E1. (See Figure J6 for tunnel cross section)

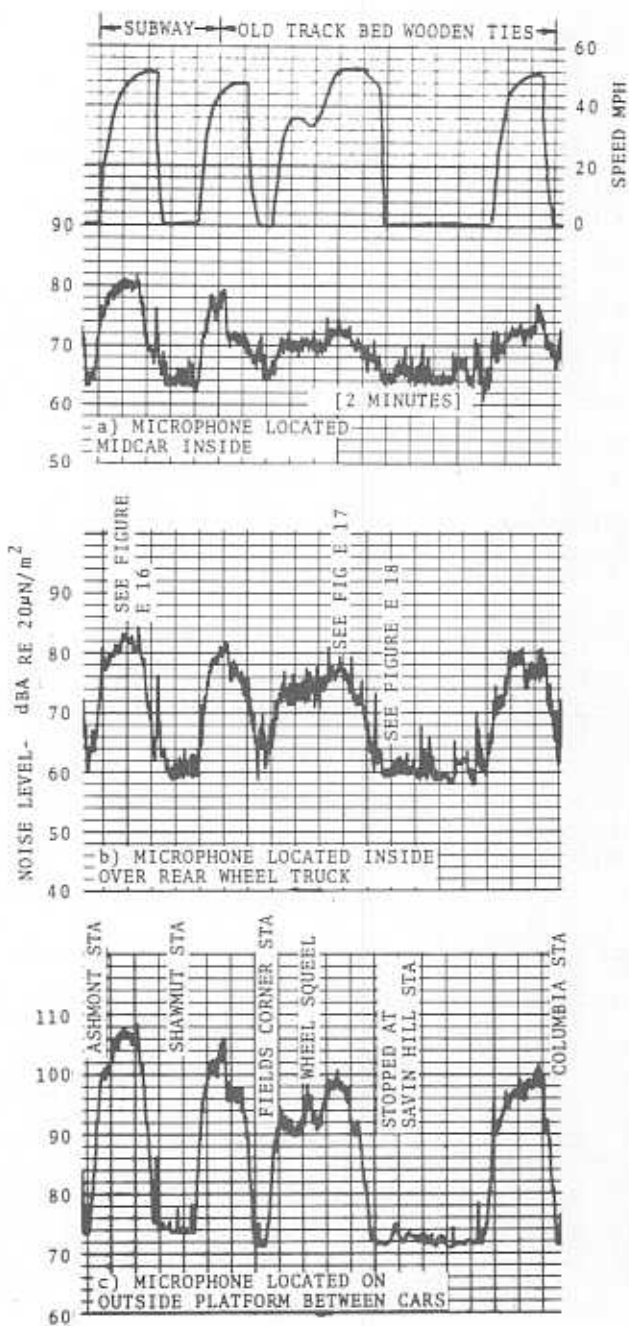


Figure E-15 Coincident Time Histories - Noise Levels measured at three locations on MBTA Type 1 So. Shore Rapid Transit Cars Ser. Nos 1503, 1506 on the MBTA Red Line (Ashmont Extension northbound). April 29, 1972. See Figure G2 for microphone locations.

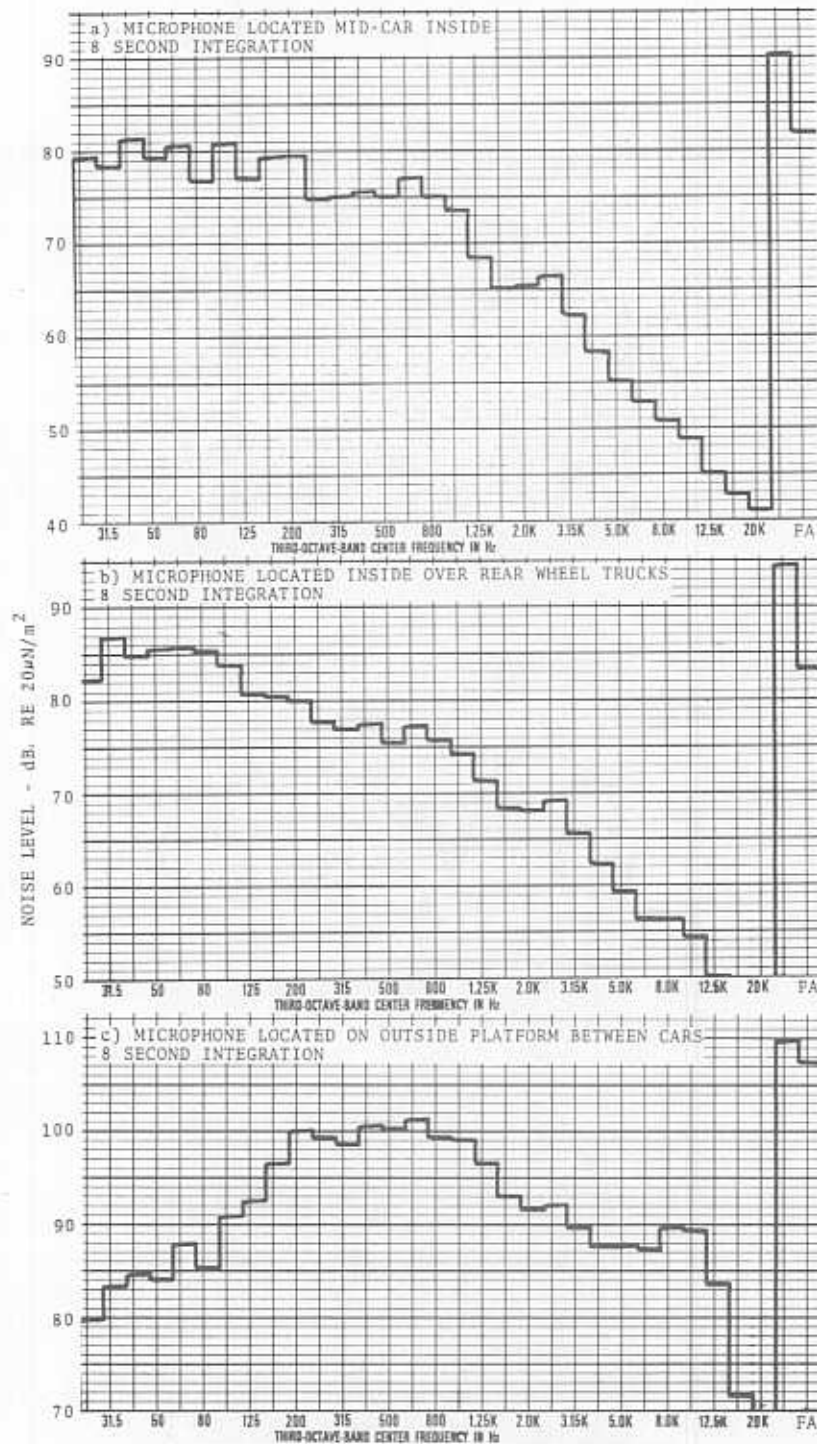


Figure E-16 Coincident Noise Spectra at three locations. Ashmont Tunnel between Ashmont and Shawmut Stations. MBTA Red Line (Ashmont Extension). April 29, 1972. See Figure B15. See Figure J-7 for tunnel cross section.

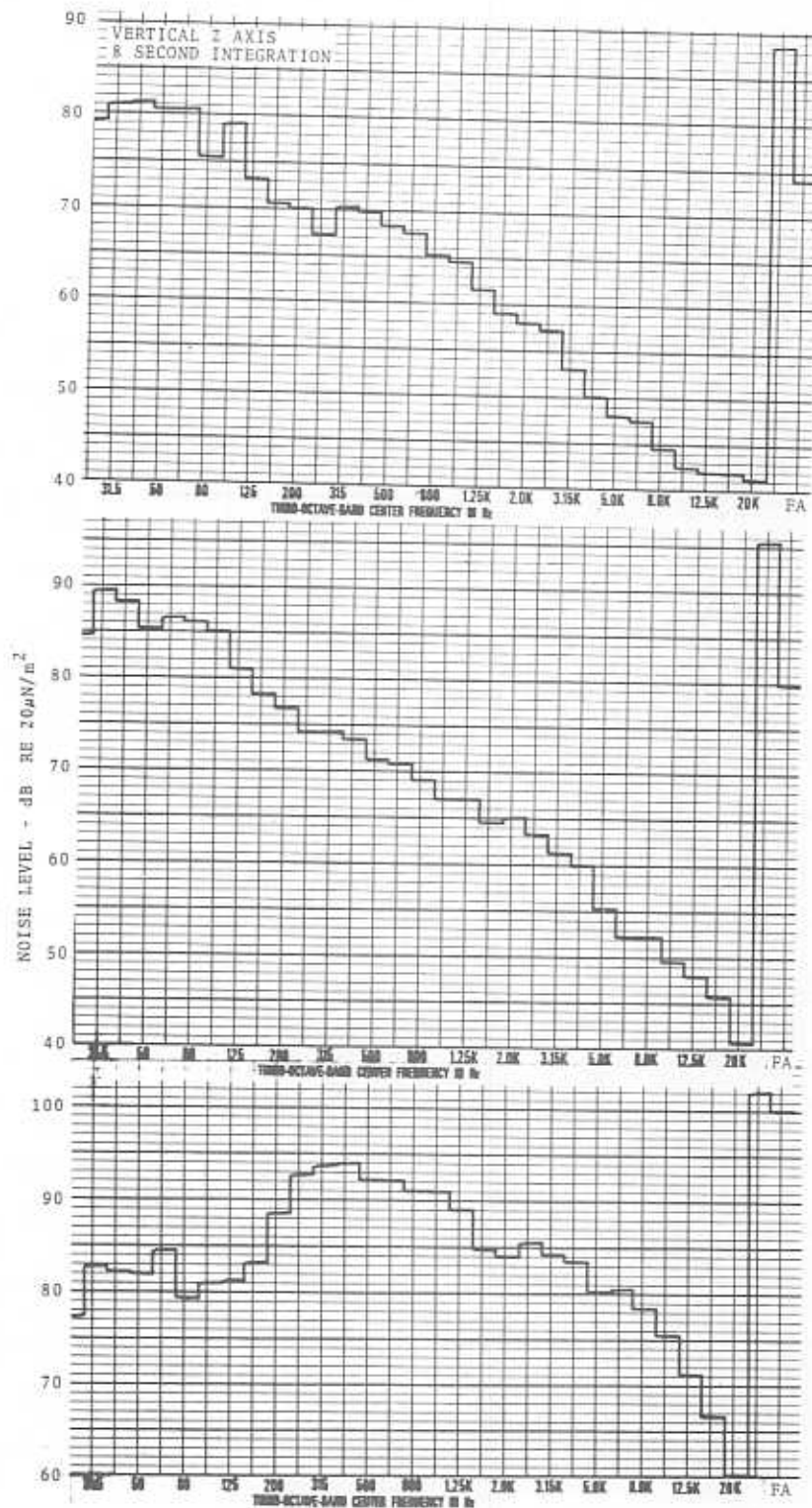


Figure E-17 Coincident Noise Spectra at three locations. Cruising on straight-run surfaceline between Fields Corner and Savin Hill Stations. MBTA Red Line (Ashmont Extension). April 29, 1972 See Figure E-15.

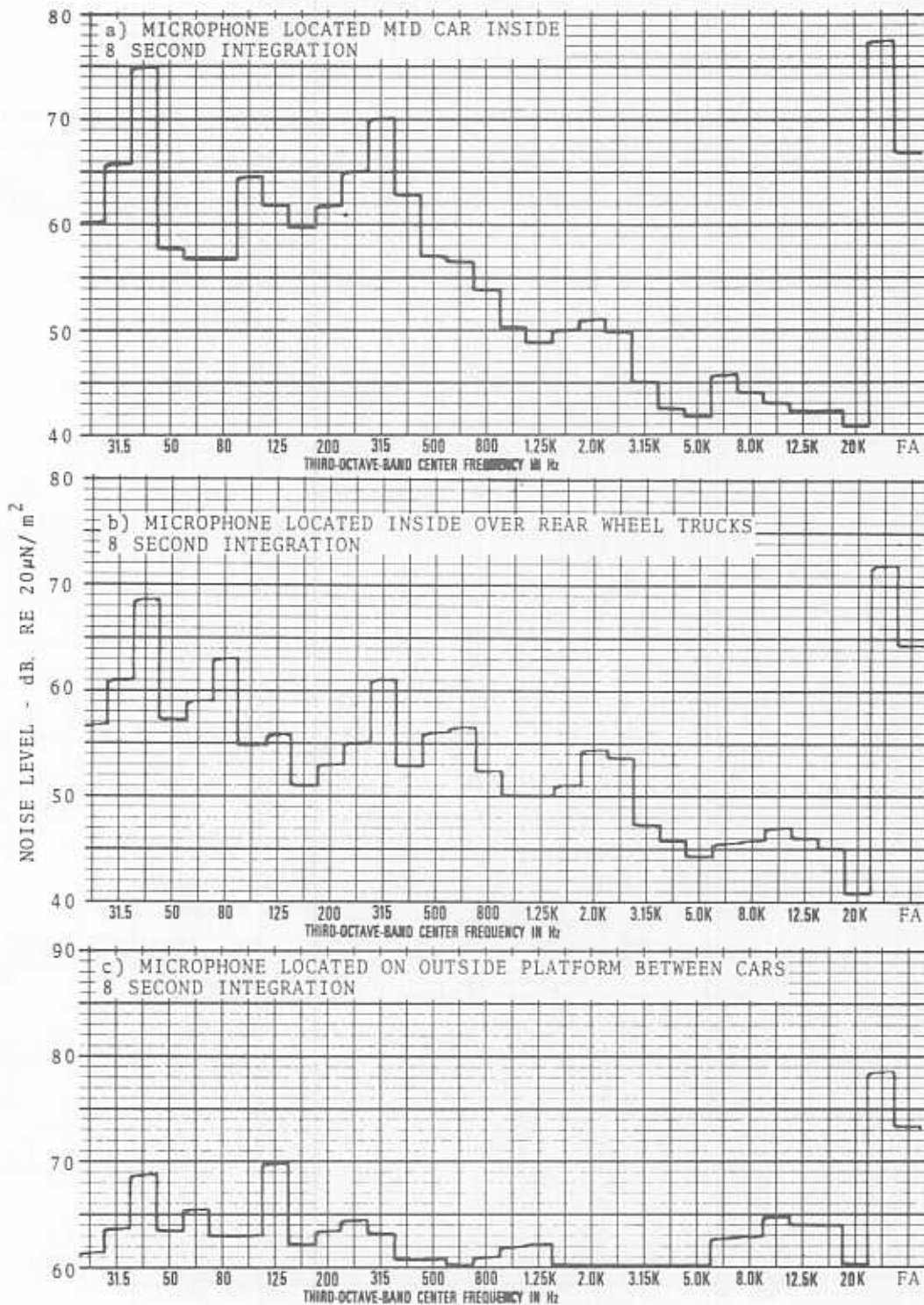


Figure E-18 Coincident Noise Spectra at three locations. Stopped with doors open at Savin Hill Station. MBTA Red Line (Ashmont Extension). April 29, 1972. See Figure E15.

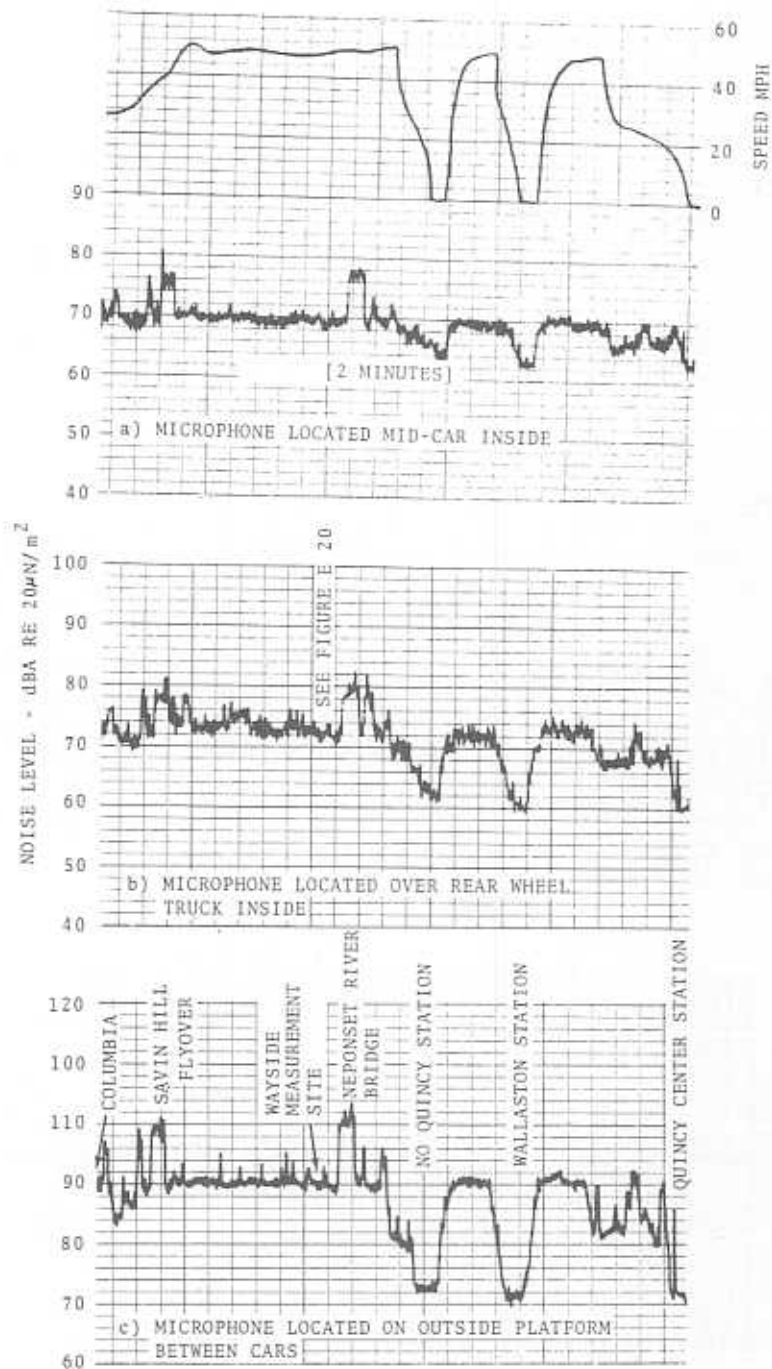


Figure E-19 Coincident Time Histories - Noise Levels measured at three locations on MBTA Type 1 So. Shore Rapid Transit Cars Ser. Nos 1503, 1506 on the MBTA Red Line (So. Shore Extension) southbound. April 29, 1972. See Figure G-2 for microphone locations.

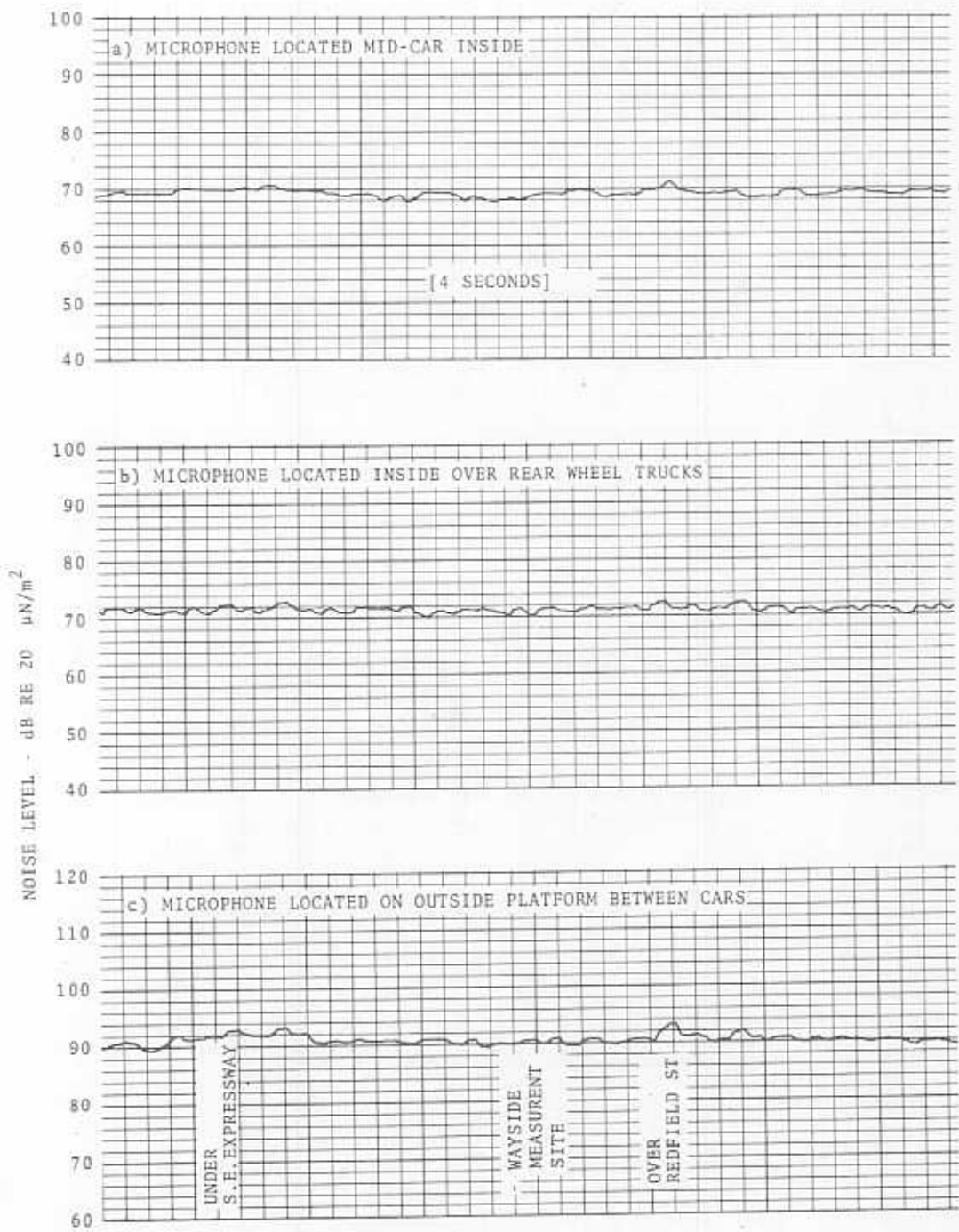


Figure E-20 Coincident Time Histories - Noise Level at three locations. Southbound Tenean St. Wayside Measurement Site. MBTA Red Line (So. Shore Extension) April 29, 1972. See Figure E19.

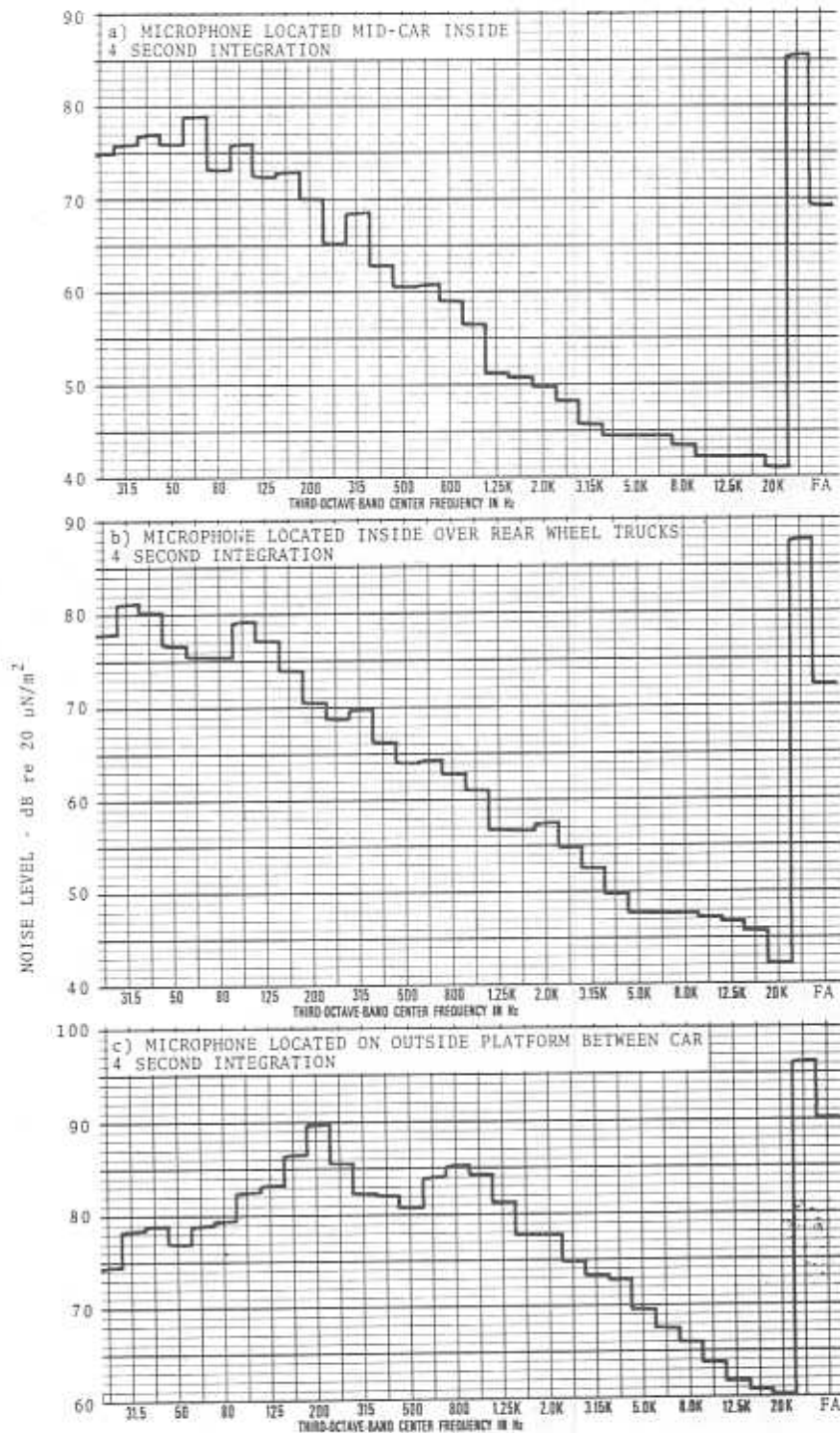


Figure E-21 Coincident Noise Spectra at three locations. Southbound Tenean St. Wayside Measurement Site. MBTA Red Line (So. Shore Extension). April 29, 1972. See Figure E20.

