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NOISE ASSESSMENT OF THE BAY AREA RAPID TRANSIT SYSTEM

S.L. Wolfe
H.J. Saurenman
P.Y.N. Lee

Wilson, Ihrig & Associates
5605 Ocean View Drive
Oakland, CA 94618

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INTERIM REPORT

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16. Abstract

This report describes the noise on and near the San Francisco Bay Area Rapid Transit System (BART). It is one of a series of coordinated assessments sponsored by the Urban Mass Transportation Administration and technically administrated through the Transportation Systems Center of the U.S. Department of Transportation. BART has approximately 75 miles of two-way revenue track (of which 19.7 miles are in subway) and 34 stations. Noise data is given for specific measurements made in cars, in stations and along the non-subway wayside at appropriate locations. Based on these measurements, the average in-car maximum A-weighted sound levels, L_A (Max), are estimated to be in the 70 to 79 dBA interval for 72 percent of the BART route. Wayside L_A (Max) levels, at 15 m (50 ft) from the near track, are in the 85 to 94 dBA interval for 90 percent of the above ground route mileage. Station L_A (Max) levels are in the 75 to 84 dBA interval for 94 percent of BART stations.

The rationale for choice of measurement sites and the methodology for arriving at the summary noise distributions from the data is discussed explicitly. Measurement and analysis instrumentation and procedures are also described.

17. Key Words
Noise, Rapid Transit, Transportation Noise, Measurement Methodology, Instrumentation, Data Analysis, Community Noise, Station Platform Noise, Vehicle Noise

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PREFACE

This report has been prepared under the Urban Rail Noise Abatement Program being sponsored by the Urban Mass Transportation Administration's (UMTA's) Office of Rail and Construction Technology. The Noise Abatement Program is being managed at the Transportation Systems Center for UMTA. The objectives of the Noise Abatement Program are to assess noise produced by urban rail transit operations and to appraise methods and costs for reduction of such noise.

This report is one in a series of six noise assessment reports covering noise due to transit operations on seven rail transit systems in five U.S. cities. Consistent results of the six assessments were achieved through use of standardized noise measurement and data reduction procedures developed at TSC and tested on the Massachusetts Bay Transportation Authority (MBTA) in Boston. The assessment report for the MBTA was published in 1974 (Reference 1).

Physical differences among the transit systems, as well as differences in the technical orientations of the teams, and in funds available to the teams for measurement and analysis, led to some differences in report organization, technical depth and writing style. Therefore, to provide at least introductory consistency among the reports for the reader, the front material, including the introduction of each assessment report, has been edited at TSC. The organization and technical content of each report, however, are basically as originally written by the respective teams and are, together with the accuracy of the measurements, the responsibility of the authors.

This report has been prepared by Wilson, Ihrig & Associates, Inc. under subcontract to the Boeing Vertol Company under Contract DOT-TSC-850. The measurement, analysis and discussion of the data in this report were performed by Steven L. Wolfe, Hugh J. Saurenman and Peter Y. N. Lee. Technical guidance and review were provided by Dr. George Paul Wilson. Dr. Edward G. Apgar and Dr. Robert Lotz were technical monitors of the program. Dr. Leonard Kurzweil of the Transportation Systems Center directed the final technical editing of the report.

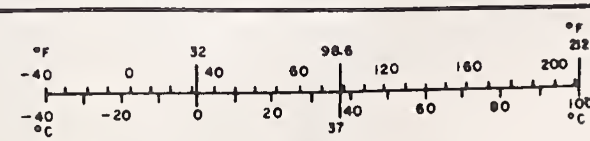
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF DEFINITIONS

L_A(Max) - Maximum A-weighted sound pressure level for a given noise event, measured in dBA.

AL_i - Instantaneous A-weighted sound pressure level for sample "i", measured in dBA.

L_{eq} - Equivalent Sound Level - in dBA.

$$L_{eq} = 10 \log \left[\frac{\sum_{i=1}^{n} \text{antilog } (AL_i/10)}{n} \right]$$

n - Number of samples of AL in a specified time period.

L_{dn} - Day-Night Equivalent Sound Level-in dBA.

$$L_{dn} = 10 \log \left[\frac{\sum_{i=1}^{n} 10^{(L_{eq}/10)} W_i \bullet T_i}{24} \right]$$

W_i - Time of day weighting factor

W_i(0700-2200) = 1

W_i(2200-0700) = 10

T_i - Time interval for "i"-th period

L_R - L_A(Max) + 10 log T_5, in dBA

T_5 - Duration between the 5 dBA-down-from-L_A(Max) points measured in seconds

L_X - The A-weighted sound level equaled or exceeded X% of the time-in dBA.

SENEL - Single Event Noise Exposure Level, measured in dBA.

$$\text{SENEL} = 10 \log \left[\sum_{i=1}^{n} \text{antilog } (AL_i/10) \bullet \Delta t \right]$$

Δt - Effective duration of noise event, measured in seconds.

CNEL - Community Noise Equivalent Level-in dB.

$$\text{CNEL} = 10 \log \left[\frac{\sum_{i=1}^{n} W_i' \bullet \text{antilog } (\text{SENEL}_n/10)}{86400} \right]$$

W_i' - Time of day weighting factor

$$W_i' \ (0700\text{-}1900) = 1$$

$$W_i' \ (1900\text{-}2200) = \sqrt{10}$$

$$W_i' \ (2200\text{-}0700) = 10$$

Hz - Frequency, measured in cycles per second

1. SUMMARY

The Urban Mass Transportation Administration is supporting a program under the technical administration of the Transportation Systems Center to determine the noise climate of the major rapid rail transit systems in the United States and to assess the impact of that noise on patrons, employees and wayside communities. The results are to be used in determining approaches and associated costs to reach various selected noise abatement levels. The methodology, measurement techniques, and analysis are common for all systems studied so that results can be compared. Noise assessment reports, covering each of the major rapid transit systems, are being issued as a series.

The San Francisco Bay Area Rapid Transit (BART) System, described in this report, consists of approximately 75 miles of two way revenue track of which 22 are subway, 23 elevated, and 30 at-grade trackage.

Track structures range over a wide variety of types, and the system passes through a variety of wayside environments (above-ground) including residential, industrial and commercial.

BART facilities and equipment include many features intended to reduce noise and vibration to lower levels than those of traditional rail rapid transit systems. The system uses continuous-welded rail; and rail grinding is employed to maintain smooth rail surface. Wheel grinders and lathes are employed to maintain wheels in smooth condition. Sound absorption treatment is incorporated in subway stations.

There are two configurations of the BART Car -- the A and the B. The A-car contains the operator's cab and the automatic train operation equipment. The B-car does not have the above features, but otherwise is identical. A standard revenue train consists of from two A-cars to two A-cars with eight B-cars. Scheduled speed is approximately 45 miles/hour with a maximum speed of 80 miles/hour. Each car axle is powered and each car has a 12-ton air conditioner with automatic heating and cooling control.

BART cars were designed with the following considerations:

1. Equipment noise and vibration level performance limits,
2. Car body sound insulation performance requirements,
3. Lightweight trucks with minimal upsprung weight, vibration isolation, and low noise braking system.

Noise assessment was of three general types:

1. Community noise

2. Station noise
3. In-Car noise.

Conditions for each type of measurement were standardized as far as possible for supporting later analysis and for ensuring comparability of results with those of other systems. In addition to the acoustic data channels, one channel of a tape track was provided for comments by the measurement observer to assist in the later description or explanation of the noise environment and phenomena.

Noise recordings were made with standardized instrumentation having a flat (unweighted) frequency response characteristic. Field calibration was performed during the data acquisition. In addition equipment was periodically calibrated using Class 2 NBS standards.

Detailed results are too extensive to show in this summary. However, the following estimates in dBA, were determined for the entire BART system (See Table 1.1).

TABLE 1.1. AVERAGE MAXIMUM A-WEIGHTED SOUND LEVEL DISTRIBUTION ON THE BART SYSTEM

	SOUND LEVELS IN dBA						
	65 to 69	70 to 74	75 to 79	80 to 84	85 to 89	90 to 94	95 to 99
Car Interior (Percent of Route Mileage)	8	43	29	20	0	0	0
Wayside at 50 ft (15m) Distance (Percent of Above Ground Route Mileage)	0	0	2	8	54	36	0
Station Platform (Percent of Stations)	0	0	18	76	6	0	0

2. INTRODUCTION

2.1 Program Scope

This report describes the noise climate of the San Francisco Bay Area Rapid Transit (BART) System. The work is part of a noise assessment study by this contractor which included BART, Southeastern Pennsylvania Transportation Authority (SEPTA), the Port Authority Transit Corporation (PATCO), and the Greater Cleveland Regional Transit Authority (RTA), formerly the Cleveland Transit System (CTS). Similar assessments have been undertaken by separate contractors of the Chicago Transit Authority (CTA), the New York City Transit Authority (NYCTA), and the Port Authority Trans-Hudson (PATH). The noise assessments for the PATCO, SEPTA, and RTA systems, as well as for those systems considered by other contractors, are reported in other documents of this series.

This work was done as part of an Urban Mass Transportation Administration (UMTA) program to assess the noise produced by various U.S. urban rail transit operations and to appraise methods and costs for reduction of such noise. The characterization of the noise climate of each rail transit system, carried out in a uniform manner, provides data to assist in determining UMTA priorities and funding decisions. The noise assessment activity has three elements:

1. Noise climate assessment.
2. Consideration of abatement technique options.
3. Cost estimation for abatement to specified noise levels.

Specifically, this activity allows noise level comparisons (a) of systems, (b) of different types of equipment or track structures on the same system, and (c) before and after noise control actions. It also provides data pertinent to the establishment of possible regulatory action to control noise levels.

The specific purpose of the work reported in this volume was to measure and otherwise describe the noise climate of the BART system as well as to describe the measurement and analysis methodology used.

The noise climate and associated information includes descriptions of the various sources and paths of noise, and their relative contribution to the noise climate at the point of measurement.

Each of the four BART lines was surveyed and classified by vehicle type, station type, roadbed construction type, and type of wayside land use. Representative measurement locations were then defined for each of these categories as well as for other locations with specified singularities (unique noise characteristics). This approach, common to all assessments, is based on the noise assessment of the Massachusetts Bay Transportation Authority (MBTA), (Reference 1), which served as a pilot study for these later assessments. Consistency of results were achieved through the use of a standardized noise measurement and data reduction process. This process was successfully validated through "round robin" tests in which the assessment teams made simultaneous measurements of noise from Massachusetts Bay Transportation Authority trains and, without communication between teams, reported the resulting reduced data. The findings of all teams correlated well.

For the purposes of this assessment activity, it is adequate to measure a limited, but statistically sufficient number of vehicles, stations, and community sites, selected to cover the major construction and operating features of the system.

The present data describe the existing system noise climate and permits a first order estimate of abatement techniques and associated costs to satisfy reduced noise level criteria. When a preliminary investigation such as this reveals noise problems, and a decision is made to proceed with their solution, more detailed measurements and analyses must be made. Normally, this would include detailed diagnostic measurements to identify the dominant sources and paths for engineering design of site-specific noise control treatments.

2.2 Reader's Guide to Report

The general measurement methodology, including sampling strategy for measurement site selections, site conditions, microphone positions, and measurement procedures for community, station, and in-car noise assessments are presented in Section 3. Details of the instrumentation and data analysis procedures are given in Section 4. Section 5 includes an overview of the BART system (Section 5.1) followed by a detailed description of the measurement results. The principal findings are summarized in Section 6.

3. GENERAL MEASUREMENT METHODOLOGY

3.1 Wayside Community Noise

Sampling Strategy - The purpose of this survey was to determine noise levels in the wayside community caused by revenue train operations. Measurements of noise in the community have been categorized, as shown in Table 3.1, by source, path and receiver. In each case, the variables which affect either the physical noise during generation, propagation, or reception, or the response of the listener to that noise, have been itemized. The type of rail car in use, as well as the rail type and quality, tend to be the same within each transit line investigated. However, a wide variation in roadbed type, background noise, conditioning of residents to noise, and land usage was noted.

Except for areas where wheel squeal, rail joint noise or other noise singularities prevailed, the sites were selected based on operational characteristics of the transit systems. Thus, locations were selected along the wayside to ensure measurements over the range of normal operating conditions, including full speed operations as well as characteristic acceleration and deceleration near stations.

Complete noise measurements at each site are costly and time consuming as well as unnecessary for defining the community noise of each system. Therefore, sites were selected to ensure a representative sampling based on the following parameters:

Track Structure Type

(1) Aerial Structure
(2) At-grade
(3) Underground
(4) Other sites with singularities

Building Construction Type

(1) Residential
(2) Commercial

The measuring microphone for all types of transit structures was 1.6 m (5.3 ft) above the ground. Previous BART wayside noise measurements for aerial structure operations indicated that the differences in the noise levels measured 1.5 m (4.9 ft) above grade and 9.1 m (29.9 ft) above grade at 15 m (50 ft) from the near track centerline were negligible as shown in Figure 3.1. Thus, it was not necessary to obtain noise measurements 1.2 m (4 ft) above the top-of-rail for aerial structure operations. Wayside noise measurements made 1.5 m (4.9 ft) above the ground were sufficient to characterize the wayside noise from aerial structure operations at 15 m (50 ft) or more from the near track centerline.

TABLE 3.1 BART COMMUNITY NOISE SURVEY STRATEGY

Sound Source Parameters

Car
  No. Cars, Wheel Quality

Rail Type
  Welded, Surface Roughness, Type of Fastener
  (i.e. ballast and tie, concrete trackbed)

Track Construction
  Tangent, Curve

Sound Path Parameters

Roadbed Type
  Open-cut (Concrete, Grassy), At-grade, Elevated
  Structure (Concrete, Composite-Concrete deck
  with steel box girder), Underground

Terrain Attenuation
  Housing Density, Terrain Type

Sound Receiver Parameters

Background Noise

Time of Day (Waking/Sleeping)

Conditioning of Residents to Noise

Land Use
  Residential, Commercial

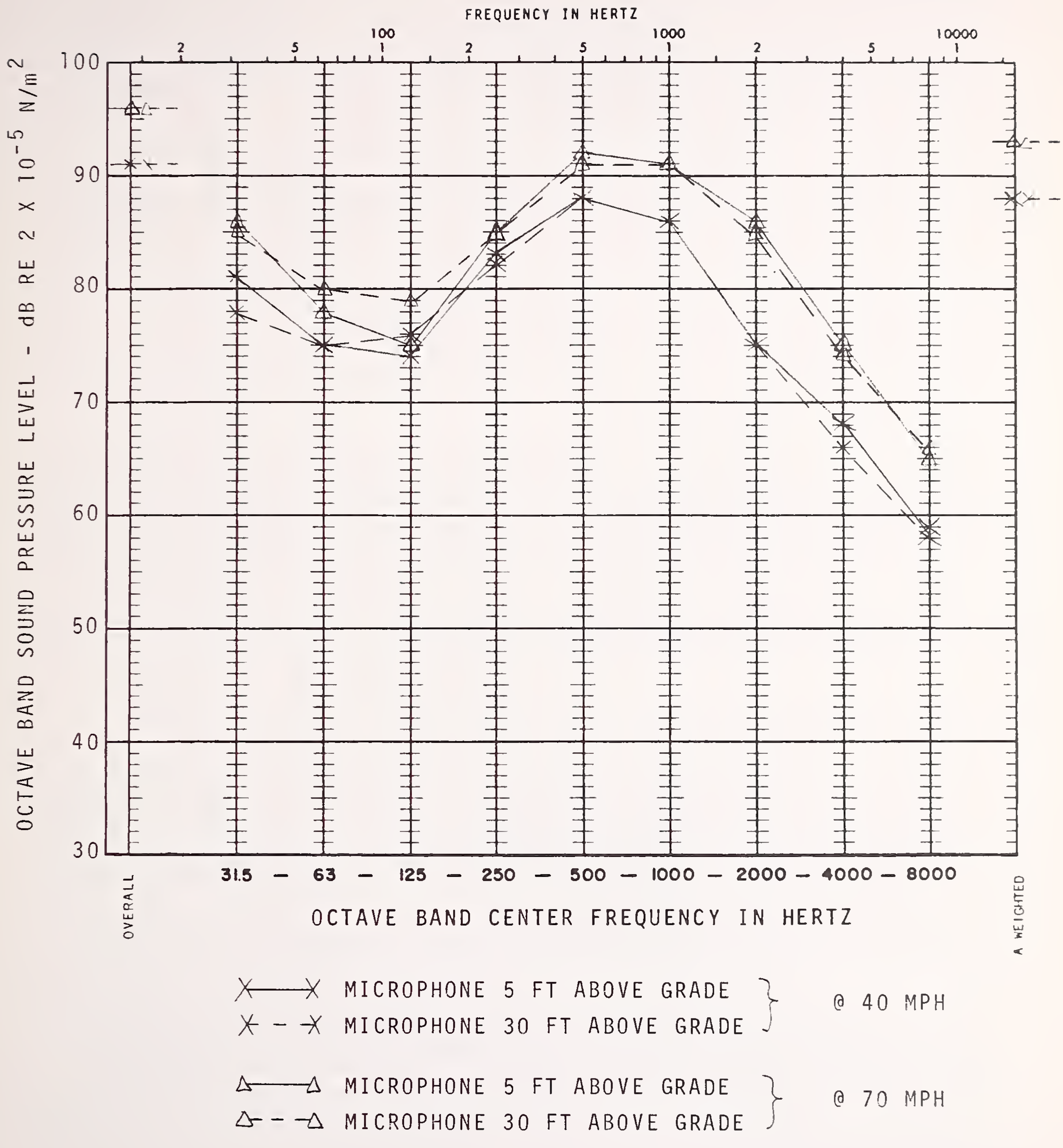

FIGURE 3.1 WAYSIDE PASSBY NOISE LEVELS FOR BART 2-CAR TRAIN OPERATING ON AERIAL STRUCTURE 50 FT FROM TRACK CENTERLINE

Conditions at Measurement Site - The measurement sites were chosen such that no obstacles were in the vicinity of the microphone to disturb the sound field. The area between the track and measuring microphone was as open as possible. Meteorological conditions such as temperature and wind were noted. (No measurements were made in winds above 7 meters/second (23 ft/sec)). Photographs of each measurement site were taken.

Microphone Positions - The basic distance for measurement of noise for all wayside measurement was 15 m (50 ft) from the near track centerline. Alternate distances of 7.5 m, 30 m and 60 m (25, 100 and 200 ft, respectively) were selected where the 15 m distance was not achievable.

Microphones were located no closer than 2 m (6.6 ft) from any reflecting surface (other than the ground).

The microphone with attached windscreen was oriented vertically at a distance of 1.6 m (5.3 ft) above local ground level for all measurements.

Measurement Procedure - The International Standard, ISO-3095-1975 (E), "Acoustics-Measurement of Noise Emitted by Railroad Vehicles", in draft form at the time of the measurements, was used as a guide for measurement procedures and practices. A calibration tone was recorded on each tape track just prior to and immediately following each measurement period. A sound level meter was employed as a verification measurement system. Recorder gains were set to provide optimum dynamic range coverage.

For each train passby, additional information such as vehicle identification number and wheel condition, or specific noise sources, either related or unrelated to the transit train, was recorded. In general, 30 minute recordings were made at each microphone location three times during a normal day, and included measurements during daytime off-peak service (10:00 a.m. to 2:00 p.m.) , rush hour (4:00 p.m. to 6:00 p.m.), and evening (7:00 p.m. to 10:00 p.m.). No nighttime measurements were made because BART had no nighttime operations during the measurement programs.

To assess subsystem noise from each type of vehicle, external vehicle noise measurements of individual on-car components were made at a distance of 4.6 m (15 ft) from the geometric center of the unit. A car was positioned on a yard track such that interference from other noise sources or vehicles was 10 dB or less than the noise of the particular subsystem under test. Each individual subsystem was then operated sequentially. In this manner each subsystem could be identified for its contribution to the vehicle's total noise signature. No "spin" testing of the car on jacks was performed.

Although a complete diagnostic study of the data was not performed, sufficient information was obtained to idenfity sources which contribute to the car's signature in the community.

3.2 Station Noise

Sampling Strategy - Station platform noise measurements were intended to determine the noise environment to which the transit system patrons and employees are exposed. Noise measurements of noise in transit stations were categorized by station platform layout (i.e., center platform, side platform) and roadbed category (i.e., aerial, at-grade, subway, freeway median).

Conditions at Measurement Site - The microphone locations were chosen so that no permanent obstacles were present near the microphone. The platform locations selected were open visually and acoustically to all tracks at that station so that all trains had direct-incident sound waves arriving at the microphones. In all cases, shielding of the microphones by patrons was minimal. Meteorological conditions such as temperature and wind were noted. No measurements were made in winds above 7 m/sec. Photographs of each measurement site were taken.

Microphone Positions - The microphones were located 1.6 m (5.3 ft) above the platform level, and displaced a distance of 2 m (6.6 ft) or one-half the platform width (whichever was smaller) away from the platform edge. One microphone was even with the middle of a stopped train, and one was even with one of the ends. Each microphone was oriented vertically and was protected by a windscreen.

Measurement Procedure - Procedures for measurement of noise levels on station platforms generally followed those outlined for community noise recordings.

3.3 Vehicle Interior Noise

Sampling Strategy - Measurements of the interior noise within transit vehicles were made to document the acoustic environment which patrons and operating personnel experience under typical service conditions. In-car noise measurements were taken during two round trips between Daly City and Concord, and between Richmond and Fremont. Noise samples for five different commute trips were also made between various sets of stations to determine the noise exposure of a typical commuter.

Continuous recordings were made in the second car of multi-car trains. Two microphones were used during each of the round trip recordings. The microphone location was random depending on seating availability, but was generally maintained at an ear level (seated) position.

Conditions at Measurement Site - Data were taken during non-rush hour conditions so that the area within 1 m (3.3 ft) of the microphone was free of riders. This also improved the chances for obtaining data which was clear of conversation and other nonvehicle noise. No effort was made to correct for these sources. The car chosen for recording was free from unusual noise sources. General vehicle conditions and unusual conditions, such as slowing for maintenance or construction personnel, were noted.

Microphone Positions - The microphones for the round trip measurements were oriented vertically at the ear level of a seated passenger at a mid-car position, and over the lead bogie, 1.2 m (4 ft) above the floor. One end to end sample of noise data was also recorded in the train operator's cab at the operator's car level. To standardize with other program measurements, a windscreen was placed over the microphone.

Measurement Procedure - The procedure for recording vehicle interior noise levels for the round trips was to calibrate the onboard microphones prior to data recording. Data records were initiated at a station stop with doors open, and then a continuous recording was taken over the traveled route. At the end of the trip, with car doors open, the tape recorder was stopped and the microphones recalibrated.

Measured or estimated speeds were reported on the tape at least once between adjacent stations. Each car in the train surveyed was identified on the tape by car number and unusual conditions of any nature in the car were similarly reported.

4. INSTRUMENTATION AND DATA ANALYSIS

4.1 Instrumentation

Data Requirements - The noise of the transit system was recorded on a magnetic tape system having a flat, or unweighted, frequency response characteristic. The noise data were later summarized in tabular and graphic formats in a standard manner so that the comparisons may be made among measurements for each test condition and among the different transit systems.

Data Acquisition System - The prime data acquisition system (illustrated on Figure 4.1) consisted of Bruel and Kjaer 1 in. microphones, and cathode followers, either battery powered or driven from a power supply integral to the magnetic tape recorder. These microphones were fitted with random incidence correctors and windscreens for both interior and exterior noise measurements.

The output of each microphone was tape recorded in the direct mode (amplitude modulation) on a portable Kudelski Nagra IV SJ tape recorder. The tape recorder was battery-operated and run at a tape speed of 7-1/2 in./sec for wayside measurements and 3-3/4 in./sec for interior noise measurements.

To supplement laboratory calibrations, field equipment checks were made using a Bruel and Kjaer type 4230 Acoustic Calibrator for a single frequency, single level calibration. This was done prior to the start and after the completion of any measurements recorded on each tape reel.

The data recorded on magnetic tape was also checked for fidelity and overloads by the simultaneous use of a headset on the output of the tape recorder while data was in the process of being recorded. Tape recorder gain settings were optimized for maximum signal-to-noise ratio or for dynamic range.

Equipment Calibrations - In addition to the field calibrations performed during the acquisition of the data, microphones, calibrators, tape recorders, and analysis equipment were periodically calibrated using class 2 reference instruments and signal generators whose calibrations are traceable to the National Bureau of Standards.

4.2 Data Analysis

Graphic Level Recorder Calibration - Since the data contained in this report will be compared with the acoustical environment measurements of other transit systems, it is important that the levels reported are correct on an absolute basis. It is also important because this data will form a base line against which changes in system noise will be measured when improvements have

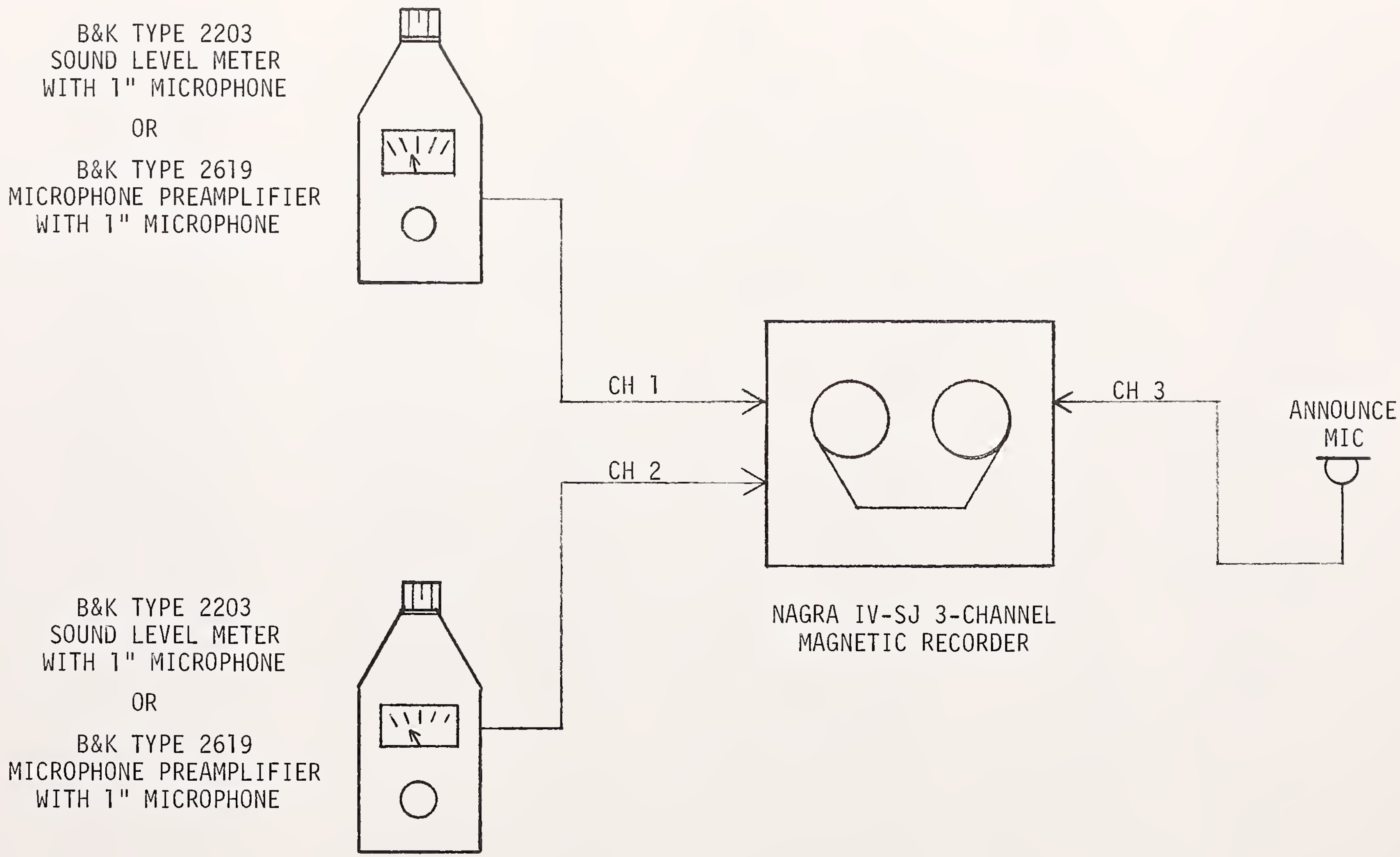

FIGURE 4.1 BLOCK DIAGRAM OF NOISE MEASUREMENT INSTRUMENTATION

been incorporated. An effort has therefore been made to insure that the basic noise level data, reported in terms of sound level dBA, is reproducible. The average maximum levels of acoustic events are therefore desired from graphic level recorder traces simulating the "Slow" response of a sound level meter meeting ANSI S 1.4-1971 Type 1 accuracy standards. The equivalence of a graphic level recorder response to such a sound level meter accuracy was initially ensured by using the techniques described in a paper by Webster and Farinacci* (Reference 2). Subsequently, an alternate, and less time consuming instrument calibration method was adopted when laboratory comparisons indicated that ordinary train and other environmental noises were accurately reproduced, and even transient noises were correctly represented with errors of at most 2 to 3 dBA.

<u>Individual Event Analysis</u> - Typical acoustical events have been illustrated in a dBA time history format with calibrated amplitude and time axes on a strip chart. These are annotated to illustrate special, as well as expected, acoustic events such as wheel squeal, door closings, etc.

Figure 4.2 illustrates both the basic noise measurement and analysis equipment in schematic form. Specifically, the typical events illustrated on the strip chart recordings are:

Community Noise:	Passby as a function of distance from track
Station Noise:	Passby Train Arrival Train Departure Train Stopped
In-Car Noise:	Acceleration Steady Speed Deceleration Special Noises

A-weighted time histories of the above types of noise events are used to determine the average maximum level, L_A(Max), and the duration (T) in seconds of the noise event measured 5 dBA below the L_A(Max). The duration is then used to calculate L_R:

$$L_R = L_A(\text{Max}) + 10 \log T_5 \qquad \text{dBA}$$

where L_A(Max) = maximum A-weighted sound level for a given noise event

*Webster, W.J. and Farinacci, J.W., "Use of Graphic Level Recorders as Indicating Instruments, Part 1: Meeting the Specifications of a Sound Level Meter", Bureau of Noise, New York State Department of Environmental Conservation, Albany, New York, 1974.

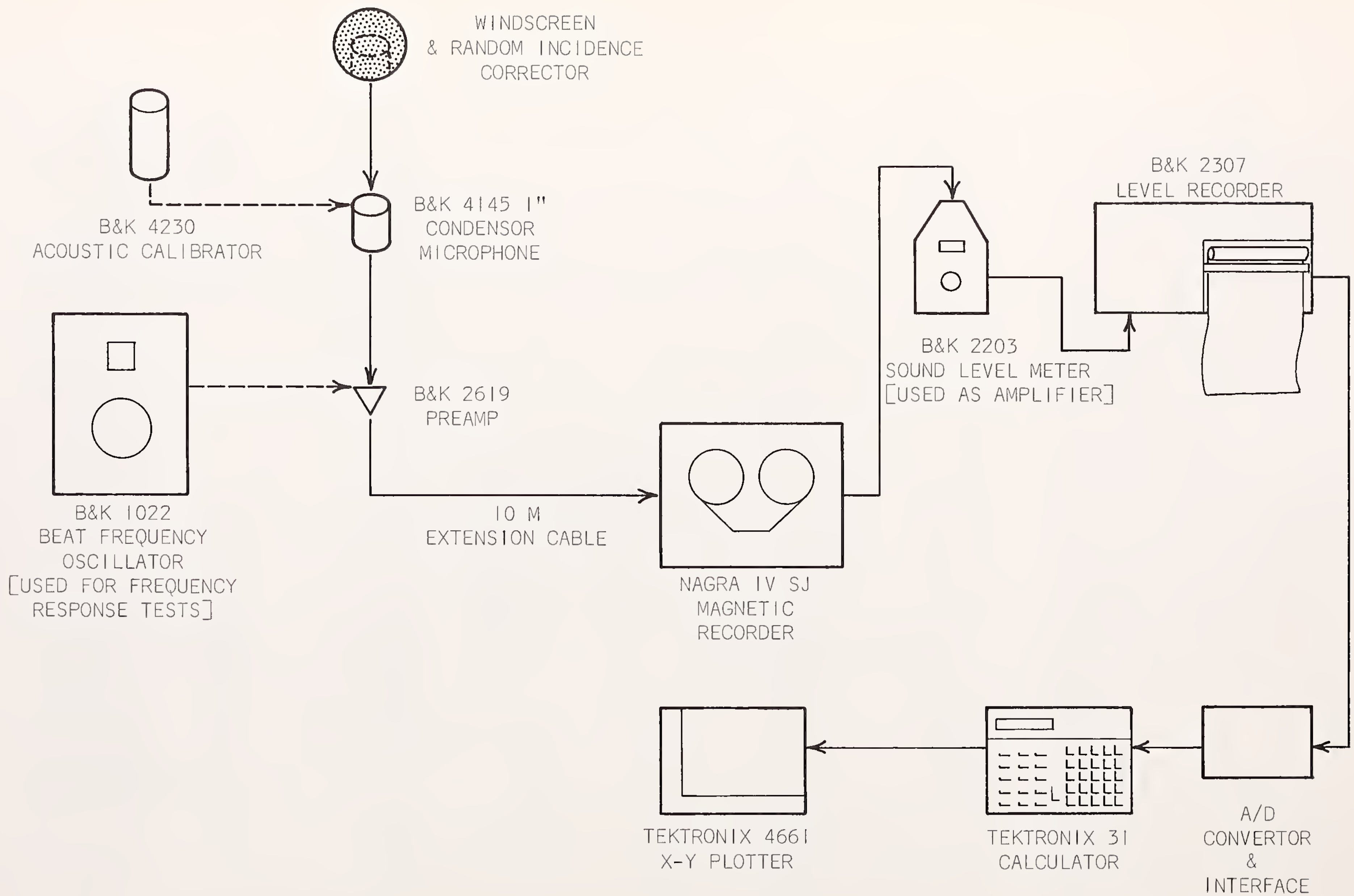

FIGURE 4.2 NOISE MEASUREMENT AND ANALYSIS INSTRUMENTATION USED FOR TRANSIT SYSTEM EVALUATION PROGRAM

T_5 = duration in seconds of the 5 dBA-down points from L_A(Max)

L_R is, in effect, an approximation to SENEL, the Single Event Noise Exposure Level used in computing the Community Noise Equivalent Level (CNEL). L_R was suggested by Schultz (Reference 3) and has been applied to urban rail transit vehicle noise as a measure of the total sound energy contained in a discrete noise event as measured at a standard receiver location. L_R has been applied to data measured as a part of this program at community wayside locations.

Special noises noted in the tape are generally specific to a particular site. Such noises include train squeal, pure tones from equipment, and wheel impact noise at turnouts and crossovers.

<u>Grouped Data Analysis</u> - In order to assess the statistical significance and the level of confidence which can be expected from the results of this measurement program, a detailed statistical analysis was performed on the noise data gathered at one of Philadelphia's subway station platforms. The analysis showed that the measurement results of a sample of 4 to 6 passbys at any site (with a standard deviation of less than or equal to 2.2 dBA) were necessary and sufficient to detect a subsequent average noise reduction of 5 dBA with 95% confidence. The measurement results summaries therefore list, in addition to data means, the standard deviation of each noise sample.

<u>Statistical Analysis</u> - For data collected at each measurement site, a summary table of the statistical measures of each noise sample (L_1, L_{10}, L_{90}, L_{EQ}), along with the average maximum levels of the BART train passbys on the near and far tracks, are given. Also given, in the table of wayside noise, are the average levels of L_R for the passbys on the near and far tracks, and an approximate level of L_{eq} due to train passbys only. Characteristic noise profiles were also prepared in terms of cumulative sound level amplitude distribution plots so that L_X statistics can be used to derive additional transit system noise attributes. Figure 4.2 also illustrates the analysis equipment used to derive statistical and other environmental noise parameters.

5. NOISE ASSESSMENT DATA

5.1 Description of Transit System

Routes and Service - The BART system consists of four branches in the San Francisco Bay Area - Fremont, Concord, Richmond, and Daly City - as shown in Figure 5.1. The system is 75 miles long and has 34 stations (33 in operation at the time noise measurements were made). Revenue operation began in 1972 with the opening of service between Fremont and MacArthur Stations. Service was extended to the Richmond Station in early 1973. Later that same year, service was initiated between the MacArthur Station and between Daly City Station and Montgomery Street Station. The final link through the Trans-Bay Tube was opened in 1974. At the time noise measurements were made, BART operated a limited schedule of service, from 6:00 a.m. to 8:00 p.m., Monday through Friday. At the present (1978) levels of service, BART operates approximately 18 hours a day, seven days a week.

Engineering Features - The design of facilities and equipment for new transit systems, such as the BART system, include many features intended to produce lower noise and vibration levels than those traditionally expected for rail transit systems. The BART system contains many of the general and special design features which are intended for and do result in lower noise. The results from the BART system indicate considerable success in achieving lower noise operations with noise levels experienced at BART facilities being typically in the range of 20 to 30 decibels (dB) less than have been or are experienced at older facilities or older systems where noise and vibration were not considered as important or limiting design parameters.

In the planning and design of the BART system facilities and equipment, data obtained from various operational and experimental transit vehicle structures and systems were used to determine the noise characteristics to be expected. Using the known noise characteristics of the best state-of-the-art components, equipment or facilities, and estimating the improvements in performance which could be made by changes in the design, through the use of noise limit specifications on the equipment and as determined from experimental vehicles, projections were made of the expected performance for the system facilities. The results obtained with the BART vehicles and facilities are very close to the performance expected.

FIGURE 5.1 BART SYSTEM SCHEMATIC

Roadbed - There are several varieties of way structures, track designs and station designs included in the BART system. The following table indicates the main categories of the various types of facilities:

a. Above-Ground Track Structures

(1) Ballast and tie at-grade tracks
(2) Concrete aerial structure
(3) Composite steel concrete aerial structure with trapezoidal girders
(4) Composite steel concrete aerial structure with I-beam girders
(5) Bridge with ballasted deck

b. Underground Structures

(1) Concrete double box section (2) Single box section (3) Concrete round tunnel (4) Steel-lined round tunnel	With concrete trackbed and resilient rail fasteners

(5) Concrete double box section with ballast and tie track

c. Additional Features

(1) Continuous welded rail
(2) Concrete aerial structures with resilient rail fasteners
(3) Resilient direct-fixation rail fasteners in subways
(4) Use of a rail grinder for smoothing the rails before commencing revenue operations and for maintaining the rails in smooth condition

Rail Vehicles - There are two configurations of the BART car. The "A" car contains the operator's cab and the automatic train operation equipment. The "B" car is identical to the "A" car except it does not contain the cab or automatic train operation equipment. A standard revenue train consists of anywhere from two "A" cars to two "A" cars and eight "B" cars. The system schedule speed is approximately 45 mph with a maximum speed of 80 mph. The trains run on wide gauge track (5'-6"). Each axle of each car is powered, receiving the power from the 1,000 volt DC third rail. Each car is air conditioned by a 12-ton capacity refrigeration evaporator with automatic heating and cooling control. Three-view illustrations are shown in Figures 5.2a-c. with respect to noise and vibration, the BART car was designed with the following considerations:

(1) Car equipment noise and vibration level performance limits
(2) Car body sound insulation performance requirements
(3) Lightweight trucks with minimized unsprung weight, with rubber mounts and inserts for vibration isolation and with a low noise braking system
(4) Use of wheel grinders and lathes for maintaining the wheels in smooth condition.

<u>Stations</u> - Stations on the BART system can be grouped as follows:

a. Above Ground Stations

(1) At-grade center platform in residential/commercial area.
(2) At-grade side platform in:
    - Industrial/commercial area
    - Residential area
(3) Aerial center platform in:
    - Freeway median
    - Commercial area
    - Residential/commercial area
(4) Aerial side platform in:
    - Commercial area
    - Residential/commercial area
    - Residential area

b. Underground Stations

(1) Center platform, two track single level
(2) Single track multi-level

Sound absorption treatment has been included for subway stations.

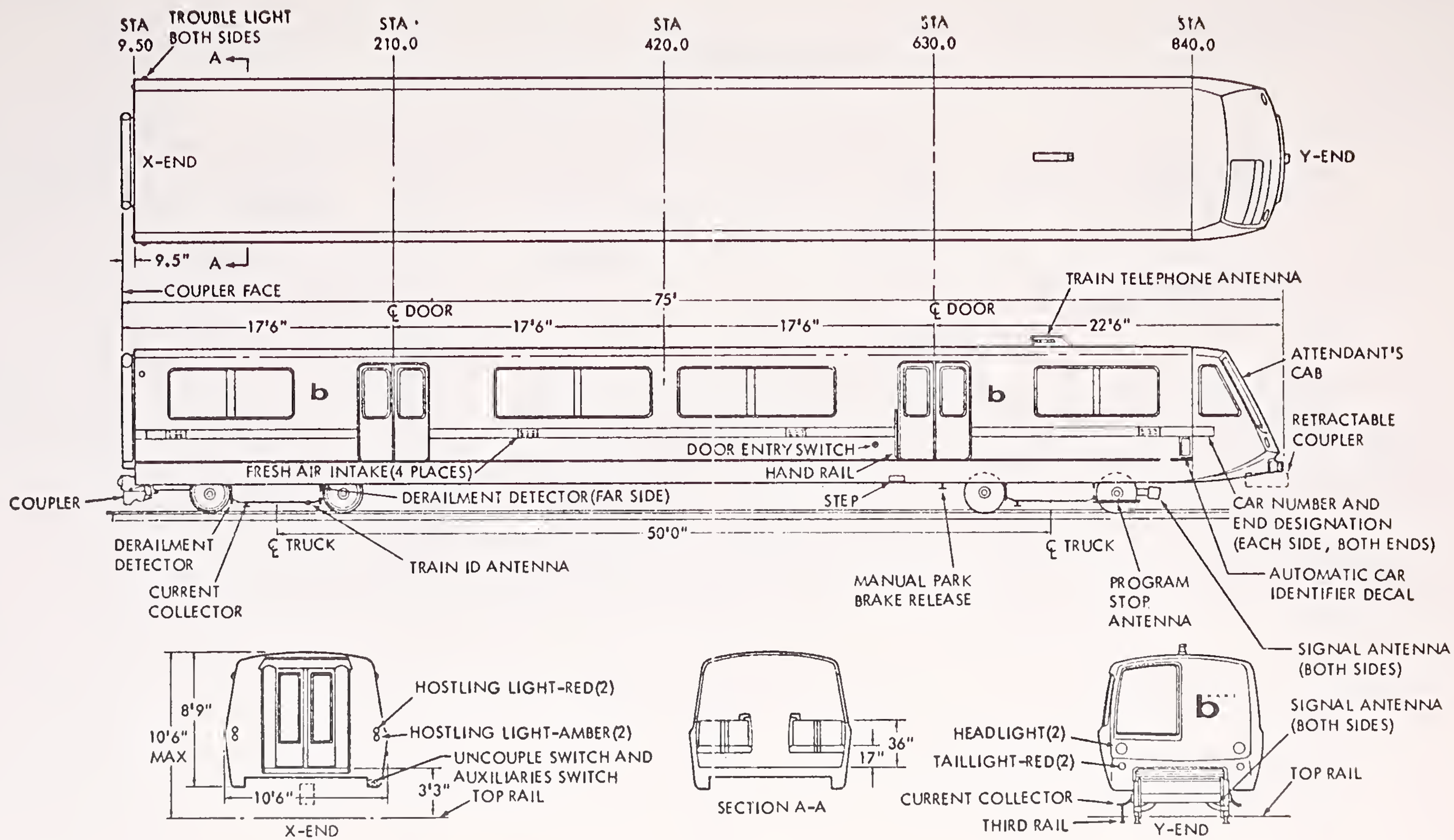

FIGURE 5.2a. A-CAR CONFIGURATION

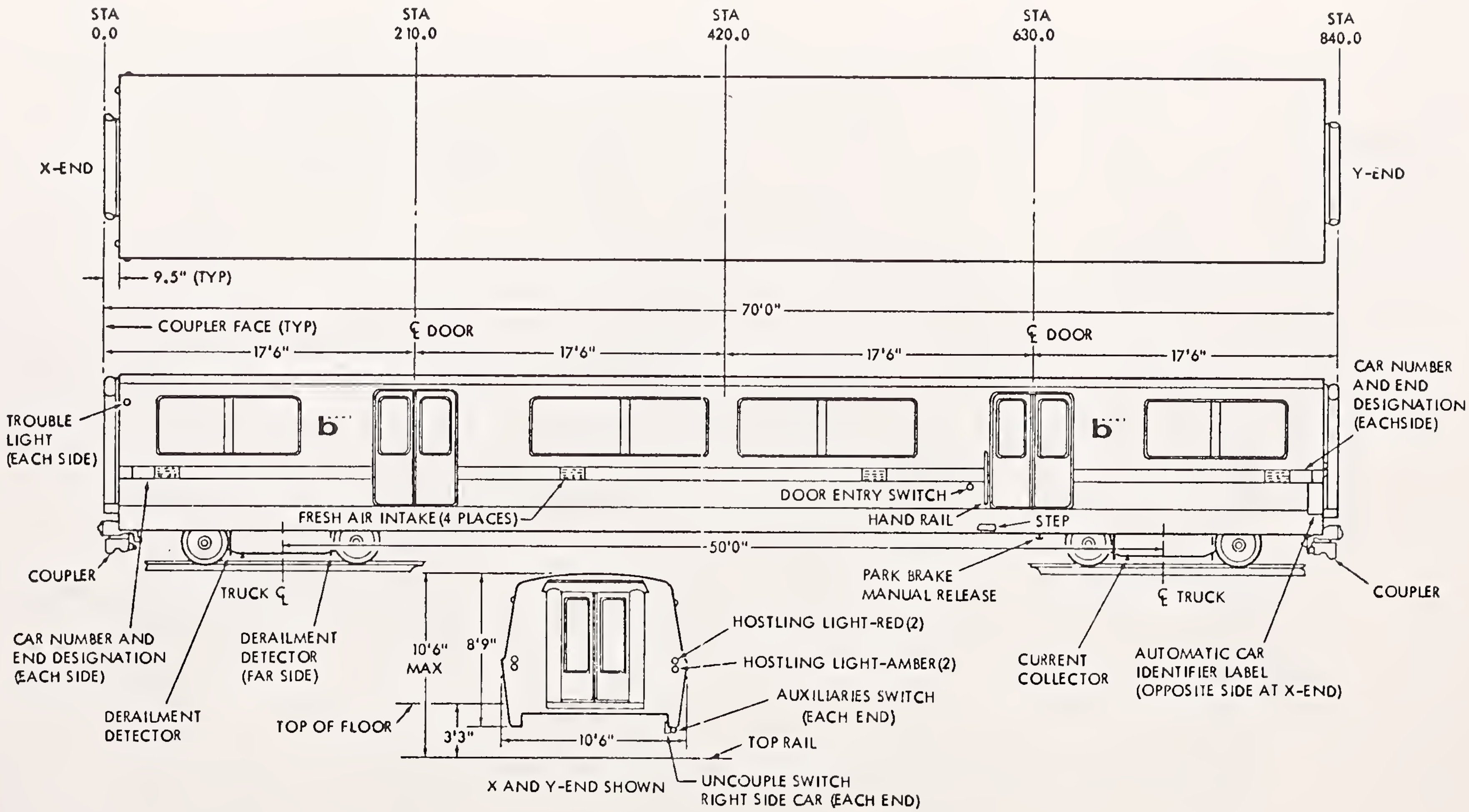

FIGURE 5.2b. B-CAR CONFIGURATION

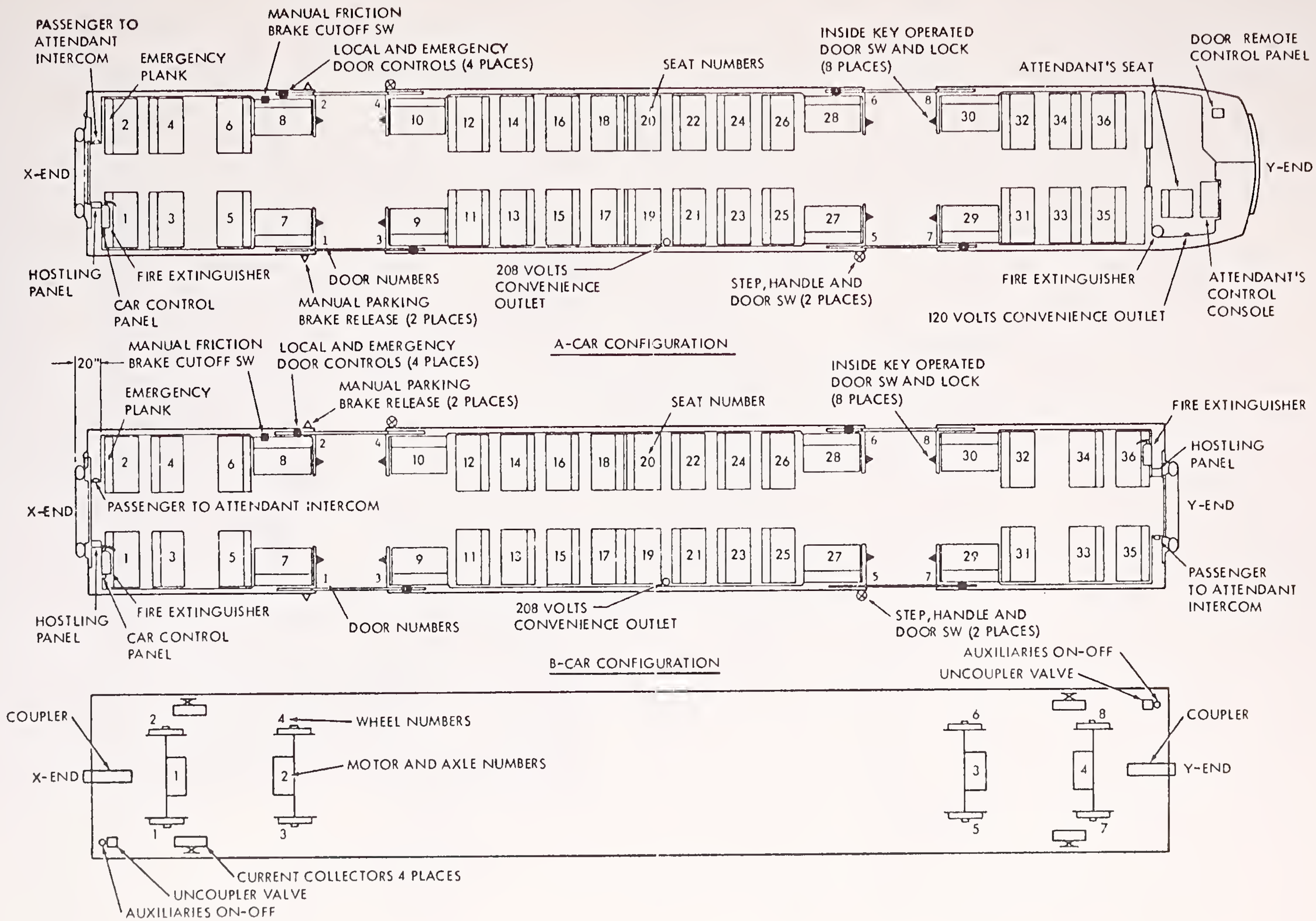

FIGURE 5.2c. SEAT, DOOR, WHEEL, AND TRUCK NUMBERING SYSTEM

5.2 Noise Assessment Data

5.2.1 Wayside Noise Measurements - Discussion and Summary

In order to provide the necessary data for assessment of community noise adjacent to the BART system, wayside noise measurements were taken at 13 locations along the Fremont, Concord and Richmond Lines of the BART system. The locations were chosen to be representative of typical conditions along the BART system. Figure 5.3 is a general map of BART showing the sites of the measurement locations. Table 5.1 summarizes the location, type of structure and community type for each of the locations.

A detailed summary of the data collected at each measurement site along with descriptions of the sites are contained in Section 5.2.2. The purpose of this Section is to give a summary analysis of the results and trends of the noise radiated into the community by BART revenue operations as indicated by the noise samples taken in this study.

Table 5.2 gives a summary of the overall results at each location combining the three 30-minute noise samples at each location. An overall summary combining the measurements adjacent to BART aerial structures and combining the measurement samples adjacent to at-grade tracks is given in Table 5.3.

Some of the general factors to be noted about the results summarized in Tables 5.2 and 5.3 are:

(1) The passby levels at each particular measurement location are consistent. Also, there are significant differences in the average results at two different measurement locations with the same train speeds and track structures.

(2) The maximum passby noise levels for trains on the BART concrete aerial structure are 3 to 6 dBA higher than for trains on ballast and tie at-grade tracks.

(3) At 50 and 100 ft from the BART at-grade and aerial structures, the train passby noise generally dominates the level of L_{EQ} except in locations where traffic noise levels are very intense. However, the train noise does not generally have a strong influence on L_{10}.

(4) The noise radiated from the two vent shafts was not a significant contributor to the noise climate during the samples.

(5) The maximum wayside levels radiated from the Walnut Creek Bridge were actually lower than the average maximum wayside levels observed

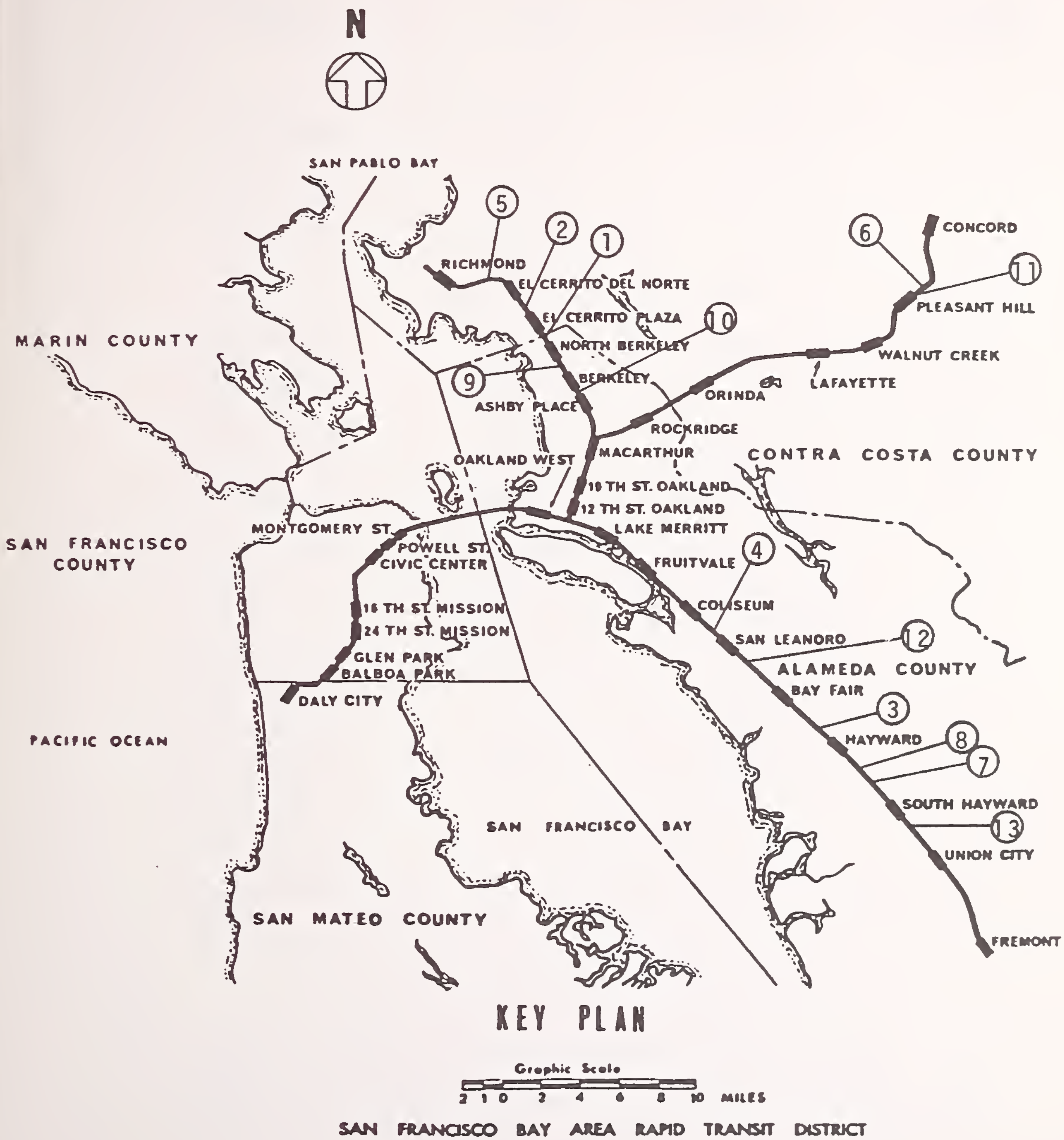

FIGURE 5.3 WAYSIDE NOISE MEASUREMENT LOCATIONS

TABLE 5.1 WAYSIDE NOISE MEASUREMENT LOCATIONS

Location Number	Structure	Line	Community Type
1	Aerial	Richmond	Residential
2	Aerial	Richmond	Commercial
3	Aerial	Fremont	Residential
4	Aerial	Fremont	Commercial
5	At-Grade	Richmond	Commercial
6	At-Grade	Concord	Residential
7	At-Grade	Fremont	Residential
8	At-Grade	Fremont	Commercial
9	Vent Shaft	Richmond	Residential
10	Vent Shaft	Richmond	Commercial
11	Walnut Creek Bridge	Concord	Residential
12	Aerial Crossover	Fremont	Residential/ Commercial
13	At-Grade Crossover	Fremont	Residential

TABLE 5.2 SUMMARY OF AVERAGE MAXIMUM TRAIN PASSBY LEVELS AND L_{EQ} FOR ALL THREE SAMPLES AT EACH LOCATION

Location And Line	Track Structure	Train Speed MPH - [Approx]		L_{EQ} - dBA				Average Maximum Levels - dBA			
				Measured		Trains Only [Approx]		Near Track		Far Track	
		Near	Far	50 FT	100 FT	50 FT	100 FT	50 FT	100 FT	50 FT	100 FT
1 Richmond	Aerial	80	80	69	68	70	68	93 0.5[1]	91 1.1[1]	80 0.7[1]	77 0.3[1]
2 Richmond	Aerial	80	80	71	69	69	67	93 0.9	90 1.1	81 1.1	79 0.9
3 Fremont	Aerial	80	80	70	68	69	67	89 0.3	86 0.7	79 1.3	76 1.1
4 Fremont	Aerial	80	80	72	71	69	68	88 0.9	87 0.8	79 0.8	79 0.5
5 Richmond	At-Grade	80	80	66	64	66	64	87 1.0	84 1.2	85 1.0	82 1.8
6 Concord	At-Grade	80	80	68	62	61	57	84 1.2	81 1.3	76 2.2	72 1.7
7 Fremont	At-Grade	70	80	66	64	66	64	85 0.8	83 0.8	77 1.8	75 1.7

[1] Standard Deviation of level

TABLE 5.2 [cont.]

Location And Line	Track Structure	Train Speed MPH - [Approx] Near	Far	L_{EQ} - dBA Measured 50 FT	100 FT	Trains Only [Approx] 50 FT	100 FT	Average Maximum Levels - dBA Near Track 50 FT	100 FT	Far Track 50 FT	100 FT
8 Fremont	At Grade	80	80	68	66	67	65	87 *1.1*[1]	84 *1.2*	79 *1.0*	76 *1.3*
9 Richmond	Vent Shaft	50	50	61[2]	58[3]	--	--	--	--	--	--
10 Richmond	Vent Shaft	60	60	67[2]	67[3]	--	--	--	--	--	--
11 Concord	Walnut Creek Bridge	80	80	65	62	64	60	87 *1.2*	83 *1.1*	78 *1.4*	75 *1.1*
12 Fremont	Aerial Crossover	60	80	68	67	68	67	87 *1.3*	85 *1.5*	76 *1.6*	76 *1.7*
13 Fremont	At-Grade Crossover	80	80	--	63	--	59	--	78 *2.0*	--	73 *2.2*

[1] Standard Deviation of level

[2] 25 FT

[3] 50 FT

TABLE 5.3 COMBINED LEVELS OF L_{EQ} AND AVERAGE PASSBY LEVELS FOR AT-GRADE POSITIONS AND AERIAL STRUCTURE POSITIONS

Structure	Measurement Locations	L_{EQ} - dBA Measured 50 FT	L_{EQ} - dBA Measured 100 FT	L_{EQ} - dBA Trains Only [Approximate] 50 FT	L_{EQ} - dBA Trains Only [Approximate] 100 FT	Maximum Passby Levels - dBA Near Track 50 FT	Maximum Passby Levels - dBA Near Track 100 FT	Maximum Passby Levels - dBA Far Track 50 FT	Maximum Passby Levels - dBA Far Track 100 FT
Aerial	1 to 4	71	69	69	68	91 *2.6	88 *2.4	80 *1.0	78 *1.5
At-Grade	5 to 8	67	64	66	63	86 1.5	83 1.4	79 4.0	76 4.2
At-Grade	6 to 8	68	64	65	63	85 1.5	83 1.5	77 1.5	74 2.1

*Standard Deviation of level

adjacent to the normal all-concrete aerial structure. However, the Walnut Creek Bridge radiated more low frequency noise than the all-concrete aerial structure.

[6] Although many modern noise control features have been used to reduce noise levels adjacent to the tracks radiated to the community by the BART trains, the maximum passby levels are still high enough to cause some intrusion.

Each of the general observations outlined above are discussed in some detail in subsequent sections.

It should be noted that when the measurements reported in this study were taken, January 1975 to April 1975, BART trains were not running either on the weekends or late at night. On weekdays the system closed to patrons at 8:00 p.m., although the trains continued running considerably later, generally until about 10:00 p.m., in order to clear out the system. However, shortly after 8:00 p.m. trains would start to be taken out of service with the result that the number of trains passing a specific location during a half-hour sample made after 8:00 p.m. would be less than during normal revenue operations. For this reason virtually all the evening samples were taken between 7:00 p.m. and 8:30 p.m. in order to guarantee a normal schedule of trains.

Wayside Noise Measurement Positions

Wayside noise measurements were taken at a total of 13 locations along the Richmond, Concord and Fremont Lines of the BART system. Table 5.1 summarizes the location, type of structure and community type for each of the locations.

The first eight locations were chosen to be representative of the normal high speed train operations both along at-grade ballast and tie tracks and along concrete aerial structures. The BART aerial structures are generally all concrete. Only where a span longer than 70 ft was necessary is the aerial structure not all concrete. For longer than 70 ft spans the aerial structure is a composite steel/concrete structure with some type of steel girder supporting a concrete trackway.

Measurement Locations 9 to 13 have been chosen to document noise adjacent to unusual BART facilities including subway vent shafts, aerial and at-grade crossovers and composite steel/concrete aerial structure.

The first four locations are adjacent to the typical BART aerial structure. The aerial structure design throughout the BART system, with only a few exceptions, is reinforced concrete with each trackway supported by a separate trapezoidal concrete girder. Locations 1 and 2 are along the Richmond Line and 3 and 4 along the Fremont Line. Two of the locations are in residential communities and two are in areas where the land use is predominantly commercial/ industrial.

Locations 5 through 8 are adjacent to at-grade BART tracks along the Richmond, Concord and Fremont Lines. Locations 5 and 8 are in large parking lots adjacent to commercial areas along the Richmond and Fremont Lines, respectively. Locations 6 and 7 are in residential communities along the Concord and Fremont Lines, respectively.

Locations 9 and 10 are both at vent shafts above the subway section of the Richmond Line in Berkeley. They were chosen to illustrate the level of sound radiated from vent shafts along BART subway sections.

The Walnut Creek Bridge at Location 11 represents a relatively unique situation on the BART system. The structure is a composite steel/concrete bridge about 210 ft long between at-grade ballast and tie track sections. The longest single span is 84 ft. The structure is basically two concrete slab trackways each supported by a separate trapezoidal steel girder. Due to the large undamped steel plates in the supporting girder, the bridge radiates intense low frequency noise, which has been previously noted.

Locations 12 and 13 are aerial and at-grade crossover sections where the impact noise due to the wheels passing over the discontinuities in the special trackwork contribute a noticeable component of the passby noise.

More detailed descriptions of the measurement locations and the surrounding community are given in Section 5.2.2.

Data Reduction

At each location three half-hour samples were taken using two microphones. The microphones were located 50 ft and 100 ft from the centerline of the near track for the majority of the measurements. At Location 13 the equipment could not be positioned for a 50 ft sample, hence the microphones were located at 100 and 200 ft. The samples at the vent shafts, Locations 9 and 10, were taken at 25 and 50 ft from the vent shafts. Even so, the train passby noise at the microphone positions at the vent shafts was often entirely masked by the normal community noise.

The methodology and equipment used to collect and analyze the community wayside noise samples is described in Section 4.

In order to facilitate a comprehensive evaluation of the community noise samples, and the influence of the BART passby noise on the community noise climate, the noise samples were analyzed to determine the following quantities:

[1] The complete statistical distribution of each 30 minute sample including L_{99}, L_{90}, L_{50}, L_{10}, and L_1.

[2] The equivalent energy level [L_{EQ}] for each 30 minute sample.

[3] The maximum level L_A(Max) for each BART train passby. Due to the masking effect of the background noise at the vent shaft sites, Locations 9 and 10, and at the 200 ft position for Location 13, L_A(Max) could not be determined at these locations.

[4] The level of L_R for each BART train passby.[1]

[5] The arithmetic average of L_A(Max) and L_R for trains on the near and far tracks for each 30 minute sample. The standard deviations for the average levels were also calculated.

[6] Using the calculated levels of L_R, a "trains only" level of L_{EQ} was calculated. The "trains only" level of L_{EQ} is defined below.

[7] A final compilation was done combining all three samples at each location. The values of L_{EQ}, L_{99}, L_{90}, L_{50}, L_{10} and L_1 combining all three time periods were computed [the percentage exceedence levels were merely appoximated as the average of the values for the three samples]. Also computed were the average levels of L_A(Max) and L_R for all the passbys during the three samples.

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[1] L_R is defined as L_A(Max) + 10 log T_5 where T_5 is the time in seconds between the 5 dB down points.

Section 5.2.2 contains the reduced data for each location including plots of the statistical distribution for the three 30 minute samples.

The "trains only" level of L_{EQ} is approximated using the values of L_R for all the train passbys during the sample. L_R gives an approximation of the total acoustic energy of a specific sound pulse such as a train passby referenced to one second. Since L_R does not account for the effect of the shape of the noise pulse, it is only an approximation of the level of acoustic energy of the pulse. However, it has been found to approximate the total energy for a wide variety of pulse shapes with an error of less than 2 dBA.

For a number of train passbys in a time period of T seconds, the "trains only" level of L_{EQ} for the time period is approximated as:

$$L_{EQ} = \bar{L}_R - 10 \log T$$

where $\bar{L}_R$ is the decibel sum of L_R for all the train passbys during the sample. For a 30 minute sample, the "trains only" L_{EQ} is:

$$L_{EQ} = \bar{L}_R - 33$$

It is important to understand that the level of "trains only" L_{EQ} is only as accurate as the levels of L_R. Hence, the "trains only" L_{EQ} gives an idea of the contribution of the train passby noise to the overall level of L_{EQ}, but it cannot be considered to give a more accurate value of L_{EQ} than L_R gives of the total acoustic energy for any specific train passby. The accuracy is certainly no better than ±1 to 2 dBA. An example is the fact that several of the levels of "trains only" L_{EQ} are 1 dBA higher than the measured level of L_{EQ}, which is clearly impossible physically.

As described in later sections, the accuracy of ±1 to 2 dBA has been verified on a number of samples with very low background noise where BART train passbys were clearly the dominant source of acoustic energy. In such cases "trains only" L_{EQ} was generally within 1 dBA of the measured level of L_{EQ}.

Under normal operating conditions, the speeds on BART are very consistent. The trains are normally controlled by the computer control system, and the speed variation from train to train at any specific point is only ±2 to 3 mph. Also, the trains are evenly spaced. At several locations on the Richmond Line the trains during the sample were running on a 12-minute headway with less than a 15 second variation through the 30 minute sample. The spacing on the Fremont Line, where the normal headway is 6 minutes, was somewhat more variable, however, under "normal" operating conditions the trains on the Fremont Line were very evenly spaced also.

In spite of the computer controlled speed and spacing on the BART system, there is a significant percentage of the time that BART is not operating on its normal high speed schedule. The variations from the high speed schedule range from only a few minutes up to much longer periods. Since it was not possible to document the train speeds for each passby, the degree to which train speed variations account for the variation in maximum wayside level cannot be determined.

Although speed variations did exist during some of the samples, overall the measurements of BART passbys at each location were very consistent. The average standard deviation for all the locations is 1.2 dBA, which indicates that at a specific location the maximum passby level will be within about ±2 dBA of the average level for 90% of the passbys. Of course, this estimate of the expected range of the passby levels is based on the assumption that L_A(Max) is a random variable with a Gaussian distribution. This is not an entirely valid assumption since the speed variation is not entirely random. Under the normal high speed operation schedule the speeds are very consistent and L_A(Max) could be expected to have a Gaussian distribution with a small standard deviation [less than 1 dBA]. However, due to the occasional slow downs of the system, it would be possible to have a situation where 80% of the trains pass by at 75 to 80 mph and 20% at 35 to 45 mph. In this case, L_A(Max) would not have a Gaussian distribution.

In several locations the variations in passby level were significantly greater than at the rest of the locations, due primarily to several very slow train passbys. The number and the occurrence of the trains at lower speeds was relatively random and did not appear to be a function of the specific location.

During each 30 minute sample when the weather conditions and train speeds were constant, the passby traces on the strip charts were virtually identical for different trains of the same length going in the same direction. The shape of the passby traces would be significantly different for different length trains, however, the maximum levels were not strongly changed by the train length. The consistency during specific samples is illustrated by approximately 10% of the samples where L_A(Max) was the same for all the passbys in one direction.

The fact that the passby levels were more consistent for each 30 minute sample compared to the total number of passbys during the three 30 minute samples at a specific location is illustrated by the lower average standard deviation for the passbys during a 30 minute sample. The average of the standard deviations given in Section 5.2.2 for the 30 minute samples is 0.83 dBA compared to the average standard deviation of 1.2 dBA for all the passbys at each location. One possible reason for the somewhat higher standard deviation is the change in weather conditions [wind speed and direction, humidity, temperature] between samples. Wind speed and direction is known to have an influence on the propagation of sound. It is possible that a more extensive series of measurements covering a wider variety of weather conditions would result in a larger variation of L_A(Max).

There is a significant difference in the average maximum passby levels at different measurement locations even when the parameters such as train speed, train length, and track structure are identical. The difference between specific locations results in relatively large standard deviations for average passby levels for all at-grade and all aerial structure locations as given in Table 5.3. The average standard deviation from Table 5.3 combining the aerial structure locations, 1 to 4, and combining the at-grade locations, 5 to 8, is 2.3 dBA.

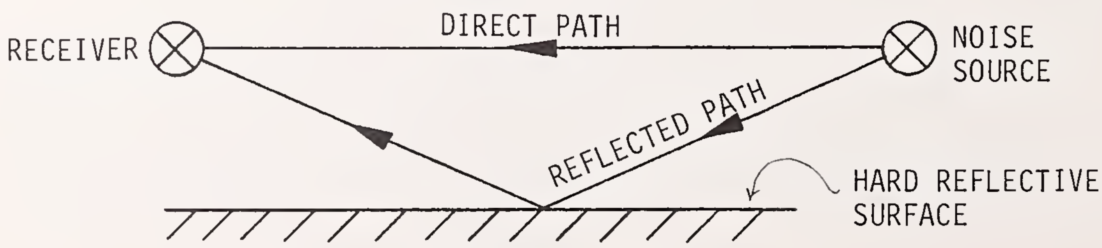
Although establishing the specific reasons for the variation of the passby levels at different wayside locations when the parameters of train speed, train length and track structure are constant, is beyond the scope of this study, one variation was felt to be significant enough to warrant further investigation. Locations 5 and 8 are both in large parking lots adjacent to at-grade tracks on embankments about 5 ft high. The locations are very similar in almost all aspects, including the elevation of the tracks, the asphalt surface on the parking lots, the lack of any large reflecting surface on either side of the tracks, and the fact that neither of the parking lots were busy near the measurement locations. Also, the tracks at both locations are long straight sections with 80 mph speed limits.

