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NOISE LEVEL MEASUREMENTS ON THE UMTA MARK I DIAGNOSTIC CAR (R42 MODEL)

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16. Abstract

The R42 Model mass transit car currently operating on the "N" line of the New York City Transit System was selected for experimentation and tests. For this purpose, the car was instrumented and designated as the UMTA Mark I Diagnostic Car.

Noise levels generated by "stop and go" operations of the Diagnostic Car were measured and tabulated in this report. Measurements were made inside of and outside the car during operation on the "N" line of the New York Transit System and during operation at the DOT High Speed Ground Test Center at Pueblo, Colorado.

The report contains tabulations of the noise levels measured, time history charts, 1/3-octave frequency analyses and pertinent comments on the information obtained.

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PREFACE

Measurements were made to determine the noise characteristics of typical late-model rapid transit cars during operational runs. The car selected for noise analysis was the Model R42 car, manufactured by the St. Louis Car Company in conjunction with the Westinghouse Corporation, and currently in operation on the "N" line of the New York City Transit Authority. A Model R42 car has also been instrumented for extensive vehicle/ground vibration experimentation, and has been designated the UMTA Mark I Diagnostic Car.

Sincere appreciation is expressed for the assistance provided during this measurement program by personnel of the New York City Transit Authority, and the DOT High Speed Ground Test Center, Pueblo, Colorado. Without the fine cooperation of these groups, the measurements tabulated in this report would not have been possible.

Other than the primary authors, the following individuals of the Noise Abatement Group, Transportation Systems Center, contributed to the preparation of this report: Robert L. Mason, Stanley C. Skeiber, and John E. Wesler.

SUMMARY

The noise characteristics of a typical late-model mass transit car are tabulated and analyzed in this report. A Model R42 car, manufactured by the St. Louis Car Company in conjunction with the Westinghouse Corporation, and currently in operation on the "N" line of the New York City Transit Authority, was selected for this study. This type car was also selected by the Urban Mass Transportation Administration (UMTA) as a test vehicle as part of its overall program to advance mass transportation technology. This test vehicle has been designated the UMTA Mark I Diagnostic Car.

Noise measurements were made at three locations on a Model R42 car, while it served as the lead car of an eight-car train on a typical run along the "N" line of the NYC Transit Authority. Analyses of these measurements taken during a 43-minute run under normal "stop-and-go" operating conditions yielded the following statistical characteristics:

	Coincident Noise Levels		
	Inside Location Mid-Car	Inside Location Over Rear Wheels	Outside Location on Car Platform
Median Noise Level	79.1dBA	81.9 dBA	92.2 dBA
Maximum Noise Level	99	102	116
Level Exceeded 10% of Time	86.9	89.2	103.0
Level Exceeded 90% of Time	71.1	74.7	85.5
Noise Pollution Level	98.1	99.5	116.1
Range of Noise Levels	41	41	43

Maximum noise levels measured in the NYC operation were caused by wheel squeal, lasting for periods of approximately four seconds at each occurance. Excluding these phenomena, the maximum noise levels occurred during operation at 44 mph, producing levels of 90, 92, and 106 dBA at the three locations on the car tabulated above.

Noise level measurements were also taken at wayside, on a passenger platform of the 59th Street NYCTA subway station, for a period of 22 minutes. During this interval, trains of various model cars arrived and departed under normal operating schedule for non-rush-hour service. Analyses of these measurements produced the following results:

Median Noise Level	65.1 dBA
Maximum Noise Level	103
Level Exceeded 10% of Time	91.0
Level Exceeded 90% of Time	55.3
Noise Pollution Level	121.7
Range of Noise Levels	54.

For comparison purposes, similar noise levels measurements were made on the same Model R42 car, after it was shipped to the DOT High Speed Test Center at Pueblo, Colorado. There, the car operated as the lead car of a two-car train along the at-grade open track. Because of the relatively short length of track then available at Pueblo, statistical analyses of the noise levels during a continuous run were not considered meaningful. Measurements made at the same three locations on the car yielded maximum values of 86 dBA inside the car, and 98 dBA on the platform between cars, while the train ran at a speed of 58 mph. Wayside measurements at a point 40 feet from the center of the track produced a maximum level of 84 dBA, at the same operating speed. In general, these levels measured at the UMTA track were considerably lower than those measured in NYC, as should be expected. The UMTA track represents a high-quality road bed, with smooth welded rails. This factor, combined with the resonance effects in the NYC subway tunnels, created the different results.

INTRODUCTION

The Urban Mass Transportation Administration (UMTA) of the U. S. Department of Transportation has undertaken an extensive program to advance the state of technology of mass transportation systems in the United States. In support of the UMTA program, the Transportation Systems Center (TSC) undertook a project to measure and document noise levels produced by a typical late-model rail rapid transit car, representing the performance of current technology in this field. This project is the first in a longer-range program at TSC to assist UMTA in reaching its goals of providing efficient, safe, and convenient urban mass transportation.

The car selected for noise level measurements for this project was the Model R42 car, manufactured by the St. Louis Car Company in conjunction with Westinghouse Corporation. Cars of this model are quite new, and were first placed in operational service in the New York City Transit Authority system during 1969 and 1970 (see Appendices J and K for details). In order to obtain realistic noise data under normal "city" operating conditions, an eight-car train of Model R42 cars was operated on a typical run along the "N" line of the NYC Transit Authority on May 6, 1971. No revenue passengers were carried on this run. One of the cars was instrumented for measurement of noise levels at two locations inside the car and one location on its platform between cars. Wayside measurements were also made on a passenger platform at one subway station along the "N" line.

Similar noise measurements were made at the DOT High Speed Ground Test Center at Pueblo, Colorado, during the period August 17-19, 1971. Here a two-car train of type R42 cars was formed for the test program and measurements were made on the car and trackside simultaneously. These two cars were acquired by UMTA for use as test vehicles in a series of development programs planned to advance the state of the art involving mass transportation technology. The cars have been instrumented and designated as UMTA Mark I Diagnostic Cars. It is noted that these cars were the identical cars instrumented and used in the New York City test runs as part of the eight-car train. They were shipped to Colorado via railroad freight when the New York City tests were completed.

This report documents in some detail noise data measured as described above, and provides a basis for establishing development objectives for reducing noise generated by mass transit cars.

PROCEDURES FOR OBTAINING NOISE MEASUREMENT DATA

Microphone locations and procedures used in obtaining and reducing measurement data are detailed in Appendices F and G.

As an aid in reducing and analyzing the data recorded, a time history chart recording of noise level in dBA vs. time was prepared for each microphone output. Special events as determined from this history were selected for further analysis. A 1/3 octave frequency analysis of special short term events has been performed and bar graph chart recordings prepared as an aid in determining the cause of the noise.
Statistical analyses of data obtained have been prepared showing dBA levels vs. frequency of occurrence along with calculated noise indices in order to form a basis for comparison.

DISCUSSION

A. *Measurements made on the Mark I Diagnostic Car on the "N" line of the New York City Transit System from the 86th St. Station to the 57th St. Station on May 6, 1971, from 1022 A.M. to 1106 A.M.*

Appendix A contains time histories, statistical analyses and one-third-octave frequency analyses of noise level measurements made on the Mark 1 Diagnostic Car operating as the lead instrumented car of an eight-car train. The entire run was in the subway tunnel, except for the crossing of the Manhattan Bridge.

Figure A1 contains coincident time histories of noise measurements made at three locations (Appendix F, Figure F1) on the test car. Noise levels are plotted in dBA vs. time with points of interest identified. Coincident values of train speed have also been superimposed on the time history charts.

Specific occurrences identified from these histories have been selected for one-third-octave analyses and examination.

No noise data were obtained from approximately the Prince St. Station to the 14th St. Station since the reel of magnetic tape was being changed on the tape recorder during that period of time.

A comparison of the noise level history versus speed (Figure A1) reveals a close correlation between the noise measured at three locations and the speed of the transit cars. A further comparison with vibration data (Appendix H, Figure H1) shows a further correlation between the vibration information and the noise levels measured.

Specific events such as wheel squeal (which was caused by the transit cars negotiating a sharp curve) generated noise far in excess of that normally caused by the motion of the transit cars. As shown in Figure A1, an instance of wheel squeal was measured prior to arriving at the 59th St. Station with peak noise levels of 97, 101 and 115 dBA respectively at the three microphone locations.

Similarly, excess noise was generated after the train passed the Canal Street Station. In this instance the noise level increased to 99, 98 and 104 dBA respectively at the three microphone locations when the test train was passed on the left by another eight-car train.

The maximum noise levels measured, attributed primarily to the cruising speed of the train, occurred just after the 59th St. Station at a speed of 44 mph when the levels reached 90, 92 and 106 dBA respectively.

Blasts from the train horn, although of short duration, can be seen in Figure A1 raising the level to 94, 95 and 108 dBA respectively at the three locations.

At the Pacific Street Station, with the train stopped and the doors on the right side of the instrumented car opened, the measured noise levels ranged between 60 and 77 dBA at both the mid-car and over the rear wheel truck locations. The low levels measured between cars on the outside platform at this point when the train was stopped is limited by the dynamic range of the recording system. The 79 dBA indicated is not the measure of the low level noise at this point. Other measurements made indicate low level noise on the car platform to be approximately 73 dBA. Thus, the noise range on the outside platform between cars when the train is stopped is approximately 73 to 91 dBA.

Figure A2 contains expanded coincident time histories at the three car locations while the train was crossing the Manhattan Bridge. Marked on the chart are the points in time that the train emerged from the tunnel, moved onto the bridge, and finally re-entered the tunnel. The bridge was the lower level of a two-level structure with open sides. The increase in noise levels as the train moved onto the bridge was caused by a change from a solid road bed on the bridge abutment to the open elevated tracks of the bridge, plus an increase in power necessary to keep the speed of the train constant on the steep upgrade. The drop in the noise level at the first concrete pier column resulted from the change from open elevated track to tracks on a solid road bed on the concrete pier, plus a simultaneous decrease in power and speed.

The noise level from this point through the crest of the bridge to the end of the bridge was essentially constant as was the speed of the train. The noise level is seen to decrease as the train passes over the second concrete pier column, increase again on the open elevated track, and drop further as a result of the change from open elevated tracks to those on solid fill on the opposite abutment at the end of the bridge. As the train re-enters the tunnel, the noise level is seen to rise as a result of tunnel acoustics. One-third-octave analyses of the noise levels measured at the entrance to the bridge, the-crest of the bridge, and the end of the bridge for the three microphone locations are shown in Figures A3, A4, and A5 for comparison.

Figure A6 contains expanded coincident time histories at the three microphone locations of the noise resulting from the test train negotiating a sharp right turn between the 8th Ave. Station and the 59th St. Station. The peak levels measured for the three microphone locations are 99, 104 and 118 dBA, respectively. One-third-octave frequency analyses (Figure A7) show noise to be predominently in the 2, 4 and 6 KHz bands.

Figure A8 contains expanded coincident time histories at the three microphone locations as the train accelerated to 32 mph and then decelerated to a stop at the Pacific St. Station. The noise levels increase and decrease as a direct function of speed. Figures A9 and A10 are one-third octave frequency analyses of these acceleration and deceleration periods.

To describe the overall characteristics of the noise levels measured during the complete run from the 86th St. Station to the 57th St. Station (minus the short period required to change tapes), statistical analyses (Appendix I) were performed for the three microphone locations. These are shown as Figures A11, A12, and A13. At the three locations, the dynamic ranges of the noise measured were 41, 41, and 43 dBA. The median noise levels were 79.1, 81.9, and 95.2 dBA, and the noise pollution levels were 98.1, 99.5 and 116.1 respectively. Other pertinent noise indices are included along with a histogram of noise levels vs. frequency of occurrences. Note that the noise exposure for a passenger located over the rear wheel trucks of the test car, during the approximately 43-minute test run, represented 13.6% of the allowable noise exposure as defined for industrial workers under the Walsh-Healey Act (see Appendix I for explanation of Walsh-Healey Act provisions).

A tabulation of typical maximum noise levels recorded during this run for the three microphone locations is shown in Table 1. Points selected were chosen where the speed of the car was constant for a short period of time before and after to obtain a representative noise level unaffected by accelerations or decelerations. (See Figure A-1)

TABLE 1. TYPICAL MAXIMUM NOISE LEVELS MEASURED ON MARK I DIAGNOSTIC CAR[1] ON N LINE IN NEW YORK CITY TRANSIT SYSTEM ON MAY 6, 1971

Typical[2] [3] Condition	Speed MPH	Noise Level dBA: Inside Location[4] Mid-Car	Inside Location Over Rear Wheel	On Outside Platform
Cruising	16	75	78	90
	30	80	82	96
	44	90	92	106
Crest of Manhattan Bridge	16	81	83	98
Brake Squeal	--	79	82	97
Wheel Squeal Sharp Right turn	14	97	101	115

(1) Mark 1 instrumented car in lead of 8 car train made up of type R42 cars.
(2) All measurements made were inside the subway with exception of measurements made on Manhattan Bridge.
(3) Air conditioning system off.
(4) Locations defined in Appendix F.

B. *Measurements made on the Mark 1 Diagnostic Car on the "N" Line, New York City Transit System (34th Street Station to crest of Manhattan Bridge, May 6, 1971)*

Appendix B contains coincident time histories of noise levels measured at three locations (Appendix F, Figure F1) on the Mark 1 Diagnostic Car during an express run in a reverse direction from the main data run (Appendix A). This time the instrumented car was the last car in an eight-car train (rather than the lead car). No speed information was available but was estimated by the test director on board to be 40 to 50 mph between the 34th St. Station and the Prince St. Station. This was not a controlled run in that no instructions were given the motorman nor did he know that measurements were being made. The time history has been marked to indicate points of interest. It is interesting to note that upon emerging from the subway tunnel onto the Manhattan Bridge, the noise level increased as it did in the main data run (see Appendix A, Figure A1).

C. Measurements made on the passenger platform in the 59th St. Subway Station, New York City Transit System, May 6, 1971.

Appendix C contains time histories, one-third octave frequency analyses and a statistical analysis of noise levels measured during a 20-minute time period on the platform in the 59th St. subway station (Appendix F, Figure F3 and F4).

Figure C1 is a 20-minute time history of the noise levels measured. The low levels indicated are limited by the dynamic range of the recording system. Low level information was simultaneously recorded on a second channel (Figure C2). One of the objectives of this test was to measure the noise of the test train as it traveled as an express train through the station. Unfortunately (as shown in Figure C1), as the test train entered the station on track 3, an unidentified train was leaving the station on track 1. This train almost completely masked the noise data from the test train. Also shown in Figure C1 are the levels measured upon the arrival, stop and departure of eight-car trains made up of R2, R27, R30, R-32 and R42 type transit cars. The train with the R42 type cars shown in Figure C1 is not the test train. The coincident arrival and departure of the R2, R42, and R27 trains makes the overall level measured considerably louder than the other individual arrivals and departures shown.

Figures C2 and C3 are time histories and frequency analyses of a quiet period in the subway station. A 32-second average indicated the low level ambient to be 60 dBA with a predominance of low frequencies.

Figure C4 through C6 are time histories and one-third-octave frequency analyses of the arrivals, stops and departures of three eight-car trains, one train made up of R27 cars, another of R30 cars, and the third of R32 cars. Because the arrival, stop and departure times of the R2, R42 and R27 trains overlapped as shown in Figure C1, it was not possible to make meaningful individual frequency analyses of these trains.

The statistical analysis of the 20-minute measuring period is shown in Figure C7. The dynamic range of noise measured was 54 dBA. The median noise level was 65.1 dBA and the noise pollution level was 121.7. Other pertinent noise indices are included along with a histogram of noise level vs. frequency of occurrences. Again, note the Walsh-Healey Act noise exposure (28.7%) produced by the 22-minute period on this passenger platform.

D. Measurements made on the Mark 1 Diagnostic Car at the DOT High Speed Ground Test Center, Pueblo, Colorado, August 17-18, 1971

Appendix D contains time histories and one-third-octave frequency analyses of noise levels measured on the Mark 1 Diagnostic Car operating as a two-car train at the DOT High Speed Ground Test Center, Pueblo, Colorado.

Figure D1 contains coincident time histories of noise levels measured at three locations (Fig. F1) during a north-to-south run on 2.2 miles of track. The instrumented car was the second car in the two-car train. Speed was not measured during this run. However, the speed was calculated from a knowledge of the location of trackside microphone, No. 3, relative to the location of a stationary locomotive used to power the third rail (see Appendix F, Figure F5). An oral mark was dictated on tape as the test train passed microphone 3. As the train passed the position of the locomotive the noise levels measured on the instrumented car increased due to the noise generated by the diesel engine of the locomotive (see Fig. D1). The elapsed time and distance between the locomotive blip and the blip from the oral mark enabled a calculation of speed as indicated.

At a speed of 58 mph, noise levels of 84, 86 and 98 dBA were recorded on the car. Simultaneously, an 84 dBA level was measured at microphone -No. 3 at trackside.

Figures D2, D3 and D4 are one-third-octave frequency analyses of acceleration, cruising, and deceleration periods for three locations on the car during the run.

Fig. D5 contains coincident time histories of noise levels measured in the diagnostic car while traveling in a south-to-north direction. During this run the instrumented car was the lead car of the two-car train. Speed was calculated to be 42 mph in the vicinity of trackside microphone No. 3 (Fig. F5). At this speed, noise levels of 79, 80, and 95 dBA were recorded. Simultaneously, a level of 76 dBA was observed at microphone No. 3 at trackside. Figures D6, D7 and D8 show frequency analyses of this run.

E. Measurements Made Trackside During Operation of the Mark 1 Diagnostic Car at the DOT High Speed Ground Test Center, Pueblo, Colorado August 19, 1971

Appendix E contains time histories and one-third-octave frequency analyses of measurements made trackside on the Mark 1 Diagnostic car operating as a two-car train.

Figure E1(a) contains a time history of the noise data generated by the Mark 1 cars starting from a stopped position and traveling in a south-to-north direction. The motorman was instructed to start with maximum acceleration. At a point directly across microphone No. 1 (Figure F5) the speed was estimated at 15 to 20 mph and the maximum noise level of 76 DBA was measured. A one-third-octave analysis of this acceleration pass is shown in Figure E1(b).

Also, in Figure E1(a) is a time history of the noise data recorded by microphone No. 2 (Figure F5) and generated by the Mark 1 cars cruising in a north-to-south direction past microphone No. 2. The speed was estimated by the observer to be 40 to 45 mph and the maximum noise level was also 76 DBA. A one-third-octave analysis of this pass-by is shown in Figure E1(c).

As mentioned previously in this report, noise levels generated by the cars increased as a direct function of speed. However, applying maximum propulsion power to get maximum acceleration to 15-20 mph increased the noise levels above those normally found at this speed when cruising. The noise level during this acceleration is shown in Figure E1(a) to equal the level recorded at a cruising speed of 40-45 mph.

OBSERVATIONS AND COMMENTS

In general, measurements in the car and on the outside platform of the car, in the New York City Transit System and at the DOT Test Center, were made under similar conditions. There were no passengers in the cars. Notable differences which should be kept in mind when comparing data are the following:

a. Air conditioning equipment in the cars was off, during the New York tests; and on, during the Colorado tests.
b. Except during the crossing of the Manhattan Bridge, the New York tests were all made in subway tunnels while the Colorado tests were made on surface tracks.
c. Rail sections in the New York system were not welded and no information on rail smoothness was available. In Colorado all rail sections were welded and the first mile of track from the southern extremity was recently ground smooth. The second mile had not been ground but welded joints were ground. This track was constructed in accordance with "Project 2(1), Test Loop and Access Spurs-Grading, Ballast and Tracks-HSGTC" prepared for FHWA Region 9, Denver, Colorado.
d. During the New York City test, the motorman was instructed to proceed as he would on a normal passenger run. The only exception was the doors of the test car were opened at only one stop; that is, at the Pacific St. Station.
e. Because of "flats" developed on the steel wheels in transit from New York to Colorado, the wheels of the test car were ground "true" prior to the Colorado tests.

With the above in mind, it is interesting to note that noise levels of 79, 80 and 95 dBA were measured in Colorado at the three microphone locations (Figure F1 and Figure D5) at a car speed of 42 mph. At a point during the New York City test just after the 59th St. station, at a speed of 42 mph, noise levels of 88, 90 and 105 dBA were measured at the same three locations, respectively. (Figure F1 and Figure A1). The large differences in level noted are attributed primarily to tunnel acoustics and rail conditions.

A comparison of the one-third-octave frequency analysis of a period of acceleration to 32 mph in New York (Figure A1a and A8a just before the Pacific St. Station) with the one-third-octave analysis of an acceleration to an estimated 32 mph in Colorado (Figure D6a) shows the following for the microphone located mid-car (Figure A9a vs. Figure D6a): dB level in the low frequency bands to 315 Hz are relatively similar and predominate; increase in levels in the mid-frequencies bands (400 Hz to 2.5 kHz for the New York run); the overall unweighted levels (F) are essentially the same, 93 dB(F) New York vs. 92.5 dB(F) Colorado; the A weighted level was higher in New York than in Colorado, 85 dBA-New York vs. 76 dBA-Colorado. The above indicates the dominant cause of annoyance in a below-surface transit system stems from the inherent amplification of middle frequencies (the most audible range) from tunnel reverberation or resonance. Similar comparisons are evident from the analyses at the other two microphone locations.