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 NOISE ABATEMENT GROUP

FRI 06/23/72
 13:58

 NOISE DATA FROM RUN NO. RT-47-72-1A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 01:25 TO 01:34, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

DISTRIB
 UTION DBA*

0	82	+
1	81	+
2	80	+
14	79	+
42	78	+
88	77	+
102	76	+
71	75	+
83	74	+
142	73	+
291	72	+
691	71	+
765	70	+
827	69	+
428	68	+
190	67	+
149	66	+
148	65	+
82	64	+
70	63	+
13	62	+
1	61	+
0	60	+

SAMPLES= 4200
 AVERAGE= 69.9 DBA*
 STANDARD DEVIATION= 2.9 DBA*
 ENERGY MEAN= 71 DB**
 NOISE POLLUTION LEVEL= 78.4
 1% PERCENTILE= 78.4 DBA*
 10% DECILE= 73.9 DBA*
 MEDIAN= 70.3 DBA*
 90% DECILE= 66.7 DBA*
 99% PERCENTILE= 63.4 DBA*
 WALSH HEALEY EXP.= 0 %
 RANGE= 20 DB

LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure E-22. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503, 1506 on the MBTA Red Line (So. Shore Extension) Northbound. Microphone located inside mid-car, April 29, 1972

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

FRI 06/23/72
 14:27

NOISE DATA FROM RUN NO. RT-47-72-3A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 01:25 TO 01:34, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

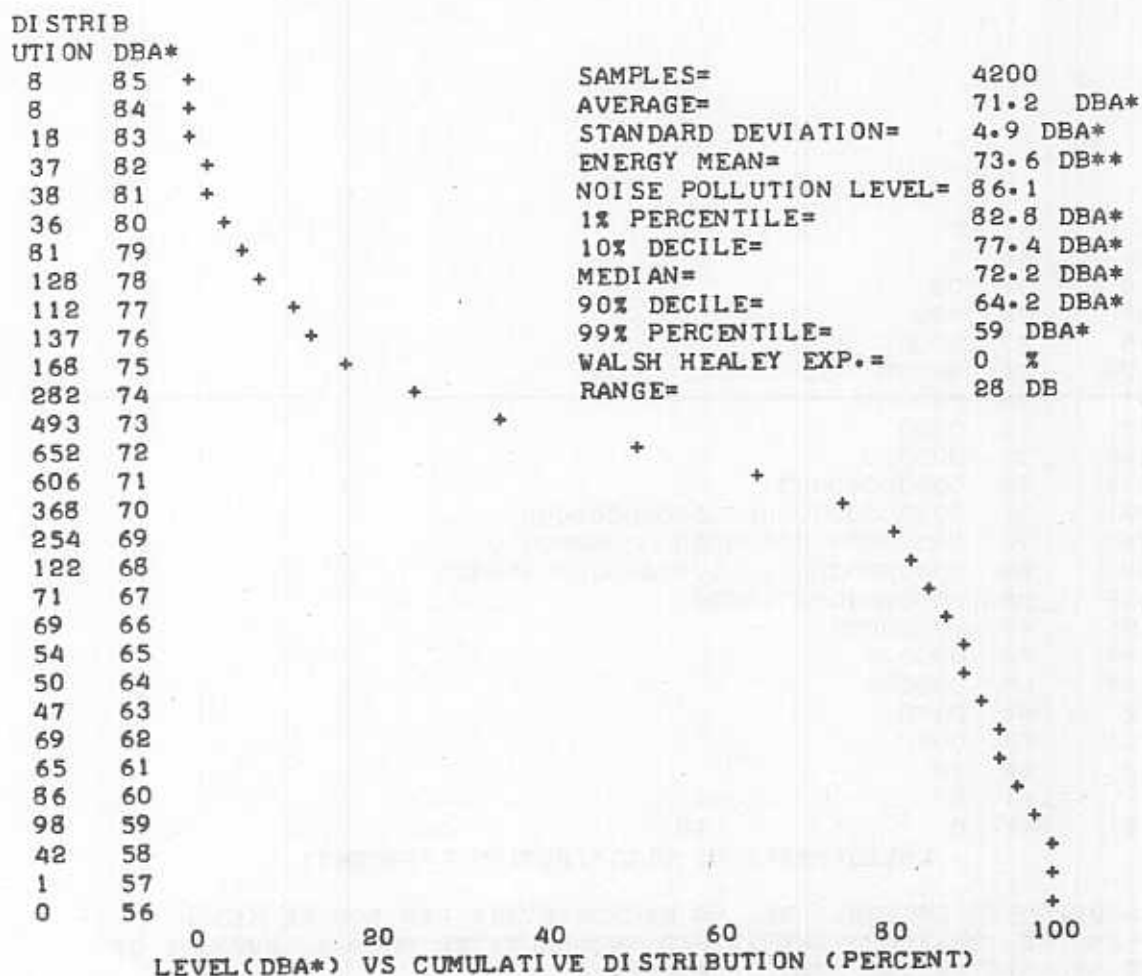
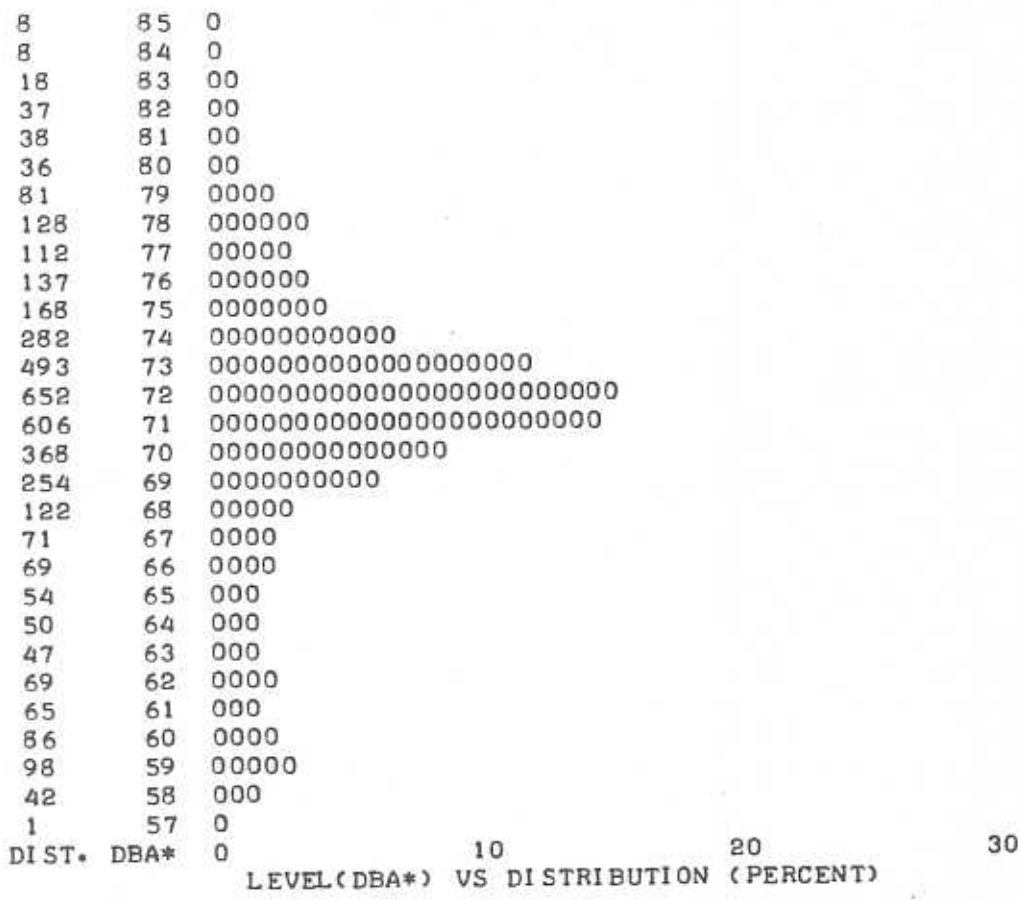


Figure E-23. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Car Serial Nos 1503,1506 on the MBTA Red Line (So. Shore Extension) Northbound. Microphone located inside over rear wheel trucks, April 29, 1972



*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF THE SQUARES OF THE SOUND PRESSURES.

Figure E-23 (Continued). Statistical Analysis - In-Car Noise Data. MBTA Type 1 So. Shore Rapid Transit Car Serial Nos 1503,1506 on the MBTA Red Line (So. Shore Extension) North-bound. Microphone located inside over rear wheel trucks, April 29, 1972

NOISE DATA FROM RUN NO. RT-47-72-4A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 01:25 TO 01:34, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

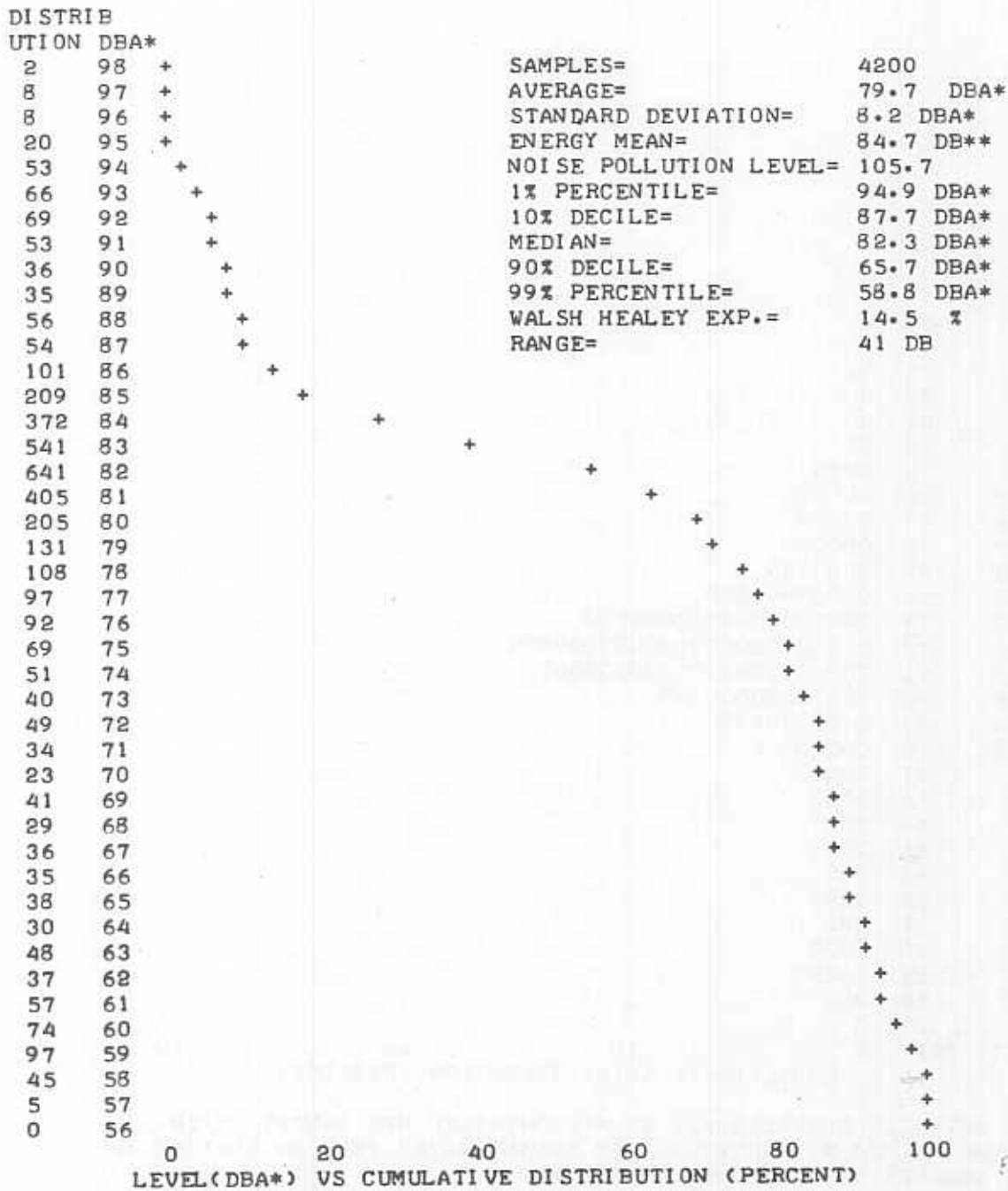


Figure E-24. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Car Serial Nos 1503,1506 on the MBTA Red Line (So. Shore Extension) Northbound. Microphone located on outside platform between cars, April 29, 1972

2	98	0		
8	97	0		
8	96	0		
20	95	00		
53	94	000		
66	93	000		
69	92	0000		
53	91	000		
36	90	00		
35	89	00		
56	88	000		
54	87	000		
101	86	00000		
209	85	000000000		
372	84	000000000000000		
541	83	0000000000000000000		
641	82	00000000000000000000000		
405	81	000000000000000000000		
205	80	00000000		
131	79	000000		
108	78	00000		
97	77	00000		
92	76	0000		
69	75	0000		
51	74	000		
40	73	000		
49	72	000		
34	71	00		
23	70	00		
41	69	000		
29	68	00		
36	67	00		
35	66	00		
38	65	00		
30	64	00		
48	63	000		
37	62	00		
57	61	000		
74	60	0000		
97	59	00000		
45	58	000		
5	57	0		
DIST. DBA*	0	10	20	30
	LEVEL(DBA*) VS DISTRIBUTION (PERCENT)			

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF THE SQUARES OF THE SOUND PRESSURES.

Figure E-24 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Car Serial Nos 1503, 1506 on the MBTA Red Line (So. Shore Extension) Northbound. Microphone located on outside platform between cars, April 29, 1972

US DEPARTMENT OF TRANSPORTATION
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 NOISE ABATEMENT GROUP

TUE 07/11/72
 13:17

NOISE DATA FROM RUN NO. RT-47-72-1A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 01:34 TO 01:49, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

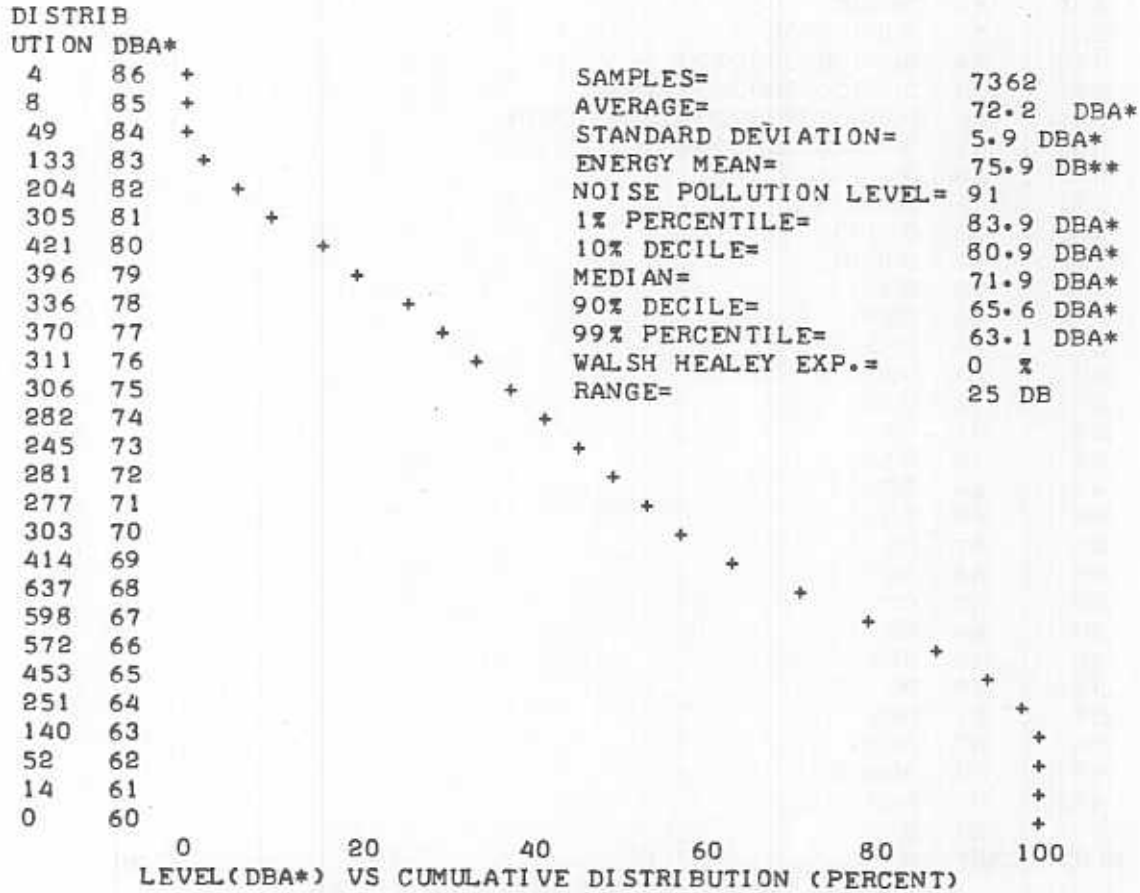


Figure E-25. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on the MBTA Red Line Northbound. Microphone located mid-car inside car Serial No. 1503, April 29, 1972

4	86	0			
8	85	0			
49	84	00			
133	83	0000			
204	82	00000			
305	81	0000000			
421	80	0000000000			
396	79	000000000			
336	78	00000000			
370	77	000000000			
311	76	0000000			
306	75	0000000			
282	74	0000000			
245	73	000000			
281	72	0000000			
277	71	0000000			
303	70	0000000			
414	69	0000000000			
637	68	00000000000000			
598	67	0000000000000			
572	66	0000000000000			
453	65	0000000000			
251	64	000000			
140	63	0000			
52	62	00			
14	61	0			
DIST. DBA*	0		10	20	30

LEVEL(DBA*) VS DISTRIBUTION (PERCENT)

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure E-25 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type 1
 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on
 the MBTA Red Line Northbound. Microphone located mid-
 car inside car Serial No. 1503, April 29, 1972

US DEPARTMENT OF TRANSPORTATION
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 NOISE ABATEMENT GROUP

TUE 07/11/72
 11:41

NOISE DATA FROM RUN NO. RT-47-72-3A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 01:34 TO 01:49, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

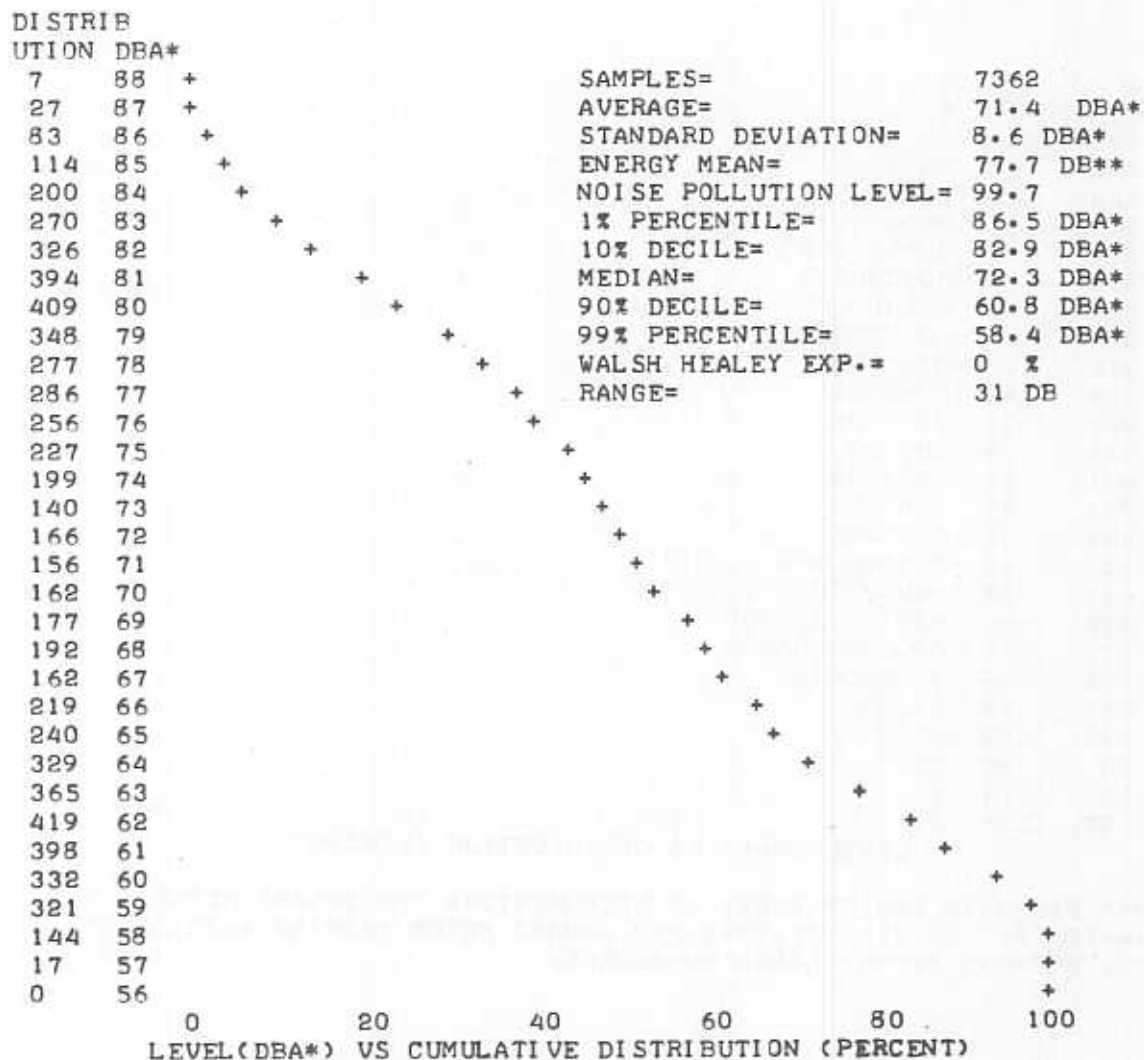


Figure E-26. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503, 1506 on the MBTA Red Line Northbound. Microphone located over the rear wheel truck inside car Serial No. 1503, April 27, 1972

7	88	0			
27	87	00			
83	86	000			
114	85	000			
200	84	00000			
270	83	0000000			
326	82	00000000			
394	81	000000000			
409	80	000000000			
348	79	00000000			
277	78	0000000			
286	77	0000000			
256	76	000000			
227	75	000000			
199	74	00000			
140	73	0000			
166	72	0000			
156	71	0000			
162	70	0000			
177	69	00000			
192	68	00000			
162	67	0000			
219	66	000000			
240	65	000000			
329	64	00000000			
365	63	000000000			
419	62	0000000000			
398	61	000000000			
332	60	00000000			
321	59	00000000			
144	58	0000			
17	57	0			
DIST. DBA*	0		10	20	30
			LEVEL(DBA*) VS DISTRIBUTION (PERCENT)		

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure E-26 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on the MBTA Red Line Northbound. Microphone located over the rear wheel truck inside car Serial No. 1503, April 27, 1972

NOISE DATA FROM RUN NO. RT-47-72-4A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 01:34 TO 01:49, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

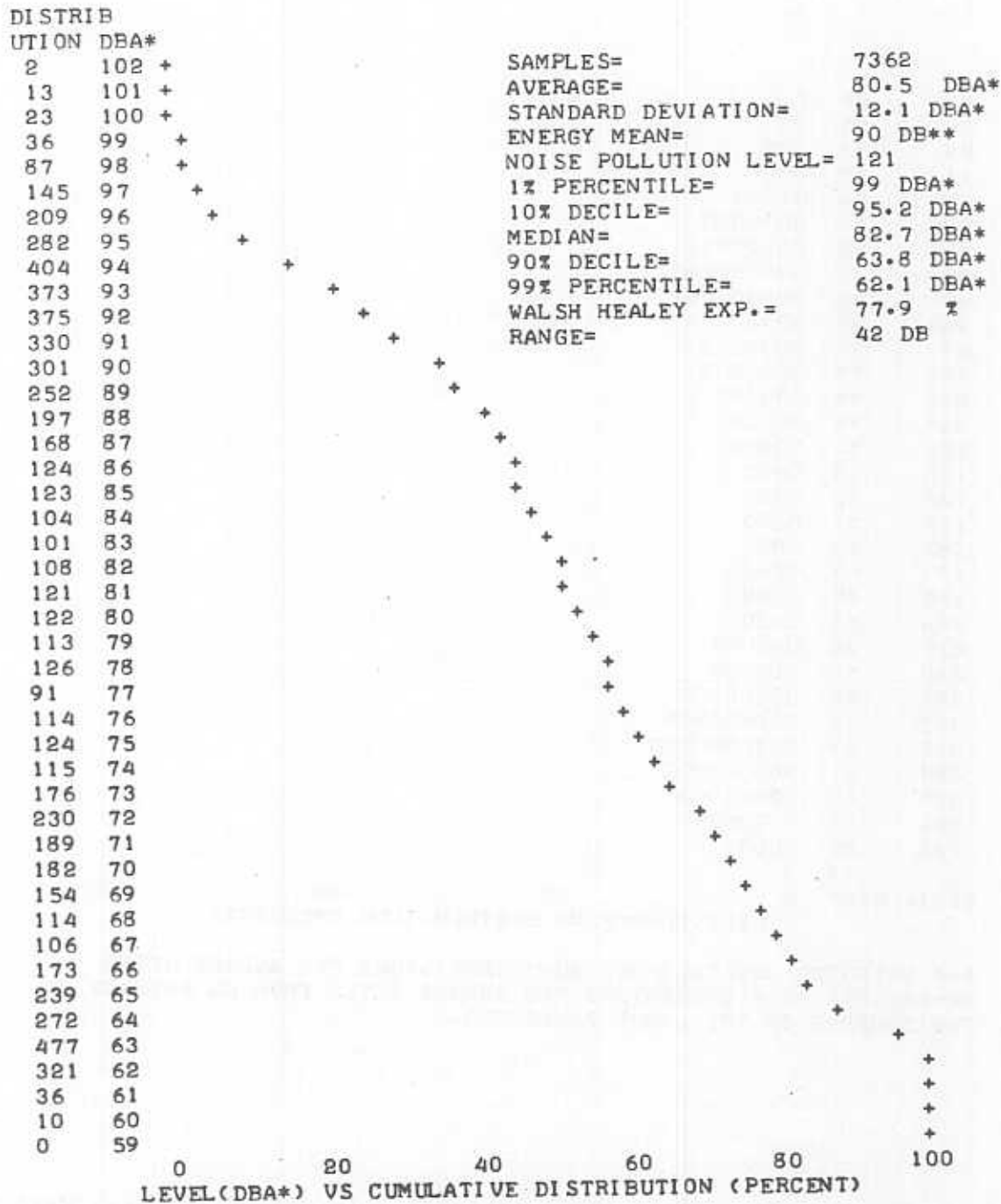


Figure E-27. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on the MBTA Red Line Northbound. Microphone located on the outside platform cars April 29, 1972

2	102	0			
13	101	0			
23	100	00			
36	99	00			
87	98	000			
145	97	0000			
209	96	00000			
282	95	0000000			
404	94	000000000			
373	93	000000000			
375	92	000000000			
330	91	00000000			
301	90	00000000			
252	89	0000000			
197	88	000000			
168	87	000000			
124	86	0000			
123	85	0000			
104	84	000			
101	83	000			
108	82	000			
121	81	0000			
122	80	0000			
113	79	000			
126	78	0000			
91	77	000			
114	76	000			
124	75	0000			
115	74	000			
176	73	00000			
230	72	000000			
189	71	00000			
182	70	00000			
154	69	0000			
114	68	000			
106	67	000			
173	66	00000			
239	65	000000			
272	64	0000000			
477	63	00000000000			
321	62	000000000			
36	61	00			
10	60	0			
DIST. DBA*	0		10	20	30
			LEVEL(DBA*) VS DISTRIBUTION (PERCENT)		

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure E-27 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type 1
 So. Shore Rapid Transit Cars Serial Nos 1503,1506
 on the MBTA Red Line Northbound. Microphone located
 on the outside platform cars, April 29, 1972

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

FRI 06/23/72
 16:03

NOISE DATA FROM RUN NO. RT-47-72-1A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 03:48 TO 03:56, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