COMPARISON OF L_A(MAX) FOR LOCATIONS 5 AND 8

	50 Ft	100 Ft
Near Track		
Location 5	87 dBA	84 dBA
Location 8	87	84
Far Track		
Location 5	85 dBA	82 dBA
Location 8	79	76

At both the 50 and 100 ft positions the average levels of L_A(Max) for trains on the near track are the same. However, the average levels for L_A(Max) on the far track at both the 50 and 100 ft positions were 6 dBA higher at Location 5 than at Location 8. The 2 dBA difference between levels on the near and far track at Location 5 was the smallest found at any of the measurement locations, even at positions where significantly different train speeds on the near and far tracks might account for the differences in noise levels. The difference of 8 dBA between trains on the near and far tracks for Location 8 was typical of most other locations.

It is difficult to determine with any certainty just why there was such a small difference in L_A(Max) between the near and far tracks at Location 5. In an effort to isolate the mechanisms contributing to this result, the octave bands of specific passbys were analyzed. The results are illustrated in Figure 5.4. The octave band spectrums for the near train passbys are nearly identical except in the 4000 Hz octave band. However, the far train results show a considerable difference in the 250, 1000, 2000 and 4000 Hz octave bands. The difference in the 2000 Hz bands appears to dominate the difference in A-weighted overall level. There is the possibility that the difference in the 2000 Hz octave band is due to constructive interference between the direct wave and the reflected wave. This is illustrated in the sketch below:



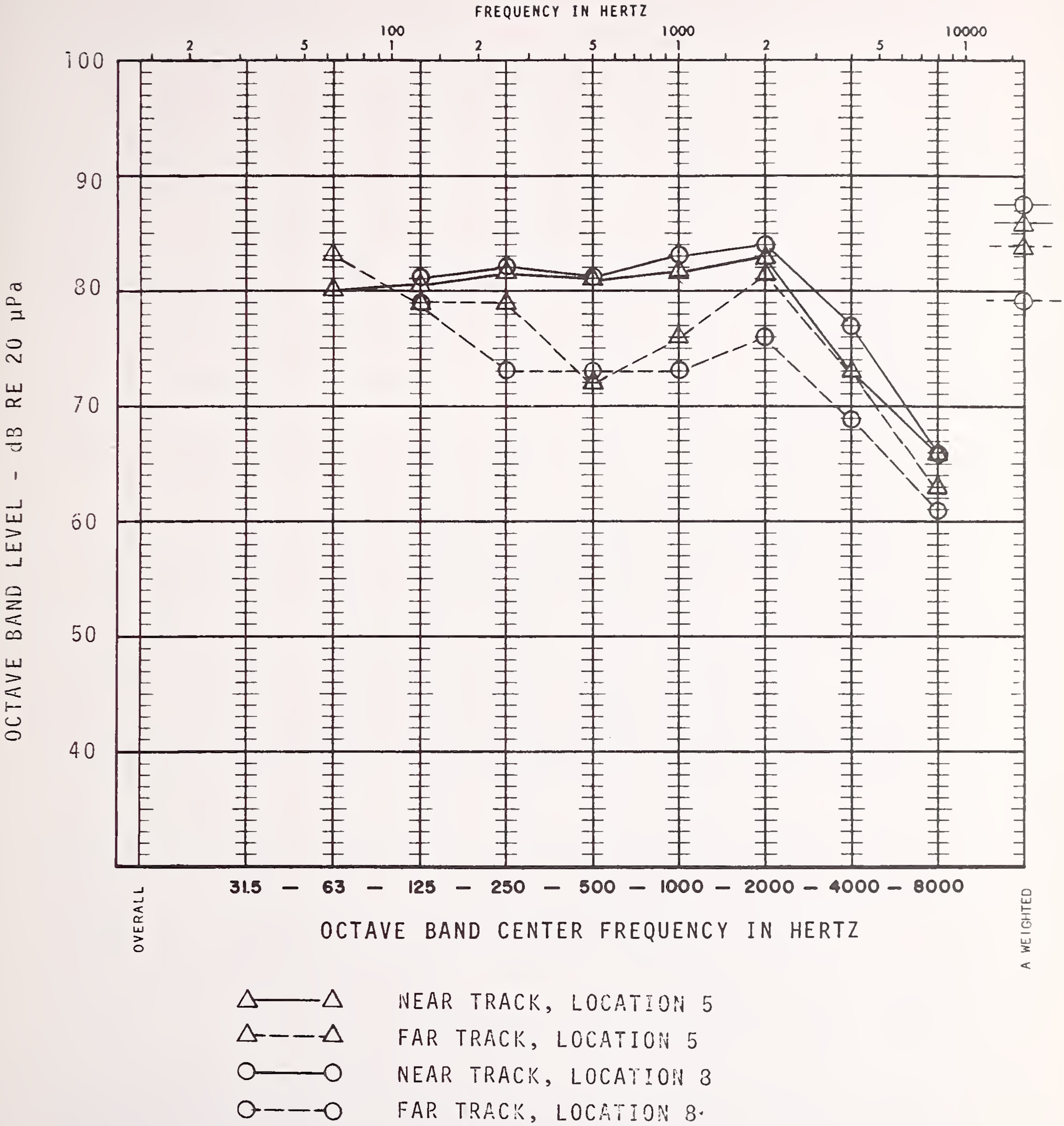


FIGURE 5.4 SPECTRUM OF MAXIMUM PASSBY NOISE FOR TYPICAL PASSBYS AT WAYSIDE LOCATIONS 5 AND 8

5-CAR TRAINS AT 75 MPH, 50 FT FROM NEAR TRACK CENTERLINE

For a noise source at a specific frequency, when the difference in path length between the direct wave and the reflected wave is exactly a wavelength, it can be expected that the waves will add to give a noise level at the receiver as much as 6 dBA higher than the direct path only. Also, when the path difference is exactly one-half wavelength, assuming the ground is a perfect reflecting surface, the direct and reflected waves will be 180° out of phase causing complete cancellation of the wave at the receiver position. Of course, such complete cancellation is virtually impossible with a random noise source such as a train, however, destructive interference could result in significantly lowered noise levels. Of course, for high frequencies when the path length difference is several wavelengths, the interference of the reflected and direct wave will be very dependent on frequency and the exact position of the source and receiver. As such, over an octave band, interference effects will be minimized.

For this specific case the maximum interference effects would be expected when the path length difference is between 0.5 to 1 wavelength. The path difference between the direct and the reflected waves is about 1 ft at the 50 ft position and 0.5 ft at the 100 ft position. As such, the maximum interference effects can be expected in the 1000 and 2000 Hz octave bands when the path length difference is 1/2 to 2 wavelengths.

Referring to Figure 5.4 showing the spectrum of passby noise at the 50 ft position, it can be seen that the maximum differences between passbys on the far track at Locations 5 and 8 occur in the 250 and 2000 Hz octave bands. The 5.5 dB difference in the 2000 Hz octave band is the dominant factor in the 5 dBA difference in the A-weighted noise levels.

At most of the other locations, conditions were enough different from Location 5 that constructive interference might have been blocked. Although the measurements were made at locations without obstructions, they were generally in developed areas with buildings and other reflecting surfaces in the vicinity that would tend to negate the effect of interference between the direct path and a path via any specific reflecting surface. There was often grass, trees, shrubs, or dirt along the propagation path.

It is conceivable that the differences in the far train results at Locations 5 and 8 could be due to small differences in geometry. At Location 5 the asphalt pavement runs right up to the edge of the embankment for the track. At Location 8 the pavement is separated from the embankment by a 6" curb and a 2 to 3 ft deep culvert. The curb and embankment at Location 8 could interfere with the reflected wave preventing the constructive interference, while the reflected path is unobstructed at Location 5.

Influence of Track Structure on L_A(Max)

The levels of L_A(Max) adjacent to the BART structures are significantly lower for ballast and tie track compared to the all-concrete aerial structure. The average level of L_A(Max) was 5-6 dBA higher on the aerial structure compared to the ballast and tie sections for trains on the near track. The noise level from trains on the far track on aerial structure was only 2 to 3 dBA higher than for trains on the far track on ballast and tie. The difference in L_A(Max) between trains on the near and far track on aerial structure is 10 to 11 dBA and 7 to 8 dBA for trains on ballast and tie at-grade tracks. The greater difference for the aerial structure is apparently due to the partial shielding of the far track structure by the near track structure.

Previous study by this contractor of wayside noise adjacent to the BART all-concrete aerial structure has led to the conclusion that the increase in A-weighted noise level compared to wayside levels adjacent ballast and tie tracks is due to the sound absorption characteristics of the ballast. The hard reflecting surface of the concrete results in higher reverberant noise levels building up under the trains. The absorptive character of the ballast minimizes this buildup under the trains resulting in lower levels of radiated noise. The obvious implication is that applying absorptive treatment to the concrete aerial structure would reduce the radiated levels of noise.

Measurements taken adjacent to both ballast and tie and aerial crossover sections [Locations 12 and 13] did not indicate any substantial change in L_A(Max) due to wheel impact noise at the joints and frogs of the crossover. Although the impact noise was clearly audible at both of these locations, the noise "spikes" from the impact are not reflected in L_A(Max) due to the manner in which L_A(Max) is determined. The results are also clouded by the relatively inconsistent speeds at the aerial crossover and the partial shielding at the at-grade crossover by the 5 to 10 ft of cut. The aerial crossover is about 1000 ft from a 50 mph speed limit curve. Hence, inbound trains are starting to decelerate at the crossover and outbound trains are still accelerating.

The only other type of track structure measured in this study was the composite steel/concrete aerial structure which is discussed separately in a following section.

Radiation of Noise from Vent Shafts

Noise radiated from vent and fan shafts is a potential source of adverse noise impact associated with rapid transit systems. In the BART system there are few vent shafts near quiet residential areas where the noise could cause significant impact. Noise measurements were taken near two vent shafts, Locations 9 and 10. Location 9 is in a residential area near a busy local two lane street. At this location, the passby noise was faintly audible at the 25 ft position and often inaudible at the 50 ft position, even during the evening sample. Location 10 is on the median strip of a busy six lane surface street. Although the median was about 30 ft wide, the traffic noise completely masked the BART passby noise.

Noise at the Walnut Creek Bridge

The Walnut Creek Bridge represents a unique structure on the BART system. In order to achieve the desired span length the bridge is a composite steel/concrete structure instead of the all-concrete aerial structure used on much of the BART system. Basically, the bridge consists of two concrete slab trackways supported by trapezoidal cross-section steel girders. Each track is supported by a separate concrete slab and steel girder.

The outdoor levels of L_A(Max) observed at the Walnut Creek Bridge were actually 1-4 dBA lower than observed adjacent to all-concrete aerial structure [See Table 5.2]. However, the intense low frequency noise radiated by the undamped steel panels has been found to be transmitted through typical residential structural walls with little attenuation. The difference in the passby spectrum is illustrated in Figure 5.5. In the low frequency octave bands there is as much as a 12 dB difference between the noise levels radiated from the Walnut Creek Bridge and the all-concrete aerial structure. Due to the A-weighting de-emphasis of the low frequency noise, the outdoor A-weighted noise levels adjacent to the bridge are not higher than found adjacent to the standard all-concrete aerial structure. However, the low frequency noise from the bridge is transmitted into nearby dwellings creating low frequency rumble not normally encountered adjacent to the standard BART aerial structure.

An in-depth analysis of the noise radiated by the bridge was performed by this contractor for BART and summarized in the report "Reduction of Noise Radiated by the Walnut Creek Bridge Structure". In order to reduce the low frequency noise, constrained layer damping treatment was recommended for the steel plates on the bridge.

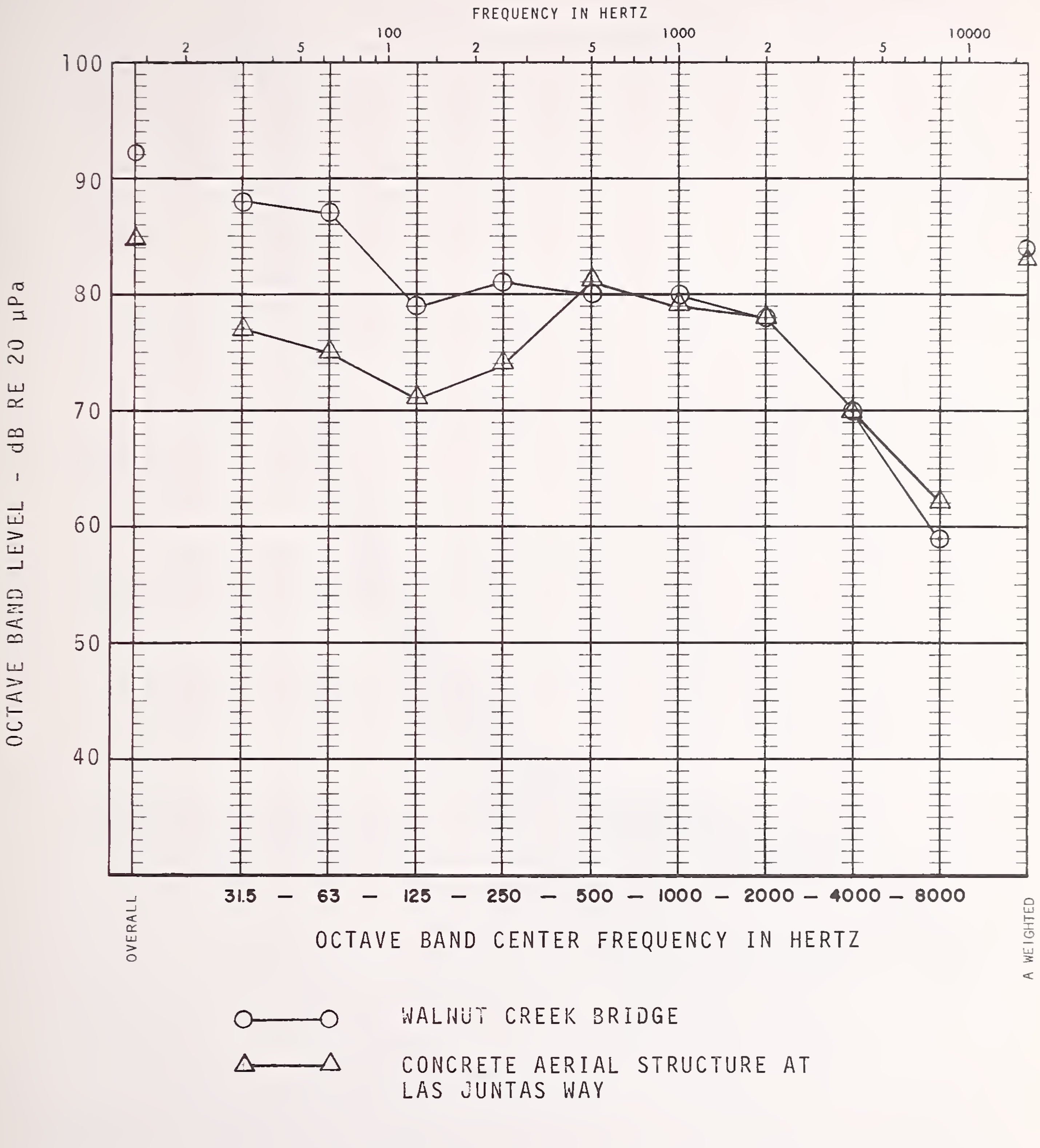


FIGURE 5.5 WAYSIDE NOISE LEVELS 100 FT FROM BART AERIAL STRUCTURES [DATA FROM WIA REPORT "REDUCTION OF NOISE RADIATED BY WALNUT CREEK BRIDGE STRUCTURE" (NOV 1972)]

4-CAR TRAINS AT 75 MPH ON NEAR TRACK

Influence of BART on Community Noise Climate

One of the most distinctive features of the measurements in this study is the apparent dominance of L_{EQ} by the BART train passbys at almost all of the measurement locations. Even at the locations near major roads or active industrial areas, the level of L_{EQ} for the trains only, excluding all other sources of noise, is approximately the same [±1 to 2 dBA] as the measured level of L_{EQ}. As mentioned above, the "trains only" level of L_{EQ} is based on the combined levels of L_R for all train passbys during a sample. Hence, the accuracy of the "trains only" L_{EQ} is limited by the accuracy with which L_R represents the total acoustic energy of the passby noise, which is ±1 to 2 dBA. While the comparison of the "trains only" L_{EQ} to the measured L_{EQ} cannot be taken as absolute proof that BART passby noise is the only significant contributor to the level of L_{EQ}, it certainly does indicate that the trains are a major contributor to L_{EQ}. The statistical distribution can be used to estimate what the levels of L_{EQ} would be without the BART passbys. For typical community noise samples the level of L_{EQ} is generally 0 to 4 dBA lower than the level of L_{10}. Of course, this is quite variable. In cases where there are occasional high energy intrusive noises, such as the BART passby noise, the level of L_{EQ} will be determined by the intrusive noises.

Since the BART passby noise occurs only for a small fraction of the sample period, in many cases the passby noise dominated the level of L_{EQ} but did not have any significant effect on the level of L_{10}. Assuming that L_{EQ} without the trains will be at least 0 to 4 dBA less than the measured level of L_{10}, the only measurement locations where the non-BART passby noise contributes significantly to the level of L_{EQ} are 4, 6, 9 an 10. Locations 9 and 10 are at vent shafts where the levels due to BART passbys are quite low. Location 4 is an industrial area near a heavily traveled surface street carrying both auto and truck traffic. Location 6 is also near a heavily traveled surface road, although the traffic is almost exclusively automobile. However, there was a total of only four BART train passbys on the near track at Location 6 during the three 30 minute samples.

The typical influence of BART passbys on the community noise climate is illustrated in Figure 5.6. One sample at the 50 ft

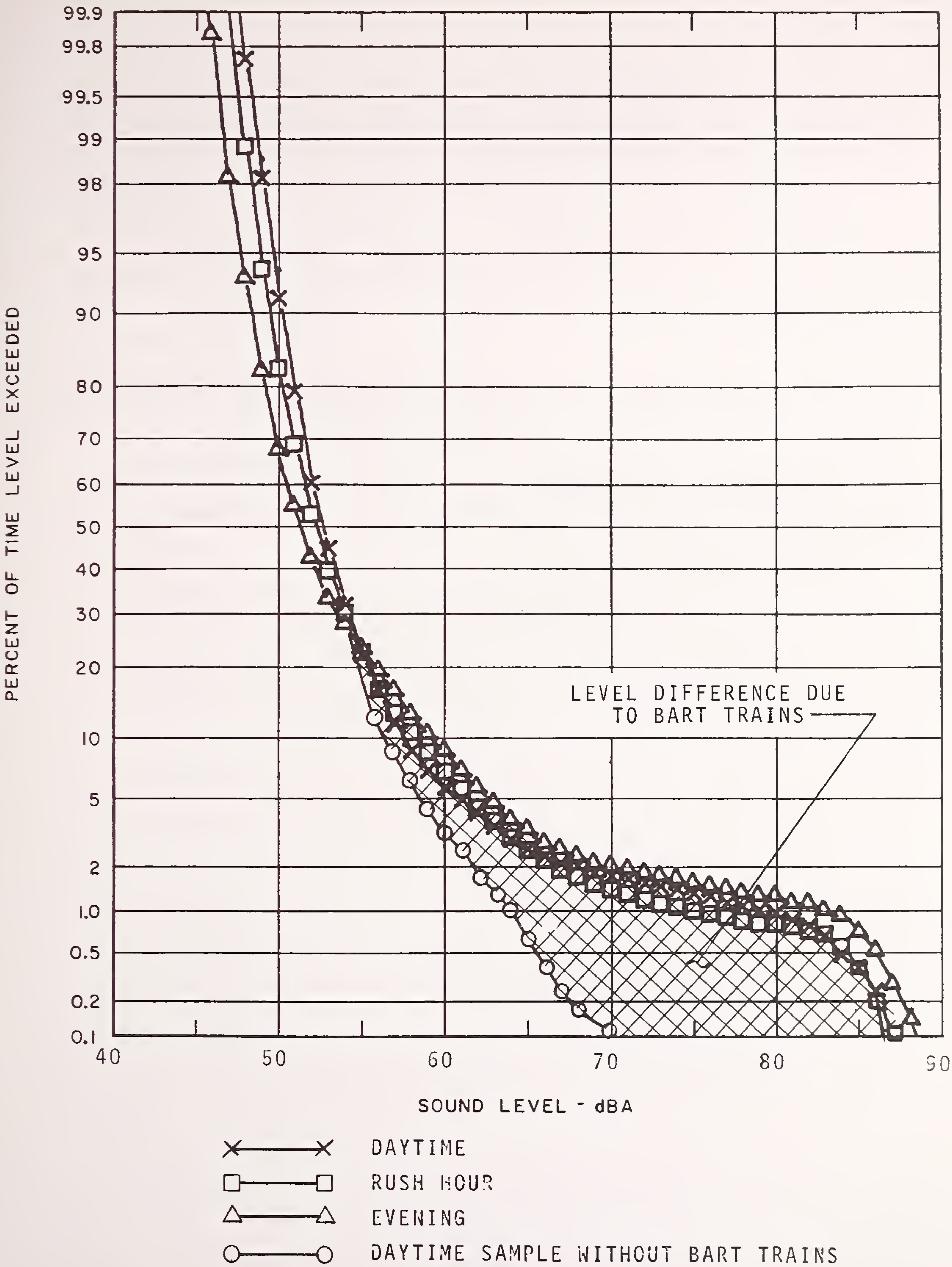


FIGURE 5.6 STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 5, 50 FT POSITION

position at Location 5 has been analyzed with the train passbys cut out. Referring to the figure, the sample with and without the trains is virtually identical up to L_{20}. The L_{10} levels are 1 dBA different. The L_1 level is strongly influenced by the train passbys. L_1 with the trains is 80 dBA while without the trains L_1 drops to 64 dBA. The level of L_{EQ} with the trains is 65 dBA, while without the trains L_{EQ} is 55 dBA, 10 dBA lower.

The general conclusion is that the noise from BART trains on either surface tracks or aerial structure dominates the wayside level of L_{EQ} at least up to 100 ft from the tracks. One cannot draw such conclusions at locations where barriers or low speed reduces the noise levels. Also, the levels of L_{10} are not generally influenced to any significant degree by the BART passby noise.

5.2.2 Site Descriptions and Data for Wayside Noise Survey

This section provides site descriptions and data on the noise survey results for each of the wayside noise measurement locations. The following data are provided at each site.

(1) Sketch of site showing location of both microphones and BART tracks.

(2) Photographs of site including both microphones and BART tracks.

(3) Statistical distribution curves for all six 30-minute samples at each site (three samples at each microphone location).

(4) A sample strip chart trace including near and far track BART train passbys at the microphone closest to the track.

(5) A summary table of the statistical measures of each noise sample (L_1, L_{10}, L_{50}, L_{90}, L_{99}, L_{EQ}), along with the average maximum levels of the BART train passbys on the near and far tracks. Also given in the table are the average level of L_R for the passbys on the near and far tracks, and an approximate level of L_{EQ} due to the train passbys only. The definition of L_R and the manner in which the levels of L_R were used to estimate a "trains only" level of L_{EQ} is given below.

(6) A short description of the important features of the measurement site.

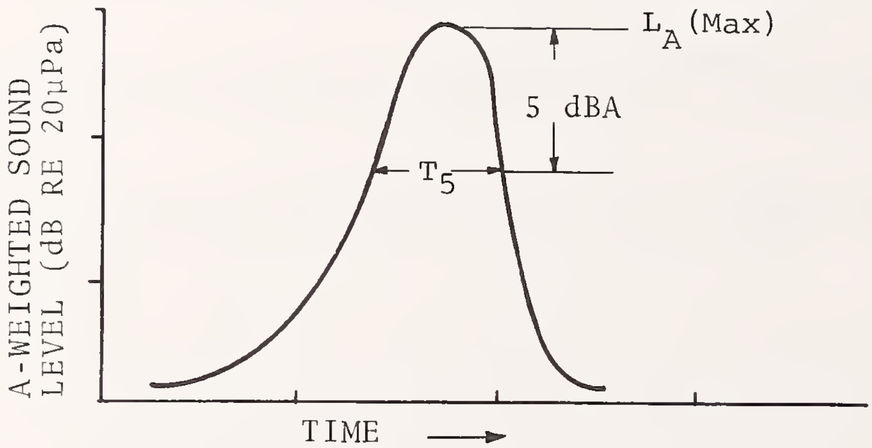
(7) A description of the noise climate identifying the major sources of noise at the location.

Table 5.17 at the end of this section gives a summary of the date, time and metrological conditions for each of the measurement samples.

The quantity L_R as defined in this report is an approximation of the sound energy level due to a train passby. L_R is defined as:

$$L_R = L_A(\text{Max}) + 10 \log T_5$$

where L_A(Max) is the maximum level in dBA from a specific passby and t is the time in seconds between the points where the level is 5 dBA less than L_A(Max). These quantities are illustrated in the sketch below of a typical passby trace.



Since L_R gives an approximation of the sound energy due to each train passby, the levels of L_R can be used to estimate the contribution of the train passby noise to L_{EQ}. The level of L_{EQ} due to the train passbys in a 30 minute sample is approximated as:

$$L_{EQ} = \bar{L}_R - 33$$

where $\bar{L}_R$ is the decibel sum of the values of L_R for all of the train passbys during the 30 minute samples.

The levels of L_{EQ} for the noise samples were generally strongly influenced and often dominated by the train passby noise, and as such the actual number of passbys was an important factor. The normal train headways on the lines used for the wayside measurements are:

Richmond Line	12 minutes
Concord Line	12 minutes
Fremont Line	6 minutes

For a 12 minute headway, either two or three trains would pass by in each direction during the 30 minute sample, and for a 6 minute headway four to five trains would pass by during a normal 30 minute sample. Often the schedule was accurate to within ± 10 seconds. However, during some of the samples, it was evident that the trains were not on the regular schedule. The train speeds and schedule would vary to a degree noticeable to the wayside observers. Under such conditions, the variance of the maximum passby level would increase. Also, there were times when fewer than the expected number of trains would pass by during the sample.

LOCATION 1 - Aerial Structure, Richmond Line, Residential Community, Albany

SPEED - 80 mph Inbound (IB) and Outbound (OB)

DESCRIPTION (See Figure 5.7a)

The land use within the neighborhood of Location 1 is almost exclusively single family residential. The houses are relatively small and placed on lots smaller than 1/4 acre. Masonic Avenue is about 40 ft wide and between the aerial structure and Masonic Avenue there is a park strip about 60 ft wide. At-grade railroad tracks parallel the east side of the aerial structure. Dartmouth Street is the closest cross street, about 200 ft to the north. San Pablo Avenue, a major surface arterial, is located 3000 ft west of Masonic Avenue and Gilman Street, a major local street is located 1000 ft south of the measurement location.

The microphone 50 ft from the near track centerline is 8 ft from the east curb of Masonic Avenue in the park strip and the 100 ft microphone is about 1 ft from the west curb of Masonic Avenue.

NOISE CLIMATE (See Table 5.4, Figures 5.7b-d)

The residual noise in this area is about 45 dBA and is primarily determined by traffic noise. Masonic Avenue is lightly traveled, generally carrying only local automobile traffic. Each car passby on Masonic Avenue causes distinct peaks in the noise level trace. There are some measurable noise contributions by normal human activities in both the adjacent residences and the park strip. The maximum levels for the BART passbys on the near track averaged 91 dBA at the 100 ft position. These levels were the loudest source of intrusive noise in the neighborhood. The BART trains were virtually the only noise source exceeding 70 dBA except loud motorcycles. Comparing the observed values of L_{EQ} with the L_{EQ} values estimated from the L_R's of the train passbys, it is evident that the BART passby noise dominates L_{EQ} in this neighborhood. This is true even though the BART noise does not appear to influence the statistical descriptors below L_{10}.

Freight trains using the track east of the BART structure could add significantly to the 24-hour levels of L_{EQ}, however, none passed during the three 30 minute samples.

Referring to the statistical distribution curves, the samples at the three time periods are very similar with the nighttime samples being somewhat quieter.

It should be noted that the measured noise levels due to traffic on Masonic Avenue are higher than would be observed at the house setback line, since both microphones are closer to the edge of the road than the house setback line.

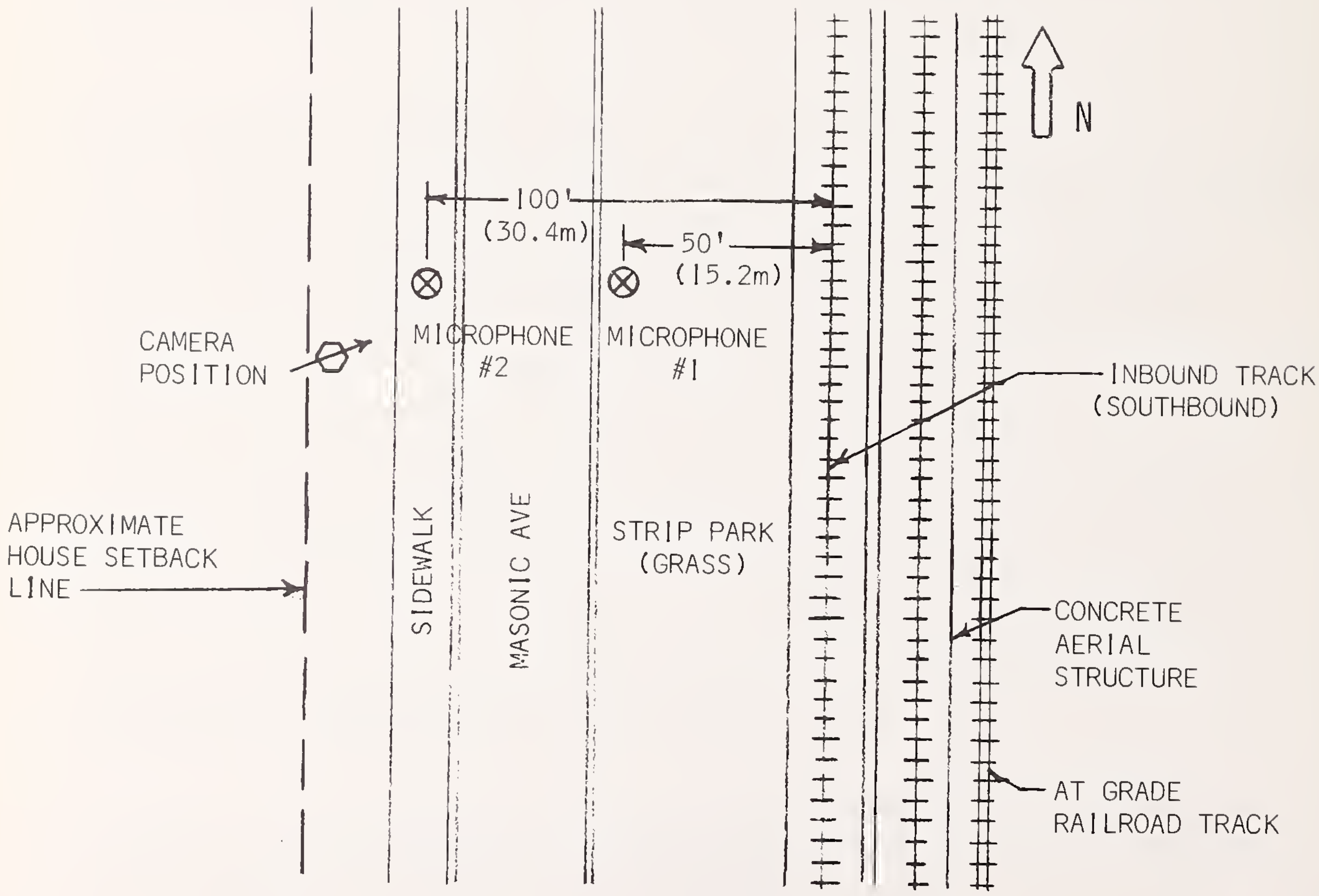


FIGURE 5.7a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 1.

TABLE 5.4 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE NOISE SAMPLES AT LOCATION 1, AERIAL STRUCTURE - RICHMOND LINE

TRAIN SUMMARY		DISTANCE	AVERAGE MAXIMUM LEVELS - dBA		AVERAGE L_R - dBA		STATISTICAL DESCRIPTORS - dBA					L_{EQ}	
IB	OB	[FT]	IB	OB	IB	OB	L_{99}	L_{90}	L_{50}	L_{10}	L_1	MEAS.	TRAINS ONLY [APPROX]
DAY													
3 - 4 car	3 - 4 car	50	94 *0.3	80 *0.9	99 *0.3	86 *0.6	45	46	53	66	82	70	71
		100	90 0.0	76 0.9	96 0.3	83 0.3	42	44	51	64	83	69	68
RUSH HOUR													
3 - 4 car	3 - 4 car	50	93 0.6	80 0.6	98 0.6	86 0.6	46	48	54	65	80	69	70
		100	91 1.5	77 0.3	97 0.6	84 0.0	45	47	52	66	79	69	69
EVENING													
2 - 4 car	1 - 4 car	50	93 0.7	80 --	98 0.4	86 --	45	46	50	62	76	67	68
		100	90 0.7	76 --	96 0.7	83 --	42	44	47	61	76	67	67
TOTALS:													
8 - 4 car	7 - 4 car	50	93 0.5	80 1.1	99 0.6	86 0.6	45	47	52	64	79	69	70
		100	91 0.7	77 0.3	97 0.7	84 0.45	43	45	50	64	79	68	68

*Standard Deviation of level

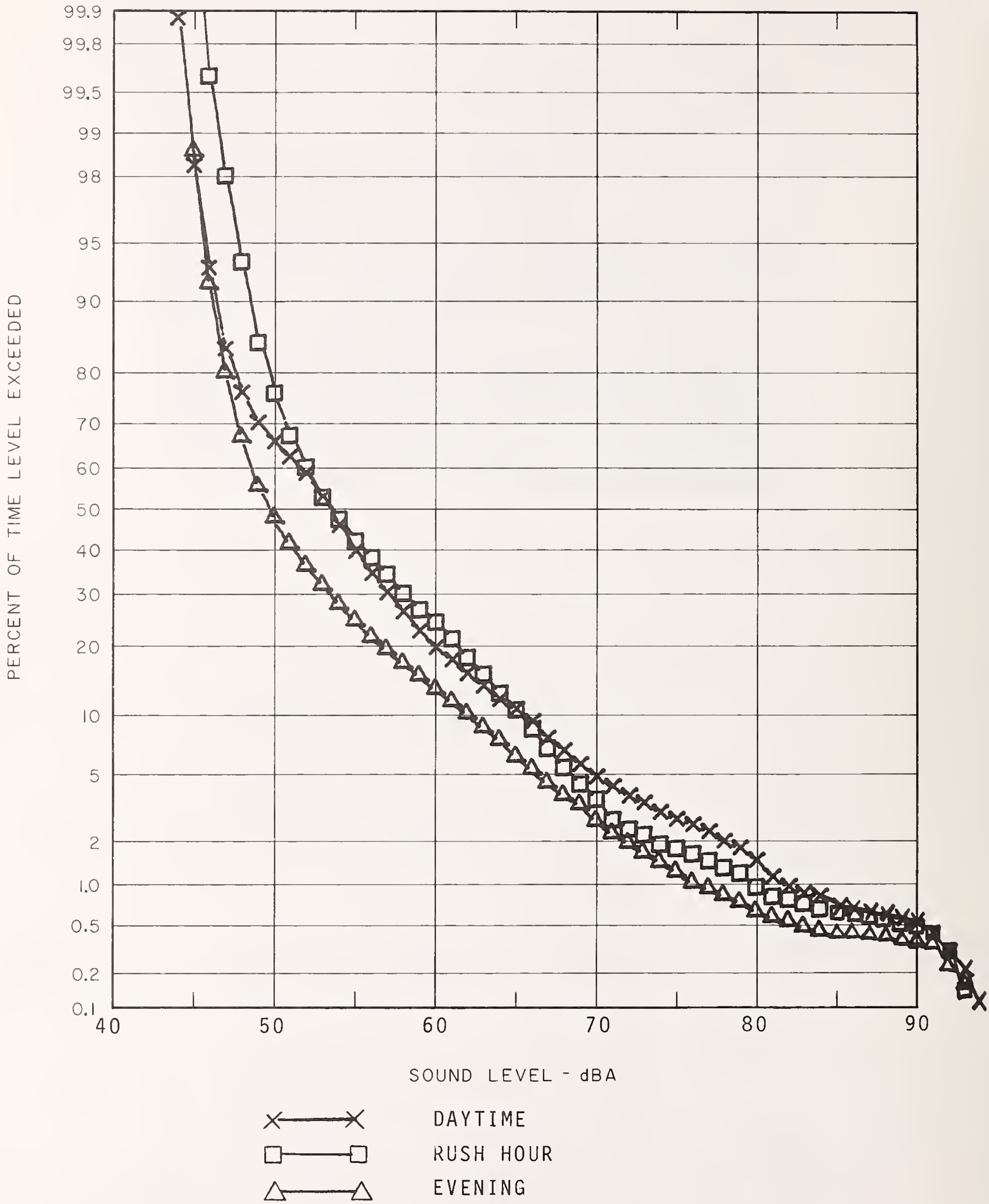


FIGURE 5.7b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 1, 50 FT POSITION.

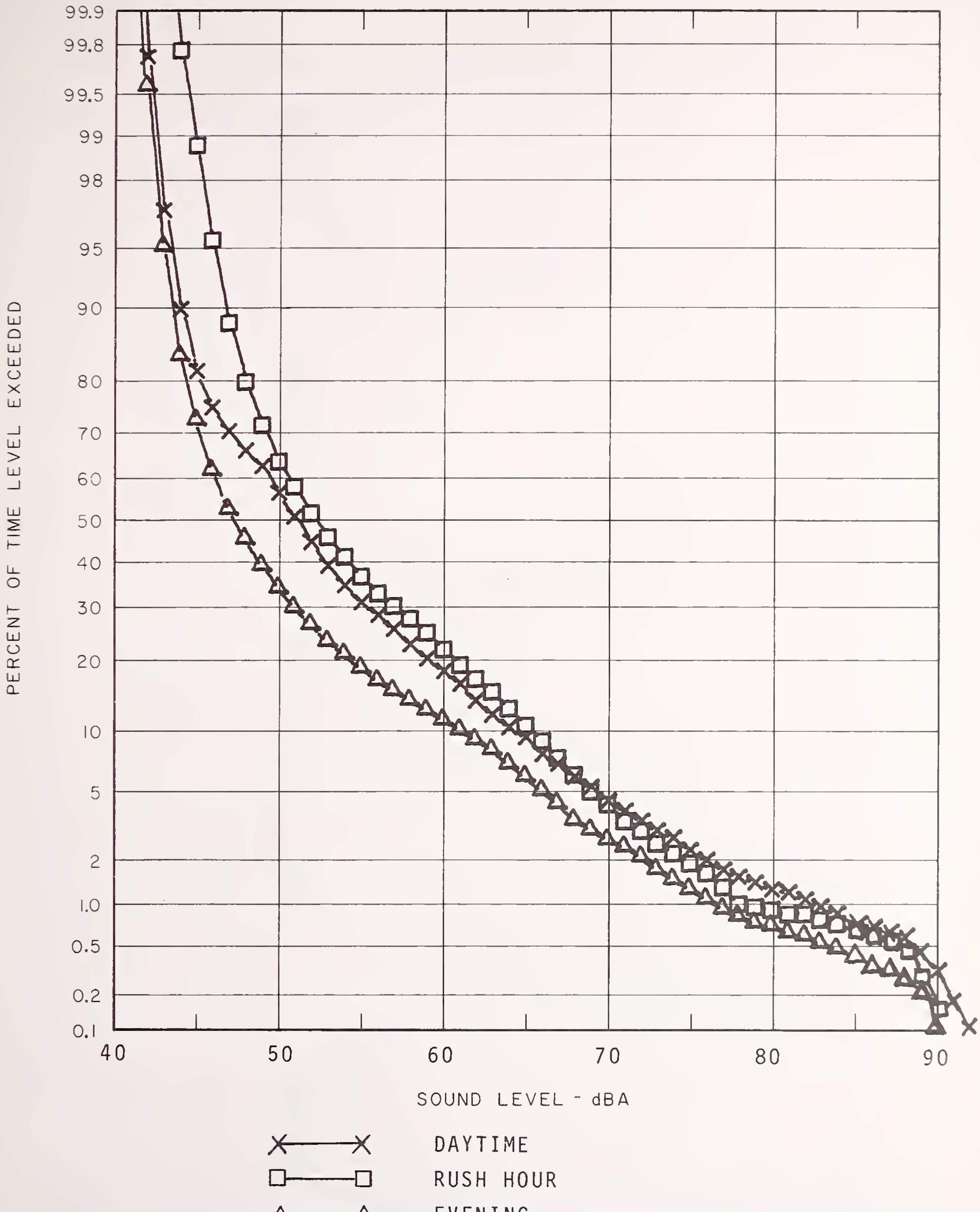


FIGURE 5.7c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 1, 100 FT POSITION.

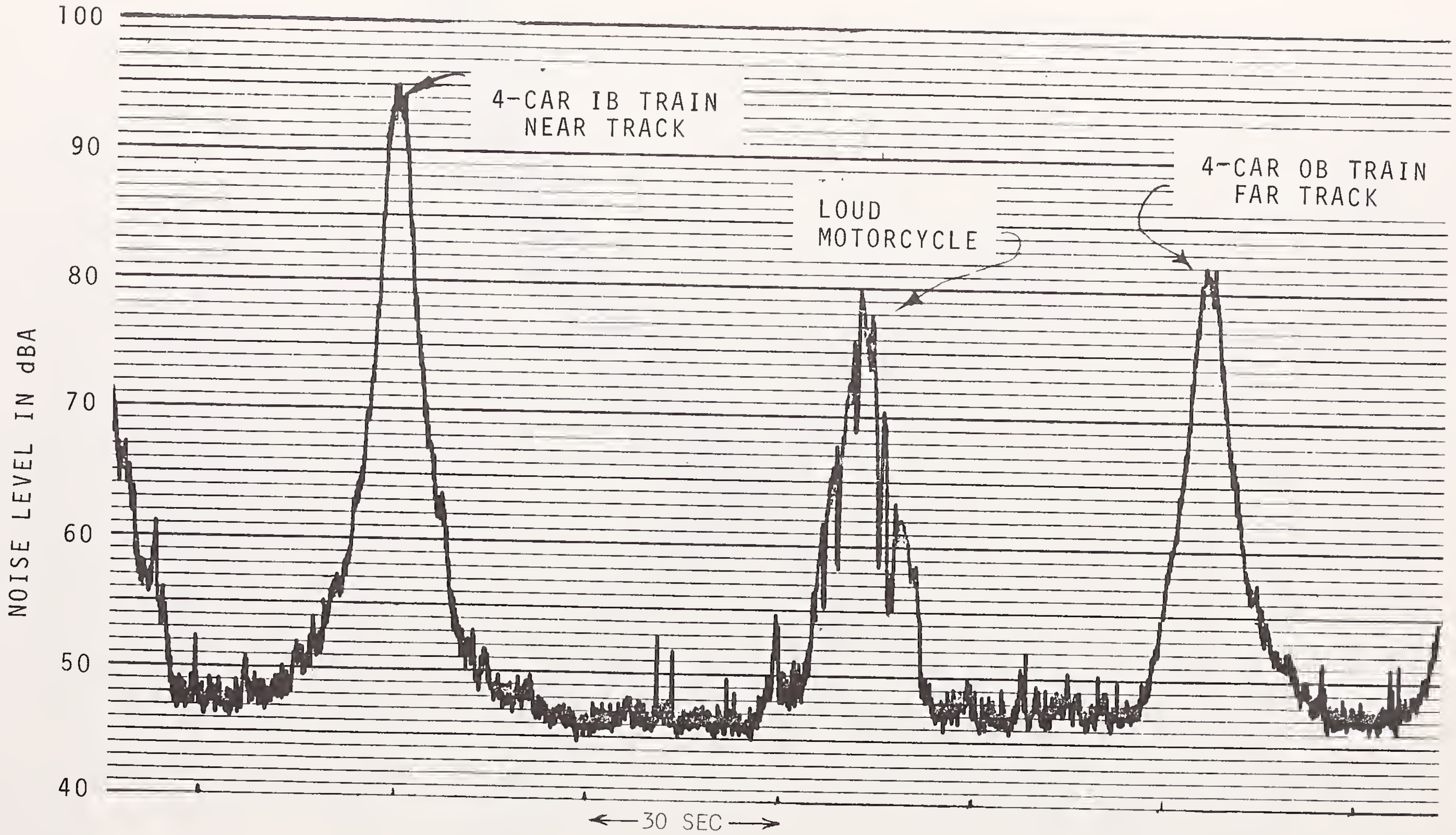


FIGURE 5.7d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 1. SAMPLE TAKEN 3/11/75, 1:15 PM.

LOCATION 2 - Aerial Structure, Richmond Line, Industrial/ Residential Community, Albany

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.8a)

Location 2 is situated on the grounds of a sawmill along Schmidt Lane in Albany. The measurement location is west of the BART tracks in a lot used for lumber storage, about 10 ft from the south curb of Schmidt Lane. West of the BART structure the land use is industrial/commercial while east of the tracks, the land use is primarily single family residential. The northern section of the BART aerial structure is partially shielded by a sawmill building.

At-grade railroad tracks run adjacent to the aerial structure east of the aerial structure. San Pablo Avenue, a heavily traveled north-south surface street is about 500 ft west of the measurement location. The only unblocked view of San Pablo Avenue from the measurement location is down Schmidt Lane.

NOISE CLIMATE (See Table 5.5, Figures 5.8b-d)

Some of the observed sources of noise in this area are: activities in the sawmill such as saws and fork lifts; traffic on Schmidt Lane and San Pablo Avenue, people using the sidewalk, and, of course, the BART trains. Freight trains could be a significant source of noise, however, none passed by the measurement location during the samples. The sawmill, a significant source of noise at this site, was active during the daytime samples only. The rush hour and evening samples were both taken after normal work hours at the sawmill.

The level of L_{EQ} for the three samples is quite consistent even for the daytime samples when there was a considerable amount of noise from the sawmill activities. The comparison of the levels of L_{EQ} for the trains only, approximated using the values of L_R, indicates that the BART passby noise dominates L_{EQ} at both the 50 ft and 100 ft positions.

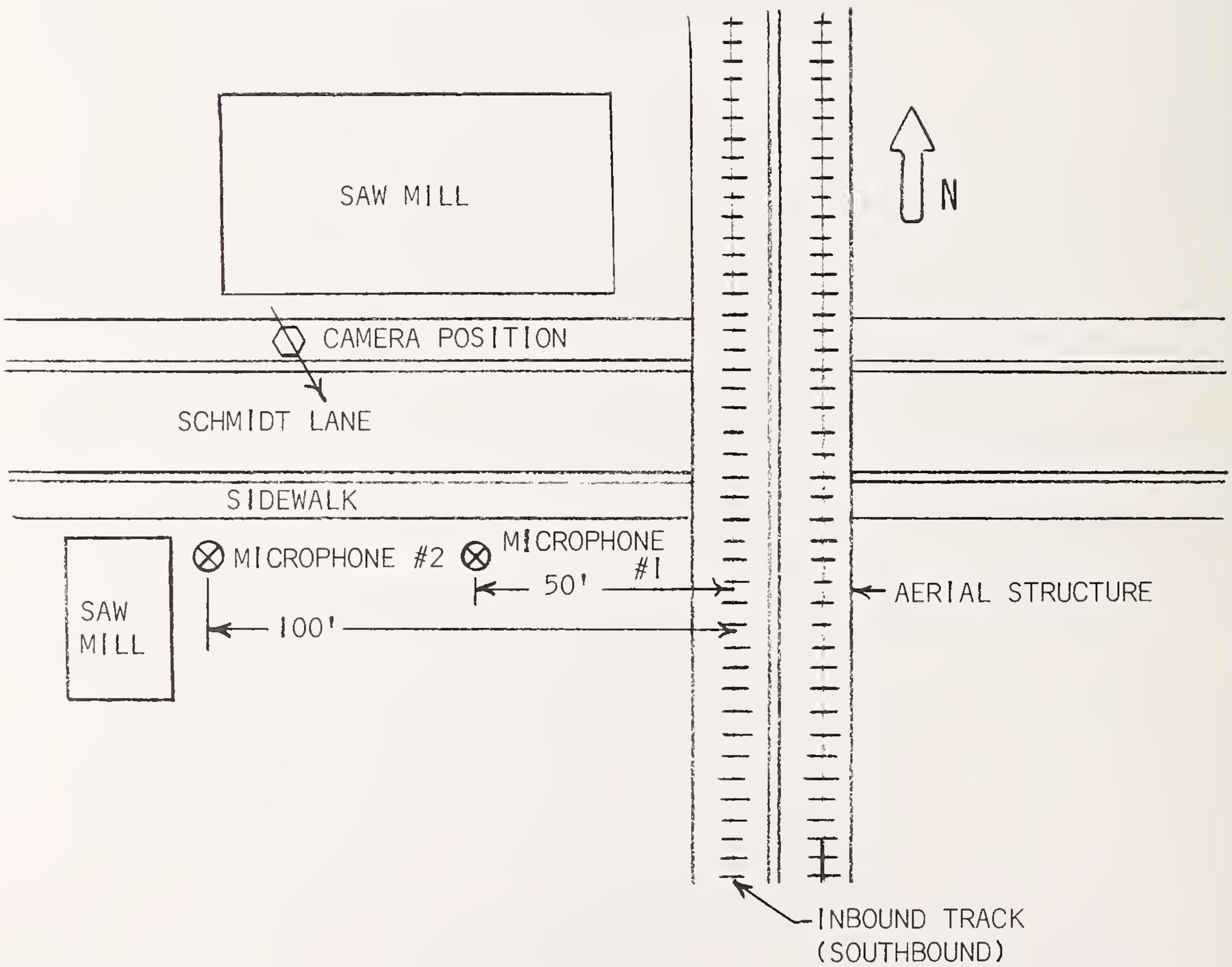


FIGURE 5.8a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 2.

TABLE 5.5 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE NOISE SAMPLES AT LOCATION 2, AERIAL STRUCTURE - RICHMOND LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
3 - 4 car	2 - 4 car	50	91 ** 0*	81 **2.1*	97 ** 0*	87 **1.8*	49	53	58	68	84	71	69
		100	89 *0.3*	79 *1.4*	95 *0.3*	85 *1.1*	49	53	59	69	83	70	67
RUSH HOUR													
1 - 4 car 2 - 5 car	3 - 5 car	50	93 *0.3*	81 *0.9*	98 *1.0*	88 *0.8*	48	50	55	65	81	71	70
		100	91 *0.3*	79 *0.8*	96 *0*	85 *0.3*	48	49	54	65	79	69	68
EVENING													
1 - 4 car 1 - 5 car	3 - 5 car	50	93 *0.4*	81 *0.9*	99 *1.1*	88 *0.6*	45	47	53	66	80	70	69
		100	91 *0*	79 *1.0*	96 *0.7*	86 *0.5*	46	48	53	65	78	67	67
TOTALS:													
5 - 4 car 3 - 5 car	2 - 4 car 6 - 5 car	50	93 *.95*	81 *1.1*	98 *1.0*	88 *0.9*	47	50	55	66	82	71	69
		100	90 *1.1*	79 *0.9*	96 *0.9*	85 *0.7*	48	50	55	66	80	69	67

**Standard Deviation of level*

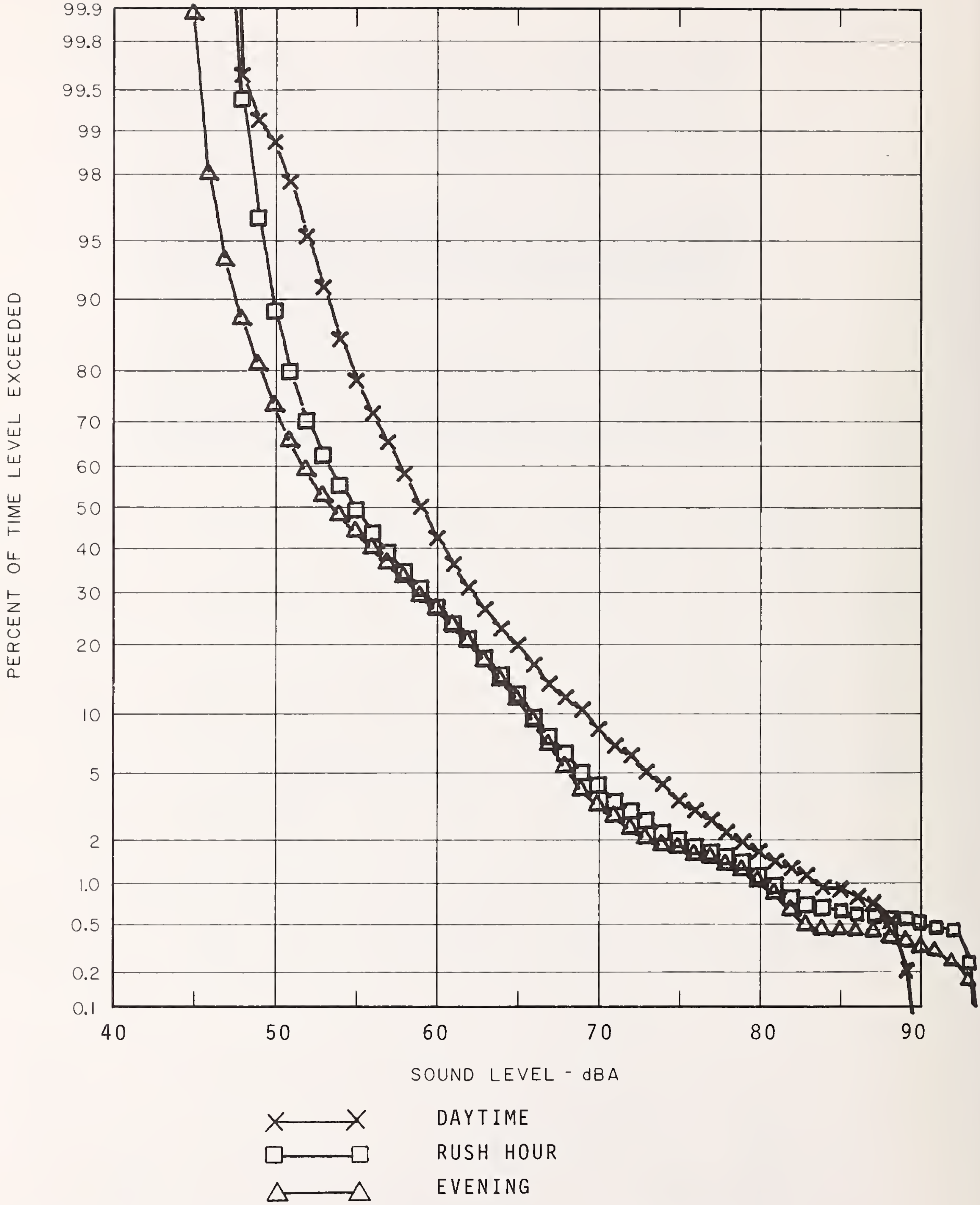


FIGURE 5.8b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 2, 50 FT POSITION.

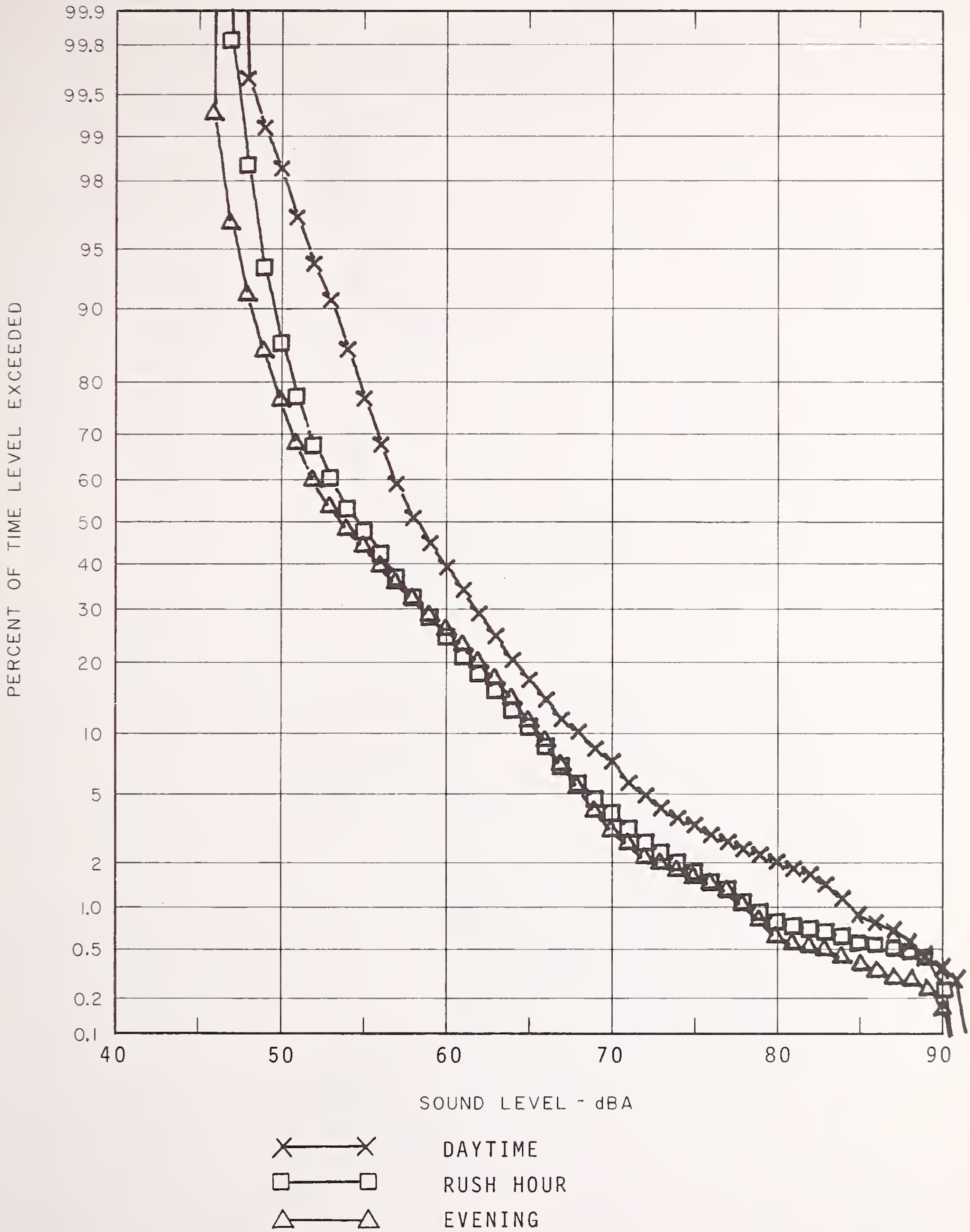


FIGURE 5.8c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 2, 100 FT POSITION.

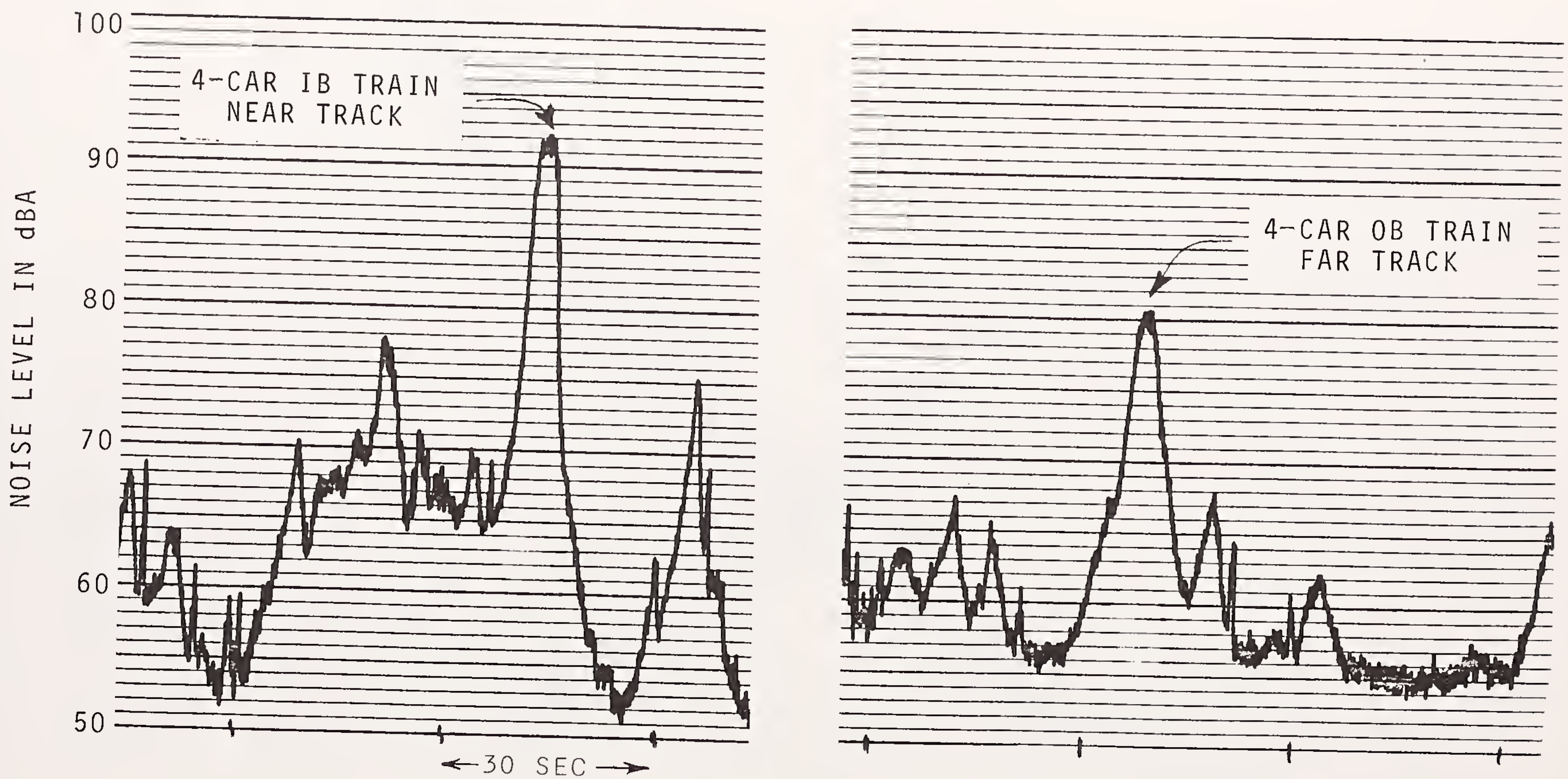


FIGURE 5.8d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 2.
SAMPLE TAKEN 3/11/75, 12:12 PM.

LOCATION 3 - Aerial Structure, Fremont Line, Residential Community, San Lorenzo

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.9a)

This location is a residential community of primarily single family houses on lots smaller than 1/4 acre. The measurement is west of the BART aerial structure with the 50 ft microphone east of Western Boulevard and the 100 ft microphone west of Western Boulevard. Western Boulevard consists of two roadways with the BART tracks partially covering the east roadway. The BART tracks and at-grade railroad tracks run in the median between the two Western Boulevard roadways. Both Western Boulevard roadways carry a light load of local two-way traffic. The railroad tracks are frequently used, however, no freight trains passed during the three 30 minute samples.

Mission Boulevard, a fairly heavily traveled surface street is located about 1500 ft east of the measurement location.

NOISE CLIMATE (See Table 5.6, Figures 5.7b-d)

The primary sources of noise at this location are automobile traffic on Western Boulevard, traffic noise from distant sources, and BART passby noises. Freight trains using railroad tracks would also contribute to the overall noise climate, however, no freight trains passed during the samples. The few cars on Western Boulevard caused distinct peaks in the noise level traces. These are higher than would actually be observed at the adjacent residences since the microphones were so close to the edge of the road.

There is very little difference between the measurement statistics for the three times of day. Indeed the statistical distributions for the 50 and 100 ft positions are almost identical except above 85 dBA.

Comparison of the "trains only" L_{EQ} and the measured L_{EQ} shows that in only one sample did they differ by as much as 2 dBA. It is evident that the train passbys dominate the levels of L_{EQ}, although the levels of L_{10} are primarily determined by traffic noise.

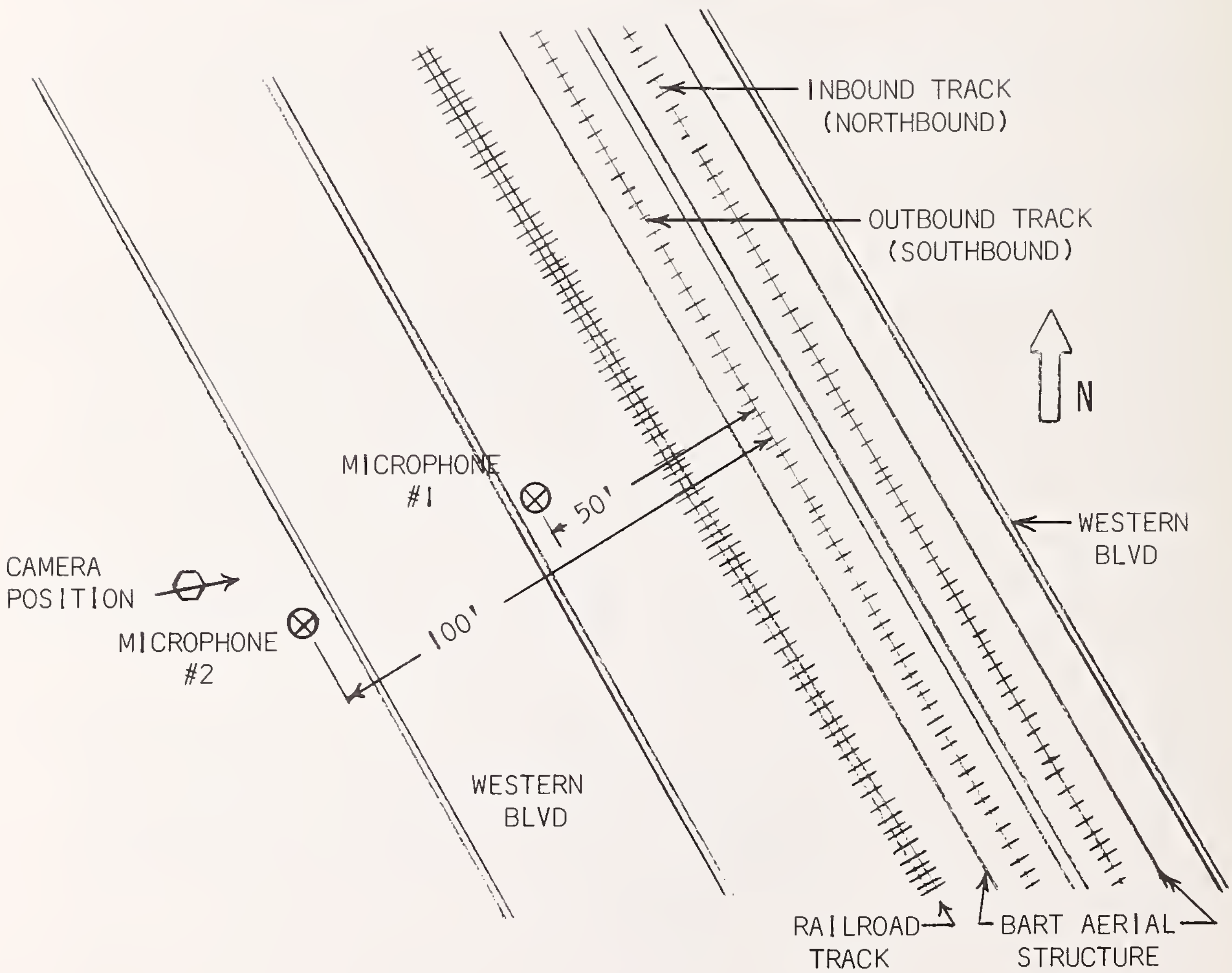


FIGURE 5.9a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 3.

TABLE 5.6 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE NOISE SAMPLES AT LOCATION 3, AERIAL STRUCTURE - FREMONT LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
2 - 4 car 2 - 5 car	3 - 4 car 1 - 5 car 1 - 6 car	50	78 **0.6*	89 **0.3*	84 **1.0*	94 **0.9*	46	48	54	64	85	69	69
		100	76 *0.3*	86 *0.6*	83 *0.3*	93 *1.0*	46	48	54	66	84	68	67
RUSH HOUR													
3 - 4 car 2 - 5 car	4 - 4 car 1 - 5 car	50	80 *1.2*	89 *0.4*	86 *0.9*	94 *0.7*	46	49	54	66	84	70	69
		100	77 *1.1*	87 *0.5*	84 *1.0*	93 *0.7*	46	48	53	67	84	69	67
EVENING													
3 - 4 car 2 - 5 car	1 - 4 car 4 - 5 car	50	79 *0.6*	89 *0.3*	85 *0.5*	95 *0.2*	46	48	53	64	86	70	69
		100	76 *0.9*	86 *0.2*	83 *0.8*	93 *0.5*	45	47	52	65	84	68	67
TOTALS:													
8 - 4 car 6 - 5 car	8 - 4 car 6 - 5 car 1 - 6 car	50	79 *1.3*	89 *0.4*	85 *1.1*	95 *0.6*	46	48	54	65	85	70	69
		100	76 *1.1*	86 *0.7*	83 *0.9*	93 *0.7*	46	48	53	66	84	68	67

**Standard Deviation of level*

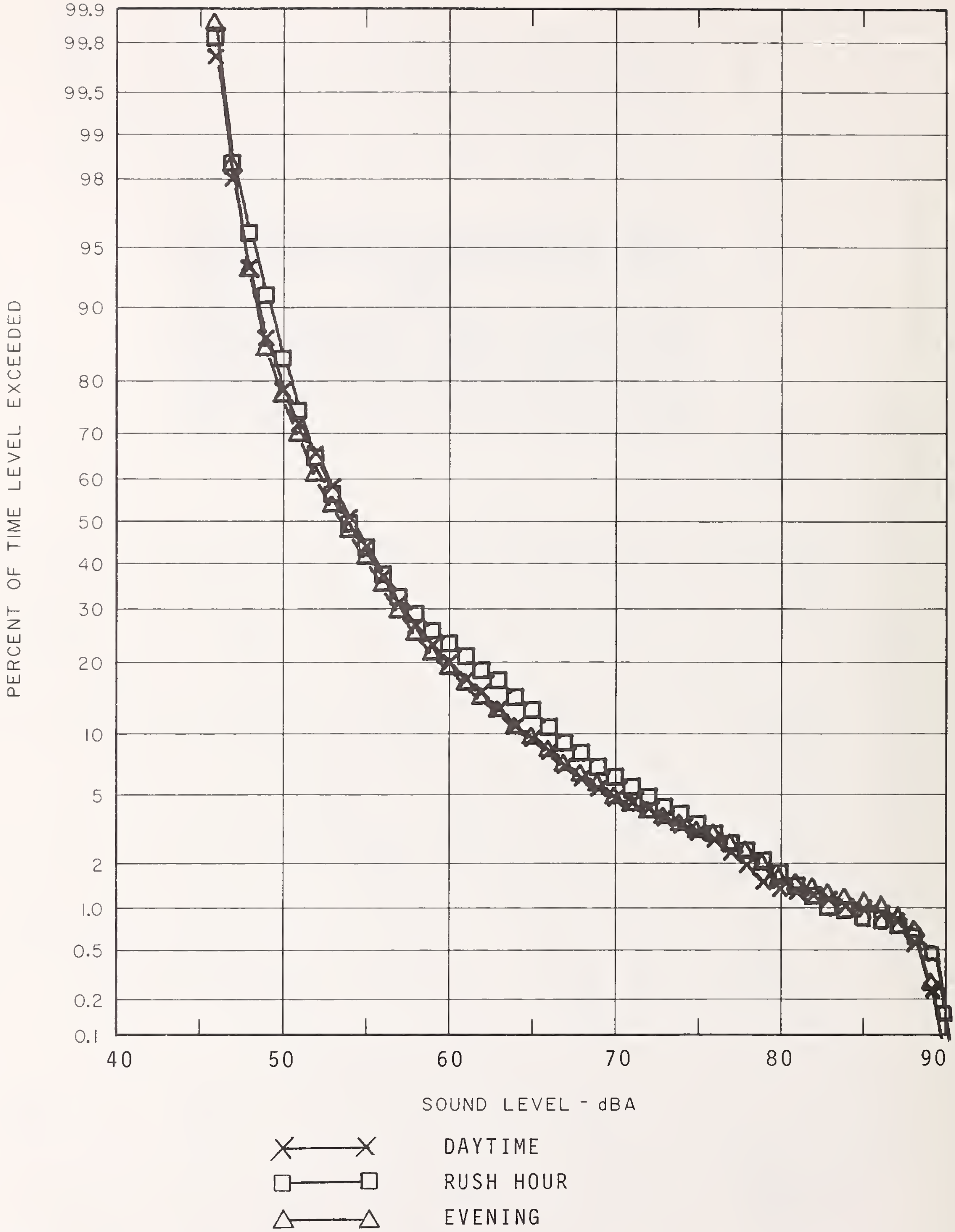


FIGURE 5.9b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 3, 50 FT POSITION.