APPENDIX A

Noise Data Measured at Three
Locations on Mark I Diagnostic Car (Type R42)
During Run from 86th Station
to 57th St. Station, May 6, 1971
on "N" Line New York City Transit System.
Mark I Instrumented Car is Lead Car of Eight-Car Train
of Type R42 Cars

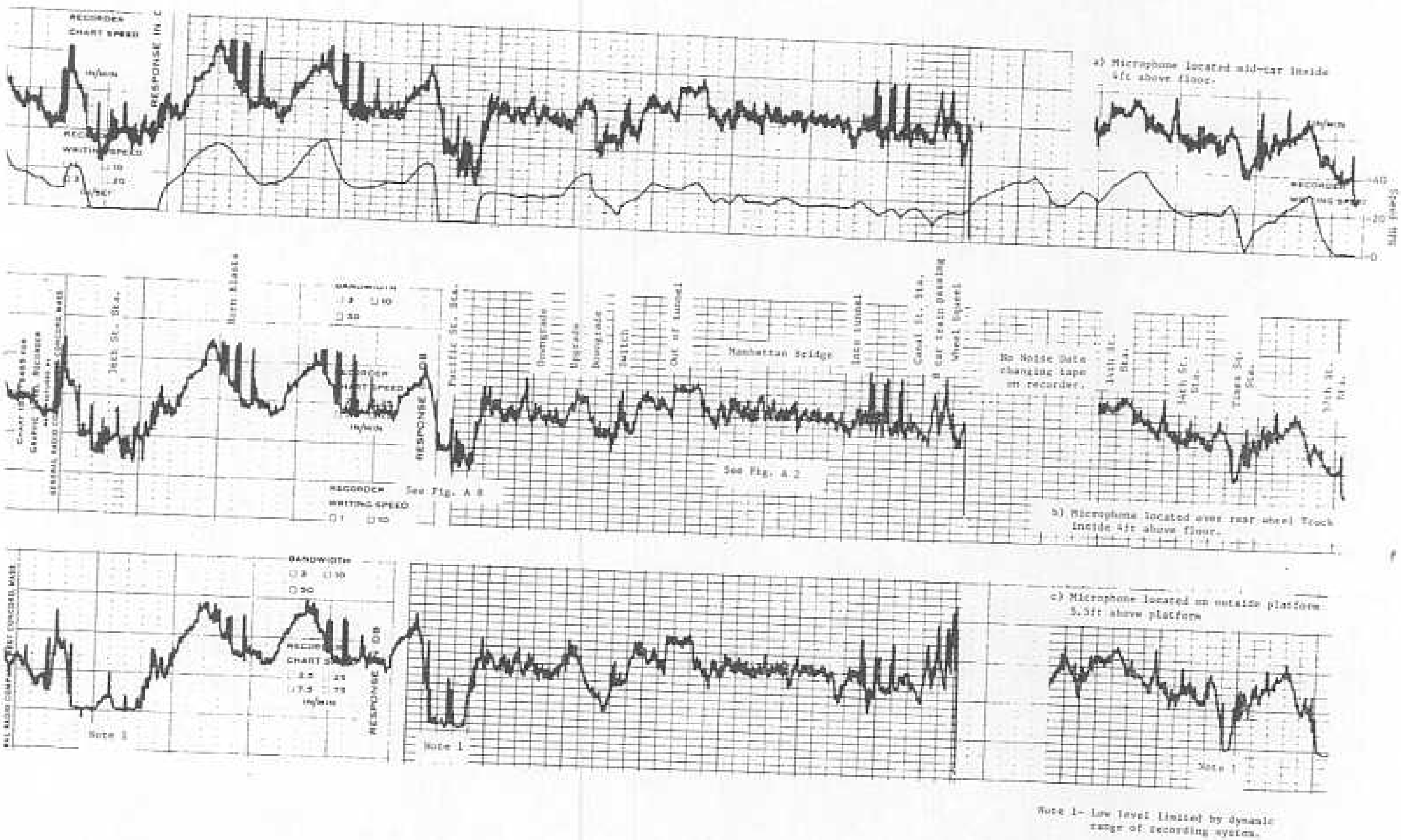
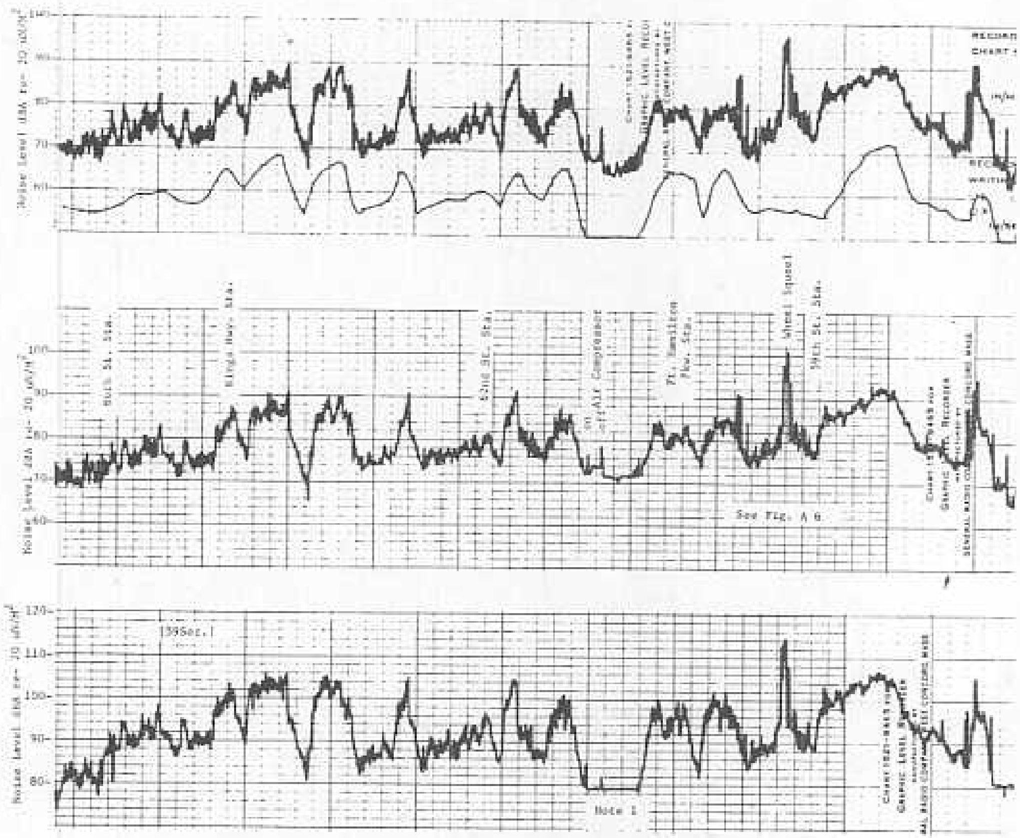


Figure A-1. Coincident Time Histories of Noise Levels Measured at three locations on the Mark I Diagnostic Car on the "N" Line NYC Transit System (see Figure F-1 for Microphone Locations) May 6, 1971.



Noise Level dBA re- 20 µN/m²
Kings Hwy. Sta.
62nd St. Sta.
Air Compressor
Ft. Hamilton Pkwy. Sta.
Wheel Squeal
59th St. Sta.
See Fig. A 6.
Note 1

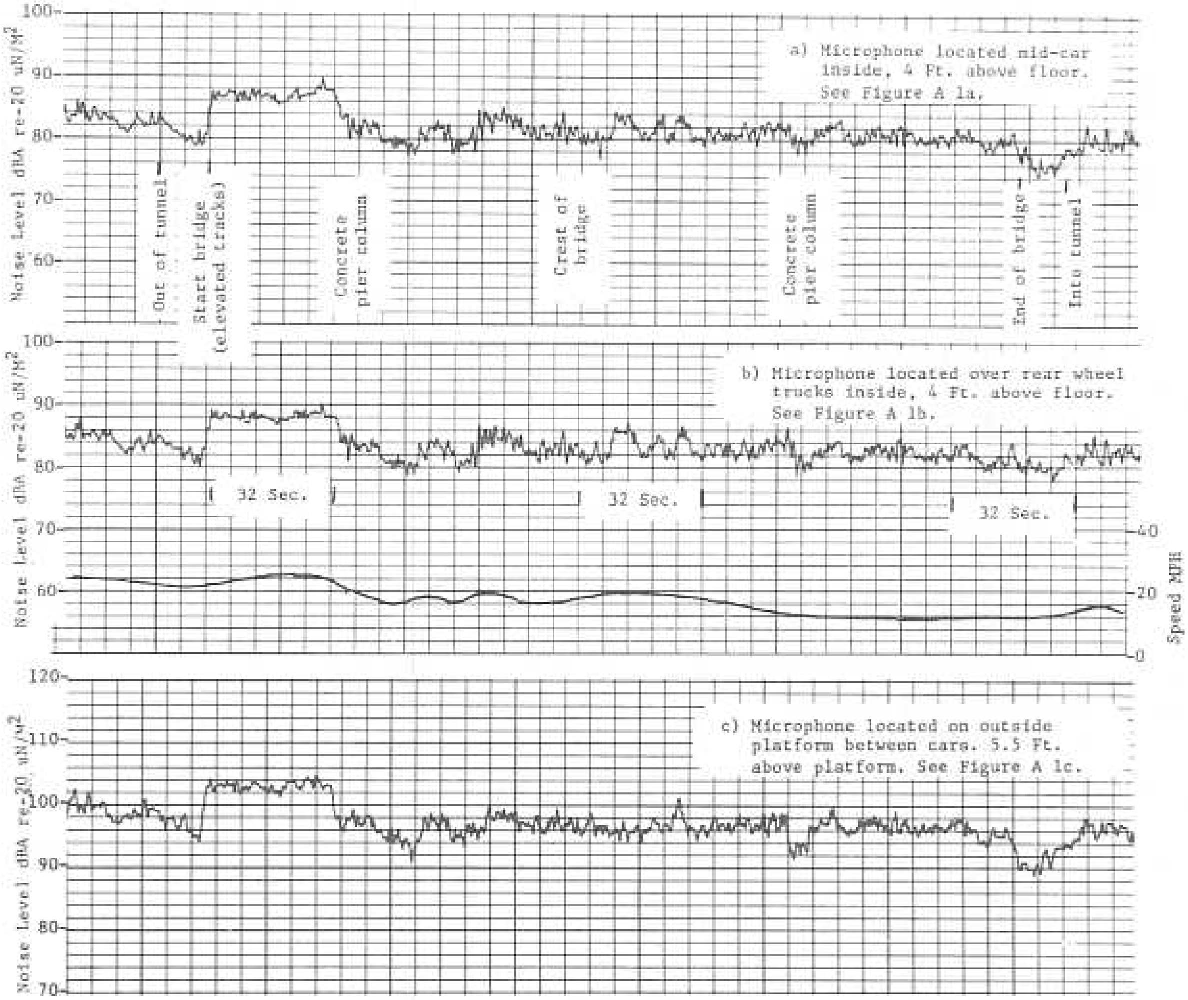


Figure A-2. Coincident Time Histories of Noise Levels for Three Locations. Manhattan Bridge "N" Line NYC Transit System. May 6, 1971.

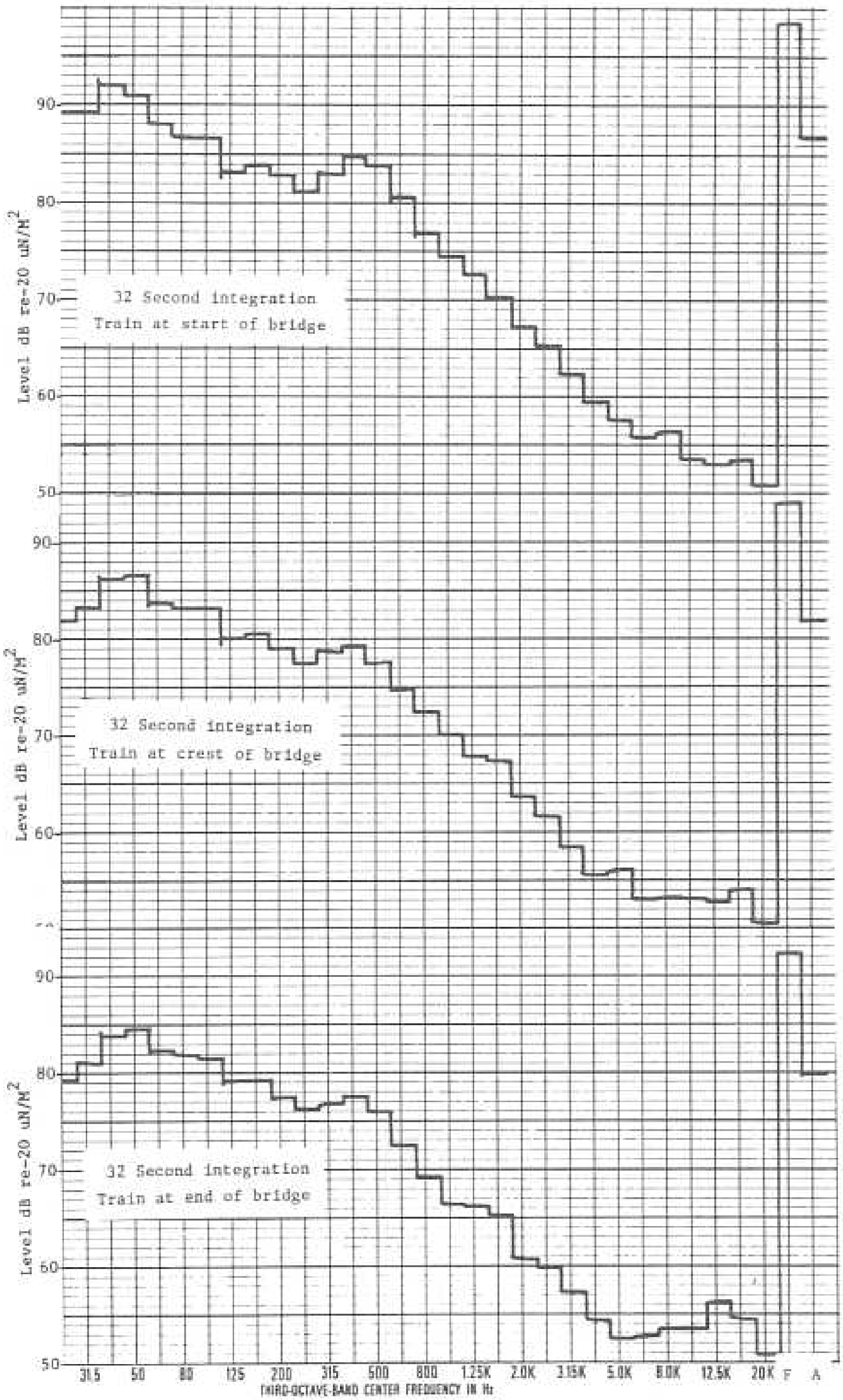


Figure A-3. Frequency Analyses Manhattan Bridge Microphone Located Mid-Car Inside 4 ft. Above Floor (See Figure A-2a) May 6, 1971.

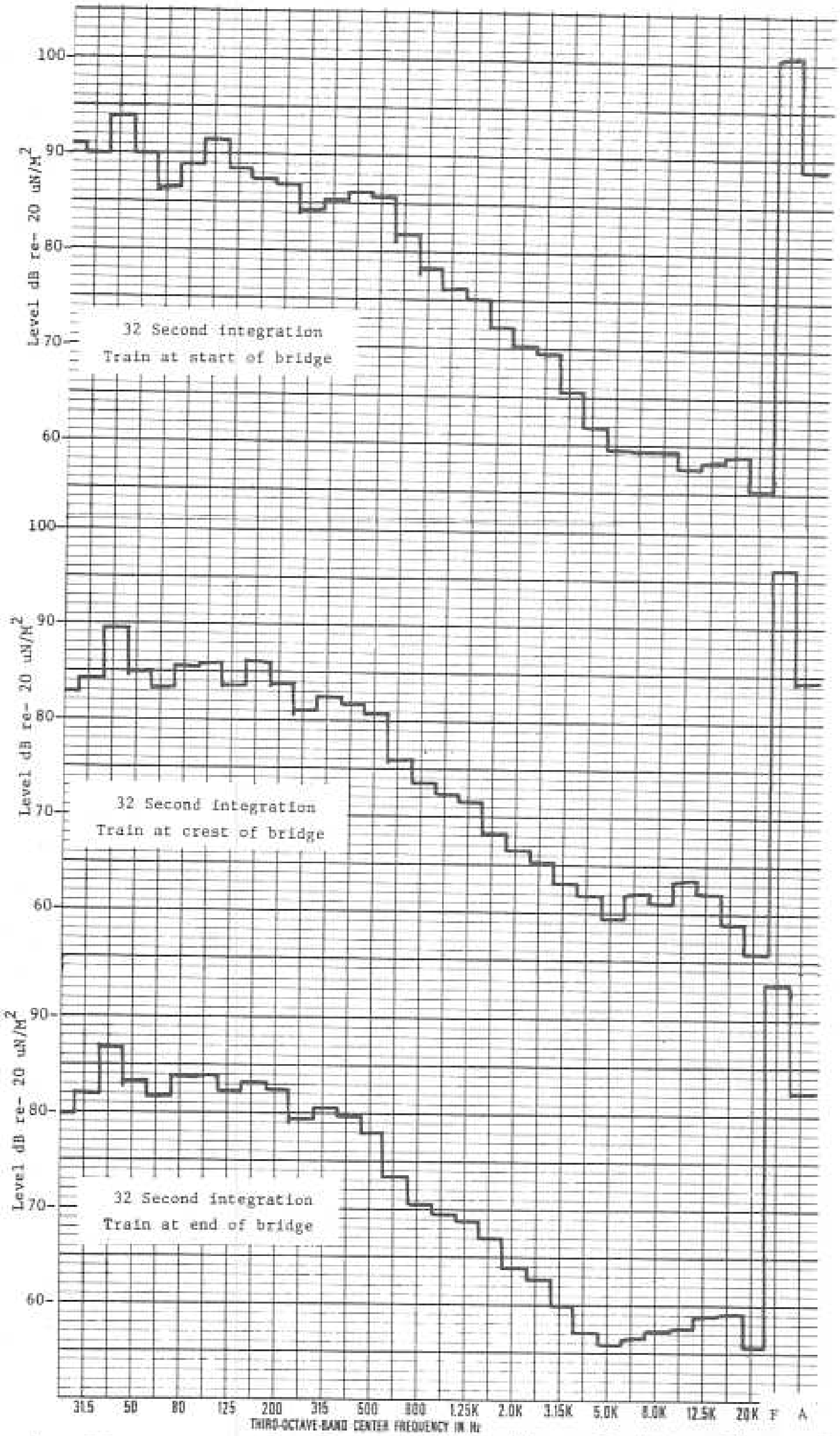


Figure A-4. Frequency Analyses Manhattan Bridge Microphone Located Over Rear Wheel Trucks Inside Car 4 Ft. Above Floor. May 6, 1971, (See Figure A-2b)

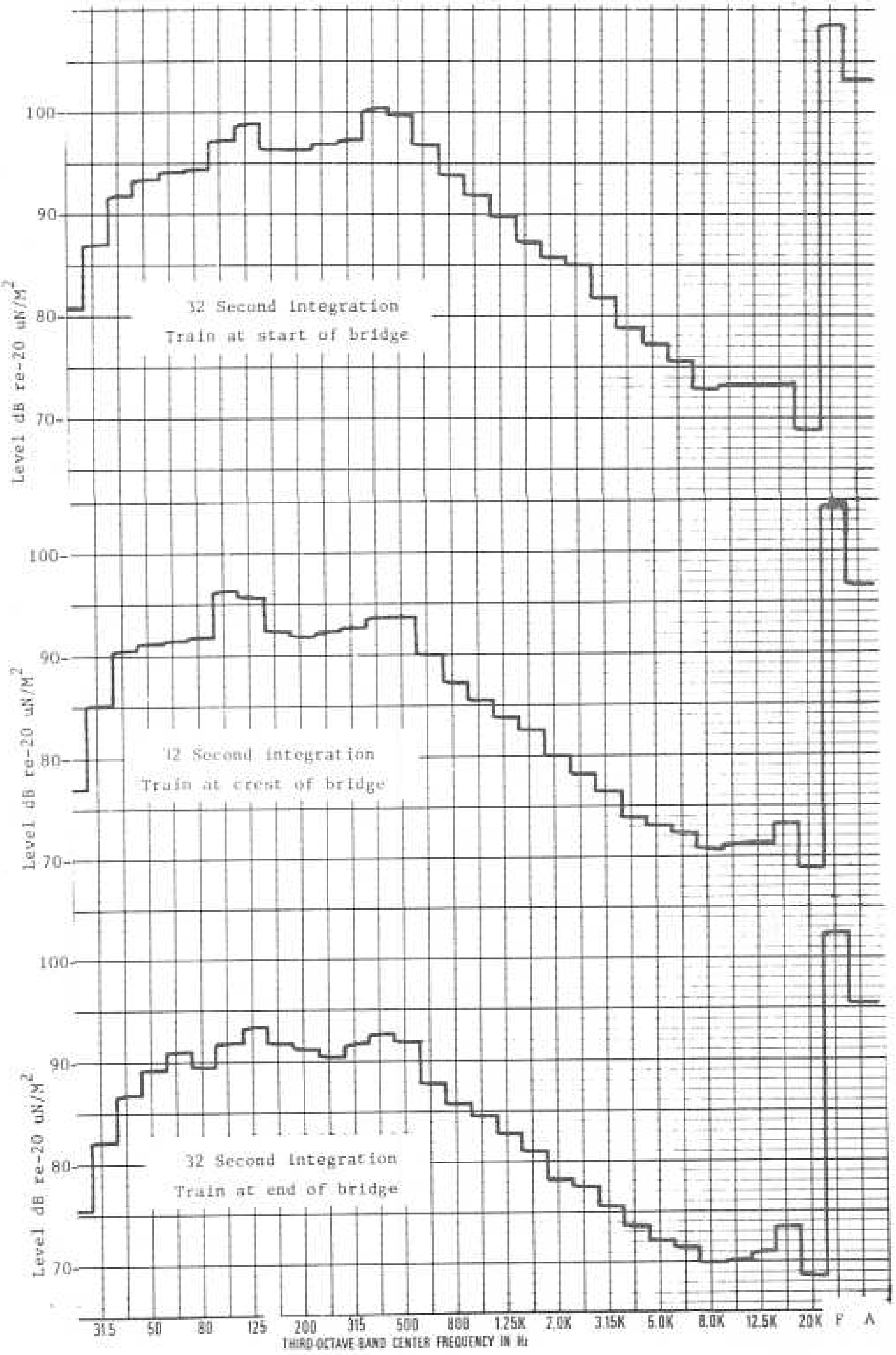


Figure A-5. Frequency Analyses Manhattan Bridge Microphone Located on Outside Platform Between Cars, 5.5ft. Above Platform. May 6, 1971 (See Figure A-2c)

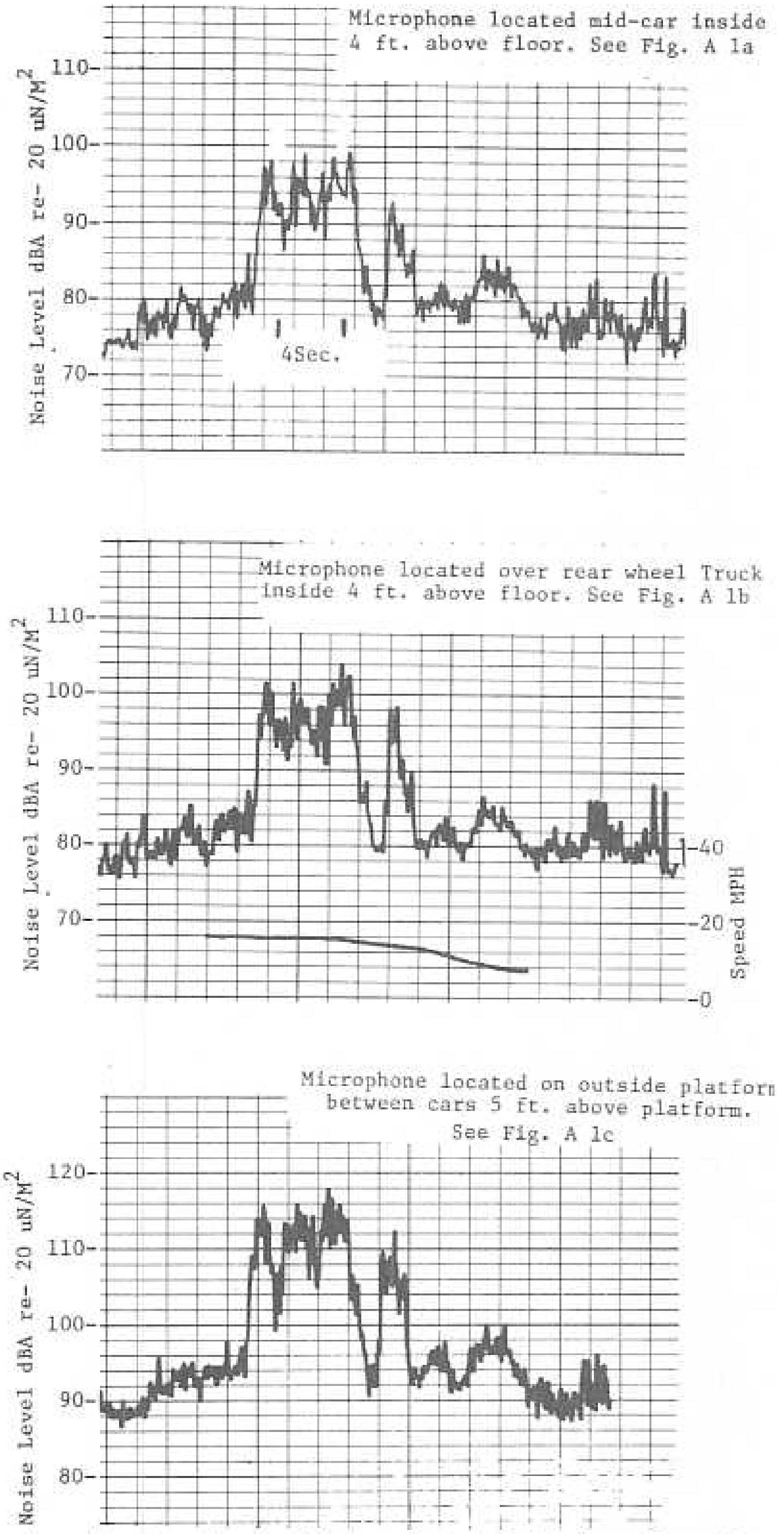


Figure A-6. Coincident Time Histories of Noise Levels at 3 Locations. Wheel Squeal on the Sharp Right Turn Between 8th Ave. Station and 59th St. Station on "N" Line NYC Transit System. - May 6, 1971.