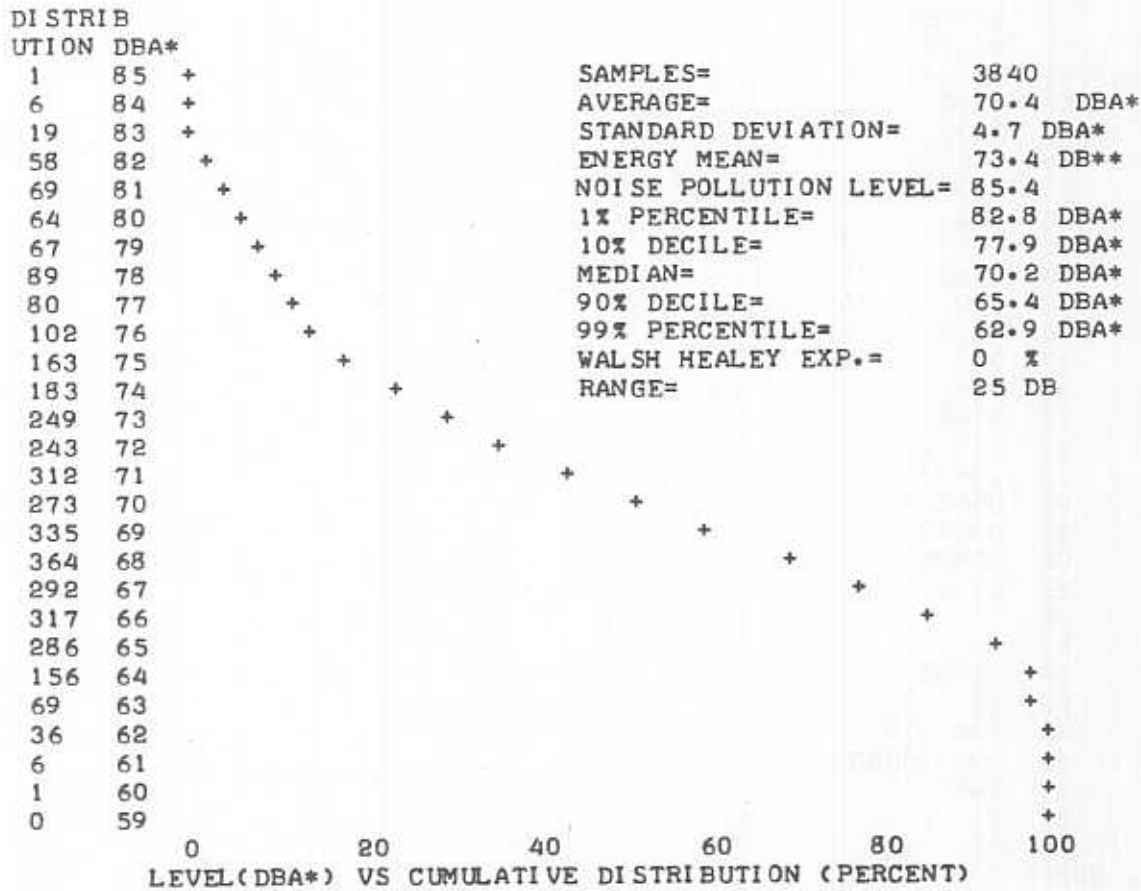


Figure E-28. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on the MBTA Red Line (Ashmont Extension) Northbound. Microphone located inside mid-car, April 29, 1972

1	85	0			
6	84	0			
19	83	00			
58	82	000			
69	81	0000			
64	80	0000			
67	79	0000			
89	78	00000			
80	77	0000			
102	76	00000			
163	75	0000000			
183	74	00000000			
249	73	00000000000			
243	72	00000000000			
312	71	0000000000000			
273	70	000000000000			
335	69	00000000000000			
364	68	000000000000000			
292	67	0000000000000			
317	66	0000000000000			
286	65	000000000000			
156	64	0000000			
69	63	0000			
36	62	000			
6	61	0			
1	60	0			
DIST.	DBA*	0	10	20	30

LEVEL(DBA*) VS DISTRIBUTION (PERCENT)

**A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure E-28 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on the MBTA Red Line (Ashmont Extension) Northbound. Microphone located inside mid-car, April 29, 1972

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

FRI 06/23/72
 16:20

NOISE DATA FROM RUN NO. RT-47-72-3A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 03:48 TO 03:56, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

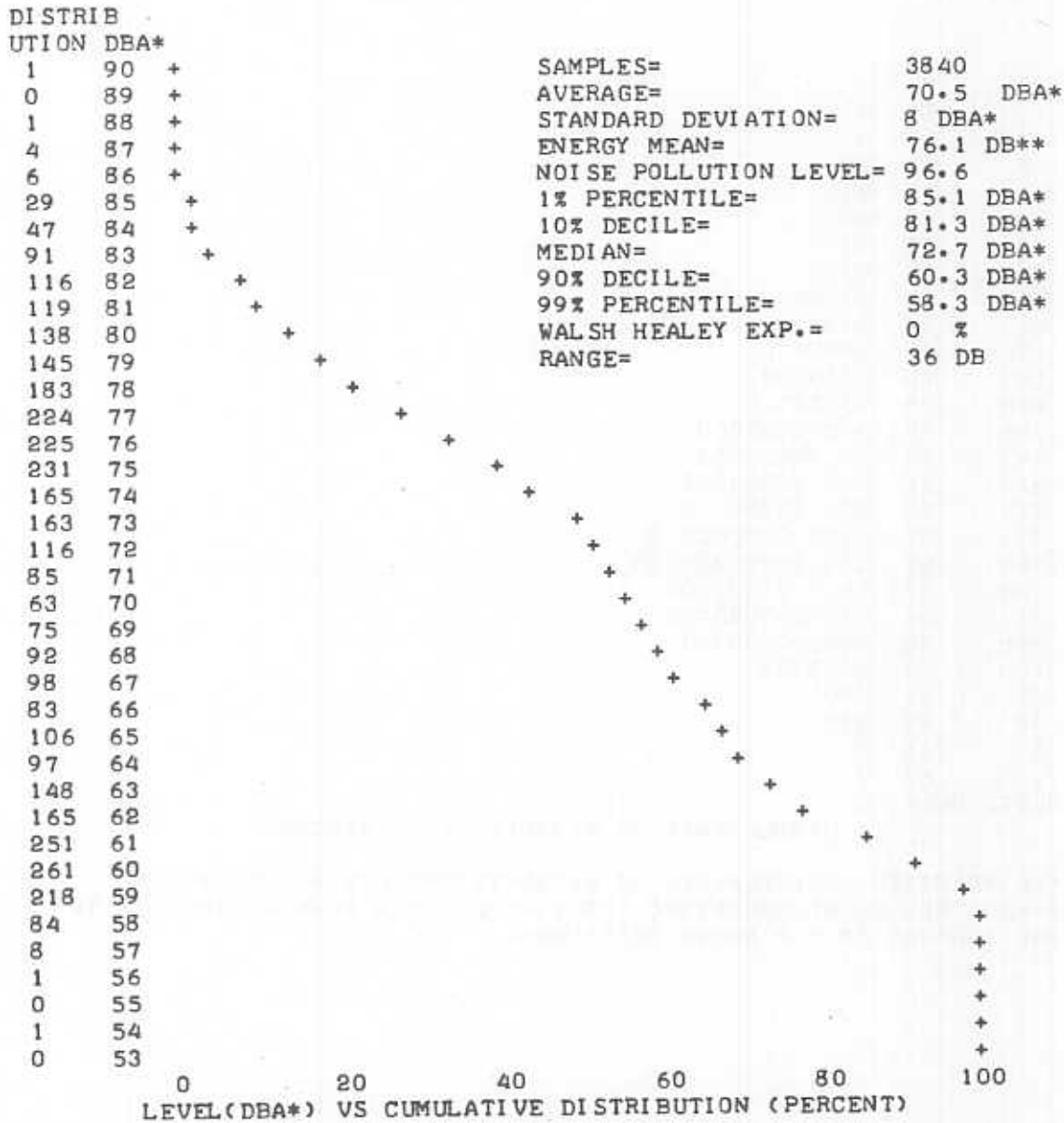


Figure E-29. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503, 1506 on the MBTA Red Line (Ashmont Extension) Northbound. Microphone located inside over rear wheel truck, April 29, 1972

1	90	0			
0	89	0			
1	88	0			
4	87	0			
6	86	0			
29	85	00			
47	84	000			
91	83	00000			
116	82	000000			
119	81	000000			
138	80	000000			
145	79	0000000			
183	78	00000000			
224	77	0000000000			
225	76	0000000000			
231	75	0000000000			
165	74	00000000			
163	73	00000000			
116	72	0000000			
85	71	0000			
63	70	0000			
75	69	0000			
92	68	00000			
98	67	00000			
83	66	0000			
106	65	00000			
97	64	00000			
148	63	0000000			
165	62	00000000			
251	61	00000000000			
261	60	000000000000			
218	59	0000000000			
84	58	0000			
8	57	0			
1	56	0			
0	55	0			
1	54	0			
DIST. DBA*	0		10	20	30
			LEVEL(DBA*) VS DISTRIBUTION (PERCENT)		

*-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure E-29 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type 1
 So. Shore Rapid Transit Cars Serial Nos 1503,1506 on
 the MBTA Red Line (Ashmont Extension) Northbound.
 Microphone located inside over rear wheel truck
 April 29, 1972.

US DEPARTMENT OF TRANSPORTATION
 TRANSPORTATION SYSTEMS CENTER
 NOISE ABATEMENT GROUP

FRI 06/23/72
 16:34

 NOISE DATA FROM RUN NO. RT-47-72-4A OF THE PORTABLE NOISE STATION ON
 APRIL 29 1972 FROM 03:48 TO 03:53, IN MBTA CAR SER. NO. 1503 & 1506
 (ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)
 (1/8 SECOND INTEGRATIONS, 8 PER SECOND)

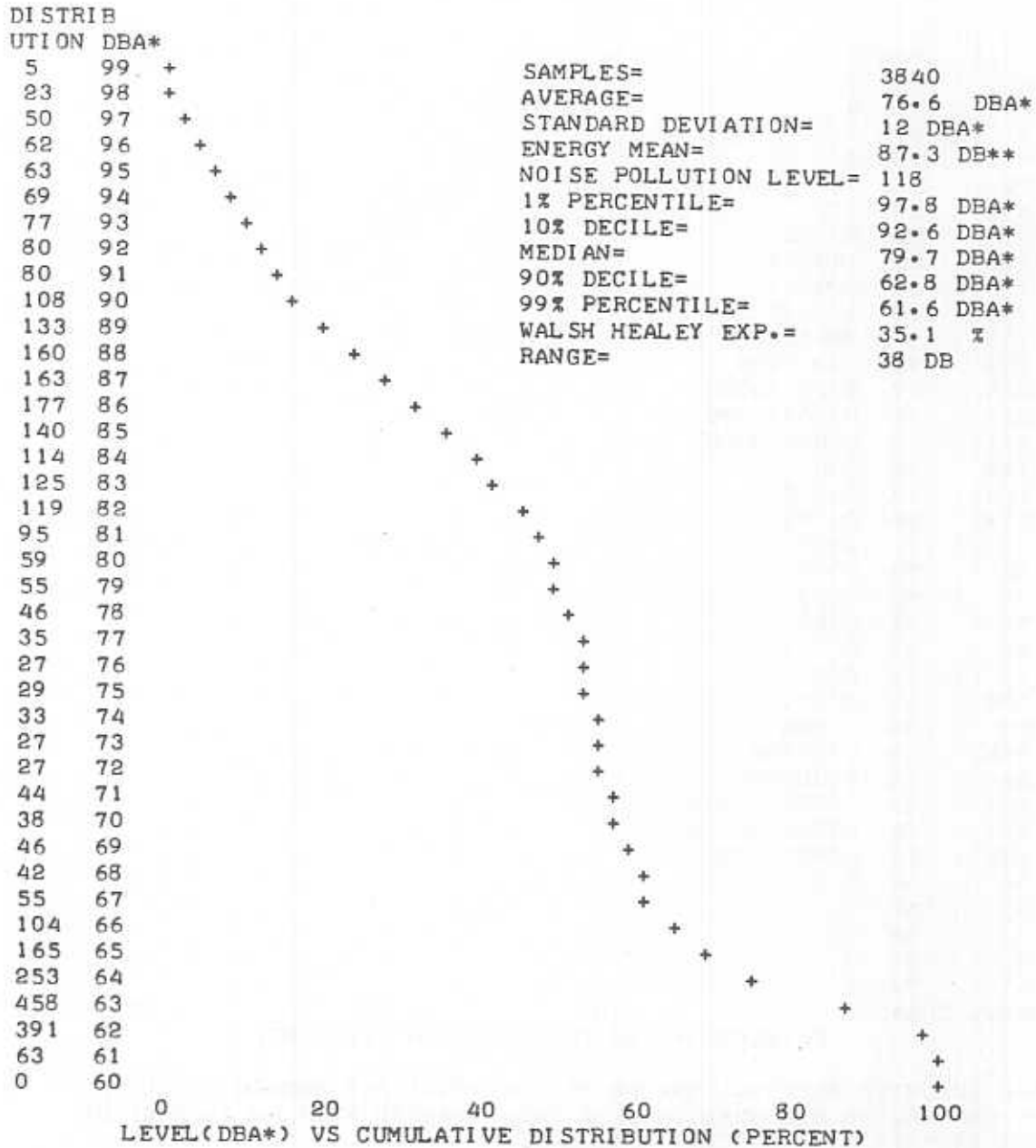


Figure E-30. Statistical Analysis - In-Car Noise Data, MBTA Type 1 So. Shore Rapid Transit Cars Serial Nos 1503, 1506 on the MBTA Red Line (Ashmont Extension) Northbound. Microphone located on outside platform between cars, April 29, 1972

5	99	0			
23	98	00			
50	97	000			
62	96	0000			
63	95	0000			
69	94	0000			
77	93	0000			
80	92	0000			
80	91	0000			
108	90	00000			
133	89	000000			
160	88	0000000			
163	87	0000000			
177	86	00000000			
140	85	0000000			
114	84	000000			
125	83	000000			
119	82	000000			
95	81	00000			
59	80	000			
55	79	000			
46	78	000			
35	77	00			
27	76	00			
29	75	00			
33	74	00			
27	73	00			
27	72	00			
44	71	000			
38	70	000			
46	69	000			
42	68	000			
55	67	000			
104	66	00000			
165	65	00000000			
253	64	00000000000			
458	63	00000000000000000000			
391	62	00000000000000000			
63	61	0000			
DIST.	DBA*	0	10	20	30

LEVEL(DBA*) VS DISTRIBUTION (PERCENT)

**-A WEIGHTED DECIBELS-RE. 20 MICRONEWTONS PER SQUARE METER
 **-DBA RE. 20 MICRONEWTONS PER SQUARE METER FROM AN AVERAGE OF
 THE SQUARES OF THE SOUND PRESSURES.

Figure E-30 (Continued). Statistical Analysis - In-Car Noise Data, MBTA Type
 1 So. Shore Rapid Transit Cars Serial Nos 1503,
 1506 on the MBTA Red Line (Ashmont Extension) North-
 bound. Microphone located on outside platform
 between cars, April 29, 1972

APPENDIX F

IN-CAR FLOOR-VIBRATION MEASUREMENTS - MBTA RED LINE

APRIL 29, 1972

[Faint, illegible text, likely bleed-through from the reverse side of the page]

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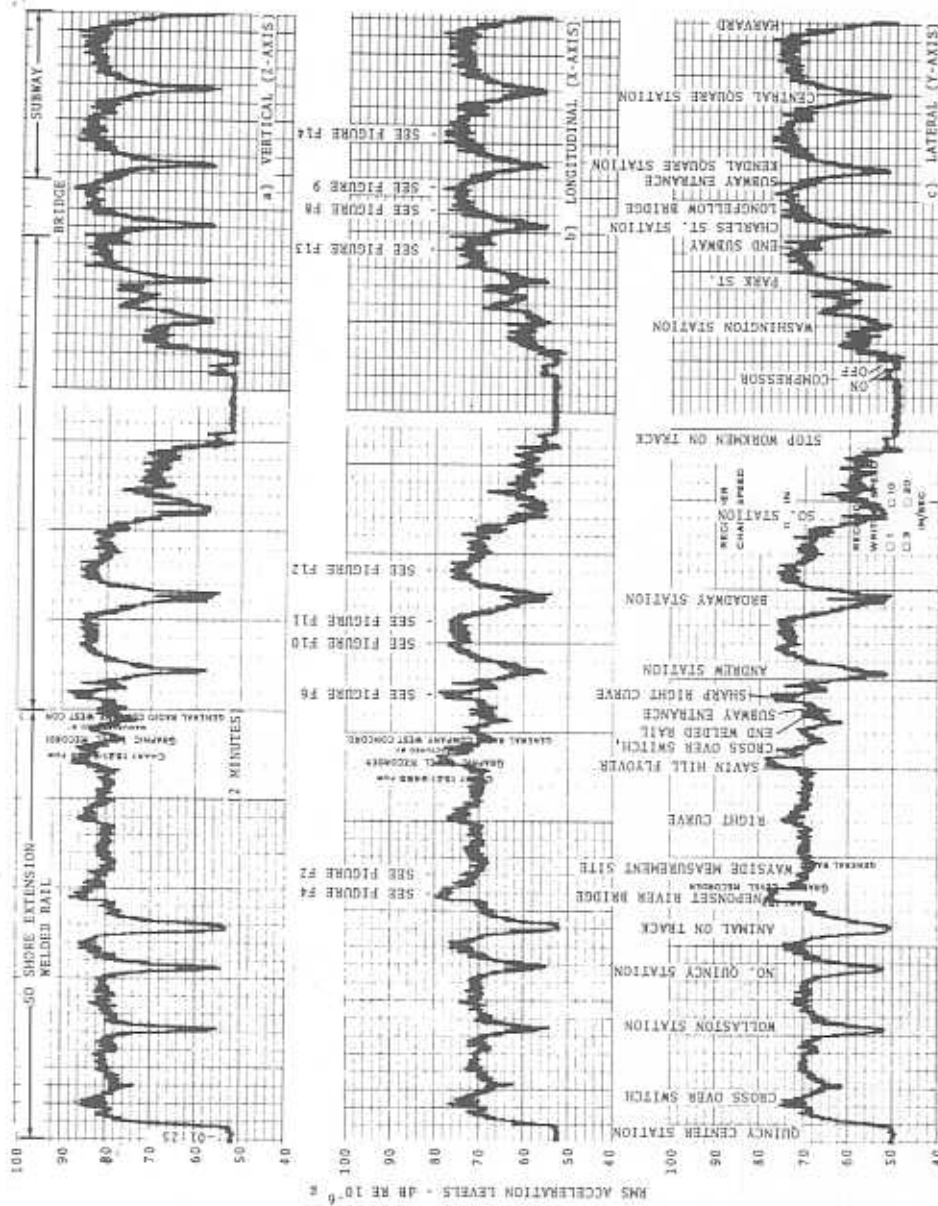


Figure F-1. Coincident Time Histories - Floor-Vibration Levels Measured in Three Axes on MBTA Type 1 So. Shore Rapid Transit Cars S/n 1503, 1506 on the MBTA Red Line and So. Shore Extension, April 27, 1972. Triaxial Accelerometer Mounted on Floor Tiles Inside Car S/n 1503 Centered Over the Rear Wheel Trucks. See figure G-2 for Accelerometer Location. See figure E-1 for Speed Profile.

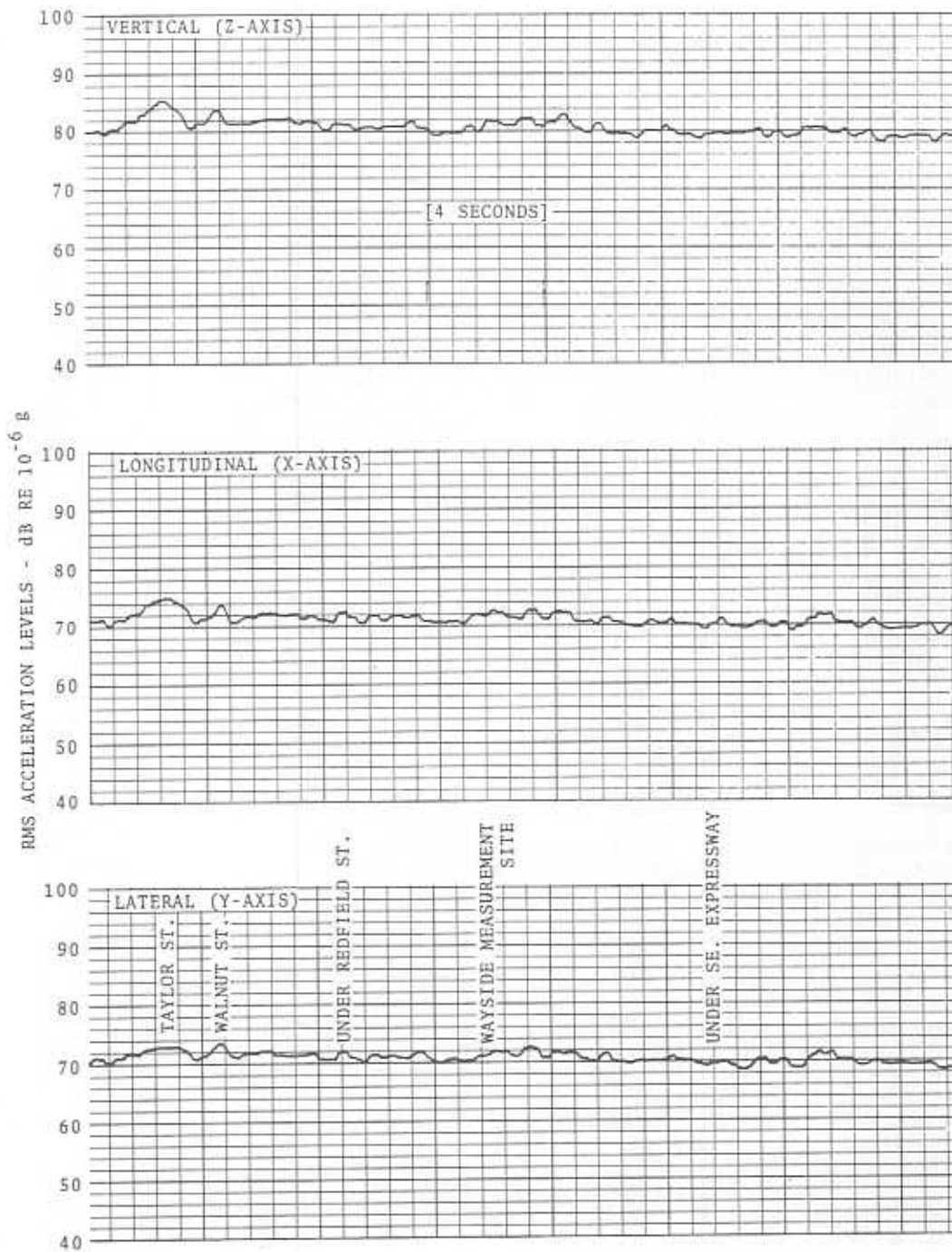


Figure F-2. Coincident Time Histories of Floor Vibration Levels in three axes. Northbound Tenean St Wayside Measurement Site. MBTA Red Line (So. Shore Extension). April 29, 1972. (See Figure F1).

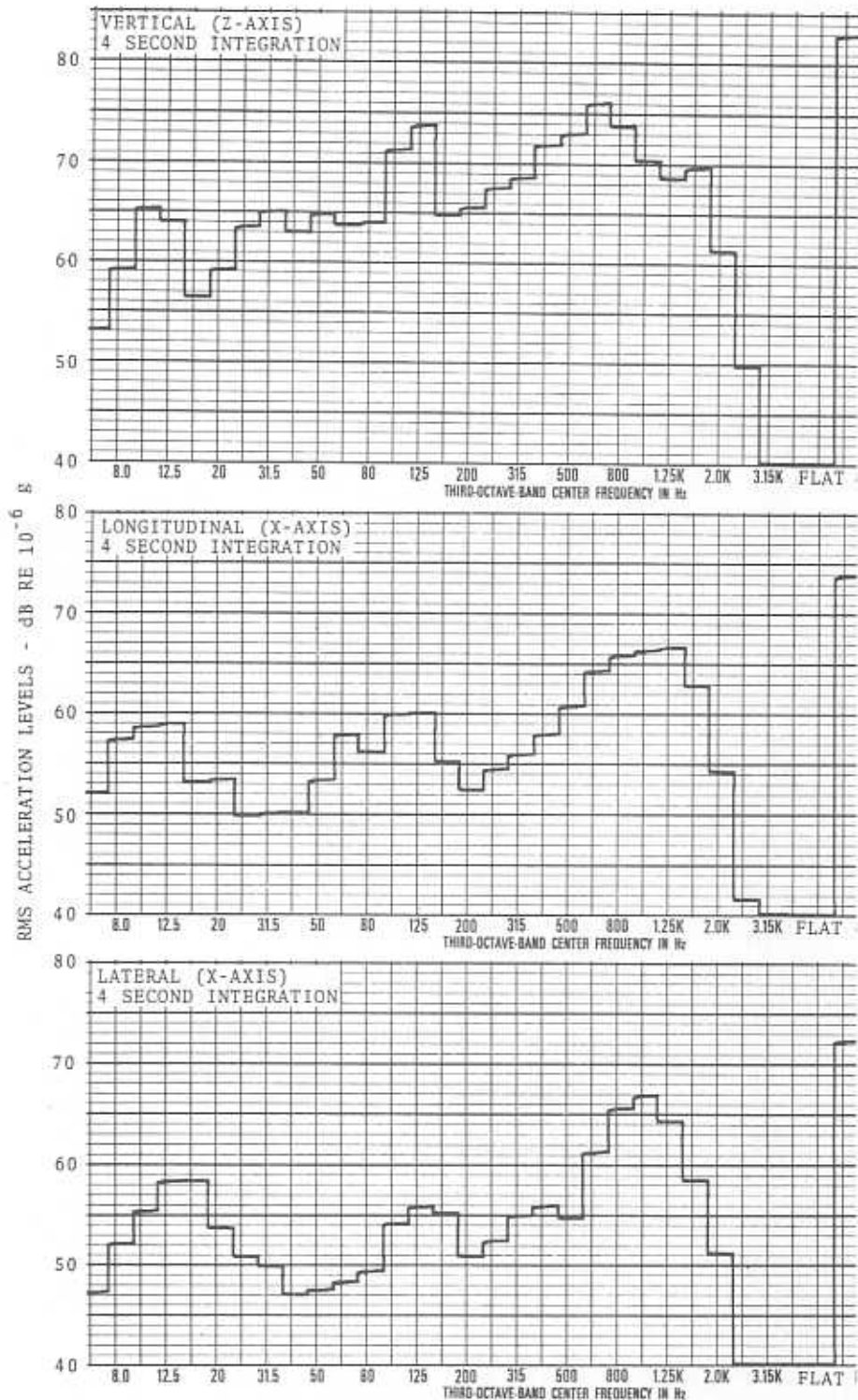


Figure F-3 Coincident Floor Vibration Spectra in three axes, Tenean St. Wayside Measurement Site, MBTA Red Line (So. Shore Extension) April 29, 1972. (See Figure F-2)

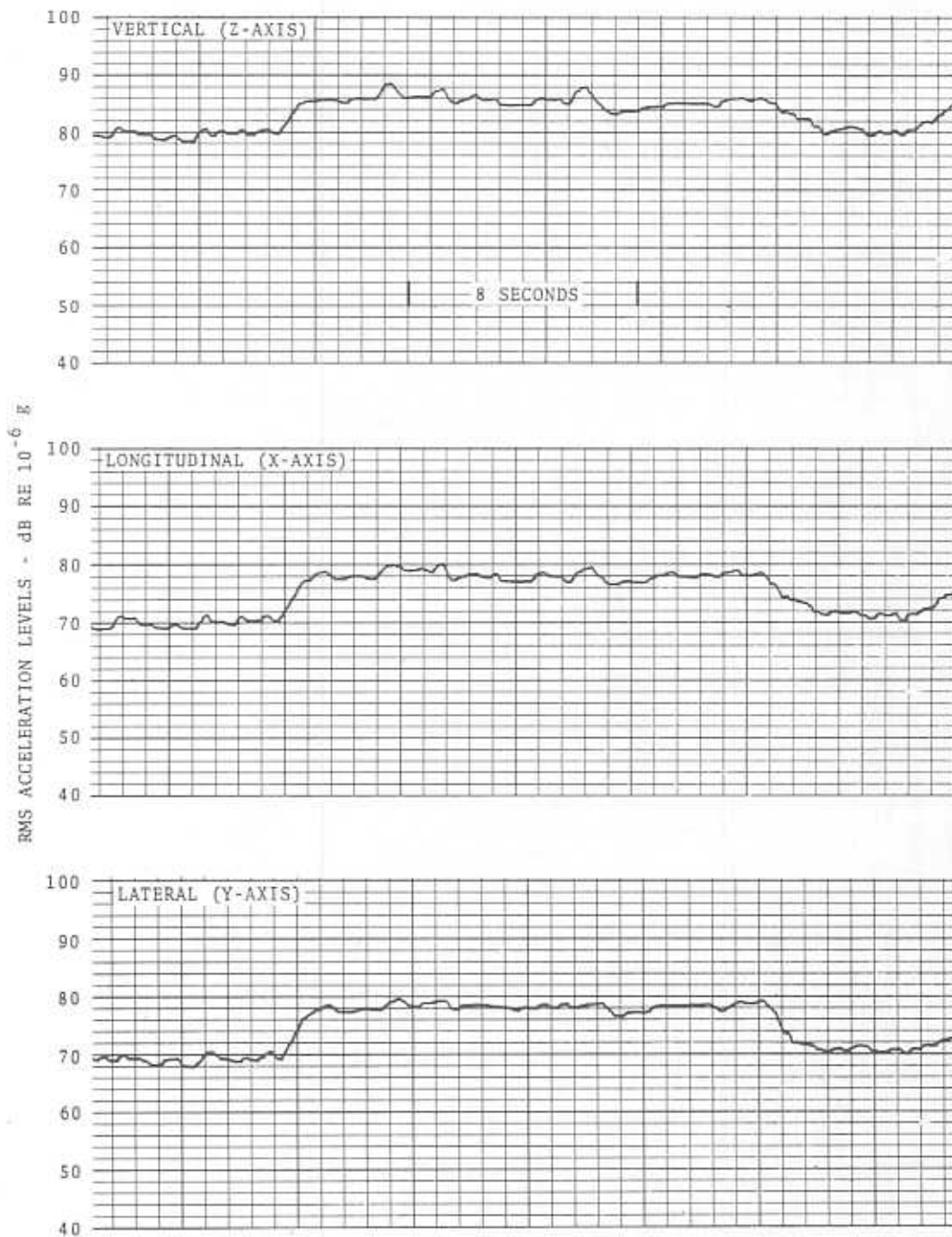


Figure F-4 Coincident Time Histories of Floor Vibration Levels in three axes. Neponset River Bridge. MBTA Red Line (So. Shore Extension) April 29, 1972. (See Figure R-1).