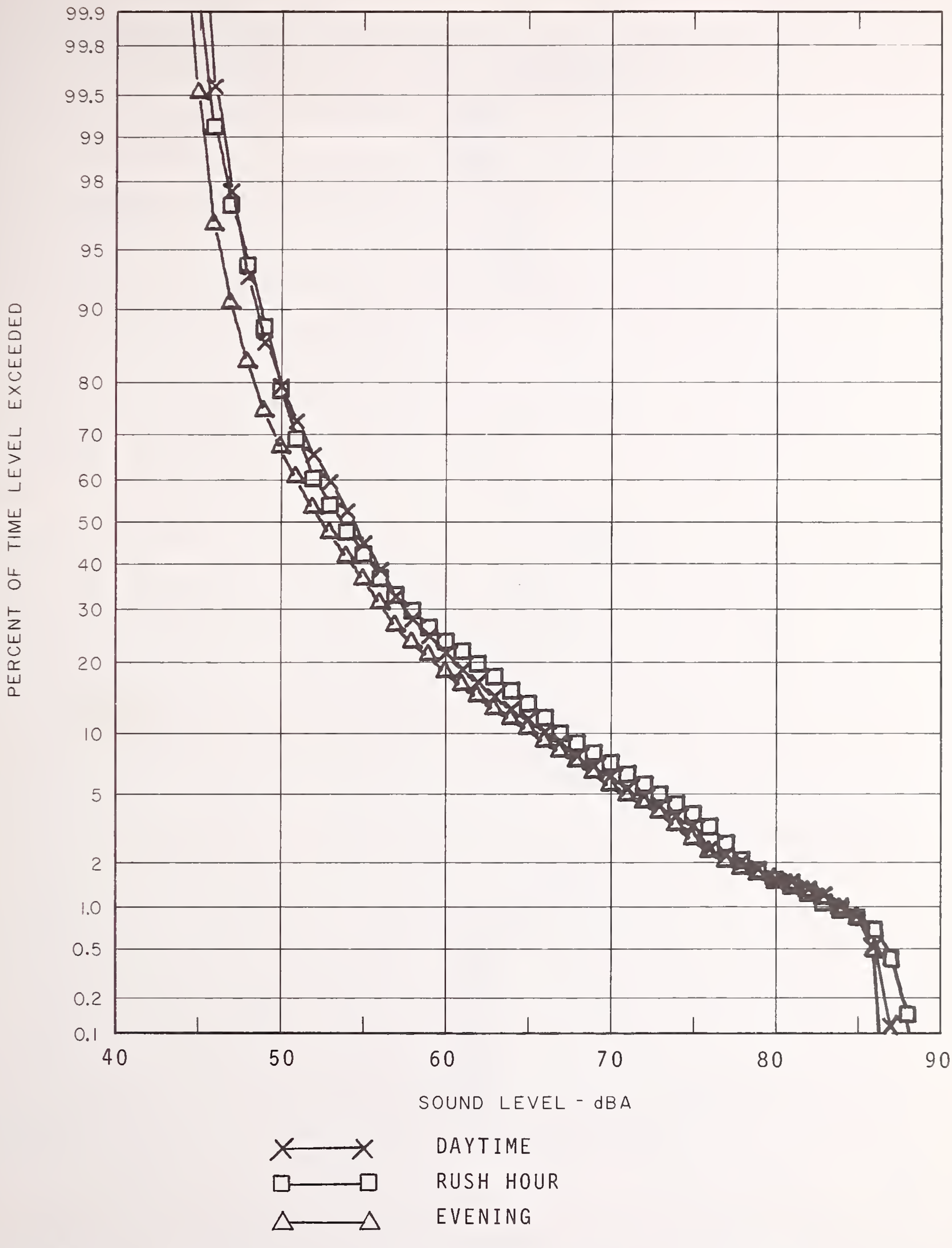


FIGURE 5.9c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 3, 100 FT POSITION.

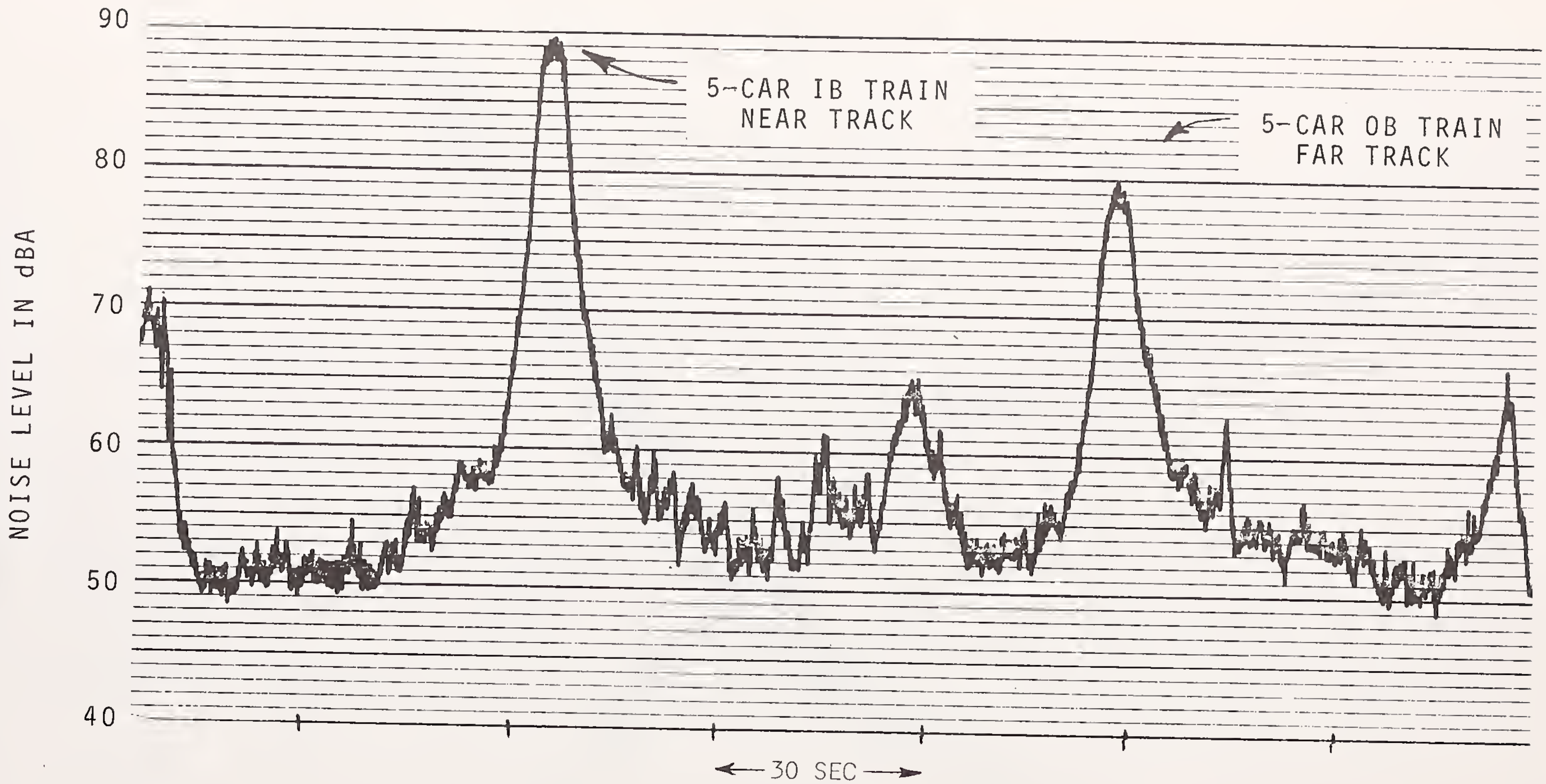


FIGURE 5.9d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 3.
SAMPLE TAKEN 4/1/75, 7:57 PM.

LOCATION 4 - Aerial Structure, Fremont Line, Commercial/ Industrial, Oakland

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.10a)

Location 4 is north of 92nd Avenue west of the BART aerial structure. The area is all commercial and industrial without any significant residential land use. San Leandro Street, a heavily traveled surface street is adjacent to the south side of the BART aerial structure in this area. The at-grade Western Pacific Railroad tracks are adjacent to the northbound side of the aerial structure. The microphones were located in a cleared dirt area without any buildings nearby. The microphone at the 50 ft position is actually on a spur of the Western Pacific Railroad tracks.

NOISE CLIMATE (See Table 5.7, Figures 5.10b-d)

The primary sources of noise at this location are traffic on San Leandro Street, 92nd Avenue and the BART train noise. There is also a contribution from freight trains on the railroad tracks. One train went past during the evening sample with a very pronounced effect on the statistical distribution curve, especially at the near microphone which was located only 10 to 15 ft from the main line Western Pacific Railroad track. The freight train passby dominates the statistical distribution above about 75 dBA. Although the noise due to traffic on San Leandro Street is quite loud at the measurement locations, generally between 60 to 70 dBA, the levels of L_{EQ} are still not much higher than the approximate levels of L_{EQ} for the BART trains only. The only exception is the evening sample with the freight train passby, where the freight train passby clearly dominates L_{EQ}. For the daytime and rush hour samples the measured L_{EQ} is 1 to 3 dBA more than the "trains only" L_{EQ}. It appears that the BART passby noise dominates the level of L_{EQ} with a significant contribution from the traffic noise. This is an example of a situation in which L_{EQ} is dominated by BART passby noise even though the traffic noise is very loud.

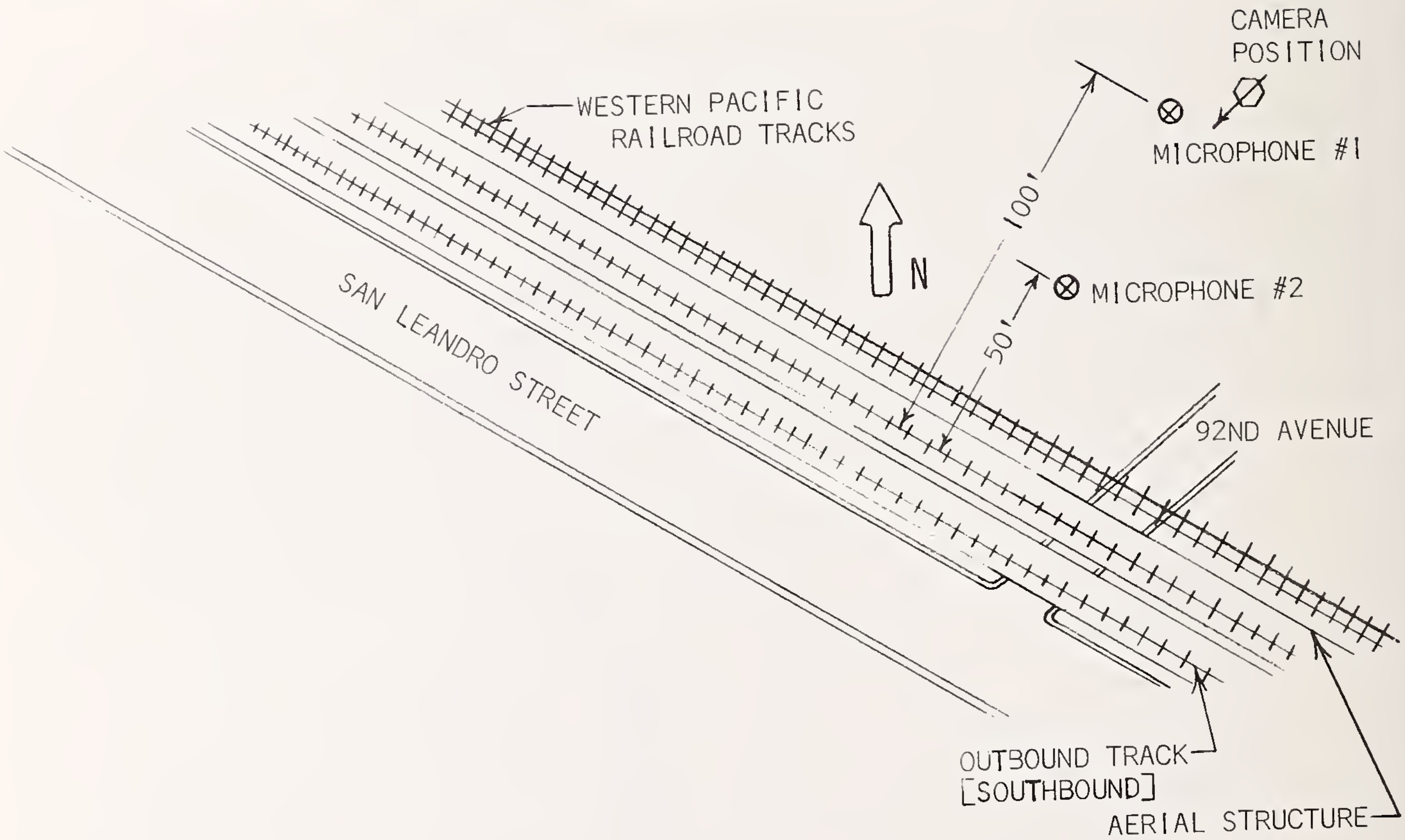


FIGURE 5.10a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 4.

TABLE 5.7 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE NOISE SAMPLES AT LOCATION 4, AERIAL STRUCTURE - FREMONT LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
2 - 4 car 3 - 5 car	4 - 4 car 1 - 5 car	50	87 *0.7	79 *1.4	93 *0.8	86 *1.4	56	59	63	70	85	71	68
		100	86 0.9	78 0.9	92 1.1	85 0.9	56	57	61	68	83	69	67
RUSH HOUR													
6 - 5 car	1 - 4 car 3 - 5 car 1 - 6 car	50	87 1.0	79 0.9	93 0.8	86 0.5	57	60	64	70	85	70	69
		100	87 1.0	79 0.5	93 0.7	86 0.4	58	60	63	69	85	70	69
EVENING													
3 - 5 car 1 - 6 car	3 - 5 car	50	88 0.3	80 0	94 0.3	86 0.3	55	56	60	67	90	74	68
		100	87 0.3	79 0	93 0.3	86 0.3	54	55	58	66	86	72	67
TOTALS:													
2 - 4 car 12 - 5 car 1 - 6 car	5 - 4 car 7 - 5 car 1 - 6 car	50	88 0.9	79 0.8	93 0.7	86 0.9	56	58	62	69	87	72	69
		100	87 0.8	79 0.5	93 0.9	86 0.8	56	57	61	68	85	71	68

*Standard Deviation of level

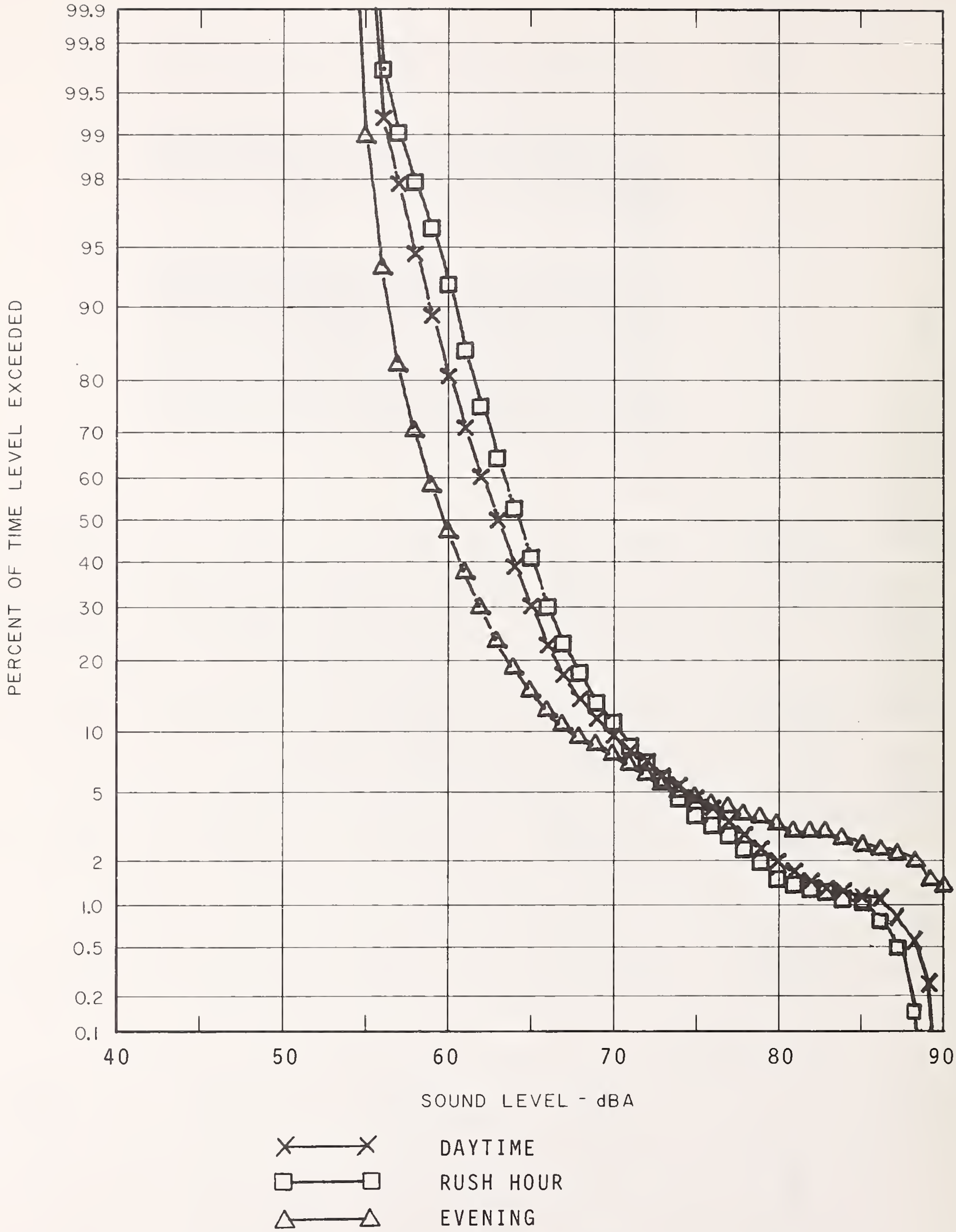


FIGURE 5.10b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 4, 50 FT POSITION.

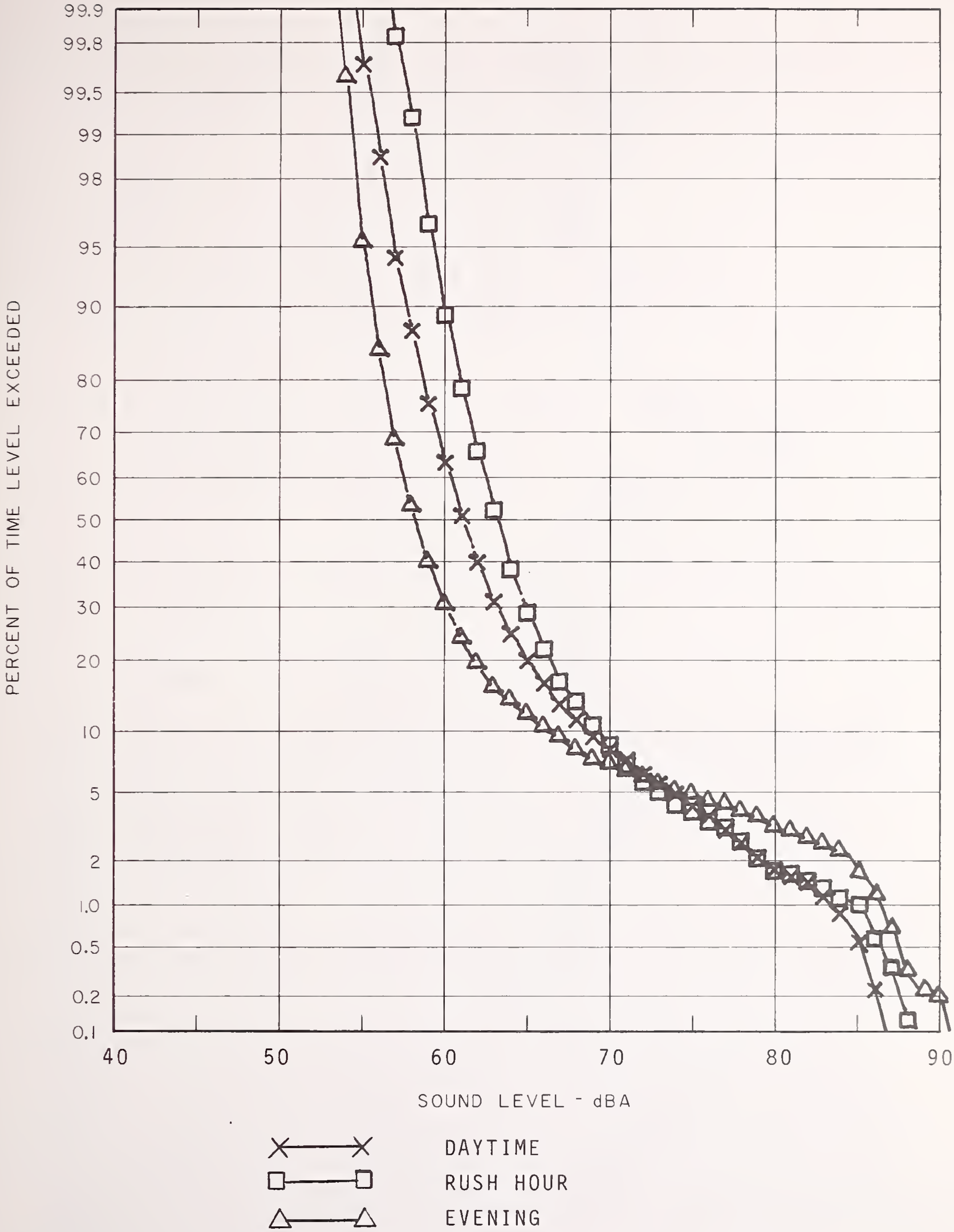


FIGURE 5.10c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 4, 100 FT POSITION.

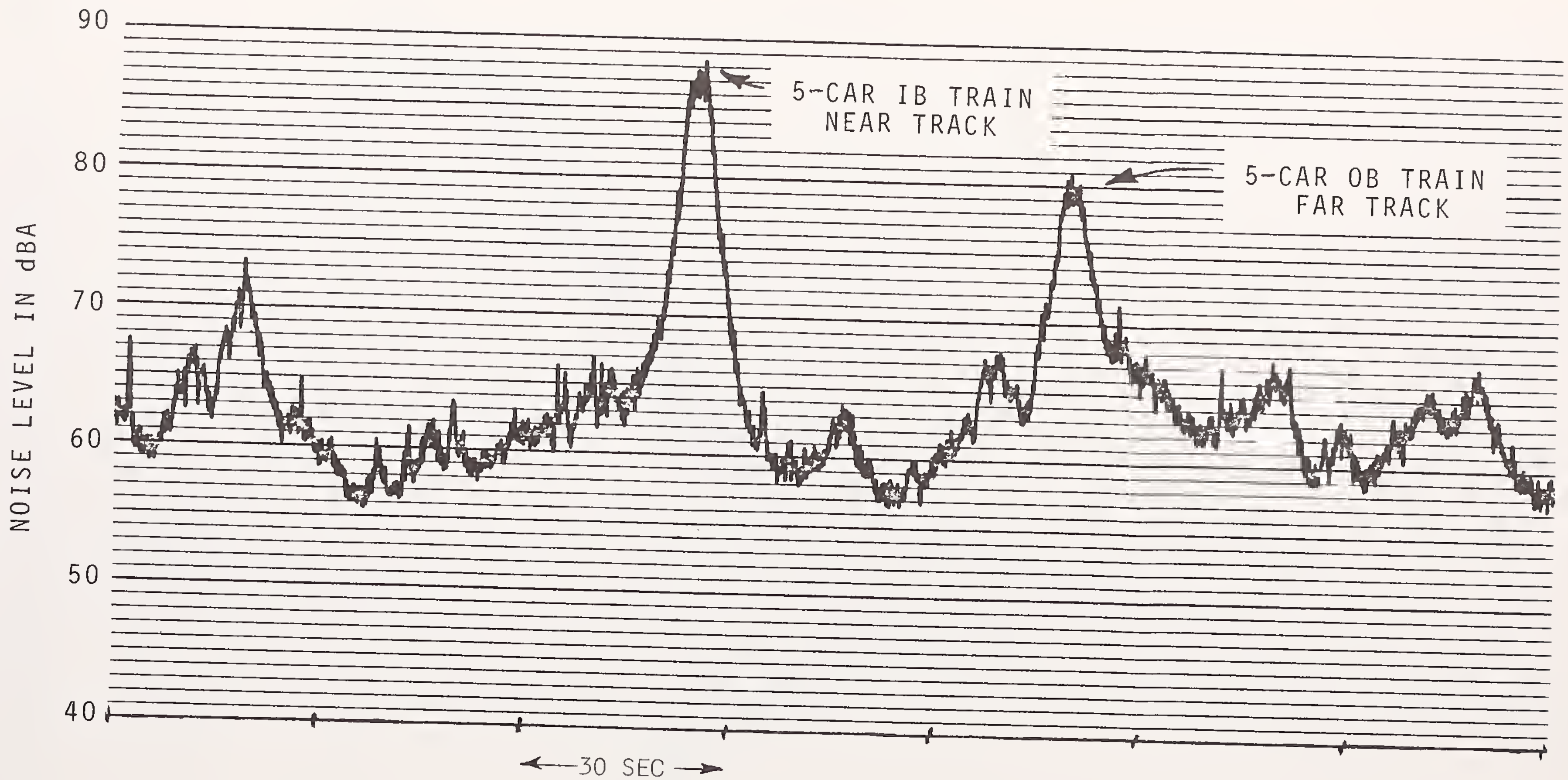


FIGURE 5.10d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 4.
SAMPLE TAKEN 3/18/75, 11:08 AM.

LOCATION 5 - At-grade Tracks, Richmond Line, Commercial, Richmond

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.11a)

This measurement location is situated in a parking lot serving a large shopping center to the east and a group of large three- to four-story office buildings to the west. However, the parking lot in the vicinity of the measurement location is rarely used.

The BART tracks are about 10 ft above the elevation of the parking lot. At-grade railroad tracks run adjacent to the south side of the BART tracks.

Across the BART tracks the land use is single family, one-story residential.

MacDonald Avenue, a busy arterial road, is 700 ft to the north and the Eastshore Freeway, Interstate 80, is 1400 ft to the east.

NOISE CLIMATE (See Table 5.8, Figures 5.11b-d)

Since the parking lot in the vicinity of the measurement location is rarely used, the noise due to the activities in the parking lot was not significant except when cars occasionally drove near one of the microphones in order to get to the other side of the parking lot. Except for the BART passby noise, the only significant source of noise is from the distant traffic on MacDonald Avenue and the Eastshore Freeway.

From the statistics in Table 5.8 and the statistical distribution curves in Figures 5.11b and 5.11c it is evident that the levels of L_{EQ} are dominated by the noise from BART passbys.

An interesting phenomenon observed at this location is the difference in peak levels for trains on the near and far tracks. Although trains in both directions generally passed at the same speed [80 mph] there is only a 2 dBA difference in the average maximum levels on the near and far tracks. This is considerably less difference than was observed at any of the twelve other measurement locations. There is no obvious explanation for the small difference between the noise levels on the near and far tracks as there are no large reflecting surfaces. This phenomenon is discussed in more detail on pages 5-19 to 5-23.

The statistical distribution of the noise levels at the 50 and 100 ft positions are virtually identical up to about 82 dBA. Also there is very little difference in the measurements at the three times of day.

In order to provide a graphic illustration of the effect the train passbys have of the noise climate at this location the daytime sample was rerun without the trains. The level of L_{10} with and without the trains is almost the same although L_1 is 64 dBA without the trains and 80 dBA with the trains. The level of L_{EQ} without the trains drops 10 dBA, from 65 to 55 dBA. These results show how the train passby noise can dominate the noise climate at a specific location without having any significant effect on the statistical descriptors of the noise climate such as L_{10} and L_{50}.

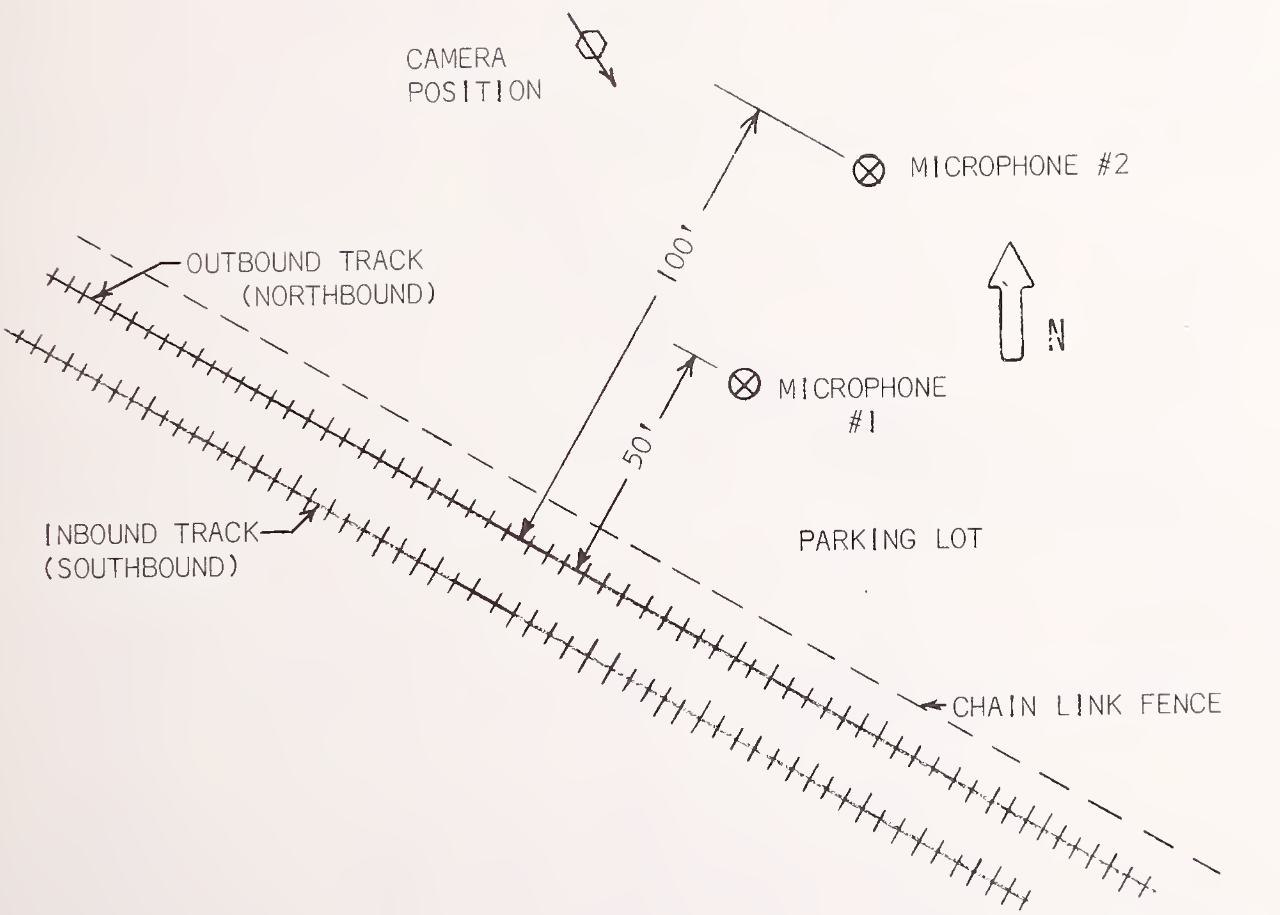


FIGURE 5.11a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 5.

TABLE 5.8 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE NOISE SAMPLES AT LOCATION 5, AT-GRADE - RICHMOND LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
3 - 4 car	3 - 4 car	50	84 *0.3	86 *0.3	88 *0.3	91 * 0	48	50	52	57	80	65	65
		100	80 0.8	84 0.6	85 0.3	89 0.5	49	50	53	58	78	63	63
RUSH HOUR													
2 - 5 car	2 - 5 car	50	85 0.7	87 1.1	90 1.1	92 0.7	48	49	52	58	75	65	64
		100	83 0.4	84 1.1	88 0.4	90 0.7	48	50	53	59	76	63	62
EVENING													
2 - 4 car 1 - 5 car	3 - 5 car	50	85 0.9	87 1.3	90 1.2	93 1.0	46	48	51	59	83	67	67
		100	83 0.8	85 1.6	88.5 0.9	92 1.0	46	48	51	59	81	65	65
TOTALS:													
5 - 4 car 3 - 5 car	3 - 4 car 5 - 5 car	50	85 1.0	87 1.0	89 1.5	92 1.0	47	49	52	58	79	66	66
		100	82 1.8	84 1.2	87 1.9	90 0.9	48	49	52	59	78	64	64

*Standard Deviation of level

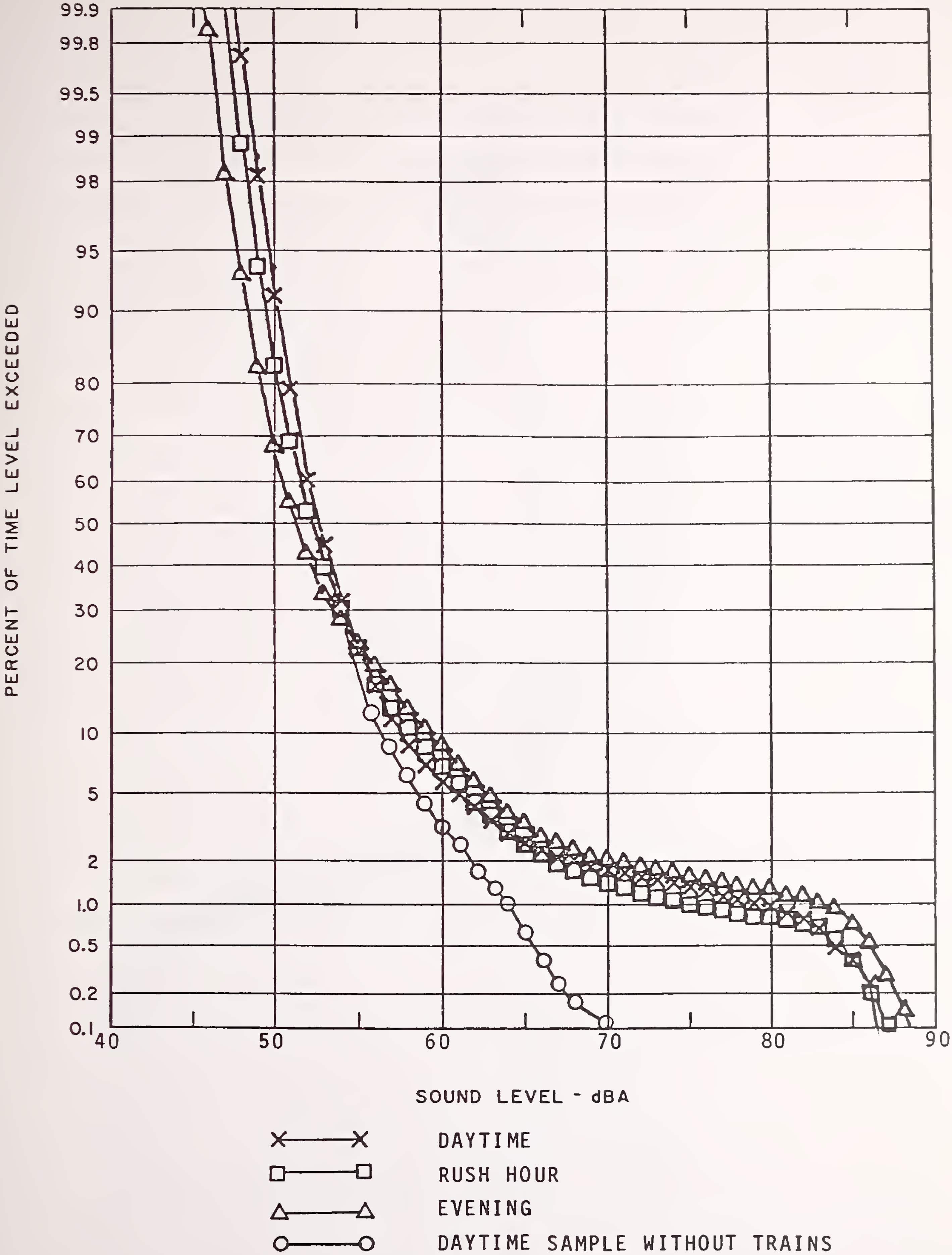


FIGURE 5.11b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 5, 50 FT POSITION

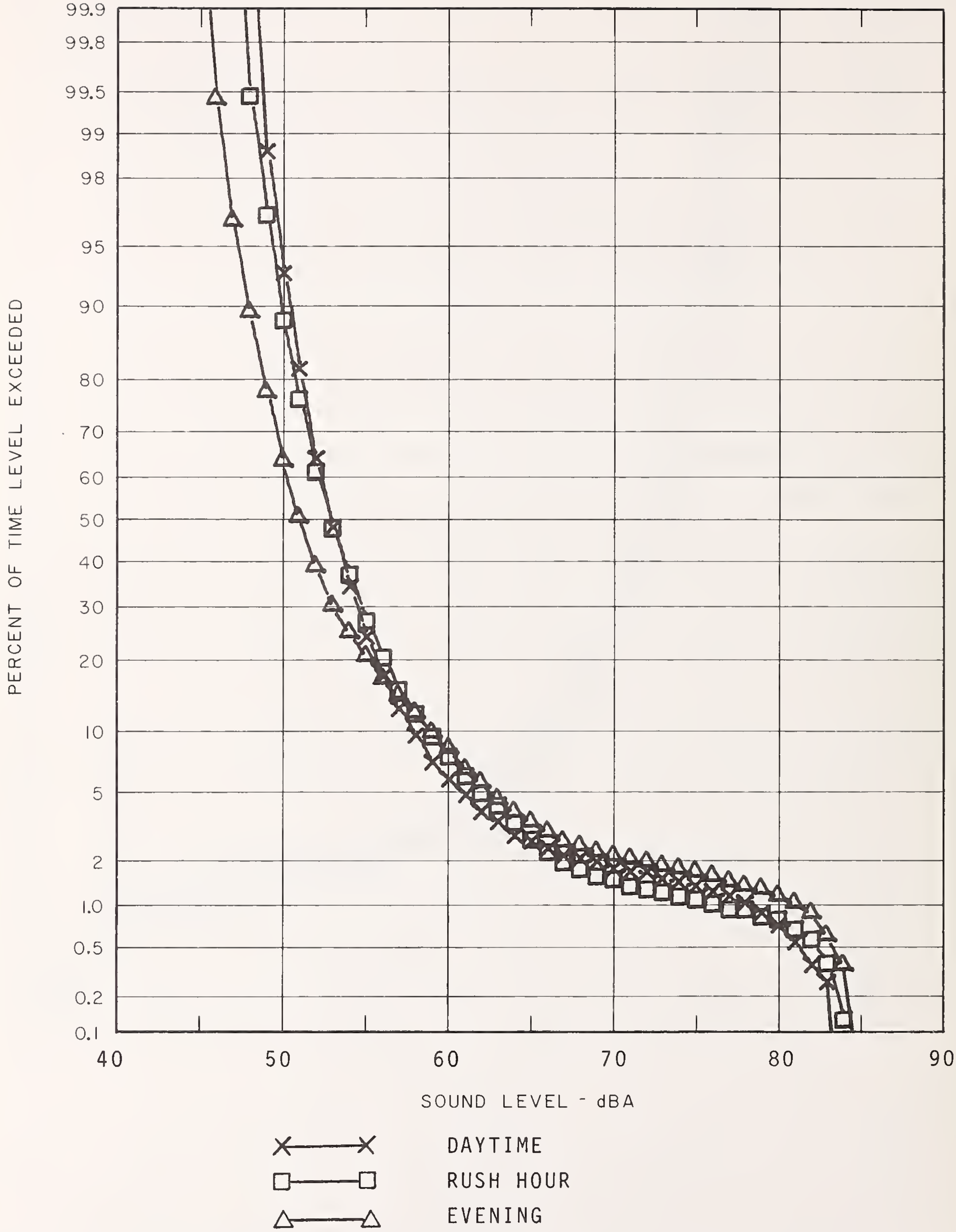


FIGURE 5.11c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 5, 100 FT POSITION.

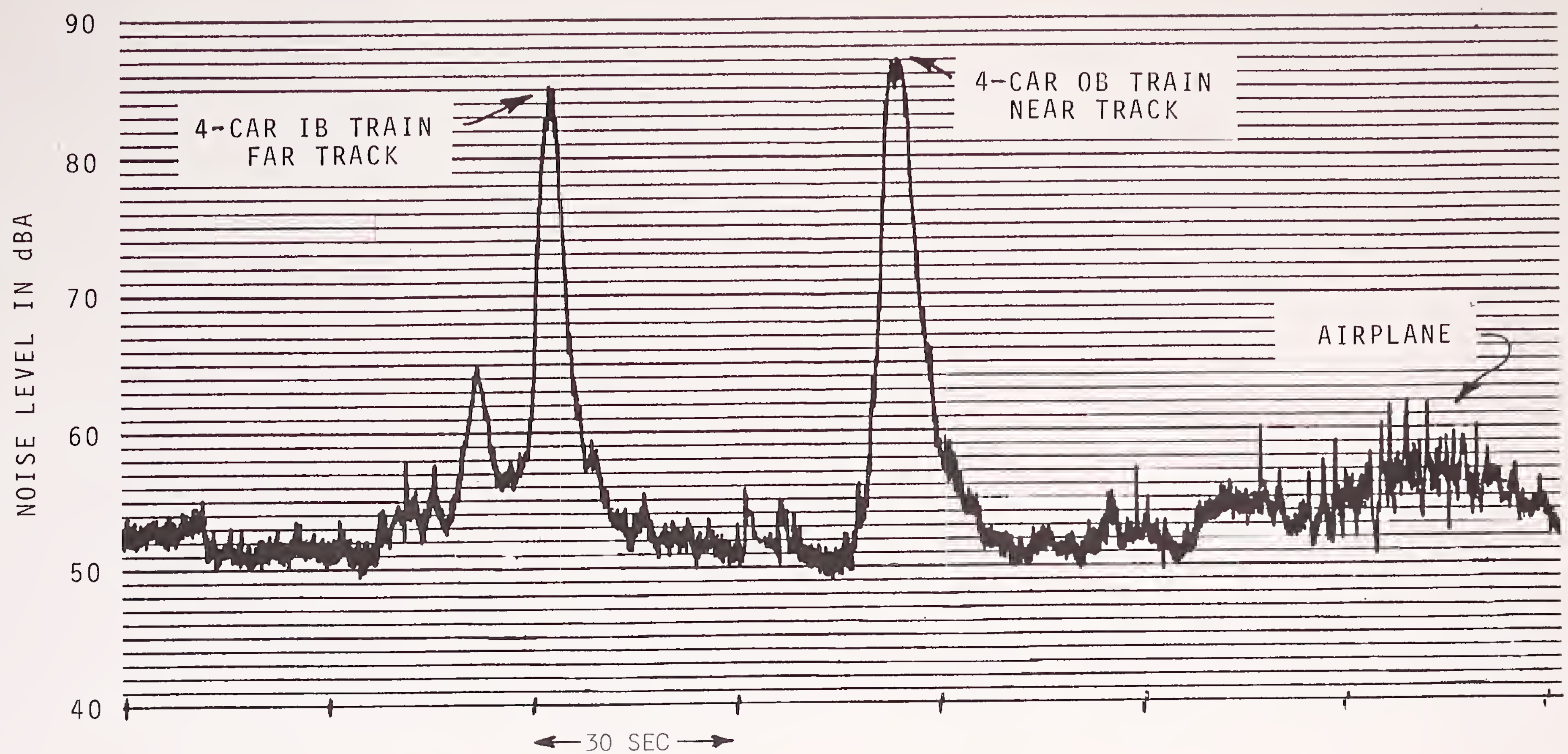


FIGURE 5.11d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 5.
SAMPLE TAKEN 3/11/75, 11:01 AM.

LOCATION 6 - At-grade Tracks, Concord Line, Residential Community, Walnut Creek

SPEED -- 80 mph, IB and OB

DESCRIPTION (See Figure 5.12a)

Location 6 is at the intersection of Getoun Road and David Road. David Road parallels the north side of at-grade BART tracks. The tracks are about 10 ft above the elevation of David Road. The land use is all single family, generally single-story, residential units on 1/4 to 1/2 acre lots. The 50 ft microphone is actually on David Road, about 5 ft from the north curb. The 100 ft microphone is on the sidewalk of Getoun Road, approximately at the setback line for the houses on David Road.

David Road is a relatively heavily traveled local road with a speed limit of 40 mph. Getoun Road is a local access street to the housing development north of the measurement site.

NOISE CLIMATE (See Table 5.9, Figures 5.12b-d)

The only major sources of noise are traffic on David Road with occasional cars on Getoun Road and the BART trains. The 50 ft position is actually on David Road, but not obstructing traffic. Westbound traffic on David Road generally passed within 10 ft of the microphone at speeds of 40 mph or higher. Hence, the peak levels at the 50 ft microphone due to car passbys are quite high, often exceeding 80 dBA. The levels at the 100 ft position more closely represent the levels found at the setback line for houses along David Road. The maximum levels for car passbys at the 100 ft position were generally between 65 to 70 dBA, occasionally getting as high as 80 dBA for unusually loud cars and motorcyles.

The normal train headway at this location is 12 minutes. With a 12 minute headway, two or three trains should pass by in each direction during a 30 minute sample. However, on the near or inbound track, only four trains passed by in the three samples. The rush hour sample had only one inbound train and there were none in the evening sample.

At this location it is evident from the comparison of the "trains only" L_{EQ} and the measured L_{EQ} that the David Road traffic noise dominated the noise climate during the measurement samples. At the 50 ft position, due to the fact that the automobiles are passing by only several feet from the microphone, for any reasonable train headway the traffic noise will still dominate the noise. However, at the 100 ft position, during the evening hours when the traffic volume is low, trains on the normal 12 minute headway schedule would dominate the L_{EQ} noise levels.

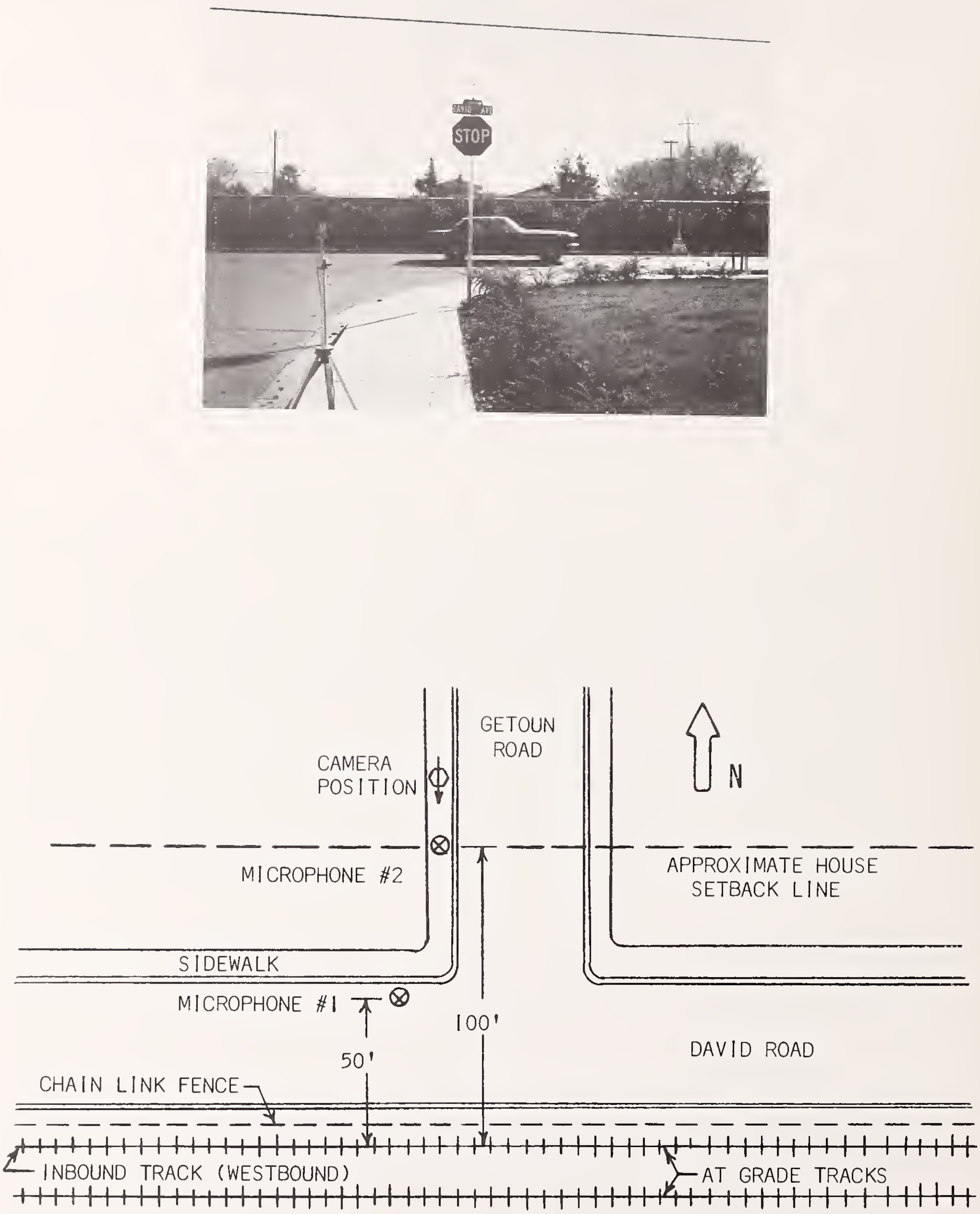


FIGURE 5.12a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 6.

TABLE 5.9 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE NOISE SAMPLES AT LOCATION 6, AT-GRADE - CONCORD LINE

TRAIN SUMMARY		DISTANCE	AVERAGE MAXIMUM LEVELS - dBA		AVERAGE L_R - dBA		STATISTICAL DESCRIPTORS - dBA					L_{EQ}	
IB	OB	[FT]	IB	OB	IB	OB	L_{99}	L_{90}	L_{50}	L_{10}	L_1	MEAS.	TRAINS ONLY [APPROX]
DAY													
3 - 5 car	2 - 5 cars 1 - 6 car	50	84 **1.3*	74 **1.0*	90 **1.0*	80 **0.8*	40	46	56	71	82	69	63
		100	81 *1.3*	71 *1.3*	87 *1.0*	77 *0.9*	40	42	51	65	74	63	60
RUSH HOUR													
1 - 8 car	3 - 5 car	50	83 --	77 *2.5*	91 --	85 *3.5*	42	47	60	74	82	70	61
		100	79 --	73 *1.8*	87 --	82 *3.2*	39	43	55	67	74	64	57
EVENING													
none	1 - 8 car 2 - 5 car	50	-- --	75 *1.7*	-- --	82 *1.9*	42	45	53	66	77	64	54
		100	-- --	73 *1.3*	-- --	80 *1.3*	42	44	48	61	71	58	52
TOTALS:													
3 - 5 cars 1 - 8 car	9 - 5 cars 1 - 6 car 1 - 8 car	50	84 *1.2*	76 *2.2*	91 *1.0*	82 *2.8*	41	46	56	70	80	68	61
		100	81 *1.3*	72 *1.7*	87 *0.8*	80 *2.6*	41	43	51	64	73	62	57

**Standard Deviation of level*

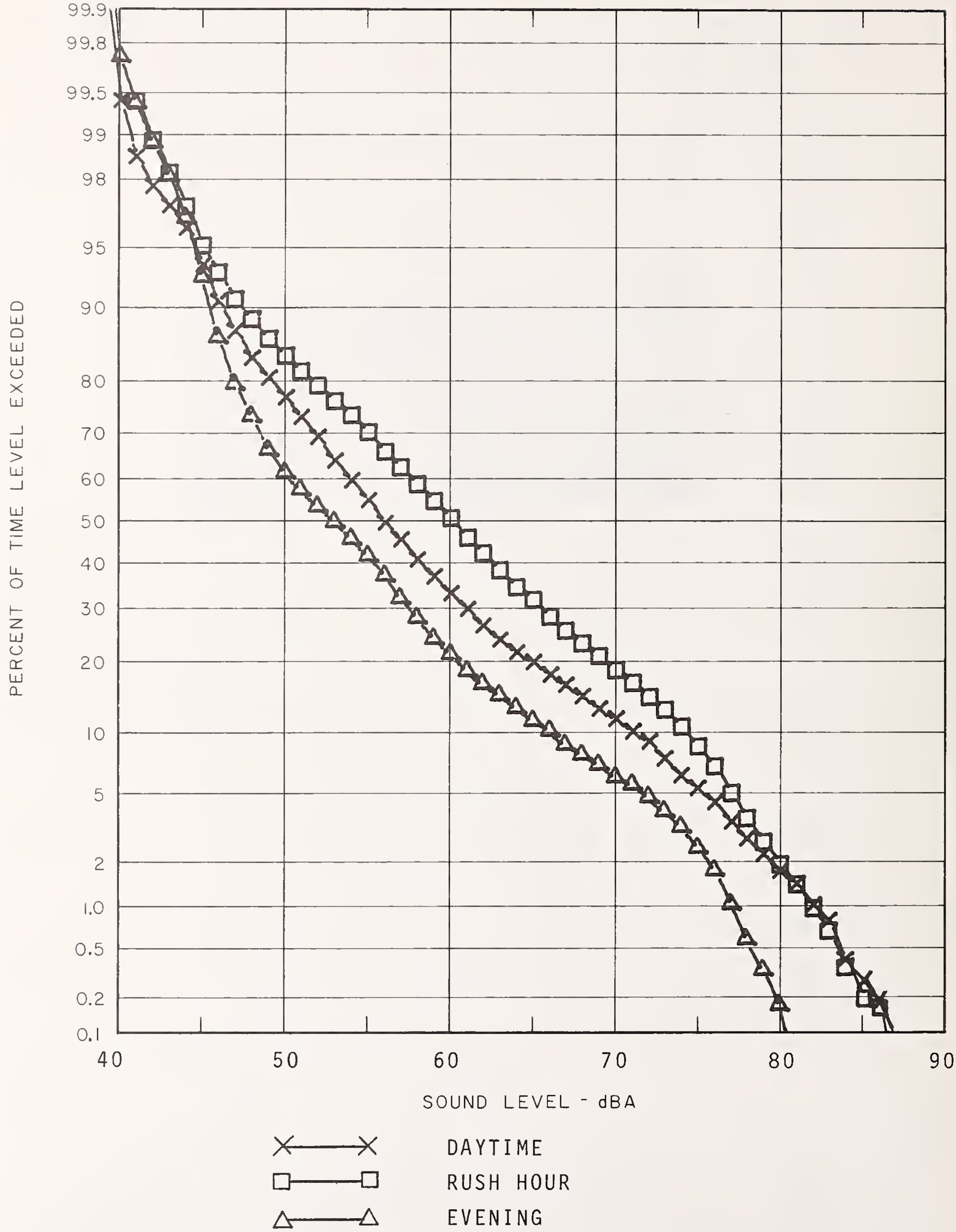


FIGURE 5.12b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 6, 50 FT POSITION.

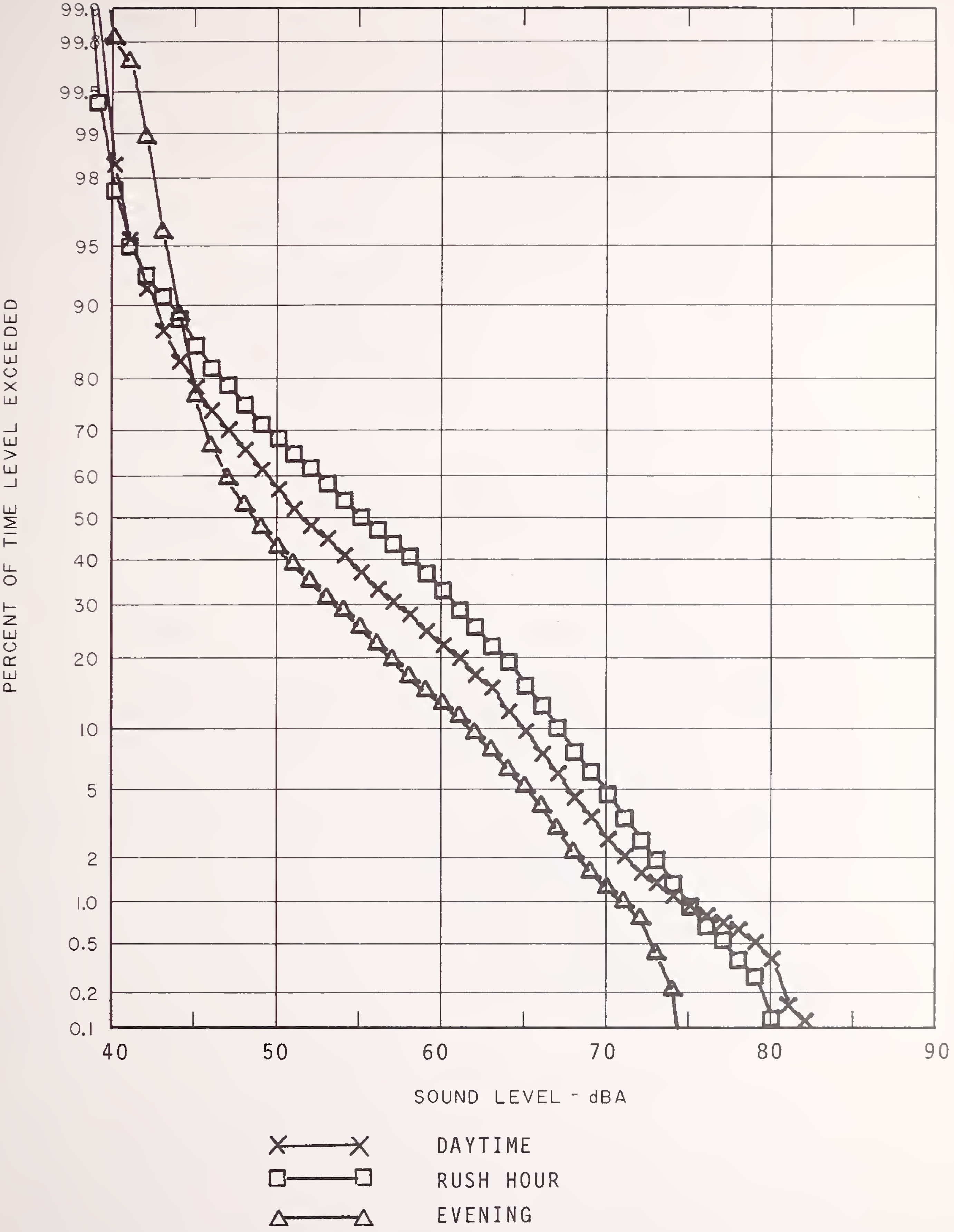


FIGURE 5.12c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 6, 100 FT POSITION.

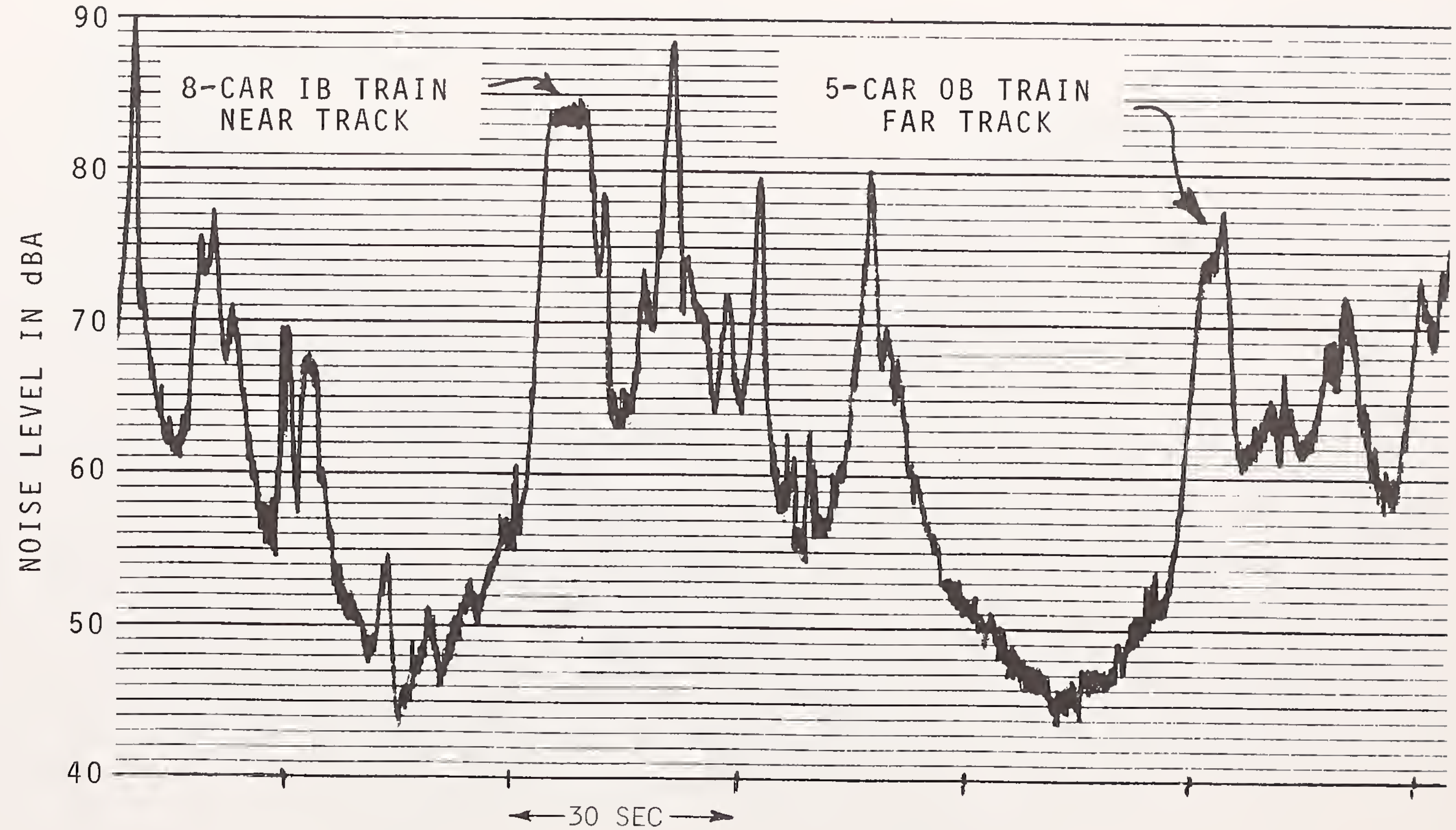


FIGURE 5.12d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 6.
SAMPLE TAKEN 1/30/75, 4:10 PM.

LOCATION 7 - At-grade Tracks, Fremont Line, Residential Community, Hayward

SPEED -- 70 mph IB [near track]

80 mph OB [far track]

DESCRIPTION (See Figure 5.13a)

Location 7 is in a residential area adjacent to the BART at-grade tracks about 1/4 mile north of the South Hayward Station. The tracks are about 10 ft above the elevation of the surrounding terrain. Mission Boulevard is 800 ft to the east and Tennyson Road 1000 ft south of the measurement site. These roads are both heavily traveled surface streets, Mission Boulevard being a major surface arterial. The 50 and 100 ft positions straddle 10th Street with the 50 ft position in an unmaintained grass/dirt buffer zone between 10th Street and the BART tracks. 10th Street carries a light load of local traffic only. At-grade railroad tracks run adjacent to the west side of the BART tracks, however, no trains passed by during the noise samples.

NOISE CLIMATE (See Table 5.10, Figures 5.13b-d)

As 10th Street is very lightly traveled, the primary sources of traffic noise in this neighborhood are Mission Boulevard and Tennyson Road with some contribution from normal residential activities. Typical background noise levels are in the range of 45 to 55 dBA with the residual noise level at about 41 to 43 dBA. The BART trains are the only significant source of high level noise. From the small difference between the measured L_{EQ} and the "trains only" L_{EQ} along with the L_{10} levels being 5 to 10 dBA less than L_{EQ}, it is evident that the BART trains dominate L_{EQ}. Without the trains, it is expected that the levels of L_{EQ} would be at least 10 dBA lower.

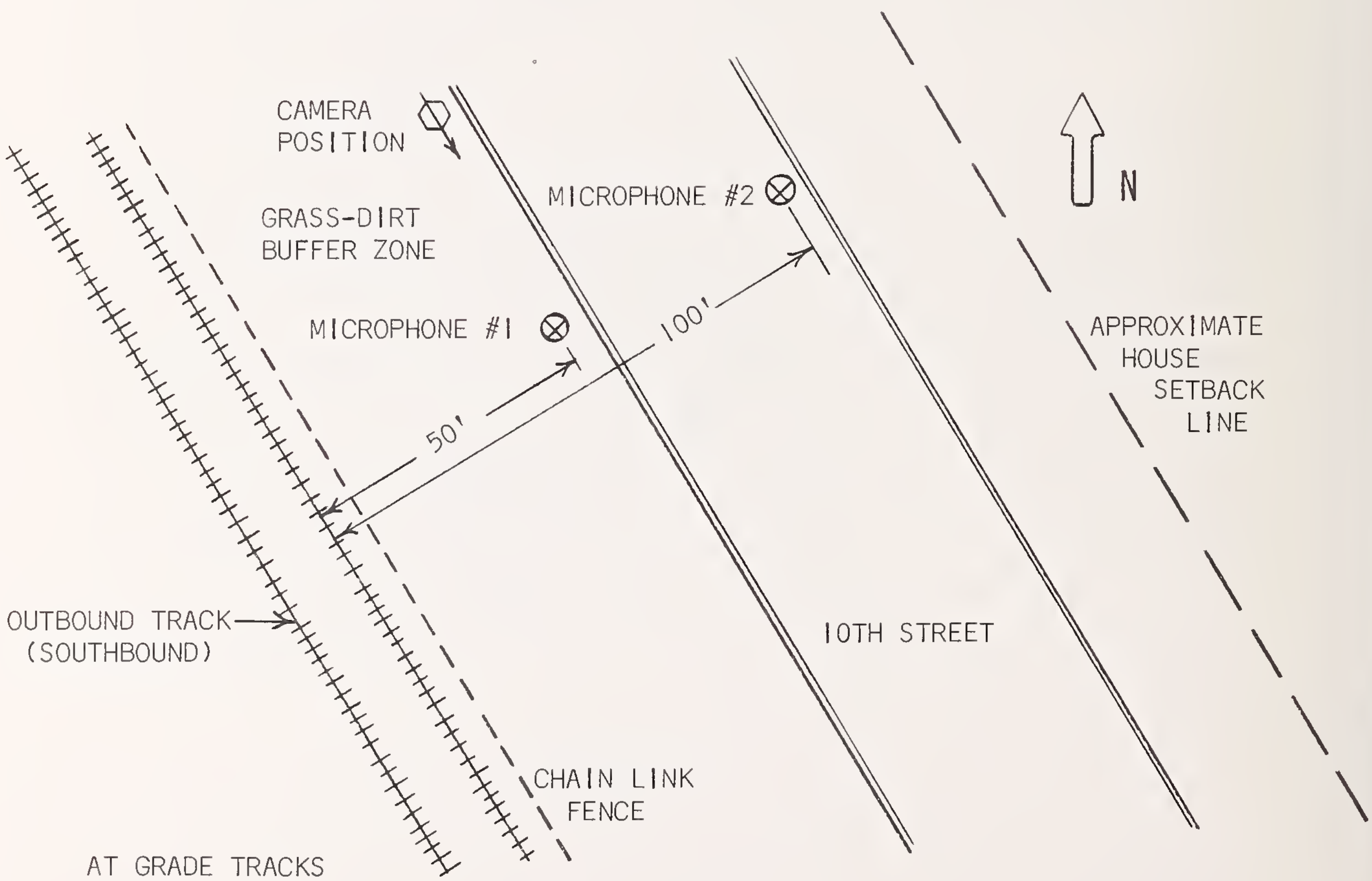


FIGURE 5.13a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 7.