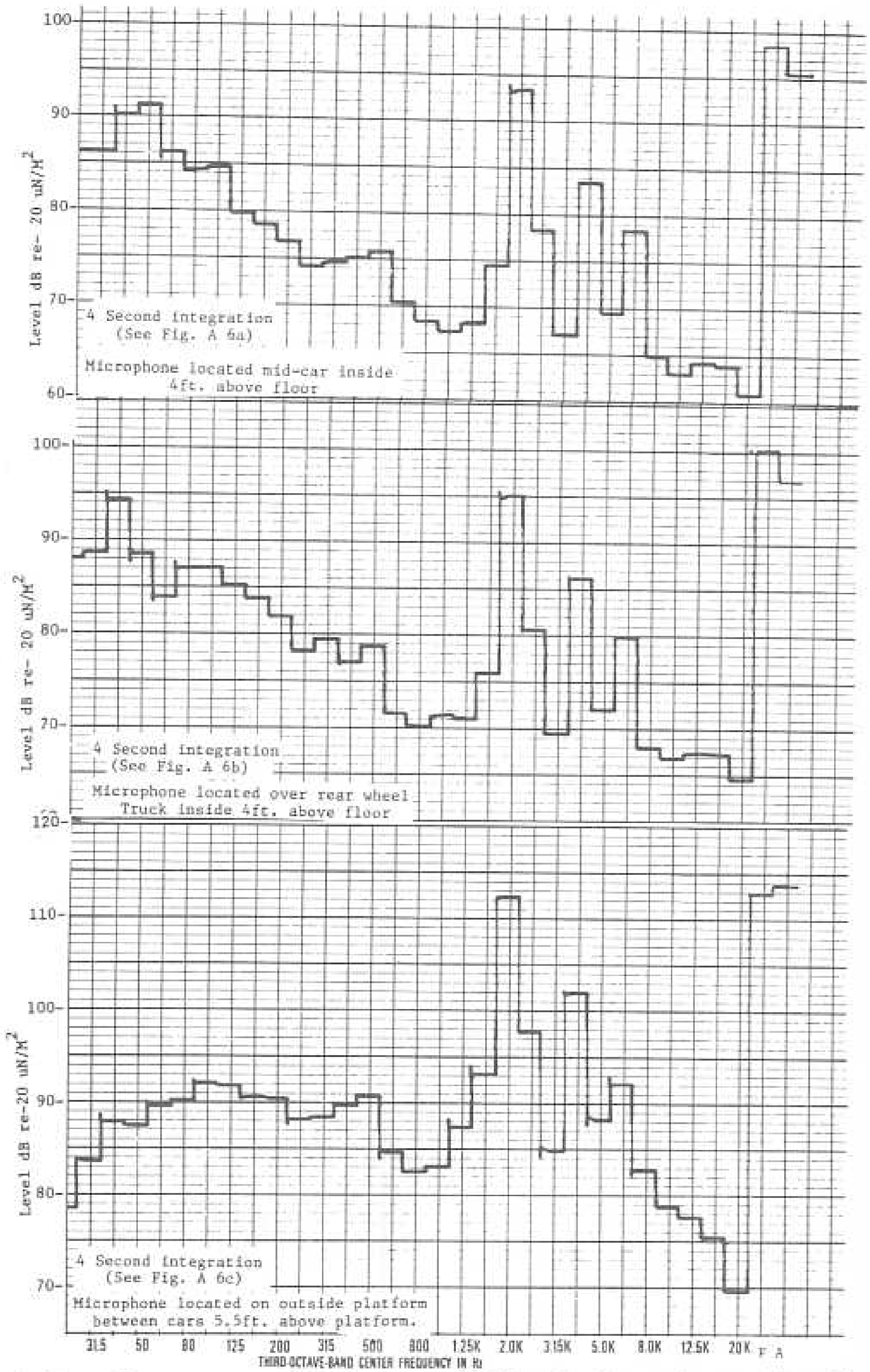


Figure A-7. Frequency Analyses of Wheel Squeal on the Sharp Right Turn Between 8th Ave. Station and 59th St. Station on "N" Line NYC Transit System. - May 6, 1971.

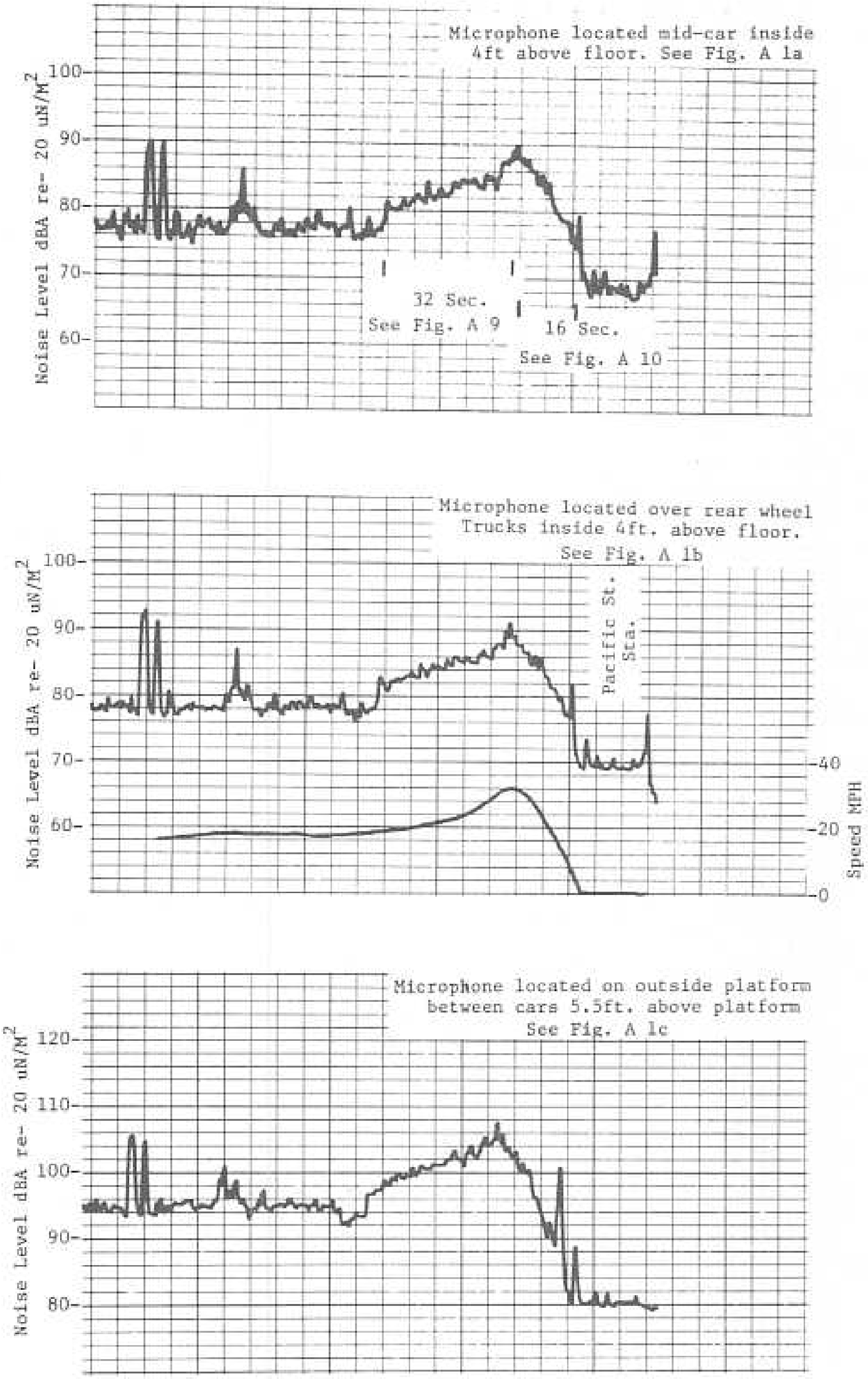


Figure A-8. Coincident Time Histories of Noise Levels Measured at 3 Locations. Acceleration to 32 MPH and Deceleration to stop. "N" Line NYC Transit System. - May 6, 1971.

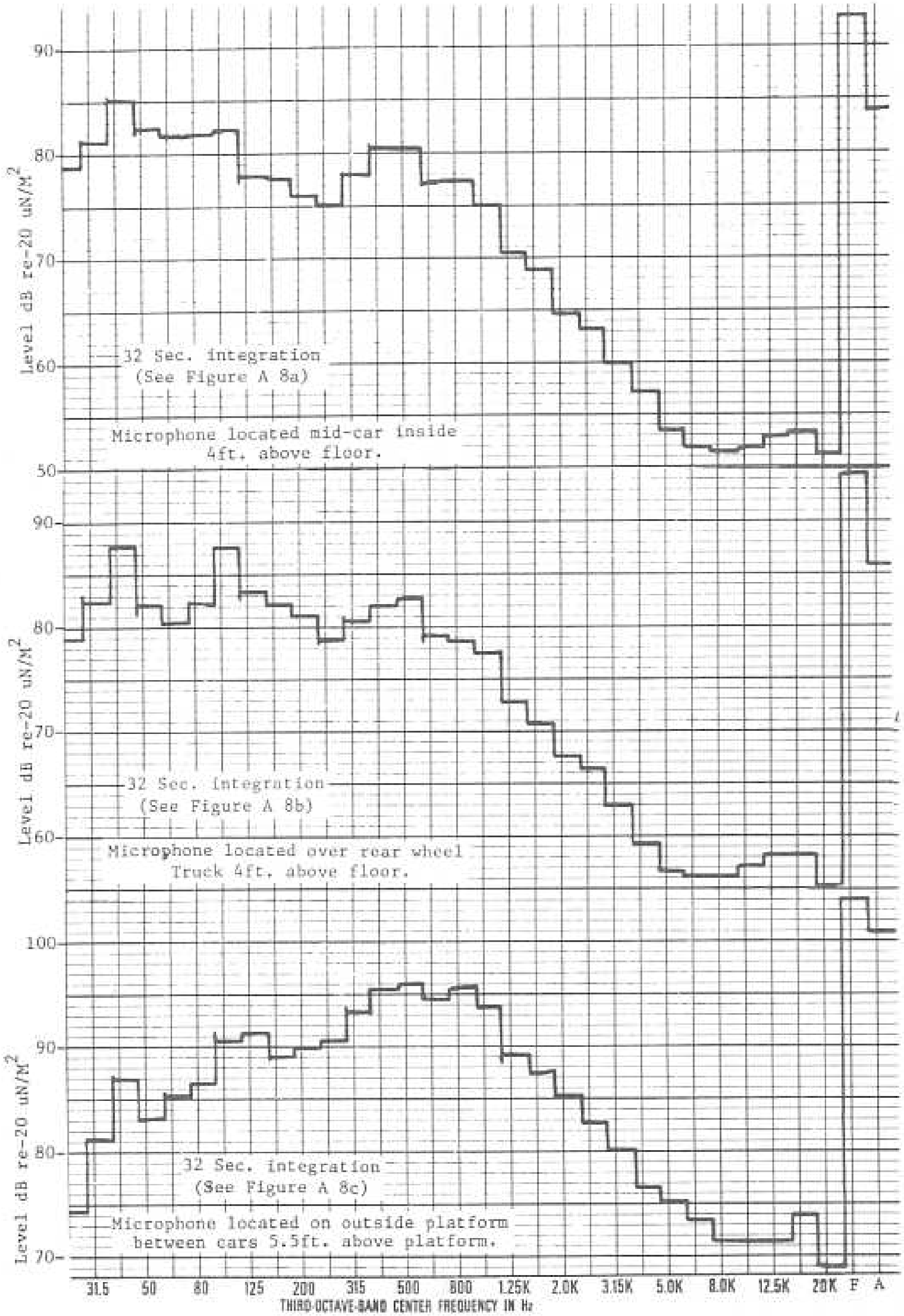


Figure A-9. Frequency Analyses of Acceleration to 32 MPH "N" Line-NYC Transit System. - May 6, 1971.

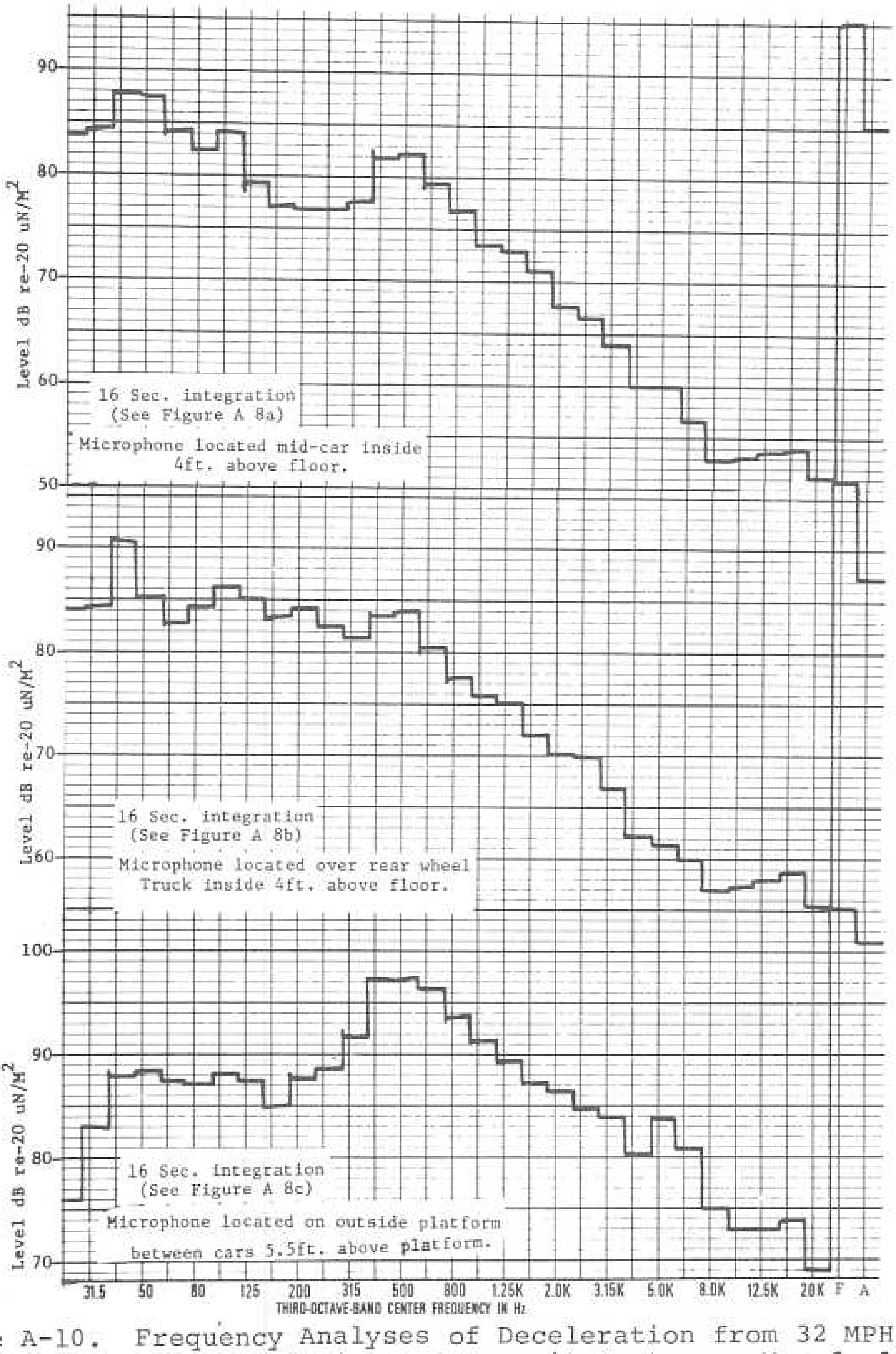


Figure A-10. Frequency Analyses of Deceleration from 32 MPH to Stop. "N" Line NYC Transit System. - May 6, 1971.

US DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
NOISE ABATEMENT GROUP

TUES 09/21/71
12:05

NOISE DATA FROM RUN NO. NY-58&59-71-1A OF THE PORTABLE NOISE STA.NO.1 ON MAY 6 1971 FROM 10:23 TO 11:06 ON THE 'N' LINE, NY CITY TRANSIT SYSTEM.

SAMPLES=	9823
AVERAGE=	78.6 DBA*
STANDARD DEVIATION=	6 DBA*
ENERGY MEAN=	82.7 DB**
NOISE POLLUTION LEVEL=	98.1
1% PERCENTILE=	93.3 DBA*
10% DECILE=	86.9 DBA*
MEDIAN=	79.1 DBA*
90% DECILE=	71.1 DBA*
99% PERCENTILE=	65.2 DBA*
WALSH HEALEY EXP.=	6 %
RANGE=	41 DB

DISTRIBUTION	DBA*
2	99
4	98
5	97
4	96
17	95
25	94
57	93
41	92
81	91
101	90
152	89
203	88
250	87
287	86
379	85
375	84
442	83
579	82
601	81
636	80
771	79
794	78
660	77
549	76
505	75
393	74
398	73
294	72
249	71
216	70
236	69
151	68
111	67
105	66
69	65
32	64
23	63
8	62
9	61
6	60
2	59
1	58
0	57

0 20 40 60 80 100

LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure A-11. Statistical Analysis - Mark I Diagnostic Car on "N" Line, New York City Transit System. May 6, 1971 Microphone Located Mid-Car, Inside, 4 ft Above Floor. (Continued on page A-13)

2	99	0
4	98	0
5	97	0
4	96	0
17	95	0
25	94	0
57	93	00
41	92	00
81	91	00
101	90	000
152	89	000
203	88	0000
250	87	00000
287	86	00000
379	85	0000000
375	84	0000000
442	83	00000000
579	82	0000000000
601	81	0000000000
636	80	00000000000
771	79	0000000000000
794	78	0000000000000
660	77	00000000000
549	76	000000000
505	75	000000000
393	74	0000000
398	73	0000000
294	72	000000
249	71	00000
216	70	0000
236	69	00000
151	68	000
111	67	000
105	66	000
69	65	00
32	64	00
23	63	0
8	62	0
9	61	0
6	60	0
2	59	0
1	58	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 - Mark I Diagnostic Car on "N" Line, New York City Transit System. May 6, 1971 Microphone Located Mid-Car, Inside, 4 ft Above Floor.

US DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
NOISE ABATEMENT GROUP

TUES 09/21/71
12:58

NOISE DATA FROM RUN NO. NY-58&59-71-1B OF THE PORTABLE NOISE STA.NO.1 ON MAY 6 1971 FROM 10:23 TO 11:06 ON THE 'N' LINE, NY CITY TRANSIT SYSTEM

DISTRIBUTION	DBA*
2	102
2	101
2	100
1	99
4	98
8	97
16	96
41	95
70	94
90	93
102	92
229	91
200	90
270	89
315	88
401	87
434	86
518	85
592	84
688	83
821	82
819	81
691	80
756	79
593	78
401	77
381	76
309	75
201	74
167	73
198	72
143	71
79	70
50	69
37	68
35	67
55	66
56	65
21	64
2	63
1	62
1	61
0	60

SAMPLES= 9802
AVERAGE= 81.4 DBA*
STANDARD DEVIATION= 5.7 DBA*
ENERGY MEAN= 84.9 DB**
NOISE POLLUTION LEVEL= 99.5
1% PERCENTILE= 94.7 DBA*
10% DECILE= 89.2 DBA*
MEDIAN= 81.9 DBA*
90% DECILE= 74.7 DBA*
99% PERCENTILE= 66.3 DBA*
WALSH HEALEY EXP.= 13.6 %
RANGE= 41 DB

0 20 40 60 80 100

LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure A-12. Statistical Analysis - Mark I Diagnostic Car on "N" Line, New York City Transit System. May 6, 1971 Microphone Located Inside Over Rear Wheel Trucks 4 ft Above Floor. (Continued on page A-15)