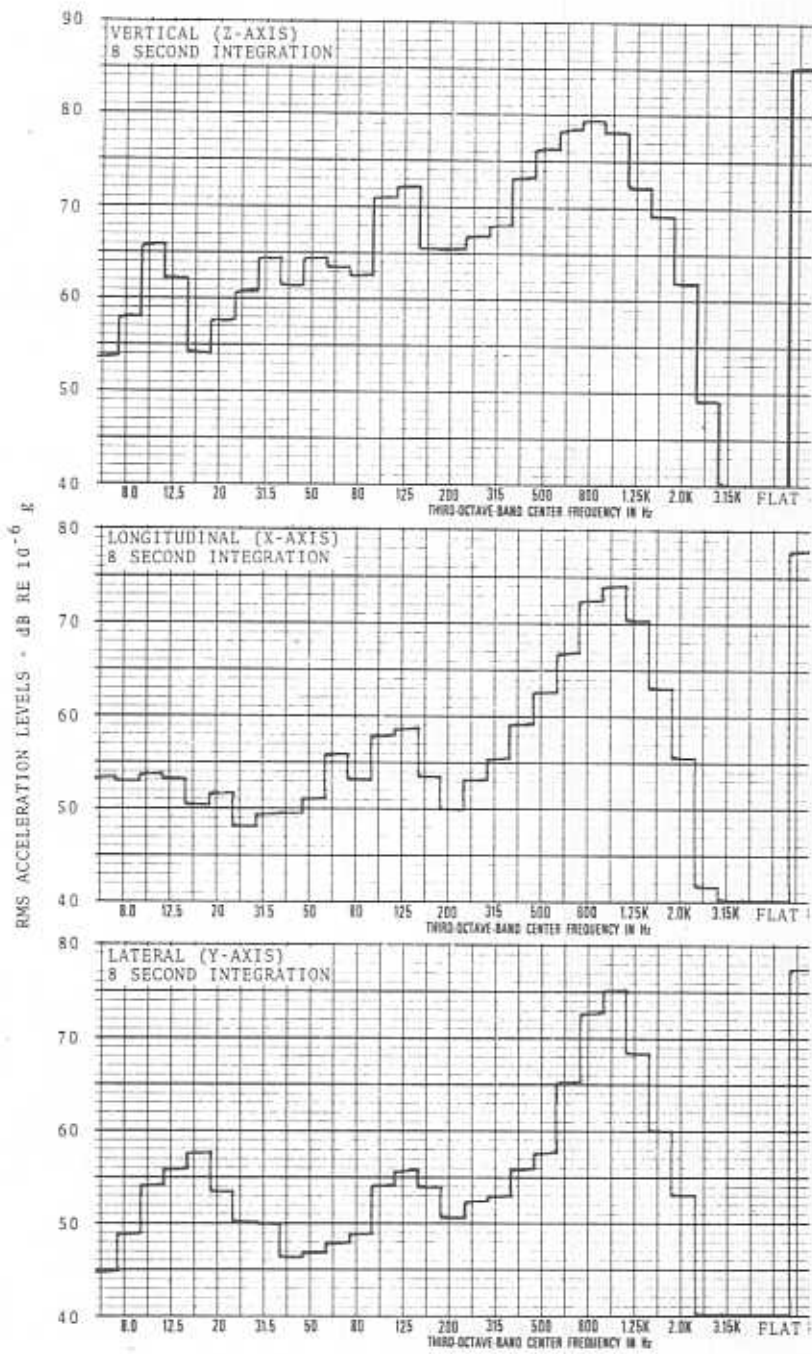


Figure F-5 Coincident Floor Vibration Spectra in three axes. Neponset River Bridge. MBTA Red Line (So. Shore Extension) April 29, 1972. (See Figure E4)

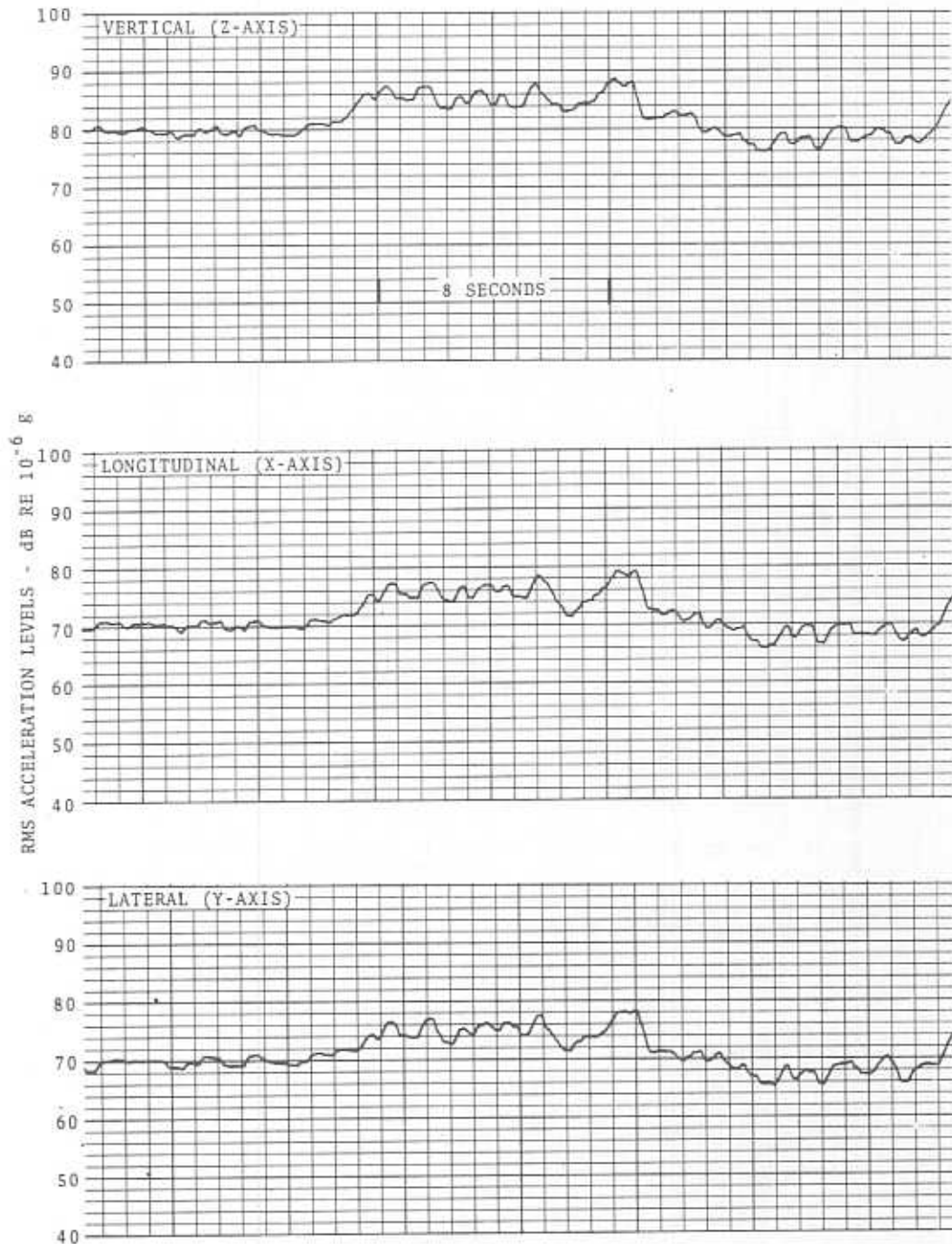


Figure F-6. Coincident Time Histories of Floor-Vibration Levels in three axes. Right-hand curve after entering tunnel before Andrew Station. MBTA Red Line, April 29, 1972. See figure F-1.

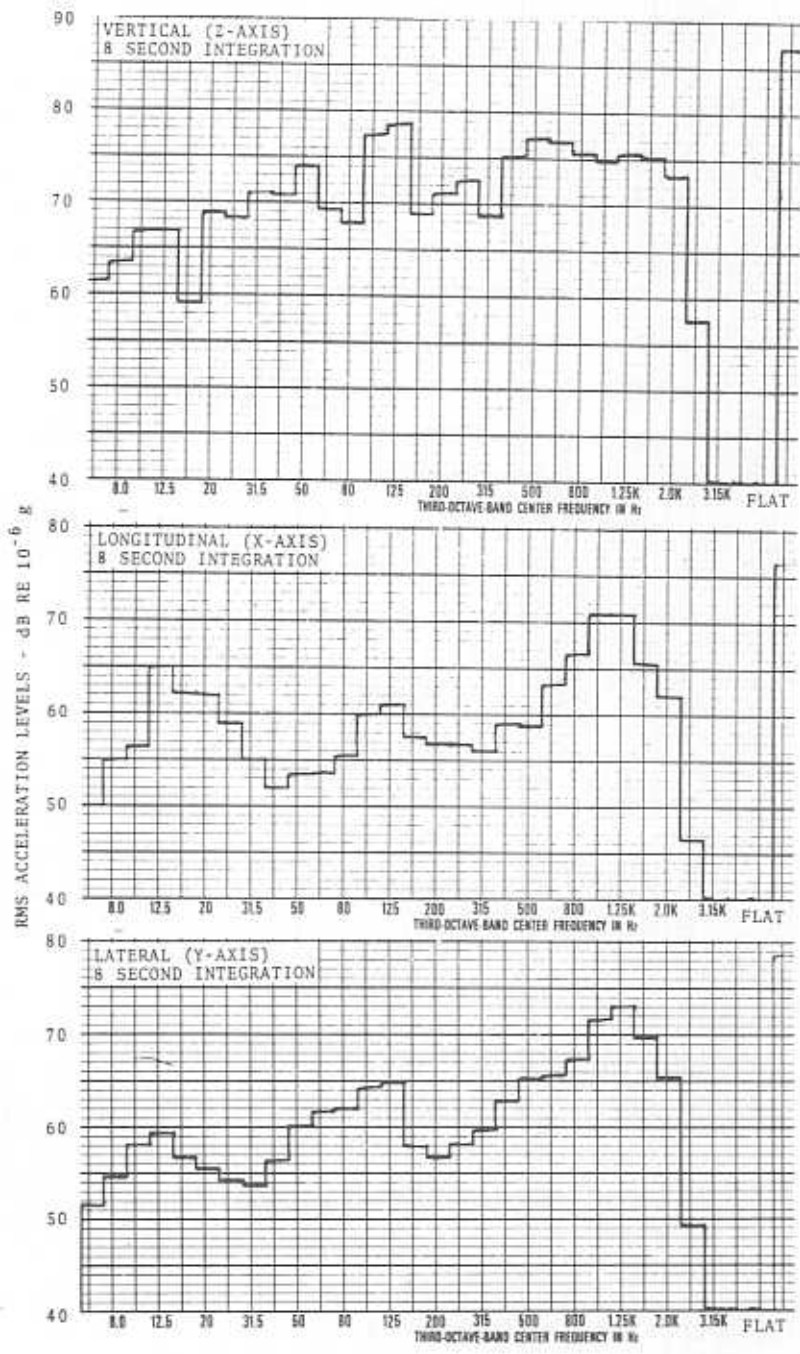


Figure F-7. Coincident Floor-Vibration Spectra in three axes. Sharp right-hand curve after entering tunnel before Andrew Station. MBTA Red Line, April 29, 1972. See figure F-6.

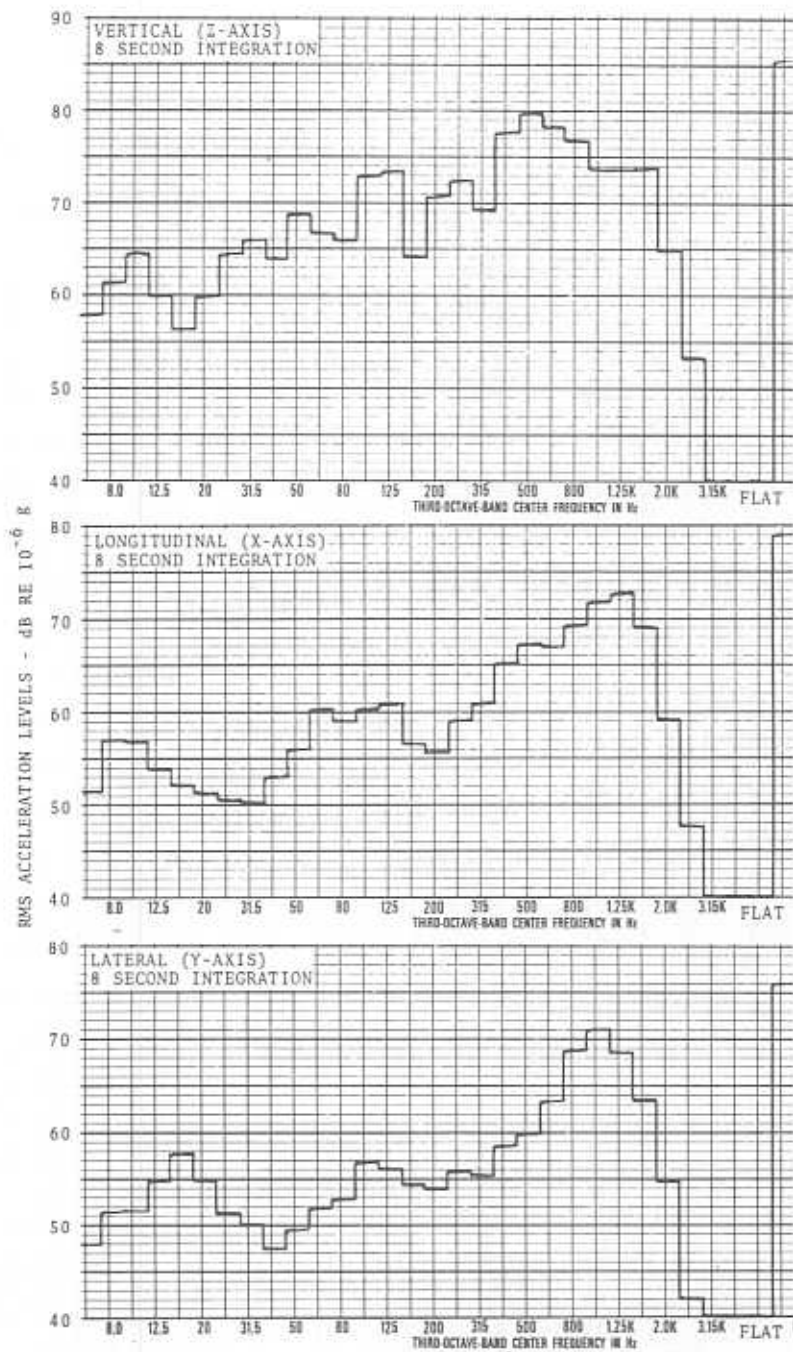


Figure F-8 Coincident Floor Vibration Spectra in three axes at Crest of Longfellow Bridge. MBTA Red Line, April 29, 1972. See Figure E1.

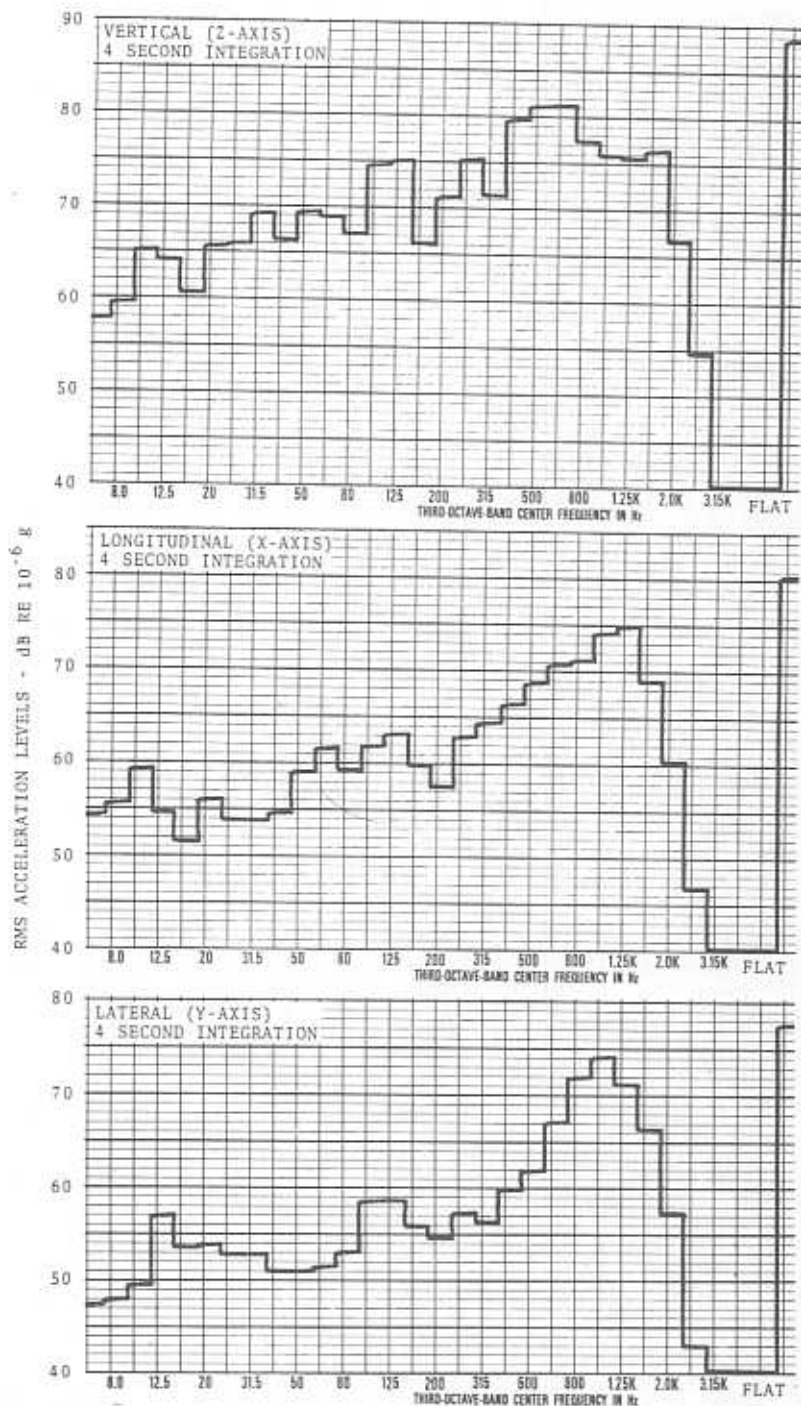


Figure F-9 Coincident Floor-Vibration Spectra in three axes at Cambridge End of Longfellow Bridge. MBTA Red Line, April 29, 1972. See figure F-1.

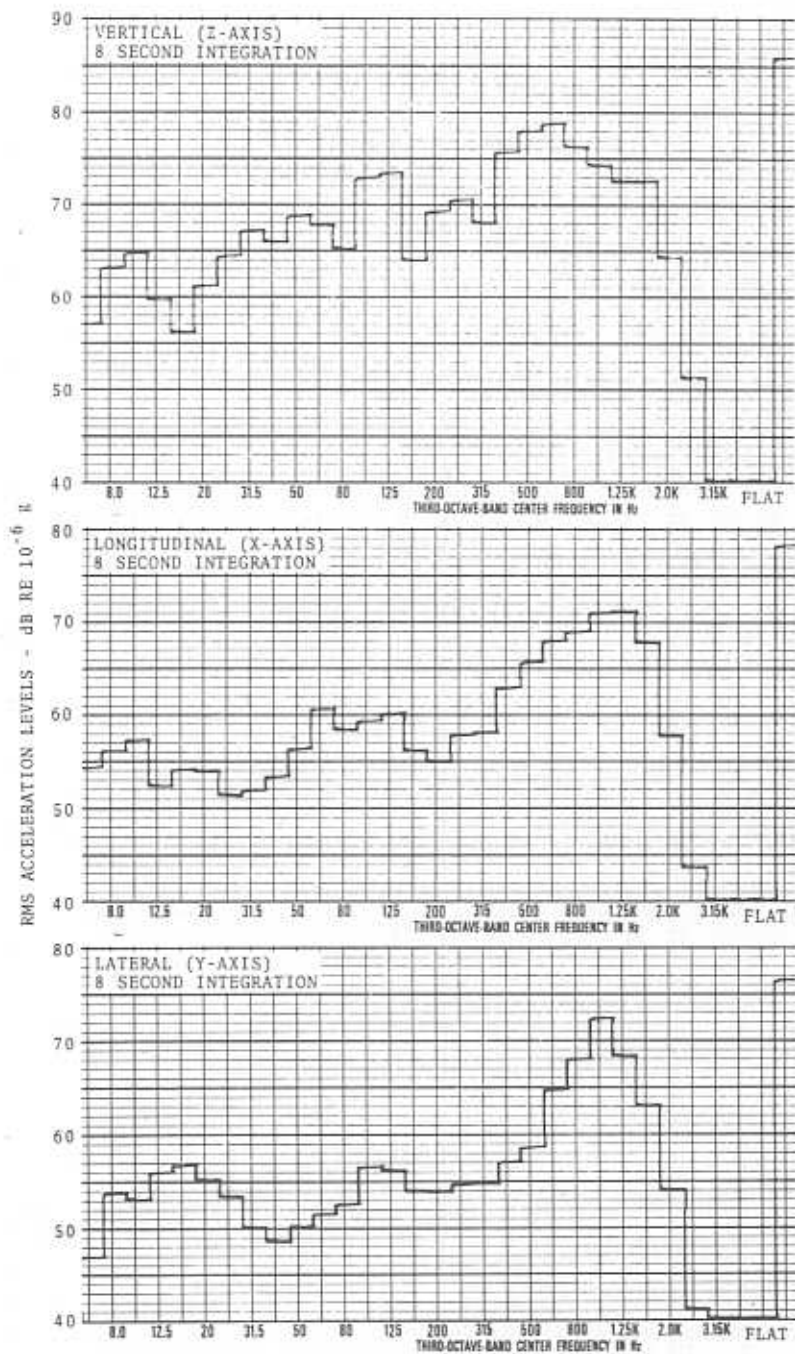


Figure F-10 Coincident Floor Vibration Spectra in three axes. Dorchester Tunnel between Andrew and Broadway Stations. MBTA Red Line, April 29, 1972. See Figure R1. See Figure F2 for tunnel cross section.

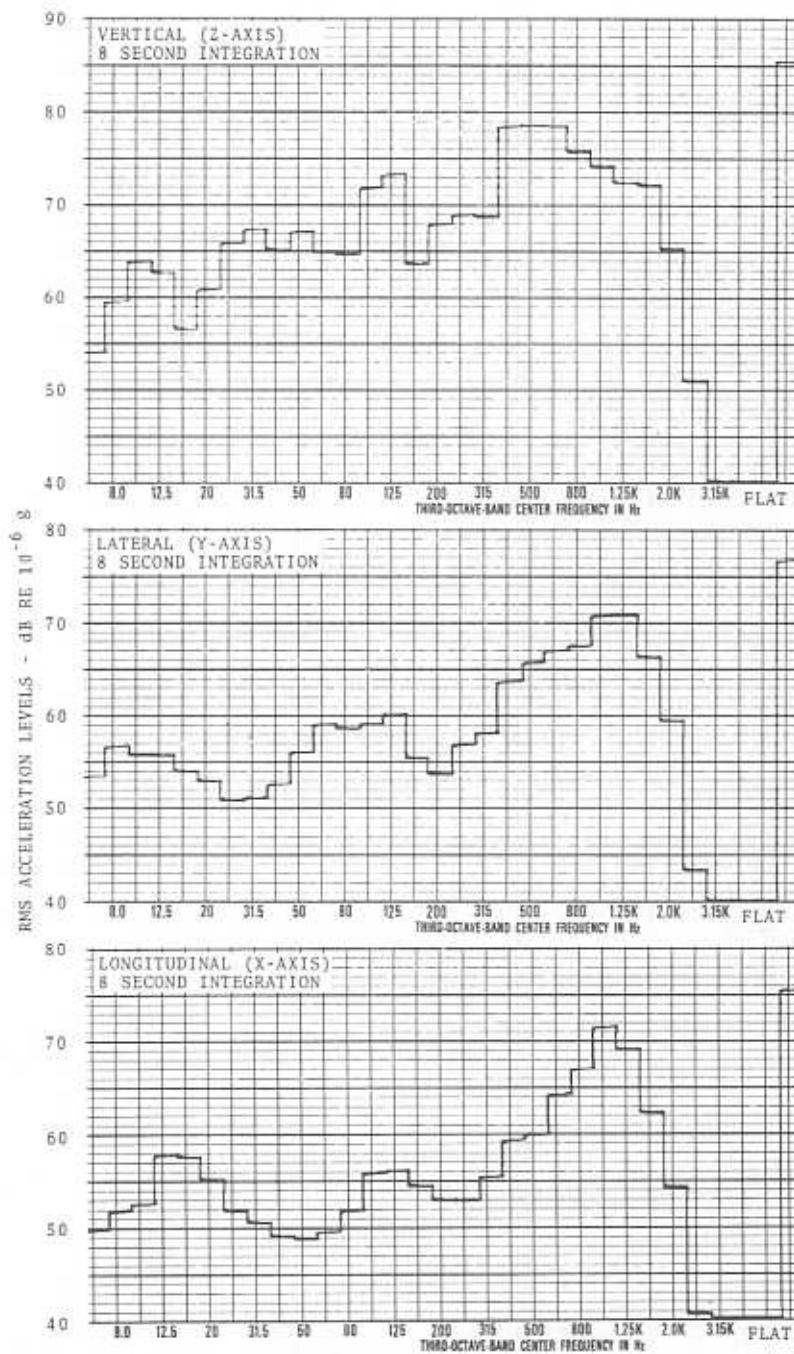


Figure F-11 Coincident Floor Vibration Spectra in three axes. Two Section Tunnel between Andrew and Broadway Stations; MBTA Red Line, April 29, 1972. See Figure E1. See Figure J-3 for tunnel cross section.