TABLE 5.10 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 7, AT-GRADE - FREMONT LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
5 - 4 car 1 - 5 car	3 - 4 car 2 - 5 car	50	86 *0.6	76 *1.0	91 *0.8	82 *0.8	44	45	48	56	81	66	66
		100	83 0.5	74 1.2	89 0.6	80 1.2	42	44	47	56	80	64	64
RUSH HOUR													
1 - 4 car 1 - 5 car 3 - 6 car	2 - 5 car 2 - 6 car	50	85 0.9	76 2.4	91 0.8	82 1.8	41	43	48	59	82	67	66
		100	82 0.8	74 1.9	89 0.9	80 1.3	42	44	48	59	80	65	64
EVENING													
3 - 6 car	3 - 4 car 1 - 5 car	50	86 0	78 1.3	92 0	83 1.5	41	42	45	61	79	66	65
		100	83 0.3	77 0.6	90 0.3	81 1.2	42	43	45	61	78	64	63
TOTALS:													
6 - 4 car 2 - 5 car 6 - 6 car	6 - 4 car 5 - 5 car 2 - 6 car	50	85 0.8	77 1.8	91 0.8	82 1.4	42	43	47	59	81	66	66
		100	83 0.8	75 1.7	89 0.8	81 1.3	42	44	47	59	79	64	64

*Standard Deviation of level

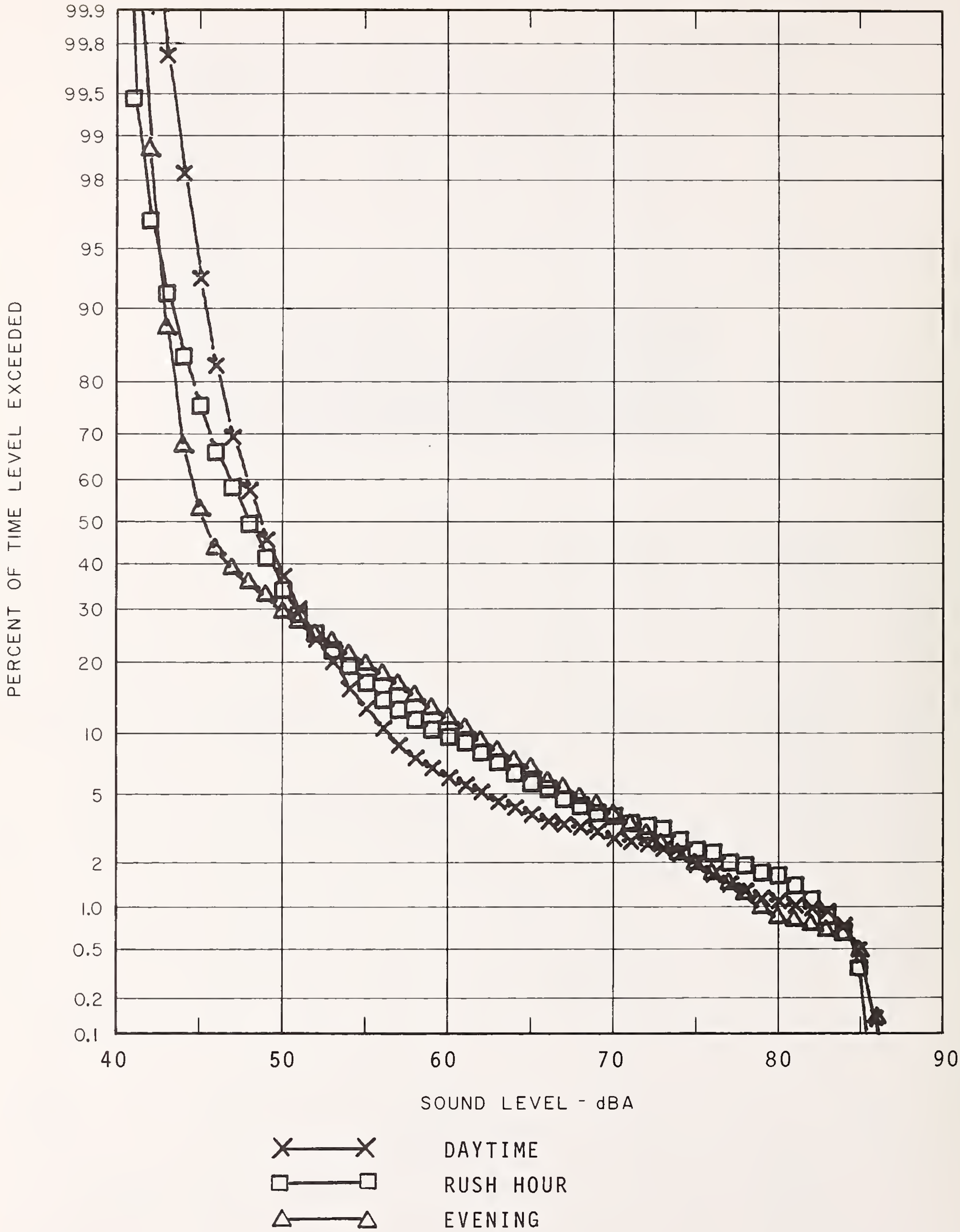


FIGURE 5.13b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 7, 50 FT POSITION.

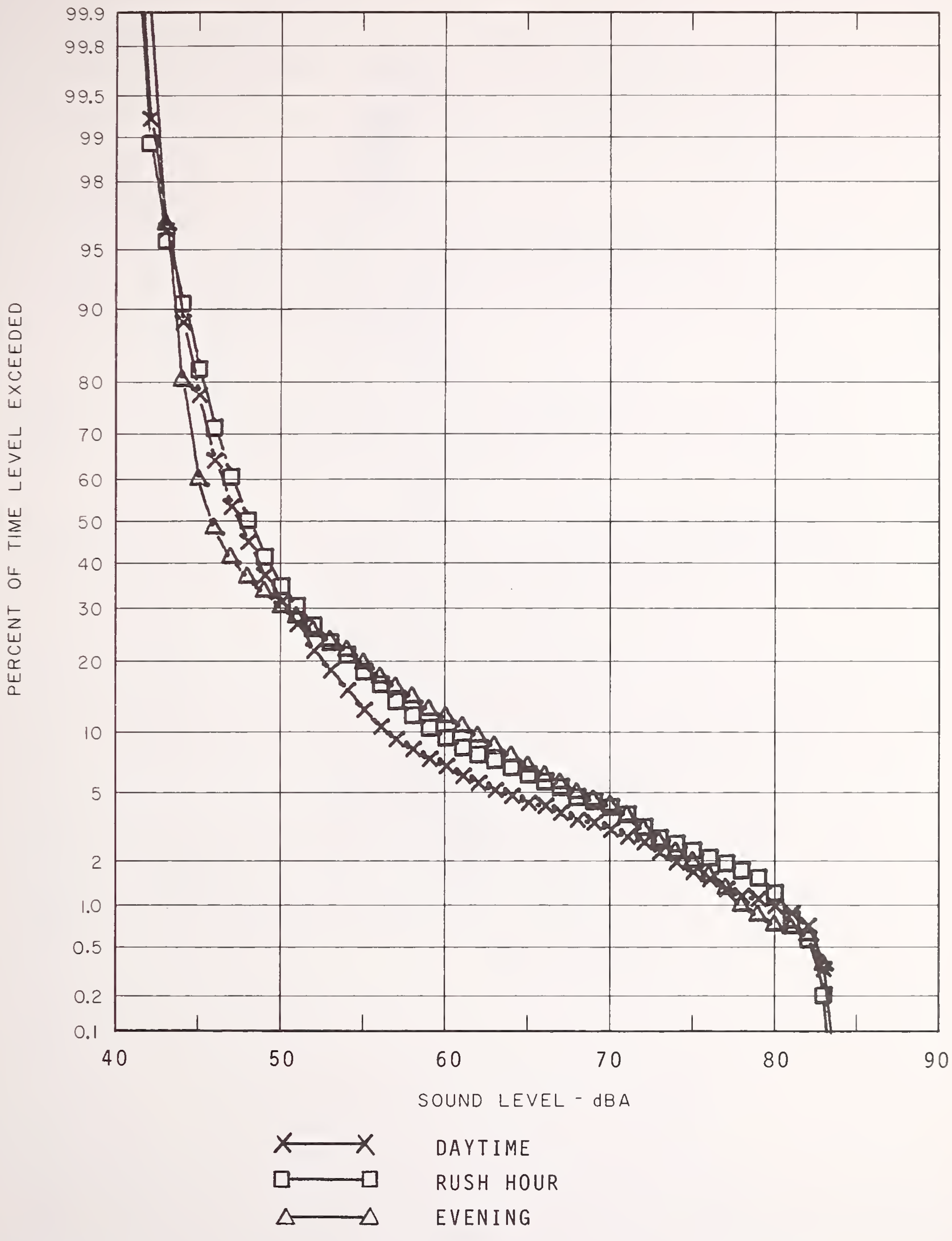


FIGURE 5.13c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 7, 100 FT POSITION.

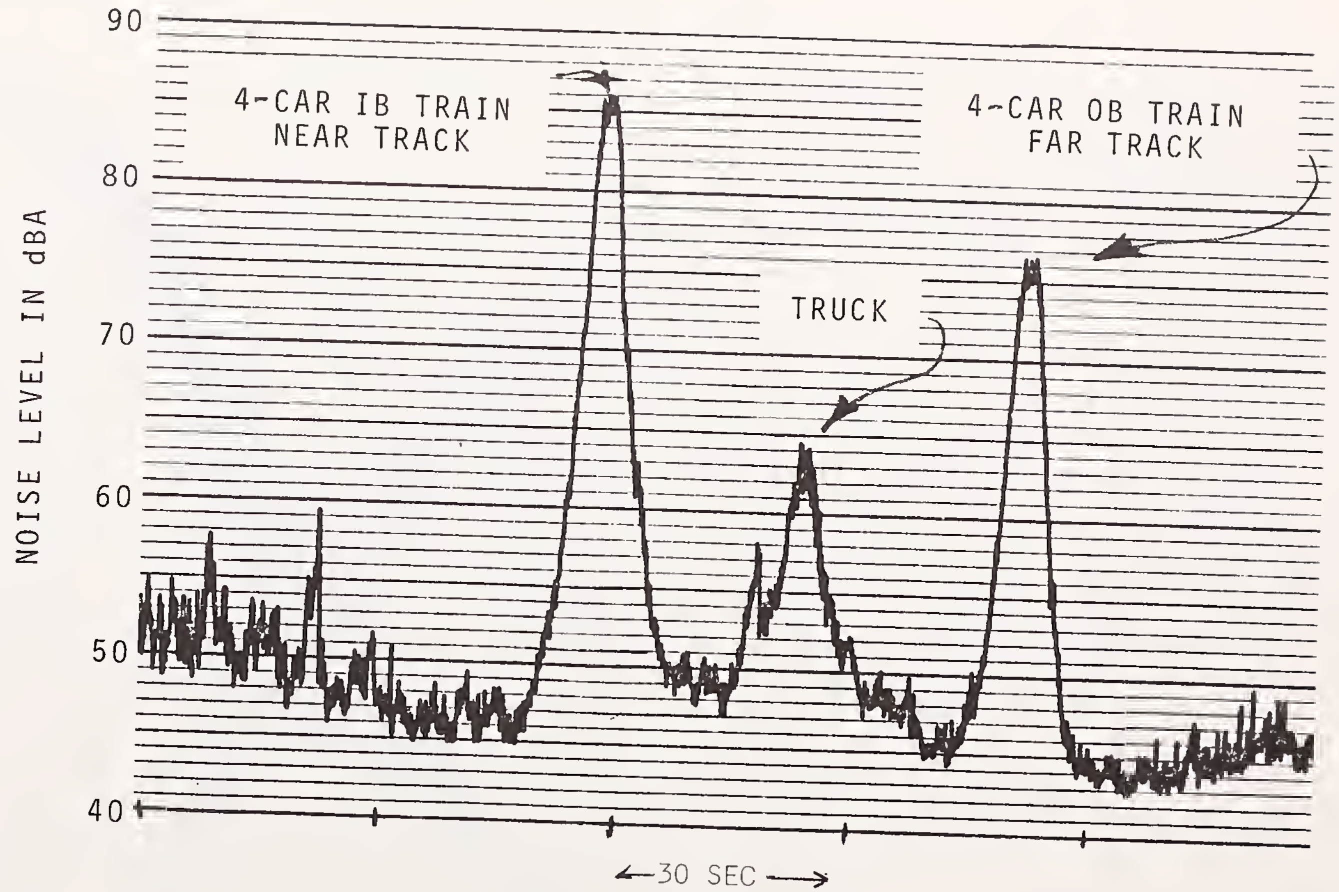


FIGURE 5.13d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 7.
SAMPLE TAKEN 1/29/75, 12:34 PM.

LOCATION 8 - At-grade Tracks, Fremont Line, Commercial, Hayward

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.14a)

Location 8 is in a large parking lot at a shopping center. During the samples there were few cars using the parking lot in the vicinity of the microphones. The location is about 500 ft from Harder Road and 700 ft from Mission Boulevard, both major surface arterials.

The BART tracks at this location are about 10 ft above the elevation of the parking lot. There is a 2 to 3 ft culvert between the edge of the parking lot and the beginning of the slope for the ballast and tie tracks.

At-grade railroad tracks run along the BART tracks on the opposite side from the measurement location. The elevation of the BART tracks blocks the view of the railroad tracks. Beyond the railroad tracks is a residential area.

NOISE CLIMATE (See Table 5.11, Figure 5.14 b-d)

Without the BART trains, the noise climate at this location is dominated by the traffic on Mission Boulevard and Harder Road. The parking lot activities contribute some noise, however, the BART trains were the loudest source of noise and clearly dominated the levels of L_{EQ}. There was one freight train passby during the daytime sample, however, the maximum level for the train passby was 81 dBA compared to an average maximum level of 87 dBA for BART trains on the near tracks. The noise level due to the freight train passby is low due to the partial shielding by the elevation of the BART tracks.

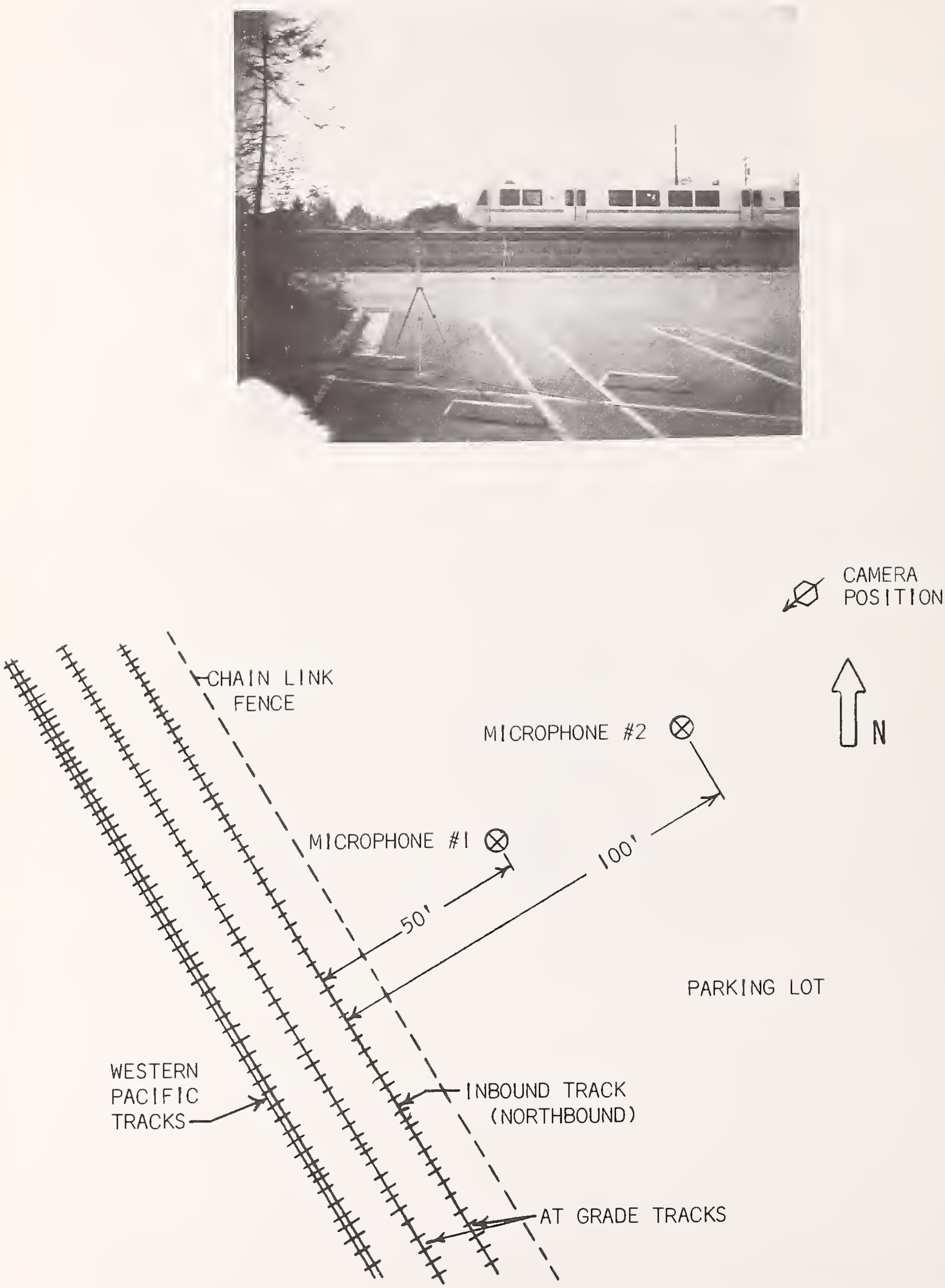


FIGURE 5.14a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 8.

TABLE 5.11 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 8, AT-GRADE - FREMONT LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
3 - 4 car 2 - 5 car	2 - 4 car 3 - 5 car	50	87 *1.0	79 *1.1	92 *0.7	85 *1.0	49	51	55	60	82	68	67
		100	84 1.4	76 1.4	90 0.7	82 1.3	50	52	55	61	81	66	65
RUSH HOUR													
2 - 4 car 2 - 5 car 1 - 6 car	1 - 4 car 3 - 5 car 1 - 6 car	50	87 1.6	80 0.9	93 1.3	85 0.8	48	50	53	59	83	68	67
		100	83 1.1	77 1.3	91 0.6	83 0.4	49	51	54	60	80	65	65
EVENING													
1 - 4 car 3 - 5 car 1 - 7 car	5 - 5 car	50	87 0.8	79 0.7	93 1.2	86 1.1	48	50	53	63	83	69	68
		100	84 0.3	77 0.7	89 0.8	83 1.1	49	51	54	65	81	67	64
TOTALS:													
6 - 4 car 7 - 5 car 1 - 6 car 1 - 7 car	3 - 4 car 11 - 5 car 1 - 6 car	50	87 1.1	79 1.0	93 1.0	85 1.1	48	50	54	61	83	68	67
		100	84 1.2	76 1.3	90 1.0	83 1.0	49	51	54	62	81	66	65

*Standard Deviation of level

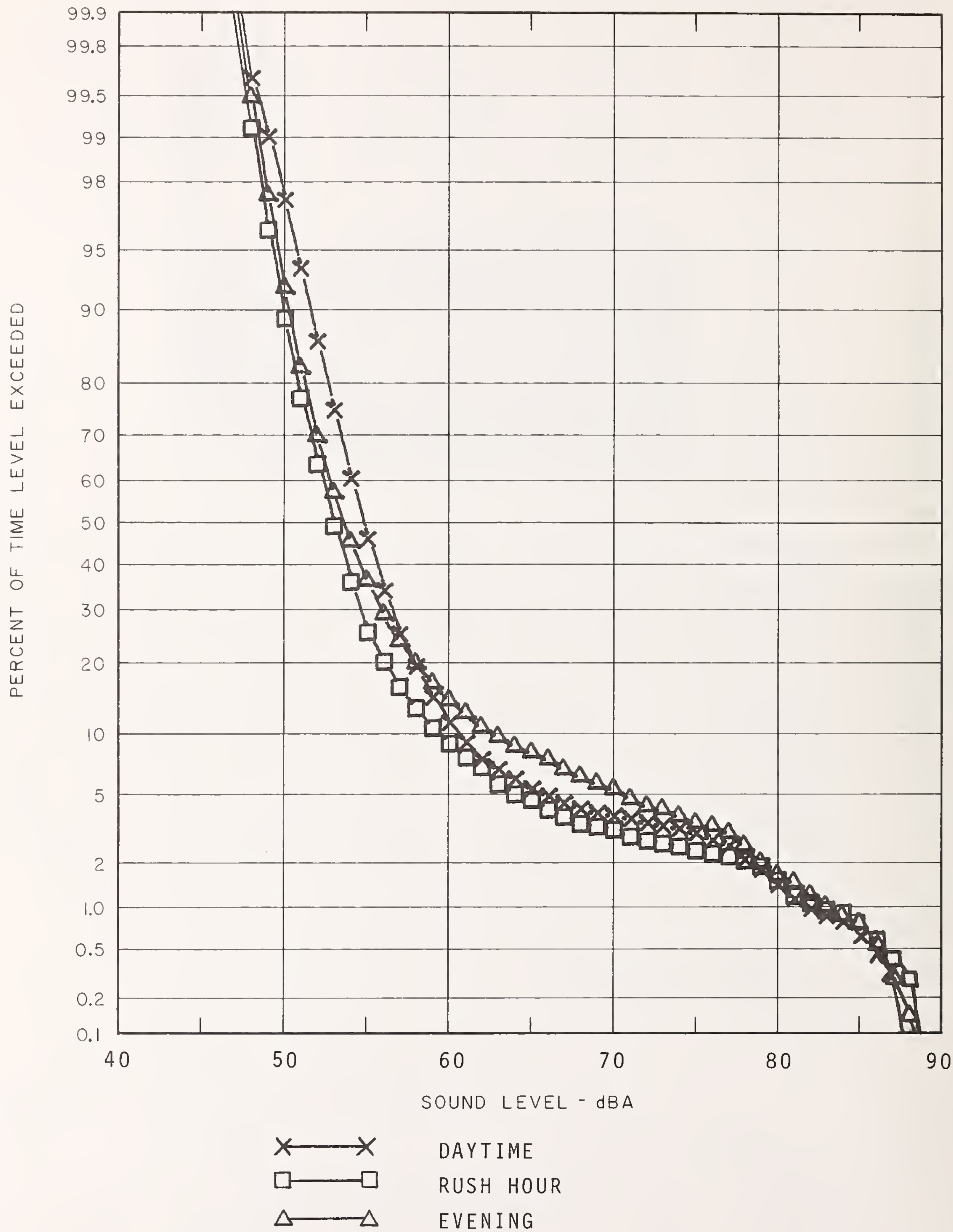


FIGURE 5.14b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 8, 50 FT POSITION.

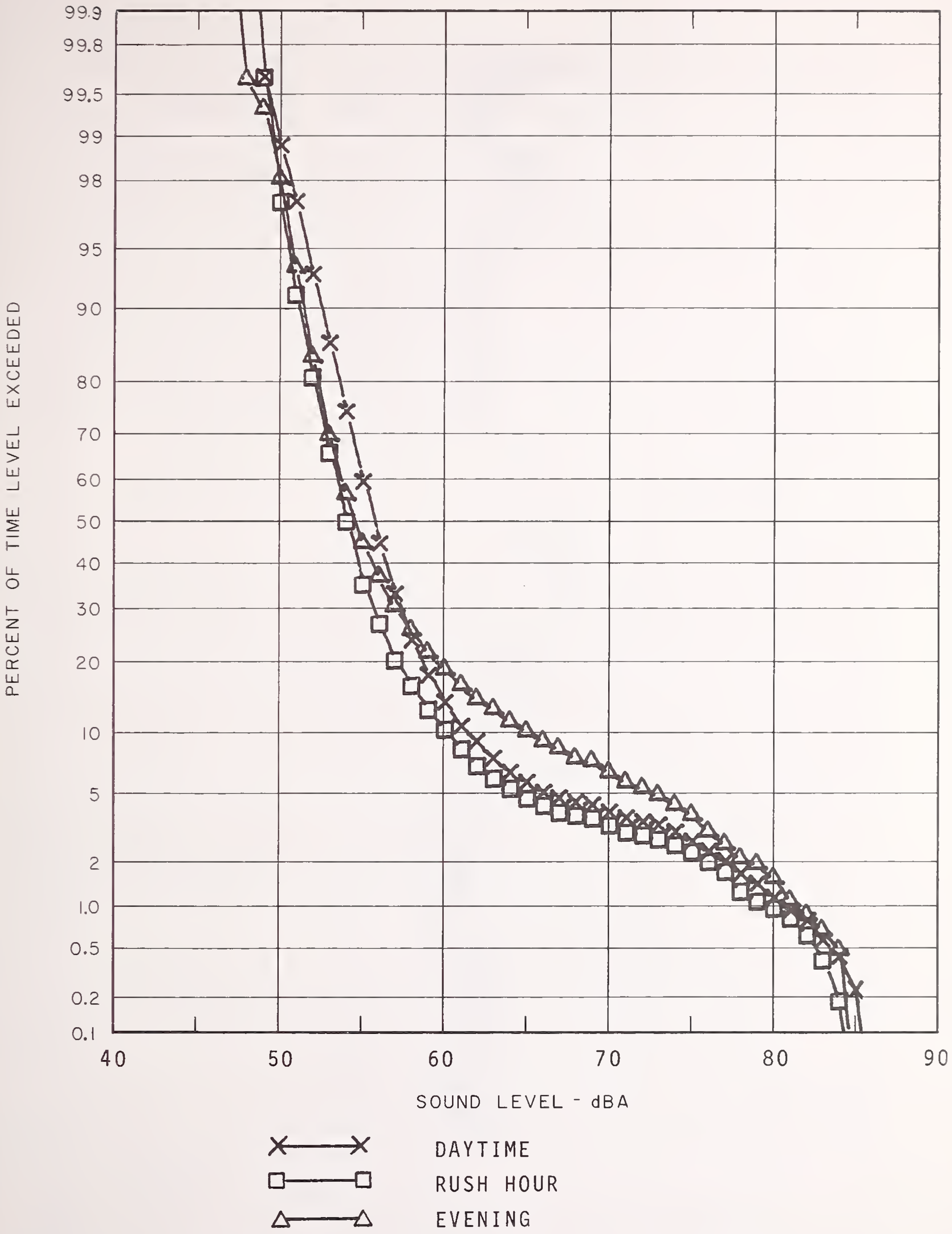


FIGURE 5.14c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 8, 100 FT POSITION.

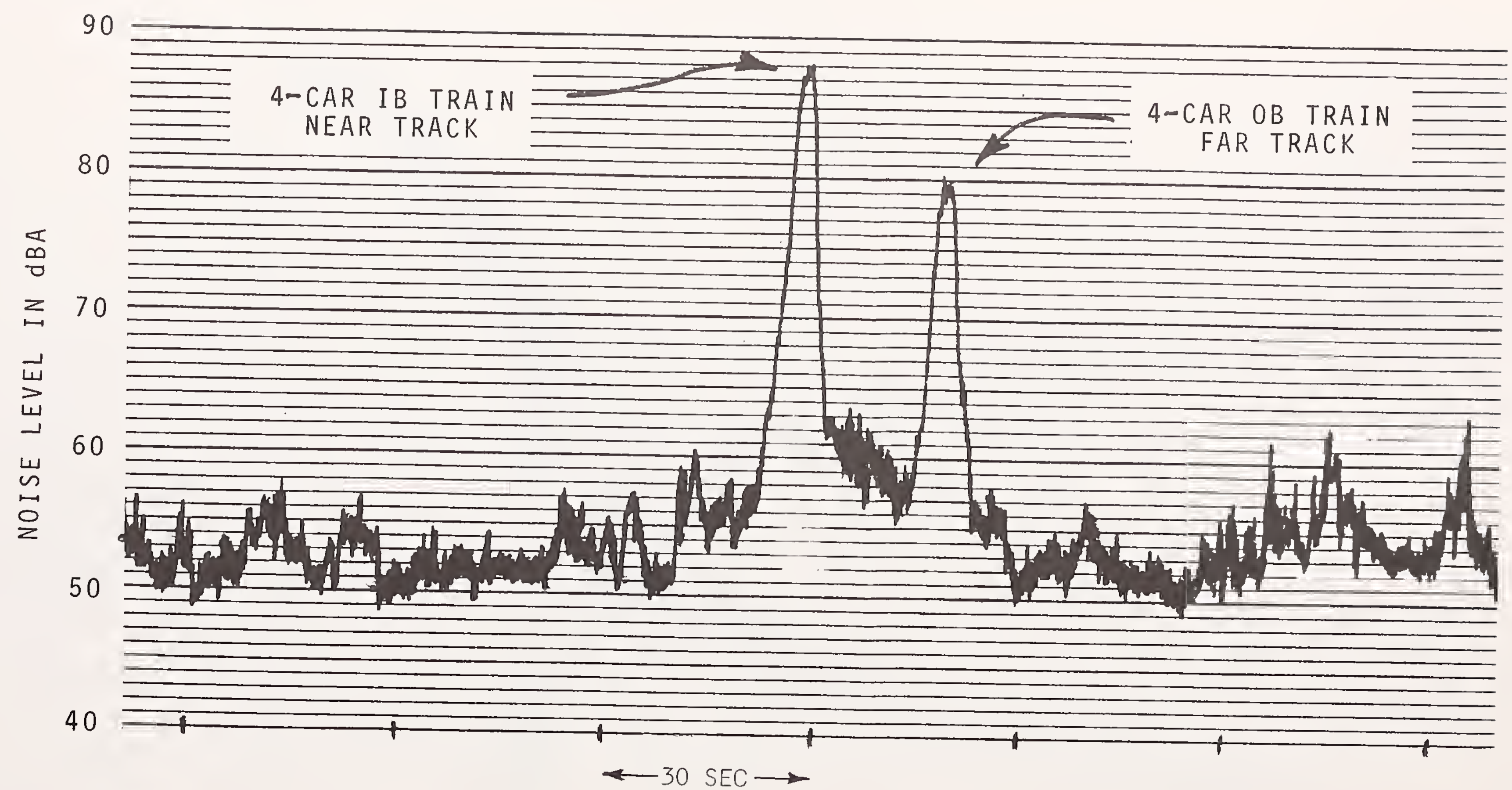


FIGURE 5.14d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 8.
SAMPLE TAKEN 1/29/75, 1:49 PM.

LOCATION 9 - Vent Shaft, Richmond Line, Residential Community, Berkeley

SPEED - 50 mph [approximate], IB and OB

DESCRIPTION (See Figure 5.15a)

In this area BART is cut-and-cover construction running parallel to Hearst Avenue. The vent shaft is located at the edge of Hearst Avenue just west of the intersection of Grant Street and Hearst Avenue. The area above the cut-and-cover section is a vacant grass/dirt area. The microphones were located in the grass/dirt area at distances of 25 and 50 ft from the vent shaft. Grant Street is lightly traveled, although Hearst Avenue carries a substantial volume of traffic, even though it is only 25 to 30 ft wide with one relatively narrow lane for traffic in each direction.

NOISE CLIMATE (See Table 5.12, Figures 5.15b-d)

The noise climate in this neighborhood is dominated by traffic on Hearst Avenue, although the residual level of noise of about 45 dBA is determined by distant sources of traffic noise. The maximum level of noise at the 25 ft position due to train passbys was about 68 dBA for trains on the near track. For trains on the far track the maximum level was about 63 dBA. The maximum passby levels are only approximate as it was generally difficult to isolate the noise due to the train passby from the traffic noise at the 25 ft position. At the 50 ft position it was almost impossible to determine the level for the train passby. The statistical distribution curves for the samples at this location are relatively typical of those found in community noise samples. They do not display the curvature to the right at the high noise levels that is typically found on the distributions for the above ground track sites.

FIGURE 5.15a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 9.

TABLE 5.12 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 9, VENT SHAFT - RICHMOND LINE

TRAIN SUMMARY		DISTANCE	AVERAGE MAXIMUM LEVELS - dBA		AVERAGE L_R - dBA		STATISTICAL DESCRIPTORS - dBA					L_{EQ}	
IB	OB	[FT]	IB	OB	IB	OB	L_{99}	L_{90}	L_{50}	L_{10}	L_1	MEAS.	TRAINS ONLY [APPROX]
DAY		25	--	--	--	--	43	46	56	64	70	60	--
		50	--	--	--	--	45	48	55	62	68	59	--
RUSH HOUR		25	--	--	--	--	45	49	58	65	70	62	--
		50	--	--	--	--	45	49	56	62	69	59	--
EVENING		25	--	--	--	--	44	47	54	64	70	60	--
		50	--	--	--	--	45	47	53	61	67	57	--
TOTALS:		25	--	--	--	--	44	47	56	64	70	61	--
		50	--	--	--	--	45	48	55	62	68	58	--

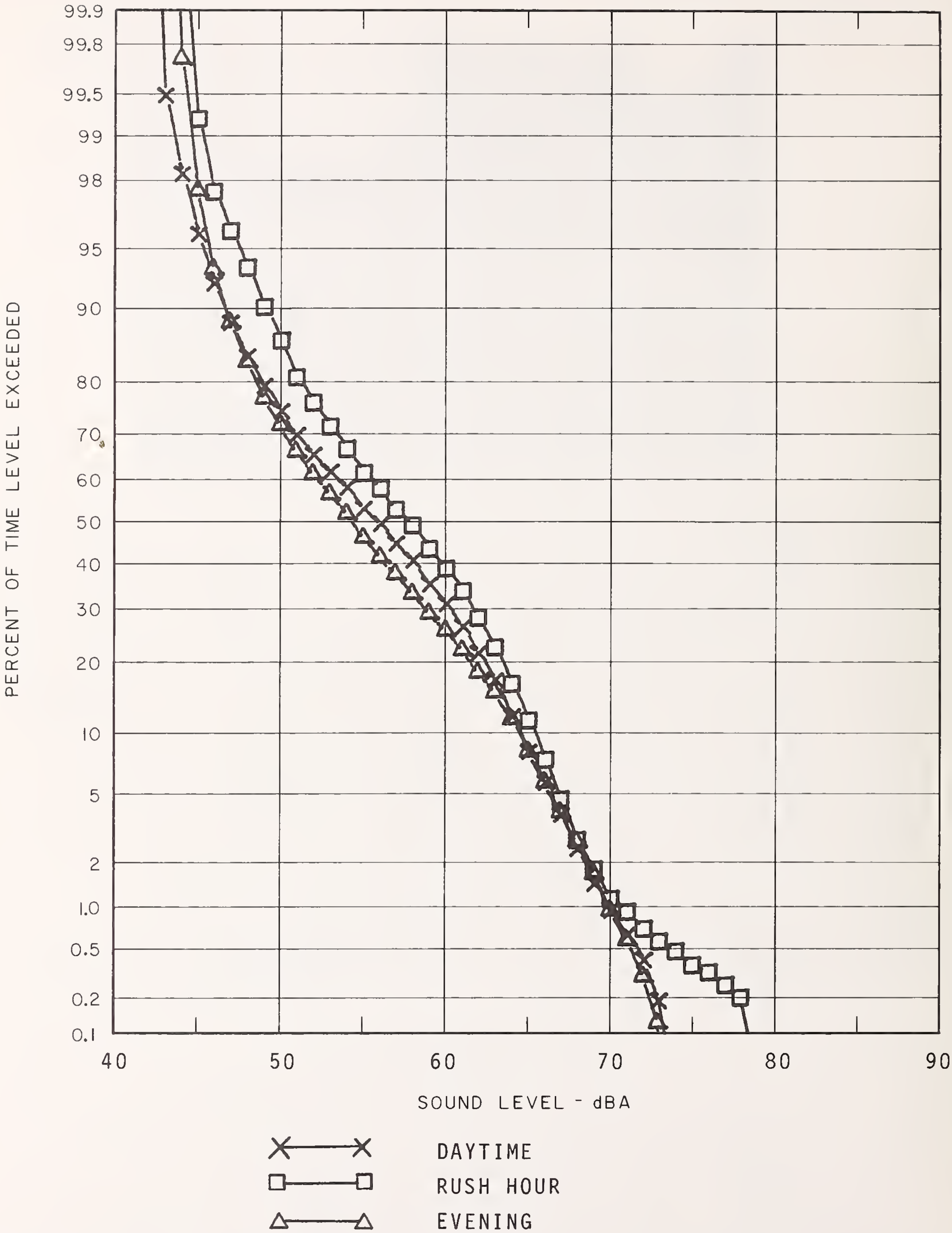


FIGURE 5.15b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 9, 25 FT POSITION.

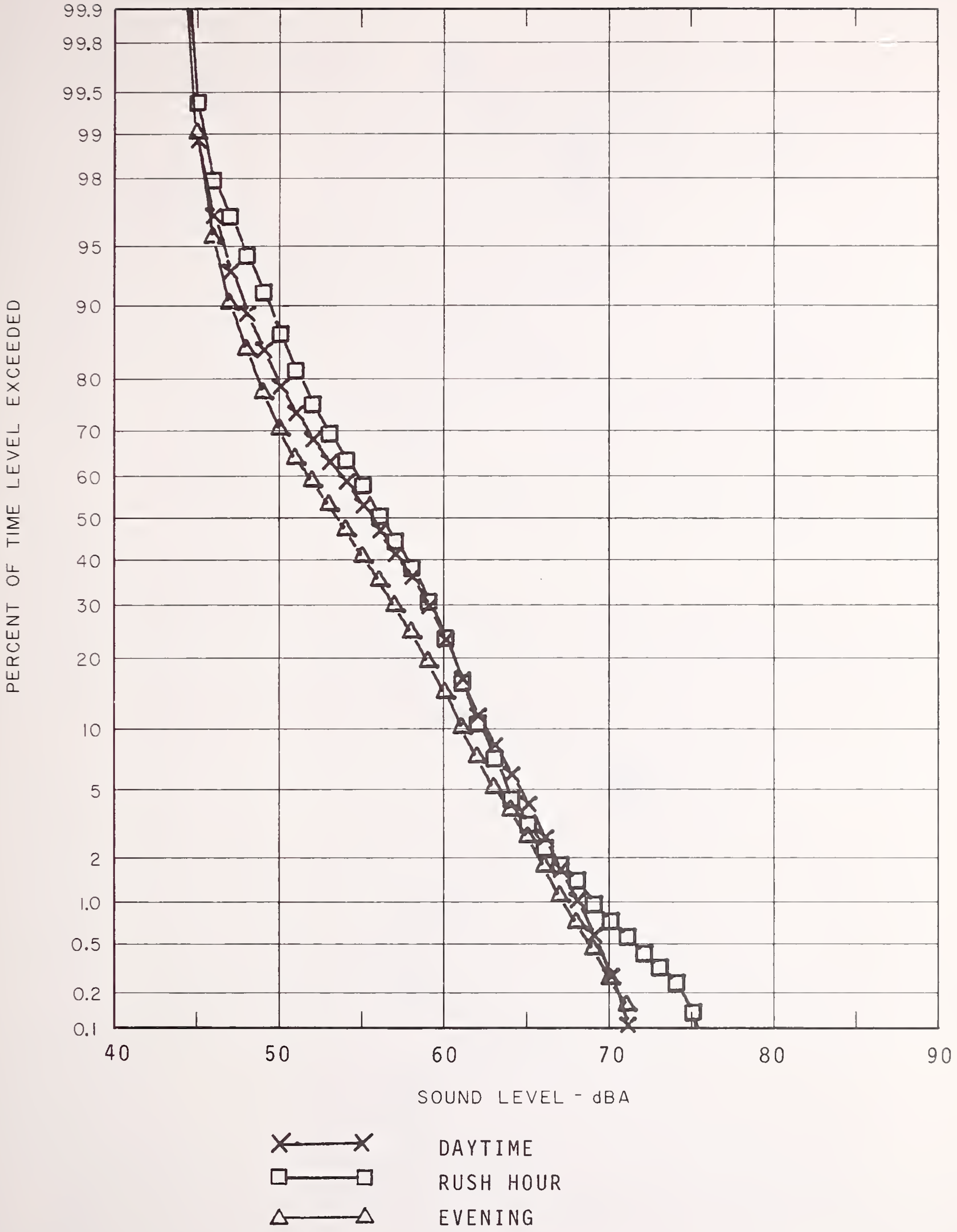


FIGURE 5.15c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 9, 50 FT POSITION.

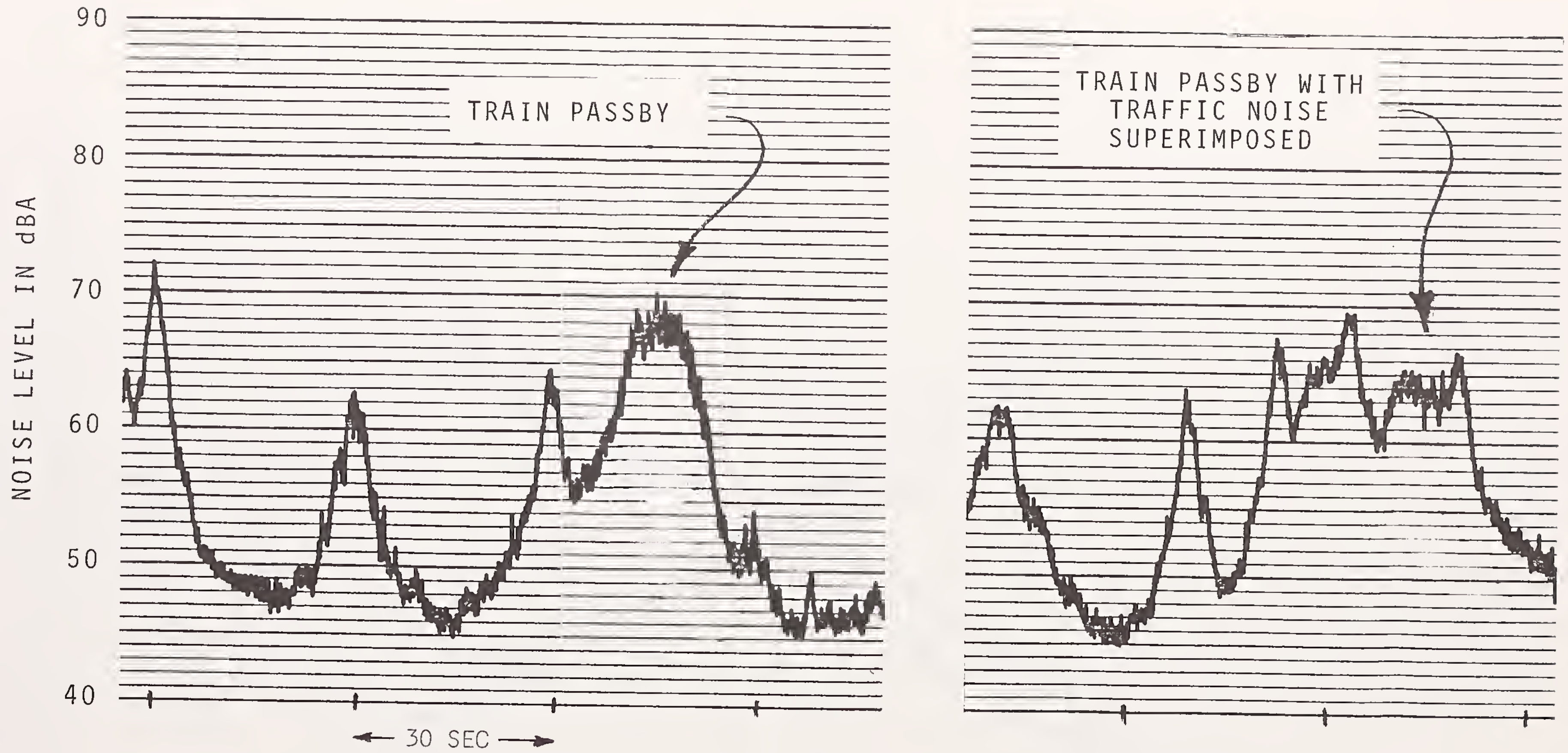


FIGURE 5.15d TYPICAL PASSBY TRACES 25 FT FROM VENT SHAFT AT LOCATION 9. SAMPLE TAKEN 3/12/75, 9:51 PM.

LOCATION 10 - Vent Shaft, Richmond Line, Commercial, Berkeley

SPEED - 60 mph [approximate], IB and OB

DESCRIPTION (See Figure 5.16a)

In this area the BART structure is cut-and-cover running under the median of Adeline Street. Location 10 is in the grass median strip of Adeline Street, near the point where Adeline Street joins Shattuck Avenue. The Adeline Street median strip is 30 to 50 ft wide in this area. The microphones are located in the median strip 25 ft and 50 ft from the end of the vent shaft. Both Adeline Street and Shattuck Avenue are major centers of commercial activity and carry heavy volumes of traffic.

NOISE CLIMATE (See Table 5.13, Figures 5.16b-d)

The major source of noise at this location was the car, bus and truck traffic on both sides of Adeline Street with some contribution from traffic on Shattuck Avenue. Due to the high levels of noise from traffic, the BART passby noise emanating from the vent shaft was only audible at positions very close to the vent shaft. At the 25 and 50 ft measurement positions the passby noise was inaudible.

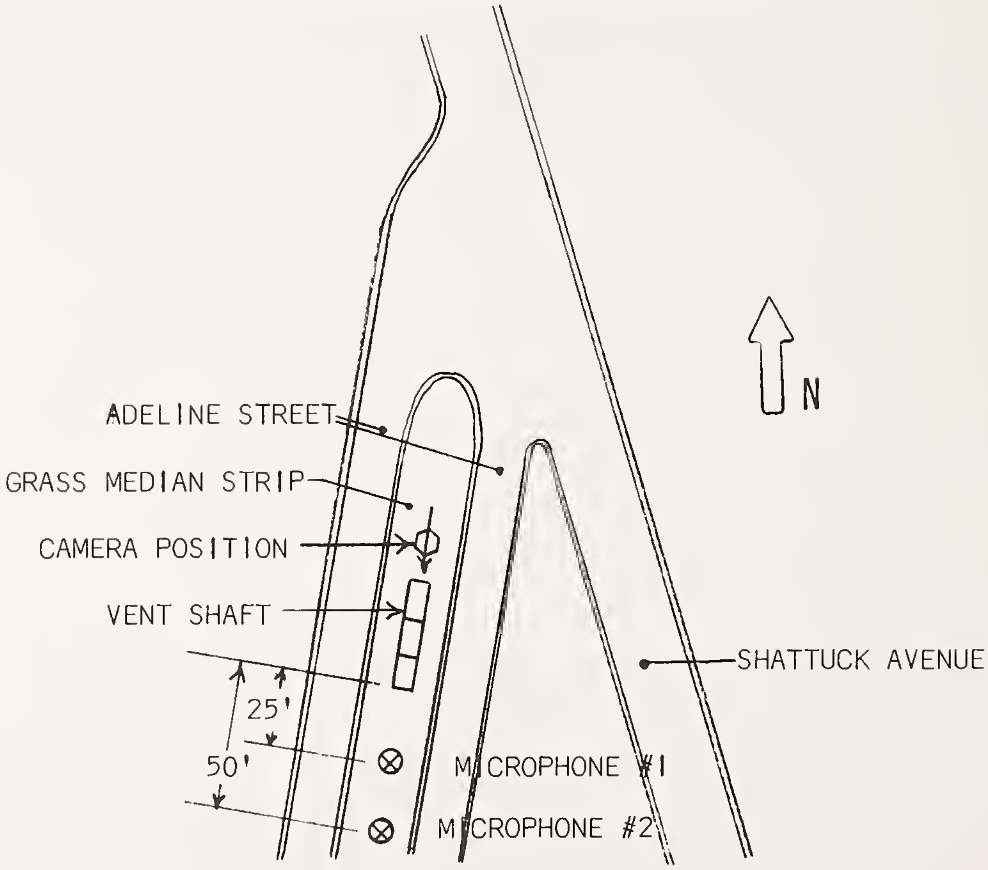


FIGURE 5.16a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 10.

TABLE 5.13 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 10, VENT SHAFT - RICHMOND LINE

TRAIN SUMMARY		DISTANCE	AVERAGE MAXIMUM LEVELS - dBA		AVERAGE L_R - dBA		STATISTICAL DESCRIPTORS - dBA					L_{EQ}	
IB	OB	[FT]	IB	OB	IB	OB	L_{99}	L_{90}	L_{50}	L_{10}	L_1	MEAS.	TRAINS ONLY [APPROX]
DAY													
		25	--	--	--	--	53	56	62	69	76	66	--
		50	--	--	--	--	53	56	62	69	76	66	--
RUSH HOUR													
		25	--	--	--	--	56	59	64	69	79	68	--
		50	--	--	--	--	56	59	64	69	78	68	--
EVENING		25	--	--	--	--	53	57	62	69	76	66	--
		50	--	--	--	--	52	56	62	68	75	65	--
TOTALS:													
		25	--	--	--	--	54	57	63	69	77	67	--
		50	--	--	--	--	54	57	63	69	76	67	--

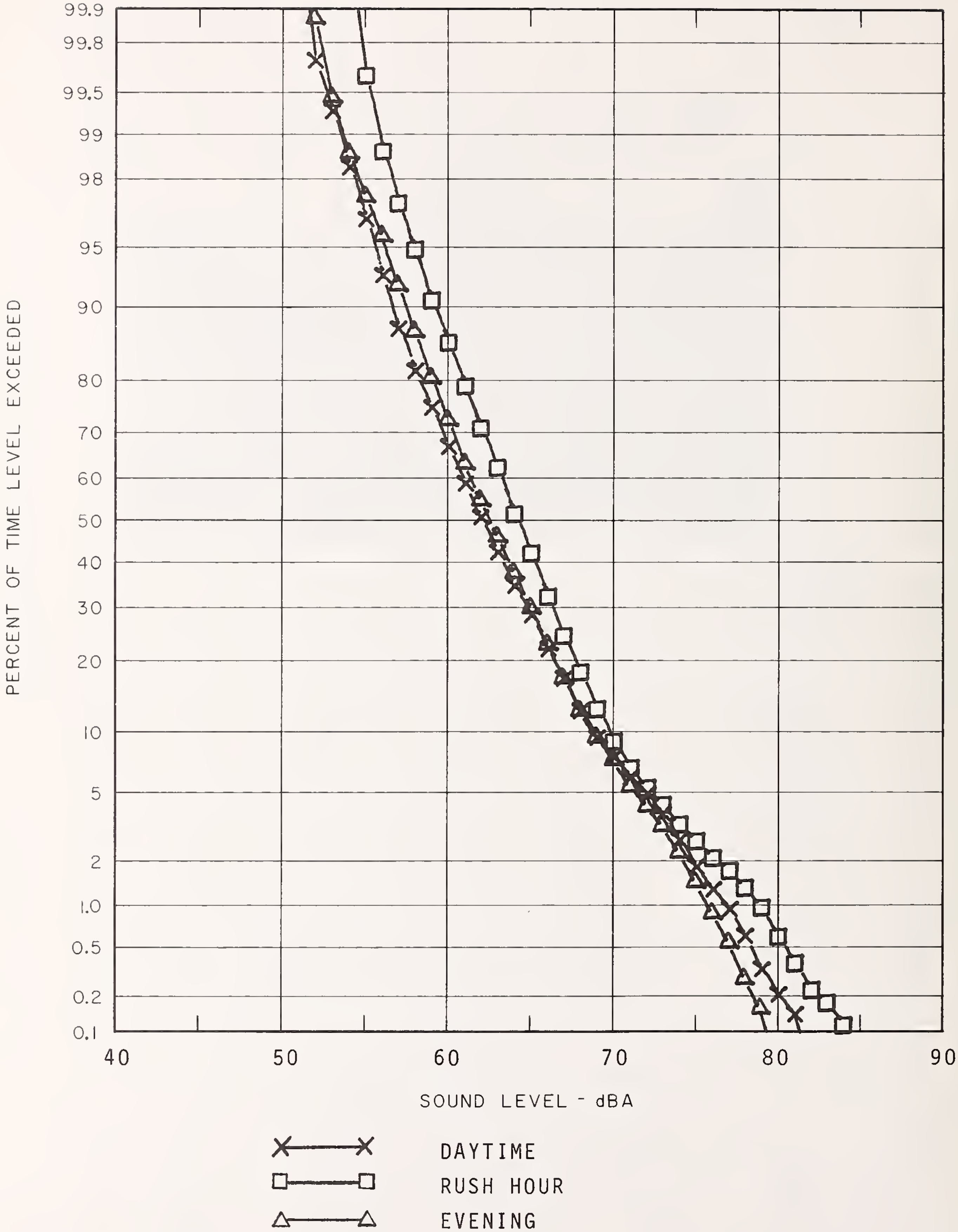


FIGURE 5.16b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 10, 25 FT POSITION.

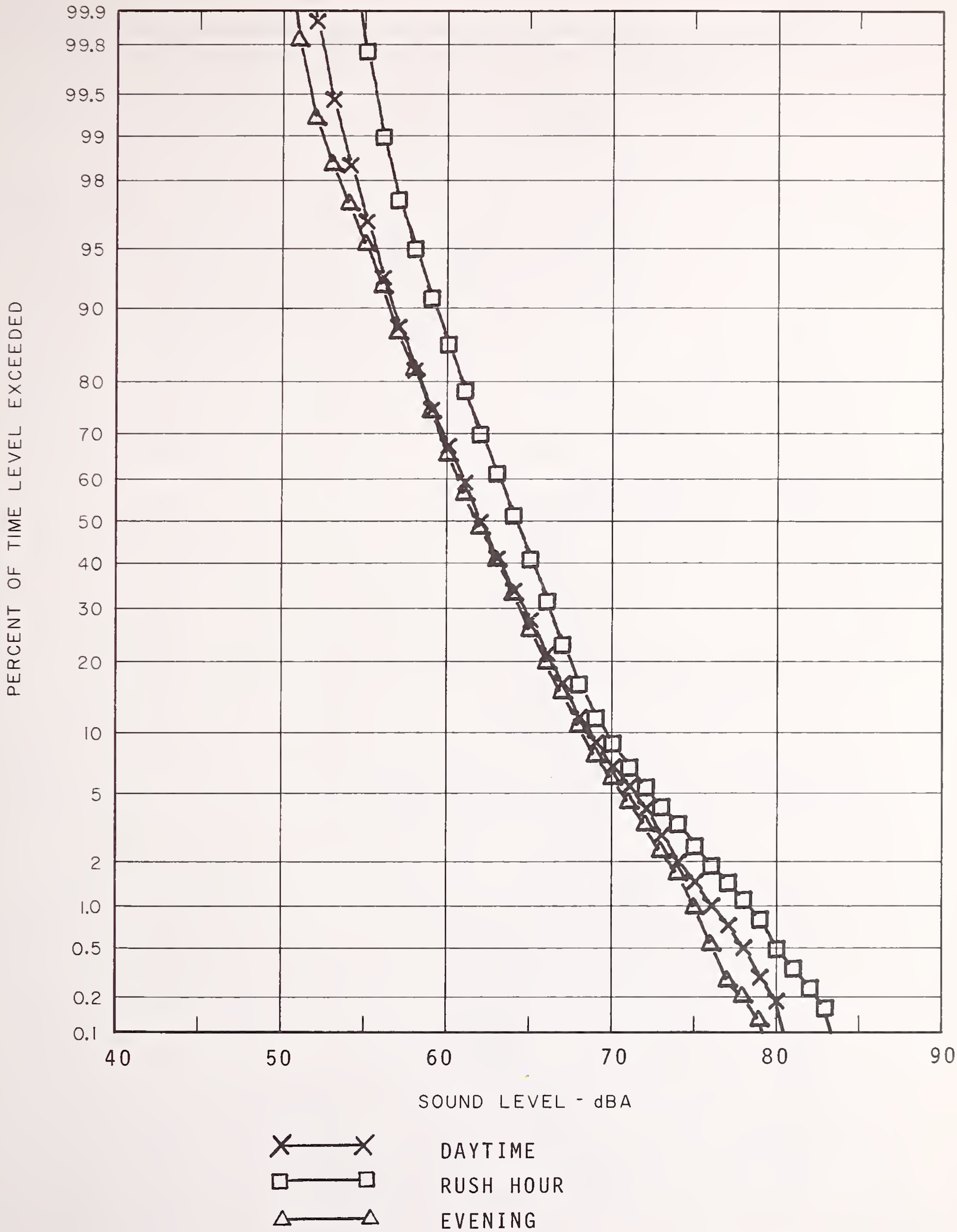


FIGURE 5.16c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 10, 50 FT POSITION.

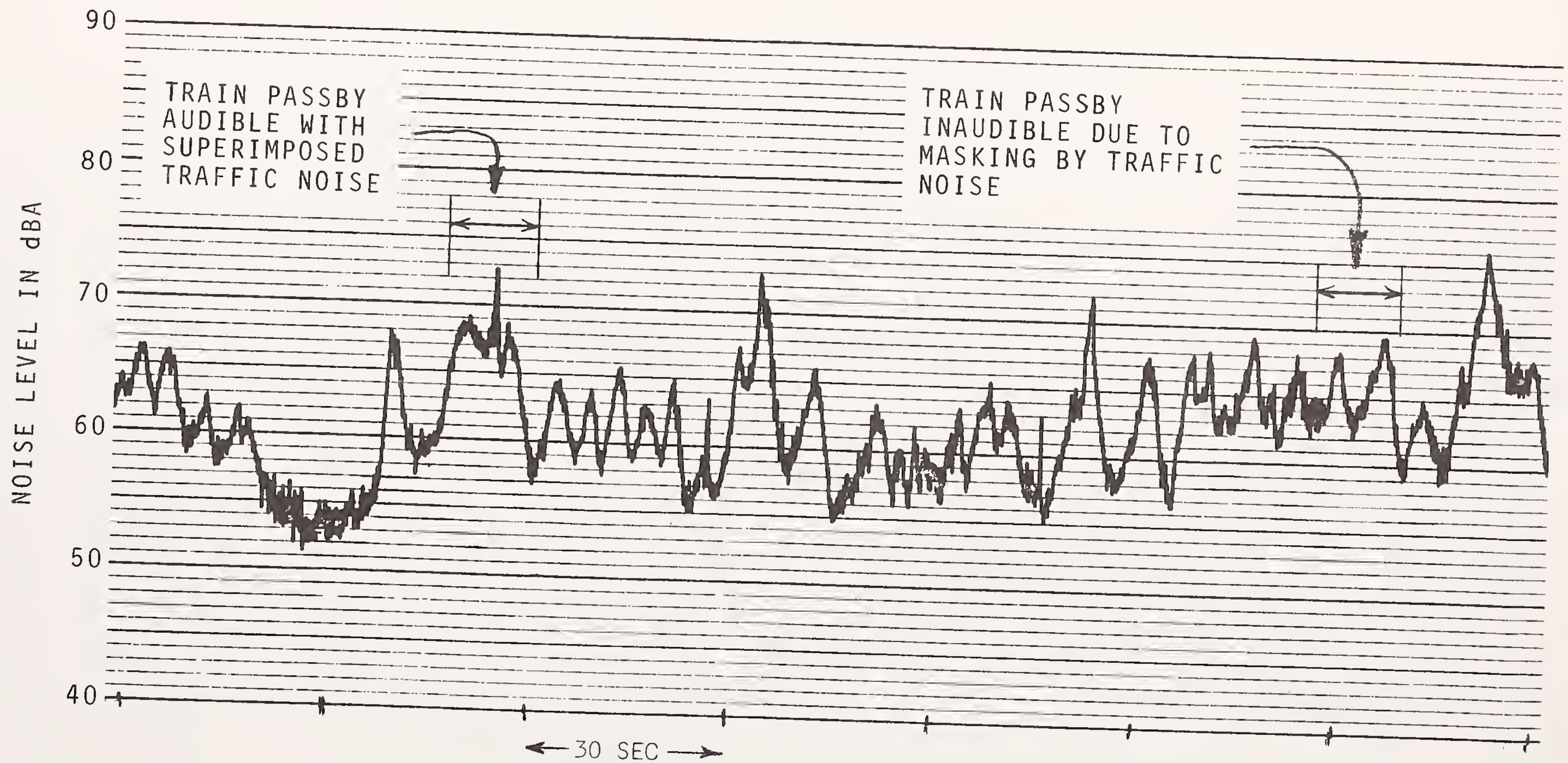


FIGURE 5.16d TYPICAL PASSBY TRACES 25 FT FROM VENT SHAFT AT LOCATION 10. SAMPLE TAKEN 3/12/75, 10:40 AM. TRAIN PASSBYS ARE NOT GENERALLY AUDIBLE DUE TO MASKING BY TRAFFIC NOISE.

LOCATION 11 - Walnut Creek Bridge, Concord Line, Residential Community, Walnut Creek

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.17a)

The Walnut Creek Bridge is a unique structure in the BART system. The bridge consists of a concrete slab trackway supported by a steel girder with a trapezoidal cross-section. The composite steel/concrete structure was used instead of the all-concrete structure used throughout most of the BART system since a long [84 ft] span was desired to span the Creek. The area along the east side of Walnut Creek, between Walnut Creek and Bancroft Road, is entirely vacant. However, there are residences along the east side of Bancroft Road, the closest being about 300 ft from the bridge. On the west side of the Creek there are residences within about 300 ft of the Creek. Bancroft Road is a fairly heavily traveled, 40 mph speed limit, local street, located about 150 ft east of the measurement location.

NOISE CLIMATE (See Table 5.14, Figures 5.17b-d)

In the periods when there is no traffic on Bancroft Road, the noise level at this location is quite low, dropping as low as 37 dBA during the daytime sample. The noise from BART passbys is by far the loudest intrusive noise in this area with maximum levels on the near track averaging 87 dBA at the 50 ft position and 83 dBA at the 100 ft position. Since the maximum levels due to traffic on Bancroft Road rarely exceed 60 dBA, it is clear that BART passby noise dominates the levels of L_{EQ}.

An interesting phenomenon occurs at the Walnut Creek Bridge. Although the maximum A-weighted level due to a BART train passby is about the same as found adjacent to BART all-concrete aerial structures, the noise level spectrum is quite different. The concrete/steel composite structure of the Walnut Creek Bridge radiates high intensity low frequency noise, that although not changing the overall A-weighted level, does add a definite low frequency "rumble" to the passby noise. This rumble is not significantly attenuated upon passage from the outside to the inside of a residential structure. An in-depth analysis of the noise radiated by the bridge was performed by this contractor for BART and reported in the report "Reduction of Noise Radiated by the Walnut Creek Bridge Structure". In order to reduce the low frequency noise, it was recommended that BART apply constrained layer damping treatment to the steel plates on the bridge.

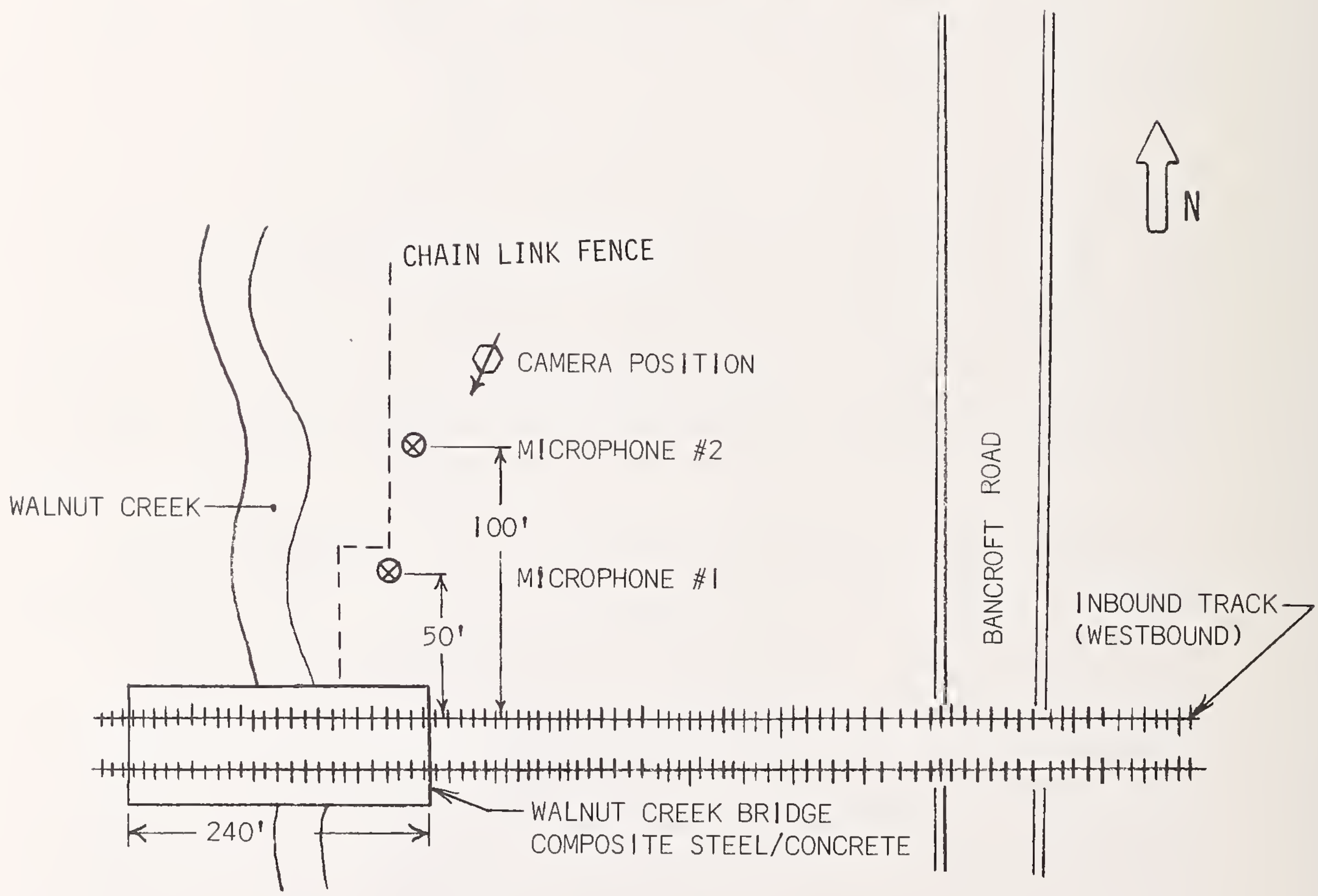


FIGURE 5.17a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 11.

TABLE 5.14 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 11, WALNUT CREEK BRIDGE - CONCORD LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
2 - 5 car	3 - 5 car	50	86	79	92	84	40	43	47	55	76	64	63
			* 0	*1.5	* 0	*1.3							
		100	83	75	89	81	40	43	48	55	73	61	60
			0.4	0.5	0.4	0.5							
RUSH HOUR													
1 - 5 car 1 - 6 car	1 - 5 car 1 - 6 car	50	86	77	94	83	48	50	51	55	74	64	63
			1.4	1.1	0.4	0.4							
		100	82	73	89	80	48	50	52	57	71	61	59
			1.4	0.7	0.7	0.4							
EVENING													
2 - 5 car 1 - 6 car	1 - 5 car 1 - 9 car	50	88	79	93	84	45	47	49	53	78	66	66
			1.3	0.4	0.9	0.7							
		100	84	75	90	82	45	47	50	56	75	63	62
			0.6	0.4	0.3	1.8							
TOTALS:													
5 - 5 car 2 - 6 car	5 - 5 car 1 - 6 car 1 - 9 car	50	87	78	93	84	44	47	49	54	76	65	64
			1.2	1.4	0.7	1.0							
		100	83	75	90	81	44	47	50	56	73	62	60
			1.1	1.3	0.7	1.3							

*Standard Deviation of level

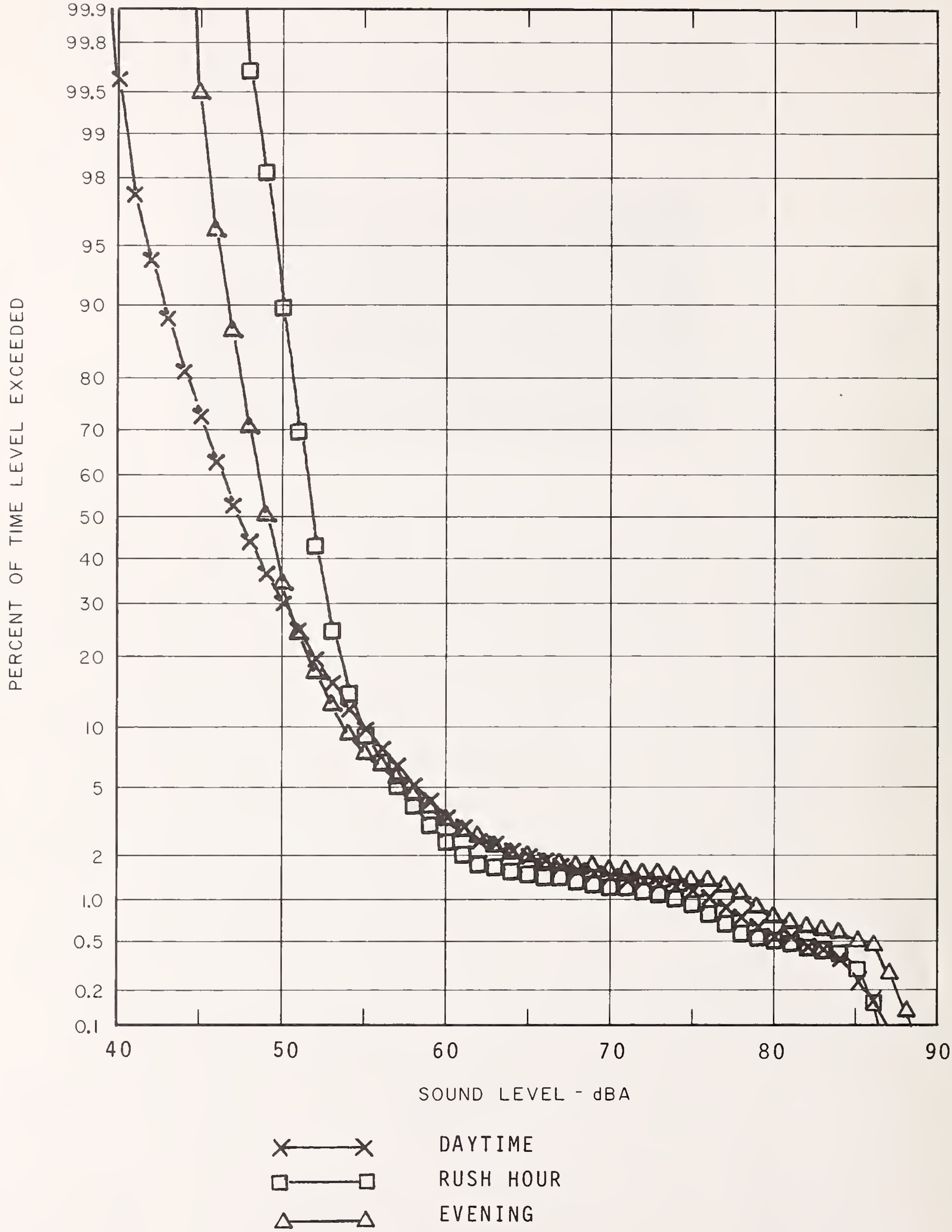


FIGURE 5.17b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 11, 50 FT POSITION.

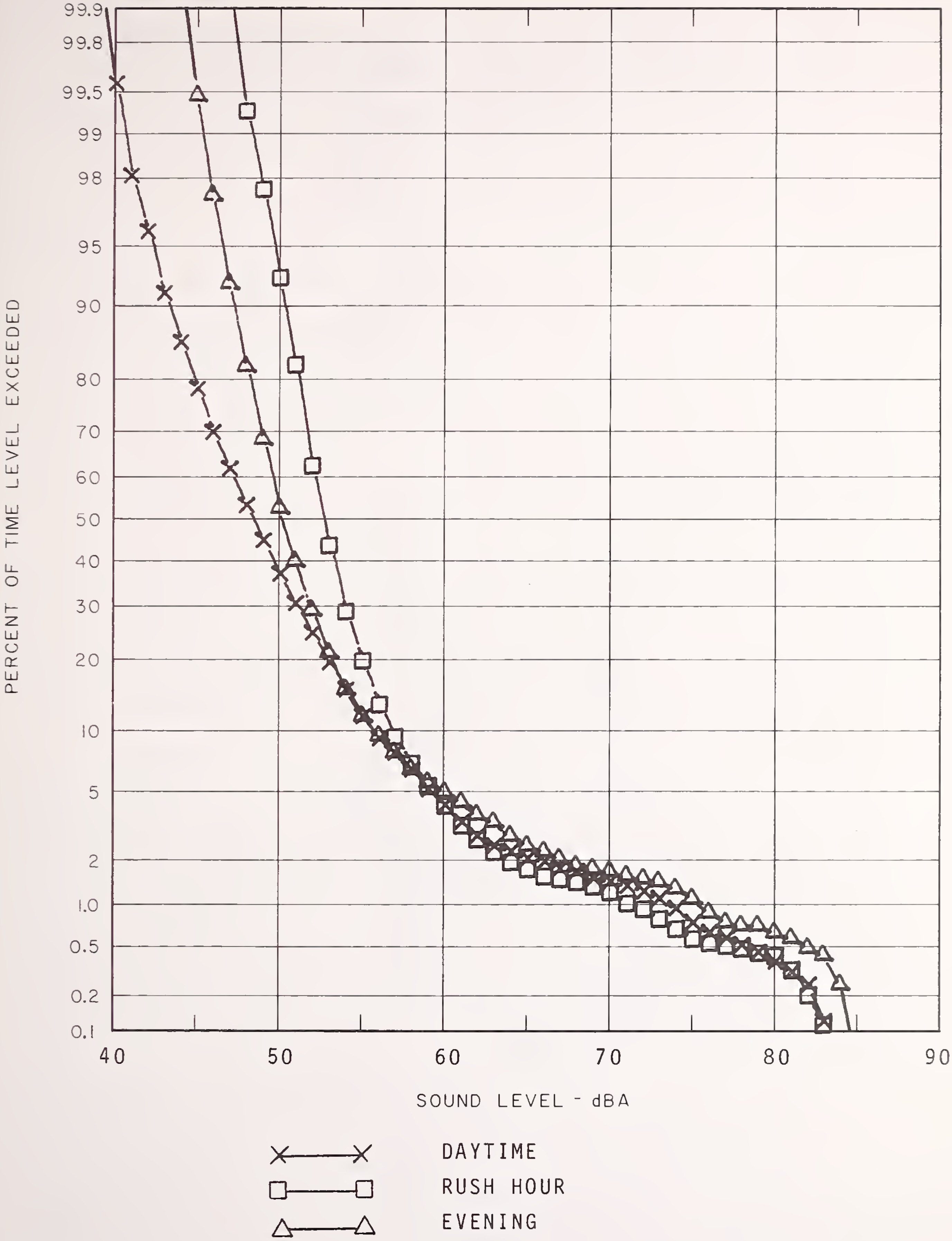


FIGURE 5.17c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 11, 100 FT POSITION.