(RUN NO. NY-58&59-71-1B CONTINUED)   TUES 09/21/71

```
 2       102 0
 2       101 0
 2       100 0
 1        99  0
 4        98  0
 8        97  0
 16       96  0
 41       95  00
 70       94  00
 90       93  00
 102      92  000
 229      91  00000
 200      90  0000
 270      89  00000
 315      88  000000
 401      87  0000000
 434      86  00000000
 518      85  000000000
 592      84  0000000000
 688      83  000000000000
 821      82  00000000000000
 819      81  00000000000000
 691      80  000000000000
 756      79  0000000000000
 593      78  0000000000
 401      77  0000000
 381      76  0000000
 309      75  000000
 201      74  0000
 167      73  0000
 198      72  0000
 143      71  000
 79       70  00
 50       69  00
 37       68  00
 35       67  00
 55       66  00
 56       65  00
 21       64  0
 2        63  0
 1        62  0
 1        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 A-12. (Continued) Statistical Analysis - Mark I Diagnostic Car on "N" Line, New York City Transit System. May 6, 1971 Microphone Located Inside Over Rear Wheel Trucks 4 ft Above Floor.

US DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
NOISE ABATEMENT GROUP

MON 09/27/71
14:49

NOISE DATA FROM RUN NO. NY-58&59-71-1D OF THE PORTABLE NOISE STA.NO.1 ON MAY 6 1971 FROM 10:23 TO 11:06 ON THE 'N' LINE, NY CITY TRANSIT SYSTEM.
(ZONE 99 UNIVERSAL GRID LOCATION 999 - 9999 .)

DISTRIBUTION	DBA*
2	116
2	115
1	114
4	113
4	112
8	111
6	110
10	109
35	108
72	107
115	106
151	105
210	104
275	103
360	102
395	101
402	100
417	99
509	98
545	97
645	96
758	95
727	94
611	93
545	92
409	91
284	90
277	89
270	88
231	87
197	86
189	85
137	84
103	83
80	82
64	81
65	80
68	79
63	78
56	77
56	76
57	75
58	74
58	73
0	72

SAMPLES=	9531
AVERAGE=	94.1 DBA*
STANDARD DEVIATION=	6.9 DBA*
ENERGY MEAN=	98.4 DB**
NOISE POLLUTION LEVEL=	116.1
1% PERCENTILE=	108 DBA*
10% DECILE=	103 DBA*
MEDIAN=	95.2 DBA*
90% DECILE=	85.5 DBA*
99% PERCENTILE=	74.6 DBA*
WALSH HEALEY EXP.=	338 % V
RANGE=	43 DB

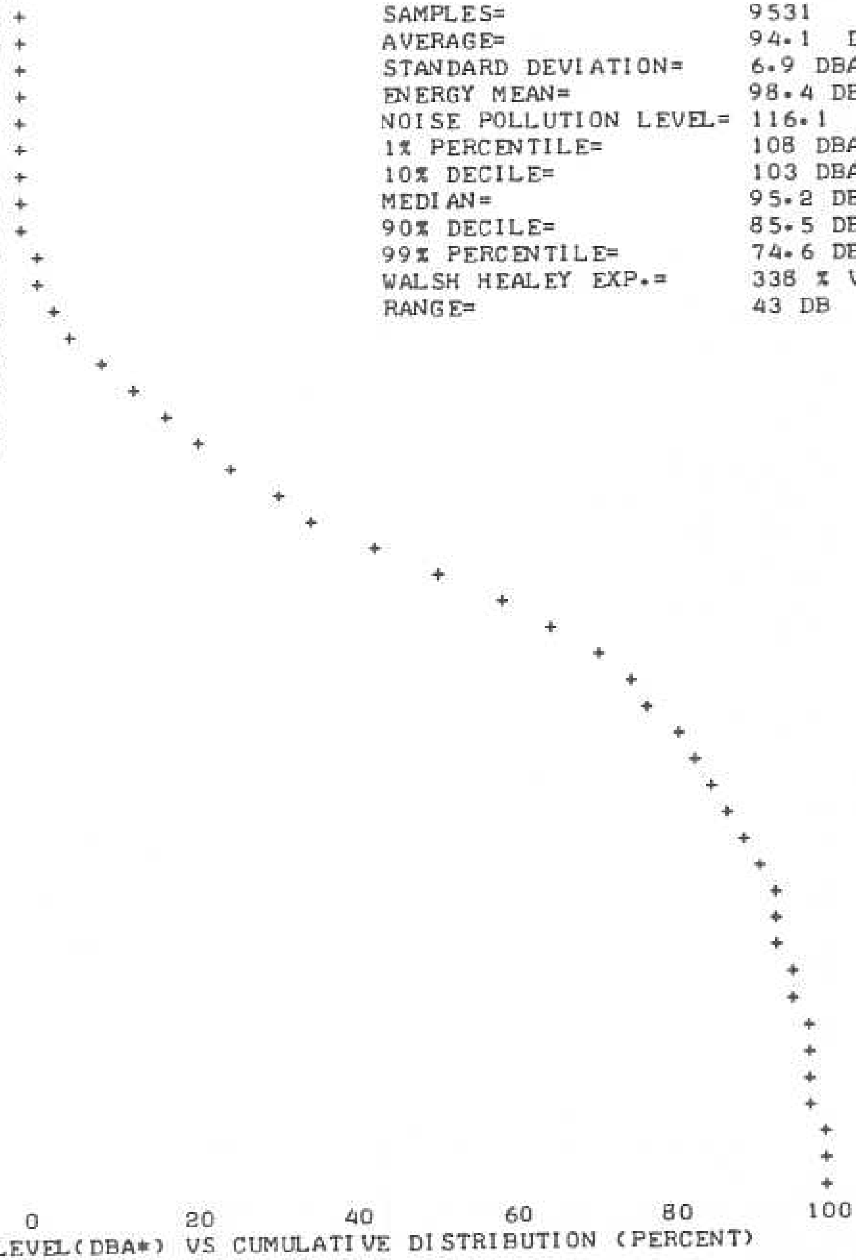


Figure A-13. Statistical Analysis - Mark I Diagnostic Car on "N" Line, New York City Transit System. May 6, 1971 Microphone Located on Outside Platform Between Cars 5.5 Ft Above Platform.
(Continued on Page A-17)

DIST.	DBA*	0 10 20 30
2	116	0
2	115	0
1	114	0
4	113	0
4	112	0
8	111	0
6	110	0
10	109	0
35	108	00
72	107	00
115	106	000
151	105	000
210	104	0000
275	103	00000
360	102	0000000
395	101	0000000
402	100	0000000
417	99	00000000
509	98	000000000
545	97	0000000000
645	96	00000000000
758	95	0000000000000
727	94	0000000000000
611	93	00000000000
545	92	0000000000
409	91	00000000
284	90	000000
277	89	00000
270	88	00000
231	87	00000
197	86	0000
189	85	0000
137	84	000
103	83	000
80	82	00
64	81	00
65	80	00
68	79	00
63	78	00
56	77	00
56	76	00
57	75	00
58	74	00
58	73	00

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-13. (Continued) Statistical Analysis - Mark I Diagnostic Car on "N" Line, New York City Transit System. May 6, 1971 Microphone Located on Outside Platform Between Cars 5.5 Ft Above Platform.

APPENDIX B

Noise Levels Measured at Three Locations On Mark I Diagnostic Car (R42) During Run from 34th Street to Crest of Manhattan Bridge on May 6, 1971, on "N" Line, New York City Transit System. Instrumented Mark I Car is Last Car of Eight-Car Train Made up of Type R42 Cars.

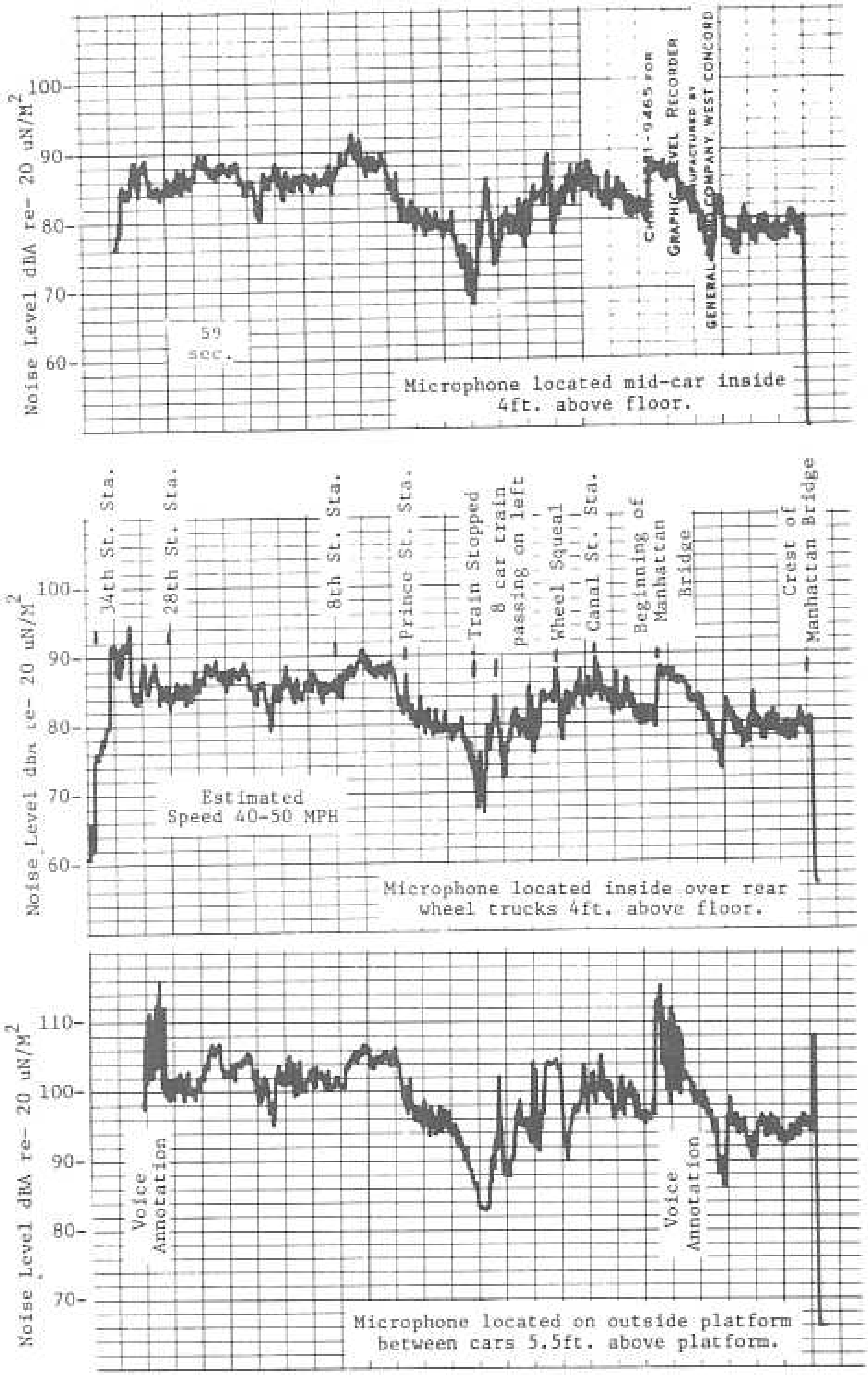


Figure B-1 Coincident Time Histories of Noise Levels Measured at Three Locations. Express Run from 34th. St. Station to Crest of Manhattan Bridge. "N" Line NYC Transit System. - May 6, 1971 See Figure F-1 for Microphone Locations. (No Speed Information Available)

APPENDIX C

Noise Data Measured on the Passenger
Platform at the 59th Street Subway Station
New York City Transit System on May 6, 1971

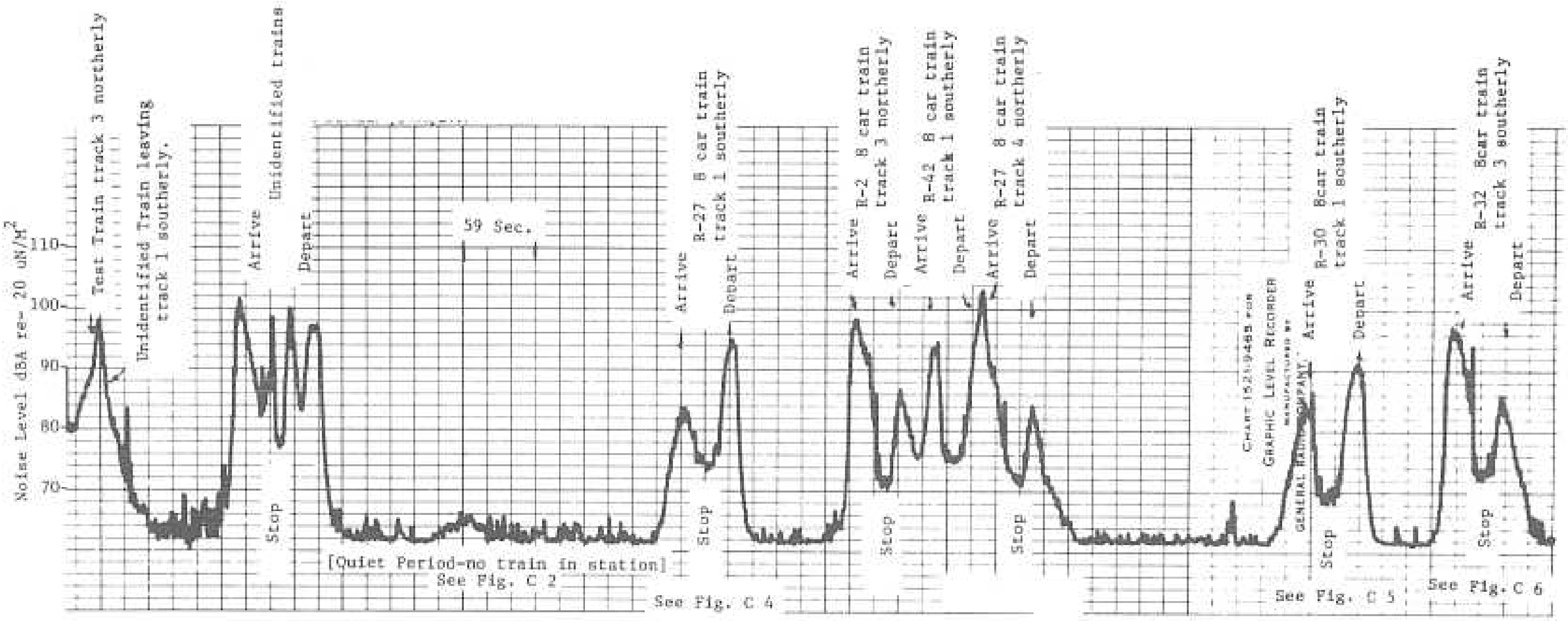


Figure C-1. Time History 59th. St. Subway Station NYC Transit System. See Figure F-3 for Microphone Location (no speed information available) May 6, 1971.

Note- Low Level Limited by Dynamic Range of Recording System (see Figure C-2 for Low Levels).

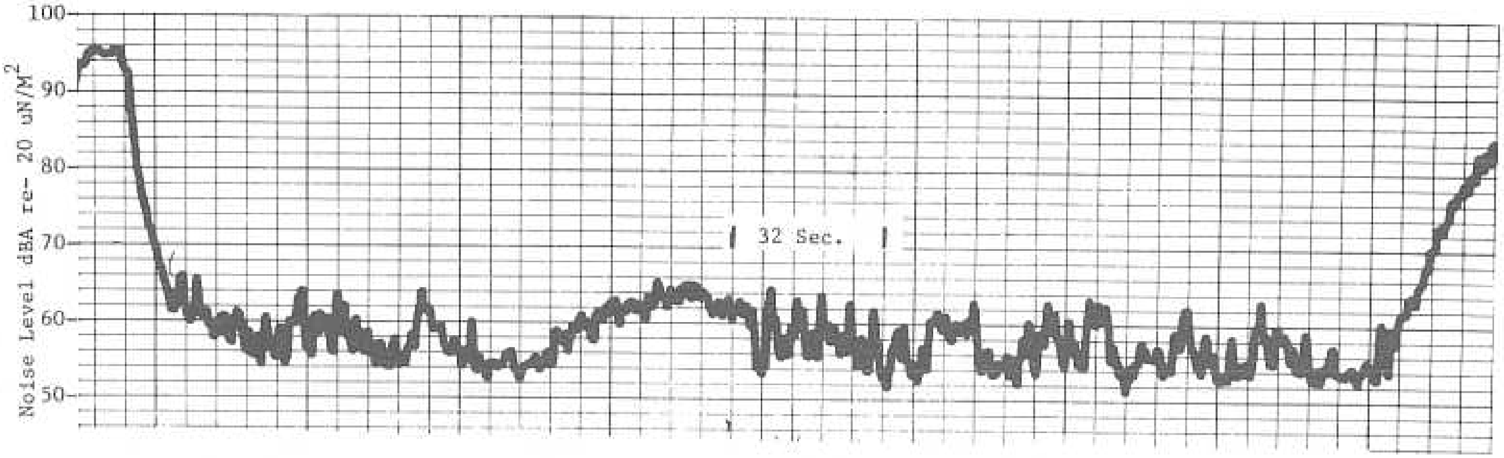


Figure C-2. Time History of Noise Level During Quiet Period in 59th. St. Subway Station (No Trains in the Station), NYC Transit System. May 6, 1971

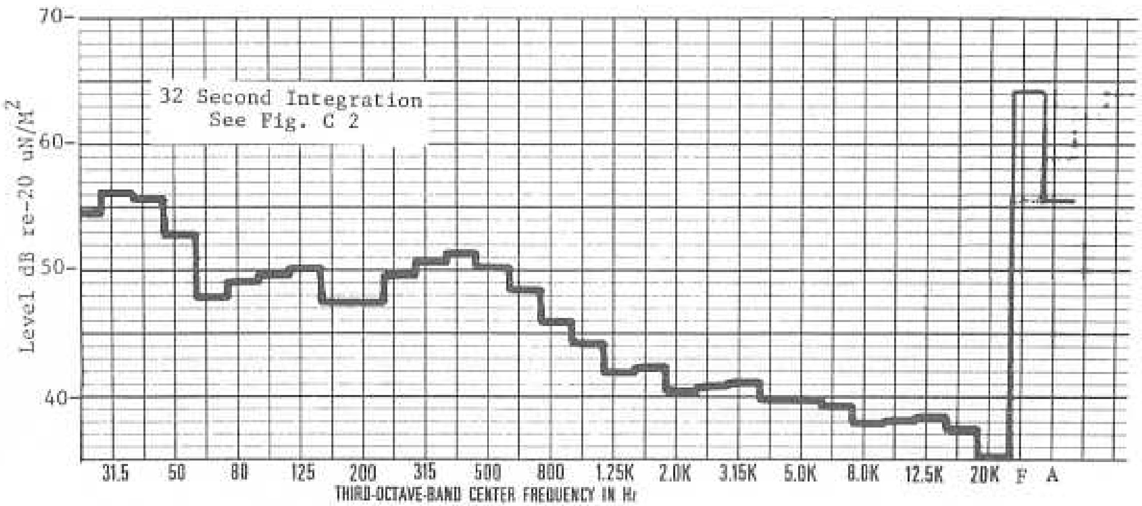


Figure C-3. Frequency Analysis of Quiet Period in 59th. St. Subway Station, NYC Transit System. May 6, 1971

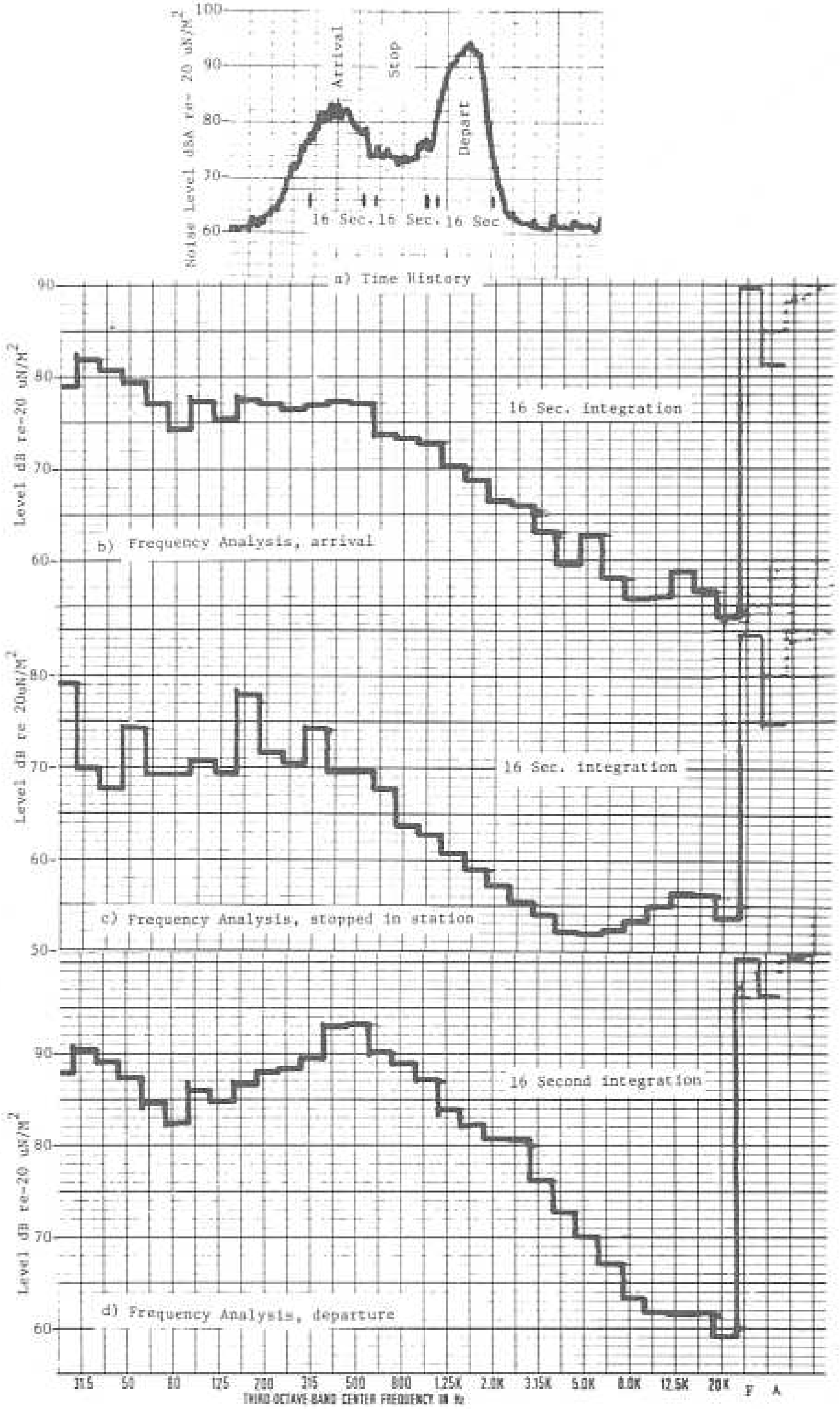


Figure C-4. Eight-Car Train (Type R-27 Cars) at 59th. St. Subway Station NYC Transit System, May 6, 1971 on Track 1 Heading South.

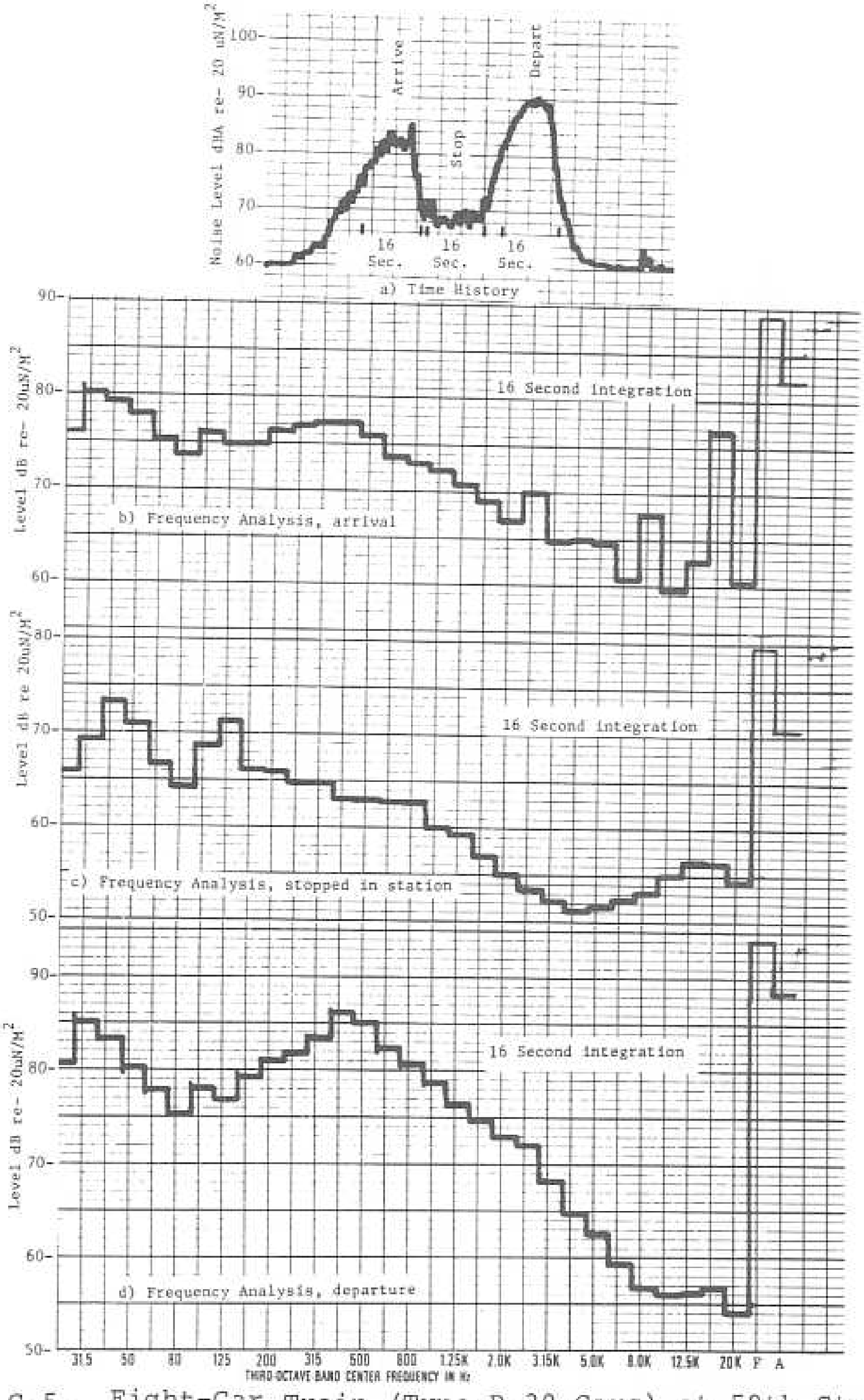


Figure C-5. Eight-Car Train (Type R-30 Cars) at 59th St. Subway Station NYC Transit System, May 6, 1971 on Track 1 heading South.

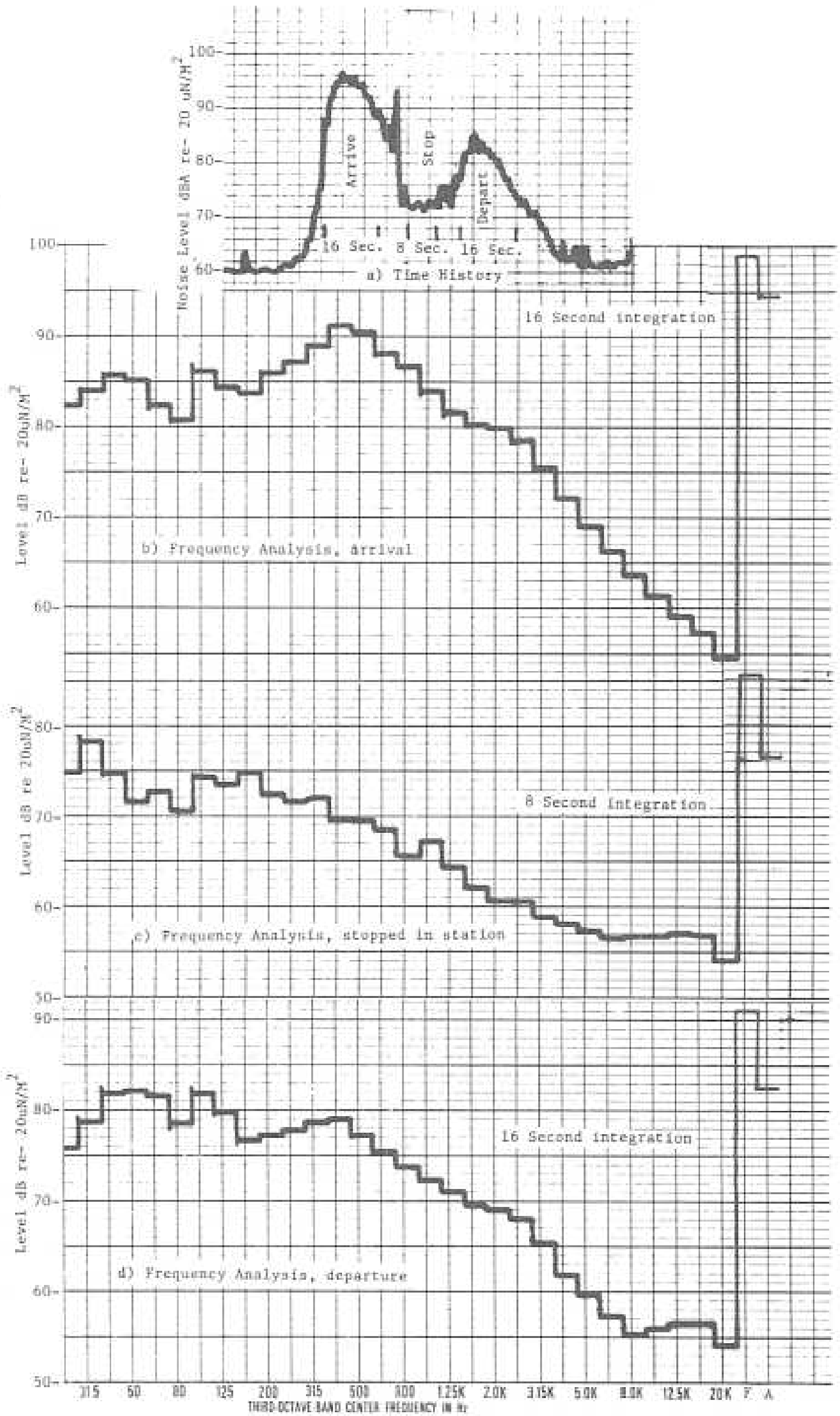


Figure C-6. Eight-Car Train (Type R-32 Cars) at 59th. St. Subway Station NYC Transit System, May 6, 1971 on Track 3 Heading South.

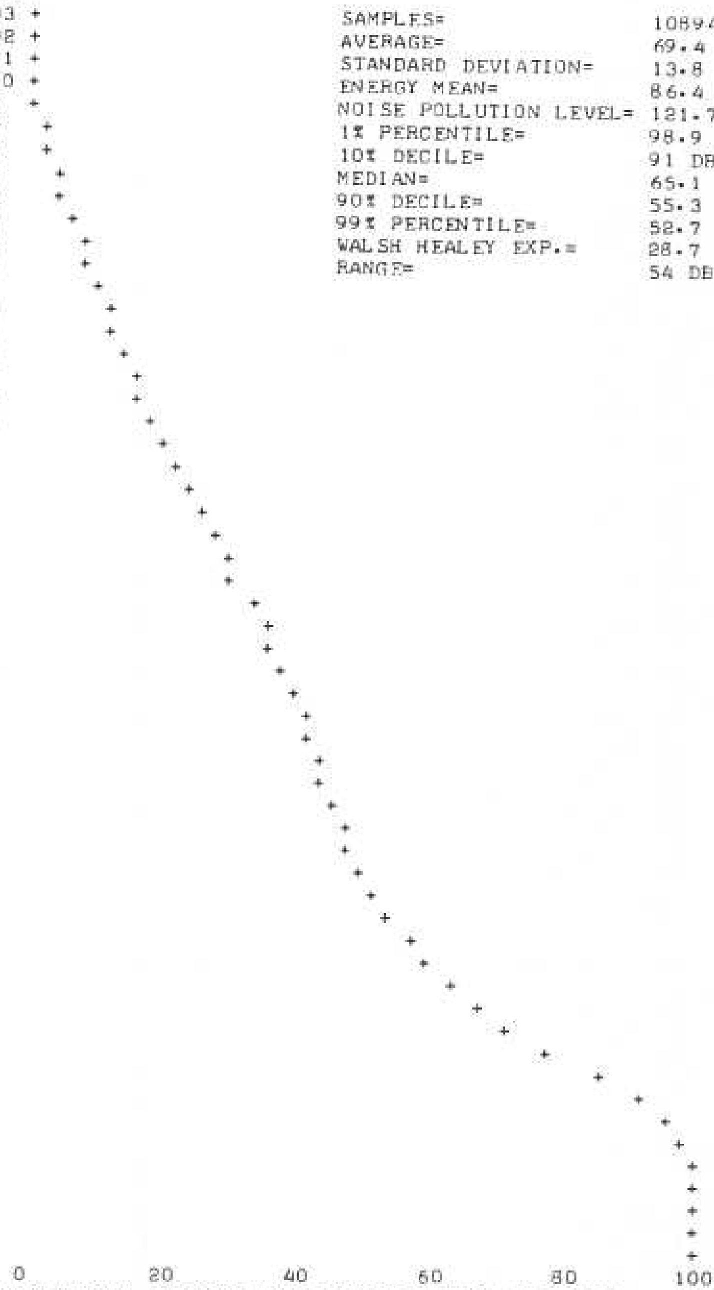
US DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
NOISE ABATEMENT GROUP

WED 10/13/71
09:49

NOISE DATA FROM RUN NO. NY-60-71-A1/2 OF THE PORTABLE NOISE STA. NO. 10
MAY 6 1971 FROM 12:35 TO 12:57 AT 59TH ST. STA., NY CITY TRANSIT SYSTEM.

DISTRIBUTION	DBA*
6	103
11	102
19	101
31	100
39	99
53	98
94	97
133	96
131	95
115	94
155	93
145	92
152	91
184	90
137	89
125	88
138	87
175	86
214	85
201	84
202	83
179	82
196	81
181	80
156	79
204	78
257	77
191	76
190	75
184	74
178	73
148	72
143	71
109	70
117	69
121	68
110	67
148	66
187	65
224	64
255	63
302	62
287	61
339	60
492	59
498	58
678	57
799	56
674	55
485	54
266	53
91	52
32	51
11	50
2	49
0	48

SAMPLES= 10894