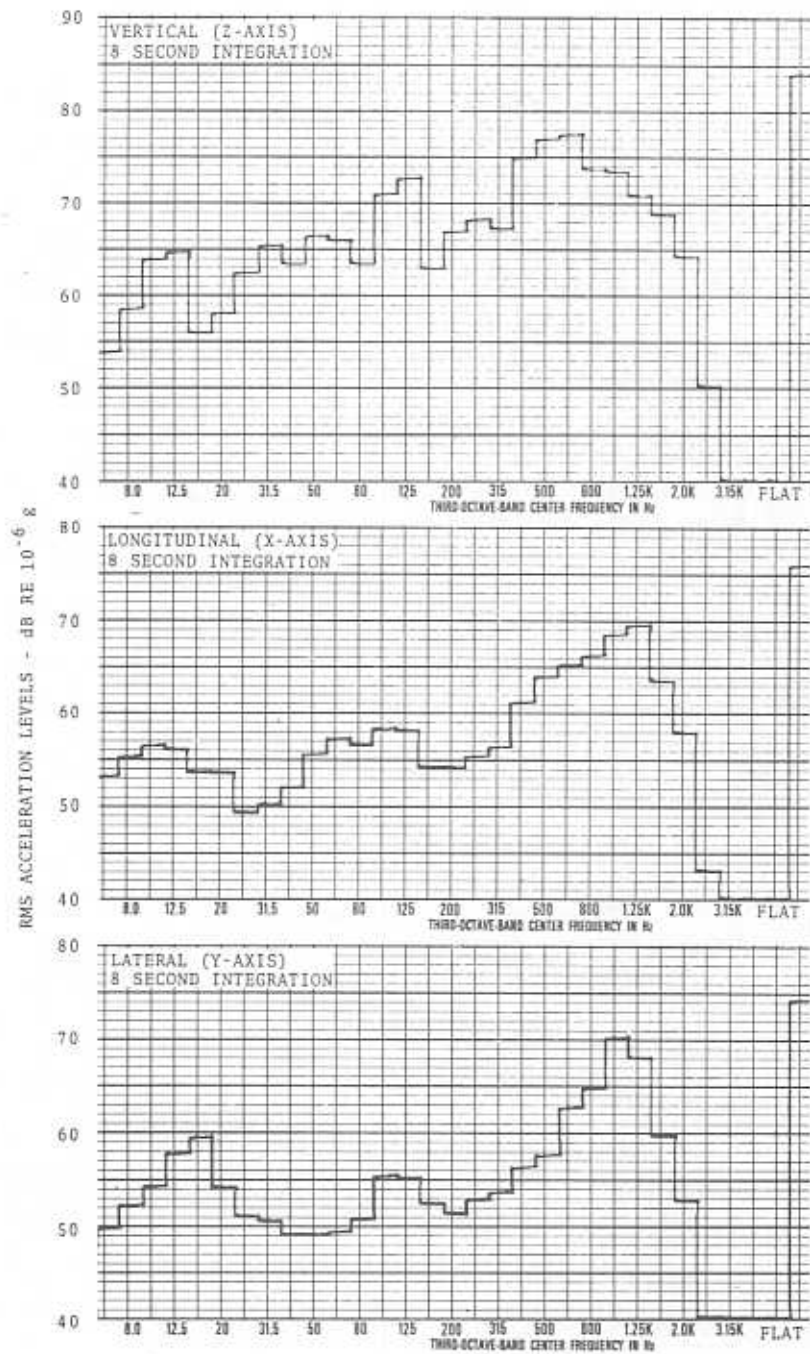


Figure F-12. Coincident Floor-Vibration Spectra in three axes. Circular Tunnel between Broadway and So Stations MBTA Red Line, April 29, 1972. See figure F-1. See figure J-4 for tunnel cross section.

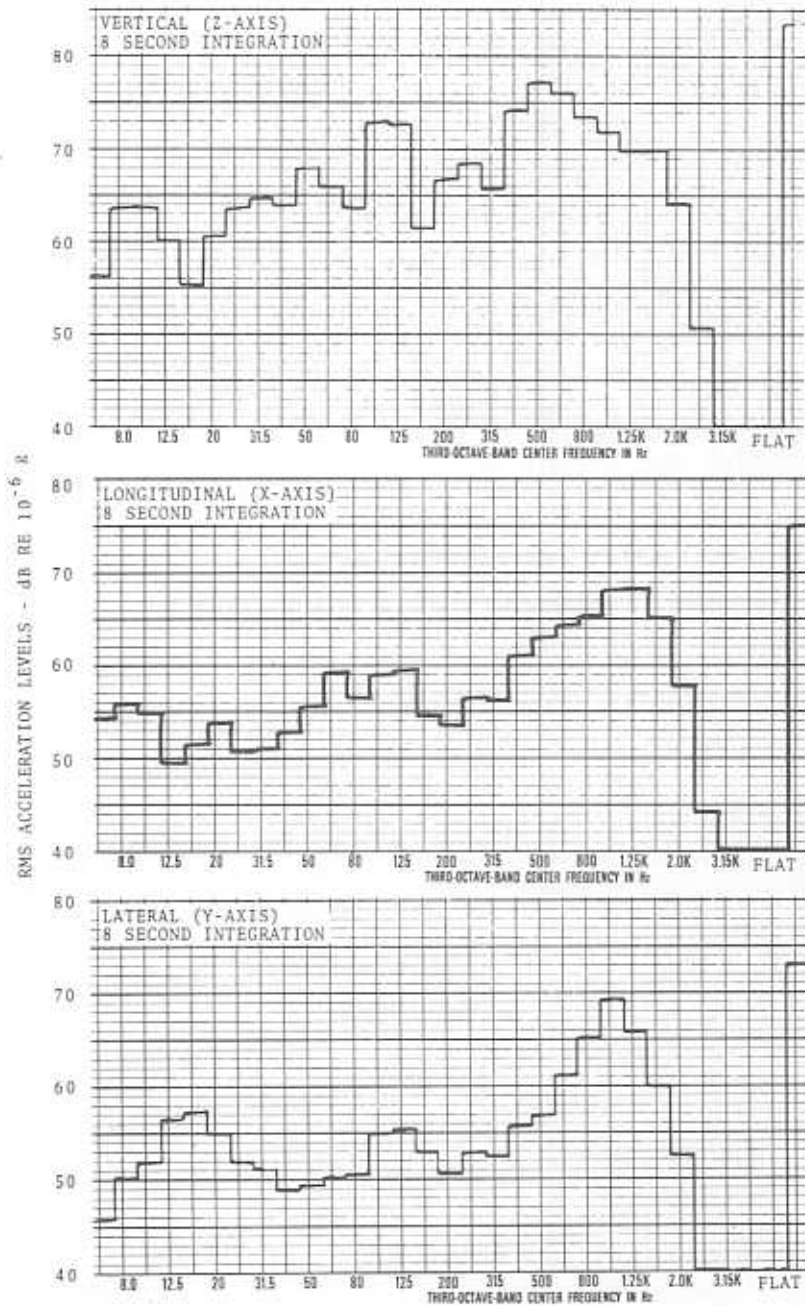


Figure F-13 Coincident Floor Vibration Spectra in three axes. Beacon Hill Tunnel between Park St and Charles St. Stations. MBTA Red Line, April 29, 1972. See Figure F-1. See Figure J-5 for tunnel cross section.

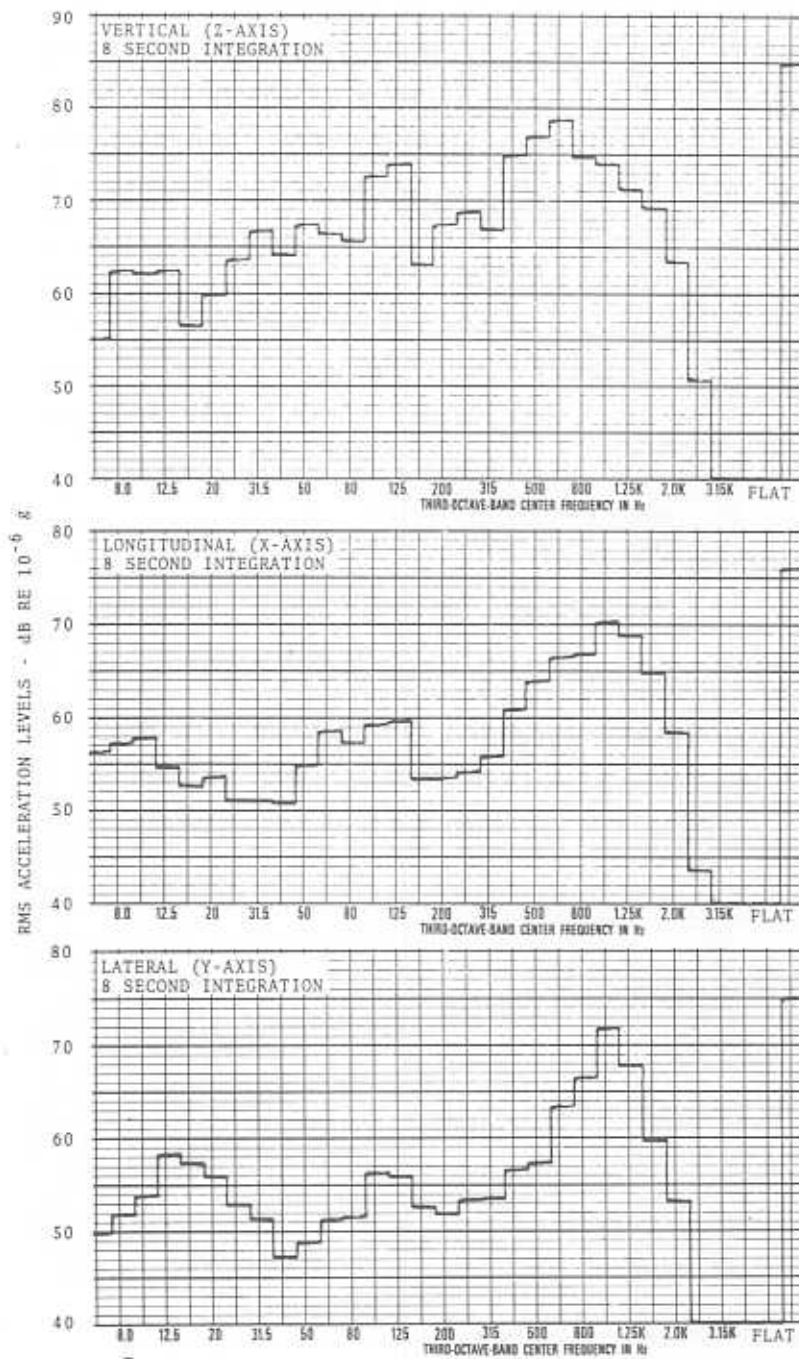


Figure F-14 Coincident Floor Vibration Spectra in three axes in Main St. Tunnel between Kendall and Central Stations. MBTA Red Line, April 29, 1972. See Figure F1. See Figure J6 for tunnel cross section.

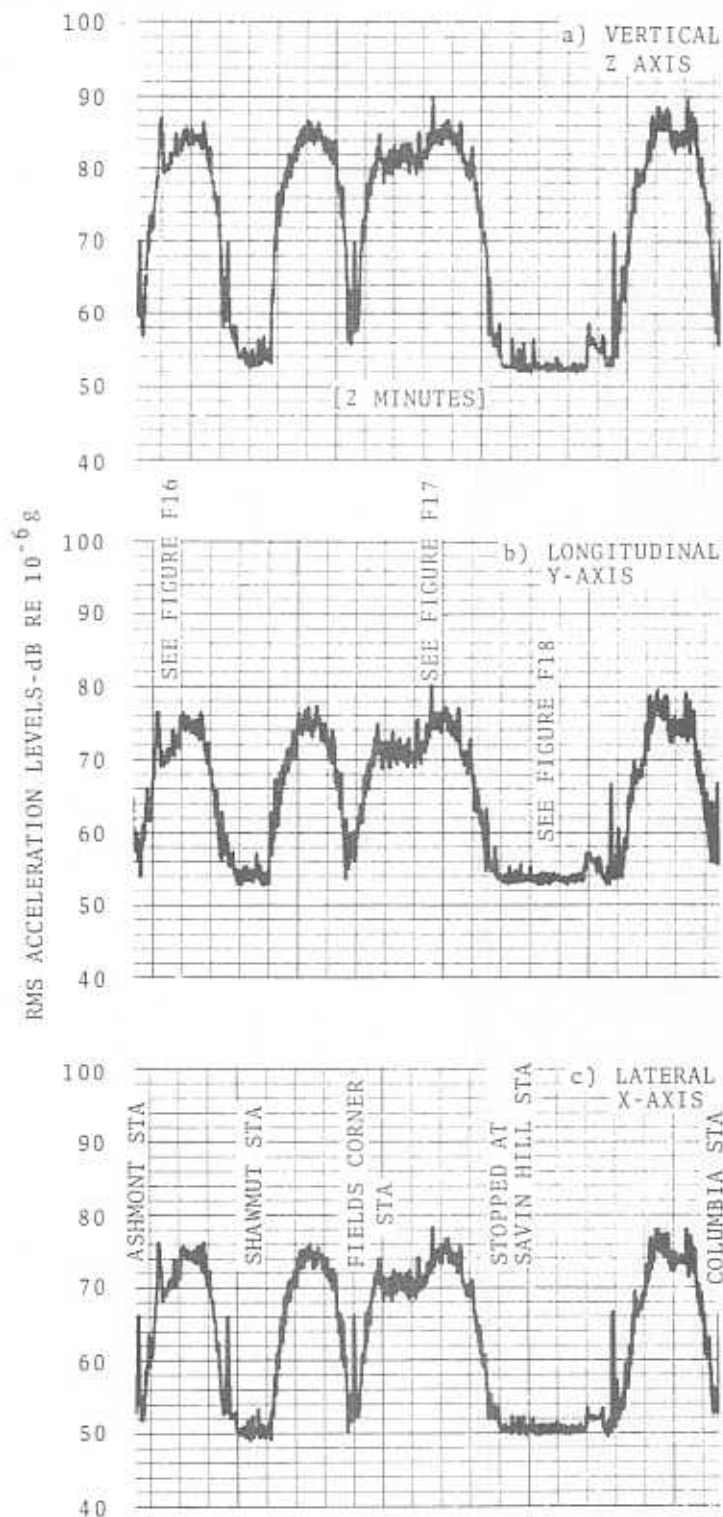


Figure F-15 Coincident Time Histories - Floor Vibration Levels measured in three axes on MBTA Type 1 So. Shore Rapid Transit Cars Ser. Nos 1503, 1506 on the MBTA Red Line (Ashmont Extension) April 29, 1972. Triaxial accelerometer mounted on the floor tiles inside Car No. 1503 centered over the rear wheel trucks. See Figure G2 for accelerometer locations. See Figure E45 for speed profile.

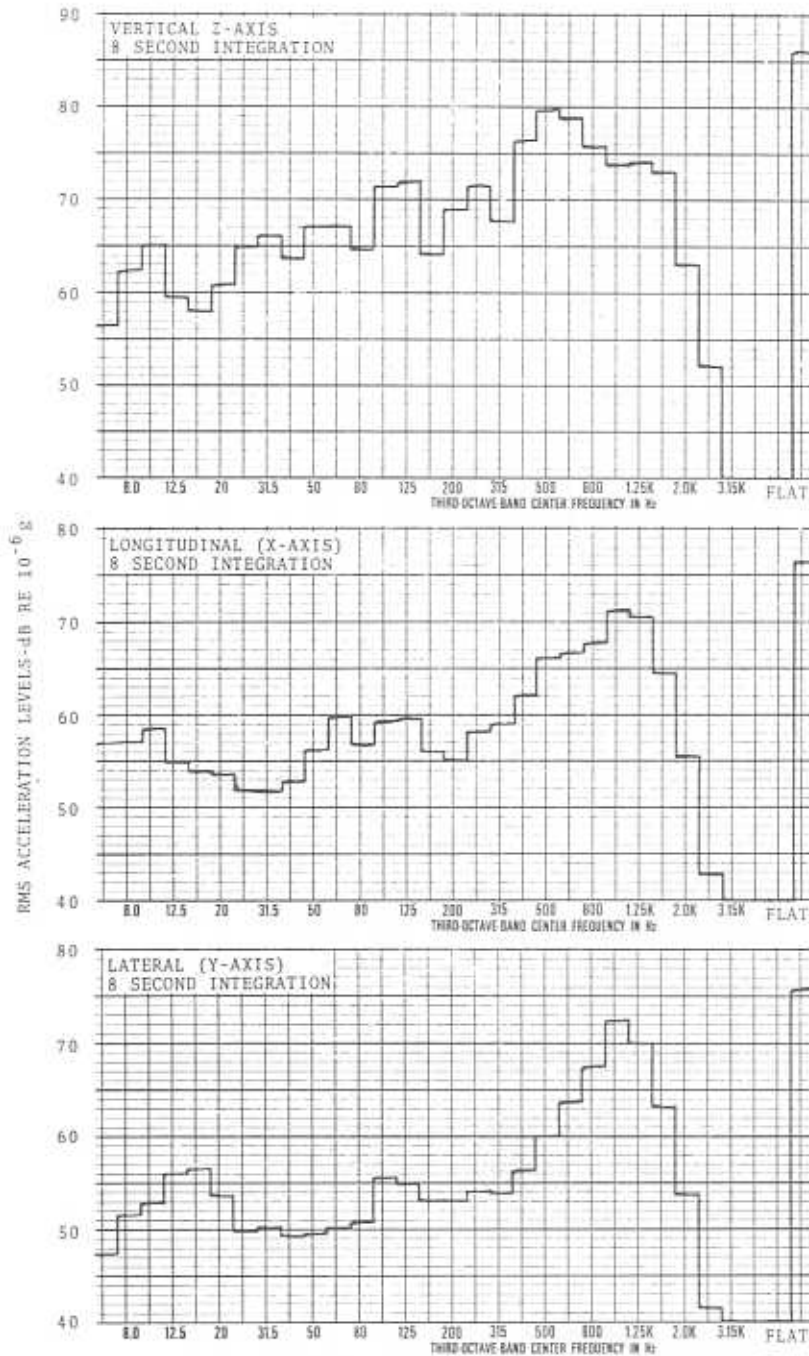


Figure F-16 Coincident Floor Vibration Spectra in three axes. Ashmont Tunnel between Ashmont and Shawmut Stations. MBTA Red Line (Ashmont Extension), April 29, 1972. See Figure F-15.

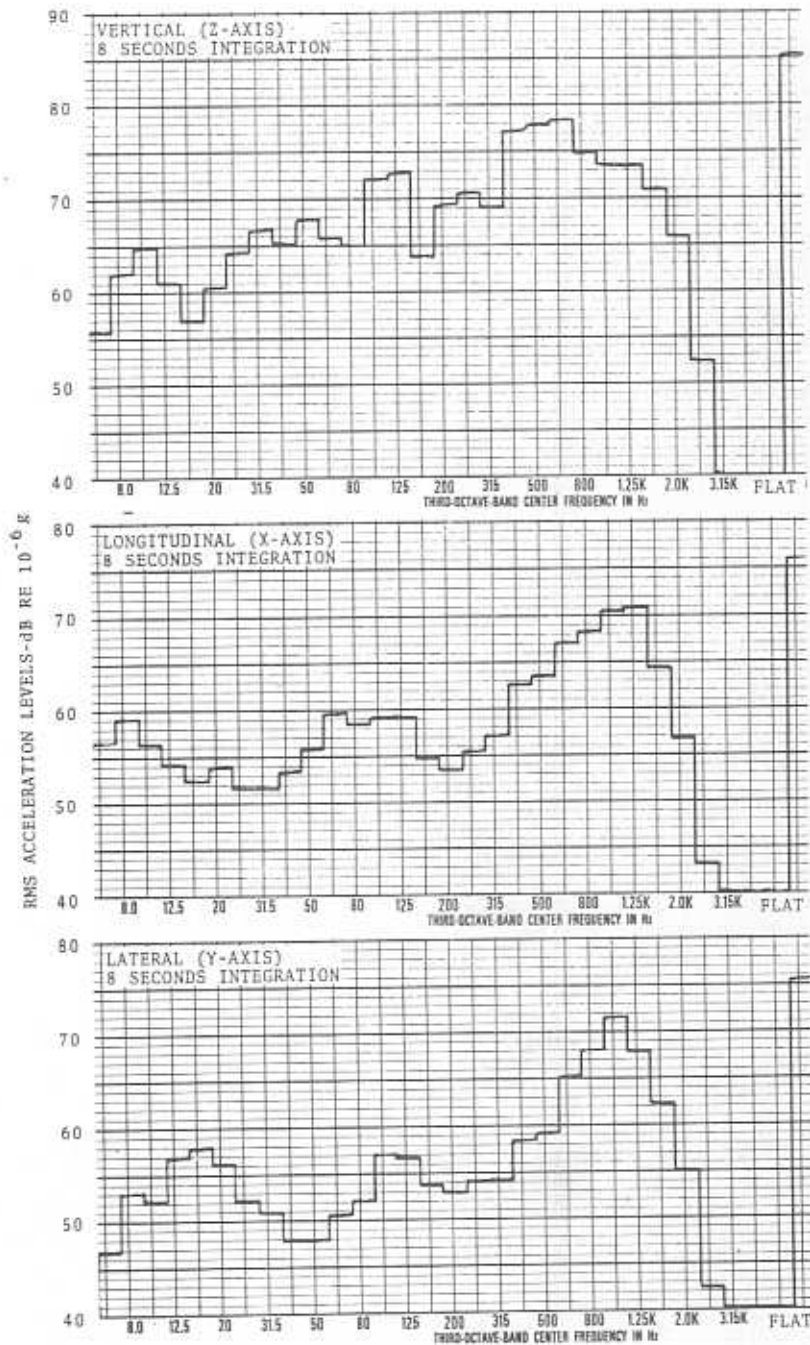


Figure F-17 Coincident Floor Vibration Spectra in three axes. Cruising on straight run, surfaceline between Fields Corner and Savin Hill Stations. MBTA Red Line (Ashmont Extension) April 29, 1972. See Figure F-15.

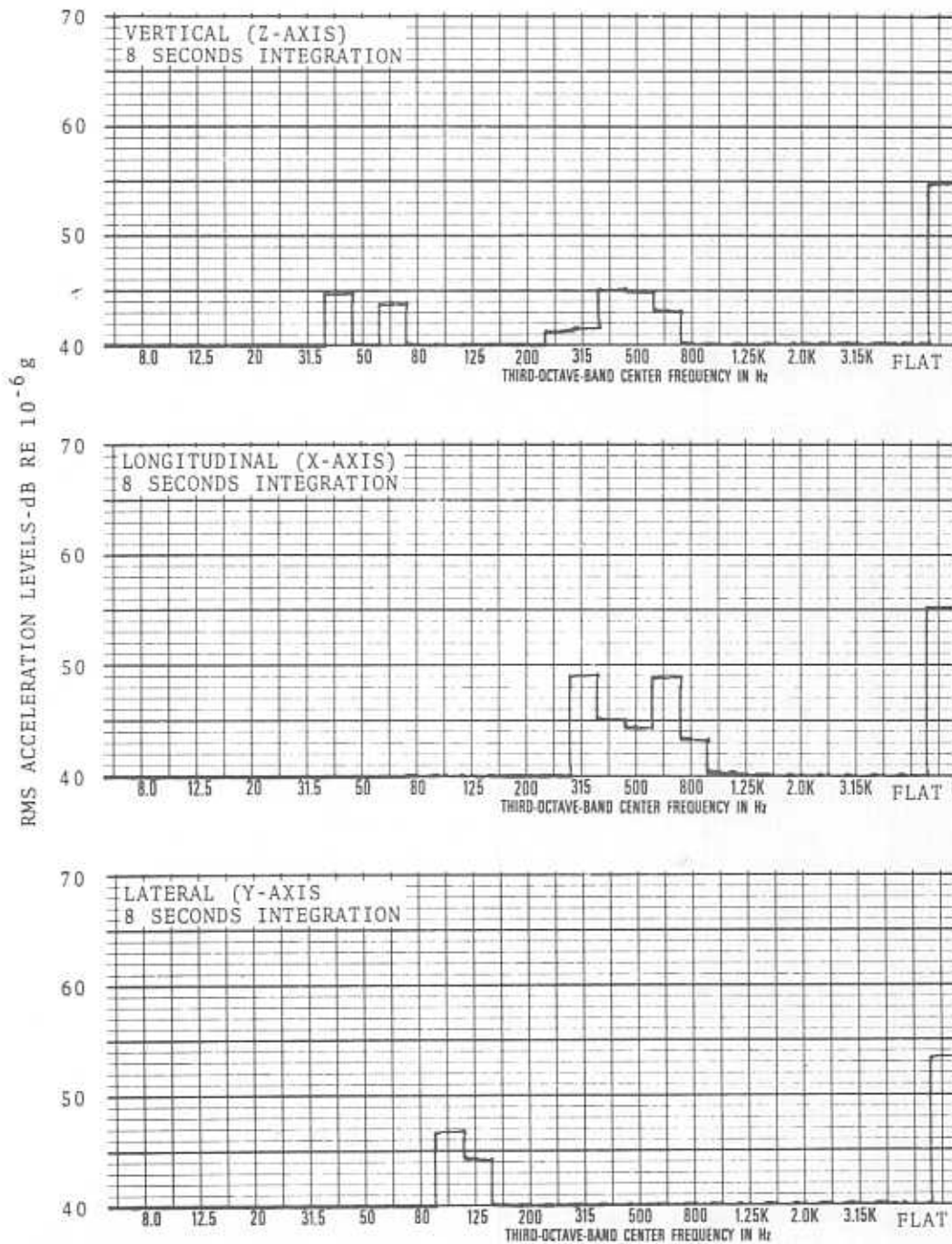


Figure F-18 Coincident Floor Vibration Spectra in three axes. Stopped with doors open at Savin Hill Station. MBTA Red Line (Ashmont Extension) April 29, 1972. See Figure F15.