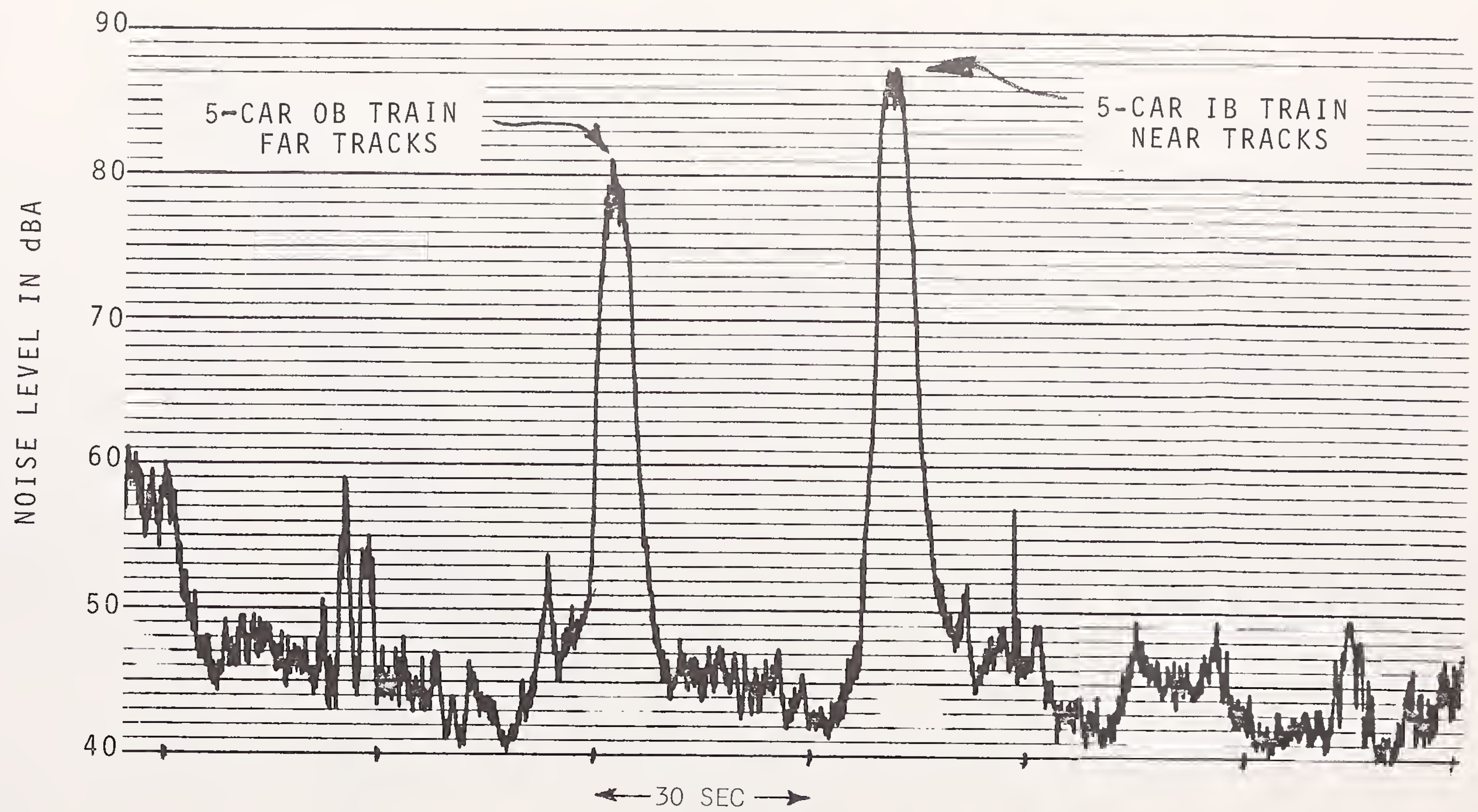


FIGURE 5.17d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 11.
SAMPLE TAKEN 1/30/75, 11:40 AM.

LOCATION 12 - Aerial Crossover, Fremont Line, Residential/ Commercial, San Leandro

SPEED - 60 mph IB [near track]

80 mph OB [far track]

DESCRIPTION (See Figure 5.18a)

Location 12 is adjacent to the aerial crossover south of the San Leandro Station. In this area, San Leandro Boulevard is adjacent to the east side and at-grade Western Pacific Railroad tracks are adjacent to the west side of the BART aerial structure. The measurement location is about 1000 ft south of a 50 mph speed limit curve in the BART tracks. At the measurement position, the northbound trains are starting to slow for the curve and the southbound trains are still accelerating out of the curve. The speeds given above are only approximate, the train speed is actually changing during passby.

San Leandro Boulevard is a heavily traveled local arterial with both automobile and truck traffic. No trains passed by on the railroad tracks during the noise samples.

The immediate neighborhood of the measurement location is primarily residential, although there is commercial and industrial activity along San Leandro Boulevard.

NOISE CLIMATE (See Table 5.15, Figures 5.18b-d)

San Leandro Boulevard carries a large volume of traffic and as such, it is the primary source of traffic noise. The level of L_{10} at the measurement positions, which averages 63 to 64 dBA, is determined primarily by traffic noise. The levels of L_{EQ}, averaging 68 dBA at 50 ft and 67 dBA at 100 ft, are dominated by BART passby noise. It is significant that even in this location near a heavily traveled surface arterial, the BART passby noise clearly dominates the level of L_{EQ}.

The purpose of this measurement location was to document the noise levels due to transit trains passing over aerial crossover track sections. The average maximum levels for trains on the near track were 87 dBA and 85 dBA at the 50 ft and 100 ft positions, respectively. The levels are lower than measured at the two other locations adjacent to aerial structure with normal track on the Fremont Line - Locations 3 and 4. The average maximum levels for trains on the near tracks at Locations 3 and 4 were 88.5 dBA and 87 dBA at 50 ft and 100 ft, respectively. It appears that the lower noise levels adjacent to the aerial crossover are due primarily to the lower train speeds. That is, the lower train speeds more than offset the increase in noise level due to the impact noise caused as the transit trains pass over the gaps at the frogs of the crossover.

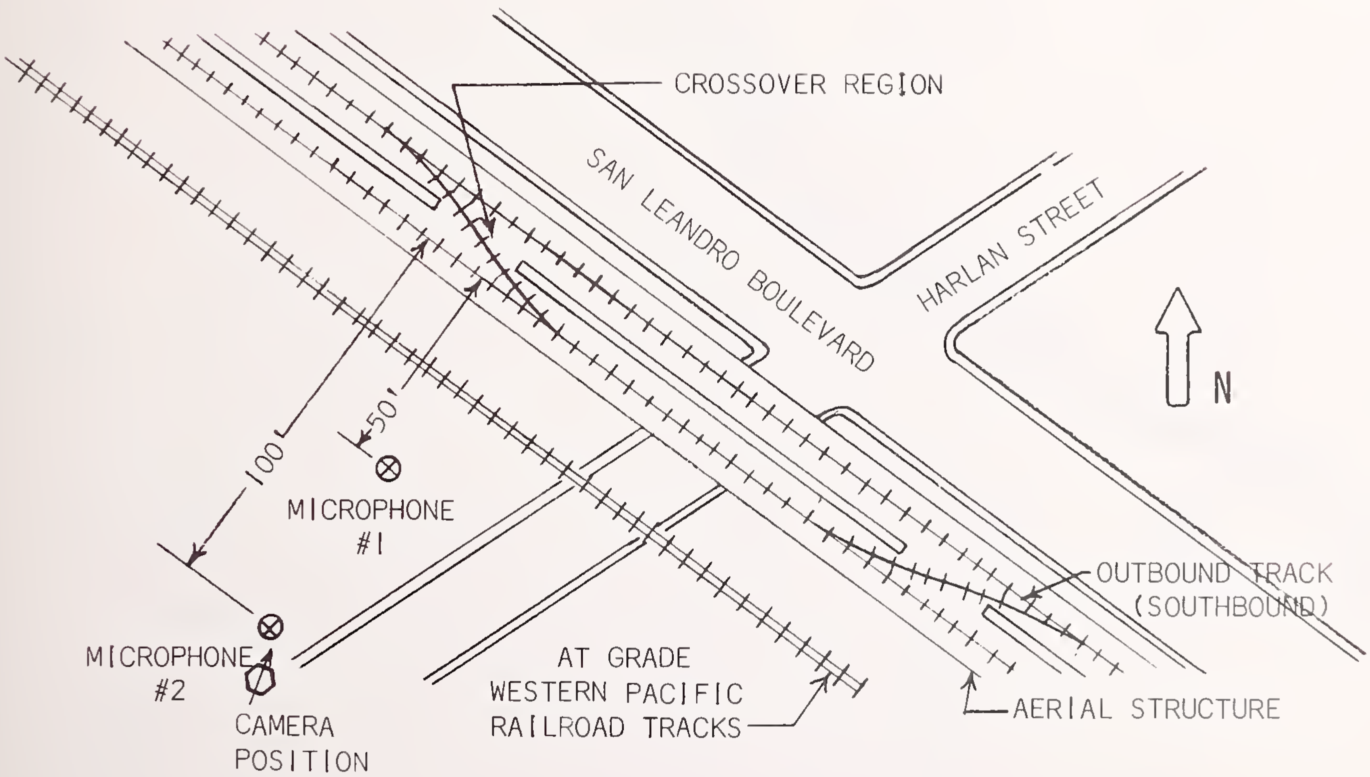


FIGURE 5.18a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 12.

TABLE 5.15 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 12, AERIAL CROSSOVER - FREMONT LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
3 - 4 car 2 - 5 car	2 - 4 car 3 - 5 car	50	76 **1.4*	87 **0.8*	83 **1.2*	93 **0.9*	51	54	58	66	84	69	68
		100	76 *1.5*	85 *1.2*	83 *1.5*	92 *1.2*	51	53	57	66	83	68	67
RUSH HOUR													
3 - 4 car 1 - 5 car	2 - 4 car 4 - 5 car	50	75 *0.5*	86 *0.4*	83 *0.7*	93 *0.6*	48	50	57	64	84	68	68
		100	74 *0.6*	84 *0.5*	82 *0.5*	91 *0.7*	48	51	56	62	82	66	67
EVENING													
1 - 4 car 3 - 5 car 1 - 6 car	4 - 5 car	50	78 *0.2*	86 *2.5*	85 *0.6*	93 *1.8*	51	53	57	63	81	68	68
		100	77 *0.3*	84 *2.6*	85 *0.4*	92 *1.5*	50	52	55	62	80	67	66
TOTALS:													
7 - 4 car 6 - 5 car 1 - 6 car	4 - 4 car 11 - 5 car	50	76 *1.6*	87 *1.3*	84 *1.2*	93 *1.0*	50	52	57	64	83	68	68
		100	76 *1.7*	85 *1.5*	84 *1.3*	92 *1.1*	50	52	56	63	82	67	67

**Standard Deviation of level*

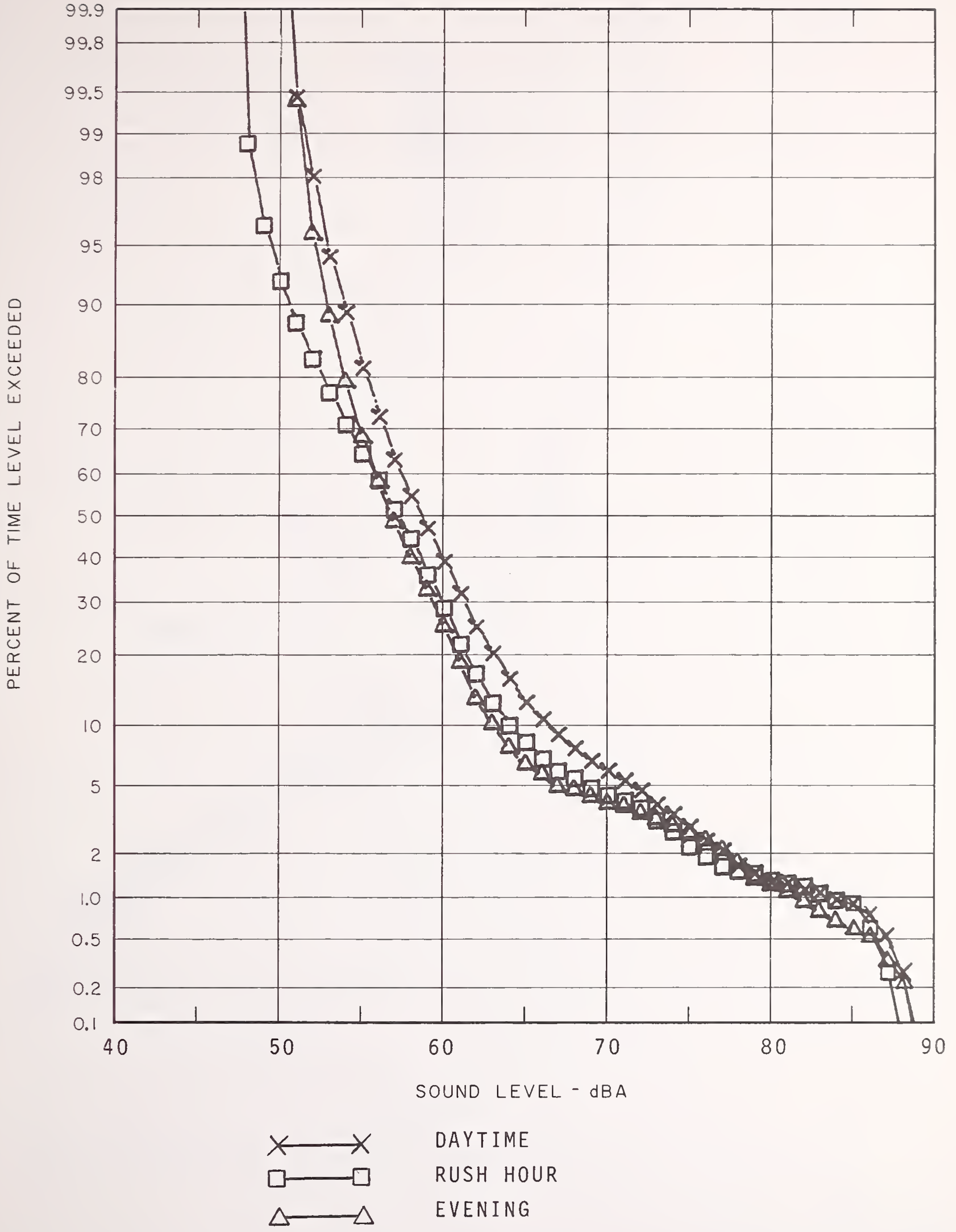


FIGURE 5.18b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 12, 50 FT POSITION.

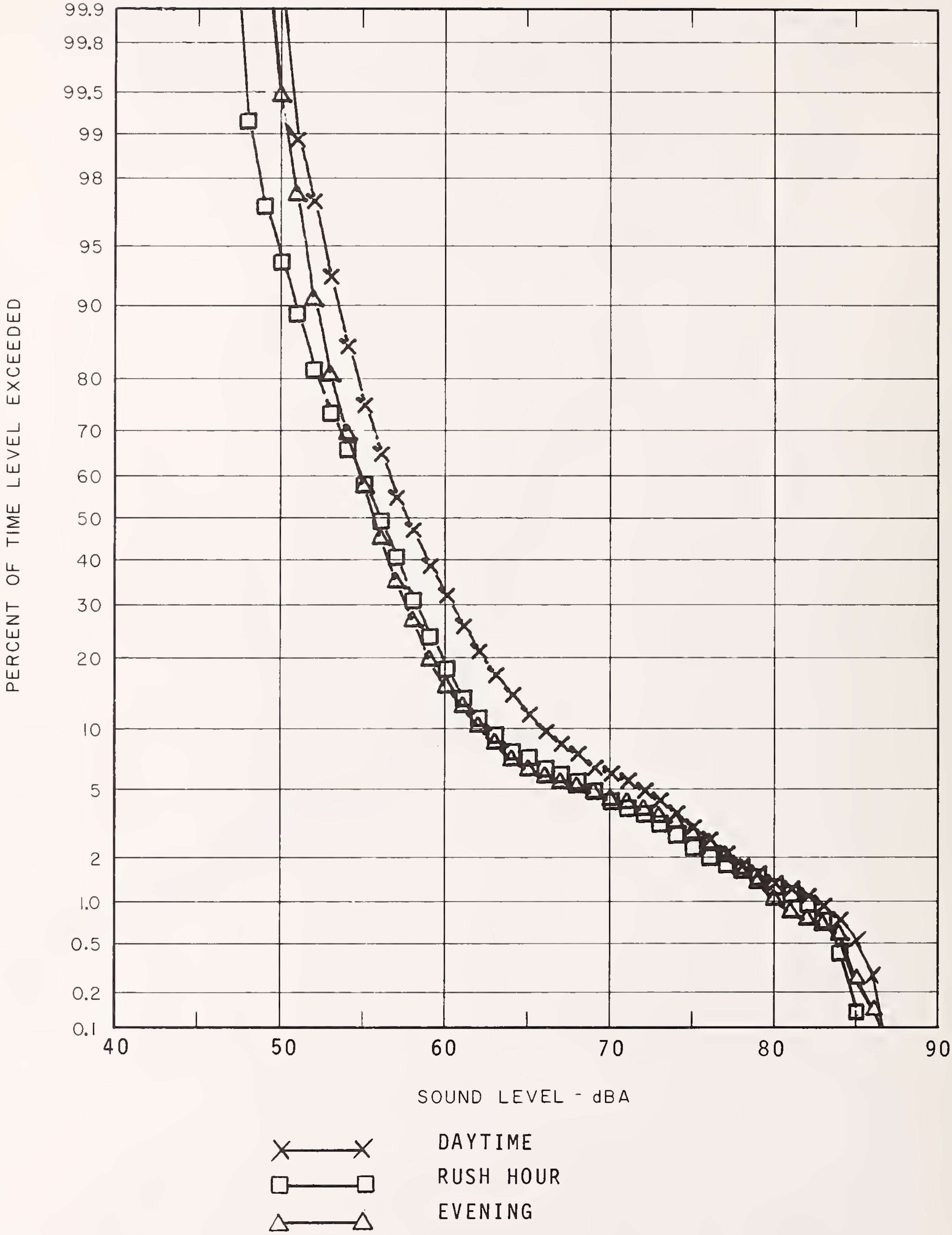


FIGURE 5.13c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 12, 100 FT POSITION.

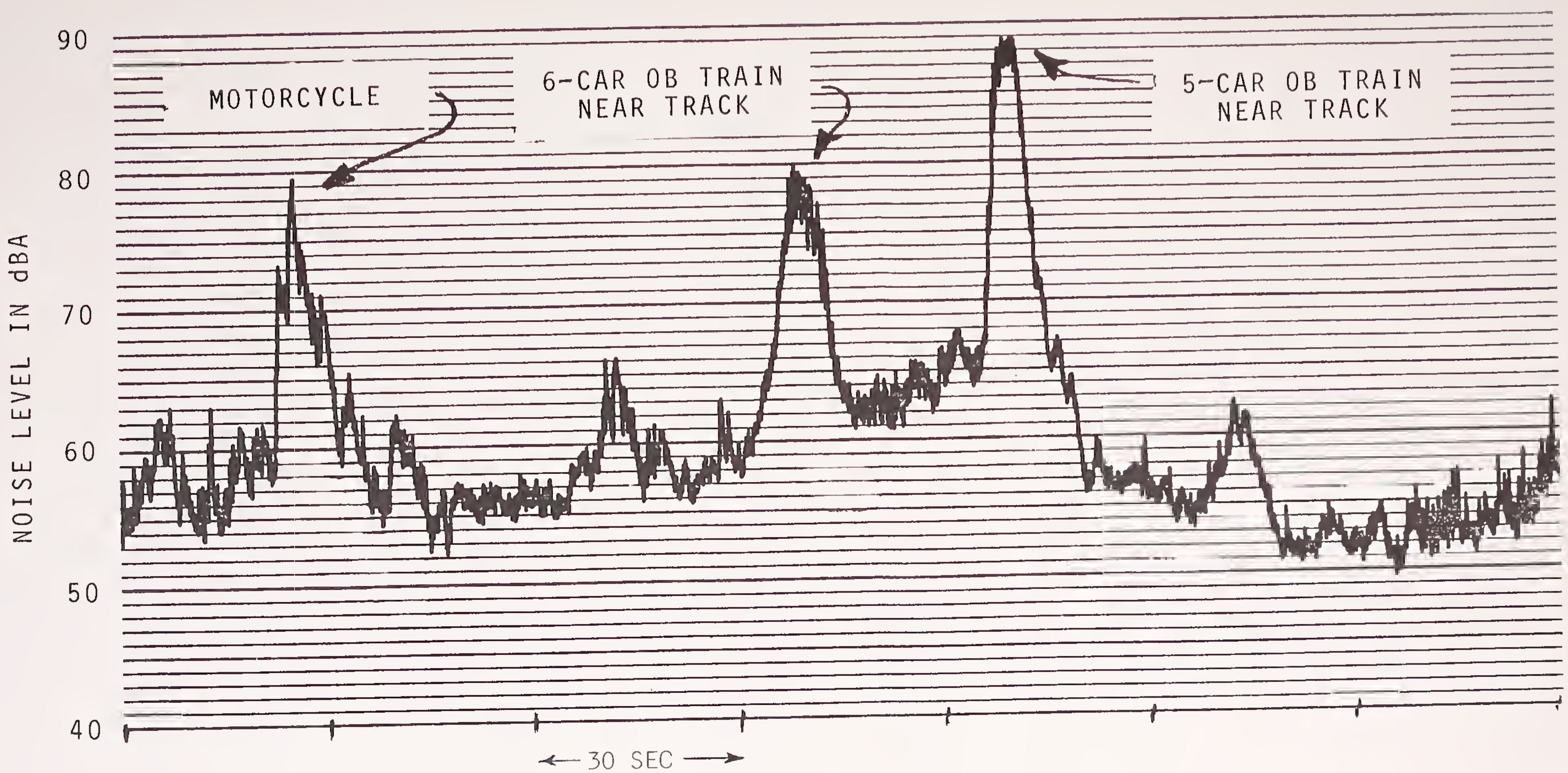


FIGURE 5.18d TYPICAL PASSBY TRACES AT 50 FT POSITION, LOCATION 12. SAMPLE TAKEN, 3/20/75, 6:56 PM.

LOCATION 13 - At-grade Crossover, Fremont Line, Industrial, Hayward

SPEED - 80 mph, IB and OB

DESCRIPTION (See Figure 5.19a)

The land use in this area includes industrial, agricultural and residential. On the side of the tracks that the measurements were taken, the land use is primarily industrial. The measurement location is on the property of a pipe company although the closest building is more than 600 ft from the measurement locations. The BART tracks at this point are slightly depressed, being 5 to 10 ft below mean terrain in cut.

Whipple Road carries a heavy volume of traffic. Included is a considerable number of large diesel trucks and school buses during the day.

The Southern Pacific Railroad tracks run adjacent to the east side of the BART tracks and about 400 ft west of the BART tracks are the Western Pacific Railroad tracks. No freight trains passed during the samples.

The conditions at this location made it impossible to position the microphone 50 ft from the near track centerline. Hence, measurements were taken at distances of 100 and 200 ft from the BART tracks. Both measurement positions were located in a plowed field along Whipple Road.

NOISE CLIMATE (See Table 5.16, Figures 5.19b-d)

The partial shielding provided at the microphone positions due to the tracks being depressed reduces the maximum levels from BART passbys by a considerable amount. At the 100 ft position, the average peak level is 78 dBA for trains on the near track, 5 dBA less than the average maximum level observed at 100 ft for the four at-grade locations, Locations 5 through 8, without any terrain sheilding and without the impact noise due to the crossover network.

At the 200 ft position, the microphone was close enough to Whipple Road that traffic noise completely obscured the BART passby noise on the strip chart recordings.

The loudest observed source of noise in this area are the heavy trucks on Whipple Road. When there was a break in the traffic noise, the noise from the industrial activities was audible.

For the samples at the 200 ft position, the traffic noise dominates both the statistical descriptors and the level of L_{EQ} with no significant contribution from BART passby noise. At the 100 ft position it appears that L_{EQ} due to traffic noise is about 3 to 5 dBA higher than the BART "trains only" L_{EQ}. Hence, both contribute to the overall level of L_{EQ}.

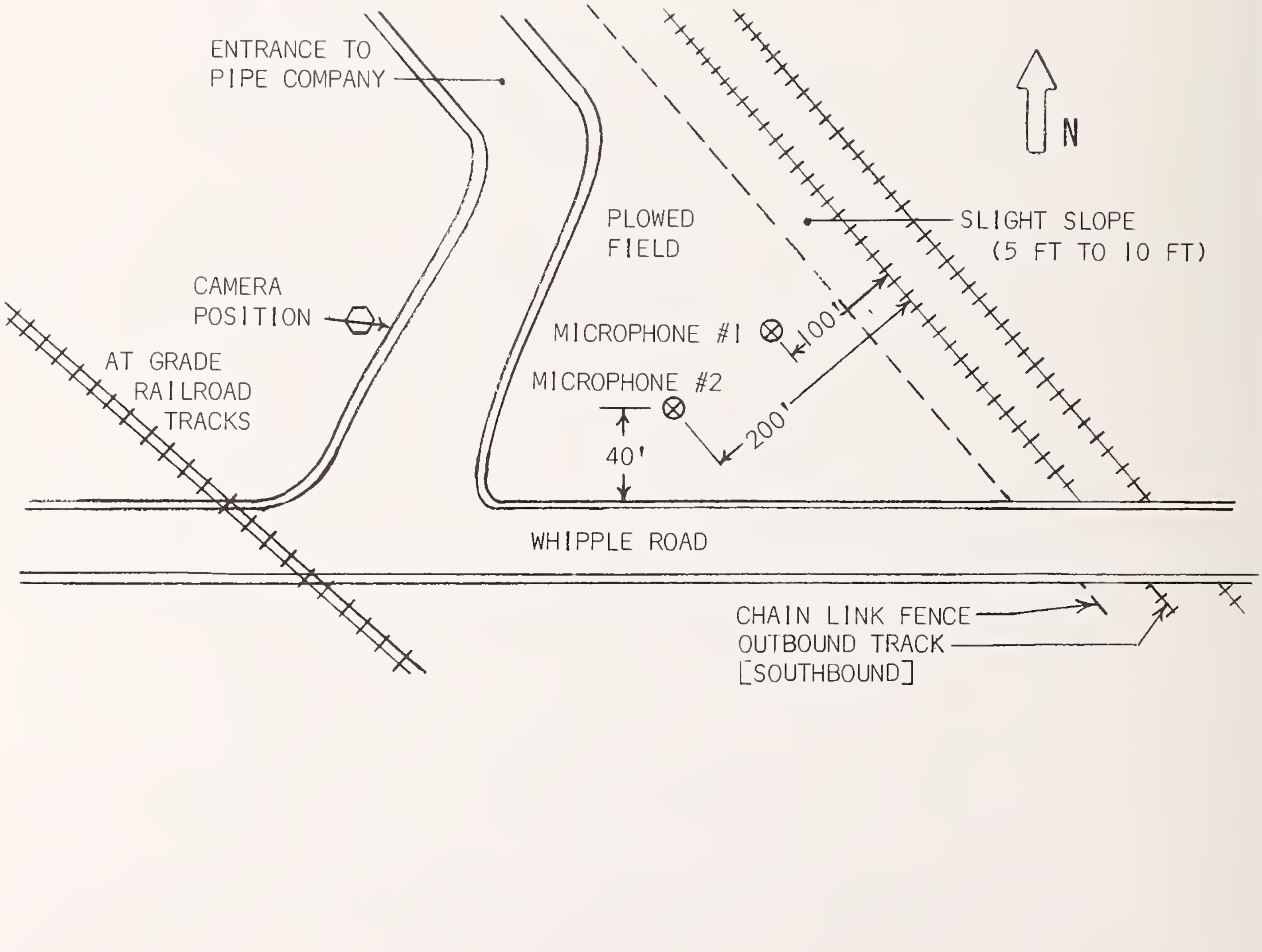


FIGURE 5.19a SKETCH AND PHOTOGRAPH OF WAYSIDE MEASUREMENT LOCATION 13.

TABLE 5.16 SUMMARY OF MEASUREMENT RESULTS FOR 30-MINUTE SAMPLES AT LOCATION 13, AT-GRADE CROSSOVER - FREMONT LINE

TRAIN SUMMARY IB	TRAIN SUMMARY OB	DISTANCE [FT]	AVERAGE MAXIMUM LEVELS - dBA IB	AVERAGE MAXIMUM LEVELS - dBA OB	AVERAGE L_R - dBA IB	AVERAGE L_R - dBA OB	STATISTICAL DESCRIPTORS - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ} MEAS.	L_{EQ} TRAINS ONLY [APPROX]
DAY													
2 - 4 car 3 - 5 car	2 - 4 car 3 - 5 car	100	74 *0.5*	80 *1.3*	80 *0.6*	85 *0.9*	49	52	57	66	76	64	60
		200	--	--	--	--	51	54	61	70	79	67	--
RUSH HOUR													
2 - 4 car 3 - 5 car	2 - 4 car 2 - 5 car	100	71 *1.8*	76 *1.4*	78 *1.7*	82 *1.0*	46	50	54	59	72	59	57
		200	--	--	--	--	49	52	58	64	71	61	--
EVENING													
1 - 4 car 3 - 5 car	2 - 4 car 2 - 5 car 1 - 6 car	100	75 *1.7*	79 *1.6*	81 *2.0*	85 *1.3*	47	51	55	62	77	65	60
		200	--	--	--	--	49	52	59	65	75	65	--
TOTALS:													
5 - 4 car 9 - 5 car	6 - 4 car 7 - 5 car 1 - 6 car	100	73 *2.2*	78 *2.0*	80 *2.1*	84 *1.7*	47	51	55	62	75	63	59
		200	--	--	--	--	50	53	59	66	75	64	--

**Standard Deviation of level*

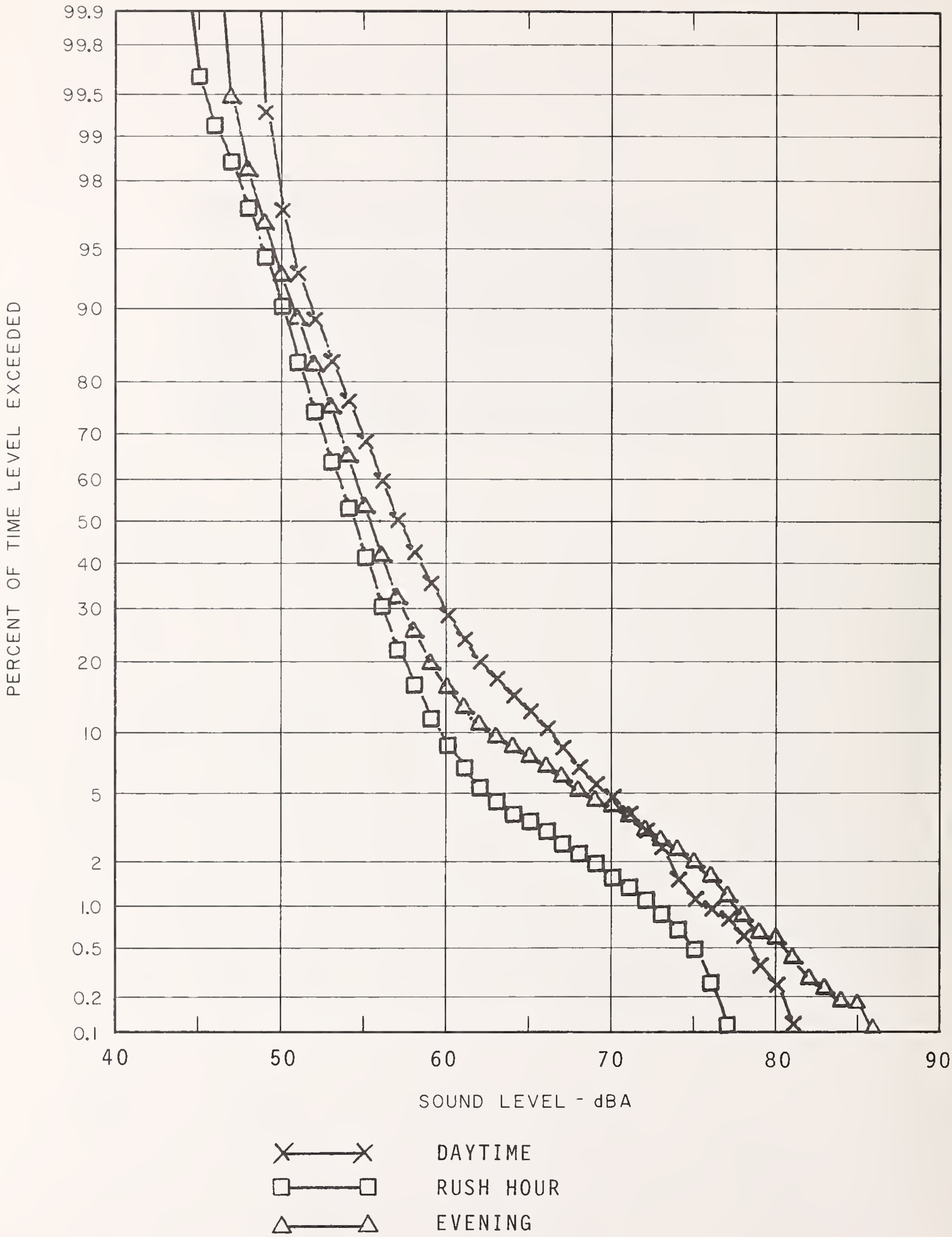


FIGURE 5.19b STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 13, 100 FT POSITION.

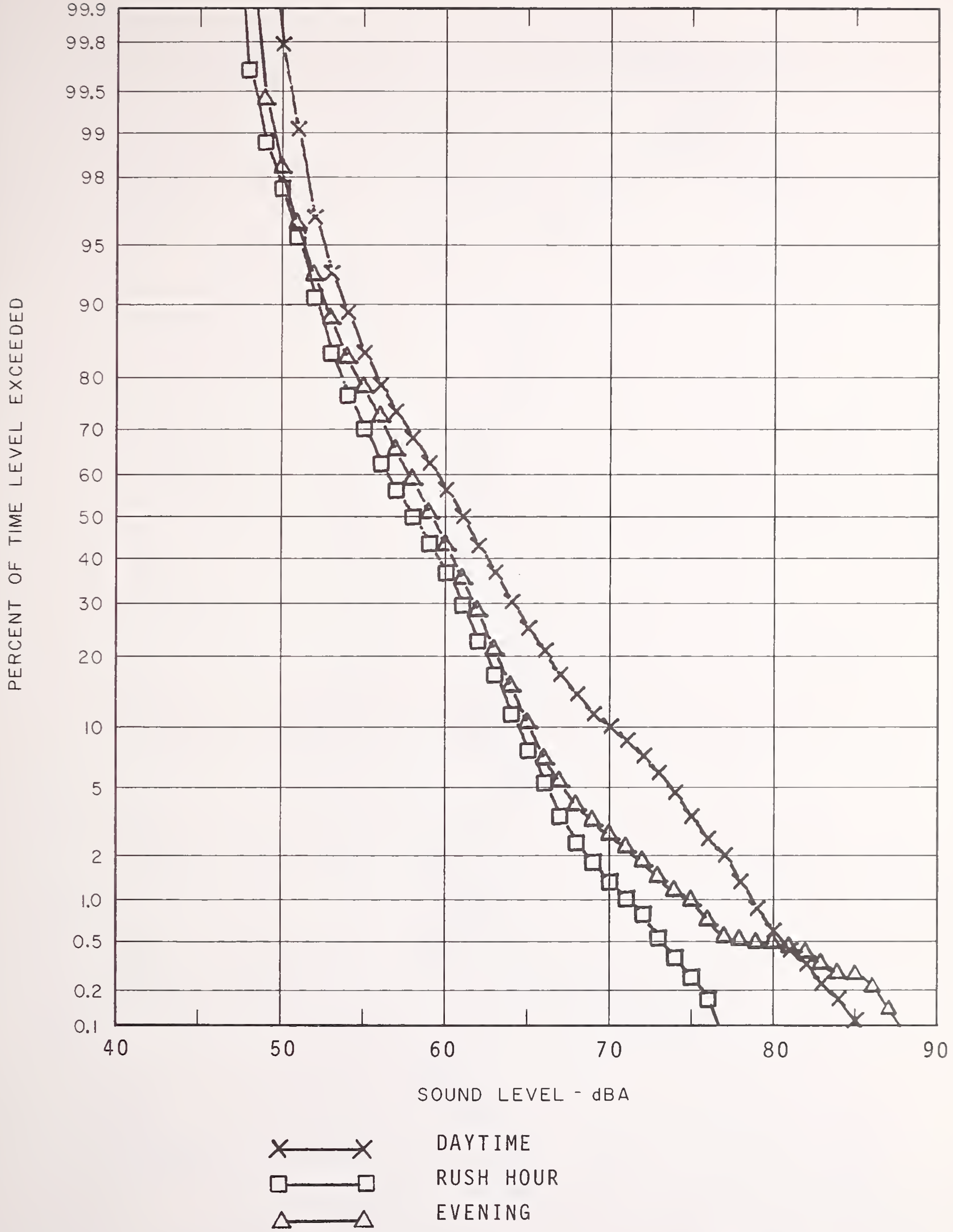


FIGURE 5.19c STATISTICAL DISTRIBUTIONS FOR THE WAYSIDE NOISE SAMPLES AT LOCATION 13, 200 FT POSITION.

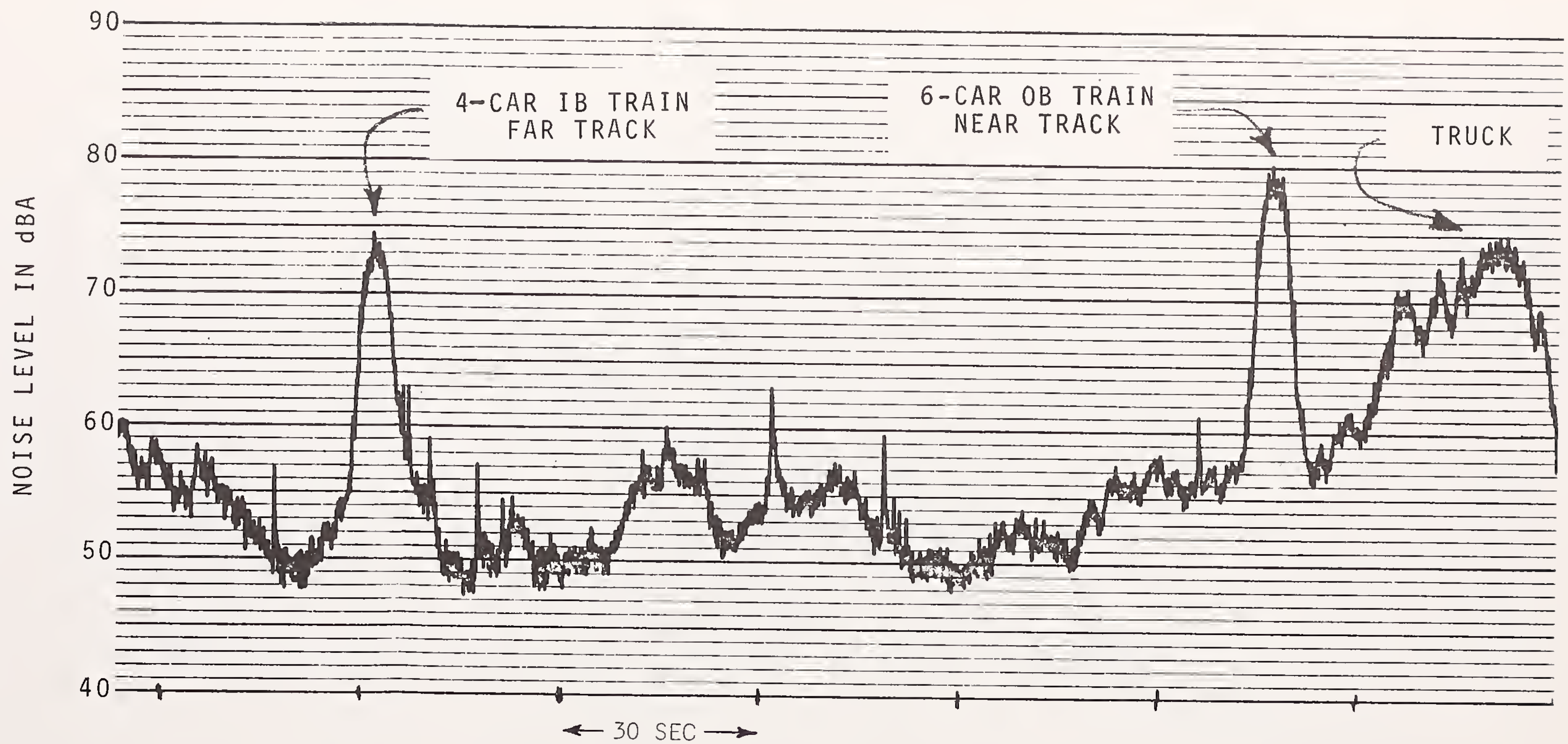


FIGURE 5.19d TYPICAL PASSBY TRACES AT 100 FT POSITION, LOCATION 13.
SAMPLE TAKEN, 3/18/75, 6:57 PM.

TABLE 5.17 SUMMARY OF THE DATE, TIME AND ATMOSPHERIC CONDITIONS FOR THE WAYSIDE NOISE MEASUREMENTS

Location	Sample	Date	Starting Time	Temp °F	Approx Wind Velocity MPH
1	Day	3/11/75	1:16 p.m.	65	5
	Rush	3/12/75	5:16 p.m.	60	5-10
	Evening	3/11/75	7:06 p.m.	64	0-5
2	Day	3/11/75	12:12 p.m.	60	10
	Rush	3/31/75	5:50 p.m.	62	5-10
	Evening	3/31/75	7:52 p.m.	56	3-5
3	Day	3/18/75	1:47 p.m.	60	0-15
	Rush	1/29/75	3:58 p.m.	50	5-10
	Evening	4/1/75	7:57 p.m.	50	0-5
4	Day	3/18/75	11:08 a.m.	59	0-10
	Rush	3/25/75	3:58 p.m.	50	5-20
	Evening	3/20/75	8:06 p.m.	48	0-15
5	Day	3/11/75	11:01 a.m.	55	10
	Rush	3/31/75	5:00 p.m.	62	10-20
	Evening	3/31/75	6:55 p.m.	61	10-15
6	Day	1/30/75	12:17 p.m.	57	5
	Rush	1/30/75	4:00 p.m.	60	0-3
	Evening	1/30/75	8:18 p.m.	39	0-3
7	Day	1/29/75	12:34 p.m.	51	5-10
	Rush	3/18/75	5:51 p.m.	65	15
	Evening	3/18/75	7:55 p.m.	55	5-15

TABLE 5.17 [cont.]

Location	Sample	Date	Starting Time	Temp °F	Approx Wind Velocity MPH
8	Day	1/29/75	1:49 p.m.	53	5-10
	Rush	3/18/75	4:30 p.m.	65	0-15
	Evening	4/1/75	6:57 p.m.	55	0-15
9	Day	3/12/75	11:51 a.m.	64	5
	Rush	3/12/75	4:18 p.m.	59	5-10
	Evening	3/12/75	7:51 p.m.	52	0-5
10	Day	3/12/75	10:40 a.m.	63	5-10
	Rush	3/11/75	4:32 p.m.	65	2-5
	Evening	3/12/75	7:00 p.m.	53	4-9
11	Day	1/30/75	10:59 a.m.	58	0-3
	Rush	1/30/75	5:04 p.m.	58	0-3
	Evening	1/30/75	7:19 p.m.	42	0-5
12	Day	3/18/75	12:25 p.m.	62	5-15
	Rush	1/29/75	5:27 p.m.	47	0-5
	Evening	3/20/75	6:56 p.m.	48	0-20
13	Day	1/29/75	11:06 a.m.	45	5-10
	Rush	4/1/75	5:42 p.m.	57	5-20
	Evening	3/18/75	6:57 p.m.	59	10

AUXILIARY EQUIPMENT NOISE*

To assess auxiliary equipment noise on the BART transit vehicle, noise measurements were made of individual on-car components at a distance of 15 ft from the geometric center of the component. Each individual component was operated individually to determine the noise of that component only.

Figures 5.20 through 5.25 show the octave band and one-third octave band sound pressure levels measured for the various compressors, evaporator fans, condenser fans, propulsion motor blower, motor alternator unit, and hydraulic pump on Car 107. The test results show that none of the components individually produce a noise level greater than 65 dBA. The results obtained are to be expected as the original BART car noise specifications indicates that the auxiliary equipment noise should be 65 dBA or less at 15 ft from the center of each component with the car at rest when each unit is operated individually.

The test results also indicate that the auxiliary equipment noise is an insignificant contribution to the wayside passby noise. However, the auxiliary equipment does contribute to the noise level on some station platforms when the train is stopped in the station during passenger loading and unloading.

*Source: Unpublished data from Wilson, Ihrig & Associates, 10/71.