AVERAGE= 69.4 DBA*
STANDARD DEVIATION= 13.8 DBA*
ENERGY MEAN= 86.4 DB**
NOISE POLLUTION LEVEL= 121.7
1% PERCENTILE= 98.9 DBA*
10% DECILE= 91 DBA*
MEDIAN= 65.1 DBA*
90% DECILE= 55.3 DBA*
99% PERCENTILE= 52.7 DBA*
WALSH HEALEY EXP.= 28.7 %
RANGE= 54 DB



LEVEL(DBA*) VS CUMULATIVE DISTRIBUTION (PERCENT)

Figure C-7. Statistical Analysis - 59th St. Subway Station New York City Transit System Microphone on Platform 5.5ft High. (Continued on Page C-8)

(RUN NO. NY-60-71-A1/2 CONTINUED)   WED   10/13/71

DIST.	DBA*	
6	103	0
11	102	0
19	101	0
31	100	00
39	99	00
53	98	00
94	97	00
133	96	000
131	95	000
115	94	000
155	93	000
145	92	000
152	91	000
164	90	0000
137	89	000
125	88	000
138	87	000
175	86	0000
214	85	0000
201	84	0000
202	83	0000
179	82	0000
196	81	0000
181	80	0000
156	79	000
204	78	0000
257	77	00000
191	76	0000
190	75	0000
184	74	0000
178	73	0000
148	72	000
143	71	000
109	70	000
117	69	000
121	68	000
110	67	000
148	66	000
187	65	0000
224	64	0000
255	63	00000
302	62	00000
287	61	00000
339	60	000000
492	59	00000000
498	58	00000000
678	57	0000000000
799	56	000000000000
674	55	0000000000
485	54	00000000
266	53	00000
91	52	00
32	51	00
11	50	0
2	49	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-7. (Continued) Statistical Analysis - 59th St. Subway Station New York City Transit System Microphone on Platform 5.5ft High.

APPENDIX D

Noise Data Measured at Three Locations on Mark I Diagnostic Car (R42) at DOT High Speed Ground Test Center, Pueblo, Colorado, on 17-18 August 1971. Two-Car Train of Type R42 cars. Instrumented - car is Lead Car in South-to-North Direction of Operation and Last Car in North-to-South Direction of Operation.

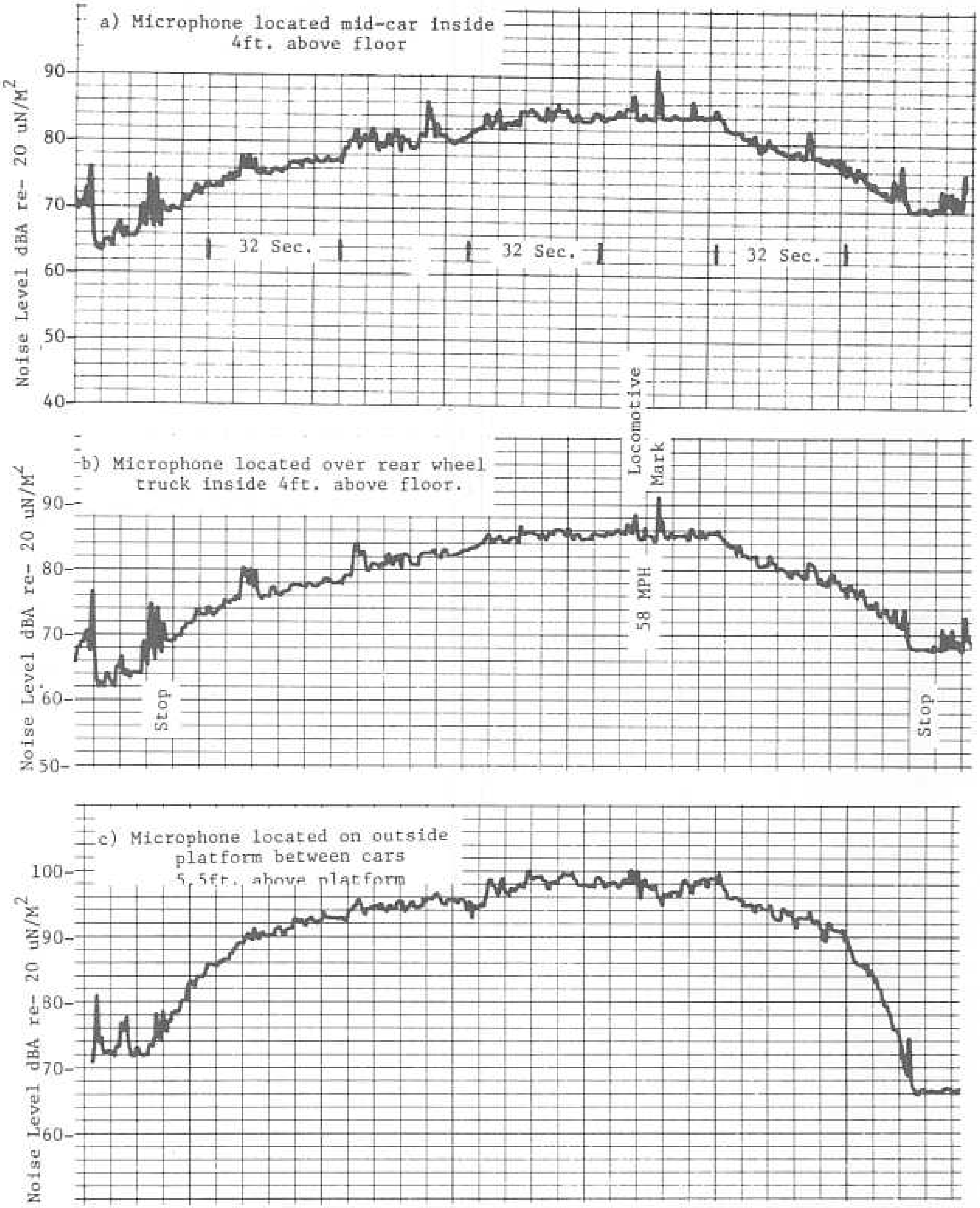


Figure D-1. Coincident Time Histories of Noise Levels at Three Locations in the Mark I Diagnostic Car During North to South Run at the DOT High Speed Ground Test Center, Pueblo, Colorado. Aug, 17, 1971 - See Figure F-1 for Microphone Locations.

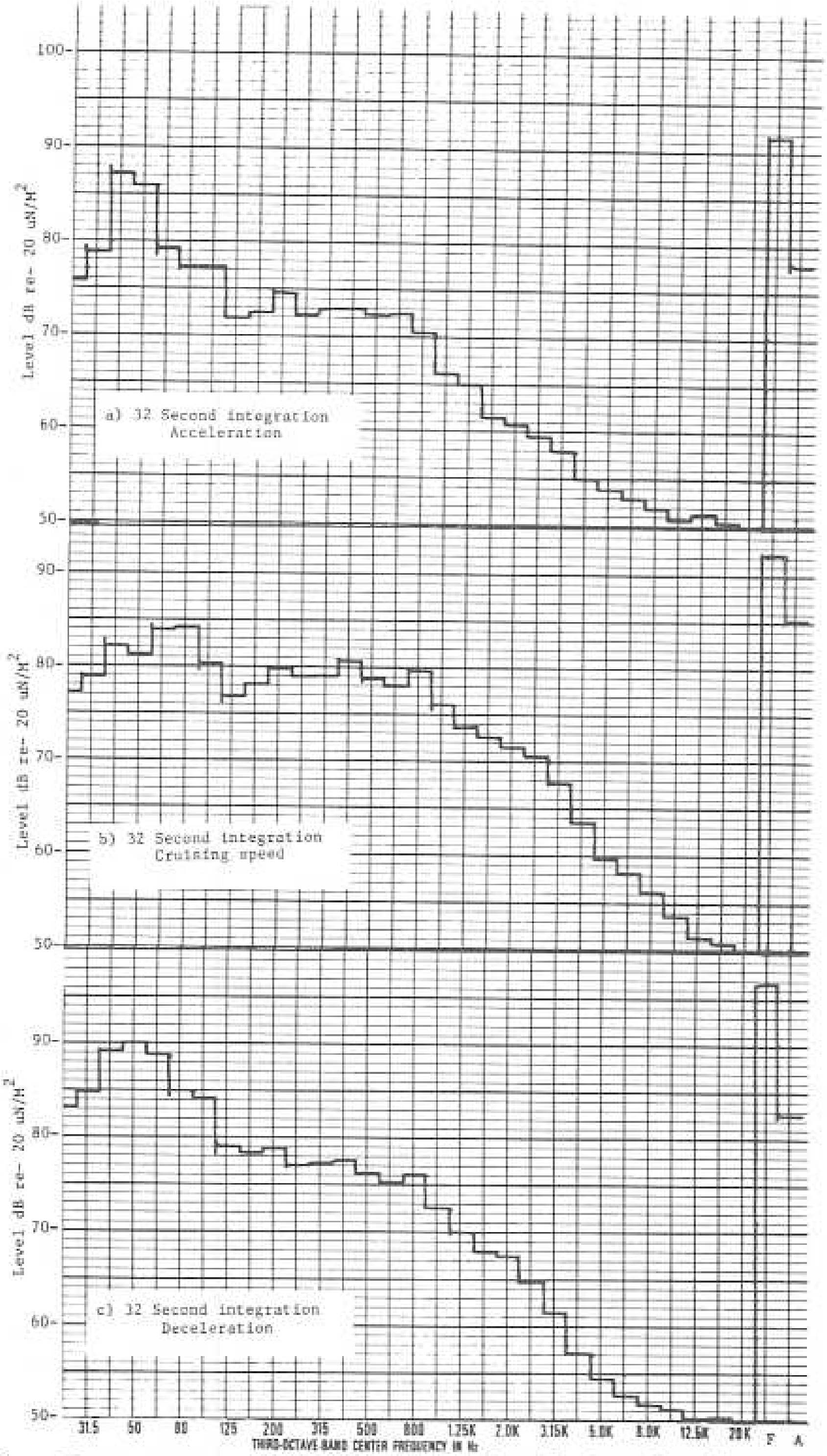


Figure D-2. Frequency Analyses of North-to-South Run at DOT HSGTC Pueblo, Colorado. Microphone Located Mid-Car Inside 4ft. Above Floor. See Figure D 1a. Aug. 17, 1971.

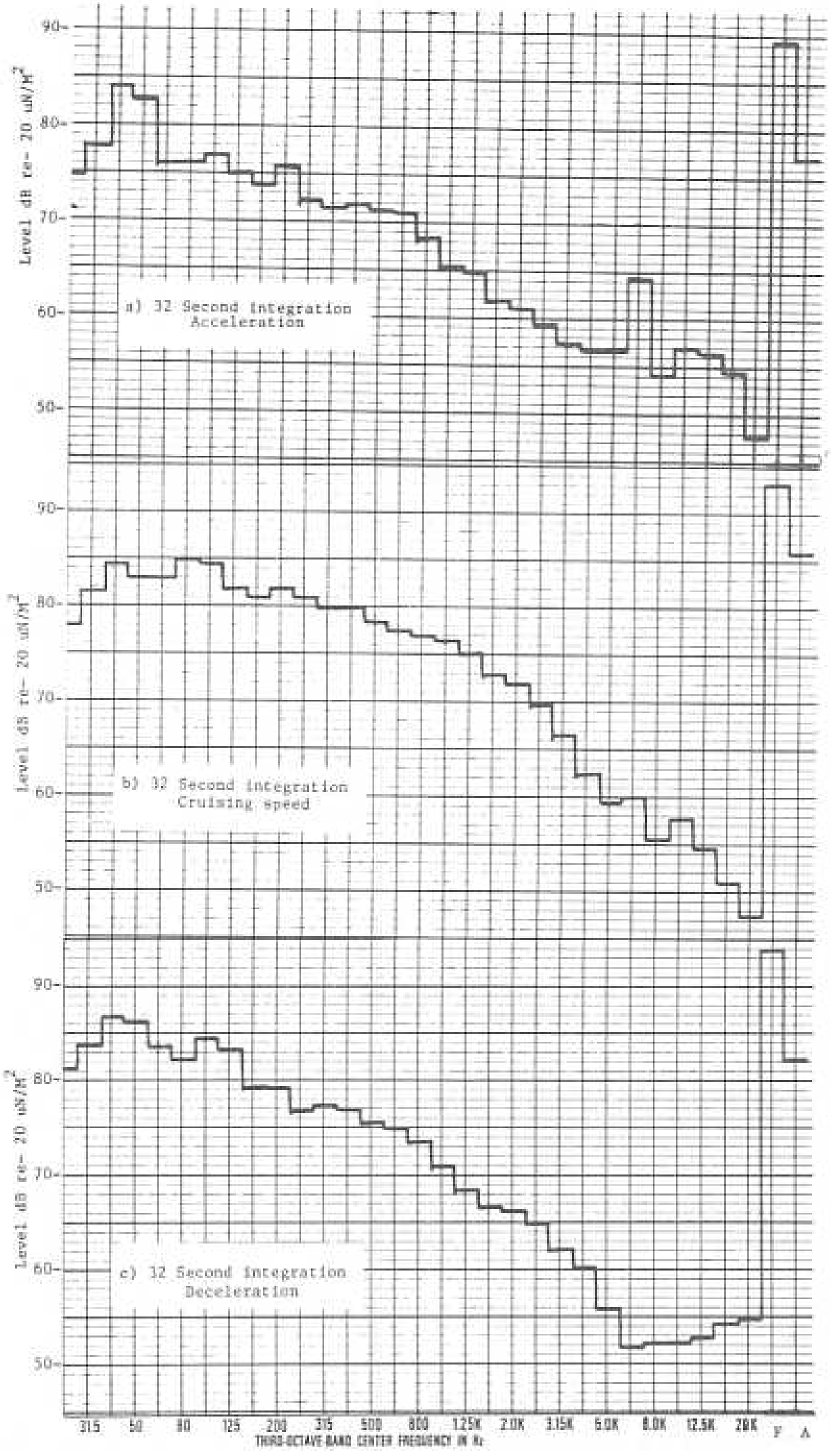


Figure D-3. Frequency Analyses of North-to-South Run at DOT HSGTC Pueblo, Colorado. Microphone Located Over Rear Wheel Truck Inside 4 ft. Above Floor. Aug. 17, 1971 - See Figure D-1b.

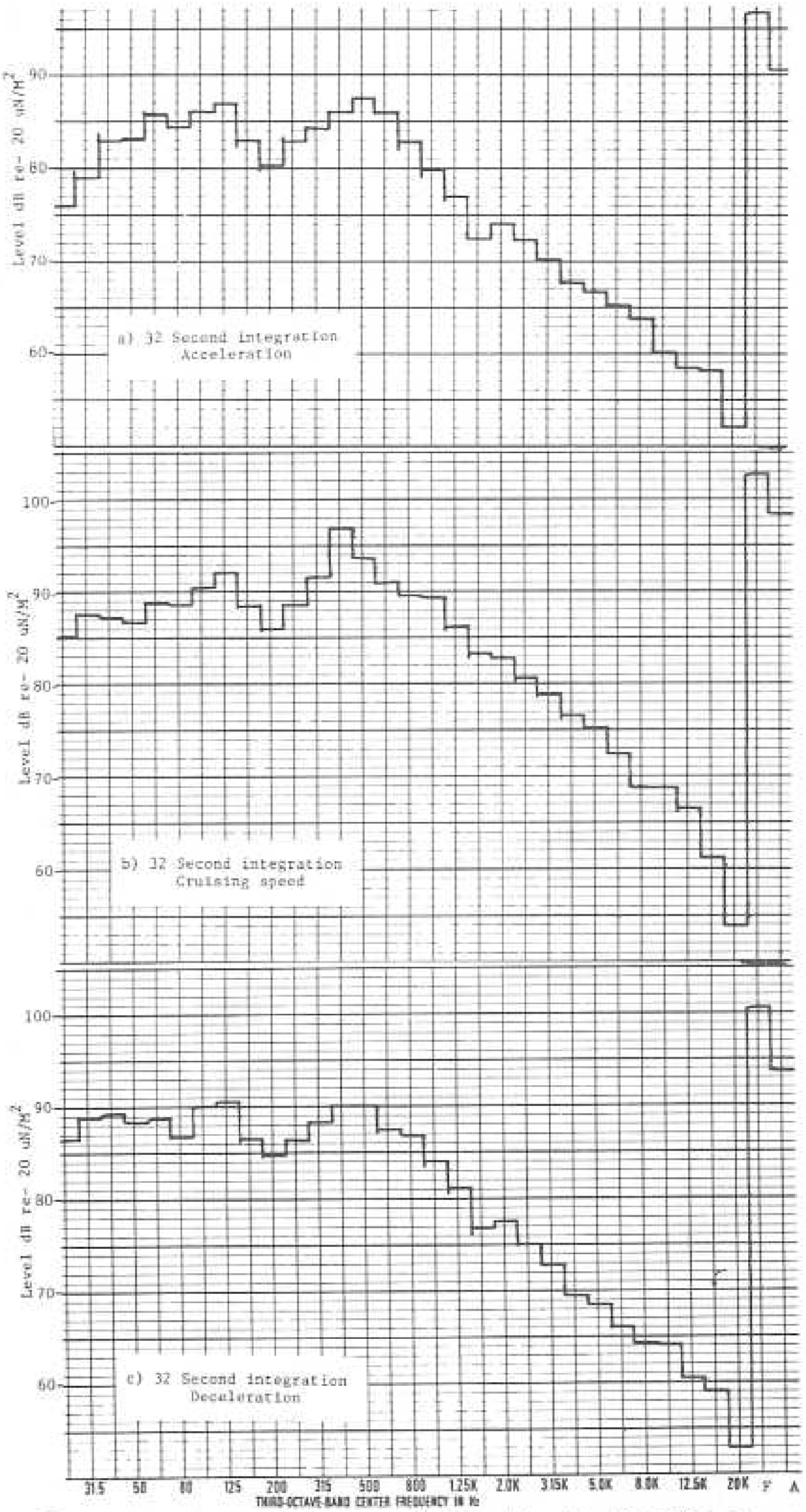


Figure D-4. Frequency Analyses of North-to-South Run at DOT HSGTC Pueblo, Colorado. Microphone Located on Outside Platform Between Cars 5.5ft. Above Platform Aug. 17, 1971 - See Figure D-1c.

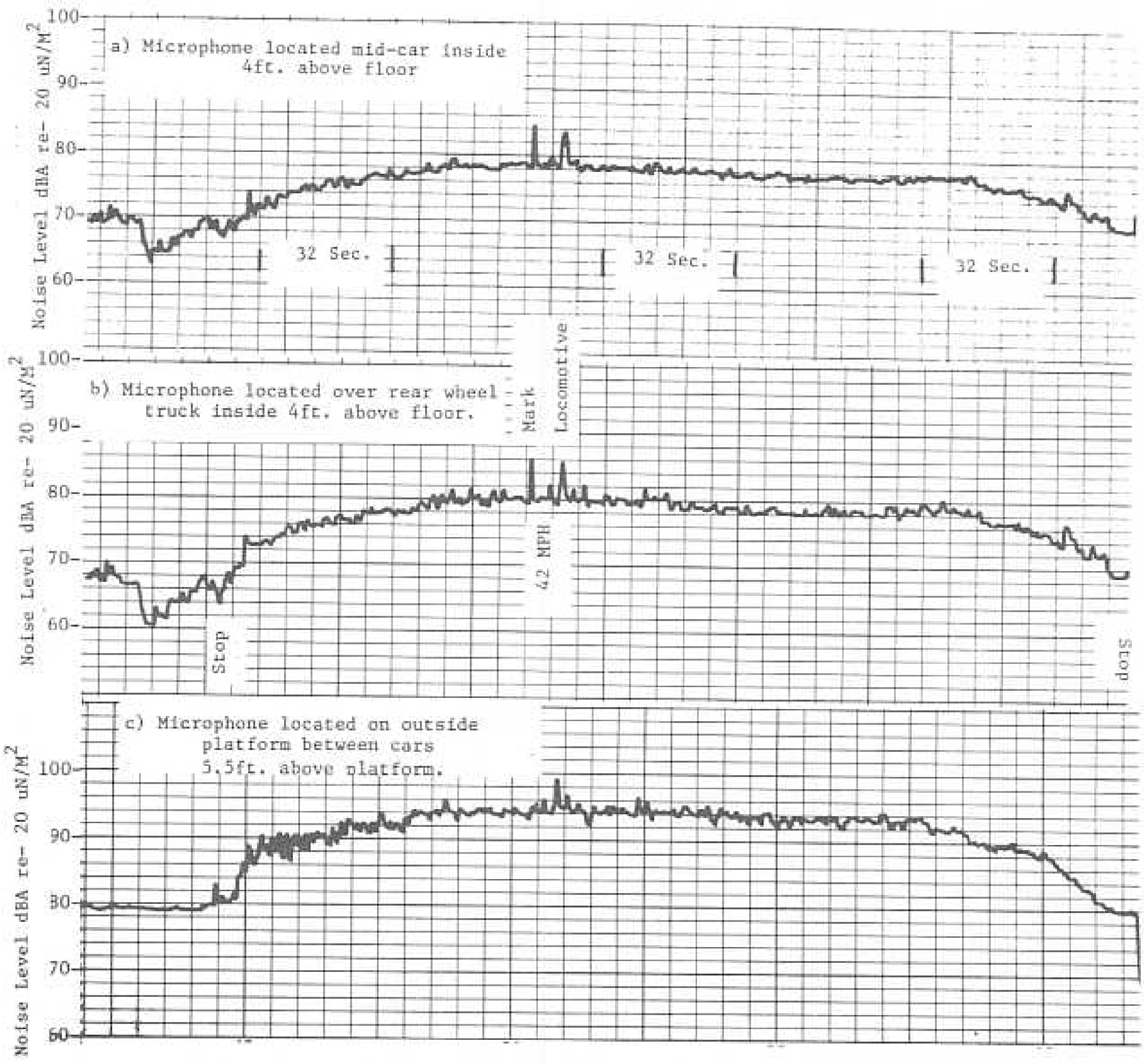


Figure D-5. Coincident Time Histories of Noise Levels at Three Locations in the Mark I Diagnostic Car during South to North Run at the DOT High Speed Ground Test Center, Pueblo, Colorado. Aug. 17, 1971 - See Figure F-1 for Microphone Locations.

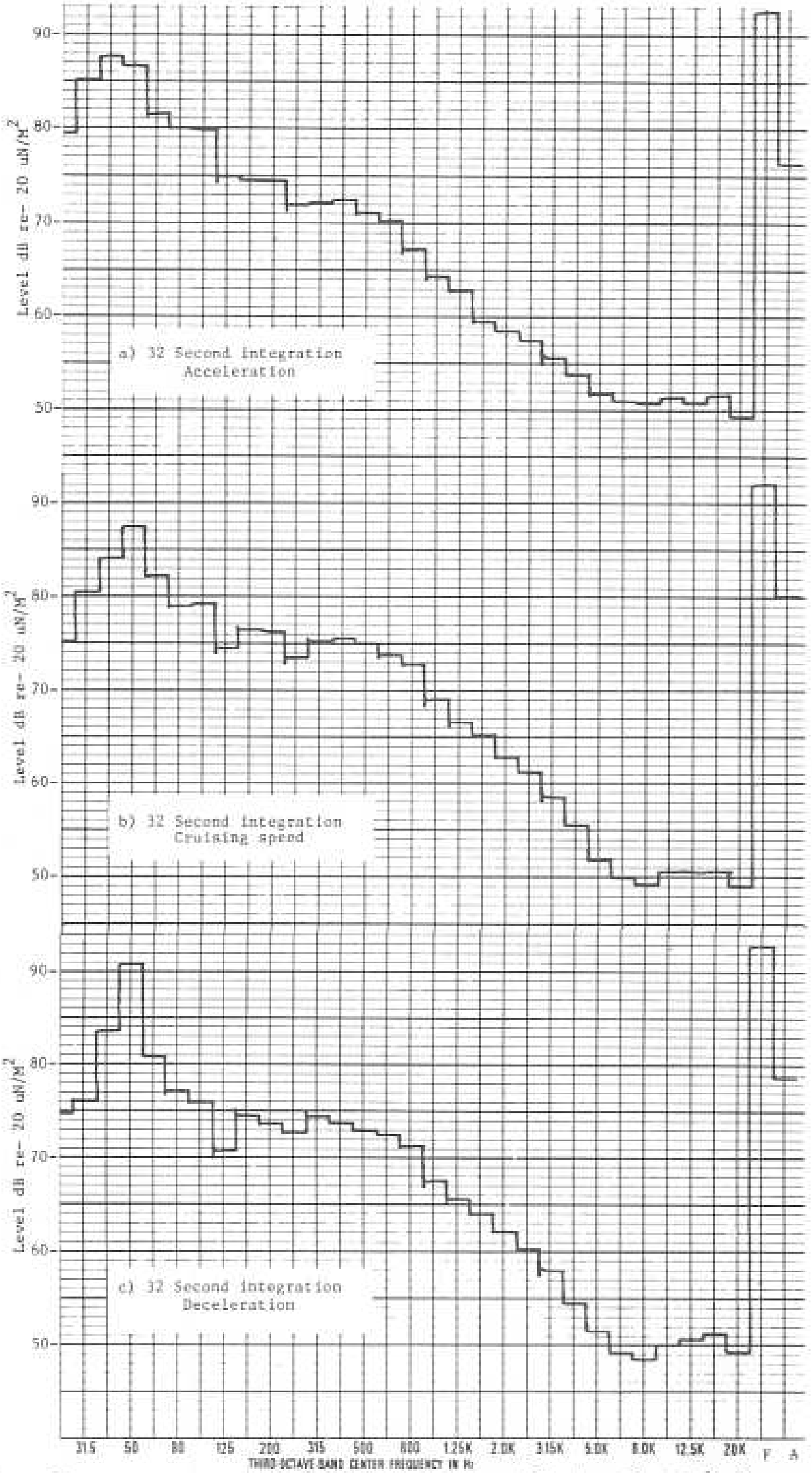


Figure D-6. Frequency Analyses of South-to-North Run at DOT HSGTC Pueblo, Colorado. Microphone Located Mid-Car Inside 4ft. above Floor. See Figure D-5a. Aug. 18, 1971.

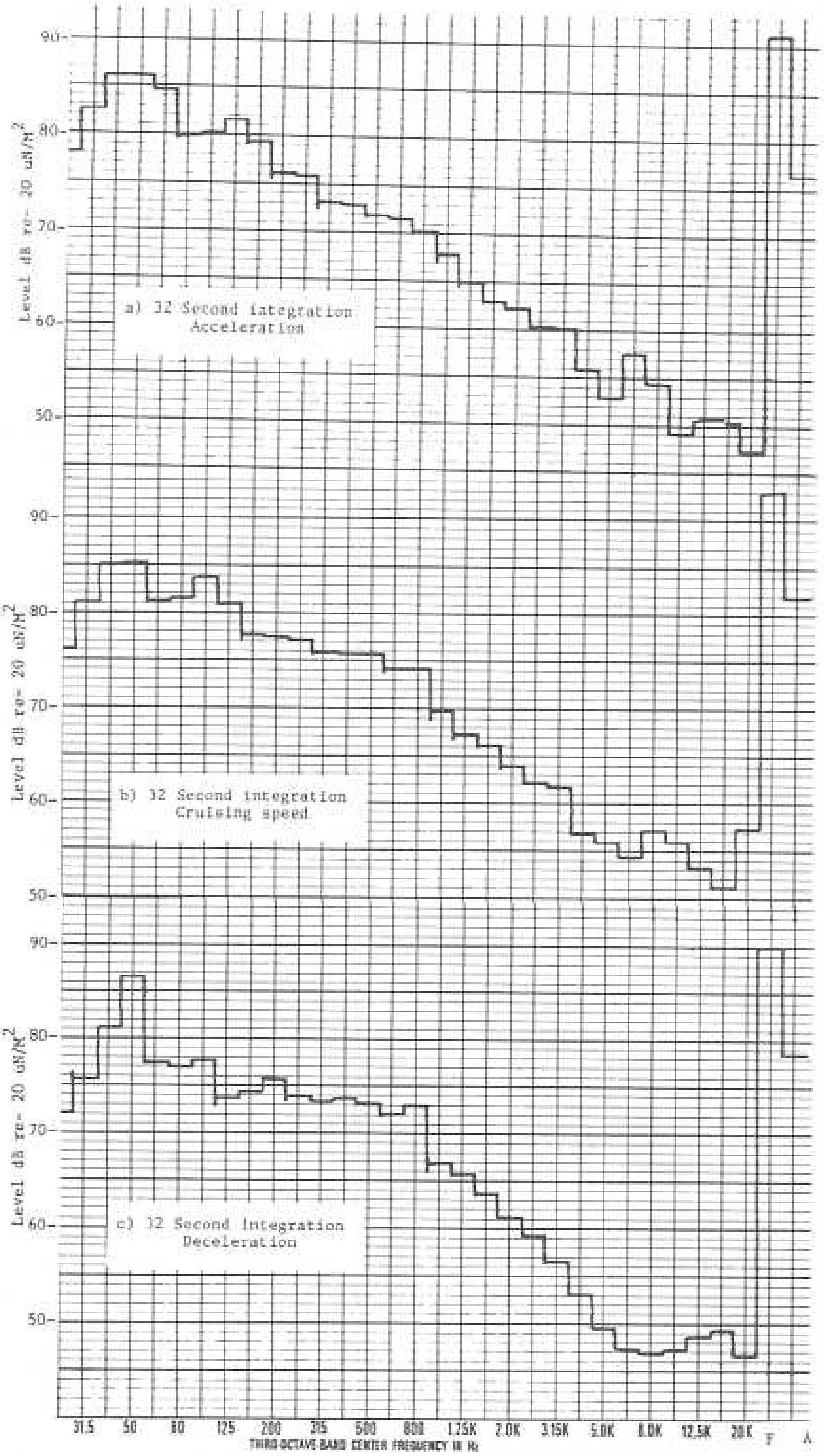


Figure D-7. Frequency Analyses of South-to-North Run at DOT HSGTC Pueblo, Colorado. Microphone Located over Rear Wheel Truck Inside 4 ft. Above Floor. Aug. 18, 1971.(See Figure D-5b)

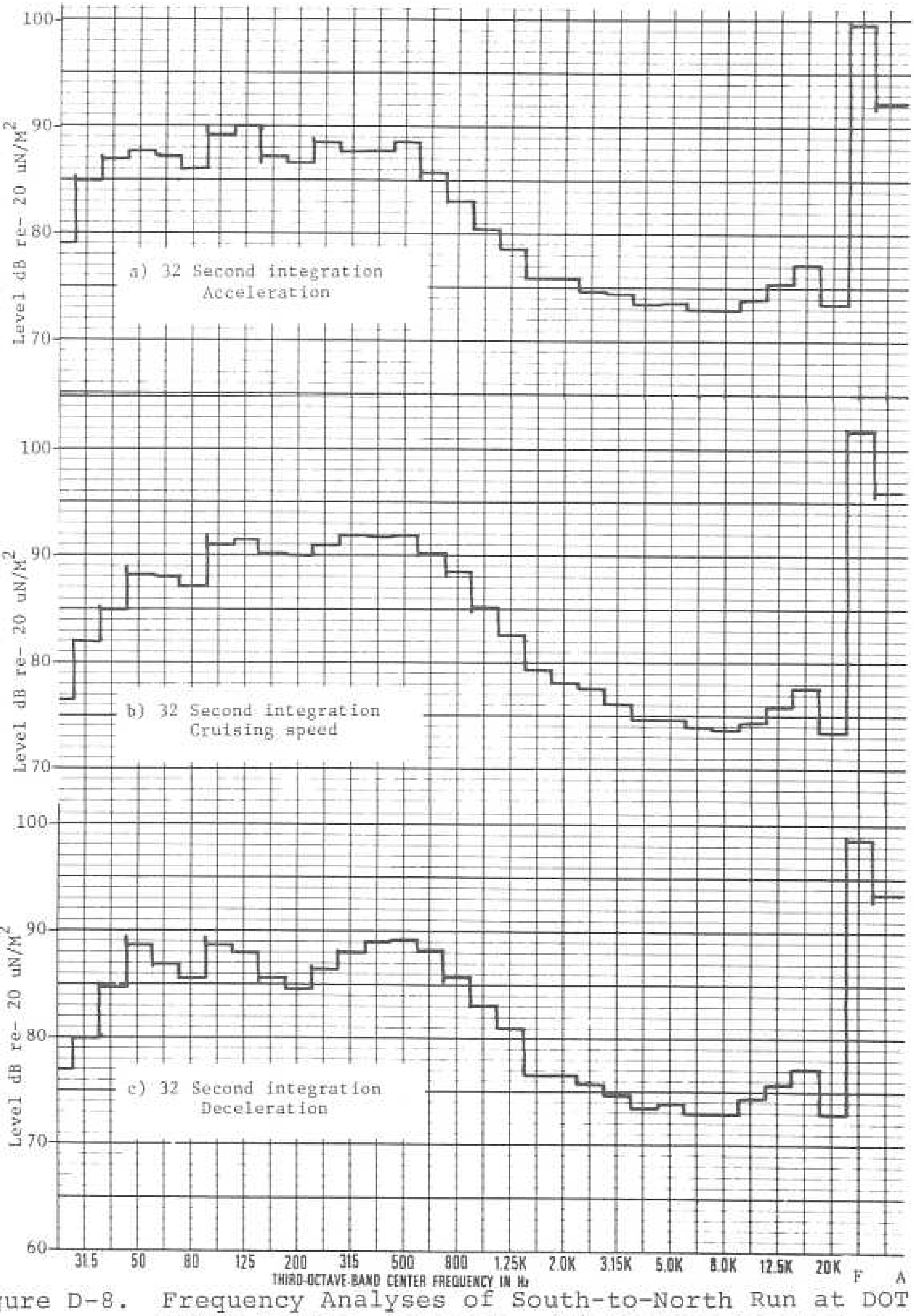


Figure D-8. Frequency Analyses of South-to-North Run at DOT HSGTC Pueblo, Colorado. Microphone Located on Outside Platform between Cars 5.5 ft. above platform Aug. 18, 1971 - See Figure D-5c.

APPENDIX E

Noise Data Measured at Trackside During Operation of Mark I Diagnostic Car as Two-Car Train of Type R42 Cars at DOT High Speed Ground Test Center, Pueblo, Colorado on August 19, 1971

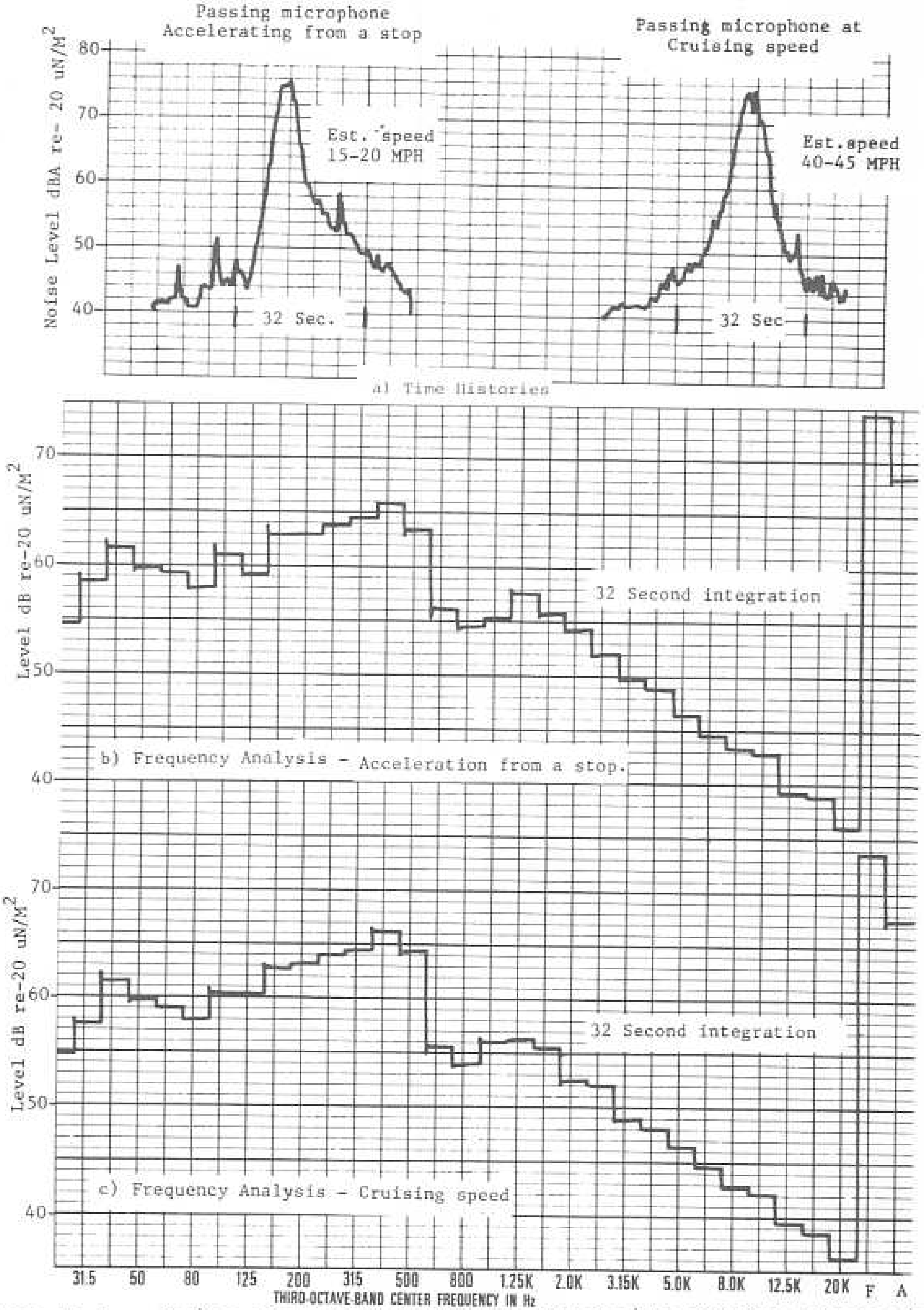


Figure E-1. Noise Data Measured at Trackside During Operation of the Mark I Diagnostic Car (2 Type R-42 Cars) at the DOT High Speed Ground Test Center Pueblo, Colorado. Aug. 19, 1971 - See Figure F-5 for Microphone Location.

APPENDIX F

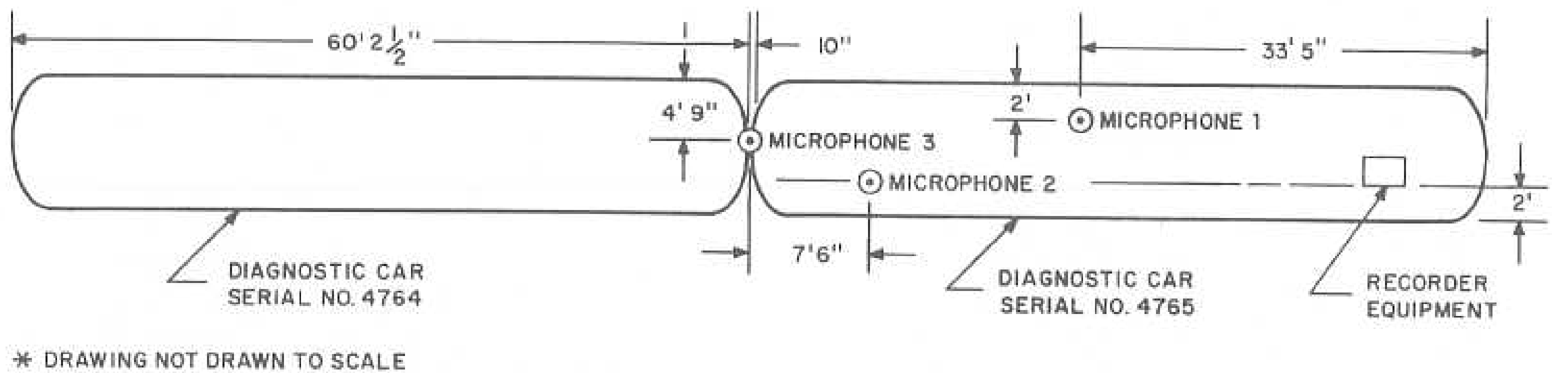
Microphone Locations

(Microphone Locations)

Microphones were set up at three locations in the test car: one microphone was placed at ear level to a seated passenger at a mid-car location (4 feet above the floor); a second microphone also at ear level to a seated passenger was placed inside the car over the rear wheel trucks; the third microphone was placed at ear level to a standing passenger (5.5 feet high) at a location on the outside platform between cars (see Figure F 1 and F 2). The same locations were used on the same cars during the measurements at the DOT Test Center and on the New York Transit Line.

Figures F-3 and F-4 depict the location of the microphone set up at a height of 5.5 feet in the 59th Street Subway Station of the "N" line on the New York City Transit System. The four tracks have been numbered 1 through 4 for convenience.

The position of the microphone at the side of the track at the DOT Test Center is shown in Figures F-5, F-6, and F-7. The microphone was placed at a height of 5.5 feet above the maintenance road surface. This placed the microphone approximately on a level with the floor of the transit car riding on the raised road bed.



1. MICROPHONE LOCATED MID-CAR AT EAR LEVEL TO A SEATED PASSENGER (4 FEET ABOVE FLOOR).

2. MICROPHONE LOCATED OVER REAR WHEEL TRUCK AT EAR LEVEL TO A SEATED PASSENGER(4 FEET ABOVE FLOOR).

3. MICROPHONE LOCATED ON OUTSIDE PLATFORM BETWEEN CARS AT EAR LEVEL TO A STANDING PASSENGER (5.5 FEET ABOVE PLATFORM).

Figure F-1. Microphone Locations Mark I Diagnostic Car (Type R-42)