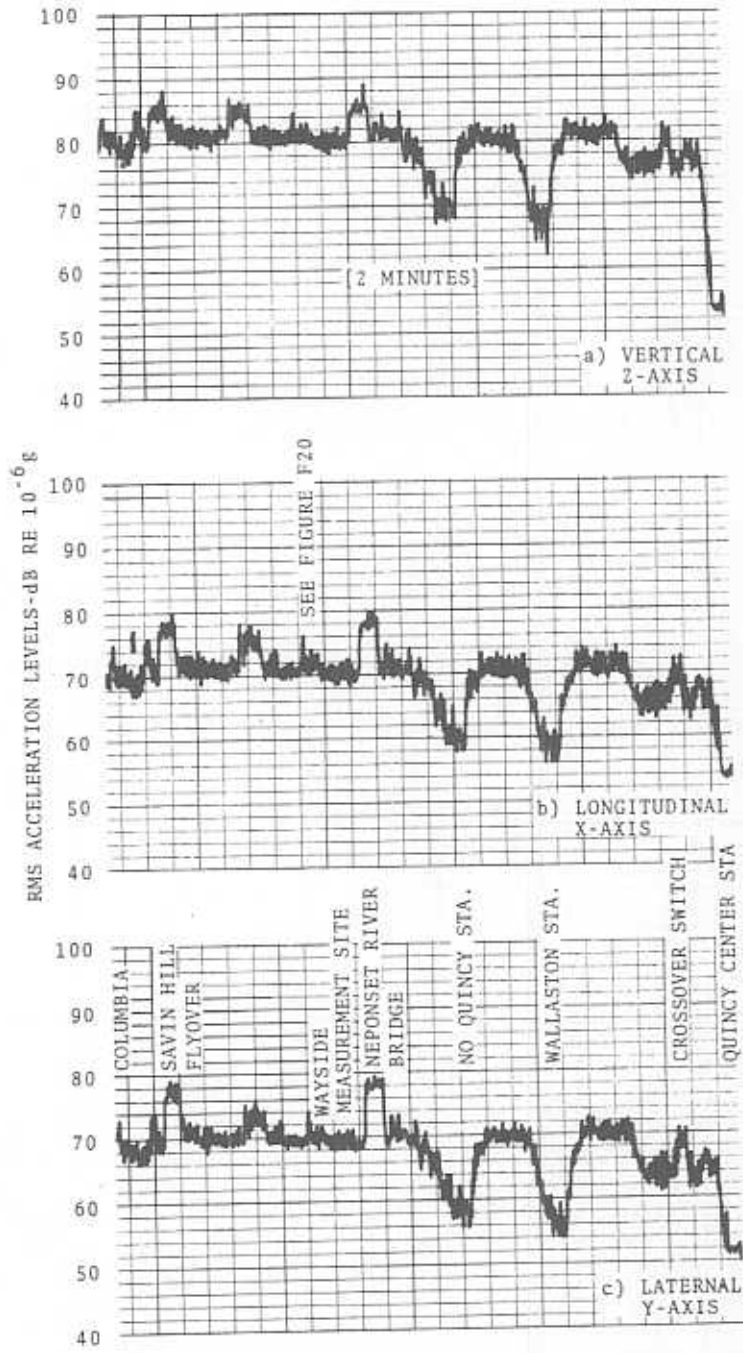


Figure F-19 Coincident Time Histories - Floor Vibration Levels in three axes on MBTA Type 1 So. Shore Rapid Transit Cars. Ser. Nos 1503, 1506 on the MBTA Red Line (So. Shore Extension) southbound. April 29, 1972. Triaxial accelerometer mounted on the floor tiles inside Car No. 1503 centered over the rear wheel trucks. See Figure G2 for accelerometer location. See Figure B19 for speed profile.

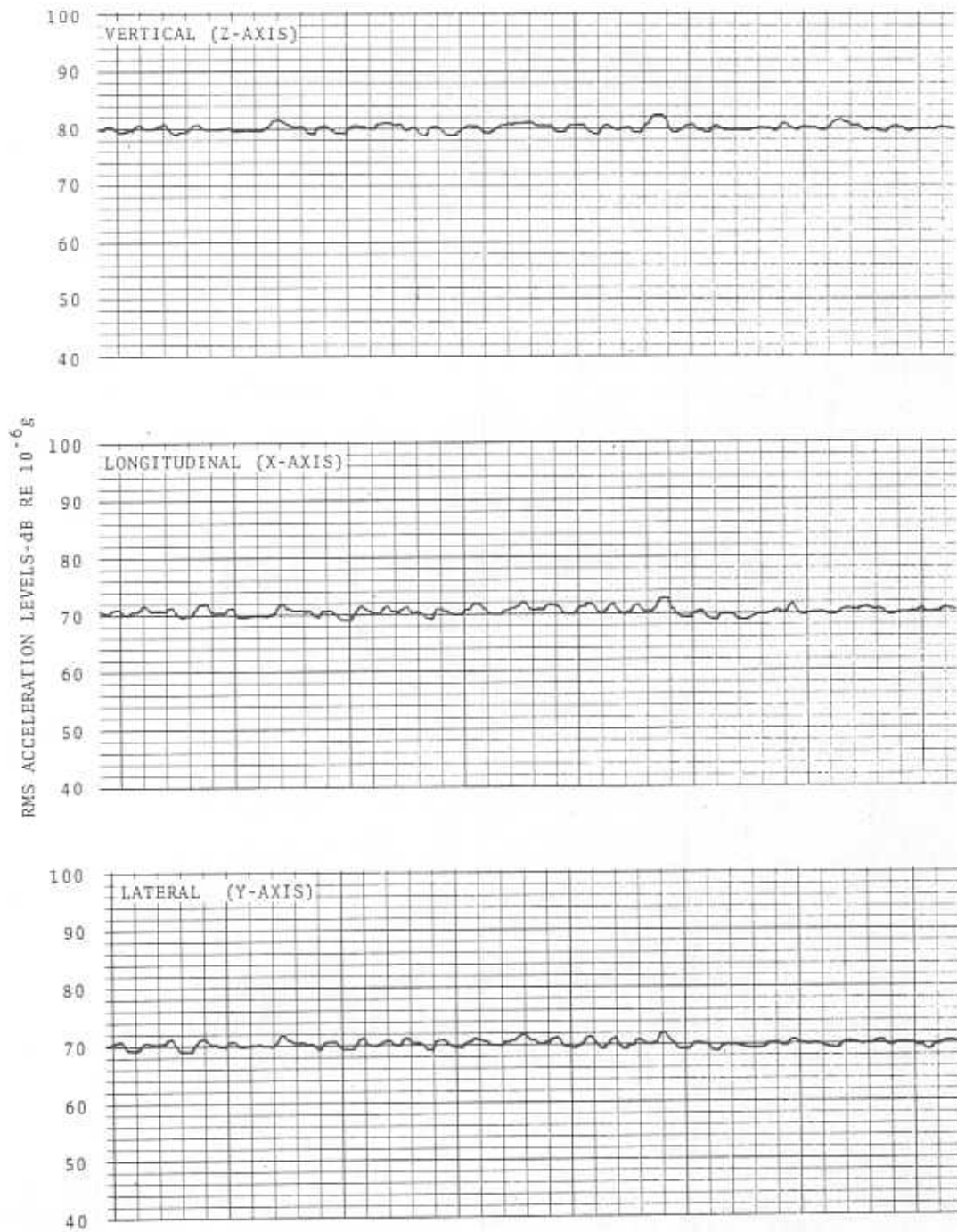


Figure F-20 Coincident Time Histories of Floor Vibration Levels in three axes. Southbound Tenean St. Wayside Measurement Site. MBTA Red Line (So. Shore Extension) April 29, 1972. See Figure E19.

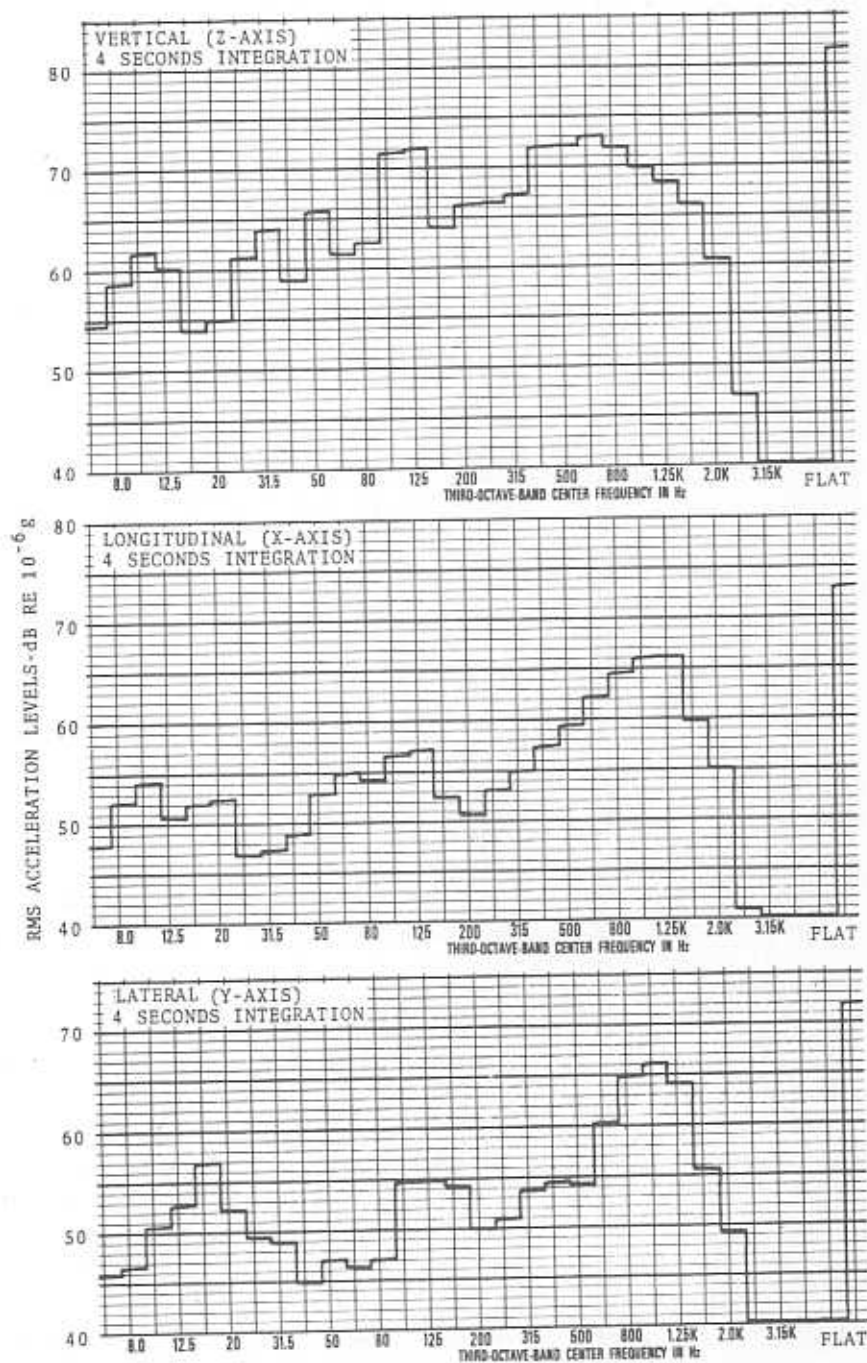
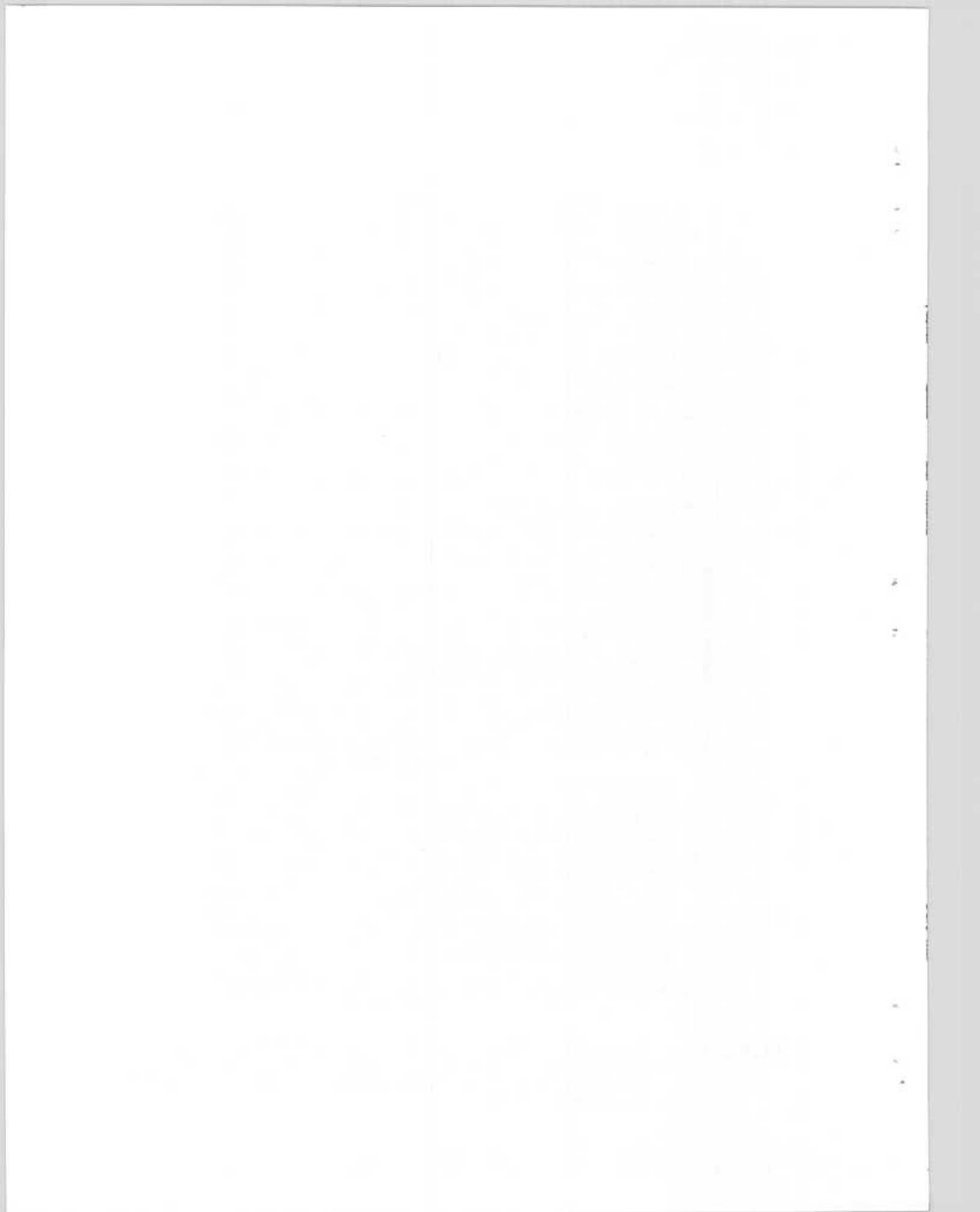


Figure F-21 Coincident Floor Vibration Spectra in three axes. Southbound Tenan St. Wayside Measurement Site. MBTA Red Line (So. Shore Extension) April 29, 1972. See figure F-20.



APPENDIX G
MICROPHONE AND VIBRATION TRANSDUCER LOCATIONS

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MEASUREMENT LOCATIONS

Figure G-1 depicts the location of the three wayside microphone systems and triaxial accelerometer systems set in an MBTA storage yard on Tenean St. Dorchester, MA next to the MBTA Rapid Transit tracks of the Red Line's So. Shore Extension. The microphones were placed 25 ft., 50 ft. and 100 ft. from the centerline of the near northbound track and six feet above level grade. The top of the rails in this location was 3 ft. 1 inch above level grade. The triaxial arrangement of accelerometers were mounted on a brass rod (2 ft. long and 7/8 inch in diameter) which was driven into the ground 25 ft. from the centerline of the northbound track at a point 2 ft. away from microphone system No. 1.

For the October 28, 1971 measurements, a robot camera was placed 100 ft. from the northbound track and was programmed to take sequential photographs of the passing trains every 1/4 second. These photographs were used to calculate the speed of the train.

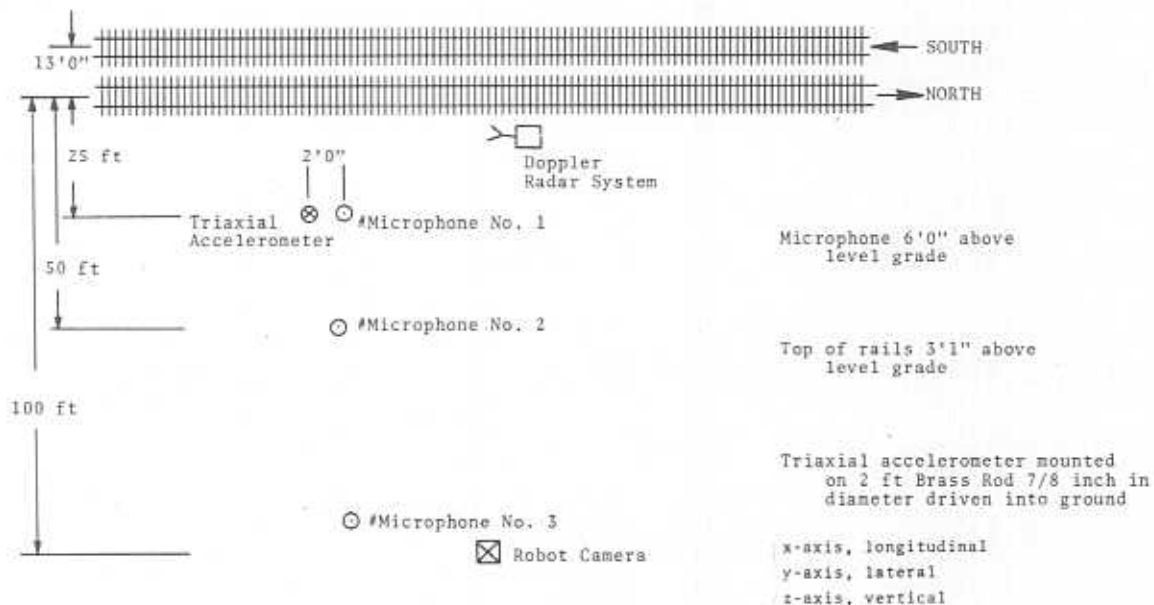
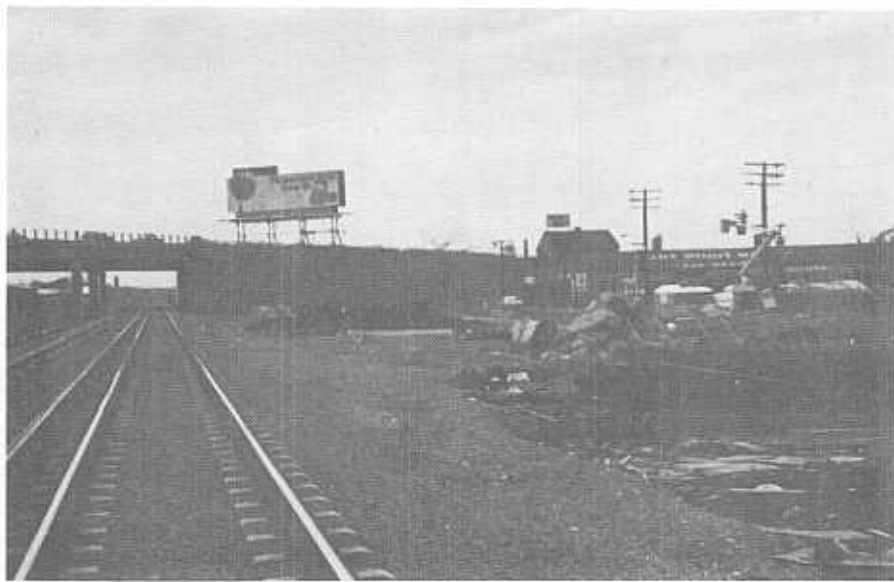


Figure G-1. Wayside Instrument Locations MBTA Red Line - So. Shore Extension, Tenean Street, Dorchester, MA

For the April 27, 1971 measurements an X-band Doppler radar system was set up trackside for speed information.

Figures G-2 through G-5 are photographs of the Tenean Street measurement site.

Figure G-6 shows the location of three microphones set up in the lead car of a 2-car train. Microphone system No. 1 was placed at ear level of a seated passenger at a mid-car location (3.5 ft. above the floor); microphone system No. 2 was placed at ear level of a seated passenger and located over the rear wheel trucks (3.5 ft. above floor); microphone system No. 3 was placed on the outside platform between cars at a height of 5.5 ft. (See photograph of car interior figure G-7.) A triaxial accelerometer was attached with a thin layer of bees' wax to the floor tiles inside and was centered over the rear wheel truck (See photograph figure G-8.) Speed of the train over the Red Line was obtained from the in-car digital speedometer in the car operator's compartment. A technician stationed in the compartment read the speed data from the speedometer and position statistics into a synchronized tape recorder.

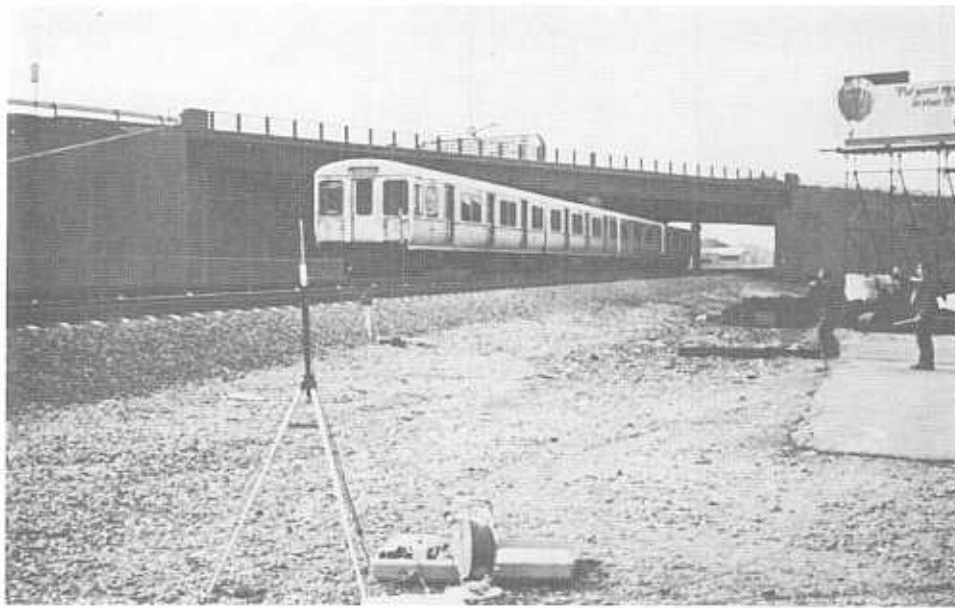


a) North bound - SE Expressway in Background

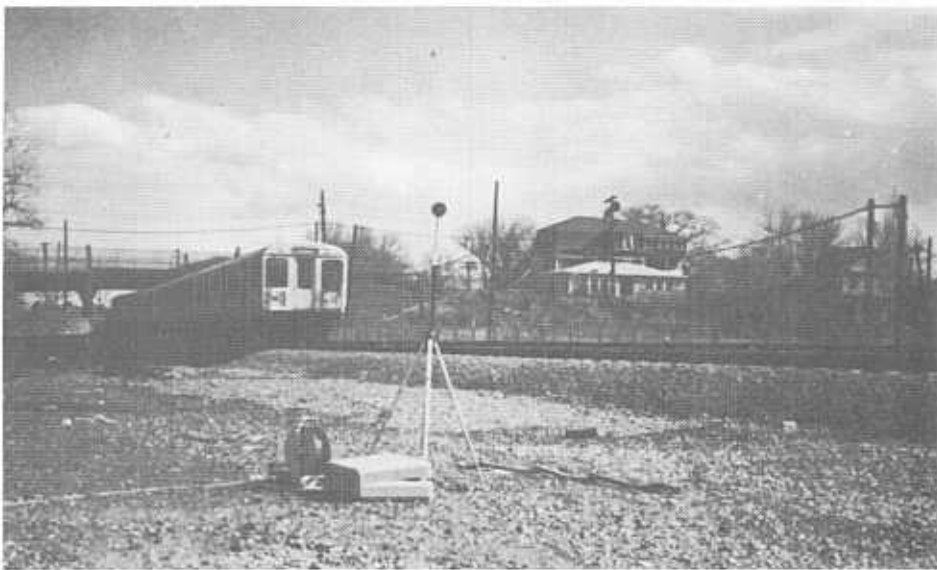


b) South bound - Redfield Street Bridge in Background

Figure G-2. Two Views at Tenean Street Wayside Measurement Site



a) Southbound

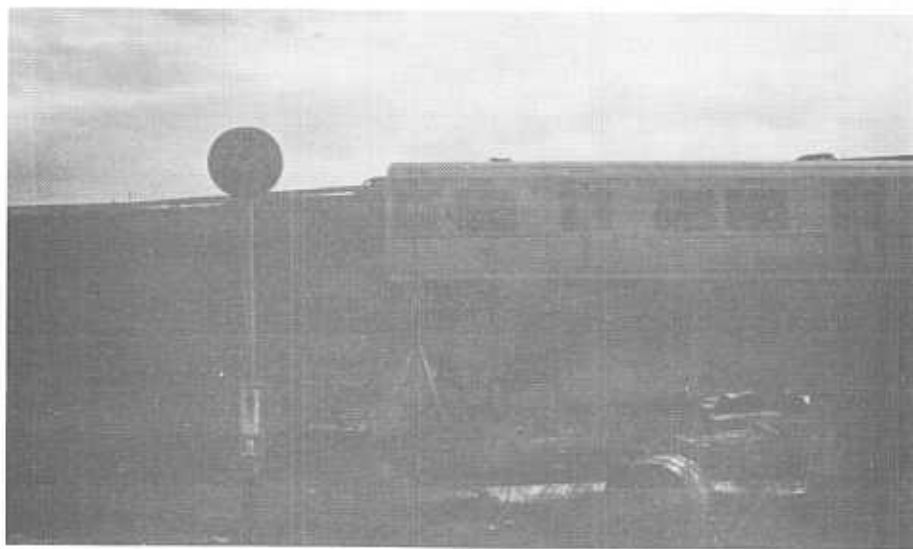


b) Northbound

Figure G-3. 4-Car Trains Approaching at Tenean St. Wayside Measurement Site. Microphone No. 1 in Foreground



a) From Trackside, Tenean St. in Background

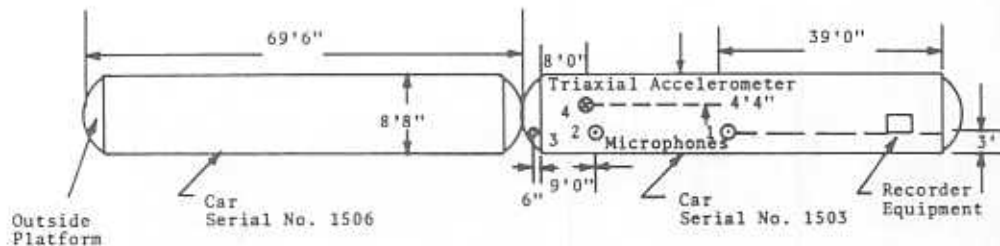


b) From Microphone No. 3

Figure G-4. Two Views of the Microphone at Tenean St. Wayside Measurement Site



Figure G-5. Triaxial Vibration Transducer Mounted on 7/8" diameter, 2 ft. brass rod driven in ground. Tenean St. Wayside Measurement Site



* Drawing not drawn to scale

1. Microphone located mid-car at ear level to a seated passenger (3.5 feet above floor).
2. Microphone located over rear wheel truck at ear level to a seated passenger (3.5 feet above floor).
3. Microphone located on outside platform between cars at ear level to a standing passenger (5.5 feet above platform).
4. Triaxial Accelerometer mounted on floor tiles with bee's wax.