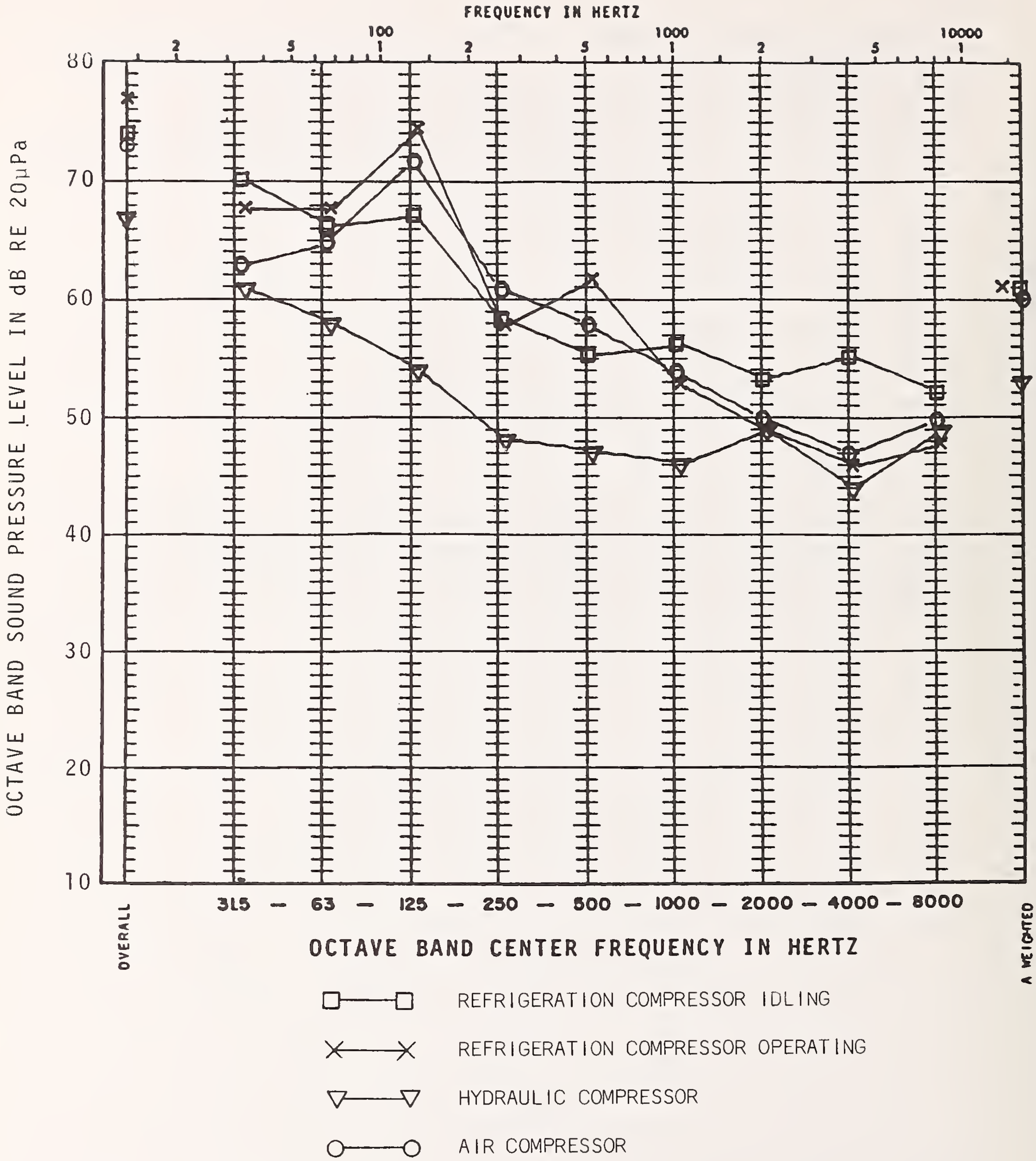


FIGURE 5.20a COMPRESSORS AT 15 FT FROM CENTER OF COMPONENT

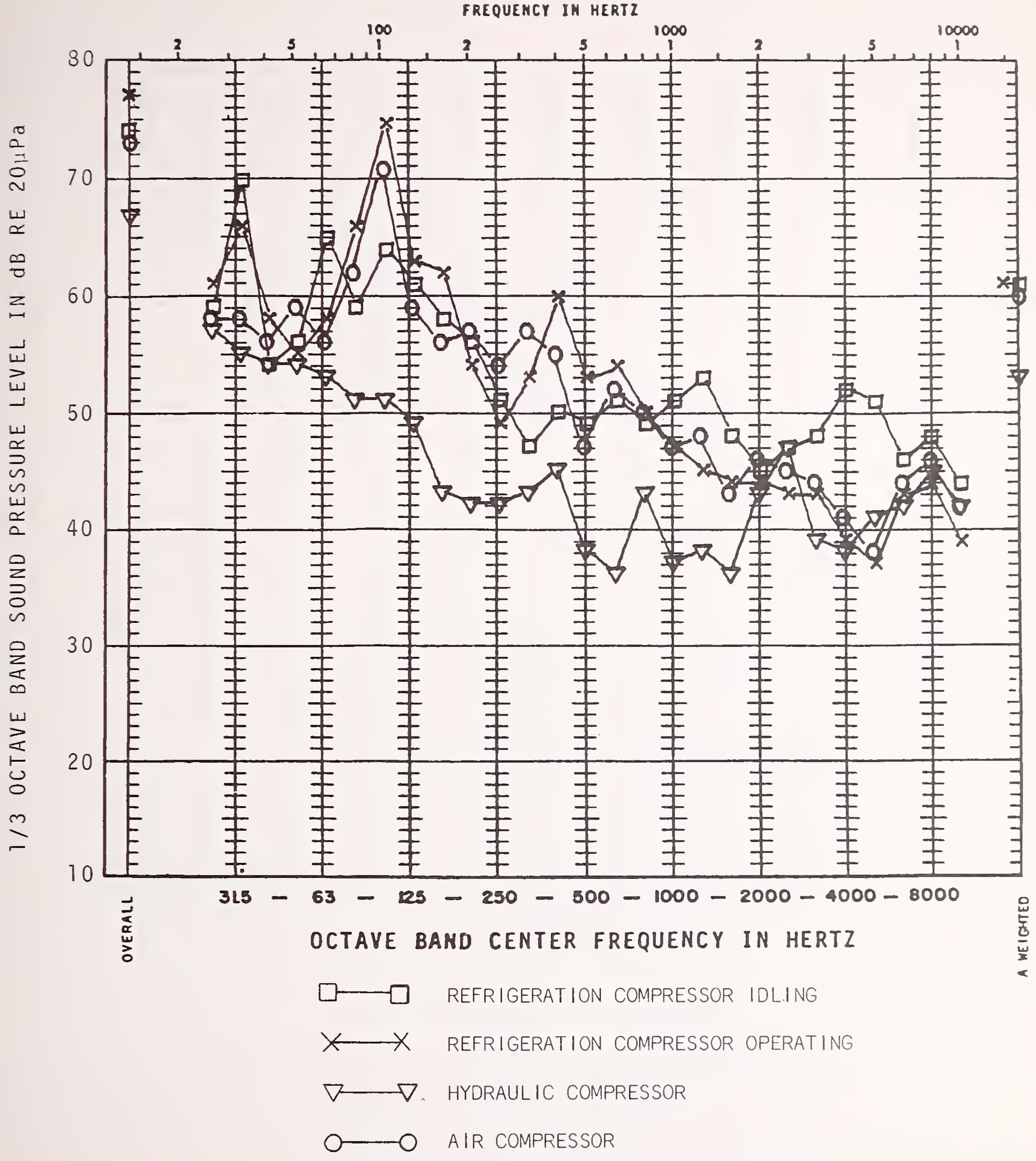


FIGURE 5.20b COMPRESSORS AT 15 FT FROM CENTER OF COMPONENT

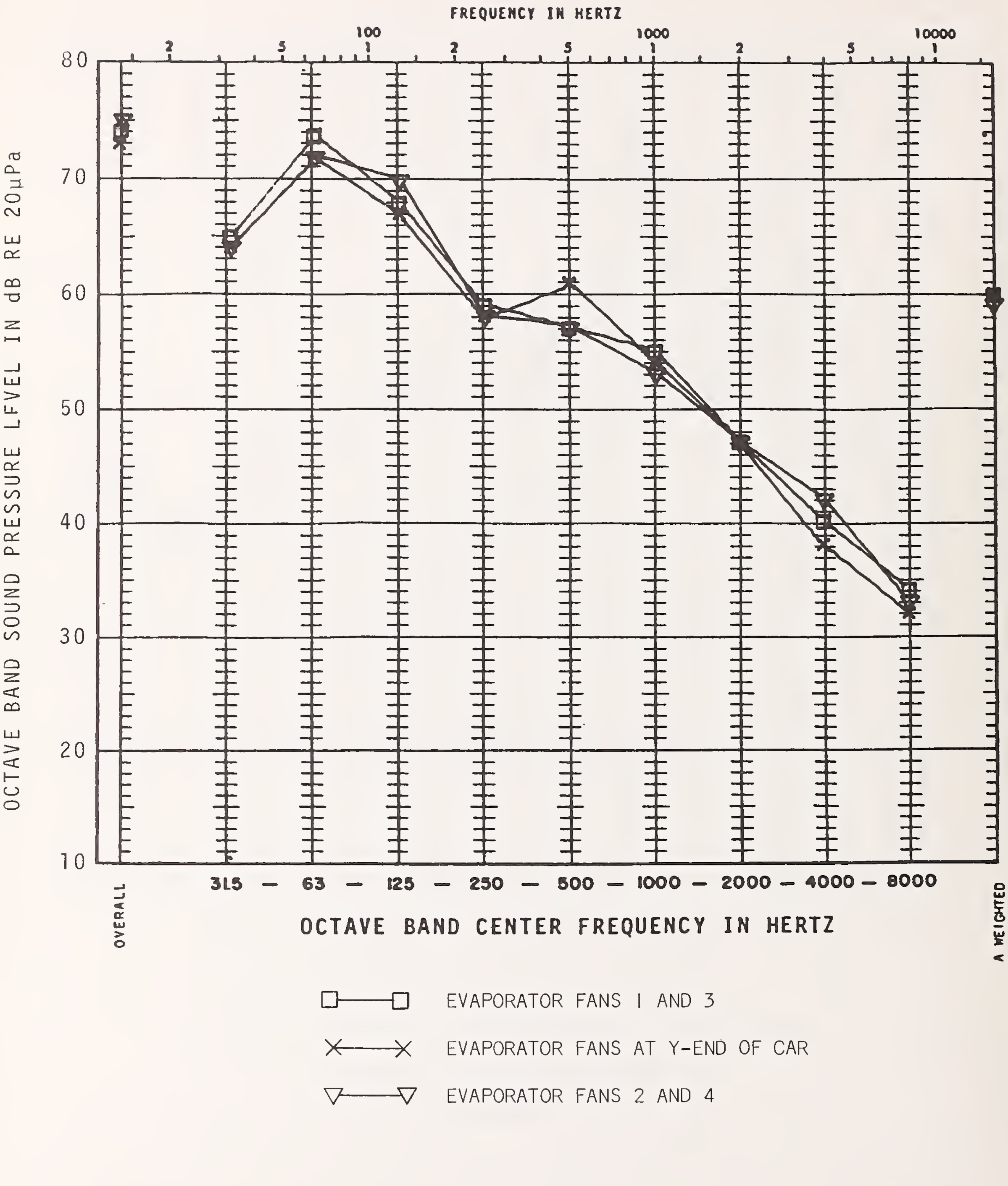


FIGURE 5.21a EVAPORATOR FANS AT 15 FT FROM CENTER OF COMPONENT

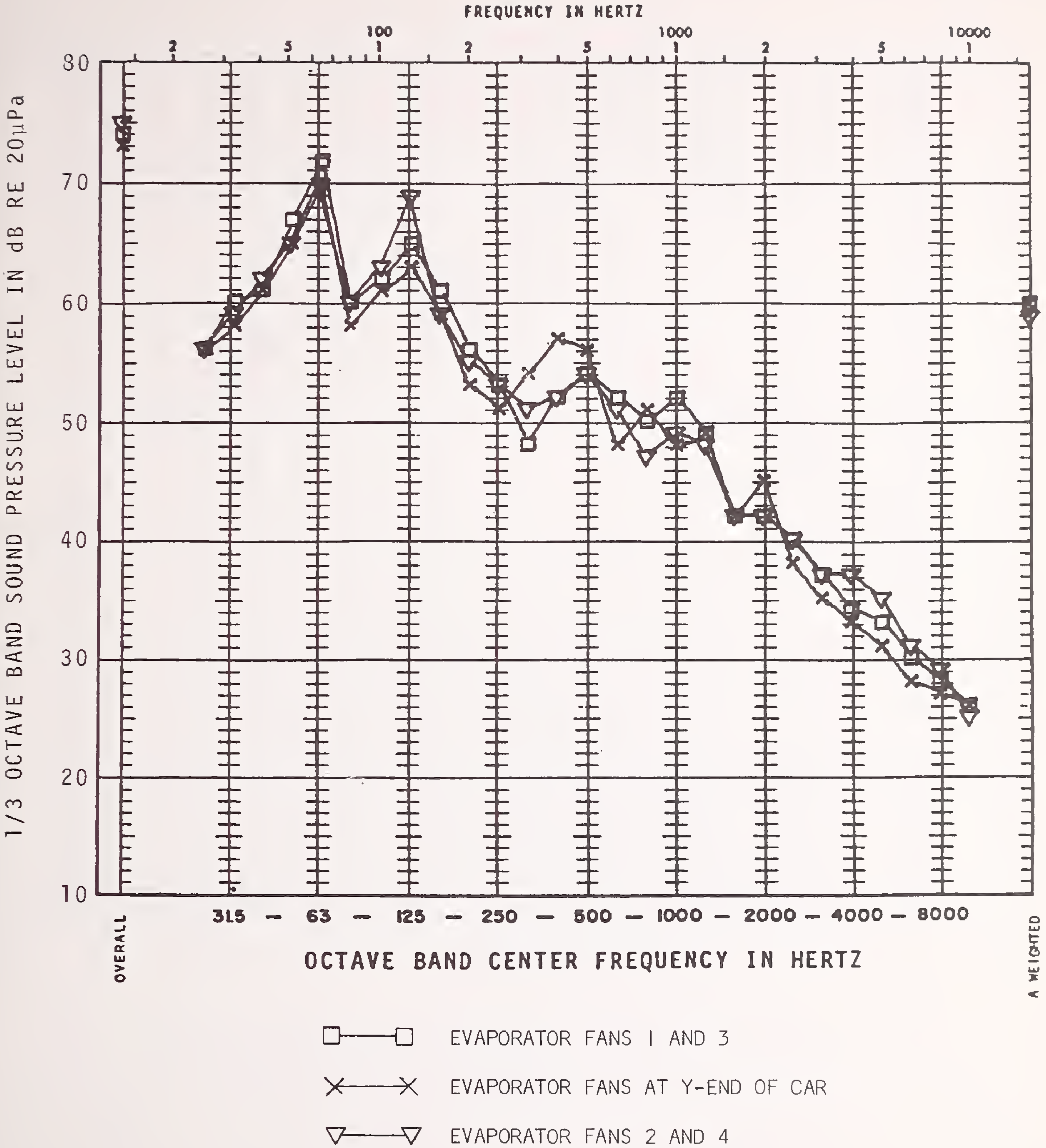


FIGURE 5.21b EVAPORATOR FANS AT 15 FT FROM CENTER OF COMPONENT

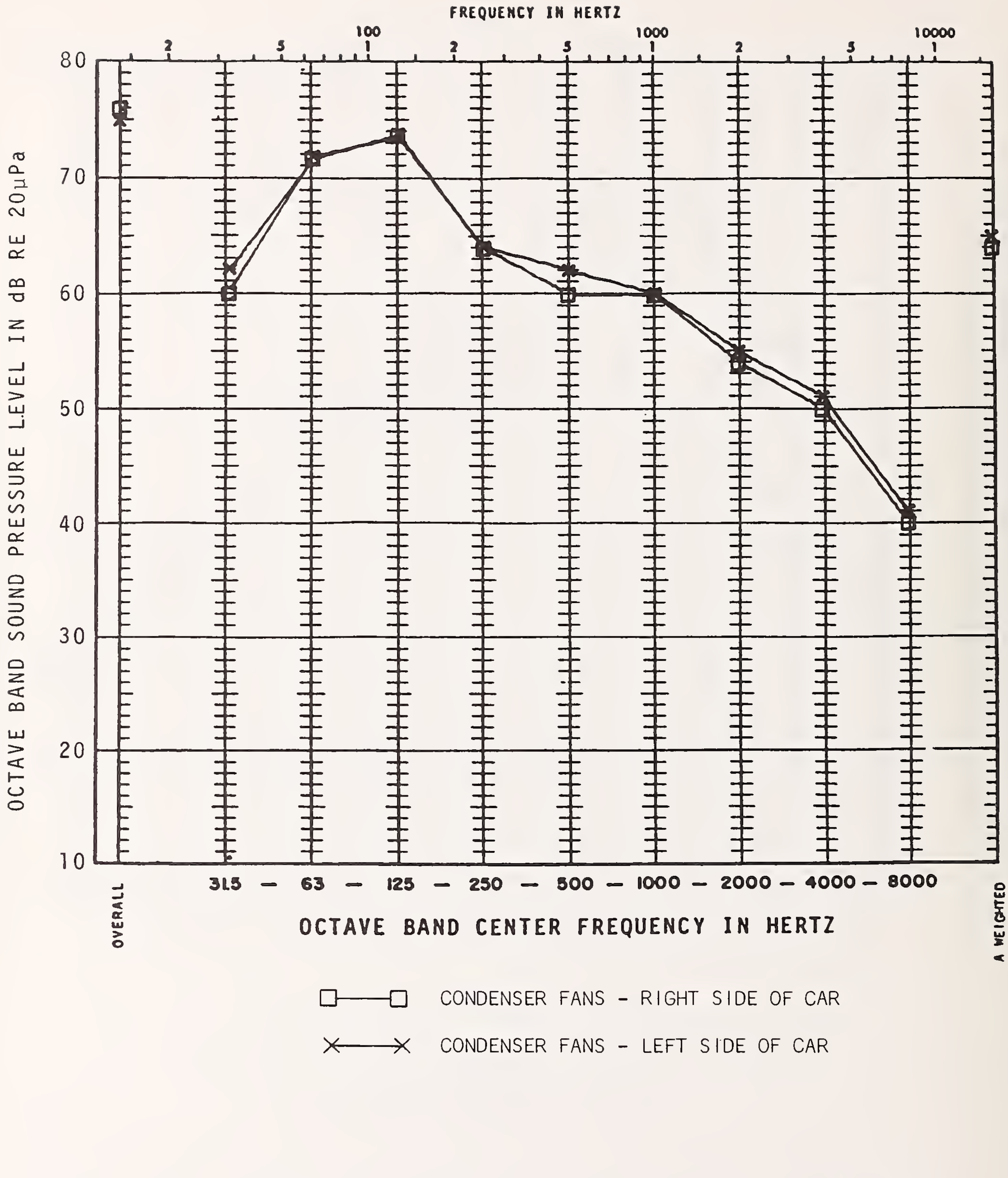


FIGURE 5.22a CONDENSER FANS AT 15 FT FROM CENTER OF COMPONENT

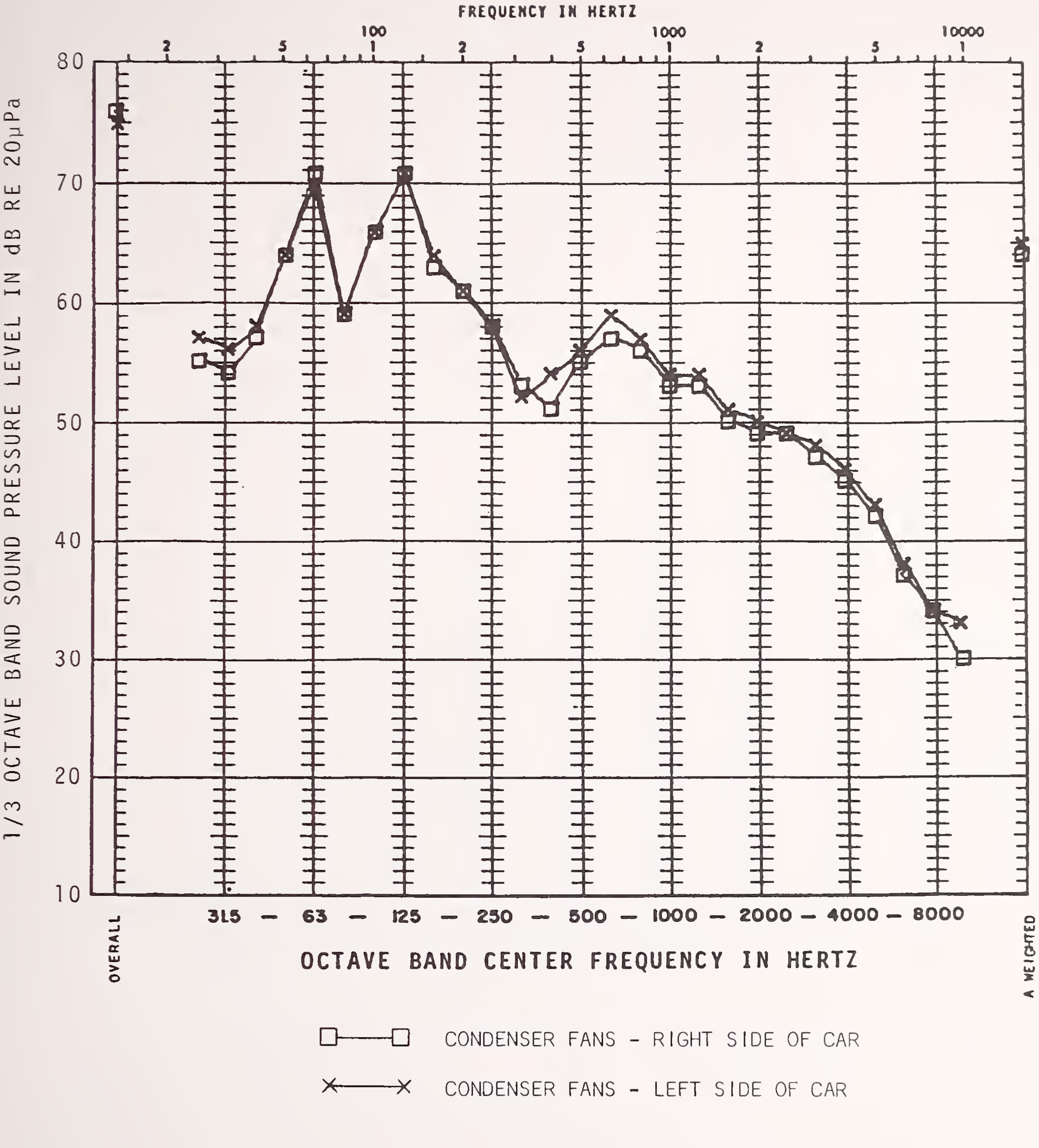


FIGURE 5.22b CONDENSER FANS AT 15 FT FROM CENTER OF COMPONENT

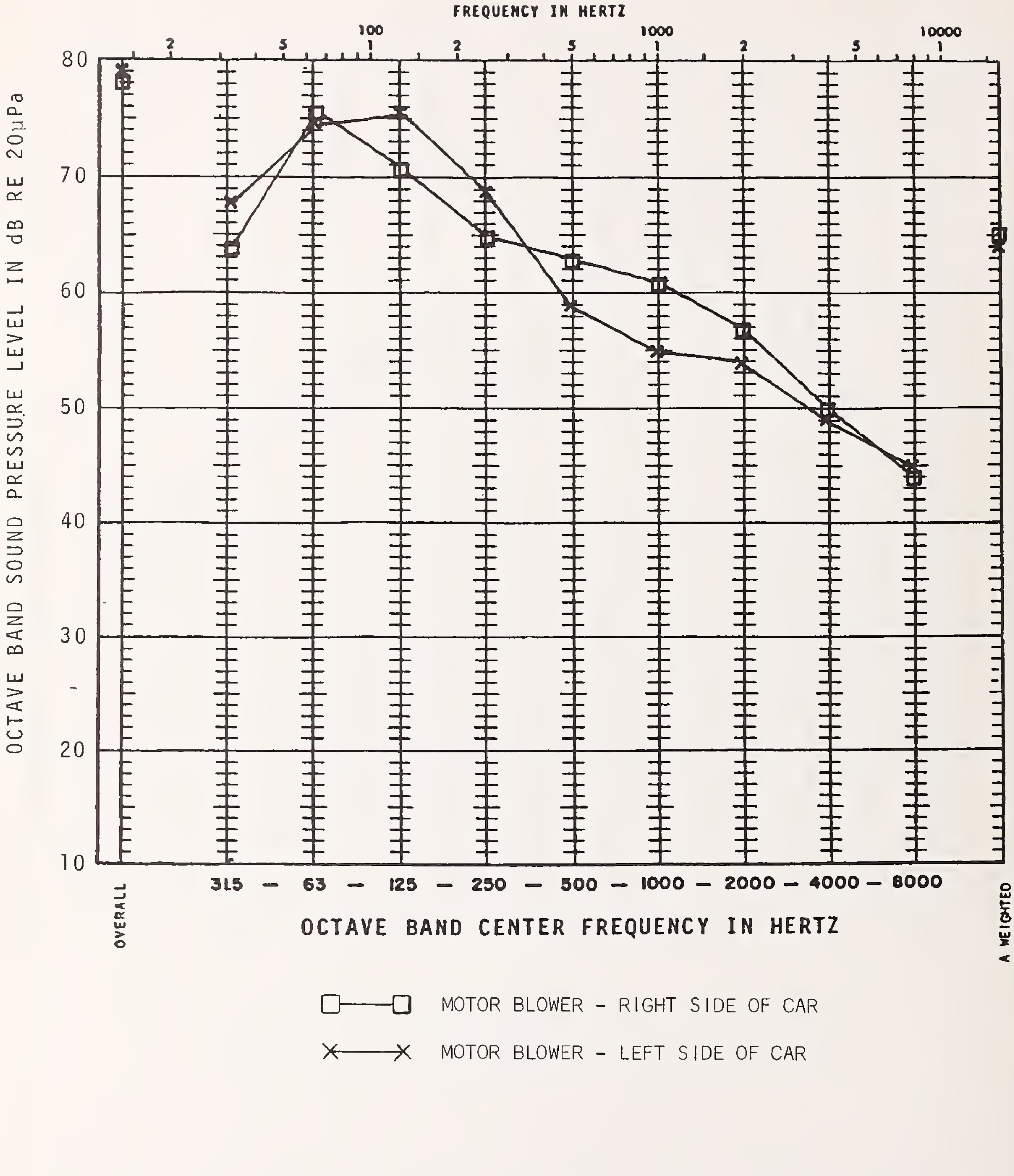


FIGURE 5.23a PROPULSION MOTOR BLOWER AT 15 FT FROM CENTER OF COMPONENT

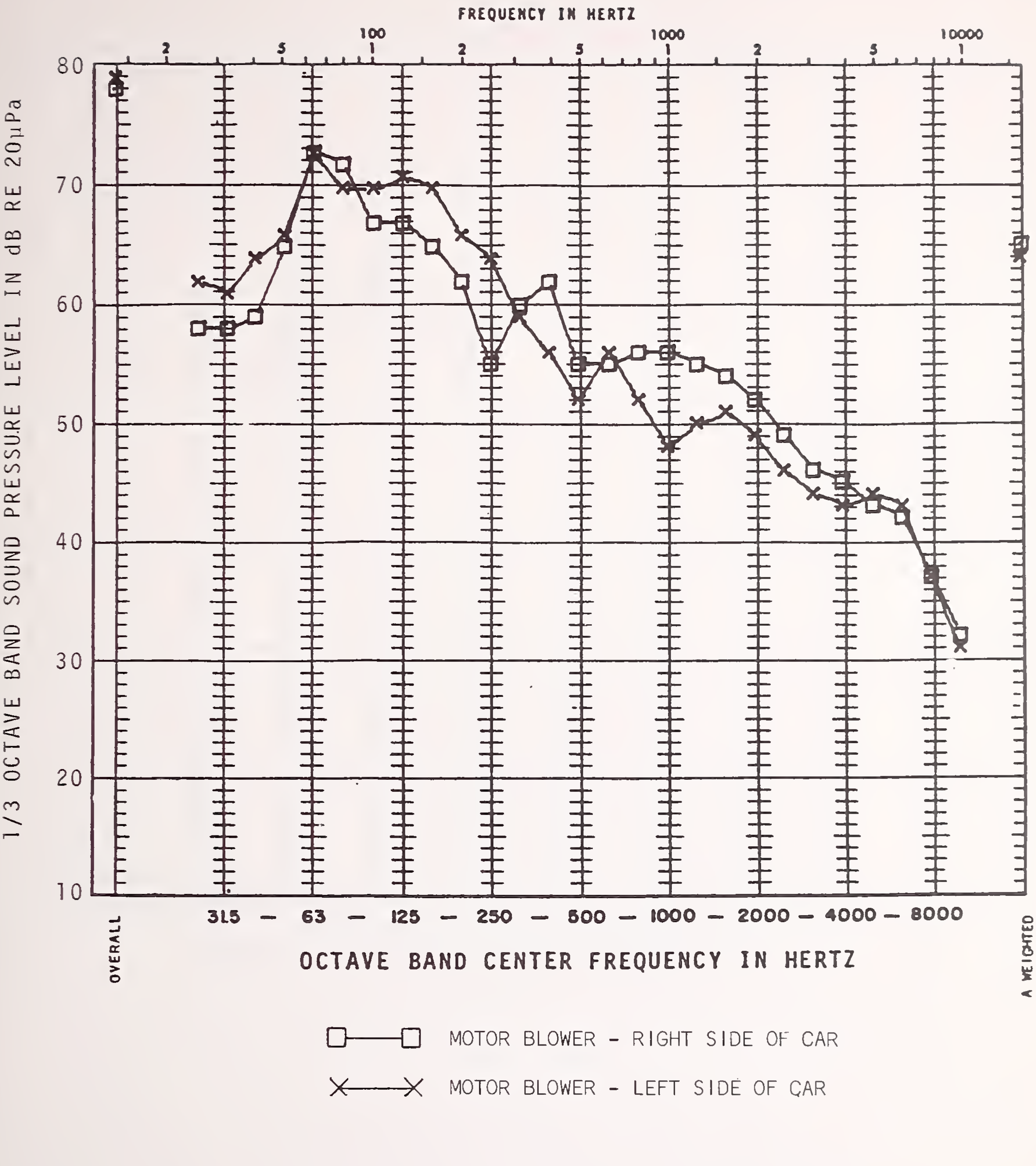


FIGURE 5.23b PROPULSION MOTOR BLOWER AT 15 FT FROM CENTER OF COMPONENT

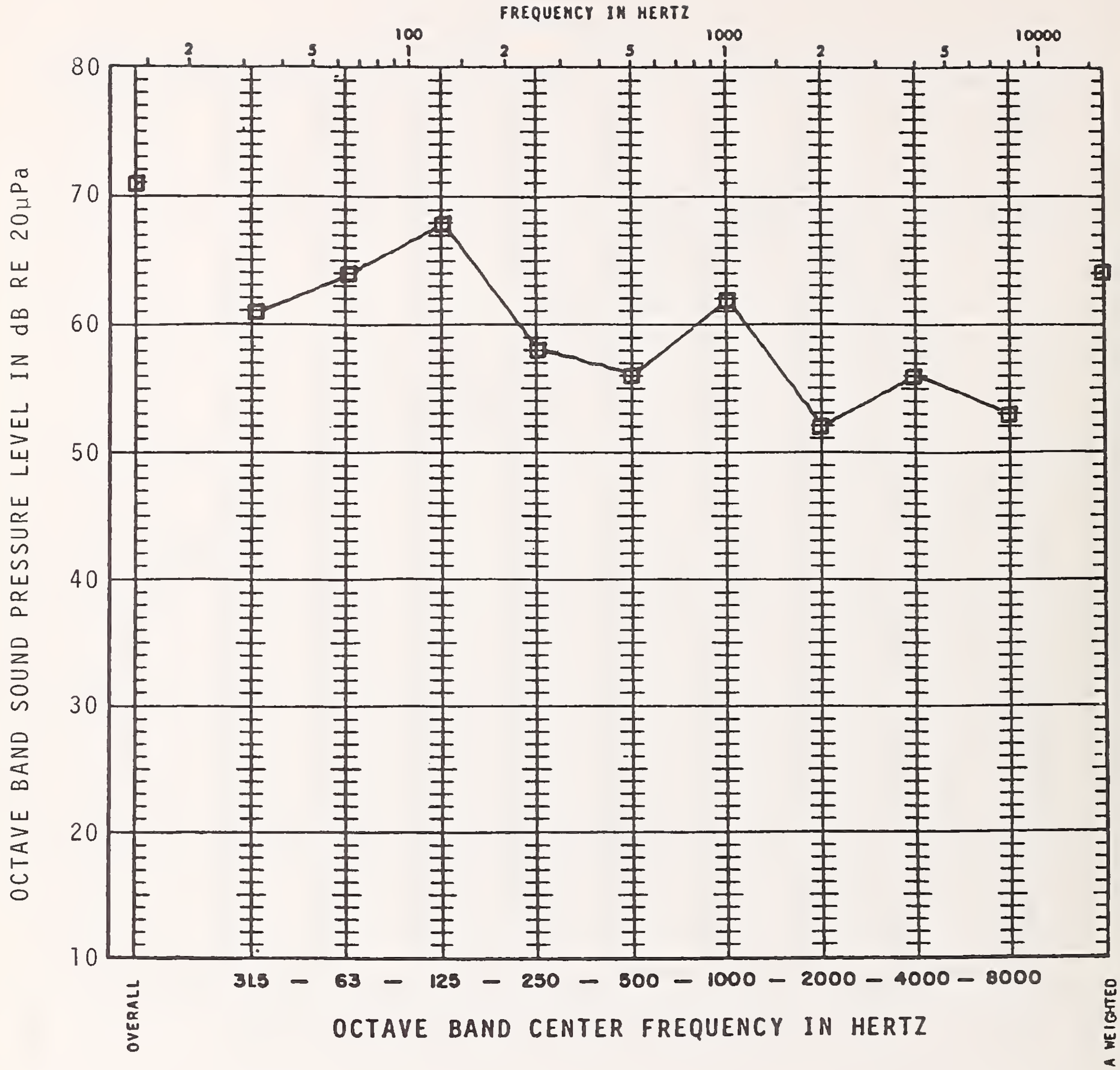


FIGURE 5.24a MOTOR ALTERNATOR UNIT AT 15 FT FROM CENTER OF COMPONENT

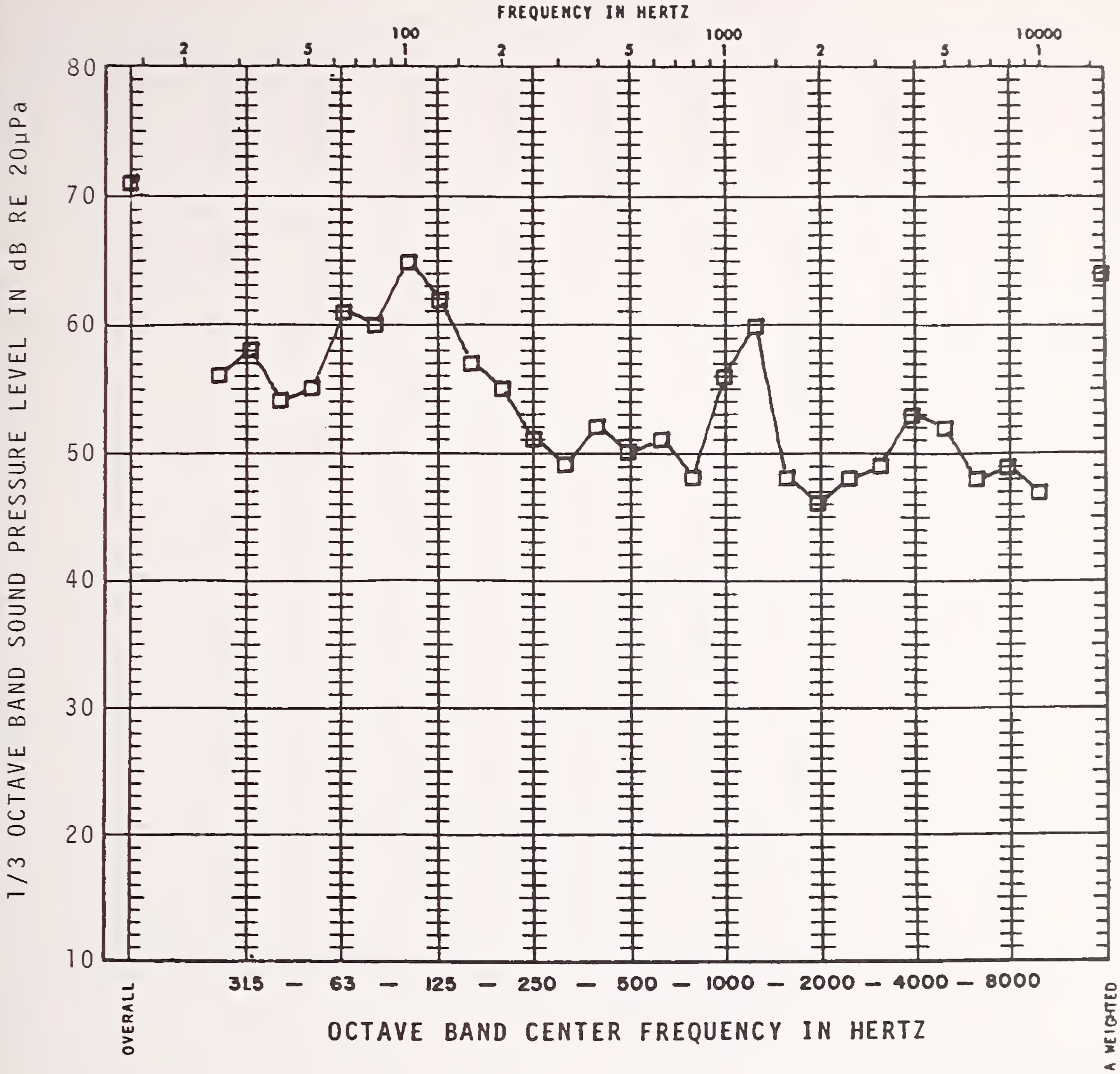


FIGURE 5.24b MOTOR ALTERNATOR UNIT AT 15 FT FROM CENTER OF COMPONENT

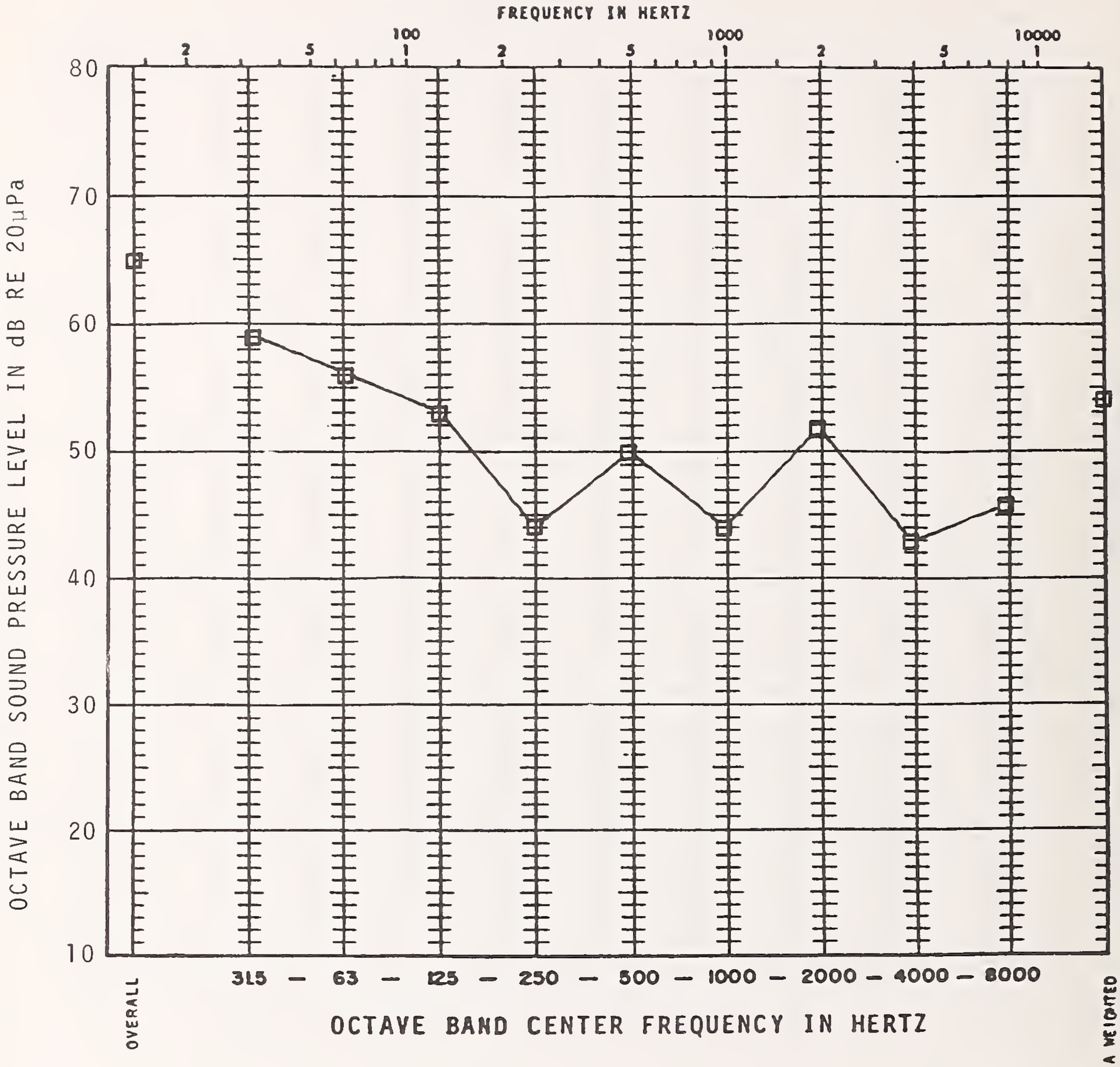


FIGURE 5.25a HYDRAULIC PUMP AT 15 FT FROM CENTER OF COMPONENT

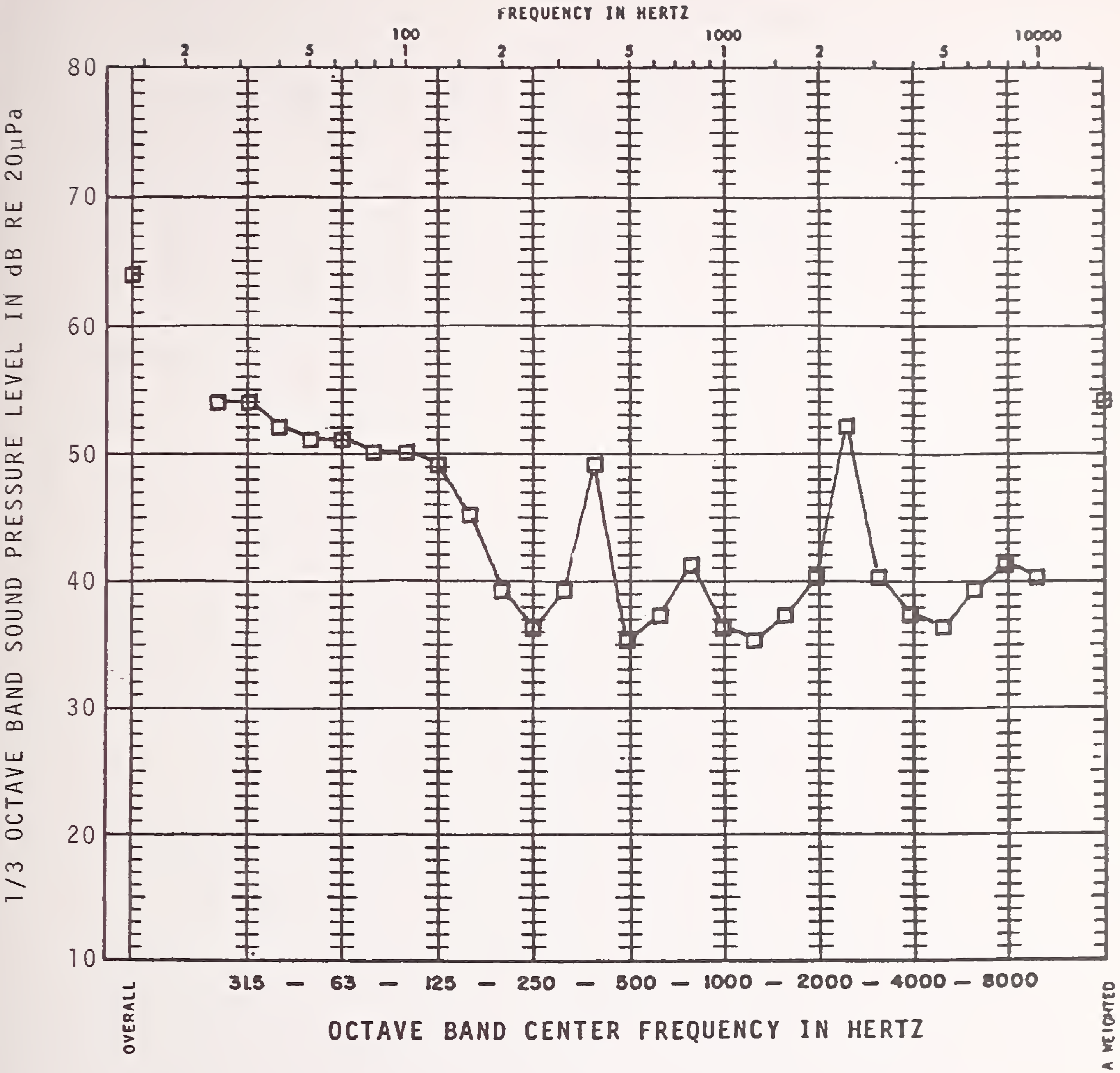


FIGURE 5.25b HYDRAULIC PUMP AT 15 FT FROM CENTER OF COMPONENT

5.2.3 Station Platform Measurements - Discussion and Summary

In this section, results and trends of the BART station measurements will be discussed. The specific results for each station together with descriptions of the measurement positions are contained in Section 5.2.4.

To assess the noise environment to which the transit system patrons are exposed while waiting on the platform, station platform noise measurements were taken at 12 stations along the Daly City-Concord Line and Richmond-Fremont Line of the BART system. These stations were chosen to represent the typical station environments and the different station configurations along the BART system. Figure 5.1 is a general map of the BART system that shows the locations of all the stations. Table 5.18 summarizes the station structure, platform and community type for each of the stations.

Six aerial stations, three at-grade stations and three subway stations were chosen for the station noise measurements. Of the six aerial stations, three are center platform and three are side platform. They are located in a freeway median, commercial area, residential area and a mixed residential/commercial area. One center-platform station and two side platform stations were chosen in the at-grade station group. In the subway station group, Lake Merritt Station and Civic Center Station are center platform with two tracks on the same level, 19th Street Station is side platform with a single track on each of two platform levels.

At the Rockridge Station, an aerial station located in a freeway median, two measurements were made to obtain noise data during off-peak hours and during the afternoon rush hour. In the 19th Street Station, two measurements were also made, one on the upper level platform and one on the lower level platform. At other stations, a single measurement was made. These noise measurements were generally made between 10:00 a.m. and 3:00 p.m. in order to avoid the congestion in the station during the measurements. At each station, one 30-minute noise sample was taken at two microphone positions on the platform. The microphone were located 1.6 m above the platform level and displaced a distance of 2 m or one-half the platform width (whichever was smaller) away from the platform edge. One microphone was even with the middle of a stopped train, and one was even with one of the ends. Each microphone was oriented vertically and had a windscreen attached.

Data obtained by the authors in connection with work for the Toronto Transit Commission is included here to permit comparisons of treated and untreated stations.

TABLE 5.18 STATION NOISE MEASUREMENT SUMMARY

Name of Station	Station Structure	Platform Type	Community Type
Rockridge	Aerial	Center	Freeway Median
Coliseum	Aerial	Center	Commercial Area
Bay Fair	Aerial	Center	Residential/Commercial Area
Walnut Creek	Aerial	Side	Commercial Area
El Cerrito Del Norte	Aerial	Side	Residential/Commercial Area
Pleasant Hill	Aerial	Side	Residential Area
Richmond	At-grade	Center	Residential/Commercial Area
Union City	At-grade	Side	Industrial/Commercial Area
South Hayward	At-grade	Side	Residential Area
Lake Merritt	Subway	Center	Commercial Area
19th Street	Subway	Side (single track multi-level)	Commercial Area
Civic Center	Subway	Center	Commercial Area

To determine the employee noise exposure at stations, noise samples were recorded inside the "station agent's" booth or information booth located at the aerial Walnut Creek and Rockridge Stations, and at the subway Lake Merritt and 19th Street Stations. A noise sample was also recorded inside the "dispatcher's" booth located on the platform of the at-grade Richmond Station.

A summary of the results of the measurement series are tabulated in Table 5.19 and 5.20. The methodology and equipment used to collect and reduce the noise data are described in Section 4.

Some of the general factors to be noted about the results summarized in Tables 5.19 and 5.20 are:

(1) The average maximum noise levels of train arrivals and departures at the aerial and subway stations are generally higher than the levels observed at the at-grade stations.

(2) For the above ground stations, L_{EQ} at the center of platform is, in general, slightly higher than L_{EQ} at the end of platform by about 1 or 2 dBA. For subway stations, the reverse holds.

(3) The platform configuration (i.e., center or side platform) does not significantly contribute to the average maximum noise levels observed on the platform.

(4) The Rockridge Station platform has the highest background noise due to its location in a freeway median.

(5) Noise levels of the train arrival, departure and idling are slightly higher on the lower platform of the 19th Street Station (narrow platform) than on the upper platform (wide platform).

(6) In the station agent's booths, L_{EQ} is highest at the two subway stations mainly because of the more frequent conversation between the agent and patrons.

The first observation indicates that the average maximum noise levels of train arrivals and departures at the aerial and subway stations are generally higher than the levels at

TABLE 5.19 SUMMARY OF AVERAGE MAXIMUM TRAIN NOISE LEVELS AND L_{EQ} FOR ALL STATIONS

Name of Station	Microphone Position†	Average Maximum Level - dBA: Train Arriving On Near Track	Train Arriving On Far Track	Train Departing On Near Track	Train Departing On Far Track	L_{EQ} - dBA
Rockridge (Off-peak hours)	1	80 *1.77	78 *0.00	82 *1.06	75 *0.00	78
	2a	77 2.47	74 0.00	77 0.00	75 0.00	76
Rockridge (Rush-hour)	1	85 0.00	81 1.77	86 0.00	87 1.44	79
	2a	77 0.00	78 0.70	86 0.00	77 0.58	77
Coliseum	1	80 0.76	78 2.00	85 1.14	78 3.48	74
	2b	87 0.45	79 4.60	72 1.06	78 5.12	74
Bay Fair	1	80 2.16	78 3.7	85 1.56	80 2.67	70
	2b	87 0.96	67 4.55	75 2.79	84 2.25	71
Walnut Creek	1	75 0.00	83 0.35	84 0.00	83 2.47	78
	2a	67 0.00	86 0.35	86 0.00	73 0.70	68
El Cerrito Del Norte	1	84 0.35	82 3.18	82 0.00	86 0.35	70
	2b	87 0.00	67 2.47	67 1.40	85 1.77	68

TABLE 5.19 (CONT.)

Name of Station	Microphone Position†	Average Maximum Level - dBA: Train Arriving On Near Track	Train Arriving On Far Track	Train Departing On Near Track	Train Departing On Far Track	L_{EQ} – dBA
Pleasant Hill	1	79 1.41	80 0.00	83 0.35	85 0.70	67
	2a	62 0.35	81 0.70	81 0.35	68 0.00	65
Richmond	1	75 0.70	71 0.70	80 1.41	80 0.58	62
	2b	76 1.06	- -	62 0.35	68 0.29	59
Union City	1	78 0.48	73 0.00	79 1.40	71 0.58	67
	2a	73 0.82	75 0.00	75 0.65	74 3.50	66
South Hayward	1	74 1.22	76 0.75	77 0.87	78 0.00	68
	2b	74 1.32	60 0.70	61 2.60	75 0.58	64
Lake Merritt	1	77 1.00	74 0.84	86 1.15	77 1.89	69
	2a	71 1.10	80 0.79	86 0.42	75 2.14	71
19th Street (Upper level)	1	83 0.75	67 2.80	85 1.30	65 1.40	70
	2a	74 1.07	- -	87 0.58	- -	70

TABLE 5.19 (CONT.)

Name of Station	Microphone Position†	Average Maximum Level - dBA: Train Arriving On Near Track	Train Arriving On Far Track	Train Departing On Near Track	Train Departing On Far Track	L_{EQ} - dBA
19th Street (Lower level)	1	84 1.52	68 0.30	87 0.68	72 0.48	72
	2a	77 1.20	- -	89 1.11	- -	73
Civic Center	1	81 1.40	74 0.74	82 2.77	80 1.02	69
	2a	74 1.27	81 0.70	90 2.70	77 1.67	72

* standard deviation of levels

† 1 - center of platform
2a - leading end of platform
2b - trailing end of platform

TABLE 5.20 SUMMARY OF NOISE MEASUREMENTS INSIDE STATION AGENT'S BOOTH

Station	Booth Location	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Rockridge	Concourse Level (Below Track Level)	50	51	60	64	72	62
Walnut Creek	Street Level (Below Track Level)	59	60	62	66	74	64
Richmond	Track Level	49	50	52	63	73	61
Lăke Merritt	Concourse Level (Above Track Level)	57	58	61	71	79	68
19th Street	Concourse Level (Above Track Level)	56	57	59	68	77	66

the at-grade stations. For the aerial and subway stations the average maximum train noise levels ranged from 75 to 87 dBA. For the at-grade stations, the maximum train noise levels ranged from 74 to 80 dBA. This indicates that the ballast in the trackbed of the at-grade stations is an effective sound absorber and contributes to the reduction of the station platform noise.

The second observation shows that for the surface stations L_{EQ} at the center of platform is greater than L_{EQ} observed at the end of the platform. This phenomenon is reversed for the subway stations, with a higher L_{EQ} at the end of the platform. This observation is reasonable, for at the surface stations, there are more reflective surfaces near the center of platform area, creating a somewhat more reverberant space. In the subway stations, the area near the end of the station platform seems more reverberant because of the reverberant train noise transmitted from the adjacent subway tunnel.

The third observation indicates that the platform configuration does not contribute to a significant variation in the average maximum train noise levels on the platform. This result is expected because there are a number of more prominent factors influencing the train noise levels experienced by a patron on the platform, such as the condition of the wheel and rail surface and the patron's relative position on the platform.

The fourth observation indicates that the Rockridge Station platform has the highest background noise due to freeway traffic which travels on both sides of the Station. The afternoon rush hour traffic raises the background noise from an average L_{99} of 66 dBA to 73 dBA while the peak traffic noise remains relatively constant at 82 to 85 dBA.

The fifth observation indicates that the train noise levels on the lower narrow platform of the 19th Street Station were slightly higher than that on the upper wide platform. This is probably due both to the narrower platform and fewer number of access openings in the ceiling (stairs, escalators) on the lower level creating a more reverberant space.

The sixth observation shows that in the information booths, L_{EQ} is highest at the booths of the two subway stations. The principal noise sources at these two booths are the conversation between the agent and patrons, and the announcements from the Public Address system. The noise due to train arrivals and departures is audible at each of the information booths and contributes to the noise exposure of the agent.

5.2.4 Station Description and Data for Station Noise Survey

This section provides station descriptions and data on the noise survey results for each of the station platform and "information booth" measurement locations. The following data are provided for each station platform site:

(1) Sketch of station platform configuration showing location of both microphones and BART tracks.

(2) Photograph of station platform showing both microphones and a BART train or tracks.

(3) Statistical distribution curves for the two 30 minute samples at each station platform (one sample at each microphone location).

(4) A sample strip chart trace showing noise levels of arriving and departing trains on the near and far tracks at the center of platform microphone position.

(5) A summary table of the statistical measures of each noise sample (L_1, L_{10}, L_{50}, L_{90}, L_{99}, and L_{EQ}) along with the average maximum levels of the BART train arrivals and departures on the near and far tracks. Also given in the table is a summary of the number of train arrivals and departures during the measurement period.

(6) A short description of the important features of the station site.

(7) A description of the noise climate identifying the major sources of noise on each station platform.

ROCKRIDGE STATION - Aerial Station in Oakland, Center Platform, Two Track

DESCRIPTION (See Figures 5.26a and 5.27a)

Rockridge Station is an aerial station on the Concord Line. It is located in the median of California State Highway #24. There is no visual or acoustical shielding between the Station platform and the freeway. A parking lot is located on the street level under the platform, tracks, and freeway. Two sets of noise measurements were made on the platform. The first measurement was recorded during an off-peak hour and the microphones were placed at the center and leading end of the platform on the side of the Daly City or inbound trains. The second measurement was recorded during the afternoon rush hour and the microphones were placed at the center and trailing end of the platform on the side of the Concord trains.

NOISE CLIMATE (See Table 5.21, 5.22; Figures 5.26b-c, 5.27b-c)

The residual noise level on the platform is about 66 dBA during the off-peak hour and rises substantially to above 70 dBA during the afternoon commute hour. The passbys of vehicles on the freeway produced typical peak levels of at least 85 dBA measured at the platform while the maximum noise level produced by trains arriving and departing is 80 to 82 dBA during the off-peak hour when 5-car trains are operating. During the afternoon commute hour when 9-car trains are operating, the maximum noise level of train arrivals and departures is 85 to 87 dBA and the peak levels produced from vehicles on the freeway are still 85 dBA or higher. The general increase in traffic during the commute hours raises the residual background noise substantially from about 66 to 70 dBA, while the peak levels from nearby vehicular passbys remain constant. The L_{EQ} levels are measured to be 76 to 78 dBA during the off-peak hour and 77 to 79 dBA during the commute hour. Passengers standing on the platform are, therefore, at any hour, subjected to a high level of noise exposure due to the traffic noise from the freeway.

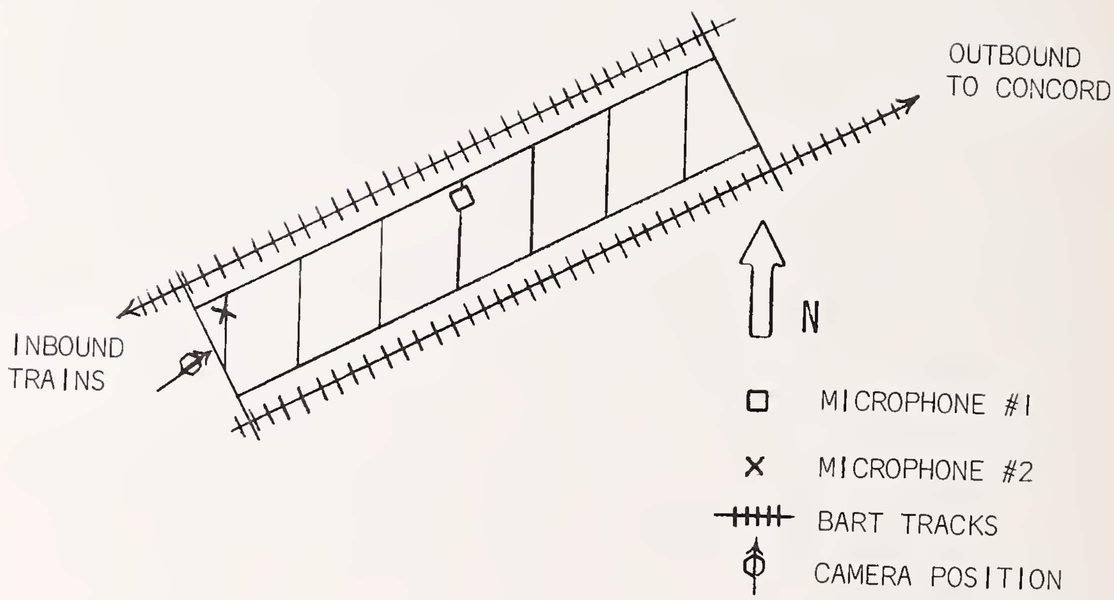


FIGURE 5.26a ROCKRIDGE AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS FOR DAYTIME NOISE SAMPLE.

TABLE 5.21 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT ROCKRIDGE STATION PLATFORM DURING OFF-PEAK HOURS

NAME OF STATION: Rockridge Station

Station Type: Aerial ; Platform Type: Center ; Location: Freeway Median

Date: 11/20/74 ; Starting Time: 11:15 a.m. ; Temp.: 60 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	80 *1.77	78 *0.00	82 *1.06	75 *0.00	66	72	77	81	85	78
Two 5-car	One 5-car	Leading End of Platform	77 2.47	74 0.00	77 0.00	75 0.00	65	70	75	78	83	76

*Standard Deviation of level

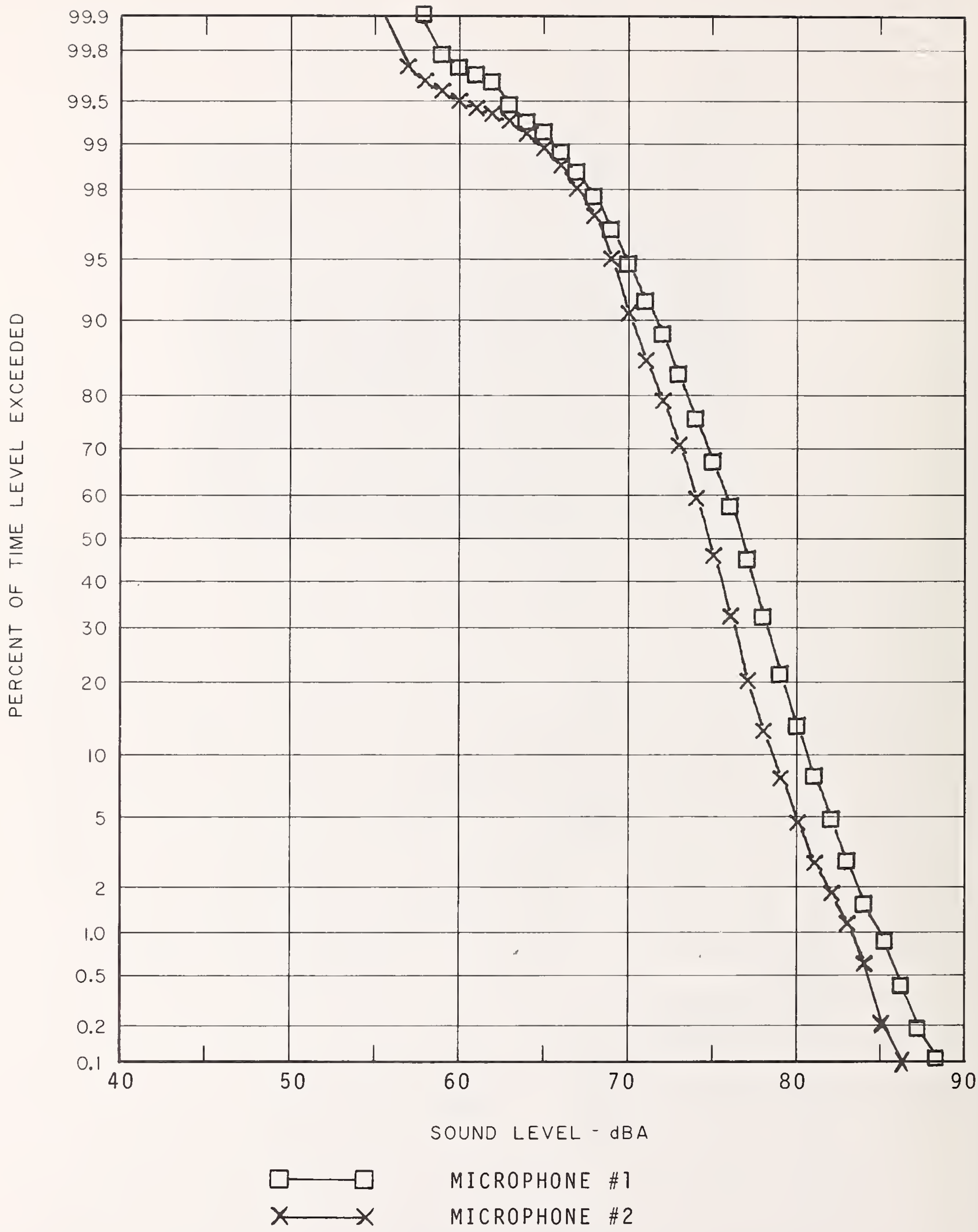


FIGURE 5.26b STATISTICAL DISTRIBUTIONS FOR ROCKRIDGE AERIAL STATION PLATFORM FOR DAYTIME NOISE SAMPLE.

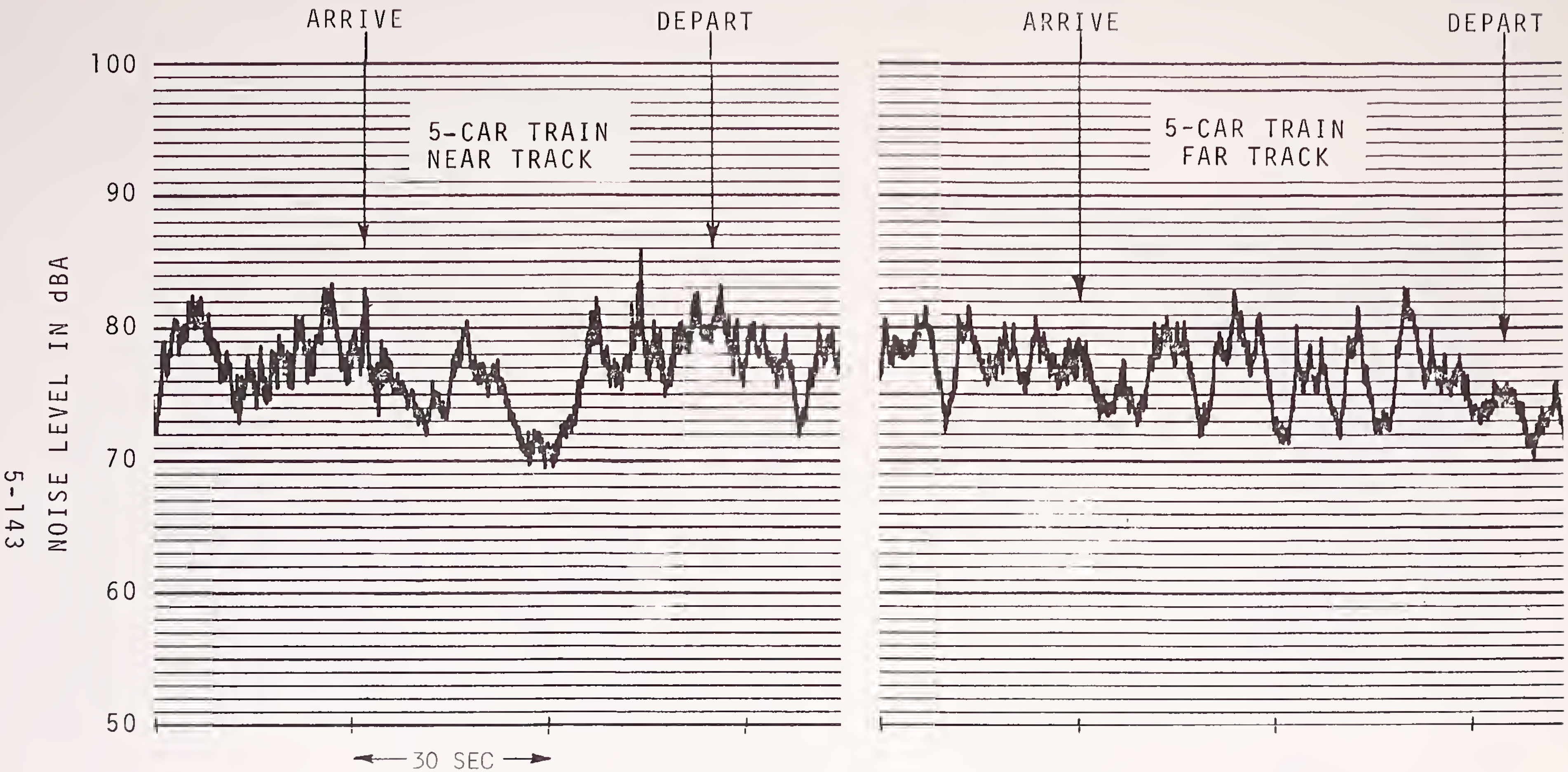


FIGURE 5.26c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT ROCKRIDGE STATION PLATFORM DURING OFF-PEAK HOUR.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

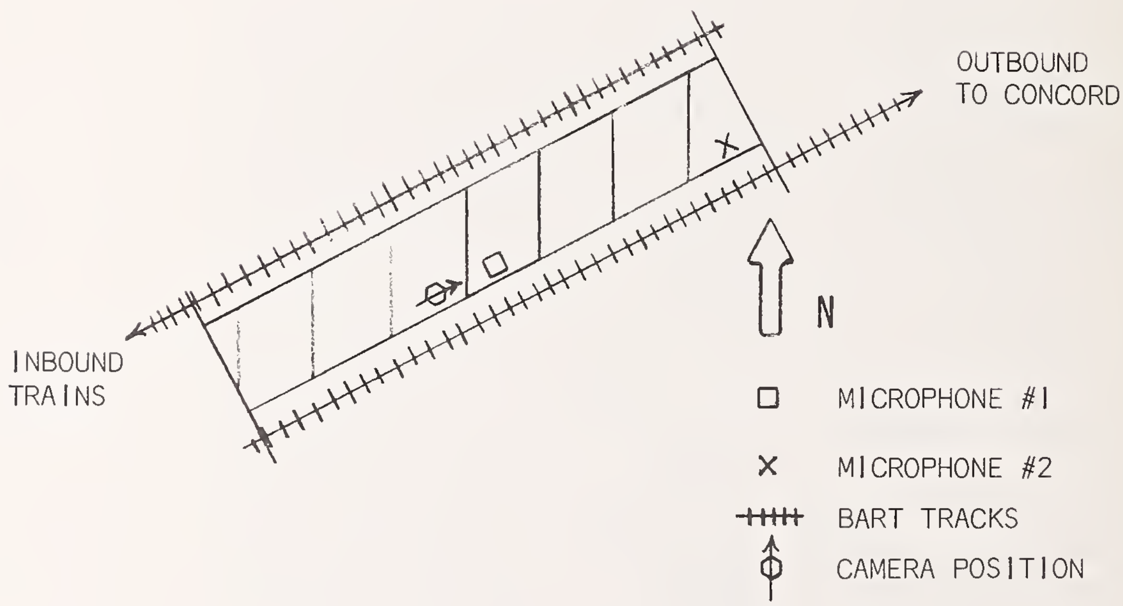


FIGURE 5.27a ROCKRIDGE AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS FOR RUSH HOUR NOISE SAMPLE.

TABLE 5.22 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT ROCKRIDGE STATION PLATFORM DURING AFTERNOON RUSH HOUR

NAME OF STATION: Rockridge Station

Station Type: Aerial ; Platform Type: Center ; Location: Freeway Median

Date: 11/20/74 ; Starting Time: 5:00 p.m. ; Temp.: 60 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	85 *0.00	81 *1.77	86 *0.00	87 *1.44	75	77	79	81	85	79
One 10-car	Two 9-car One 8-car	Leading End of Platform	77 0.00	78 0.70	86 0.00	77 0.58	71	74	76	78	82	77

*Standard Deviation of level

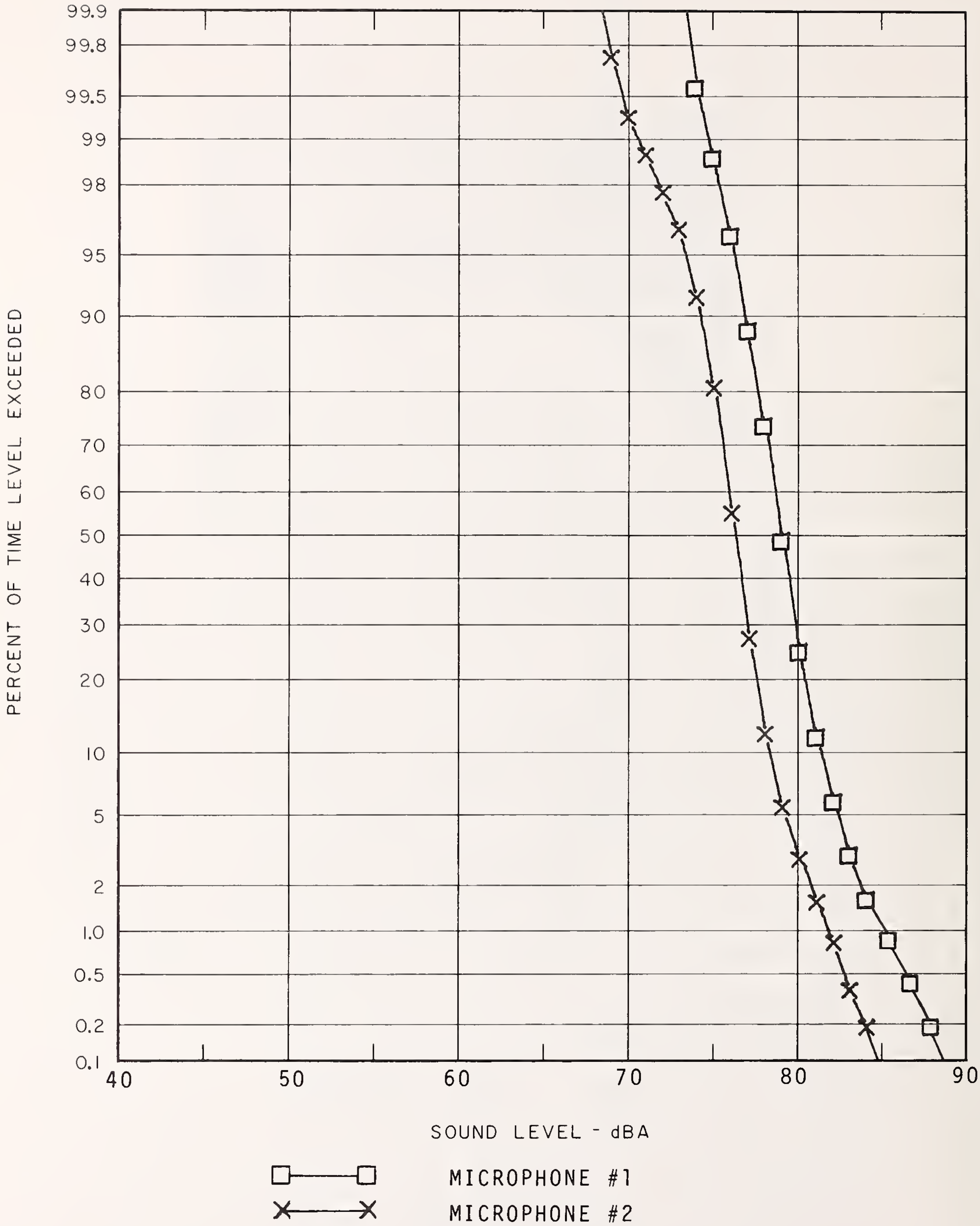


FIGURE 5.27b STATISTICAL DISTRIBUTIONS FOR ROCKRIDGE AERIAL STATION PLATFORM FOR RUSH HOUR NOISE SAMPLE.

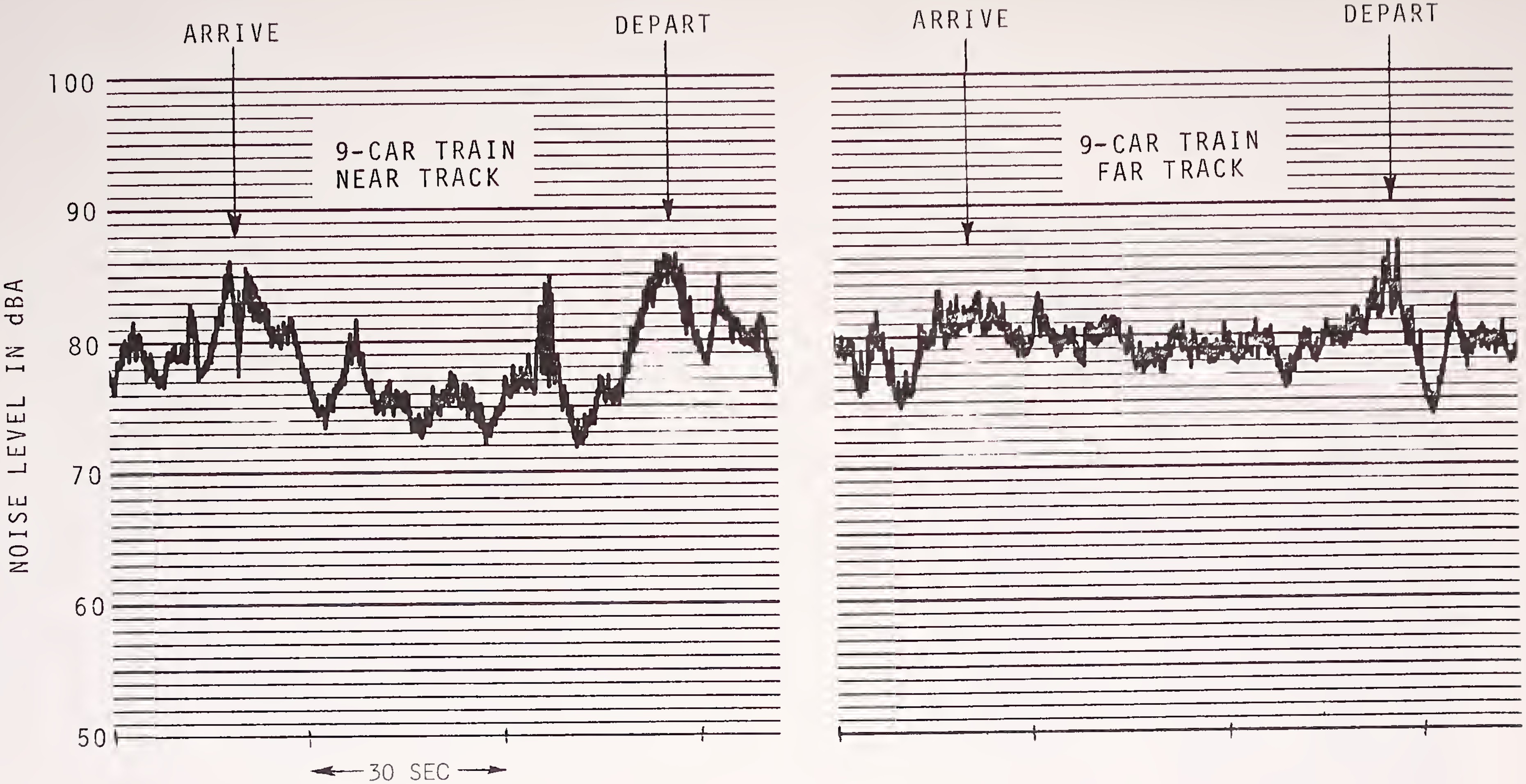


FIGURE 5.27c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT ROCKRIDGE STATION PLATFORM DURING AFTERNOON RUSH HOUR.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

COLISEUM STATION - Aerial Station in Oakland, Center Platform, Two Track

DESCRIPTION (See Figure 5.28a)

Coliseum Station is an aerial station on the Fremont Line. It is located in a commercial area with a major arterial, San Leandro Street, running parallel to the Station. A parking lot is located on the street level northeast of the Station. Two microphones were set up on the Fremont train side of the platform: one at the middle and one at the trailing end of the stopped train. The measurement was made during the off-peak hour to avoid congestion on the platform.

NOISE CLIMATE (See Table 5.23, Figures 5.28b-c)

The residual noise level is about 62 dBA on the platform. Patrons are also exposed to traffic noise from the nearby roadways as well as the noise from the transit trains. The measurements indicate that the noise levels of train arrivals and departures on the near track are significantly higher than that on the far track. The values of L_{EQ} were measured to be 74 dBA at both microphone positions.

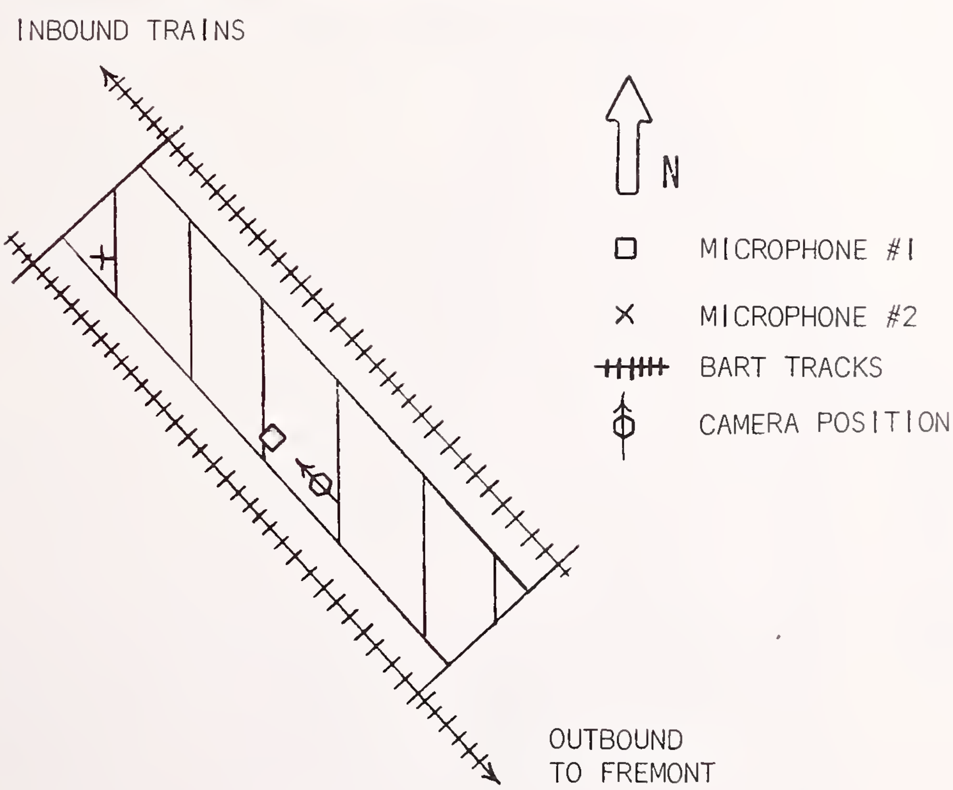


FIGURE 5.28a COLISEUM AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.23 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT COLISEUM STATION PLATFORM

NAME OF STATION: Coliseum Station

Station Type: Aerial ; Platform Type: Center ; Location: Commercial Area

Date: 11/24/74 ; Starting Time: 12:35 p.m. ; Temp.: 63 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Arrive Five 5-car	Arrive Four 5-car One 6-car	Center of Platform	80 *0.76	78 *2.00	85 *1.14	78 *3.48	62	65	70	77	84	74
Depart Five 5-car	Depart Four 5-car	Trailing End of Platform	87 0.45	79 4.60	72 1.06	78 5.12	62	64	68	76	85	74

*Standard Deviation of level

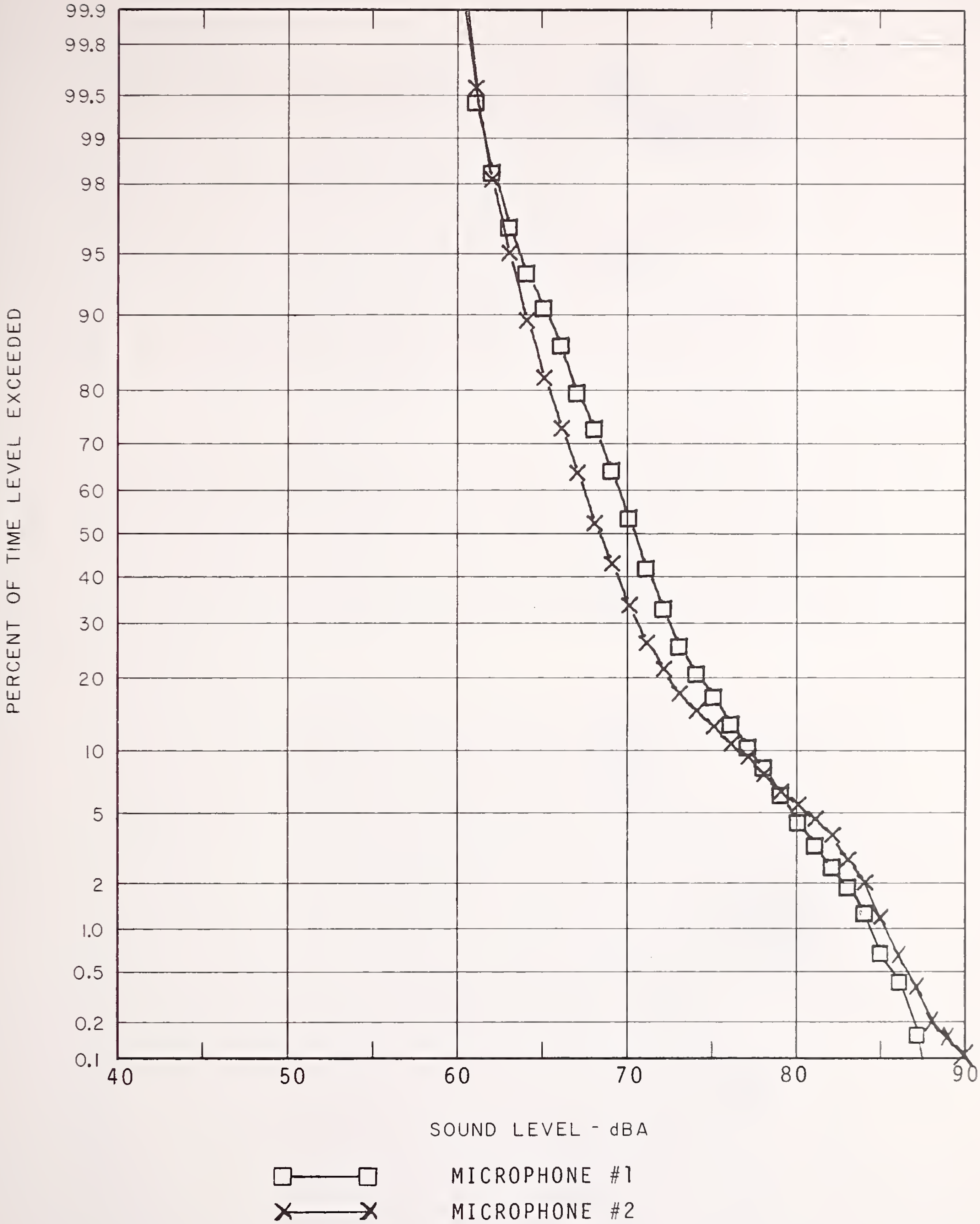


FIGURE 5.28b STATISTICAL DISTRIBUTIONS FOR COLISEUM AERIAL STATION PLATFORM.

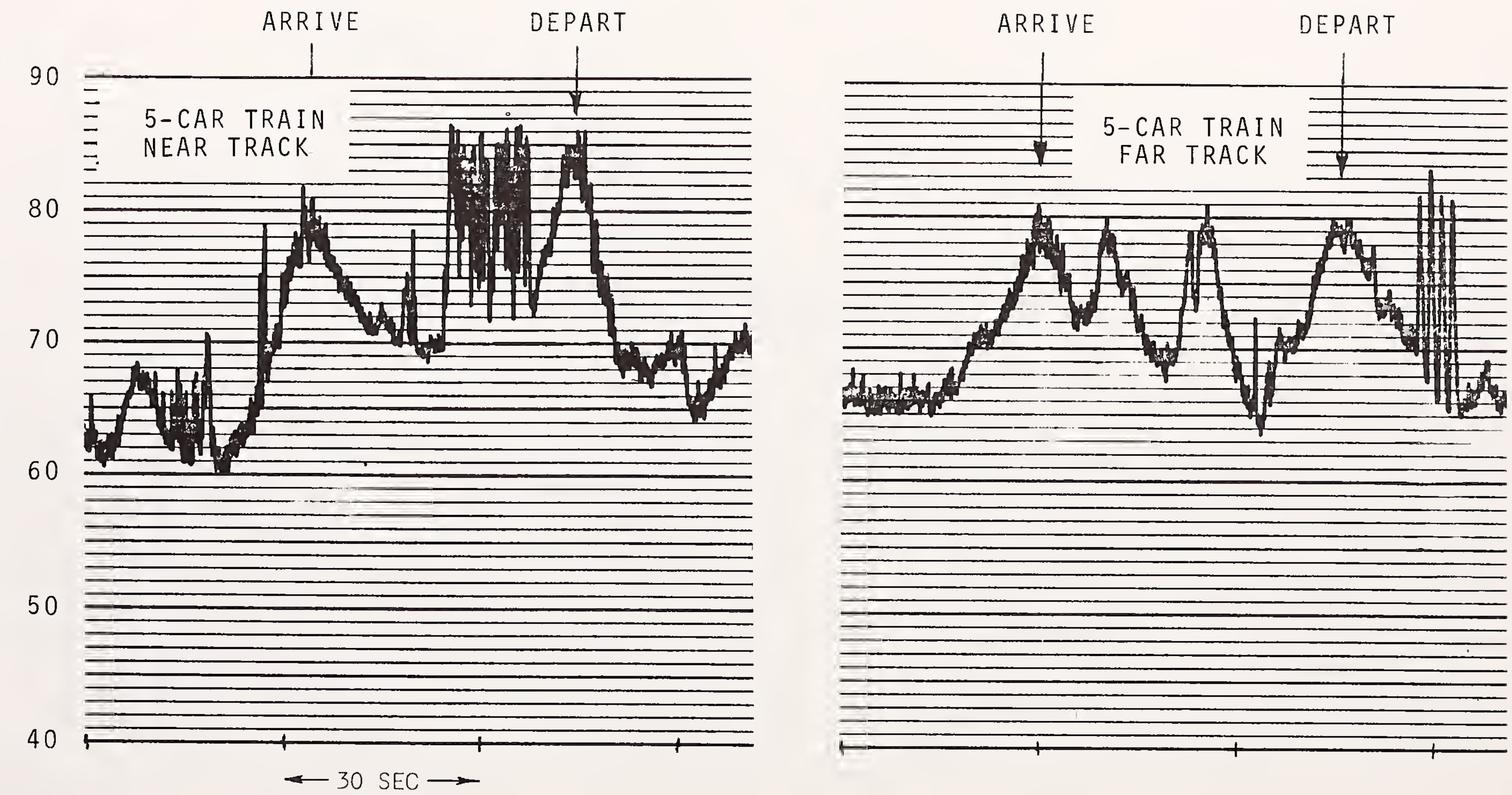


FIGURE 5.28c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT COLISEUM STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

BAY FAIR STATION - Aerial Station in San Leandro, Center Platform, Two Track

DESCRIPTION (See Figure 5.29a)

Bay Fair Station is an aerial station on the Fremont Line. It is located in a semi-residential/commercial area. The residential area is southwest of the Station and a shopping center is located northeast of the Station. Both the residential area and shopping center are separated from the Station by parking lots. Two microphones were set up on the Fremont train side of the platform: one at the middle and one at the trailing end of the stopped train.

NOISE CLIMATE (See Table 5.24, Figures 5.29b-c)

The residual noise levels range from 52 dBA at the end of platform to 54 dBA at the center of platform. There are no other nearby local noise sources that acoustically impact the patrons on the platform. The noise samples at both microphone positions on the platform are quite similar. The values of L_{EQ} were measured to be 70 and 71 dBA at the two positions.

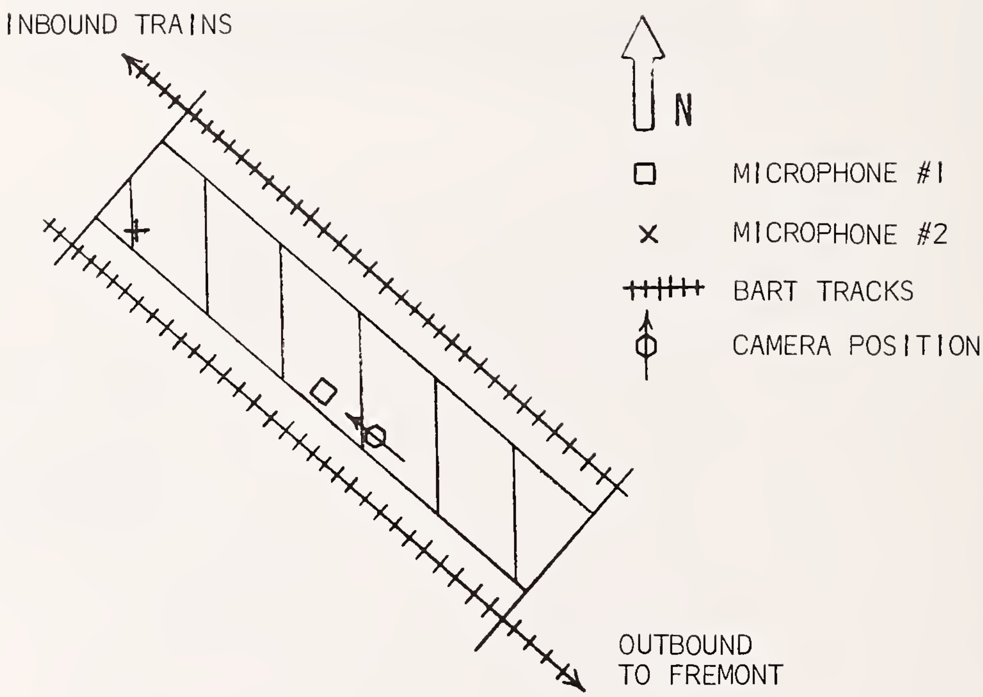


FIGURE 5.29a BAY FAIR AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.24 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT BAY FAIR STATION PLATFORM

NAME OF STATION: Bay Fair Station

Station Type: Aerial ; Platform Type: Center ; Location: Residen/Comm Area

Date: 11/22/74 ; Starting Time: 1:34 p.m. ; Temp.: 65 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive Five 5-car	Arrive Five 5-car	Center of Platform	80 *2.16	78 *3.17	85 *1.56	80 *2.67	54	56	58	74	85	70
Depart Five 5-car	Depart Five 5-car	Trailing End of Platform	87 0.96	67 4.55	75 2.79	84 2.25	52	54	56	71	85	71

*Standard Deviation in level

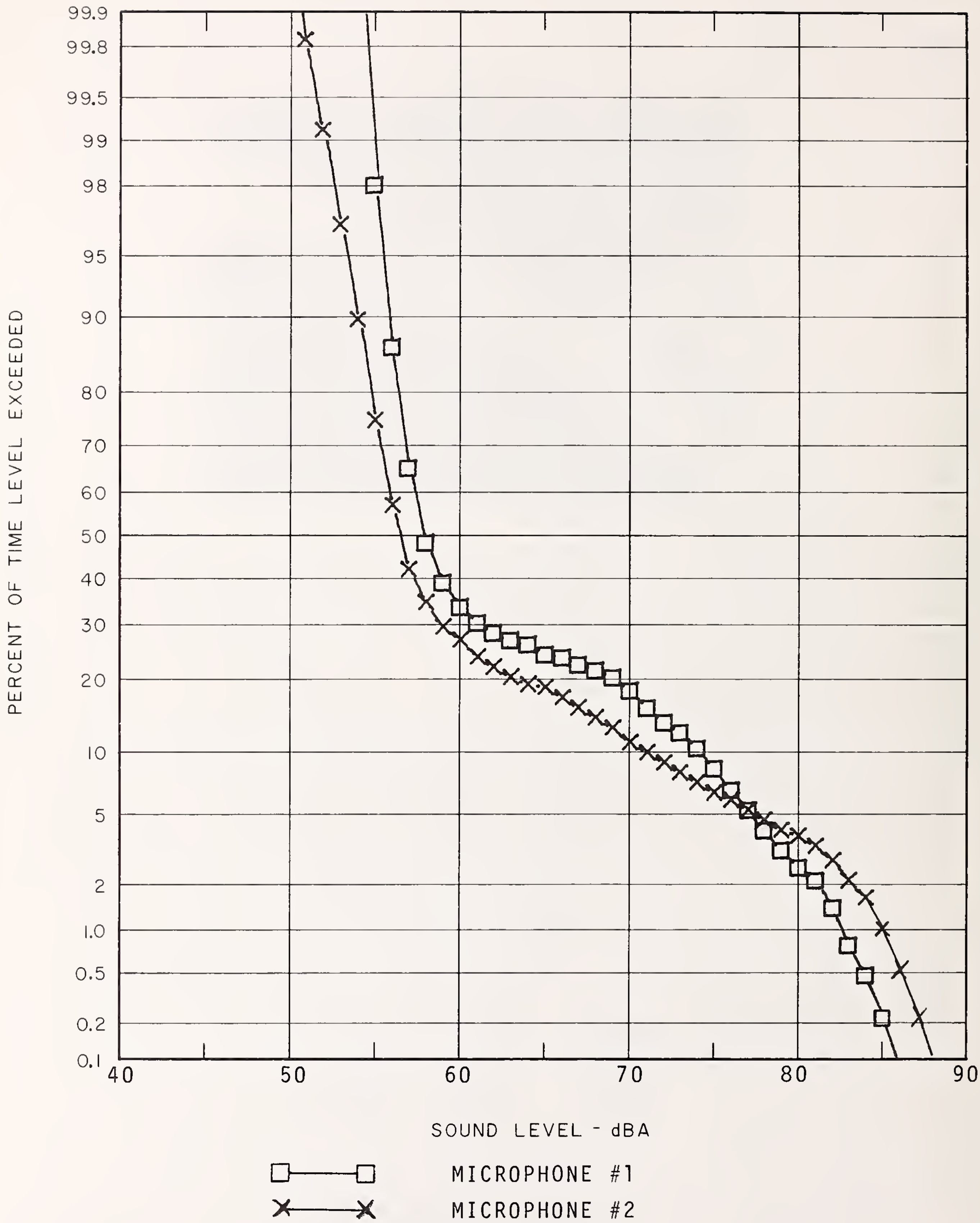


FIGURE 5.29b STATISTICAL DISTRIBUTIONS FOR BAY FAIR AERIAL STATION PLATFORM.