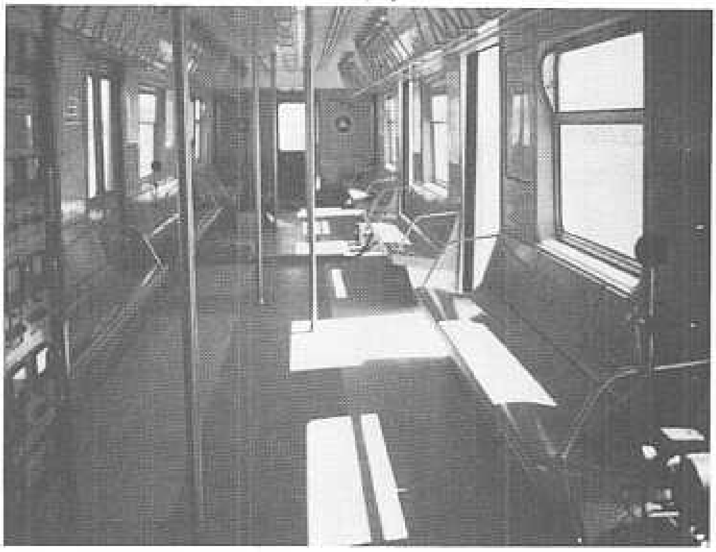


Figure F-2a. Inside Mark I Diagnostic Car Microphone Mid-Car on Left; Microphone Over Rear Wheel Truck on Right.

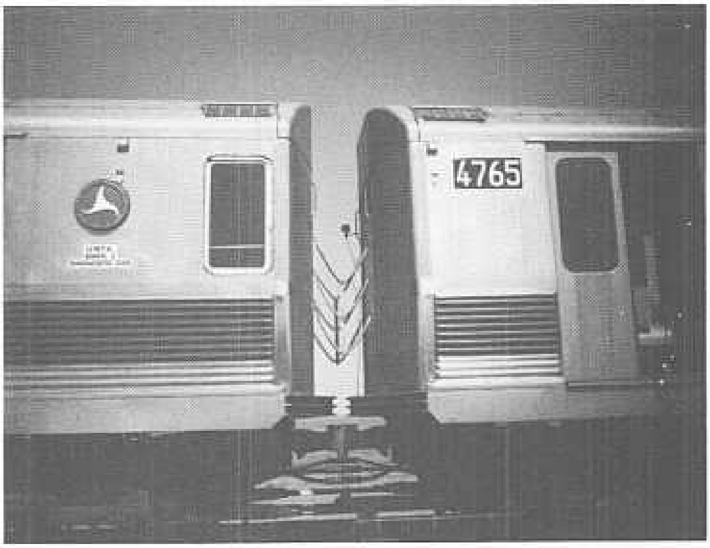


Figure F-2b. Microphone Located on Outside Platform Between Cars.

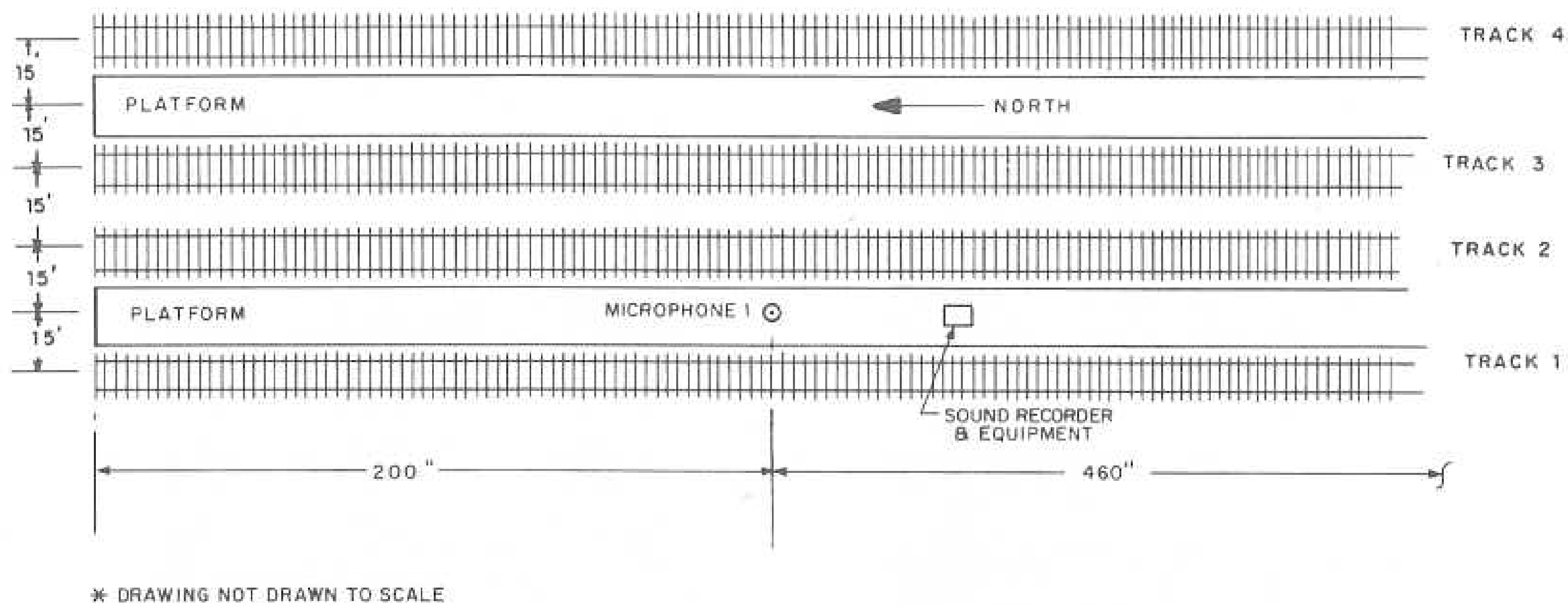
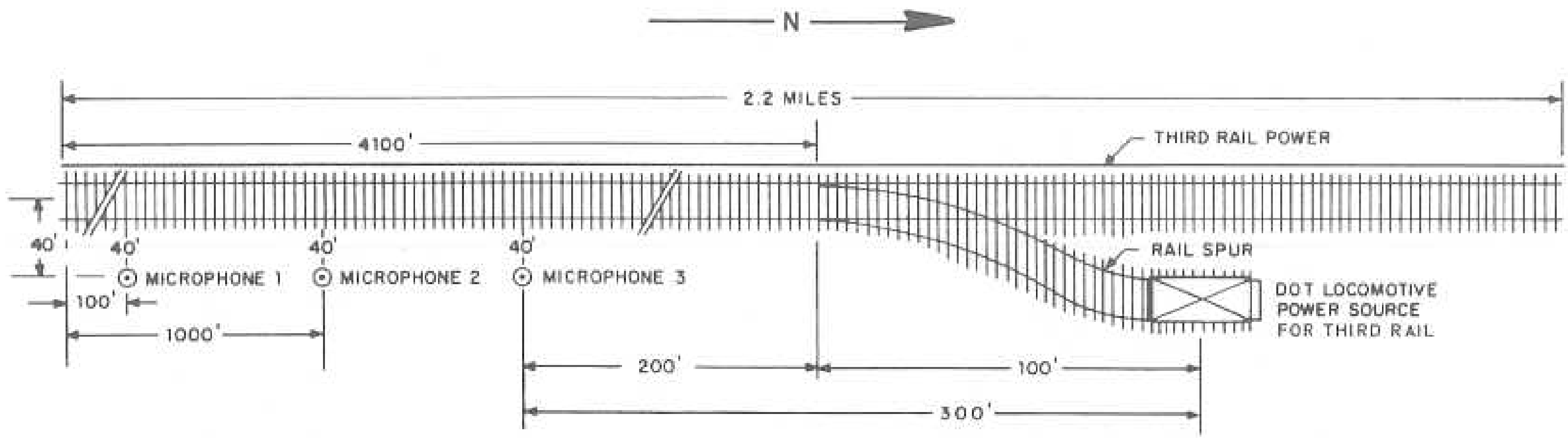


Figure F-3 Microphone Location Trackside in the 59th. St. Station New York City Transit System (Microphone 5.5 ft. High).

Figure F-4: Two Views of Microphone Located on Passenger Platform in 59th. St. Subway Station, NY City Transit System.



* DRAWING NOT DRAWN TO SCALE

1. MICROPHONE LOCATION MEASUREMENT OF NOISE LEVEL ACCELERATION FROM STOP POSITION.
2. MICROPHONE LOCATION MEASUREMENT OF NOISE LEVEL CRUISING SPEED TRAIN.
3. LOCATION OF MICROPHONE SIMULTANEOUS TRACKSIDE MEASUREMENT WHILE MEASURING INSIDE CARS.

Figure F-5: Microphone Location Trackside at DOT High Speed Ground Test Center, Pueblo, Colorado (Microphone 5.5 ft. High).

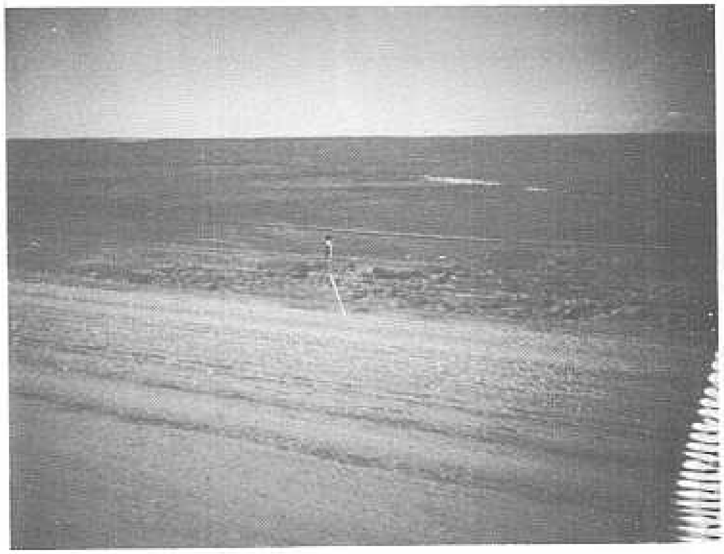


Figure F-6: Microphone No. 3 Trackside at the DOT - High Speed Ground Test Center, Pueblo, Colorado.

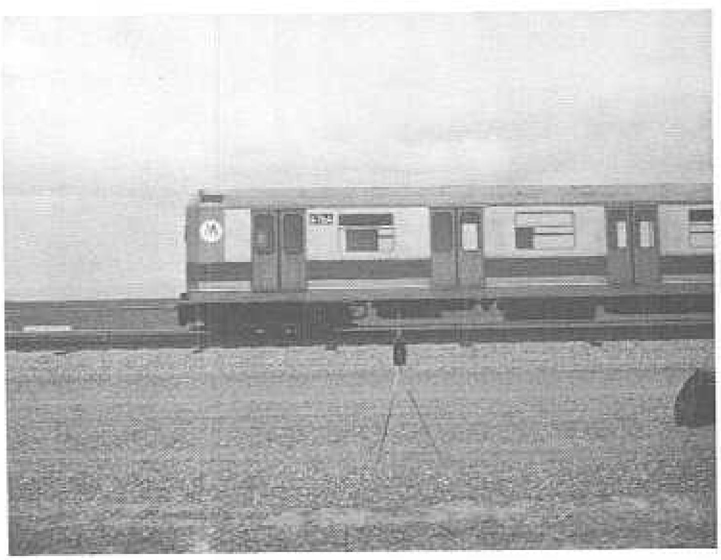


Figure F-7: Microphone No. 1 Trackside at the DOT - High Speed Ground Test Center, Pueblo, Colorado.

APPENDIX G

Measurement, Calibration, and Data Reduction Systems

Measuring Systems

For this noise measurement program, portable data-gathering equipment was used. The measuring system set up in the Mark I Diagnostic Car is shown in Figure G-1. Three microphone systems were used: one microphone placed inside in a mid-car location, a second inside at a location over the rear wheel trucks and the third microphone outside the car on the platform between cars. (Appendix F, Figure F-1)

Figure G-2 depicts the measuring system used to measure the noise data at track side locations.

In general, the same measuring systems were used in the New York City Transit System and at the DOT Test Center. The minor changes that were made would in no way affect a comparison of the data.

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 inches per second. The dynamic range of the recorder and measuring system was limited to 50 dB.

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

A calibration signal 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 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 calibration frequency selected, 1000 Hz, eliminated any necessity for A weight frequency response correction during system calibration. In addition, a passive microphone simulator was substituted for the microphone to determine the minimum discernable sound pressure level (Noise Floor) for the system.

Calibration Procedure

System field calibration included acoustic calibration of the data-gathering instrumentation using a General Radio (GR) 1562A Sound Level Calibrator. This calibrator produces an acoustic signal of 1000 Hz at a level of 114 dB re 20 micronewtons per square meter. The calibrator was placed on the microphone before and after each run and the signal recorded on tape. In the mobile laboratory the recorded calibration signal was used to adjust the gain in the data reduction instrumentation,

Figure G 3.

In addition, a passive microphone simulator was substituted for the microphone to insure that the system Noise Floor was below the minimum noise level expected at the measurement location. This signal was also preserved on tape.

Data Reduction

The configuration of the data reduction system is shown in Figure G-3. 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 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 level (root mean square) for each channel and converts this level to a digital output. Single integration or measurement periods were adjusted from 1/8 to 32 seconds. A statistical analysis of the measured noise was obtained by programming the detector to integrate for 1/8th second, compute the dB value of the "A" weighted filter output, and provide a binary coded decimal signal to the Wang Computing Calculator four times every second. This computer counted and totaled the number of samples at each sound level for a selected time period and displayed the results. These data were recorded and subsequently entered into a time-shared computer to produce statistical analysis printouts contained in Appendix A and C, Figures A11, A12, A13, and C7.

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 indices 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 Level and Walsh-Healey Exposure index. A complete description of these indices is contained in Appendix I to this report.

Some of the special events, such as wheel squeals, transit cars stopping and starting were analyzed in detail for their 1/3 octave band frequency distribution, using the same equipment described above. The Multichannel Detector was programmed to integrate for the time interval of the special event, compute the dB level for all 34 channels and provide the information to the DC Recorder which provided a hard copy (dB level vs. 1/3 octave bands) of the analysis of the sounds which occurred during the integration period. The Graphic Level Recorder simultaneously provided a time history of the special event, and time marks were placed on the graphic recording to show the start and end of the integration period.

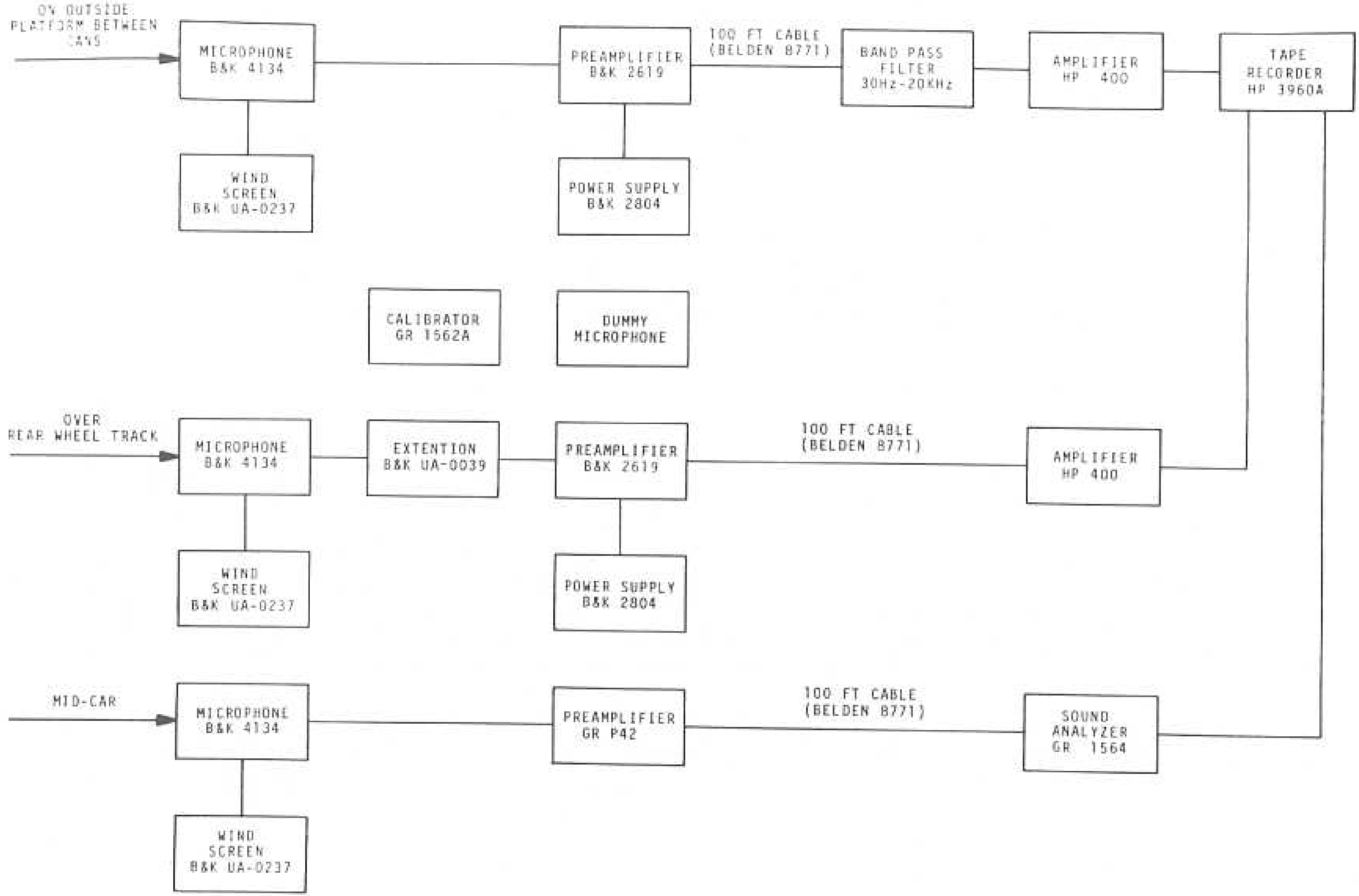


Figure G-1 Sound Measuring System on Mark I Diagnostic Car

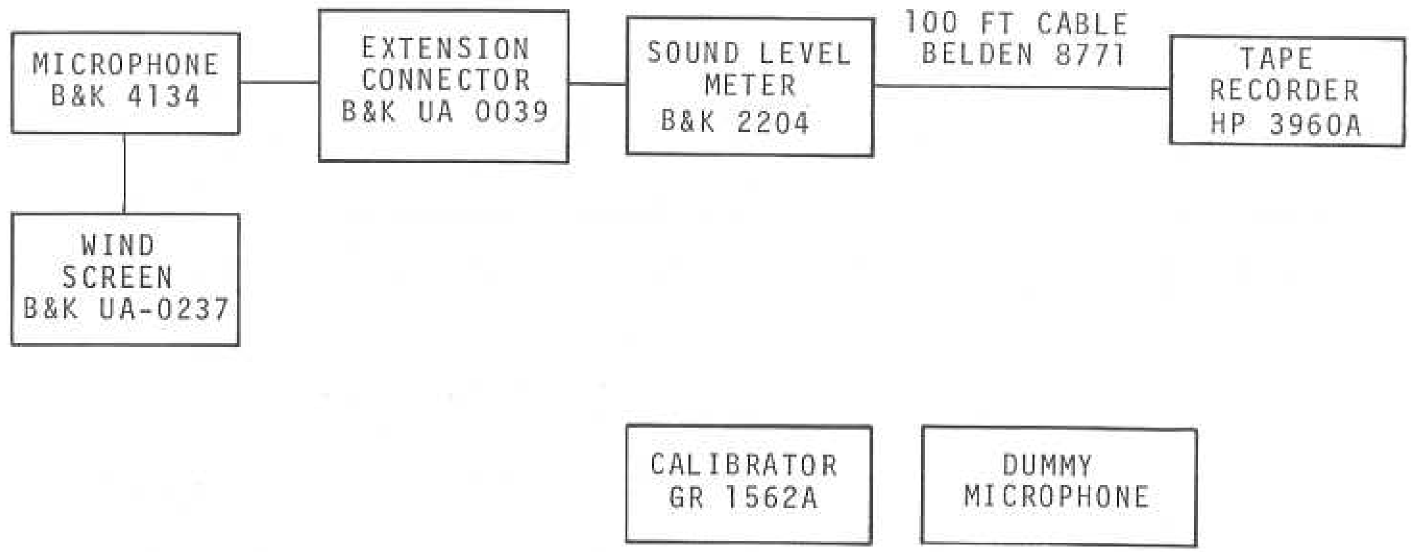


Figure G-2 Sound Measuring System Trackside

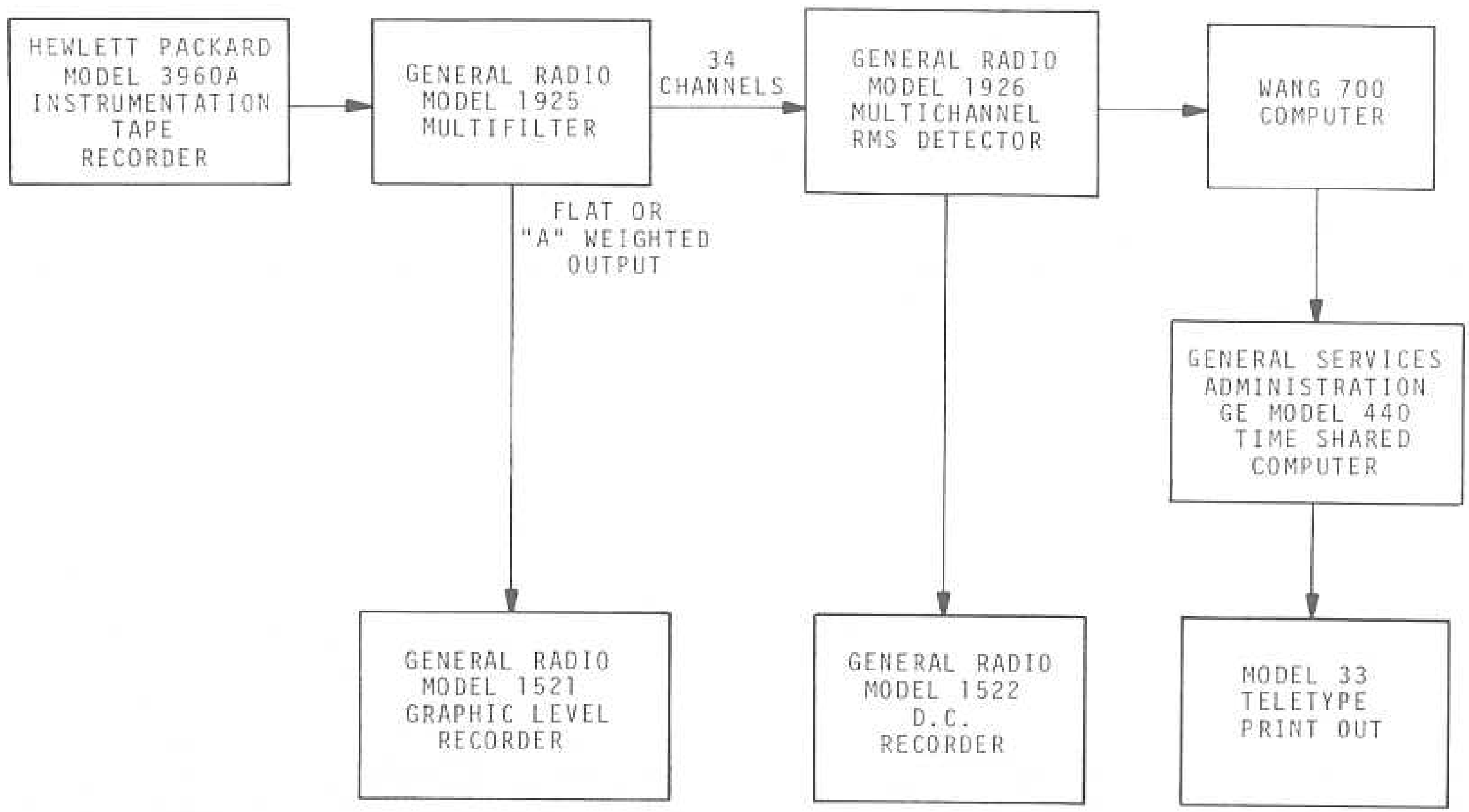


Figure G-3 Noise Data Reduction System

APPENDIX H