Figure G-6. Microphone and Vibration Transducer Locations, Pullman Standard, MBTA Type 1 So. Shore Rapid Transit Cars

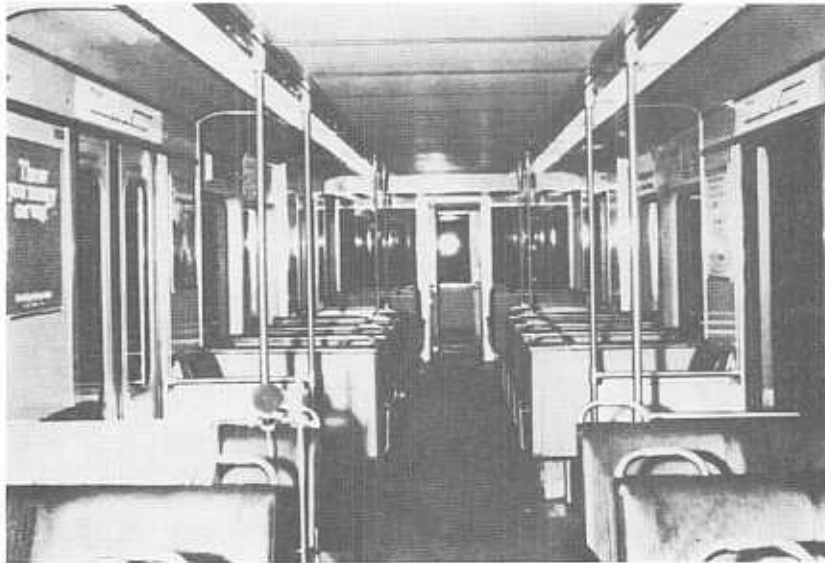


Figure G-7. Inside View - MBTA Type 1 So. Shore Rapid Transit Car. Microphone mid-car in foreground; microphone over rear wheel truck in background.

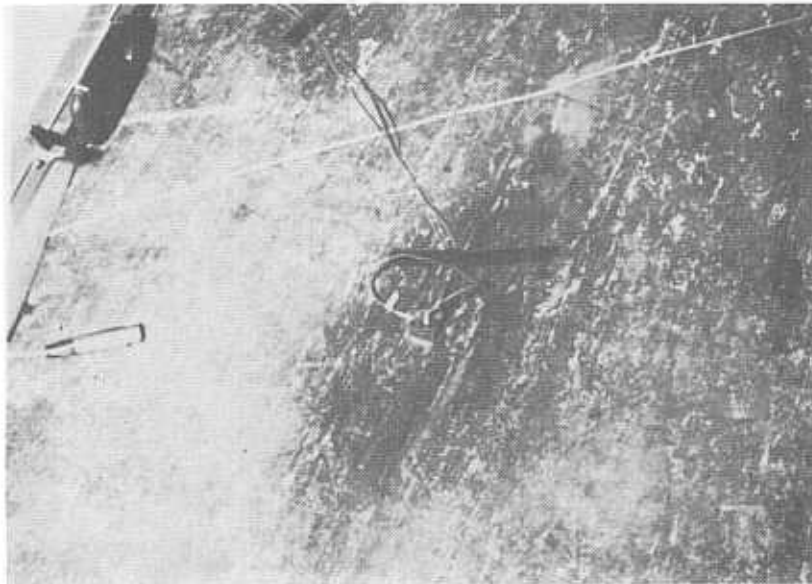


Figure G-8. Triaxial Vibration Transducer mounted on floor tiles with thin layer of bee's wax. MBTA Type 1 So. Shore Rapid Transit Car.

APPENDIX H

MEASUREMENT AND DATA REDUCTION SYSTEMS

NOISE-MEASURING SYSTEM

Figure H-1 depicts the noise data gathering equipment used at the three wayside location and at the three in-car measurement locations. Figures G-1 and G-2 show the exact locations for each system at the wayside measurement site and in the transit car.

A magnetic tape recorder, capable of essentially flat recordings from 30 Hz to 15 kHz, was used. The recorder was operated in the direct mode at a tape speed of 3-3/4-inch per second. The dynamic range of the recorder and measuring system was 50 dB.

Prior to each run, a short verbal annotation was recorded on tape giving the following: date, time, location, tape number, tape recorder channels used, and gain setting for each channel.

A calibration signal of 1000 Hz at a level of 114 dB re 20 micronewton per square meter was recorded on tape before and after each run to provide a reference for the data-reduction instrumentation and detect any system instability. The calibrator used was a General Radio Model #1562A. In this calibrator, the signal is generated by a solid-state oscillator driving a small magnetic loudspeaker.

The calibrator is placed on the microphone and the resultant signal at the specified sound pressure level is fed through the system and recorded on tape. The calibration frequency selected, 1000 Hz, eliminated any necessity for "A" weighted frequency response correction during system calibration. In addition, a passive microphone simulator was substituted for the microphone to determine the minimum discernible sound-pressure level (Noise Floor) for the system. This signal is also preserved on tape.

The fourth channel on the recorder is for verbal annotation and to record a time code signal (hours, minutes, and seconds) to synchronize data between channels and between recorders.

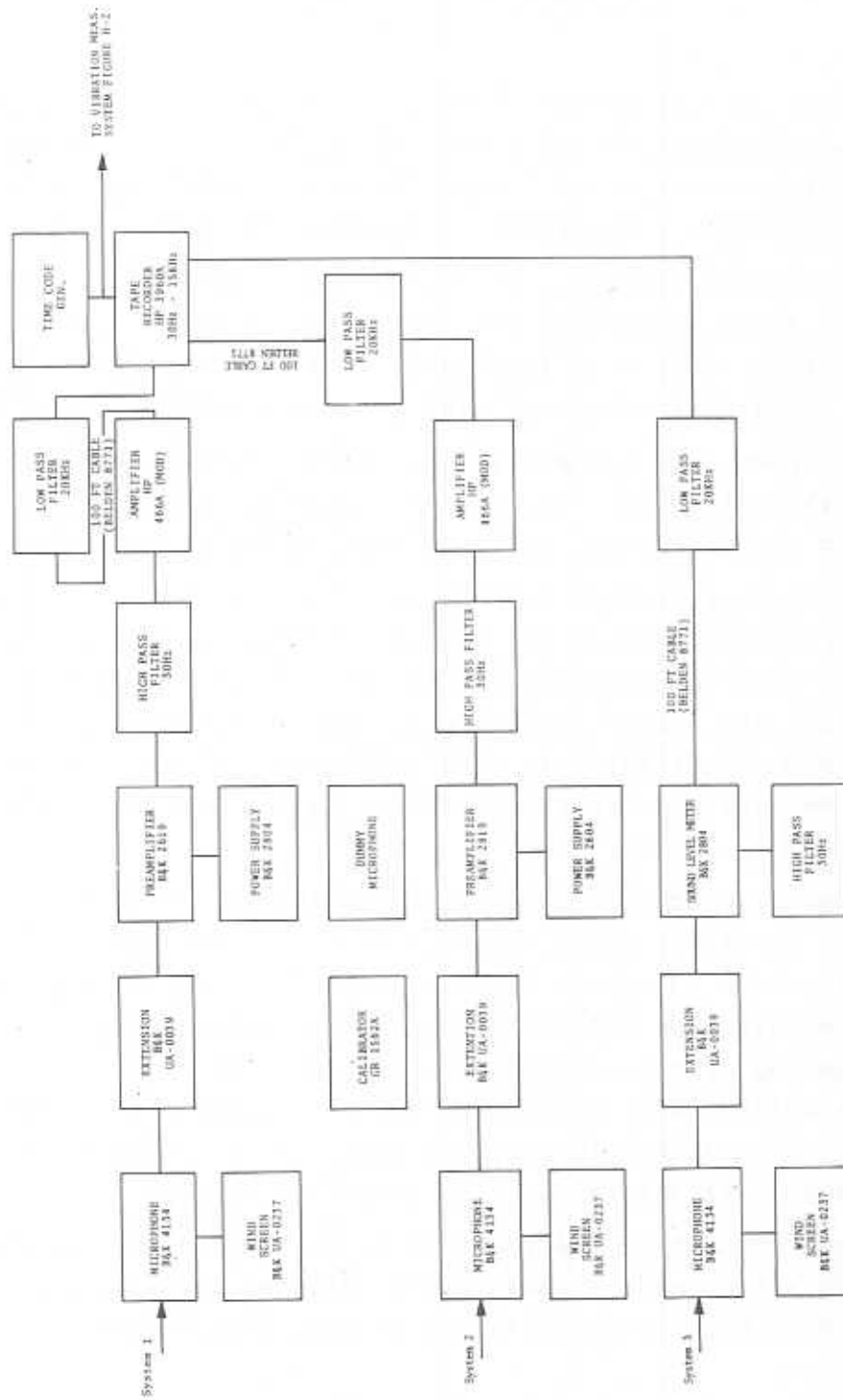


Figure H-1. Three Microphone Noise-Measuring System

Noise Data Reduction

The configuration of the data reduction system is shown in figure H-2. The noise data plus the calibration signal recorded on magnetic tape at the test site were reproduced and fed to a General Radio (GR) 1921 Real Time Analyzing System made up of a GR 1925 Multifilter and a GR 1926 Multichannel RMS Detector. The necessary gain adjustments were made in the multifilter and graphic level recorder with the calibration signals.

The GR 1921 multifilter contains a set of 30 parallel 1/3-octave band filter channels ranging from 25 Hz to 20 kHz, plus additional channels with standard "A," "B," and "C" sound-level meter weighting networks and an unfiltered channel with a flat frequency response. The output of the "A" weighted channel was selected and fed to the Graphic Level Recorder to produce a chart of sound level vs. time (time history) of all recorded data. All 34 outputs from the multifilter are fed into the multichannel detector. The multichannel detector simultaneously computes the rms (root mean square) level for each channel and converts this level to a digital output. Single integration or measurement periods are adjustable from 1/8 to 32 seconds. A statistical analysis of the measured noise was obtained by programming the detector to integrate for 1/8 second, compute the dB value of the "A" weighted filter output, and provide a binary coded decimal signal to the Wang Computing Calculator eight times every second. This computer counted and totaled the number of samples at each sound level for a selected time period and a punched tape was produced. These data were subsequently entered into a time-shared computer to produce statistical analysis printouts contained in appendixes A, C, and E.

These statistical analyses contain a histogram presentation of dBA value versus frequency of occurrence and a cumulative distribution curve of dBA value vs frequency of occurrences. Selected indexes were also calculated and tabulated; e.g., average noise level dba, standard deviation, energy mean, range of values measured, median, selected percentiles and deciles, the noise-pollution

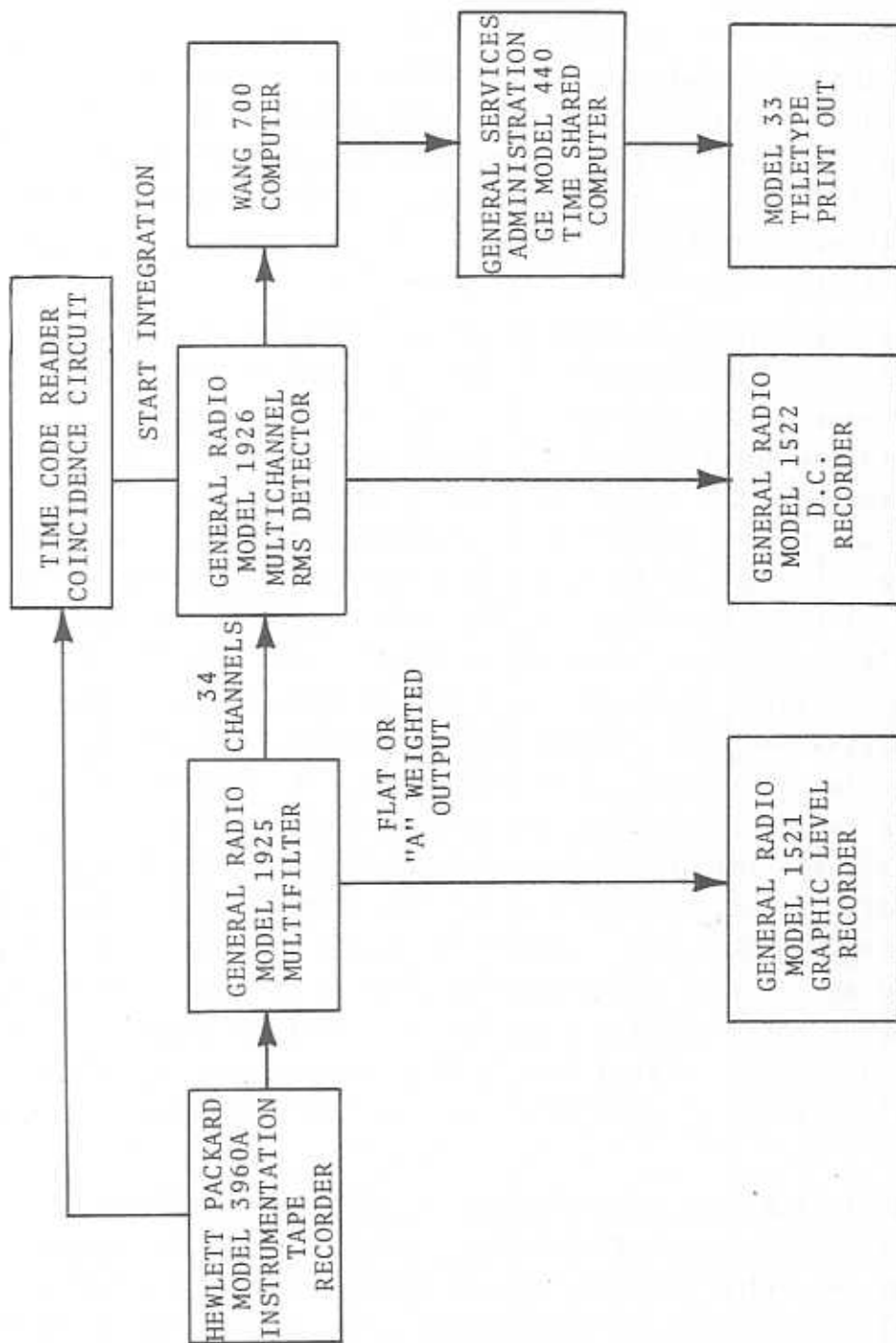


Figure H-2. Noise and Vibration Data Reduction System

level and Walsh-Healey Exposure index. A complete description of these indexes is contained in Appendix K.

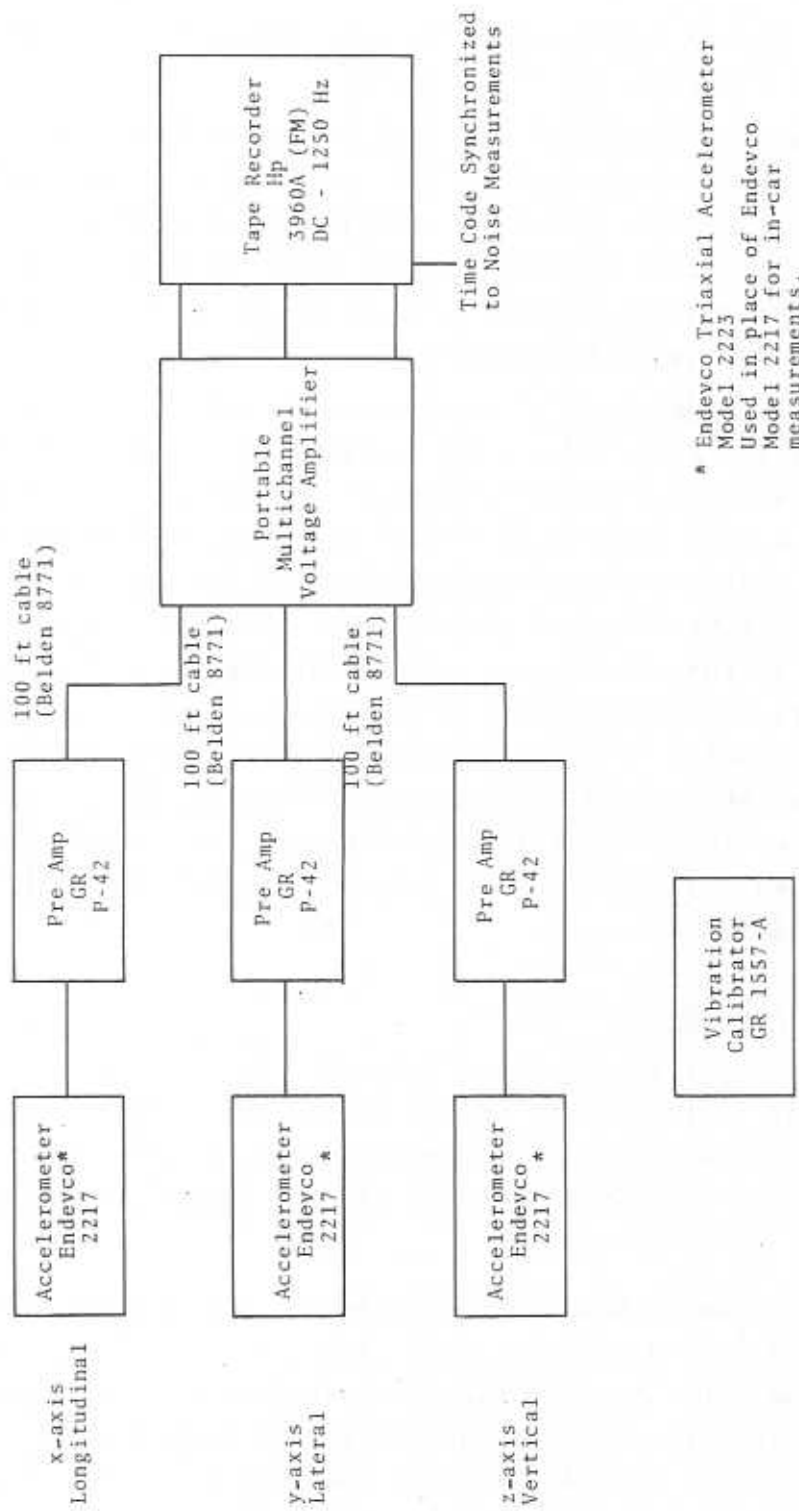
Special selected events are analyzed in detail for their 1/3 octave band frequency spectra using the same equipment just cited and the GR 1522 dc Recorder which in conjunction with the GR 1926 Multichannel RMS Detector provides a hard copy bar graph of level (dB) vs 1/3 octave frequency bands from 25 Hz to 20 kHz, including the flat (F) and "A" weighted outputs.

The Multichannel detector is programmed to integrate over the time interval of the selected event, compute the level in dB for all 32 channels and provide a dc output to the recorder. The recorder provides a hard copy of the level dB vs 1/3 octave bands for the event. The start of the integration period is controlled by a coincidence circuit in the time code reader; thus insuring the identical start of the integration period for events on multichannel recorders or between recorders which have been synchronized with time code signals. The graphic recorder at a pen writing speed of 3 inches per second simultaneously provides an expanded "A" weighted time history of the special event. Time marks are manually placed on the graphic recording to show the start and end of the integration period.

Vibration Measuring System

Figure H-3 depicts the equipment used for data gathering of ground vibrations in three axes at the wayside measurement location shown in figure G-1 and for in-car measurements in three axes shown in figure G-2. The frequency response of this system is 3 to 1250 Hz.

For wayside ground vibration measurements, a brass rod 2 ft long and 7/8 inch wide was driven into the ground at the measurement location and three accelerometers mounted on the rod with a special adapter in a triaxial arrangement, each accelerometer was electrically insulated from one another and from the driven stake.



* Endeveco Triaxial Accelerometer Model 2223 Used in place of Endeveco Model 2217 for in-car measurements.

Figure H-3. Three-Axis Vibration-Measuring System

For in-car measurements a triaxial accelerometer was used. It was secured to the floor tiles at a location over the rear wheel truck with a thin layer of bee's wax

A magnetic tape recorder, capable of essentially flat recording from dc to 1250 Hz was used. The recorder was operated in the FM mode at a speed of 3-3/4-inch per second. The dynamic range of the recorder and measuring system was 60 dB.

Prior to each run, a short verbal annotation was recorded on tape giving the following: date, time, location, tape number, tape recorder channels used and gain setting for each channel.

A dynamic calibration signal of 100 Hz at 1 g was recorded on tape before and after each run to provide a reference for the data reduction instrumentation and to detect any system instability. The GR Type 1557A Vibration Calibrator was used to provide this on-the-spot calibration of the vibration measuring system including the accelerometer. The 1557-A is a small battery-operated unit consisting of a transistorized electromechanical oscillator and a cylindrical shaker. The accelerometer of known mass is attached to the shaker and the level control adjusted to the proper mass setting. The accelerometer is then automatically subjected to an acceleration of 1 g at 100 Hz. In addition, the accelerometer is replaced by a short circuit to determine the minimum discernible acceleration level (Noise Floor) for the measuring system. This signal was also preserved on tape.

The fourth channel on the recorder was used for verbal annotation and to record a time code signal (hours, minutes and seconds). This signal was simultaneously recorded on the multichannel recorder used to record noise data. Thus the data between channels and between recorders were synchronized.

Vibration Data Reduction

The configuration of the vibration data reduction system is as shown in figure H-3. It is noted that this is the identical system described above for Noise Data Reduction. To utilize this system, which is equipped with 1/3 octave filters down to 25 Hz, for the analysis of data with frequency components down to 3 Hz, the

following frequency transformation procedure was necessary. The vibration data which was originally recorded at a speed of 3-3/4-inch per second was played back at a tape speed of 15 inches per second. The recorded signal is thus scaled up in frequency by a factor of 4, and frequency components of the original signal that were in the 1/3-octave bands of 6.3 Hz, 8 Hz, 10 Hz, 12.5 Hz appear as 25 Hz, 31.5 Hz, 40 Hz, and 50 Hz 1/3 octave bands, respectively. Thus, the data are shifted into the usable frequency range of the 20 Hz to 20 kHz data reduction system shown in figure H-3.

The vibration data plus the 100 Hz, 1 g calibration signal recorded at 3-3/4-inch per second at the test site are reproduced at 15 inches per second and fed into the GR 1921 Real Time Analyzing system. The necessary gain adjustments are made in the Multi-filter and recorders with the calibration signal now at a frequency of 400 Hz.

Special events (as in the Noise Data Reduction Section) are analyzed in detail for their 1/3 octave frequency spectra and a hard copy bargraph of level (dB) vs 1/3 octave frequency bands from 6.3 Hz to 5 KHz plus an unfiltered flat (F) output are produced with the 1522 dc recorder in conjunction with the 1926 Multichannel Detector.

The multichannel detector is programmed to integrate over the time interval of the selected event (now occurring in 1/4 the time), compute the level in dB for all 31 channels and provide a dc output to the recorder which provides a hard copy of the level in dB vs the 1/3 octave bands from 6.3 to 1250 Hz plus flat (F) output of the vibration spectra of the event. The start of the integration period is controlled by a coincidence circuit in the time code reader, thus insuring the identical start of the integration periods for events on multichannel recorders or between recorders which have been synchronized with time code signals. The graphic recorder simultaneously provides an expanded time history of the event analyzed and time marks are manually placed on the history to show the start and end of the integration period.

APPENDIX I

DESCRIPTION (PULLMAN STANDARD) MBTA TYPE 1
SO. SHORE RAPID TRANSIT CARS

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The MBTA Type 1 So. Shore Transit Cars were designed and built by Pullman Standards, Chicago, Illinois to MBTA developed specifications, specifically for use on the new MBTA So. Shore Extension of the Red Line which was officially opened on September 1, 1971.

Figure I-1 contains basic specifications of the Type 1 cars as published by Pullman Standard .

The single unit cars, identified (with Serial No.) series "1500" are completely self-contained cars and can be run as single cars on the line. The MBTA currently runs 2-car trains and pairs up two of the 1500 series cars. The test train Serial Nos' 1503 and 1506 were single unit cars.

The 1600 series cars are a mated pair and must be operated in pairs since they share a common motor generator set, battery, air compressor, and automatic train control equipment.