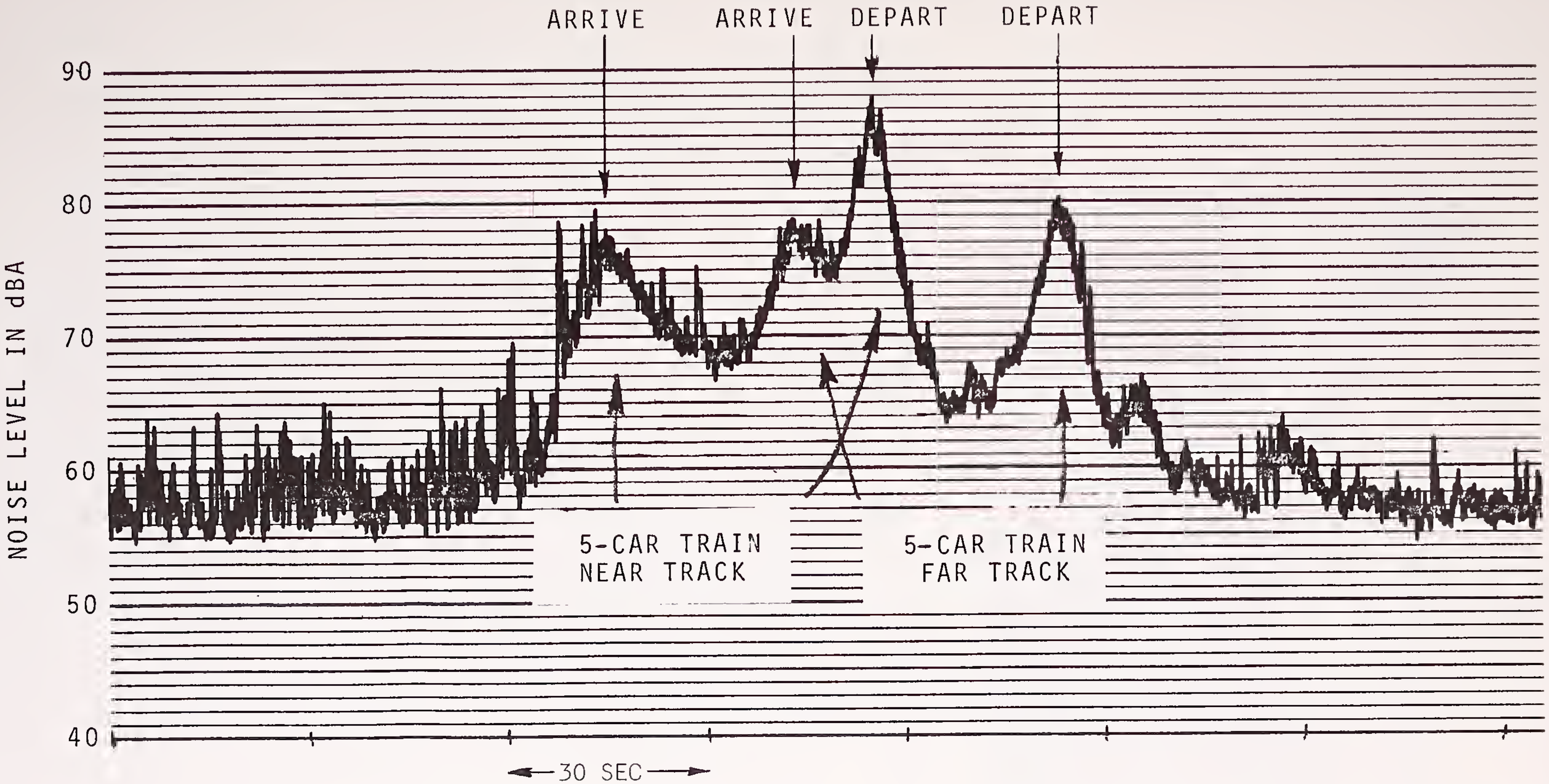


FIGURE 5.29c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT BAY FAIR STATION PLATFORM

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

WALNUT CREEK STATION - Aerial Station in Walnut Creek, Side Platform, Two Track

DESCRIPTION (See Figure 5.30a)

Walnut Creek Station is an aerial station on the Concord Line. South of the Station is a commercial area separated from the Station by a parking lot. North of the Station is the Interstate #680 freeway which is also separated from the Station by a parking lot. Two microphone positions were set up on the Concord train side of the platform: one at the middle and one at the leading end of the stopped train.

NOISE CLIMATE (See Table 5.25, Figures 5.30b-c)

The residual noise levels range from 55 dBA at the center of platform to 58 dBA at the end of platform. The higher residual level at the end of the platform is likely to be caused by the vehicles on the adjacent roadway with some influence from the freeway. The center of platform is acoustically shielded from both the adjacent roadway and the freeway. Table 5.25 indicates that L_{EQ} at the platform center position is 10 dBA higher than L_{EQ} at the end of the platform. Review of the noise traces indicates that it was caused by announcements from the Station PA system.

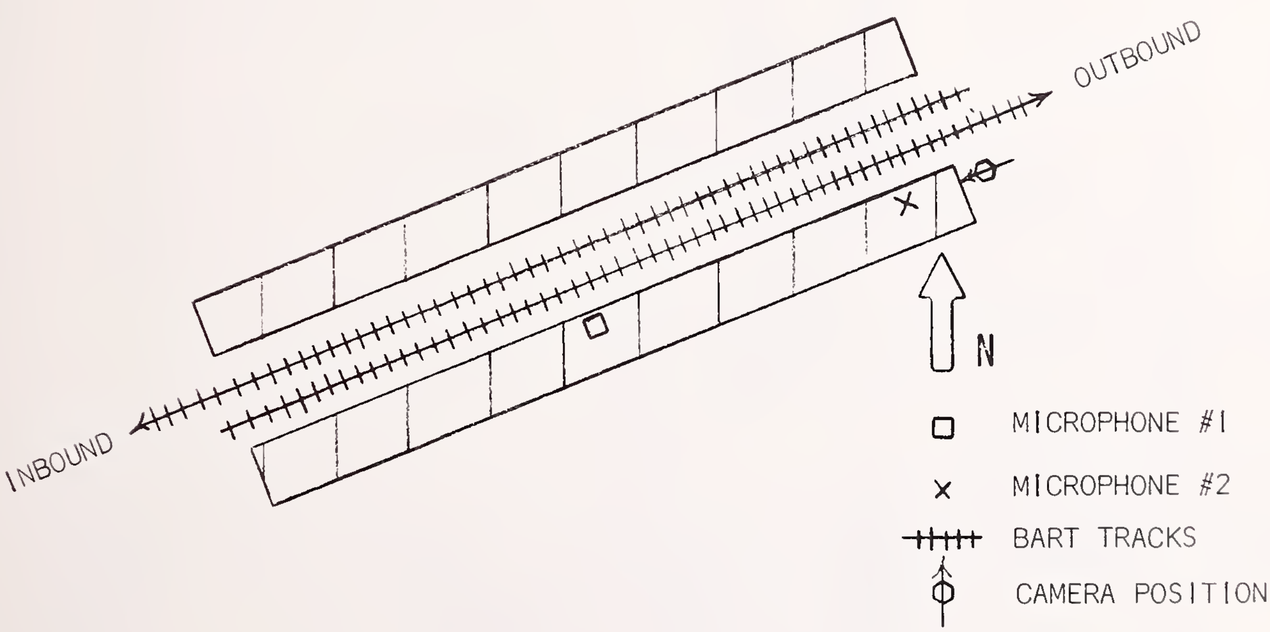


FIGURE 5.30a WALNUT CREEK AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.25 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT WALNUT CREEK STATION PLATFORM

NAME OF STATION: Walnut Creek Station

Station Type: Aerial ; Platform Type: Side ; Location: Commercial Area

Date: 11/20/74 ; Starting Time: 12:35 p.m. ; Temp.: 60 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	75 *0.00	83 *0.35	84 *0.00	83 *2.47	55	58	62	69	93	78
One 5-car	Two 9-car	Leading End of Platform	67 0.00	86 0.35	86 0.00	73 0.70	58	59	62	67	82	68

*Standard Deviation of level

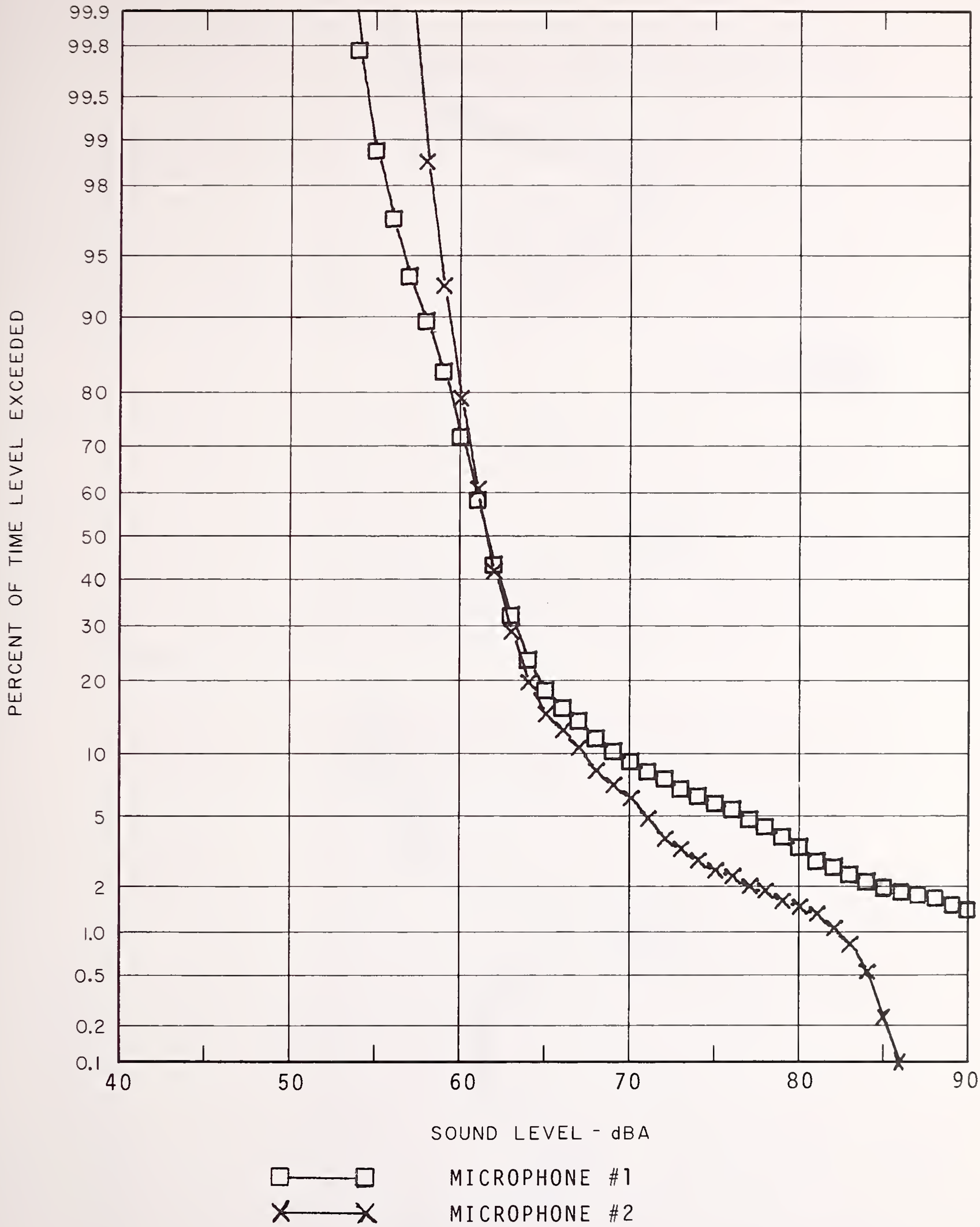


FIGURE 5.30b STATISTICAL DISTRIBUTIONS FOR WALNUT CREEK AERIAL STATION PLATFORM.

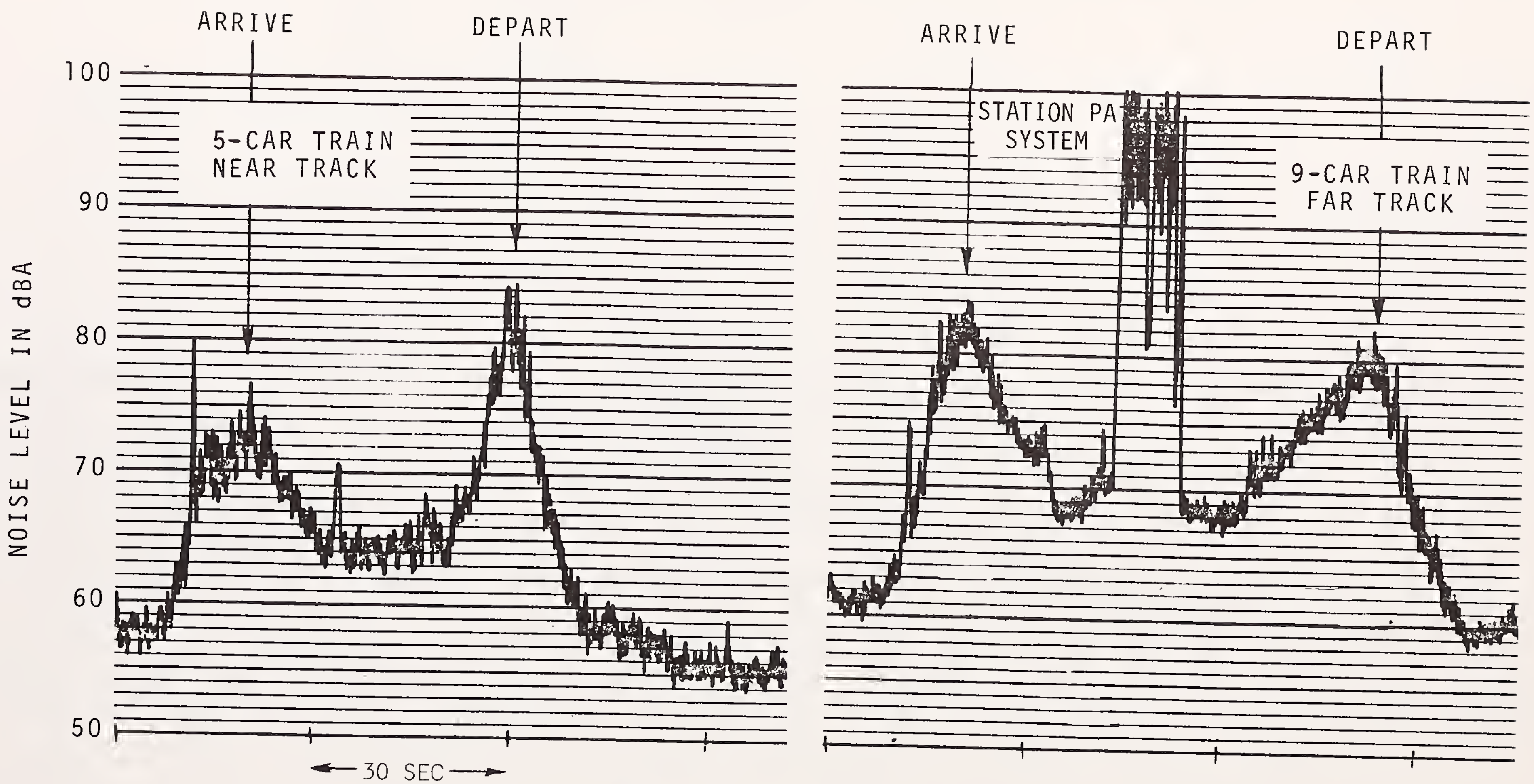


FIGURE 5.30c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT WALNUT CREEK STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

EL CERRITO DEL NORTE STATION - Aerial Station in El Cerrito, Side Platform, Two Track

DESCRIPTION (See Figure 5.31a)

El Cerrito Del Norte Station is an aerial station on the Richmond Line. It is located in a semi-residential/commercial area. The residential area is east of the Station and the commercial area is to the west, both separated from the Station by a parking lot. The two microphones were set up on the inbound side of the platform: one in the middle and one at the trailing end of the stopped train.

NOISE CLIMATE (See Table 5.26, Figures 5.31b-c)

The residual noise levels range from 56 dBA at the center of the platform to 58 dBA at the end of the platform. The difference in residual noise is due to the shielding of street traffic noise at the center of the platform. Patrons standing at the center of the platform are, however, subjected to a higher overall noise exposure due to the higher noise levels of train arrivals and departures at this position. L_{EQ} is 70 dBA at the center of the platform and 68 dBA at the end of the platform.

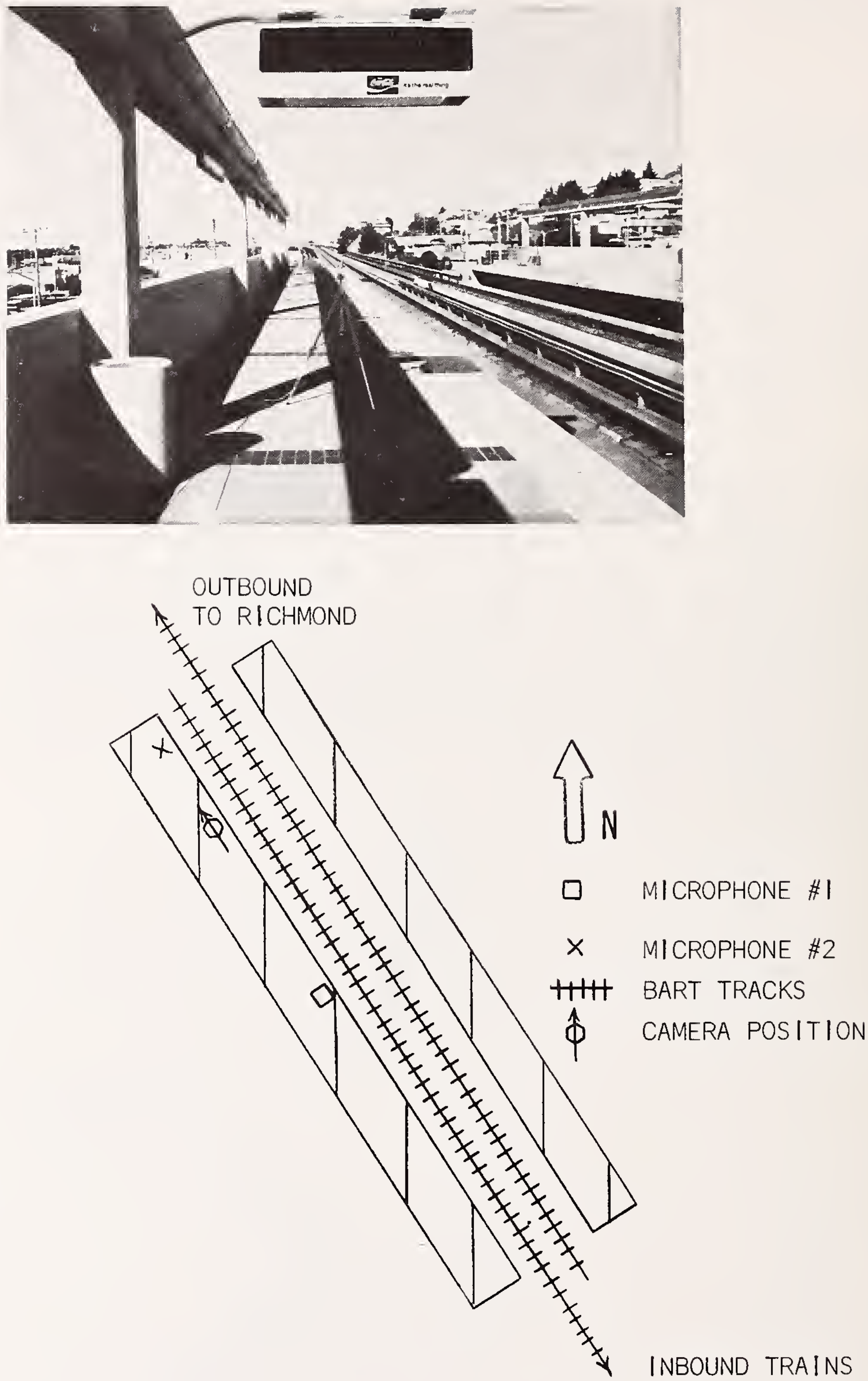


FIGURE 5.31a EL CERRITO DEL NORTE AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.26 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT EL CERRITO DEL NORTE STATION PLATFORM

NAME OF STATION: El Cerrito Del Norte

Station Type: Aerial ; Platform Type: Side ; Location: Residen/Comm Area

Date: 11/22/74 ; Starting Time: 11:09 a.m. ; Temp.: 55 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	84 *0.35	82 *3.18	82 *0.00	86 *0.35	56	57	59	72	82	70
Two 5-car	One 5-car One 6-car	Trailing End of Platform	87 0.00	67 2.47	67 1.40	85 1.77	58	59	61	66	83	68

*Standard Deviation of level

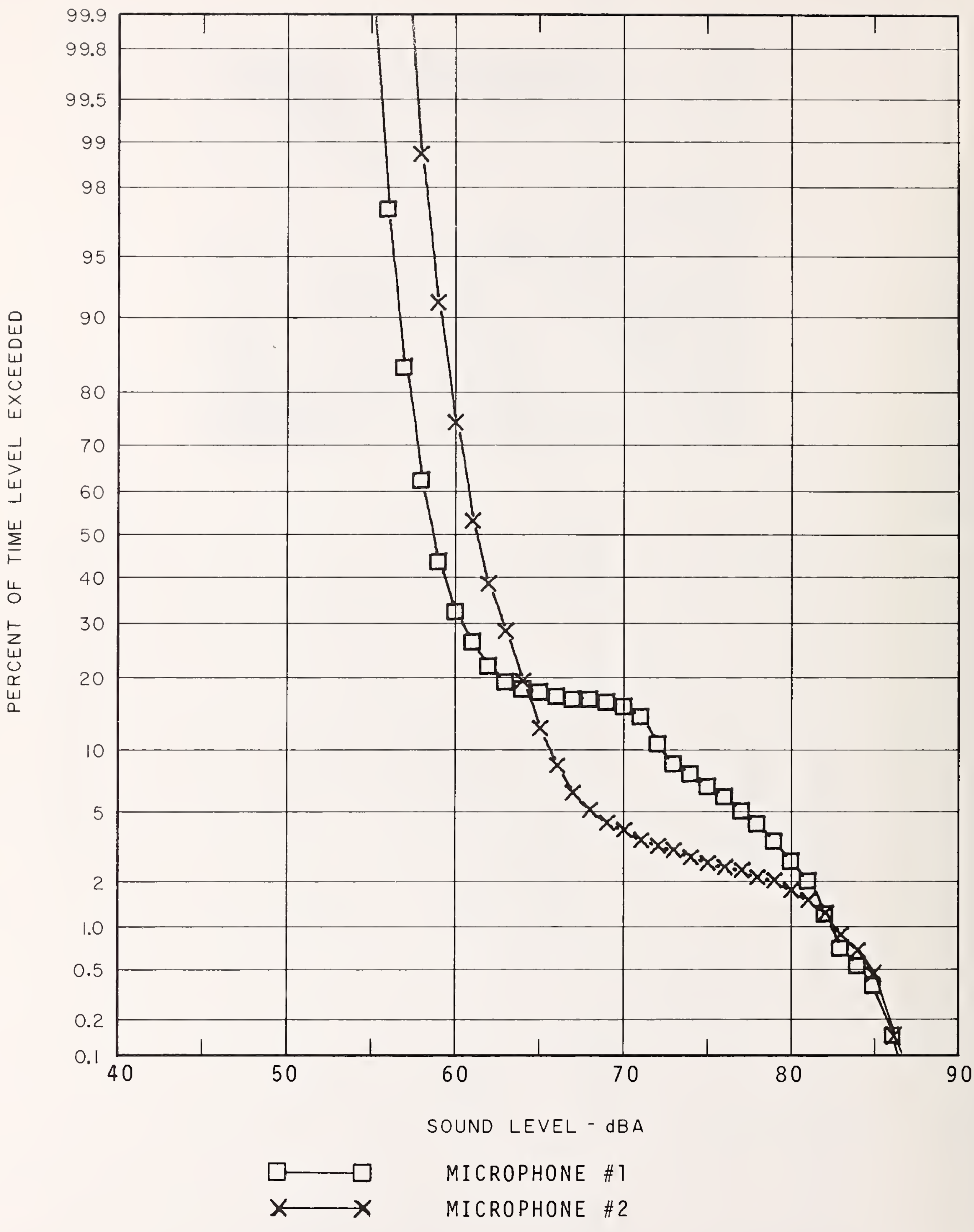


FIGURE 5.31b STATISTICAL DISTRIBUTIONS FOR EL CERRITO DEL NORTE AERIAL STATION PLATFORM.

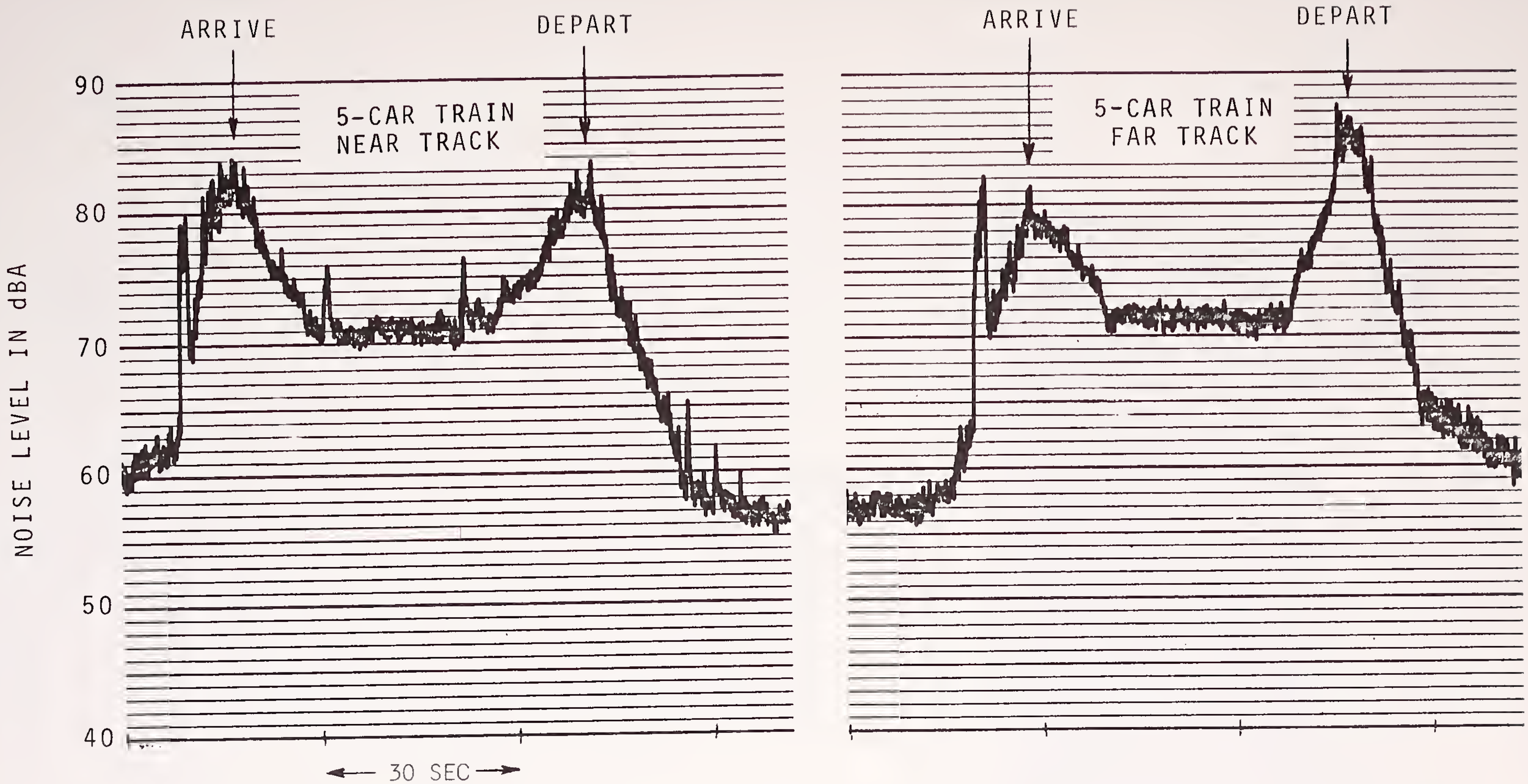


FIGURE 5.31c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT EL CERRITO DEL NORTE STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

PLEASANT HILL STATION - Aerial Station in Pleasant Hill, Side Platform, Two Track

DESCRIPTION (See Figure 5.32a)

Pleasant Hill Station is an aerial station on the Concord Line. It is located in a residential neighborhood separated from the Station by the parking lot. The two microphones were set up on the Concord train side of the platform: one at the middle and one at the leading end of the stopped train.

NOISE CLIMATE (See Table 5.27, Figures 5.32b-c)

The residual noise levels are 54 dBA at both microphone positions There are no outside nearby noise sources that acoustically impact the patrons on the platform. The value of L_{EQ} at the center of the platform was 67 dBA, 2 dBA higher than the L_{EQ} at the end of the platform, due to the higher noise levels of the train arrivals and departures at the center of the platform.

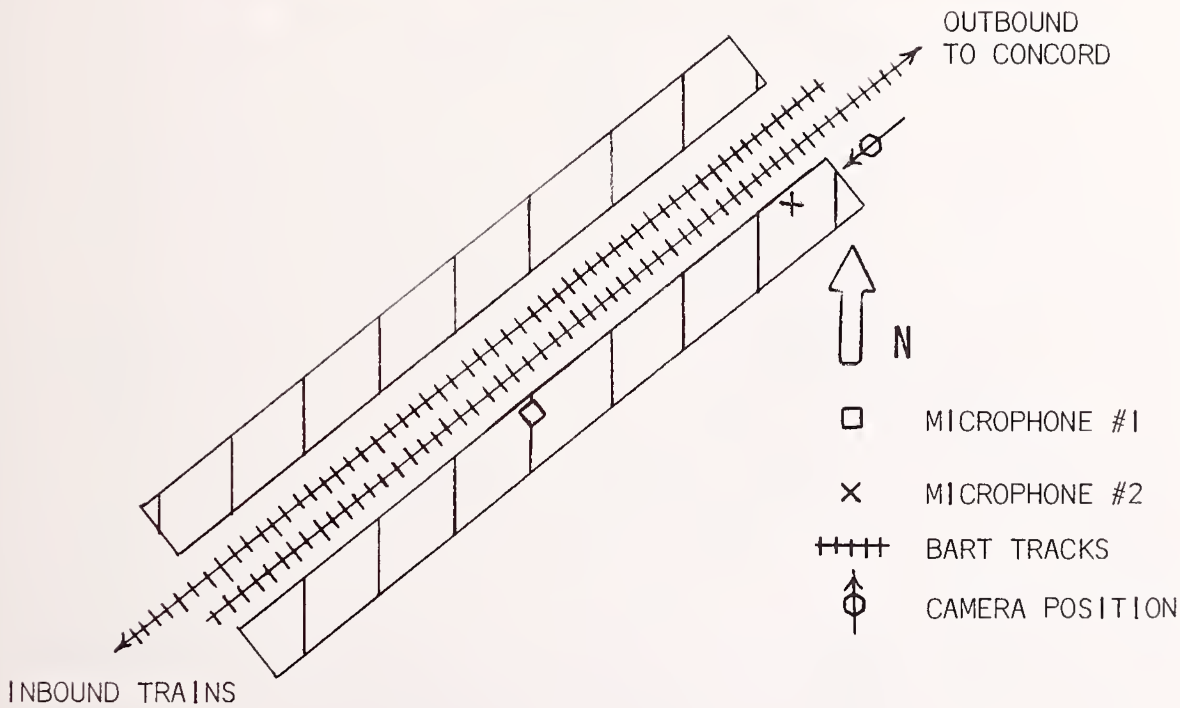


FIGURE 5.32a PLEASANT HILL AERIAL STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.27 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT PLEASANT HILL STATION PLATFORM

NAME OF STATION: Pleasant Hill Station

Station Type: Aerial; Platform Type: Center; Location: Residential Area

Date: 11/20/74; Starting Time: 1:44 p.m.; Temp.: 60 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	79 *1.41	80 *0.00	83 *0.35	85 *0.70	54	55	56	70	80	67
Two 5-car	One 5-car One 6-car	Leading End of Platform	62 0.35	81 0.70	81 0.35	68 0.00	54	55	58	63	79	65

Standard Deviation of level

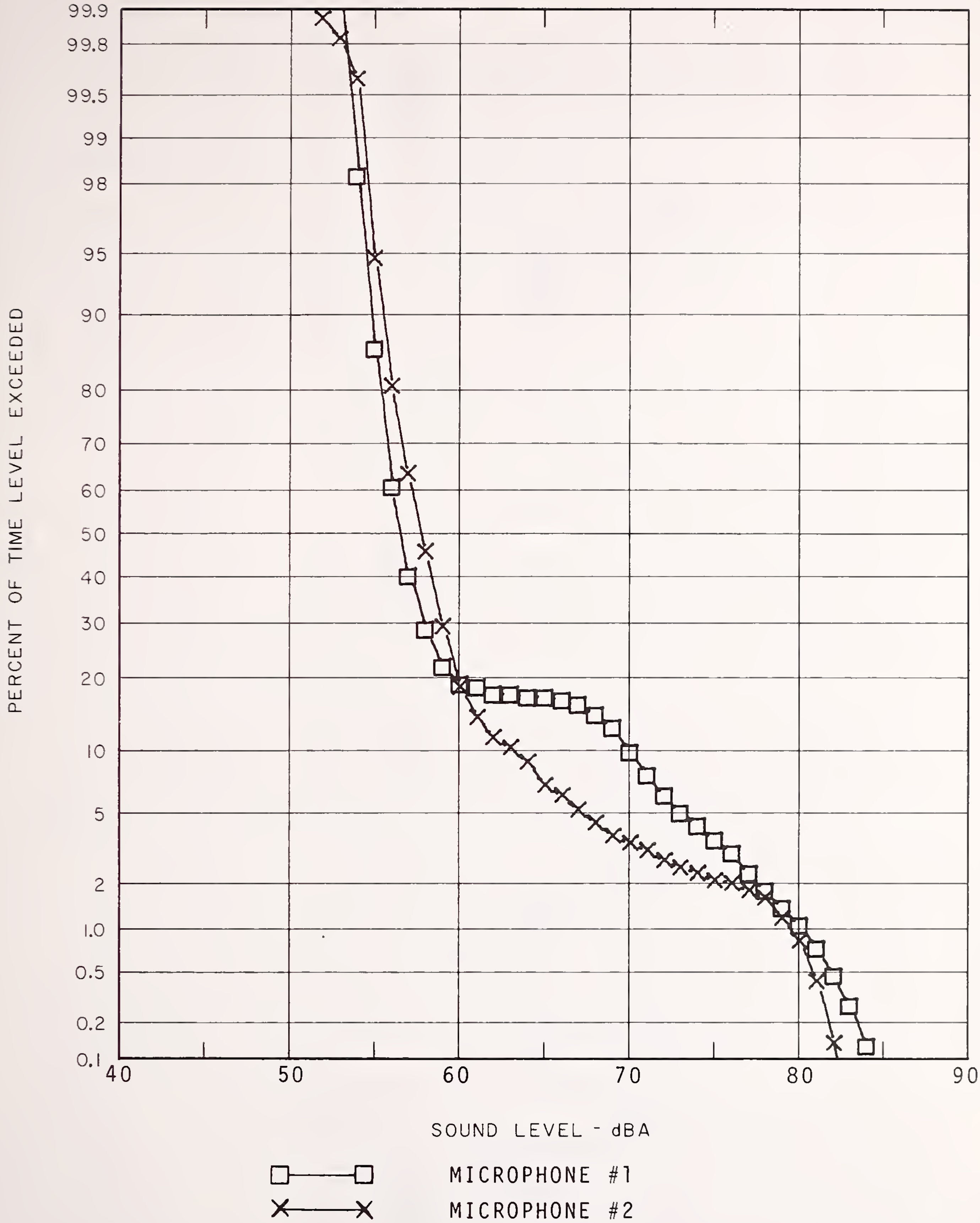


FIGURE 5.32b STATISTICAL DISTRIBUTION FOR PLEASANT HILL AERIAL STATION PLATFORM.

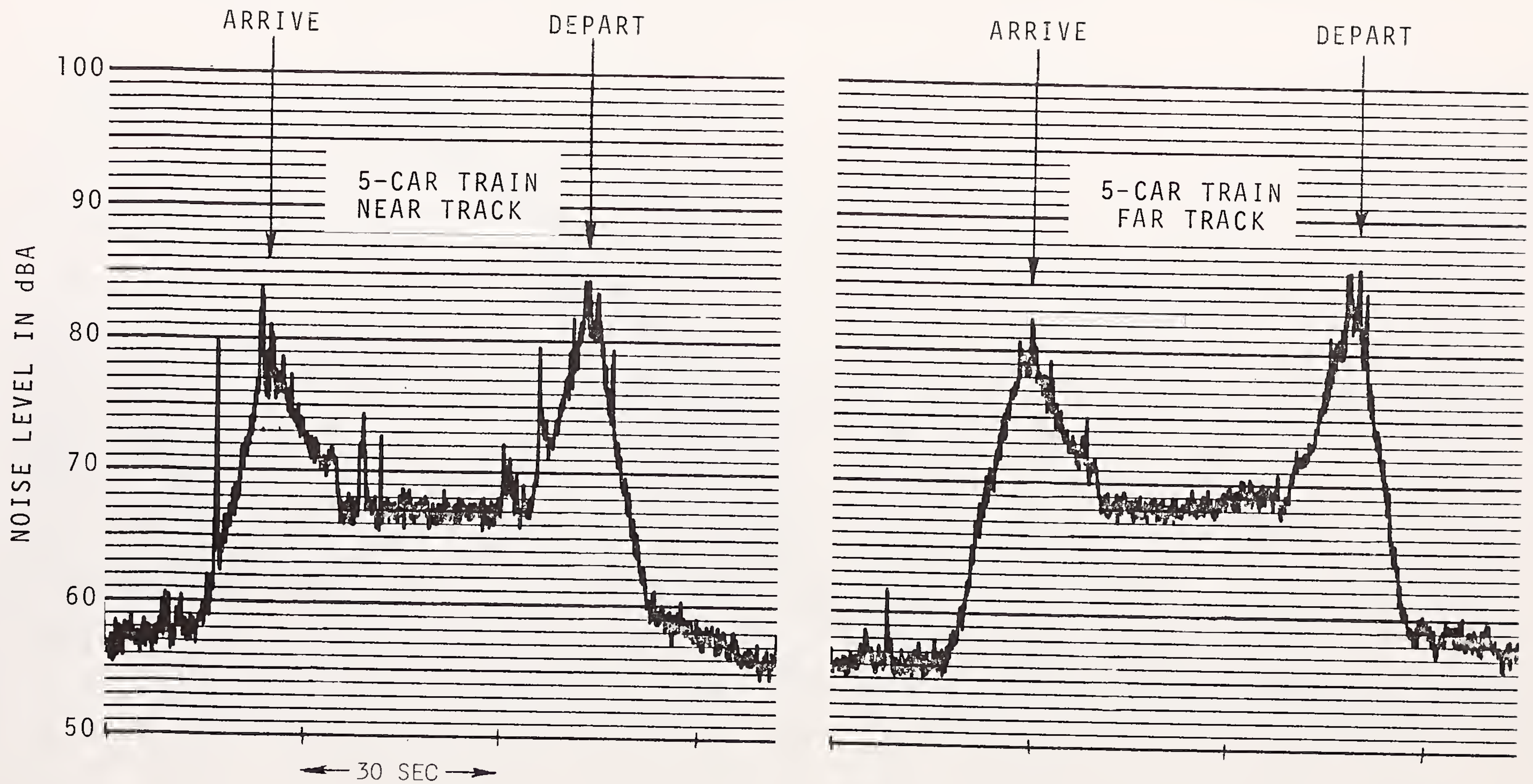


FIGURE 5.32c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT PLEASANT HILL STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

RICHMOND STATION - At-grade Station in Richmond, Center Platform, Ballast and Tie Tracks

DESCRIPTION (See Figures 5.33a)

Richmond Station is the northeast station on the Richmond Line before the Richmond Yard. There is a parking lot immediately adjacent to the Station separating the Station from the neighboring semi-commercial/residential community. Adjacent to the inbound track on the southwest side of the Station are Southern Pacific Railroad tracks. Although the tracks are frequently used, no trains passed during the platform noise measurements. The two microphones were set up on the inbound side of the platform: one at the middle and one at the trailing end of the stopped train.

NOISE CLIMATE (See Table 5.28, Figures 5.33b-c)

The measured residual noise levels were 53 dBA at both microphone positions on the platform. There were no other nearby noise sources that acoustically impact the passengers standing on the platform during the time of the platform sample. There is, however, some possibility of acoustical impact from the adjacent railroad tracks depending on the railroad train's passby speed and frequency. L_{EQ} at the center of the platform was 62 dBA, 3 dBA higher than that at the end of the platform. Probably, this is principally due to the fact that the trains coming into the Station from the Yard generally travel at a slow speed thus creating a lower noise level than the trains coming into the Station from the main line.

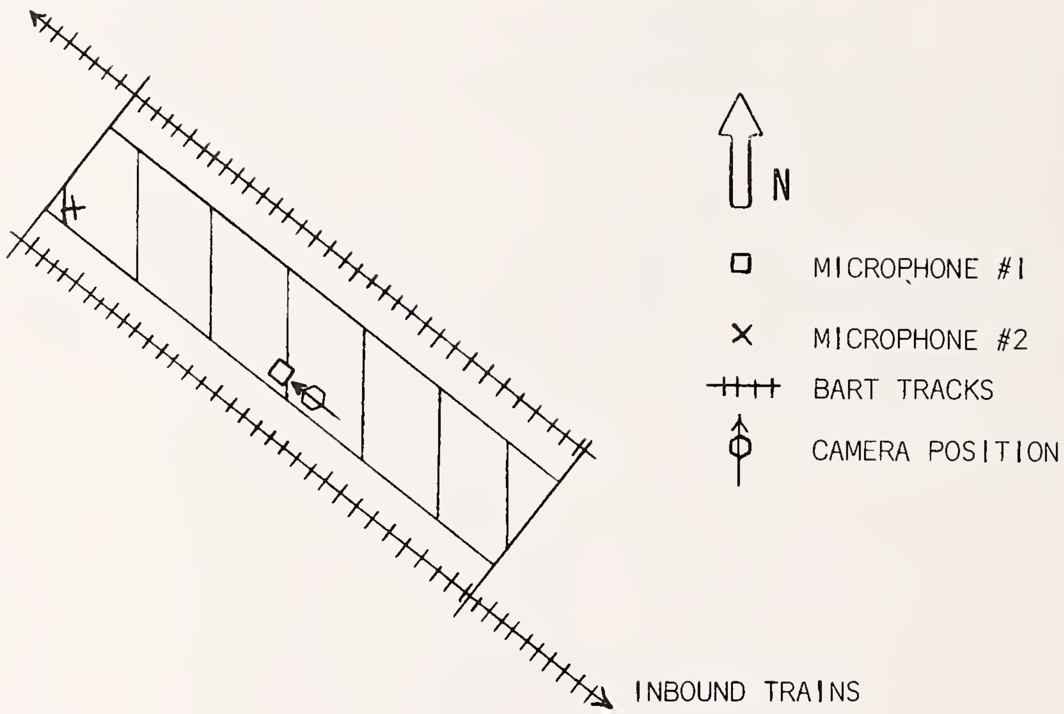


FIGURE 5.33a RICHMOND AT-GRADE STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.28 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT RICHMOND STATION PLATFORM

NAME OF STATION: Richmond Station

Station Type: At-grade ; Platform Type: Center ; Location: Residen/Comm Area

Date: 11/22/74 ; Starting Time: 10:09 a.m. ; Temp.: 55°F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Arrive & Depart	Arrive	Center of Platform	75 *0.70	71 *0.70	80 *1.41	80 *0.58	53	54	56	63	75	62
Two 5-car	Depart Two 5-car Three 5-car	Trailing End of Platform	76 1.06	-- --	62 0.35	68 0.29	53	54	56	59	71	59

*Standard Deviation of level

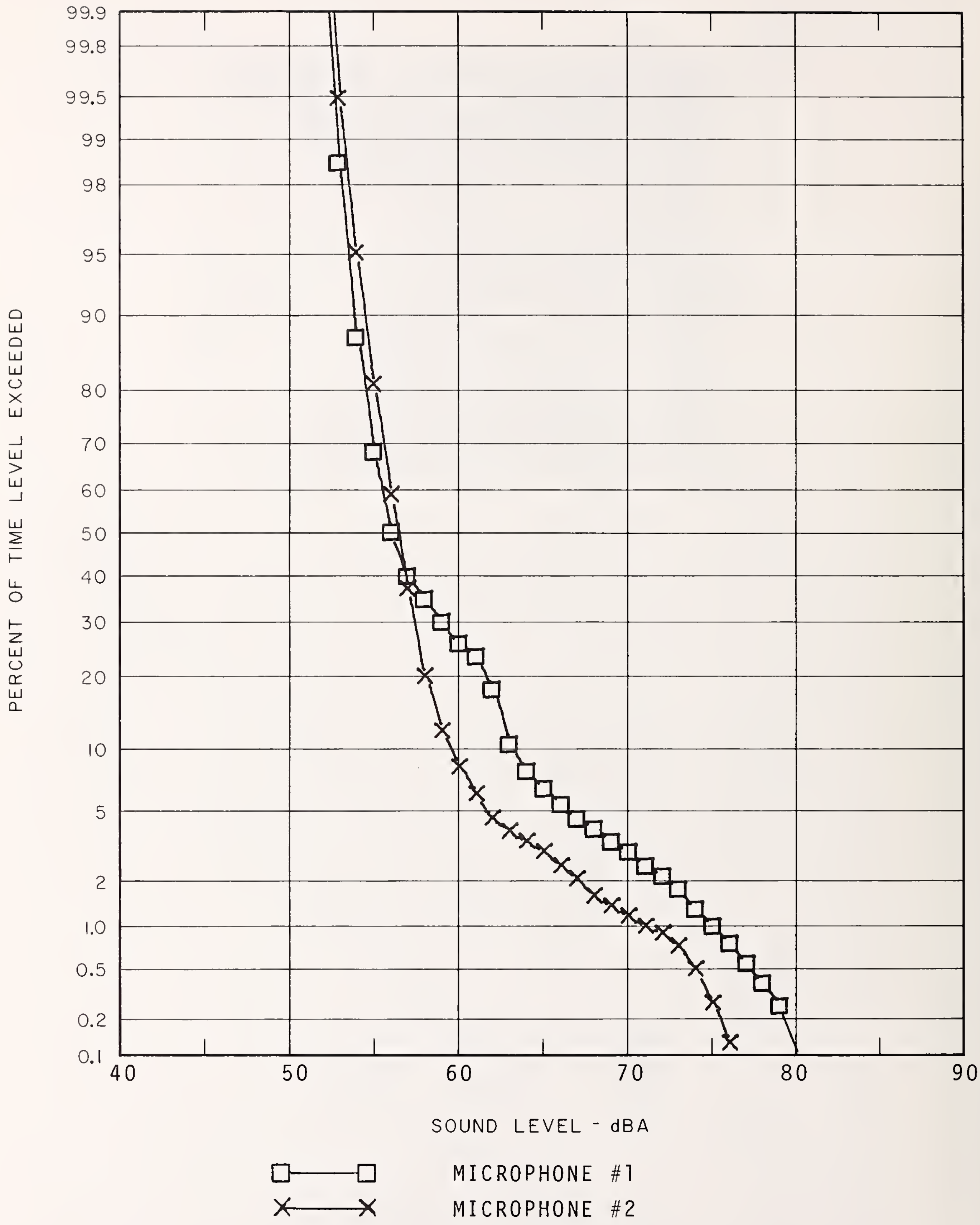


FIGURE 5.33b STATISTICAL DISTRIBUTIONS FOR RICHMOND AT-GRADE STATION PLATFORM.

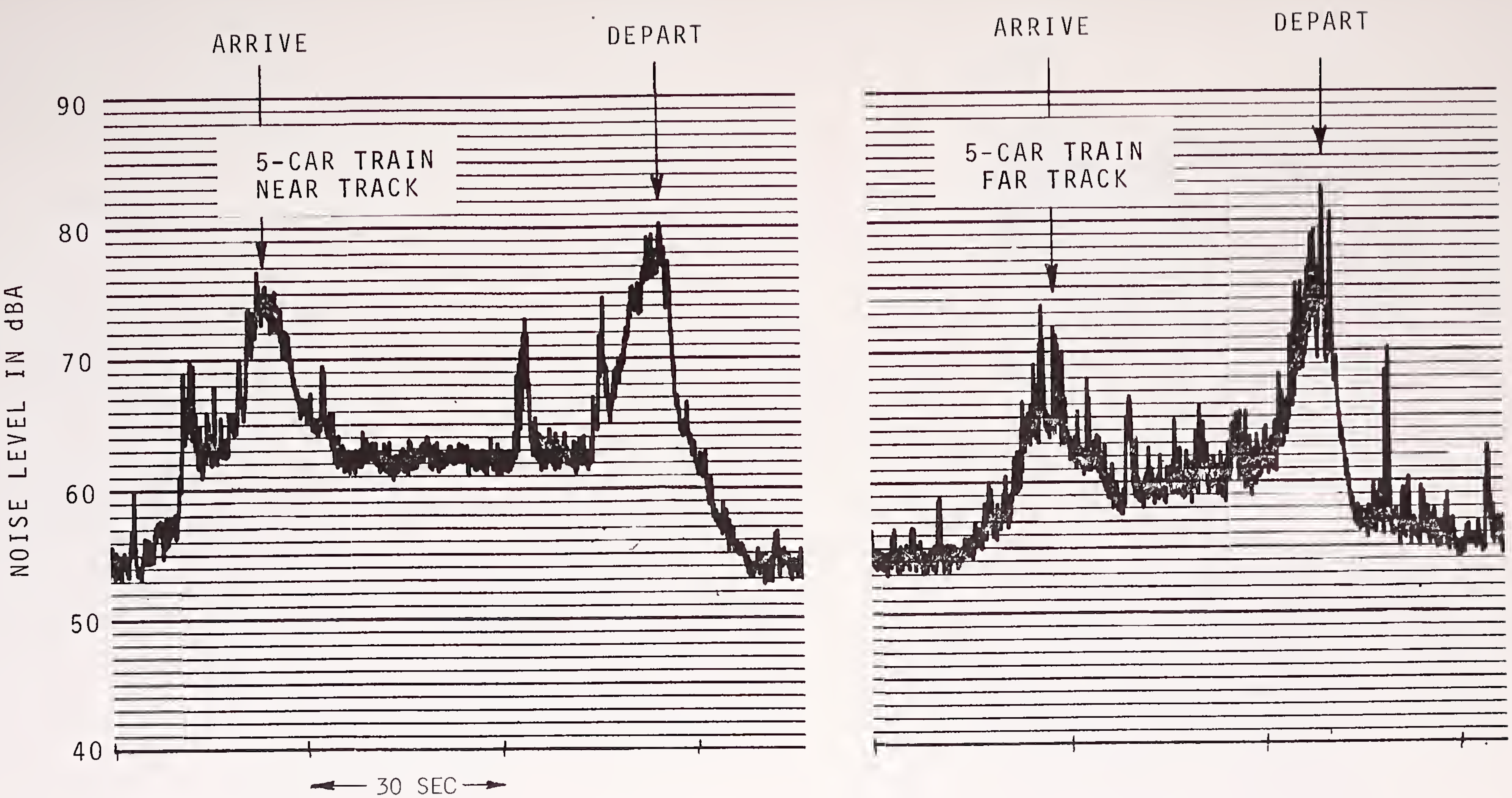


FIGURE 5.33c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT RICHMOND STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

UNION CITY STATION - At-grade Station in Union City, Side Platform, Two Track

DESCRIPTION (See Figure 5.34a)

Union City Station is an at-grade station on the Fremont Line. It is located in a semi-industrial/commercial area. The industrial plants are located east of the Station. The commercial area is located west of the Station separated by the parking lot. The two microphones were set up on the Fremont train side of the platform: one at the middle and one at the leading end of the stopped train.

NOISE CLIMATE (See Table 5.29, Figures 5.34b-c)

The measured residual noise levels were 55 dBA at both positions on the platform. The industrial plants are sufficiently remote from the Station, thus there is little or no acoustical impact from these plants on the patrons on the platform. The measurements indicate that as expected the noise levels of train arrivals and departures on the near track are higher than that on the far track.

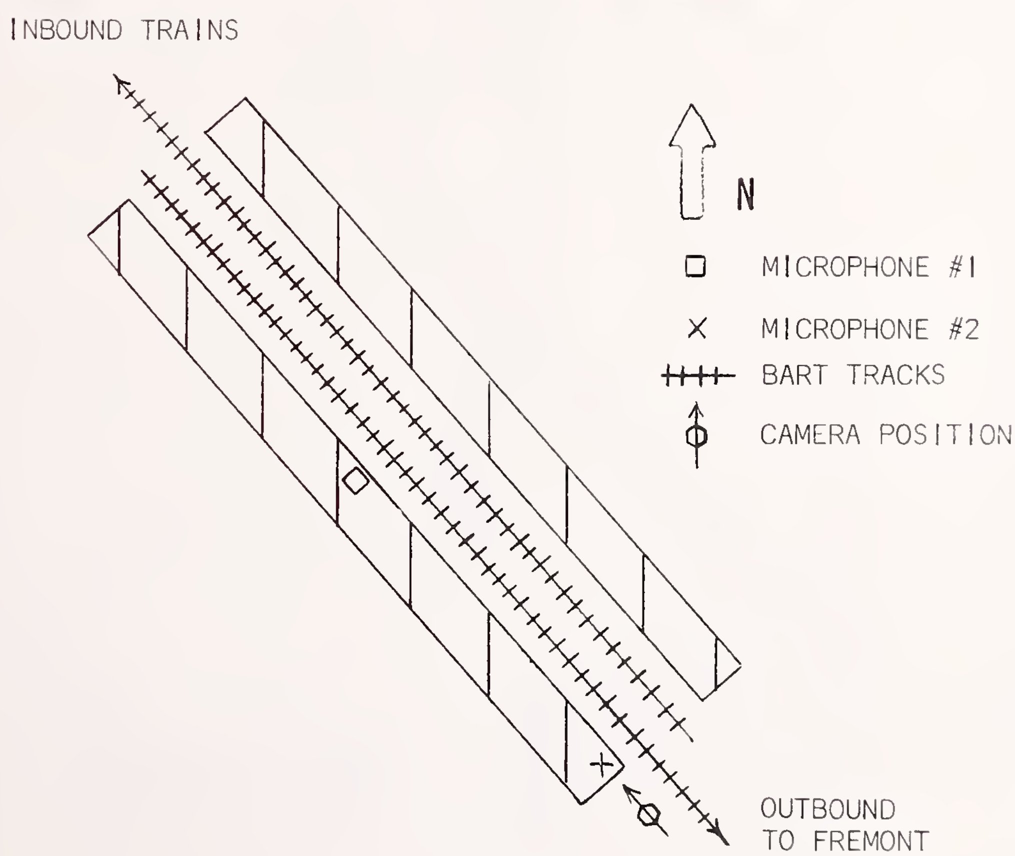


FIGURE 5.34a UNION CITY AT-GRADE STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.29 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT UNION CITY STATION PLATFORM

NAME OF STATION: Union City Station

Station Type: At-grade; Platform Type: Side; Location: Indus/Comm Area

Date: 4/2/75; Starting Time: 2:15 p.m.; Temp.: 62 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	78 *0.48	73 *0.00	79 *1.40	71 *0.58	55	57	60	68	78	67
Four 5-car One 4-car	Four 5-car One 4-car	Leading End of Platform	73 0.82	75 0.00	75 0.65	74 3.50	55	57	61	68	77	66

*Standard Deviation of level

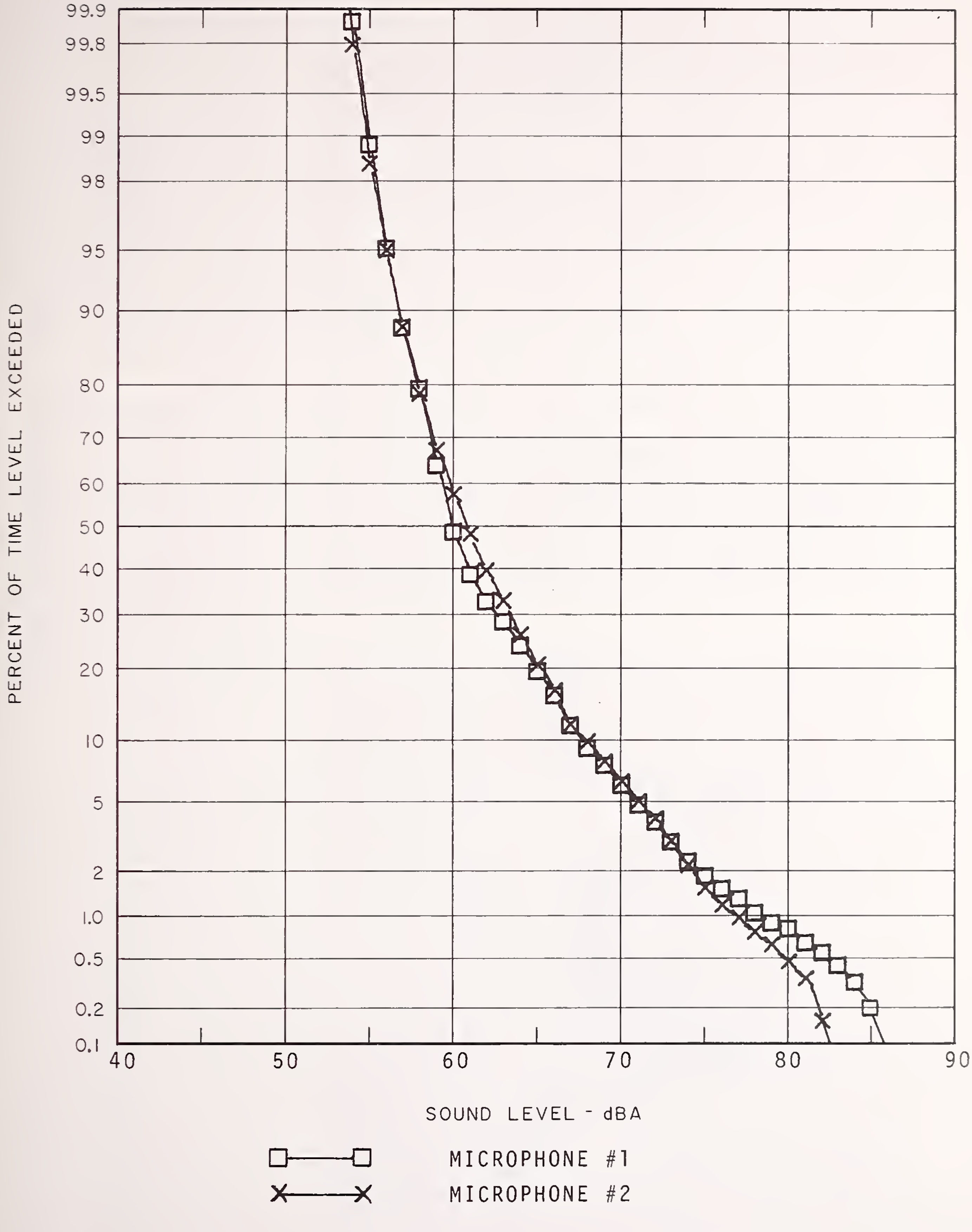


FIGURE 5.34b STATISTICAL DISTRIBUTIONS FOR UNION CITY AT-GRADE STATION PLATFORM.

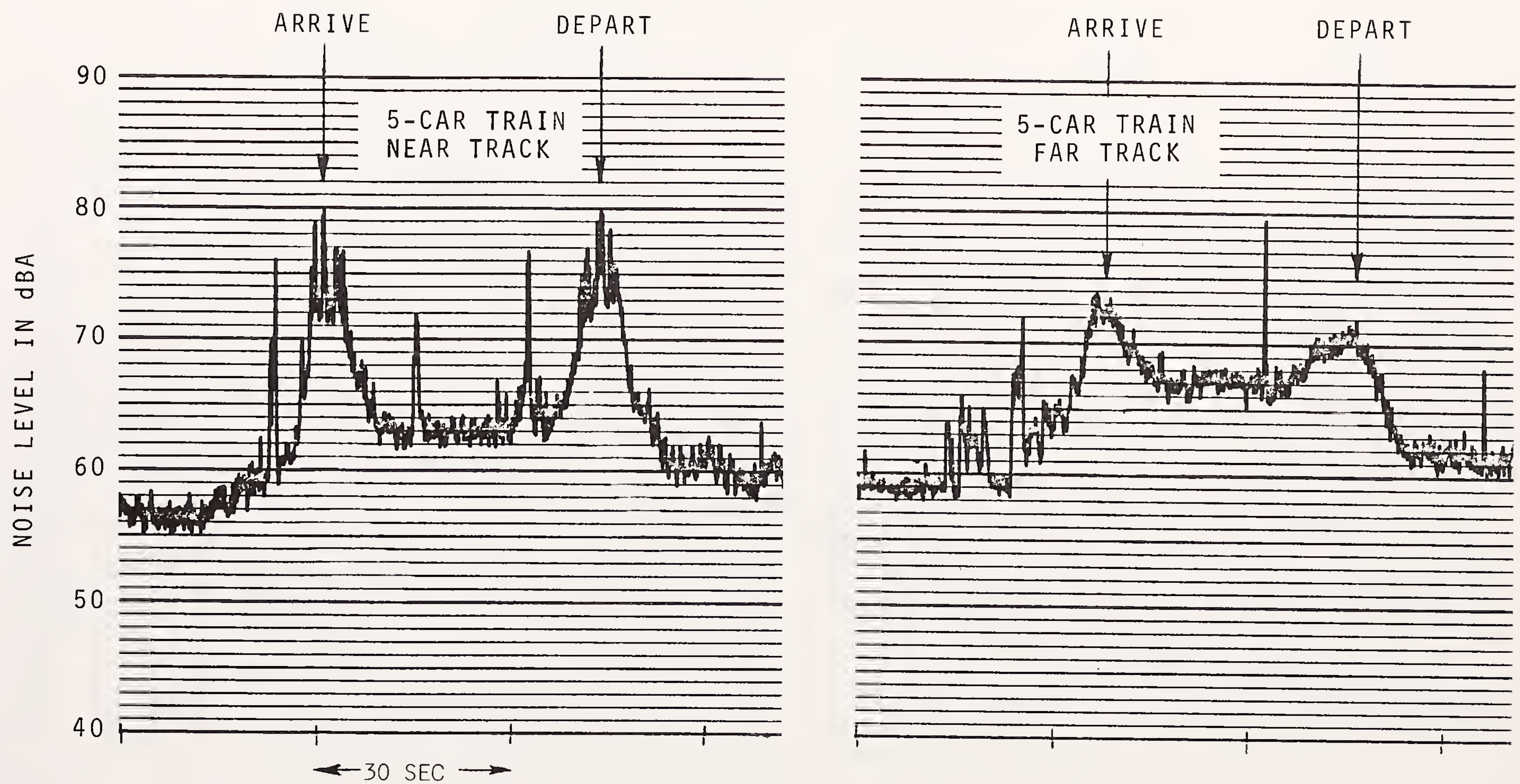


FIGURE 5.34c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT UNION CITY STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

SOUTH HAYWARD STATION - At-grade Station in Hayward, Side Platform, Two Track

DESCRIPTION (See Figure 5.35a)

South Hayward Station is an at-grade station on the Fremont Line. It is located in a residential neighborhood. Western Pacific Railroad tracks are parallel to and west of the Station. The parking lot is east of the Station separating the Station from the residential community. The two microphones were set up on the Fremont train side of the platform: one at the middle and one at the trailing end of the stopped train.

NOISE CLIMATE (See Table 5.30, Figures 5.35b-c)

The residual noise levels range from 48 dBA at the end of the platform to 54 dBA at the center of the platform. The higher background noise at the platform center is due to a steady noise from the operation of a nearby escalator. L_{EQ} at the platform center is also higher than that at the end of the platform by 4 dBA, also mainly because of the escalator operation noise.

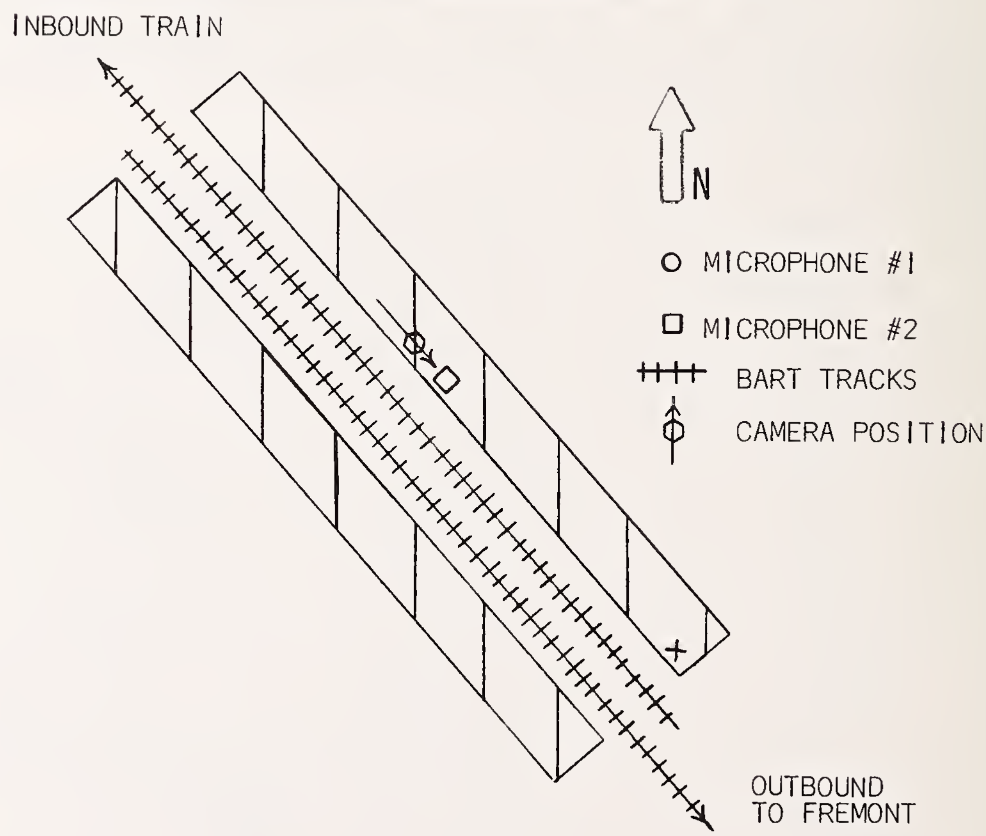


FIGURE 5.35a SOUTH HAYWARD AT-GRADE STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.30 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT SOUTH HAYWARD STATION PLATFORM

NAME OF STATION: South Hayward Station

Station Type: At-grade; Platform Type: Side; Location: Residential Area

Date: 11/22/74; Starting Time: 2:45 p.m.; Temp.: 66 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive Four 5-car	Arrive Four 5-car	Center of Platform	74 *1.22*	76 *0.75*	77 *0.87*	78 *0.00*	54	55	58	71	78	68
Depart Three 5-car	Depart Four 5-car	Trailing End of Platform	74 *1.32*	60 *0.70*	61 *2.60*	75 *0.58*	48	50	53	63	75	64

*Standard Deviation of level

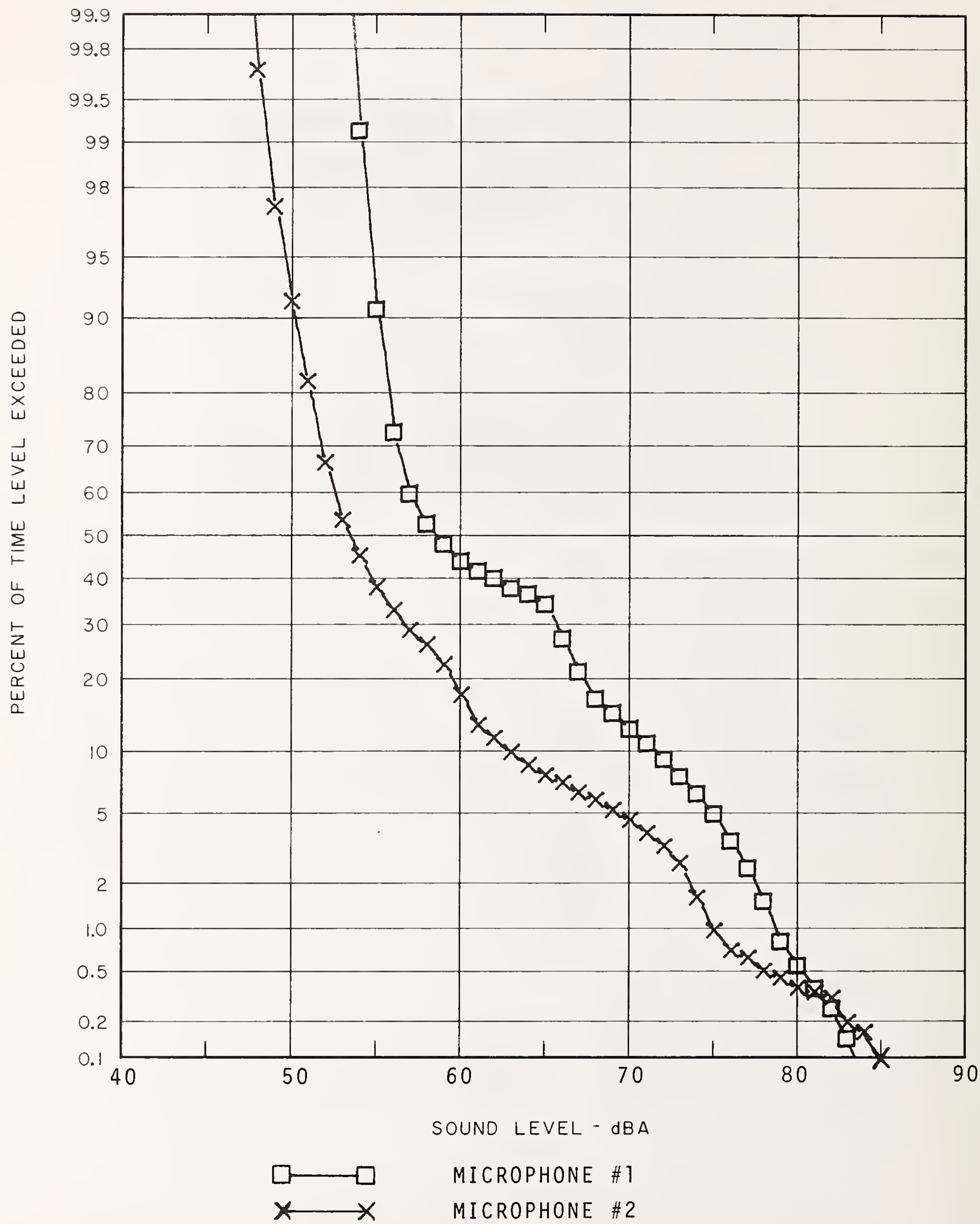


FIGURE 5.35b STATISTICAL DISTRIBUTIONS FOR SOUTH HAYWARD AT-GRADE STATION PLATFORM.