VIBRATION DATA

Accelerometers were attached to the journal box of the Mark I Diagnostic Car and recordings made of the accelerations measured in three axes during the test run on the N line on the New York City Transit System on May 6, 1971.

Two accelerometers were mounted to monitor Y-axis or lateral accelerations; three accelerometers were mounted to monitor Z-axis or vertical accelerations; and one accelerometer was mounted to monitor X-axis or longitudinal accelerations. The results of this test are shown in Figure H-1 and were provided by personnel of the Ground Systems Division of the Transportation Systems Development Directorate of the Transportation System Center.

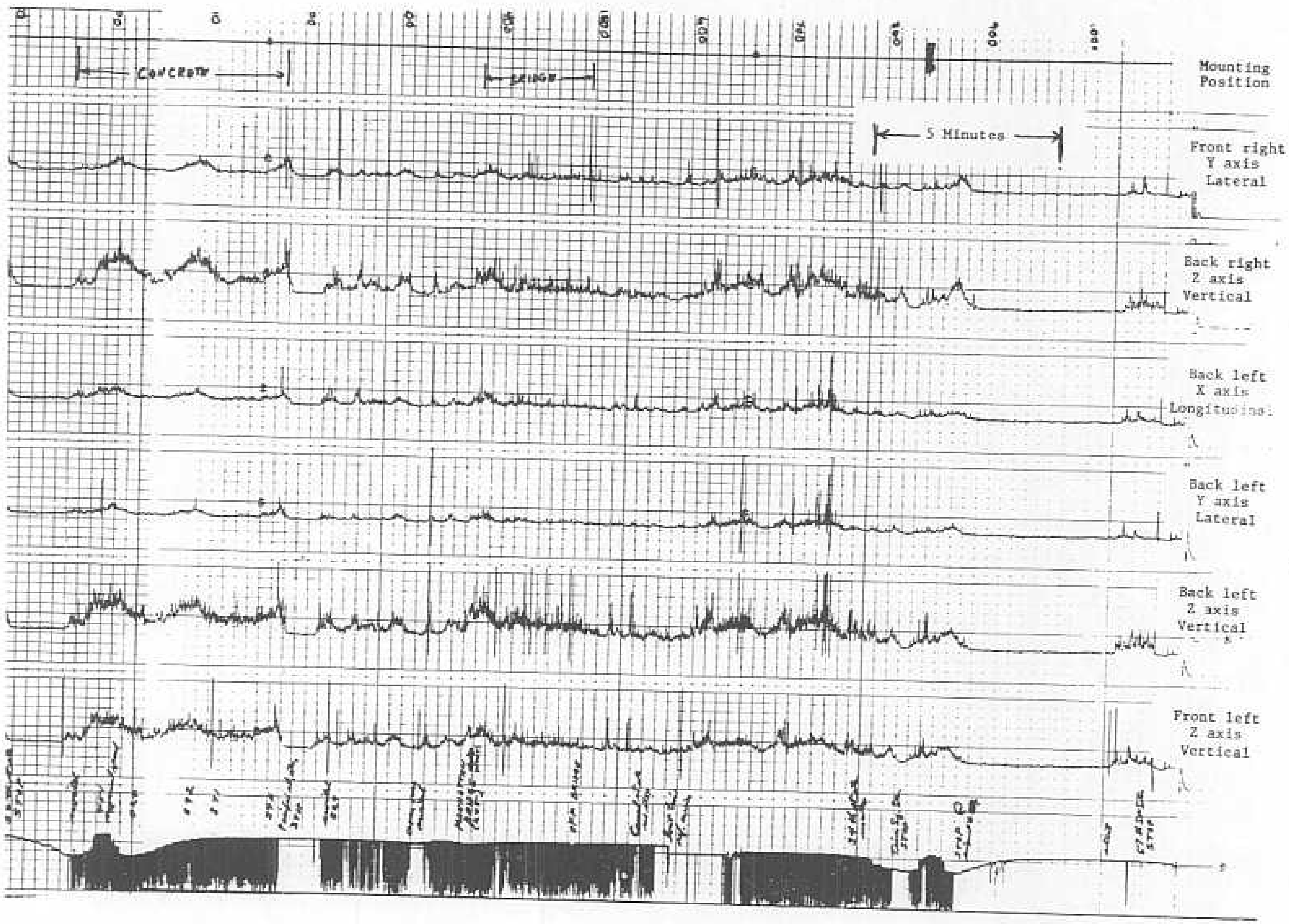
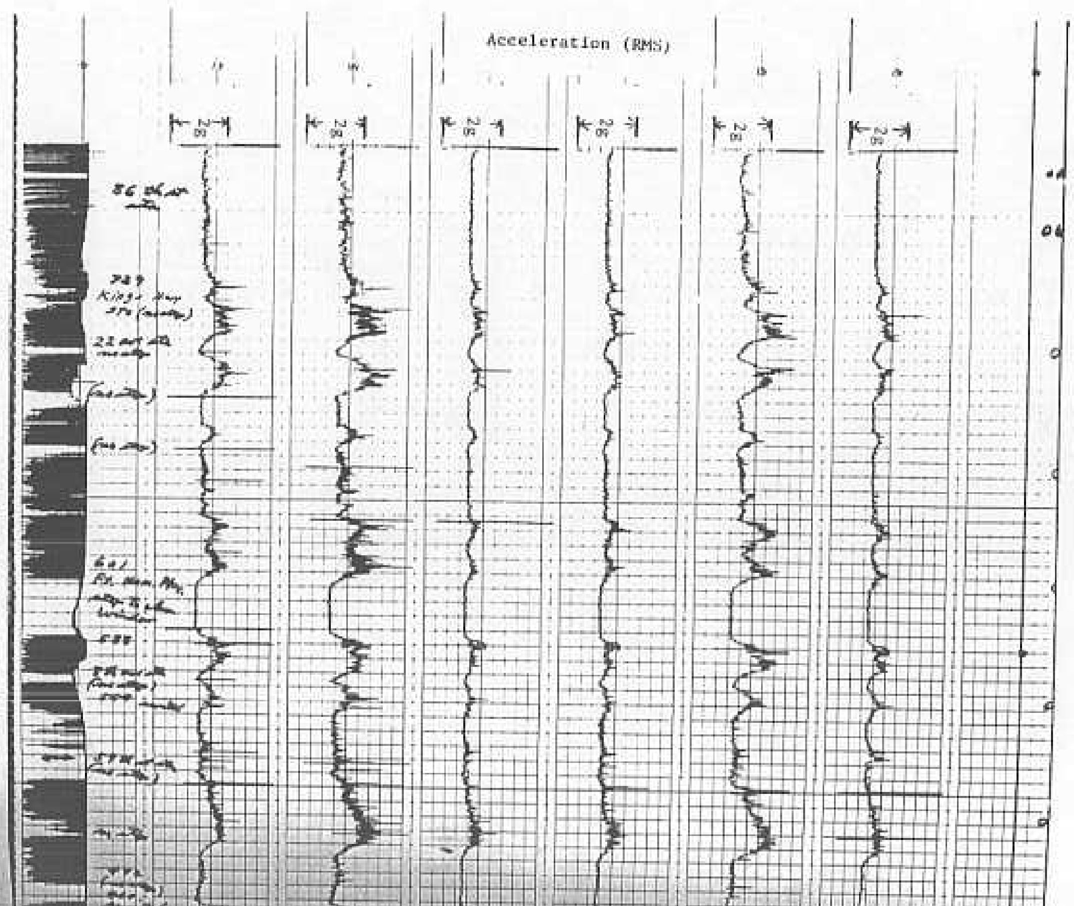


Figure H-1. Journal Box Acceleration. Mark I Diagnostic Car on "N" Line New York City Rapid Transit System. May 6, 1971



Acceleration (RMS)
2g
2g
2g
2g
2g
2g

APPENDIX I

DEFINITION OF TERMS AND CALCULATED VALUES

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 four samples per second to obtain the information contained in Appendix A and C, Fig. A-11, A-12, A-13 and C-7. The frequency response characteristics of the samples conformed to ANSI Standard for Sound Level Meters, S1.4, 1961 for "A" weighted sound pressure level.

The following terms and equations were used to compute the statistical and single number indices 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, ..., SPL_M

4. Samples at each Sound Pressure Level: C_1, C_2, ..., C_M

5. Relationships

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

   b. $SPL_M - SPL_1 + 1 = M$

6. dBA (A Weight) - 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. Reference sound pressure level - 20 micronewtons per square meter.

B. Statistical Equations

1. Cumulative Distribution, Percent (D_c)

$$D_c\, i = \frac{CM + CM-1 + \ldots + Ci}{N} \quad (100)$$

2. Statistical Distribution, Percent (D_s)

$$D_s\, i = \frac{Ci}{N} \quad (100) \qquad i = 1, 2, \ldots, M$$

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

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

4. Standard Deviation about average (s)

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

5. Energy Mean (L eq)

$$L\,eq = 10 \log_{10} \left[\frac{\sum_{i=1}^{M} C_i \, 10^{\frac{SPL_i}{10}}}{N} \right]$$

6. Noise Pollution Level (L_{NP})

$$L_{NP} = L\,eq + 2.56\, s$$

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.

   Range = $SPL_M - SPL_1$

9. Walsh-Healey Act

   a. The Walsh-Healey Act is a Federal Regulation limiting the industrial noise that a worker can be exposed to during a work day. This law is applicable to any company doing in excess of $10,000 worth of business with any agency of the U.S. Government.

   The Walsh-Healey 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 Walsh-Healey Act. Additionally, any one-time exposure over 115 dBA is a violation. In this report, if 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 Walsh-Healey exposure percentage is as follows:

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

where

W1 = Walsh-Healey 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

APPENDIX J

DESCRIPTION OF UMTA MARK I DIAGNOSTIC CAR (TYPE R42)

The R42 transit car is the latest model used on the "N" line in New York City. It operates as part of a two-car unit in an eight-car train. These cars were built by the St. Louis Car Company in conjunction with the Westinghouse Corporation who supplied the propulsion equipment. They were placed in service on the line during 1969 and 1970.

The R42 car has a stainless steel exterior with a blue strip; weighs 74,400 lbs, is 60 feet long, 10 feet wide, and 12 feet high. It will carry 220 passengers at cruising speeds of 50 mph. Powered by four direct current motors of 100 horsepower each, operating at 600 volts derived from a third rail, it has an acceleration rate of 2.5 miles/hr per second and a braking rate of -3.0 miles/hr per second.

Each car has three braking systems; mechanical for parking, air for normal and emergency use, and electrical dynamic for normal use. Each car is air-conditioned by two nine-ton units.

The Urban Mass Transportation Administration (UMTA) has acquired a two-car unit to serve as a mobile laboratory. It is this unit which was tested in the New York City subway and at the High Speed Test Center at Pueblo, Colorado. The cars have been instrumented and designated as the UMTA Mark I Diagnostic Cars. These cars will aid in calibrating the Rapid Rail Test Track at the Center and in developing instrumentation for a second generation Mark II car which is scheduled for operation by the fall of 1972. The Diagnostic Car Mark II will also serve as a mobile test laboratory to measure ride quality, rail alignment, and track geometry while operating at scheduled speeds on transit track. In addition to performing automated track measurement, the vehicle will serve as a mobile laboratory for noise and vibration investigations and instrumentation development.

Based at the newly established DOT Test Center at Pueblo, Colorado, but compatible with transit properties throughout the United States, the Diagnostic Car (Mark II) will be used for on-site assistance to these properties. Photographs of the Mark I Car are contained in Figures J-1, J-2, F-2 and F-7.

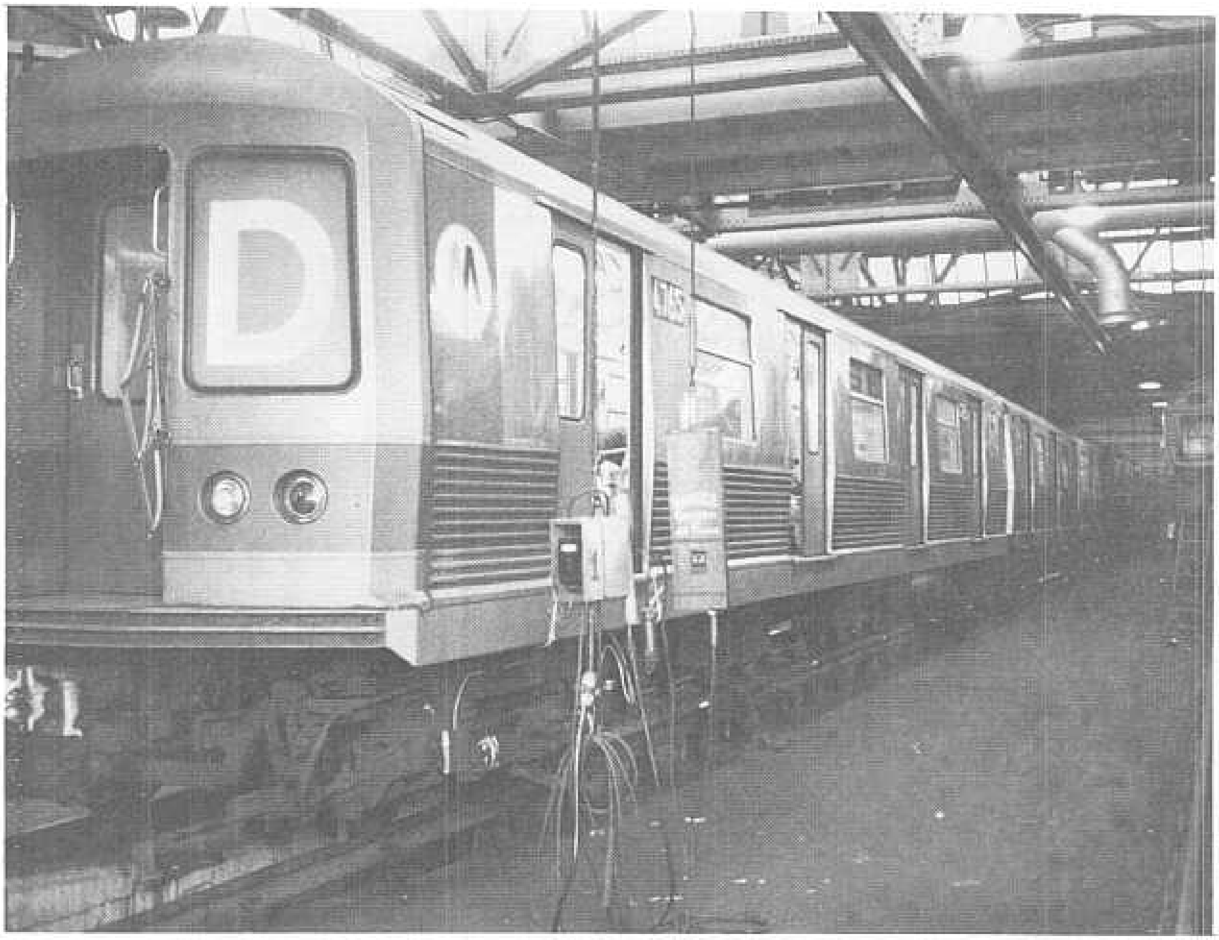


Figure J-1. UMTA Mark I Diagnostic Car
Coney Island Bay Shop NYC

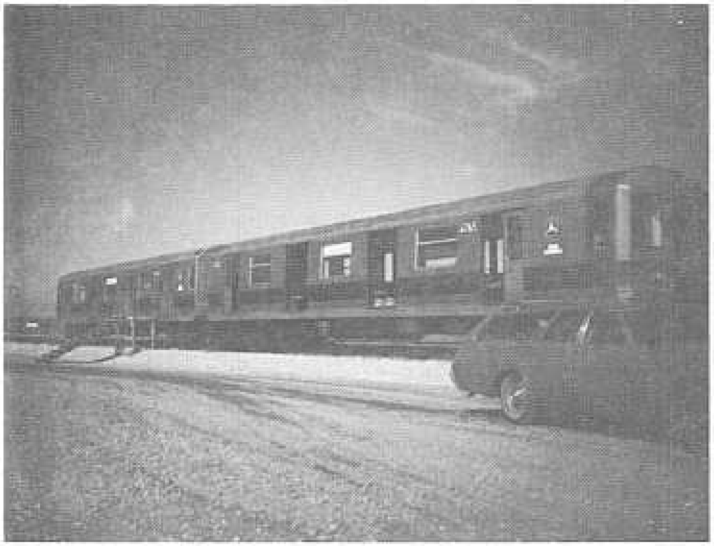


Figure J-2. UMTA Mark I Diagnostic Car
DOT High Speed Ground Test Center
Pueblo, Colorado

APPENDIX K

MAP
NEW YORK CITY TRANSIT SYSTEM
(N LINE)

R R