APPENDIX J

MBTA TRANSIT SYSTEM MAP AND TUNNEL CROSS SECTIONS

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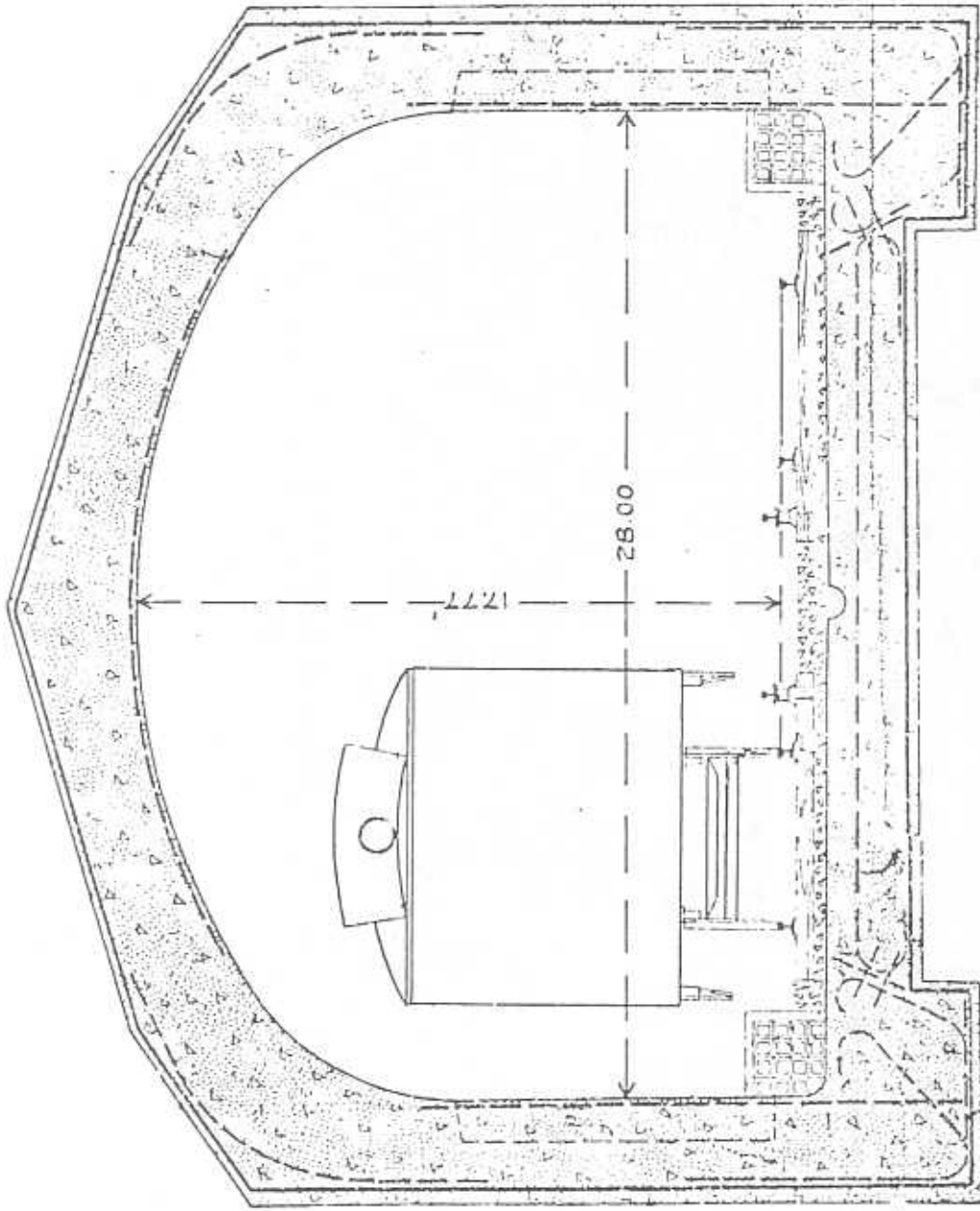


Figure J-2. Red Line-Dorchester Tunnel
 (See figure E-10 for Noise Spectra)

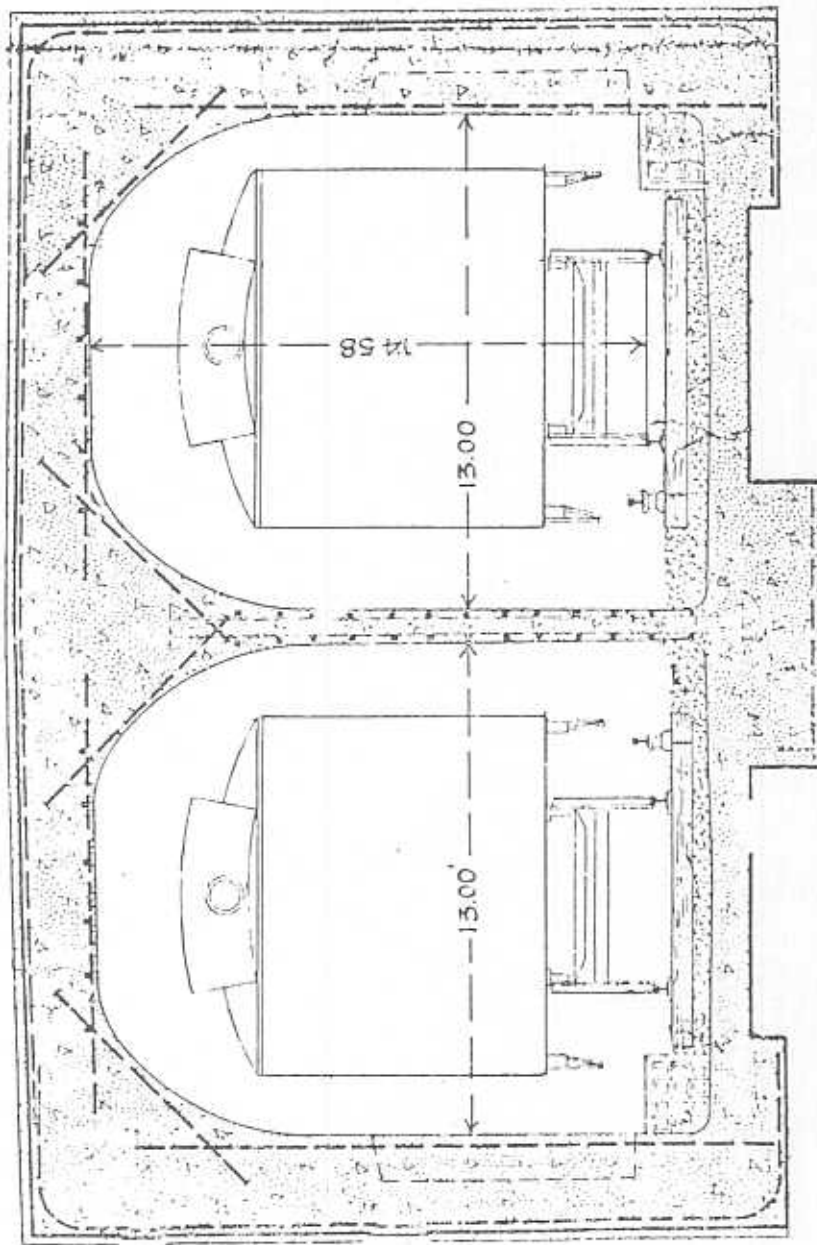
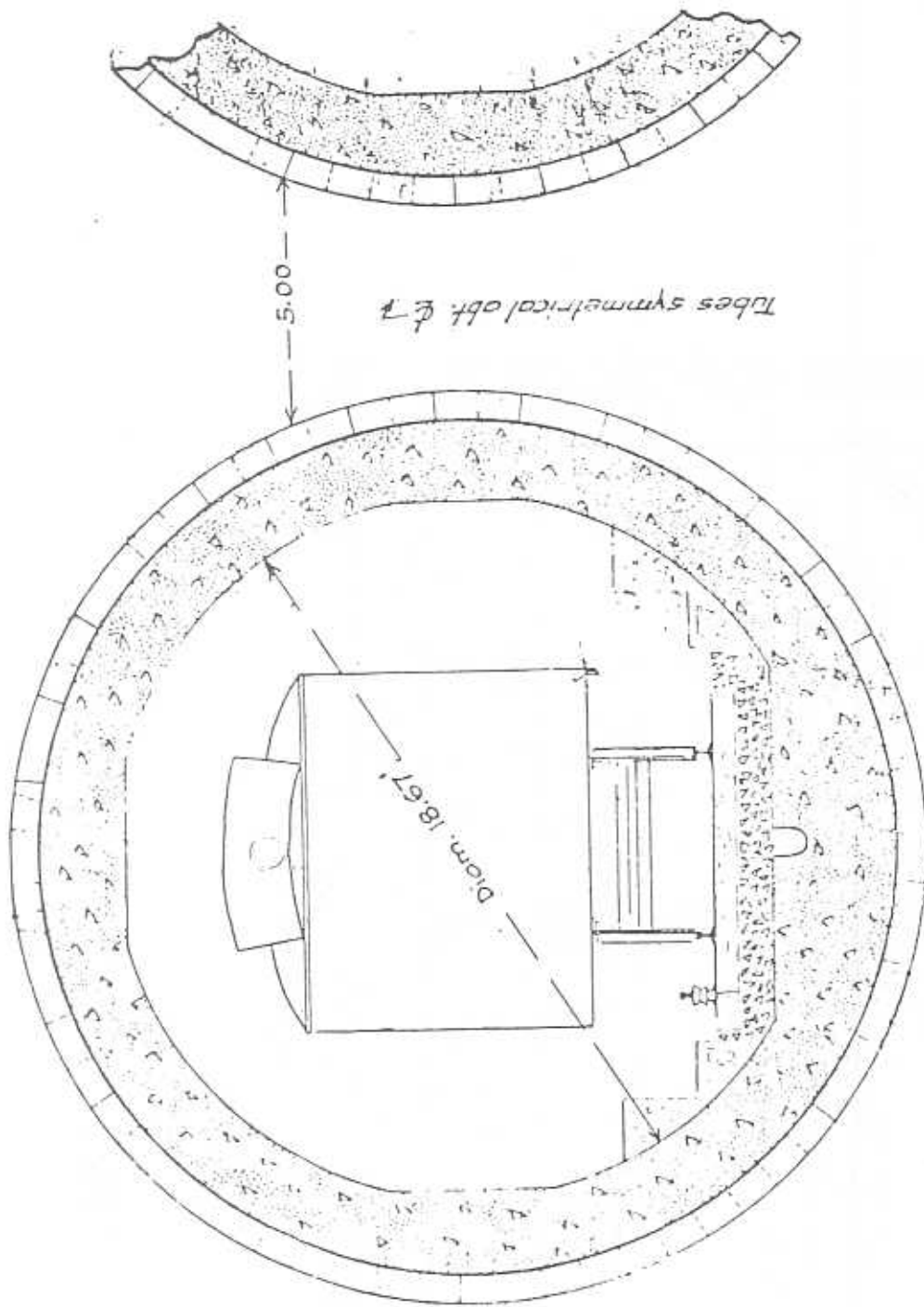


Figure J-3. Red Line--Two-Section Tunnel
(See Figure E-11 for Noise Spectra)



RED LINE
DORCHESTER TUNNEL

Figure J-4. Red Line-Circular Tunnel
(See figure E-12 for Noise Spectra)

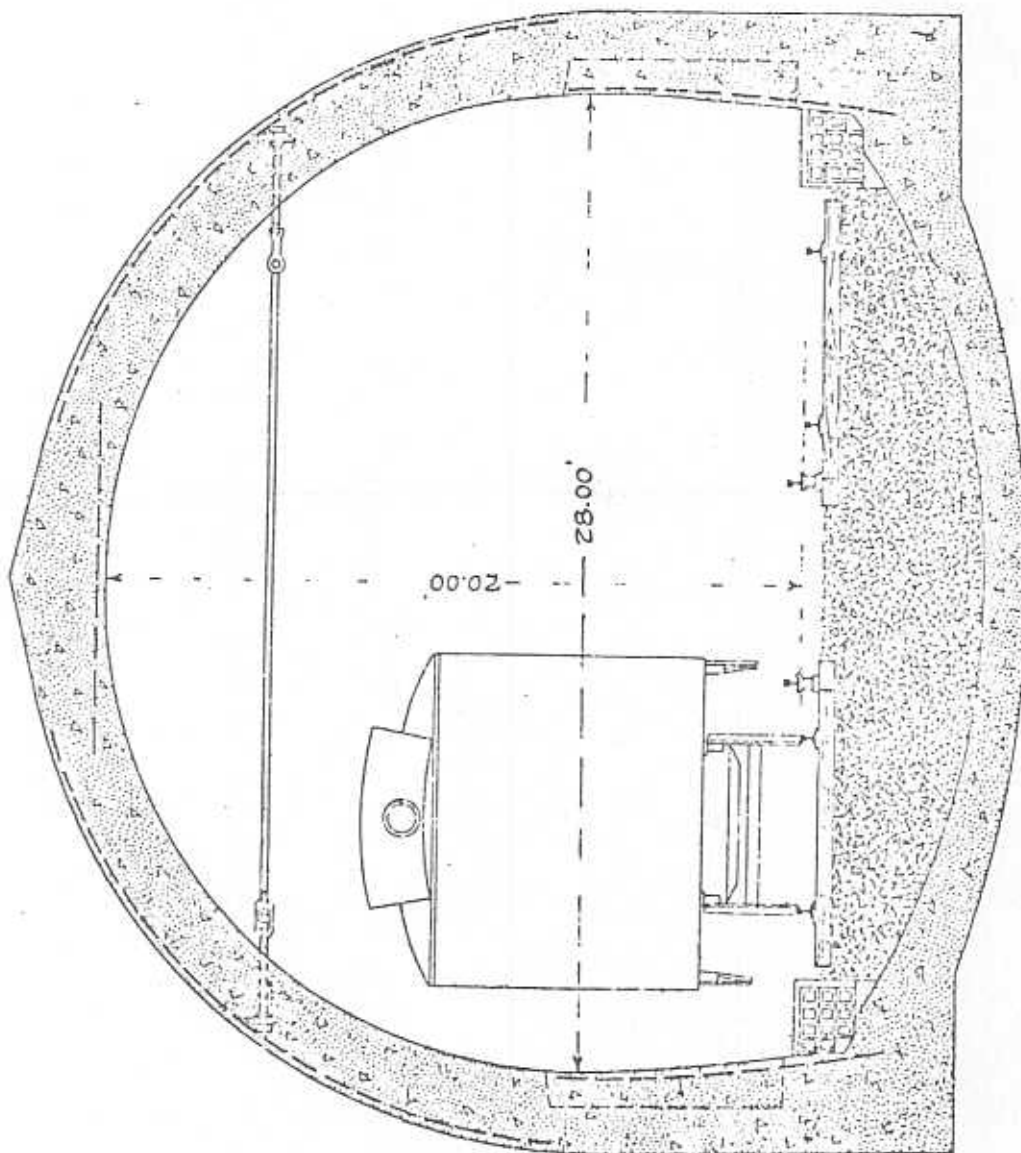


Figure J-5. Red Line - Beacon Hill Tunnel
(See figure E-13 for Noise Spectra)

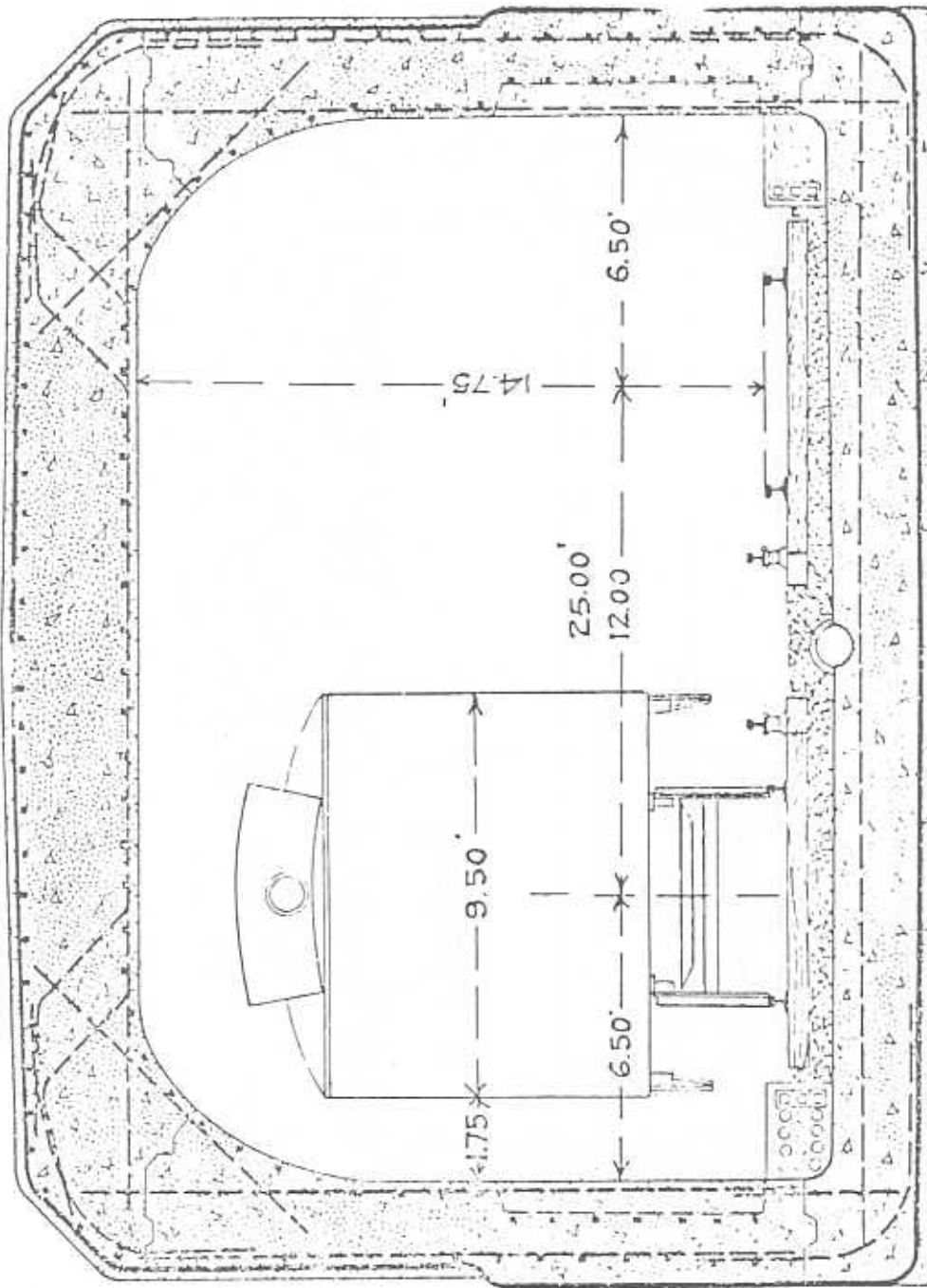


Figure J-6. Red Line - Cambridge Main St. Subway
 (See figure E-14 for Noise Spectra)

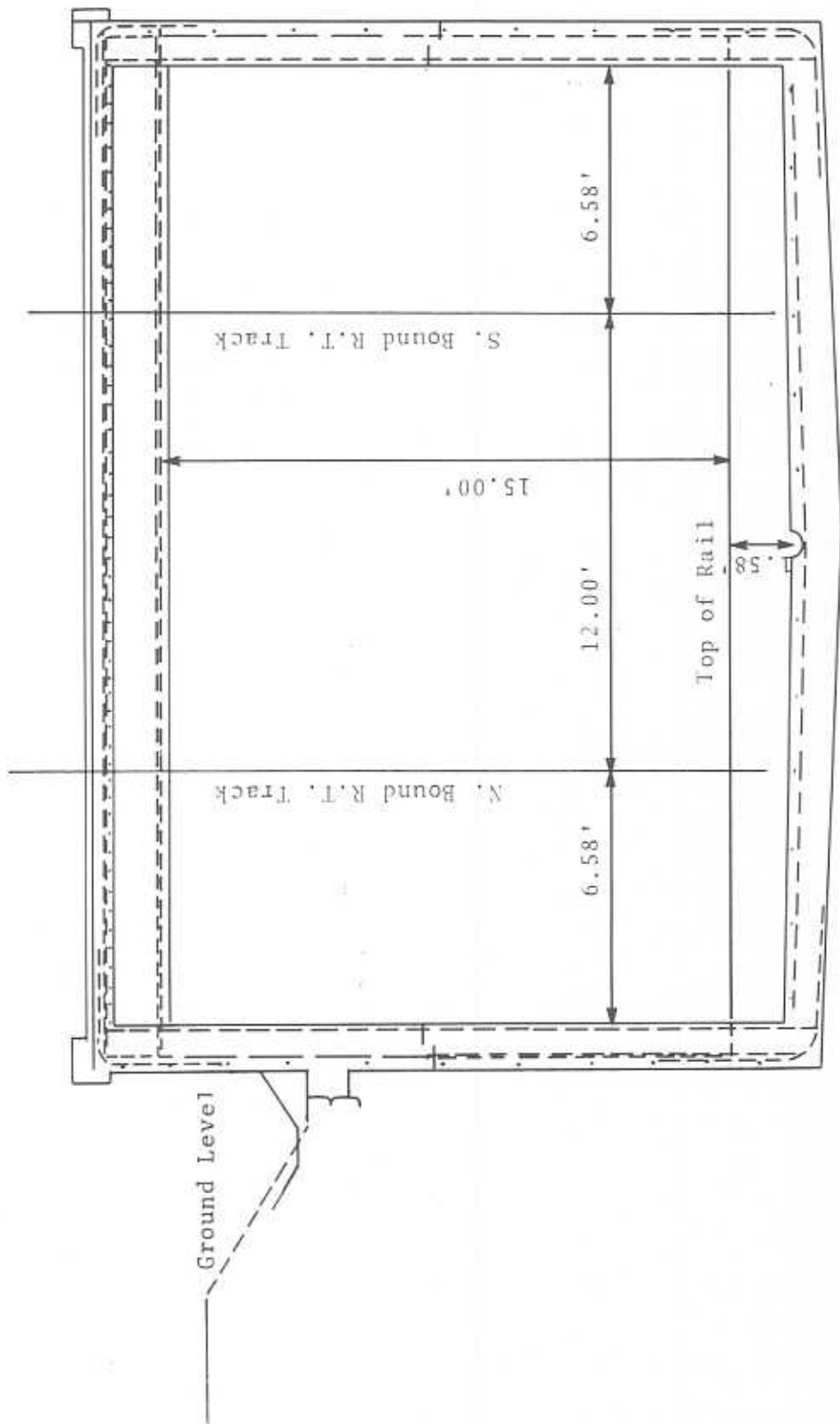


Figure J-7 Red Line - Ashmont Extension
 (See Figure E-16 for Noise Spectra)

100
100
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APPENDIX K

DEFINITION OF TERMS AND CALCULATED VALUES

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DEFINITION OF TERMS

TERM	ABBREVIATION	DEFINITION
A-Weighted Sound Level	dBA	Sound level obtained by measuring the sound pressure through a filter network having a frequency response (A-weight) conforming to American National Standards Institute (ANSI, S1.4, 1961).
Median Noise Level	L 50	Sound level (dBA) exceeded by 50% of total measurements.
10% Decile	L 10	Sound level (dBA) exceeded by 10% of total measurements.
90% Decile	L 90	Sound level (dBA) exceeded by 90% of total measurements.
Noise Pollution Level	L NP	A composite index (see Calculation B6).
Walsh Healey Exposure		Measure of noise in terms of a Federal regulation (Walsh-Healey Act) limiting the industrial noise to which a worker can be exposed.

CALCULATIONS

To describe the temporal characteristics of the noise data gathered, a statistical analysis of sound pressure level samples was performed. RMS sound pressure level samples were taken using an integration time of 1/8 second at a sample rate of eight samples per second to obtain the information contained in appendixes A, C, and E. The frequency response characteristics of the samples conformed to ANSI Standard for Type 1 Sound Level Meters, S1.4, 1971 for "A" weighted sound level.

The following terms and equations were used to compute the statistical and single number indexes appearing in this report:

A. BASIC TERMS

1. Total samples obtained: N
2. Total number of Sound Pressure Levels (from lowest level containing samples to highest level containing samples, inclusive): M
3. Sound Pressure Level (lowest to highest) $SPL_1, SPL_2, \dots, SPL_M$
4. Samples at each Sound Pressure Level: C_1, C_2, \dots, C_M
5. Relationships

$$a. \quad \sum_{i=1}^M C_i = N .$$

$$b. \quad SPL_M - SPL_1 + 1 = M .$$

6. dB ("A" Weight) - Sound level obtained by measuring through a filter network having a frequency response (A weight) conforming to American National Standards Institute (ANSI), S1.4, 1971. Reference sound level - 20 micronewtons per square meter.

B. STATISTICAL EQUATIONS

1. Cumulative Distribution, Percent (D_c)

$$D_c \ i = \frac{C_M + C_{M-1} + \dots + C_i}{N} \quad (100)$$

2. Statistical Distribution, Percent (D_s)

$$D_s \ i = \frac{C_i}{N} \quad (100) \quad i = 1, 2, \dots, M$$

3. Average (Arithmetic Mean, \overline{SPL})

$$\overline{SPL} = \sum_{i=1}^M \frac{C_i \ SPL_i}{N}$$

4. Standard Deviation about Averages σ

$$\sigma = \sqrt{\frac{1}{N-1} \sum_{i=1}^M C_i (SPL_i - \overline{SPL})^2}$$

5. Energy Mean (L eq) $\left[\sum_{i=1}^M C_i \frac{10^{SPL_i}}{10} \right]$
- $$L \ eq = 10 \log_{10} \left[\sum_{i=1}^M C_i \frac{10^{SPL_i}}{10} \right]$$

6. Noise-Pollution Level (L_{NP})

$$L_{NP} = L \ eq + 2.56 \ \sigma$$

7. Percentile Noise Levels, dBA

- a. 1% Percentile (L_1) = Level exceeded by 1% of total samples
- b. 10% Decile (L_{10}) = Level exceeded by 10% of total samples
- c. Median (L_{50}) = Level exceeded by 50% of total samples
- d. 90% Decile (L_{90}) = Level exceeded by 90% of total samples
- e. 99% Percentile (L_{99}) = Level exceeded by 99% of total samples

These percentile levels are obtained from linear interpolation of the percentage cumulative distribution values.

8. Range: Highest sound level containing samples minus the lowest sound level containing samples.

$$\text{Range} = \text{SPL}_M - \text{SPL}_1$$

9. Occupational Safety and Health Act of 1970 (O.S.H.A.)

- a. The O.S.H.A. is a Federal Regulation setting standards to assure safe and healthful working conditions for working men and women. One of the standards set by O.S.H.A. is concerned with the noise an employee may be exposed to during an eight-hour work day. The noise standards published by the Secretary of Labor in the Federal Register, dated May 29, 1971, are identical to those of the Walsh-Healey Act of 1969.

The O.S.H.A. Exposure Percentage is a measure of the noise levels in terms of Walsh-Healey Exposures normalized to an 8-hour work day. When the percentage reaches or exceeds 100%, it means that exposure of a worker to that same noise climate for 8 hours would be in violation of the Act. Additionally, any one-time exposure over 115 dBA is exceeded during the measurement period, the exposure percentage number will be followed by a "V" indicating a violation even if the number is less than 100%.

- b. The equation used to calculate the the O.S.H.A. exposure percentage is as follows:

$$W1 = \left[\frac{W2}{6} + \frac{W3}{4} + \frac{W4}{3} + \frac{W5}{2} + \frac{W6}{1.5} + \frac{W7}{1} + \frac{W8}{0.5} + \frac{W9}{0.25} \right] \times \frac{800}{N}$$

where

- W1 = O.S.H.A Exposure in percent.
W2 = Number of samples in the 90 to 92 dBA band.
W3 = Number of samples in the 92 to 95 dBA band.
W4 = Number of samples in the 95 to 97 dBA band.
W5 = Number of samples in the 97 to 100 dBA band.
W6 = Number of samples in the 100 to 102 dBA band.
W7 = Number of samples in the 102 to 105 dBA band.
W8 = Number of samples in the 105 to 110 dBA band.
W9 = Number of samples in the 110 to 115 dBA band.
N = Total number of samples where one sample represents 1/8 second.

C. CONVERTING NOISE DATA TO STANDARD DISTANCES OF 25, 50, AND 100 FT.

Point Source

By the inverse square law the change in sound pressure level with distance is

$$\Delta\text{SPL} = 20 \log \frac{r}{r_x} \quad \text{where } \left(\frac{r}{r_x}\right) \text{ is the change in distance from the noise source}$$

thus, if $r = r_x$, the sound pressure drops by 6 dB.

Line Source

$$\Delta\text{SPL} = 20 \log \left(\frac{r}{r_x}\right)^{1/2}$$

thus if $r = 2r_x$ the sound pressure drops by 3 dB.

By actual measurement the sound pressure level dropped by approximately 5 dB between the 25 ft. and 50 ft. microphone location and for the 50 and 100 ft. microphone locations. Thus, for the transition region between 25 ft. and 100 ft. at the measurement site the "best fit" for the inverse distance law is:

$$\Delta\text{SPL} = 20 \log \left(\frac{r}{r_x}\right)^y = 5 \text{ dB}$$

$$\therefore y = \frac{5}{6} \text{ in the region between 25 and 100 ft.}$$

Thus, the noise data shown in Tables 3-1, 5-1 and 5-2 for south-bound trains can be converted to standard distances of 25, 50, and 100 ft. with this relation

$$\Delta\text{SPL} = 20 \log \left(\frac{r}{r_x}\right)^{5/6}$$

Noise correction from 38 ft to 25 ft = +3.0 db,
Noise correction from 63 ft to 50 ft = +1.8db, and
Noise correction from 113 ft to 100 ft = +0.9 db.

100

100

100

APPENDIX L
ENVIRONMENTAL DATA

ENVIRONMENTAL DATA

Date	Time	Temperature	Relative Humidity	Barometric Pressure	Wind Velocity Direction	Sky
	Hours	°F	Percent	mm Hg	mph	
Oct. 28, 1971	1500-1650	70	70	761	5 SW	Sunny
April 27, 1972	1315-1605	50	50	764	2 E	Partly Cloudy
April 29, 1972	0100-0400	72	63	769	(Inside Measurements)	