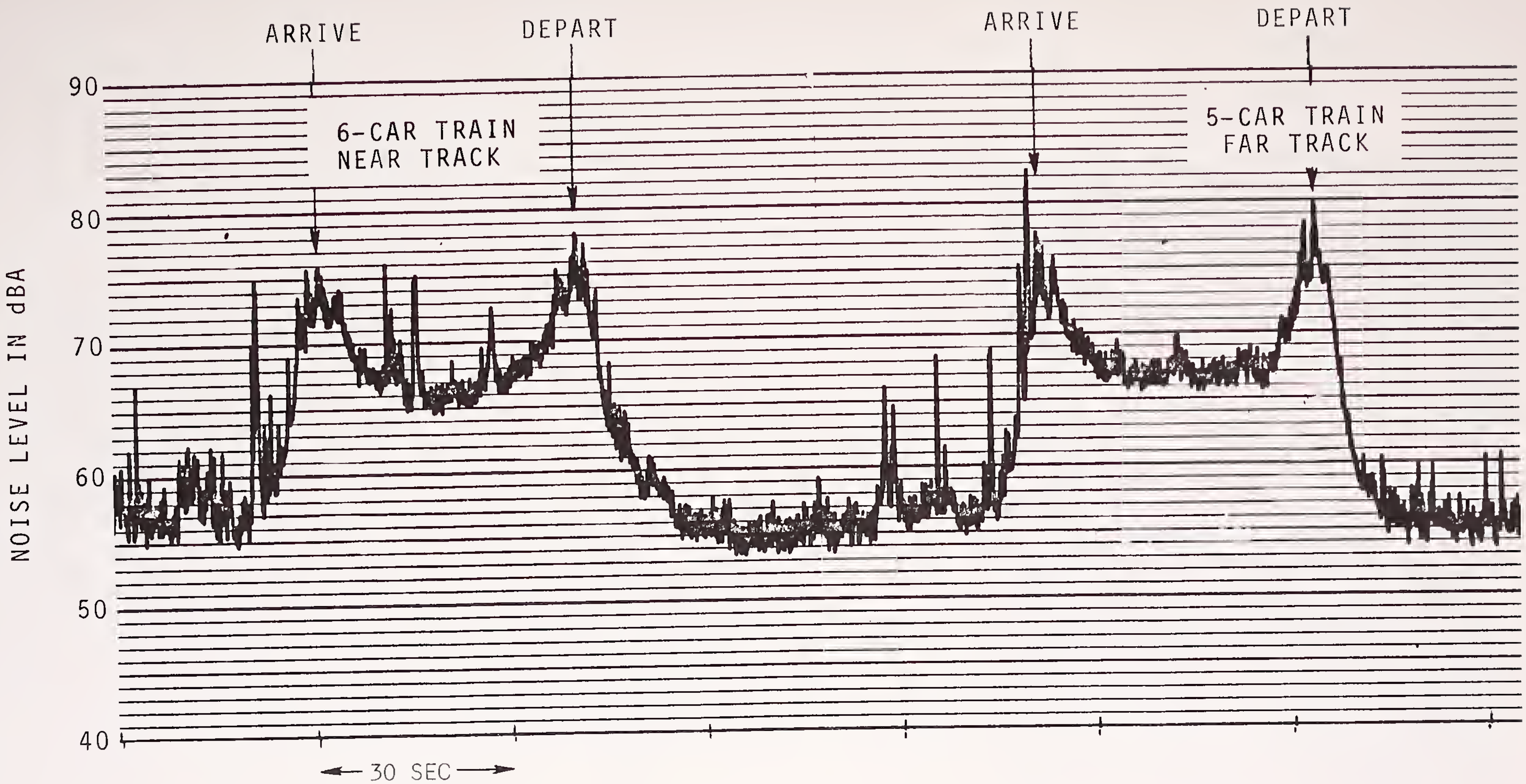


FIGURE 5.35c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT SOUTH HAYWARD STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

LAKE MERRITT STATION - Subway Station in Oakland, Center Platform, Two Track, Single Level

DESCRIPTION (See Figure 5.36a)

Lake Merritt Station is located in a semi-commercial/residential area in Oakland. It serves both the Richmond-Fremont trains and the Daly City-Fremont trains. The Station is treated with acoustical material on the ceiling area, the underplatform area, and the wall area opposite the track. The two microphones were set up on the inbound side of the platform: one at the middle and one at the leading end of the stopped train.

NOISE CLIMATE (See Table 5.31, Figures 5.36b-c)

The residual noise levels range from 51 dBA at the center of the platform to 54 dBA at the end of the platform. The measurements indicate that the peak noise level of train arrivals and departures is slightly higher at the end of the platform. Thus, L_{EQ} is also higher at the end of the platform.

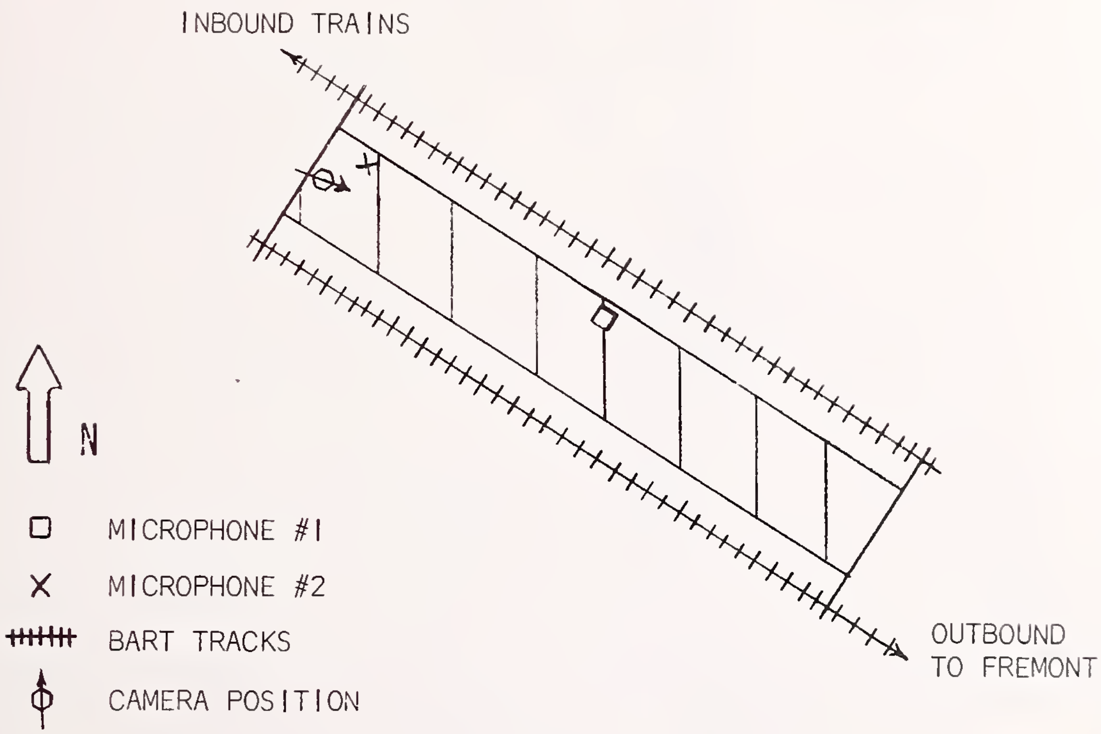


FIGURE 5.36a LAKE MERRITT SUBWAY STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.31 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT LAKE MERRITT STATION PLATFORM

NAME OF STATION: Lake Merritt Station

Station Type: Subway ; Platform Type: Center ; Location: Central Business District

Date: 4/3/75 ; Starting Time: 12:52 p.m. ; Temp.: 65 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive Five 5-car	Arrive Five 5-car	Center of Platform	77 *1.00	74 *0.84	86 *1.15	77 *1.89	51	52	59	71	81	69
Depart Five 5-car	Depart Five 5-car	Leading End of Platform	71 1.10	80 0.79	86 0.42	75 2.14	54	55	60	73	84	71

*Standard Deviation of level

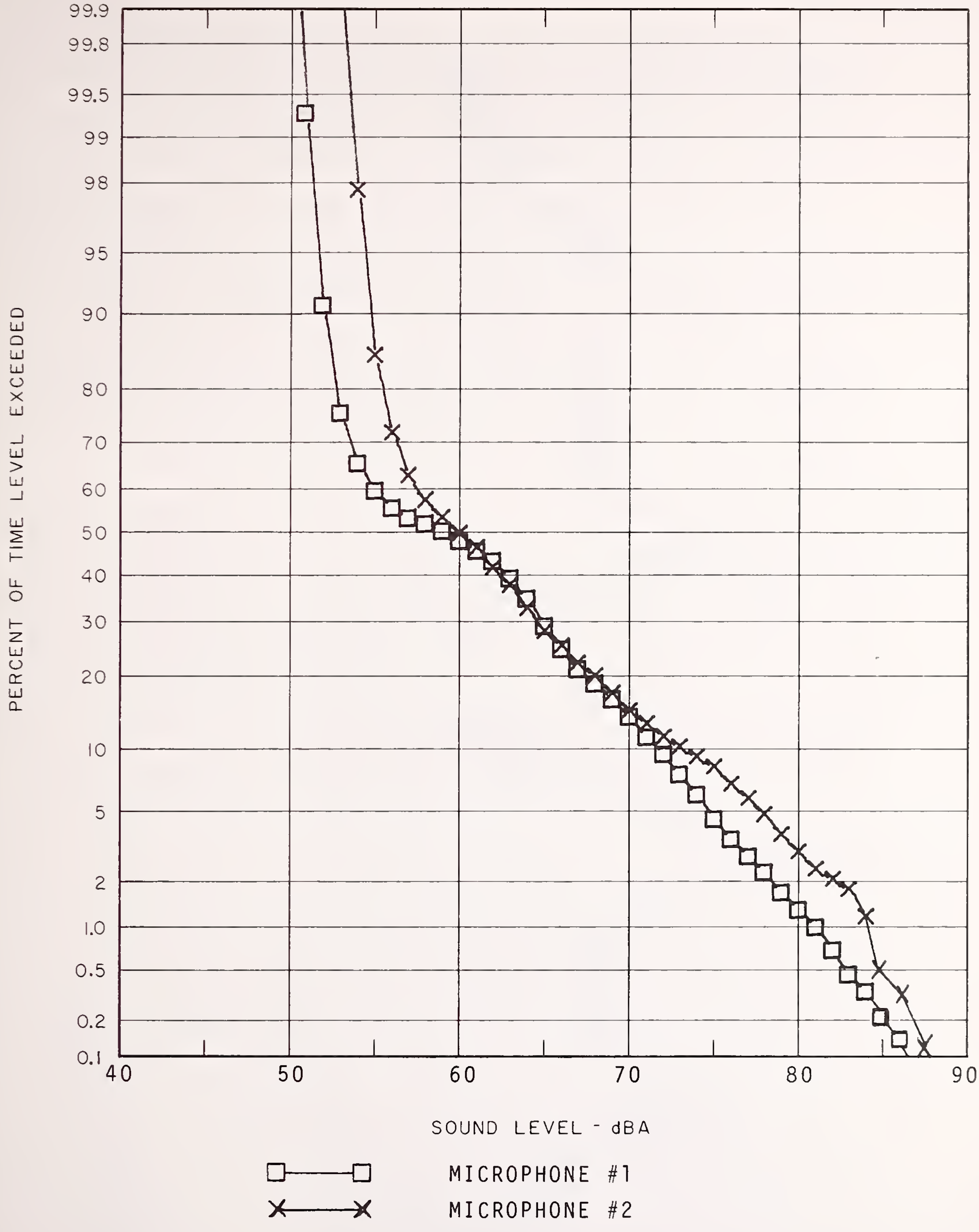


FIGURE 5.36b STATISTICAL DISTRIBUTIONS FOR LAKE MERRITT SUBWAY STATION PLATFORM.

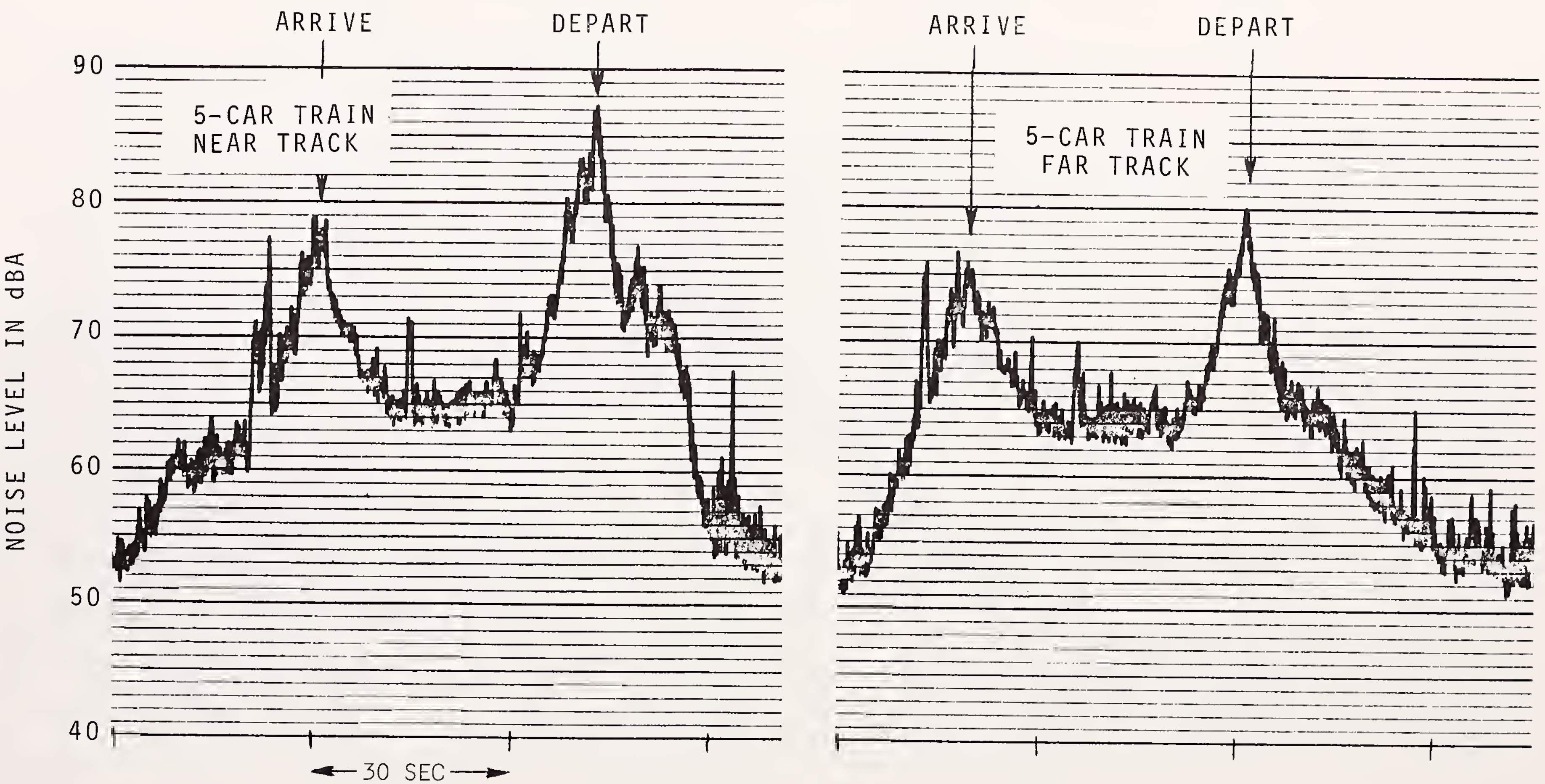


FIGURE 5.36c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT LAKE MERRITT STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

19TH STREET STATION - Subway Station in Oakland, Center Platform, Single Track, Lower Level Narrow Platform, Upper Level Wide Platform

DESCRIPTION (See Figures 5.37a and 5.38a)

19th Street Station is located in the central business district of Oakland. It is a transfer station for the Daly City-Concord Line and the Fremont-Richmond Line. The upper platform serves trains to Concord and Richmond while the lower platform serves trains to Daly City and Fremont. Two separate measurements were made for each platform. For each measurement two microphones were set up: one at the middle and one at the leading end of the stopped train.

NOISE CLIMATE (See Table 5.32, 5.33; Figures 5.37b-c, 5.38b-c)

The measured residual noise levels were 53 to 55 dBA for both platform levels. Noise levels created by the train arrivals and departures are found to be slightly higher [2 dBA] on the lower level platform. This is probably due to the narrower platform on the lower level. As a result, L_{EQ} on the lower level is 2 to 3 dBA higher than that on the upper level. The transmission of the train noise from one level to the other was found to be relatively low and thus generally unnoticeable. Depending on where the patron is standing on the platform, the average maximum level of train noise from the other level of the Station ranges from 65 to 72 dBA.

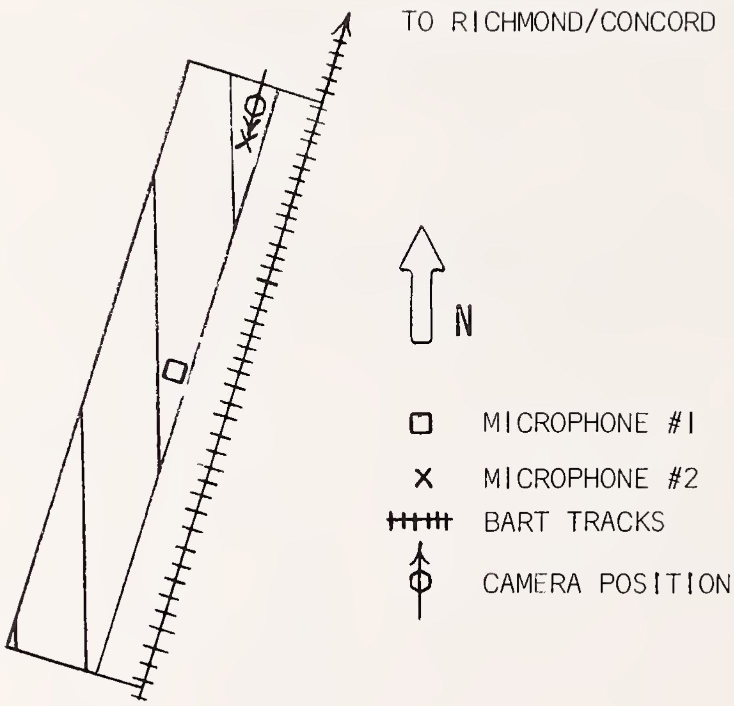


FIGURE 5.37a 19TH STREET SUBWAY STATION [UPPER LEVEL] PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.32 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT 19TH STREET STATION UPPER PLATFORM

NAME OF STATION: 19th Street Station [Upper Level]

Station Type: Subway ; Platform Type: Center ; Location: Central Business District

Date: 4/2/75 ; Starting Time: 11:05 a.m. ; Temp.: 65 °F

TRAIN SUMMARY NEAR TRACK	TRAIN SUMMARY FAR TRACK	MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA] TRAIN ARRIVING ON NEAR TRACK	TRAIN ARRIVING ON FAR TRACK	TRAIN DEPARTING ON NEAR TRACK	TRAIN DEPARTING ON FAR TRACK	STATISTICAL DESCRIPTOR [dBA] L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive & Depart Six 5-car		Center of Platform	83 *0.75*	67 *2.80*	85 *1.30*	65 *1.40*	55	56	58	70	83	70
		Leading End of Platform	74 1.07	-- --	87 0.58	-- --	53	54	56	71	85	70

*Standard Deviation of level

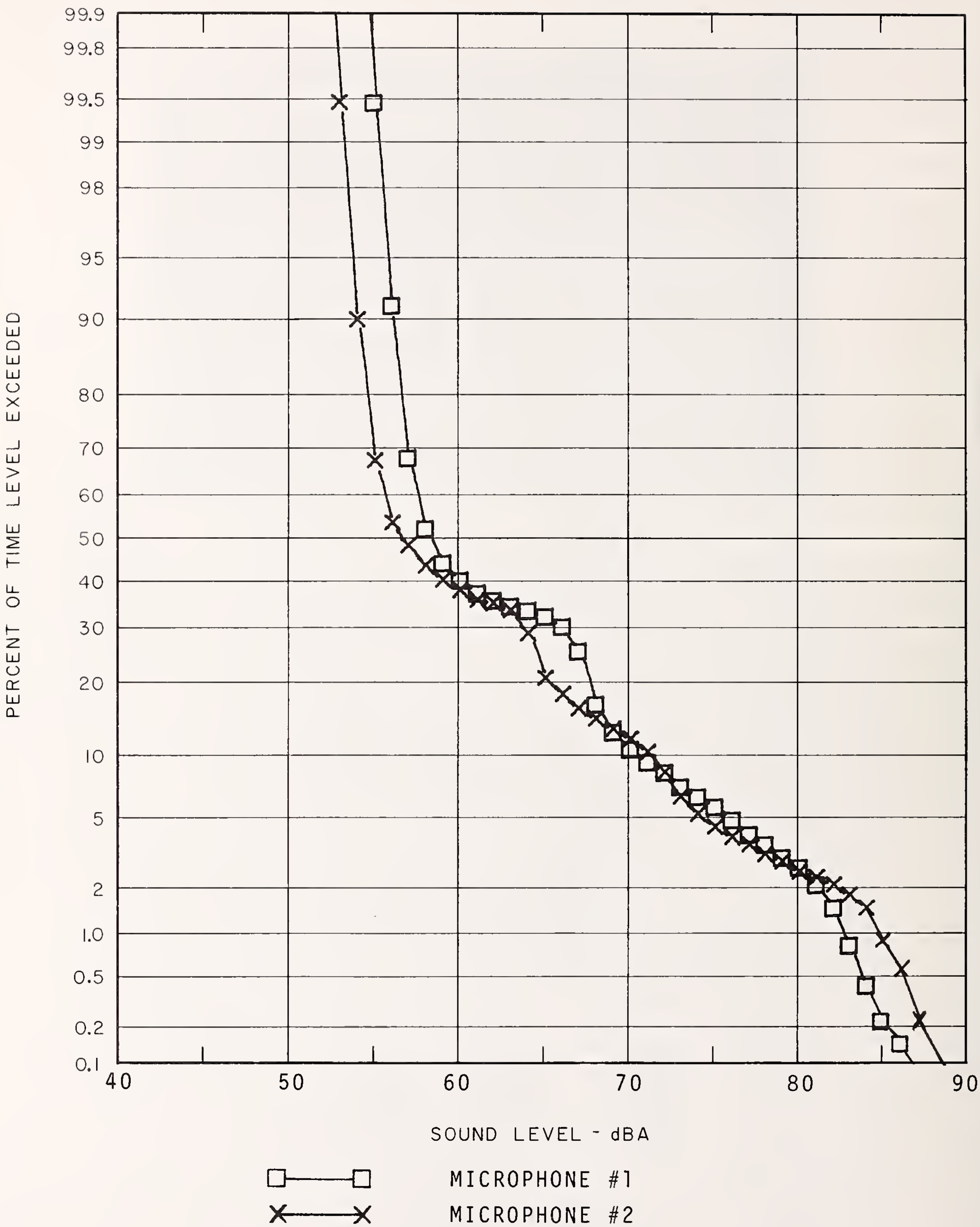


FIGURE 5.37b STATISTICAL DISTRIBUTIONS FOR 19TH STREET SUBWAY STATION UPPER LEVEL PLATFORM.

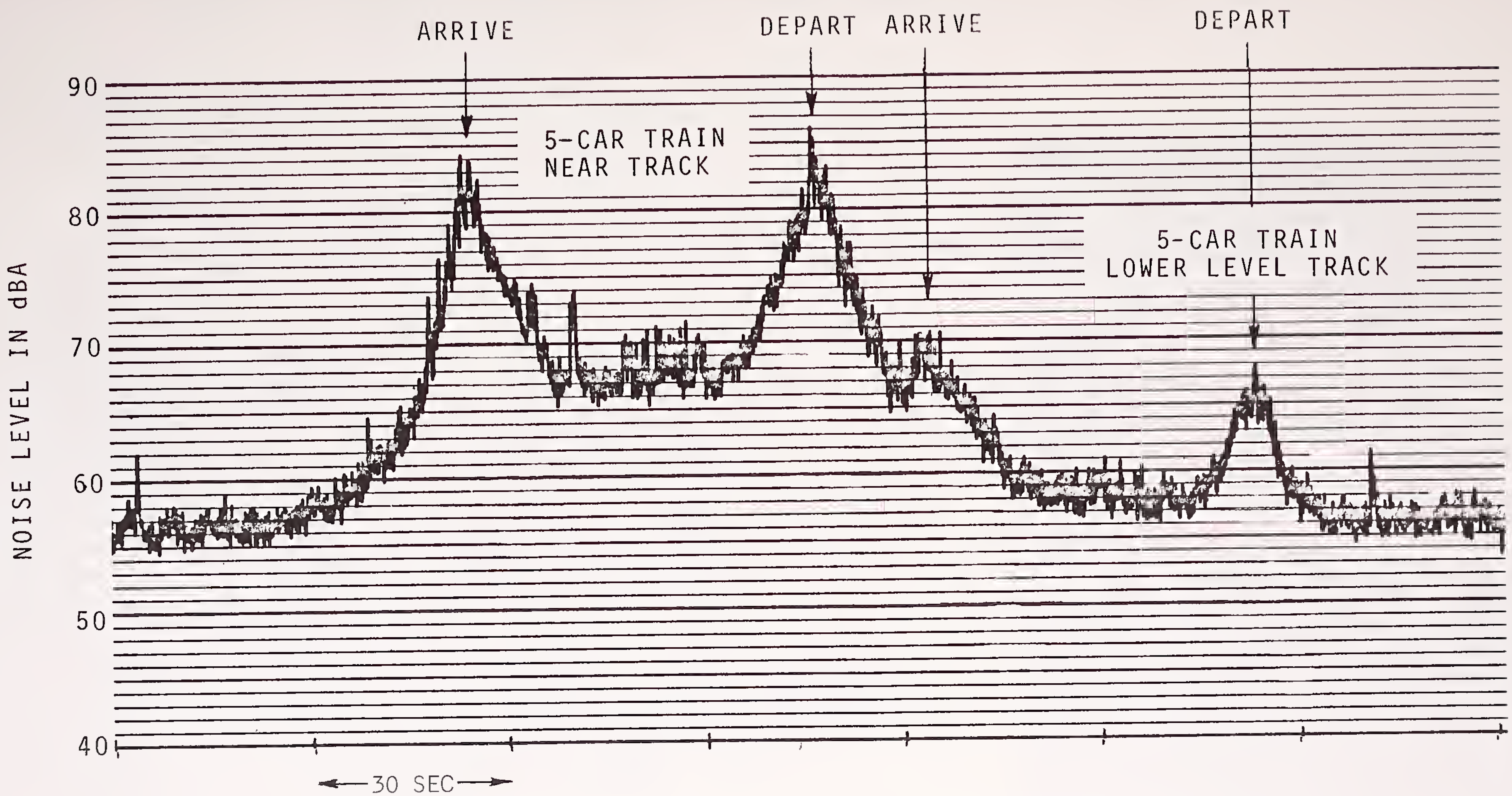


FIGURE 5.37c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT 19TH STREET STATION UPPER LEVEL PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

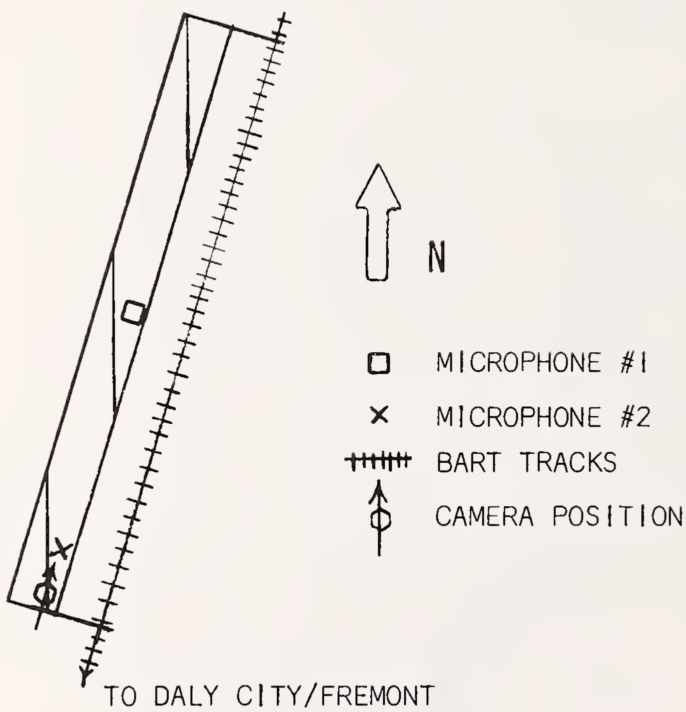


FIGURE 5.38a 19TH STREET SUBWAY STATION [LOWER LEVEL] PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.33 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT 19TH STREET STATION LOWER PLATFORM

NAME OF STATION: 19th Street Station [Lower Level]

Station Type: Subway ; Platform Type: Center ; Location: Central Business District

Date: 4/2/75 ; Starting Time: 12:06 p.m. ; Temp.: 65 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
Arrive Five 5-car		Center of Platform	84 *1.52	68 *0.30	87 *0.68	72 *0.48	53	54	56	74	85	72
Depart Six 5-car		Leading End of Platform	77 1.20	-- --	89 1.11	-- --	55	56	59	73	87	73

*Standard Deviation of level

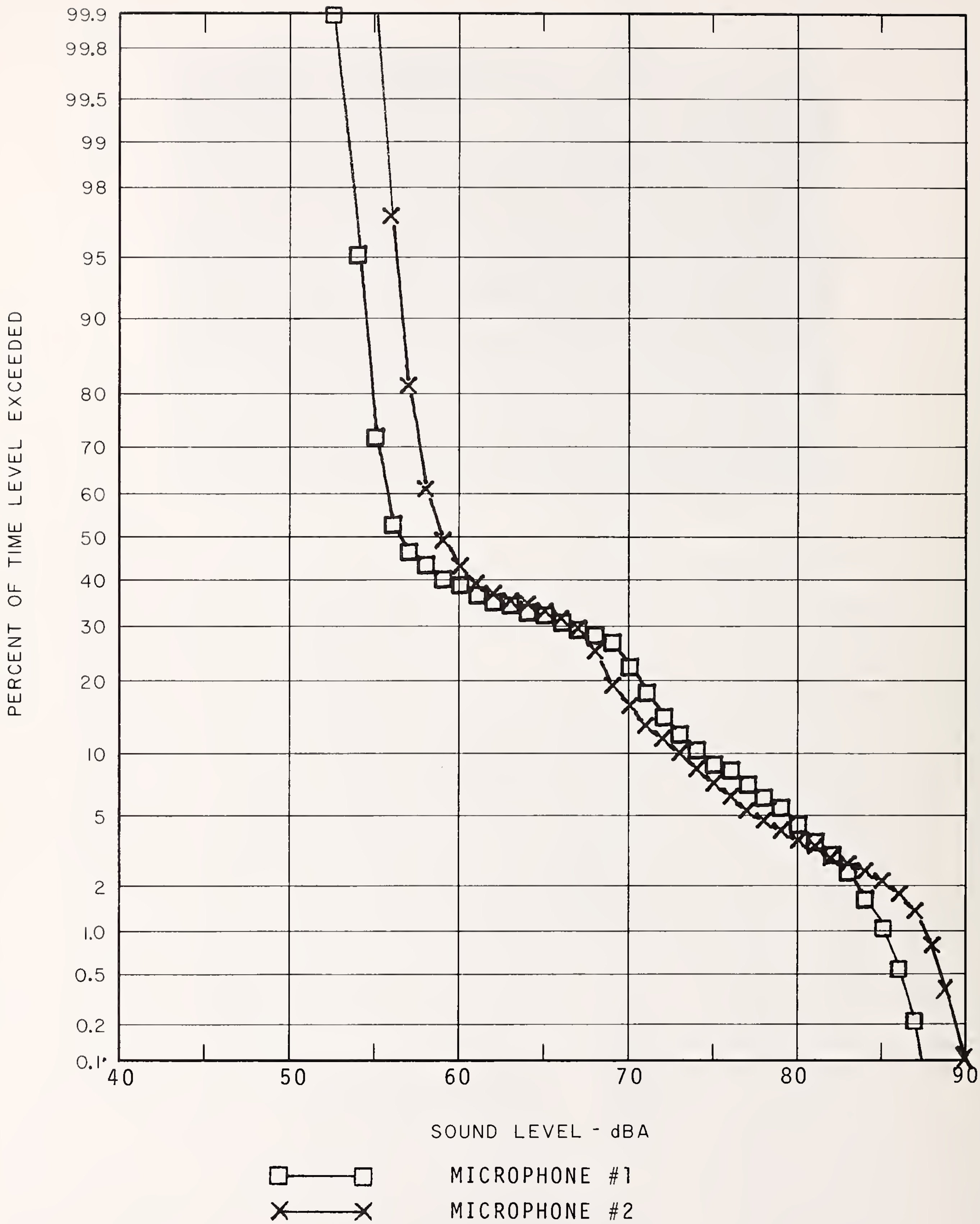


FIGURE 5.38b STATISTICAL DISTRIBUTIONS FOR 19TH STREET SUBWAY STATION LOWER LEVEL PLATFORM.

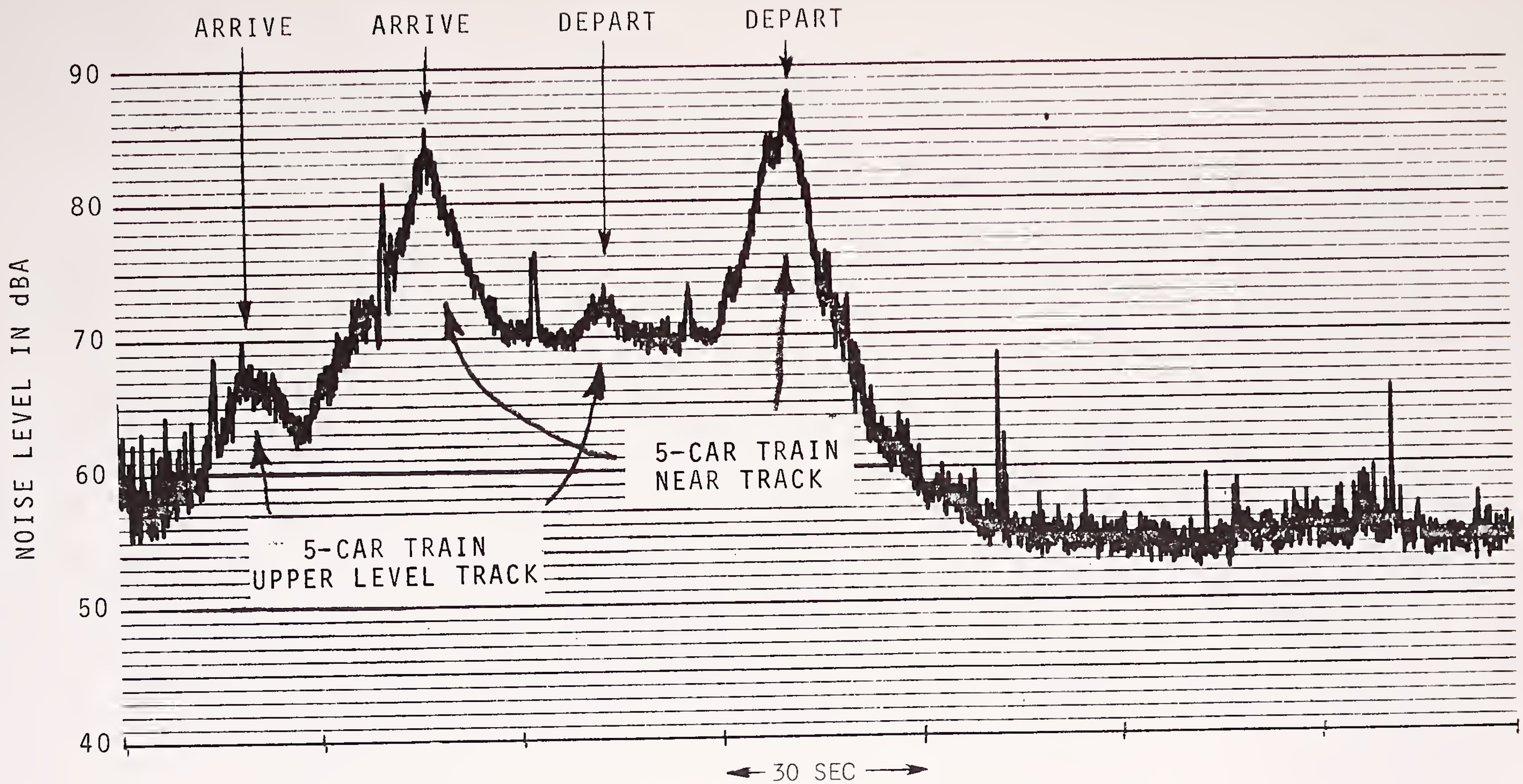


FIGURE 5.33c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT 19TH STREET STATION LOWER LEVEL PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

CIVIC CENTER STATION - Subway Station in San Francisco, Center Platform, Two Track, Single Level

<u>DESCRIPTION</u> (See Figure 5.39a)

Civic Center Station is located in the central business district of San Francisco and serves the Daly City-Concord and Daly City-Fremont trains. The Station is treated with acoustical materials on the ceiling area, underplatform area, and the wall area opposite the track. Two microphones were set up on the Daly City train side of the platform: one at the middle and one at the leading end of the stopped train.

<u>NOISE CLIMATE</u> (See Table 5.34, Figures 5.39b-c)

The residual noise level in the Station is about 53 dBA in the absence of trains. The measurement also indicates that the center of the platform area has a slightly higher background noise level than the end of the platform area. However, the departures of the near track [Daly City] trains and the arrivals of the far track [inbound] trains are significantly higher in noise levels and thus bring L_1 and L_{10} higher at the end of platform position. L_{EQ} at the end of the platform is also 3 dBA higher than that at the center of the platform.

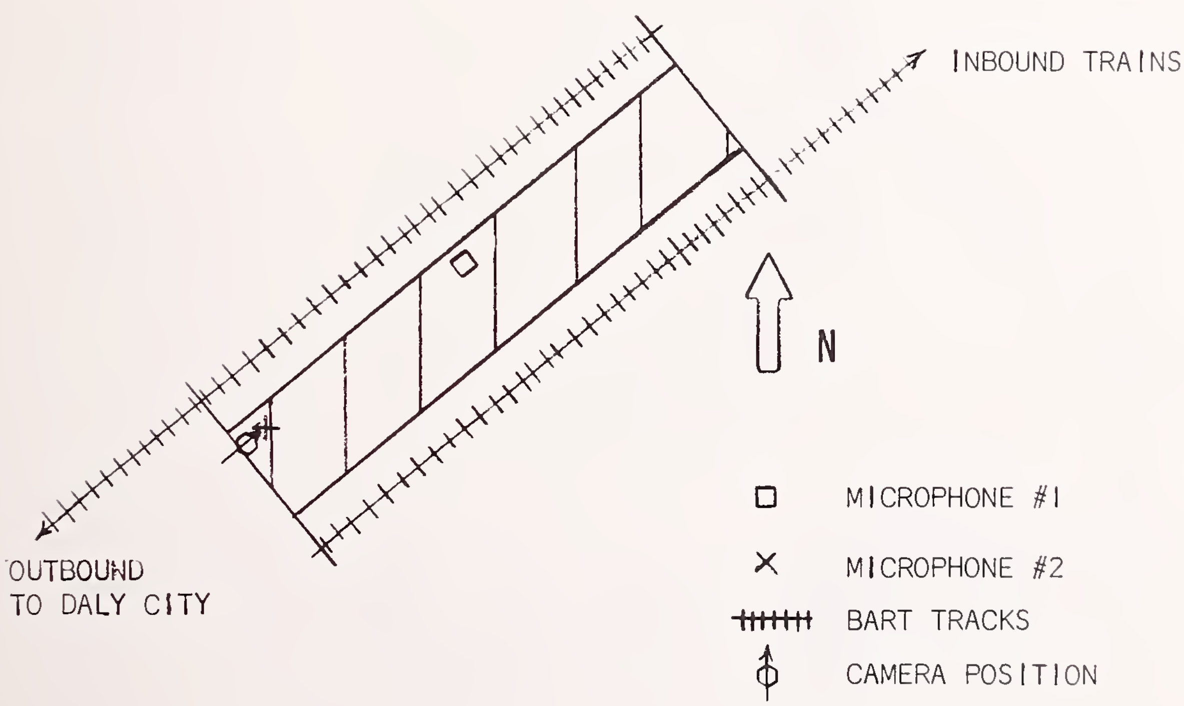


FIGURE 5.39a CIVIC CENTER SUBWAY STATION PLATFORM CONFIGURATION AND MICROPHONE POSITIONS.

TABLE 5.34 SUMMARY OF MEASUREMENT RESULTS FOR 30 MINUTE NOISE SAMPLES AT CIVIC CENTER STATION PLATFORM

NAME OF STATION: Civic Center Station

Station Type: Subway ; Platform Type: Center ; Location: Central Business District

Date: 4/3/75 ; Starting Time: 11:28 a.m. ; Temp.: 60 °F

TRAIN SUMMARY		MICROPHONE POSITION	AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
			TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK		NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Arrive & Depart	Arrive & Depart	Center of Platform	81 *1.40*	74 *0.74*	82 *2.77*	80 *1.02*	54	55	59	72	80	69
Five 5-car	Five 5-car	Leading End of Platform	74 1.27	81 0.70	90 2.70	77 1.67	52	53	60	74	85	72

Standard Deviation of level

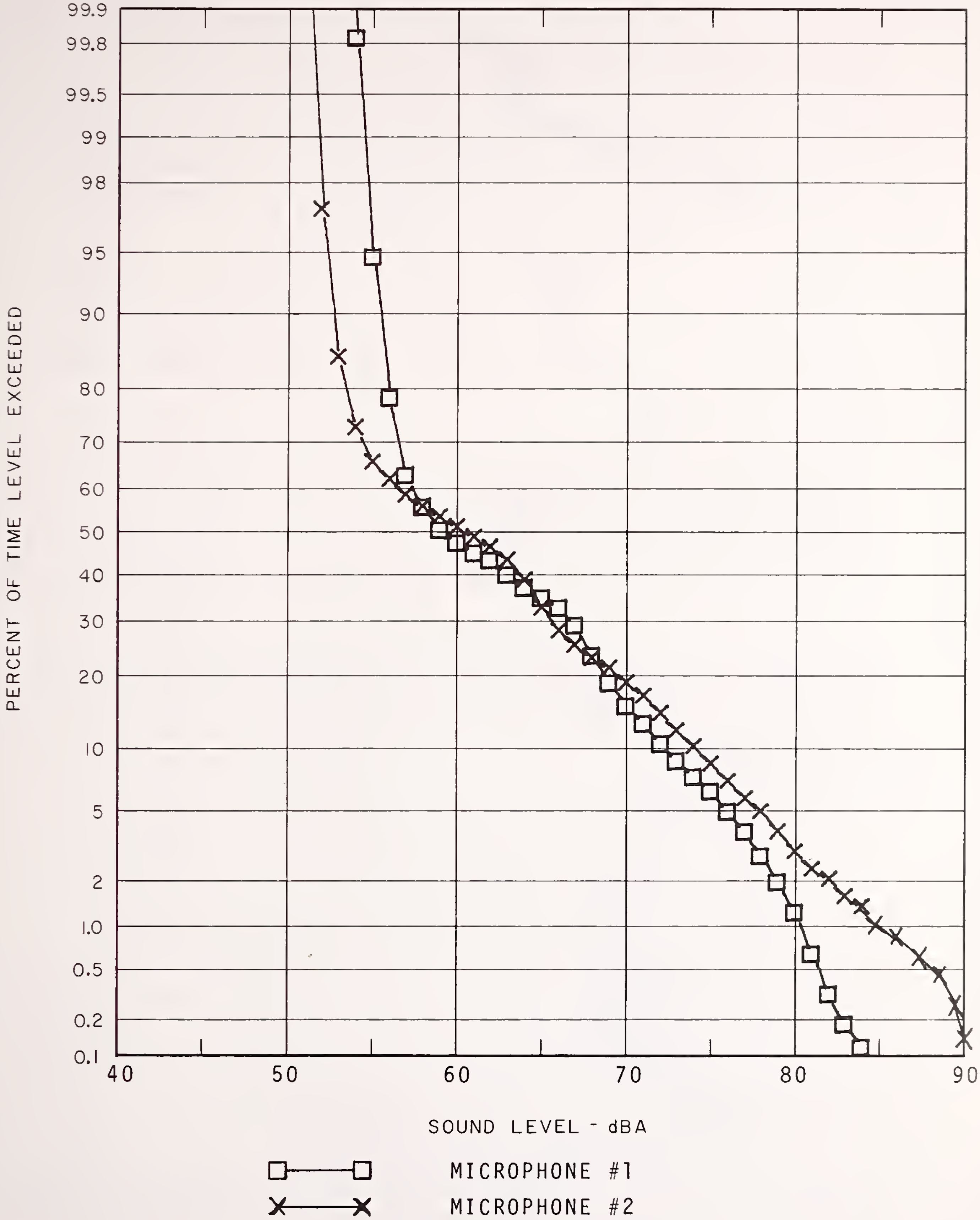


FIGURE 5.39b STATISTICAL DISTRIBUTIONS FOR CIVIC CENTER SUBWAY STATION PLATFORM.

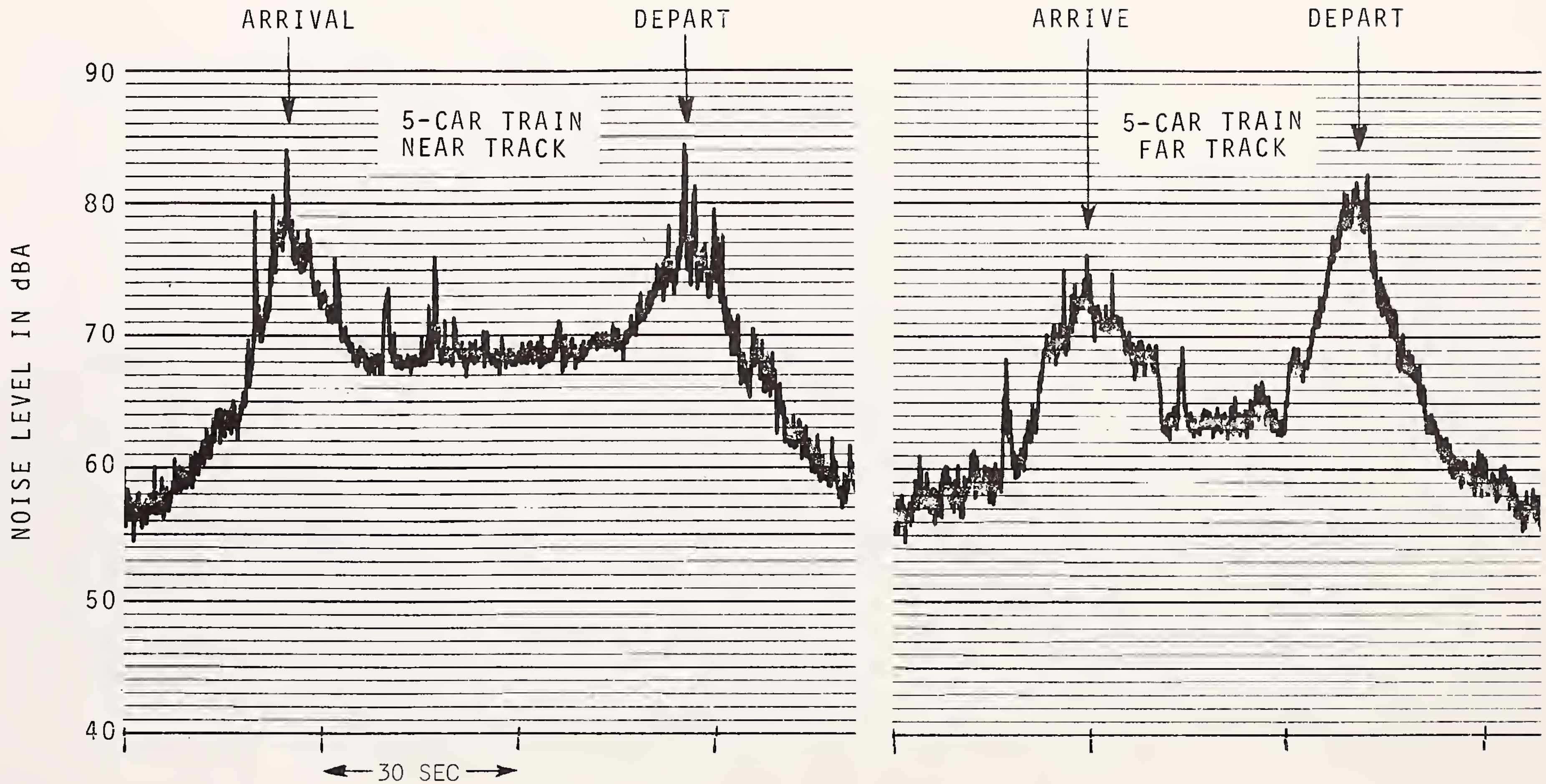


FIGURE 5.39c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT CIVIC CENTER STATION PLATFORM.

MIDDLE OF STOPPED TRAIN
2 METERS FROM PLATFORM EDGE

TORONTO TRANSIT COMMISSION - UNTREATED STATIONS*

Spadina Station - Subway Station, two track, side platform
Bay Station - Subway Station, two track, center platform
Bloor Station - Subway Station, two track, side platform

DESCRIPTION (See Figure 5.40a)

These three stations are all subway stations without acoustical treatment located on the Bloor-Danforth Line.

NOISE CLIMATE (See Table 5.35, Figures 5.40b-c)

Examination of the statistical data from the noise samples made at these TTC untreated stations shows that the maximum noise levels are, in general, greater than the noise levels from the BART trains. However, in several cases, the residual background noise is lower in the TTC stations than it is in the BART stations.

Although the statistical distribution of the data obtained on the Bloor Station platform is considerably different than those obtained for the other two untreated stations [especially in the L_{20} to $L_{99.9}$ range], the L_{EQ}'s obtained for these three stations are within 3 dBA.

*Source: Unpublished data from Wilson, Ihrig & Associates, 3/75.

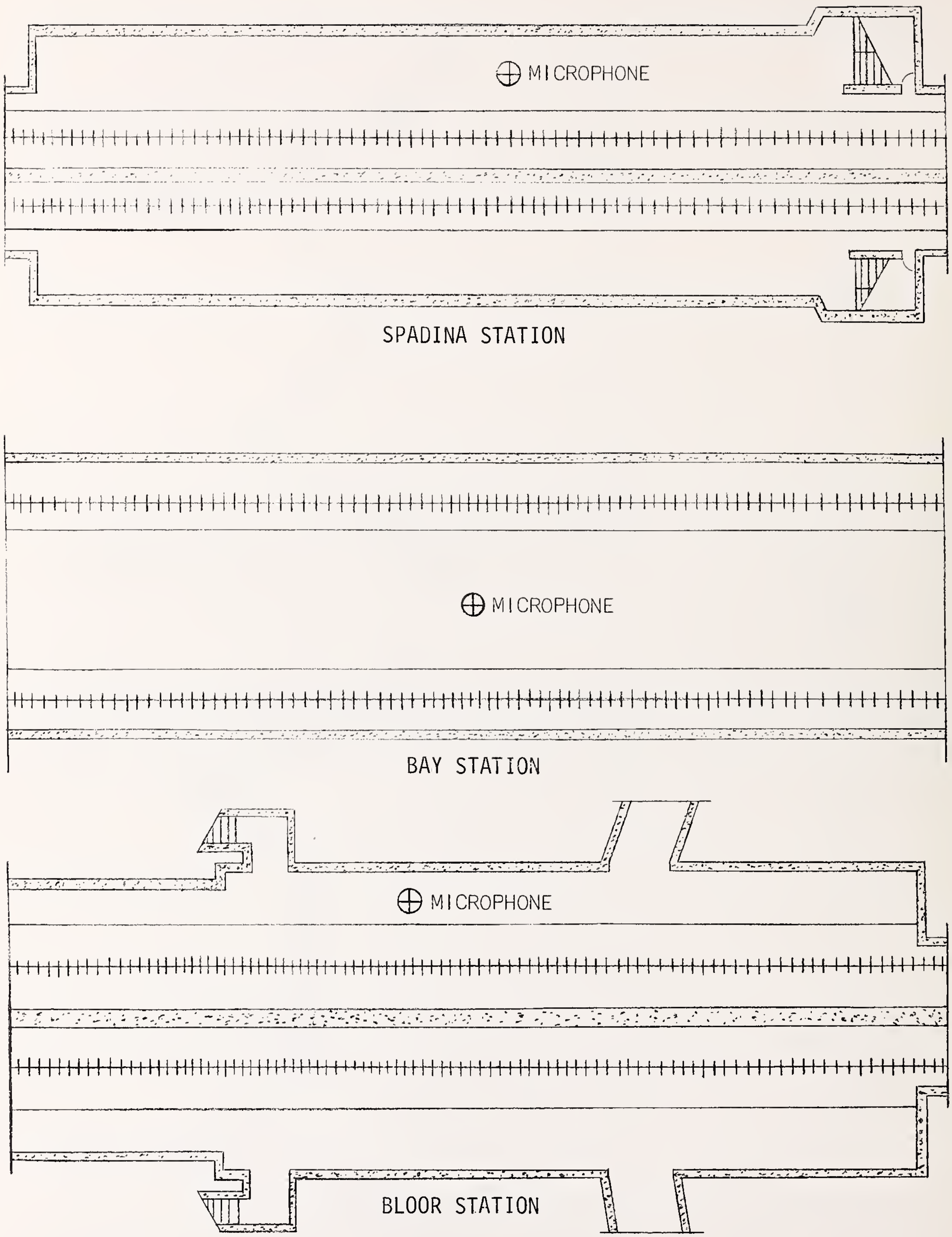


FIGURE 5.40a CONFIGURATIONS AND MICROPHONE LOCATIONS FOR NOISE SAMPLES AT TORONTO TRANSIT COMMISSION SUBWAY STATION PLATFORMS WITHOUT ACOUSTICAL TREATMENT

TABLE 5.35 SUMMARY OF RESULTS FOR NOISE SAMPLES AT TORONTO TRANSIT COMMISSION SUBWAY STATION PLATFORMS WITHOUT ACOUSTICAL TREATMENT

Spadina Station Platform Type: Side Date: 3/6/75 Starting Time: 11:00 a.m. Length of Sample: 22.4 mins

TRAIN SUMMARY		AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
		TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
4	4	90 *1.15	86 *1.15	91 *.58	87 *1.53	50	51	58	84	89	79

Bay Station Platform Type: Center Date: 6/23/75 Starting Time: 10:10 a.m. Length of Sample: 30.0 mins

TRAIN SUMMARY		AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
		TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
4	8	82 *1.89	86 *2.56	88 *1.50	83 *2.19	47	48	56	81	88	76

Bloor Station Platform Type: Side Date: 3/6/75 Starting Time: 10:30 a.m. Length of Sample: 17.4 mins

TRAIN SUMMARY		AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
		TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
5	5	86 *.96	84 *1.29	86 *1.83	84 *.82	53	58	73	83	88	78

** Standard Deviation of level*

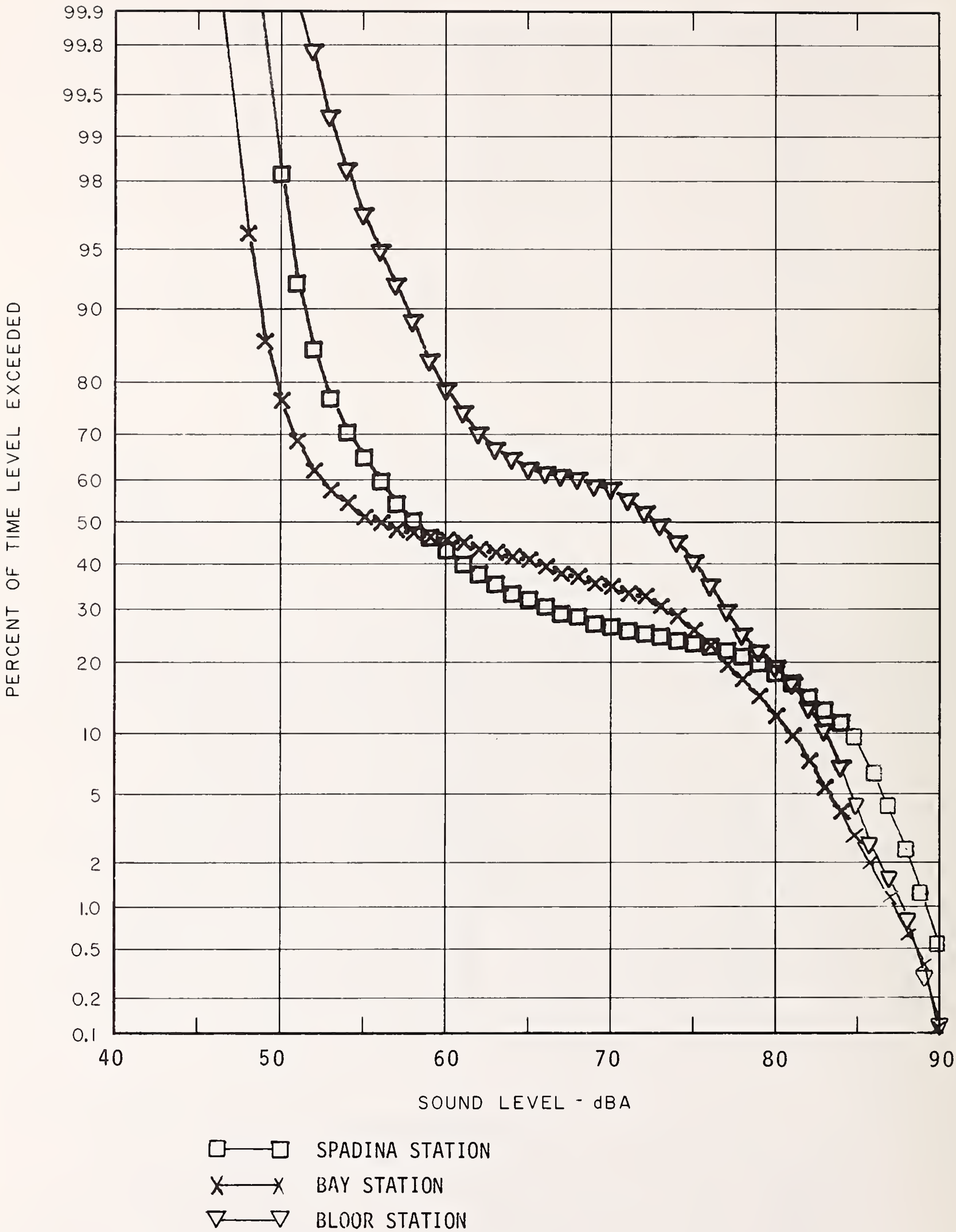
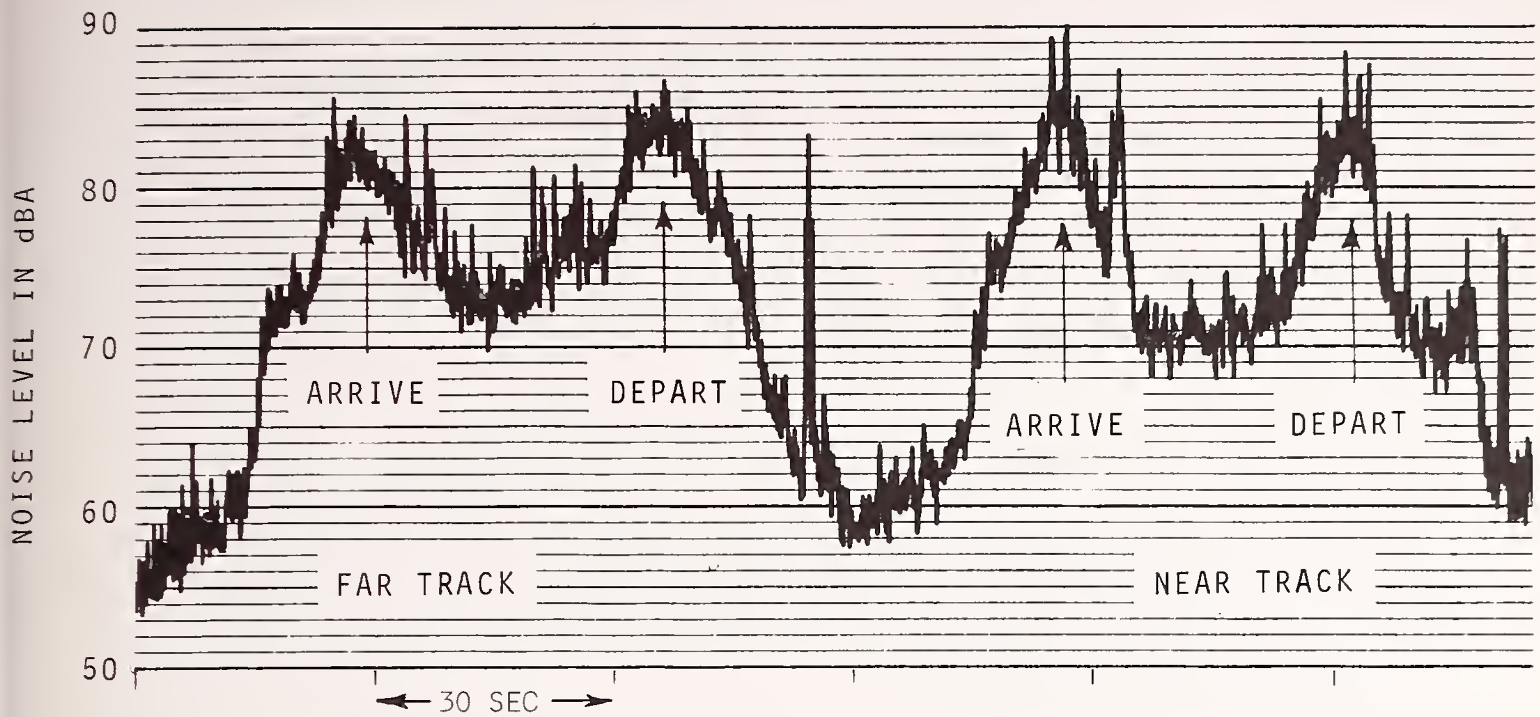
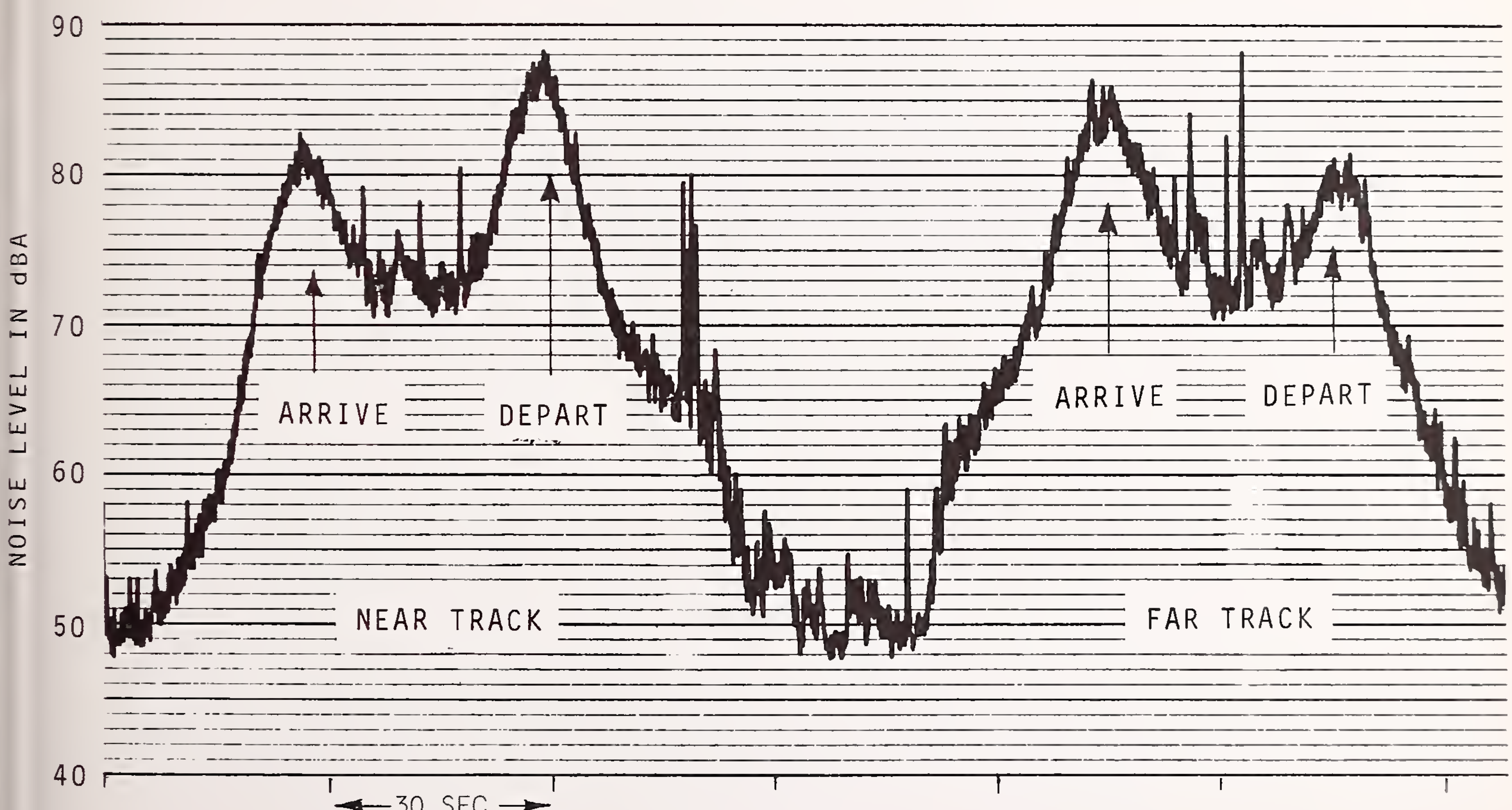


FIGURE 5.40b STATISTICAL DISTRIBUTIONS OF TORONTO TRANSIT COMMISSION SUBWAY STATION PLATFORMS WITHOUT ACOUSTICAL TREATMENT



BLOOR STATION



BAY STATION

FIGURE 5.40c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT BLOOR AND BAY STATION PLATFORMS

TORONTO TRANSIT COMMISSION - TREATED STATIONS

Yonge Station Lawrence Station York Mills Station	Subway Stations, two track, center platform

DESCRIPTION (See Figure 5.41a)

The three stations listed above are all center platform subway stations with acoustical treatment located on the Yonge Street Line. The Lawrence Station and the York Mills Station have sprayed-on acoustical treatment. The Yonge Station has suspended acoustical tile.

NOISE CLIMATE (See Table 5.36, Figure 5.41b-c)

Examination of the statistical data shows that, in general, the noise levels in these treated stations are greater than those obtained in the BART stations. When compared with the untreated TTC stations, the Lawrence and York Mills Stations exhibit little difference in the statistical noise levels obtained. However, the Yonge Station does exhibit a markedly different distribution of noise levels [see Figure 5.41b] and has an L_{EQ} 5 to 8 dBA less than that obtained at any of the other treated or untreated TTC stations.

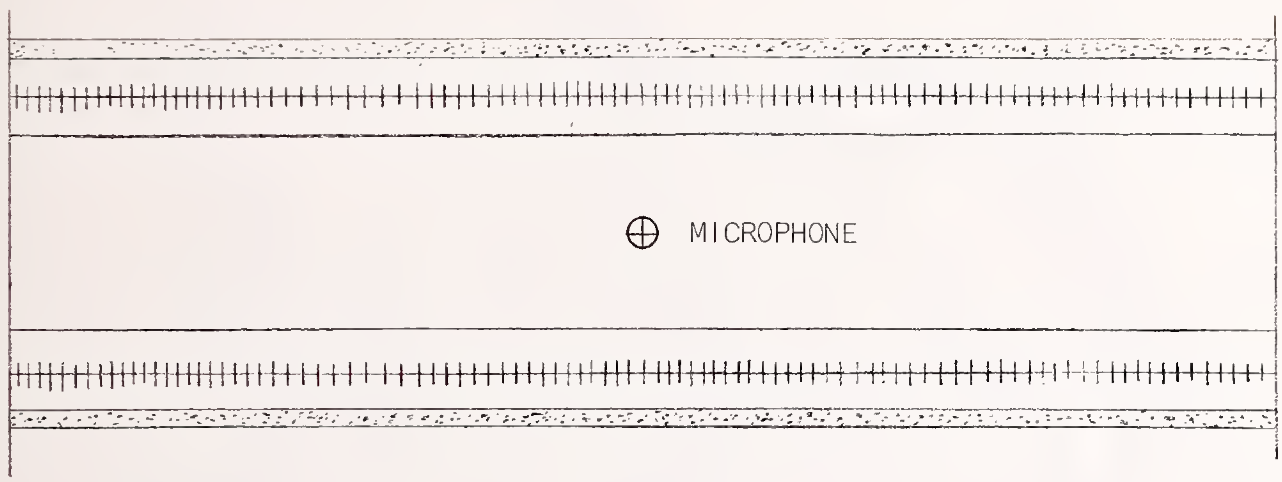


FIGURE 5.41a CONFIGURATION AND MICROPHONE LOCATION FOR NOISE SAMPLES AT TORONTO TRANSIT COMMISSION SUBWAY STATION PLATFORMS WITH ACOUSTICAL TREATMENT

TABLE 5.36 SUMMARY OF RESULTS FOR NOISE SAMPLES AT TORONTO TRANSIT COMMISSION SUBWAY STATION PLATFORMS WITH ACOUSTICAL TREATMENT

Yonge Station Platform Type: Center Date: 6/23/75 Starting Time: 11:08 a.m. Length of Sample: 26.7 mins

TRAIN SUMMARY		AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
		TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
6	4	79 *2.45	82 *4.04	82 *2.41	79 *2.65	56	57	61	74	82	71

Lawrence Station Platform Type: Center Date: 6/23/75 Starting Time: 11:52 a.m. Length of Sample: 21.0 mins

TRAIN SUMMARY		AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
		TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
7	7	86 *3.38	84 *2.25	84 *2.40	83 *3.27	50	51	59	82	88	78

York Mills Station Platform Type: Center Date: 6/25/75 Starting Time: 1:51 p.m. Length of Sample: 24.2 mins

TRAIN SUMMARY		AVERAGE MAXIMUM LEVEL [dBA]				STATISTICAL DESCRIPTOR [dBA]					
		TRAIN ARRIVING ON		TRAIN DEPARTING ON							
NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	NEAR TRACK	FAR TRACK	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
7	7	83 *2.73	82 *1.51	82 *1.0	82 *.98	48	50	69	82	86	77

** Standard Deviation of level*

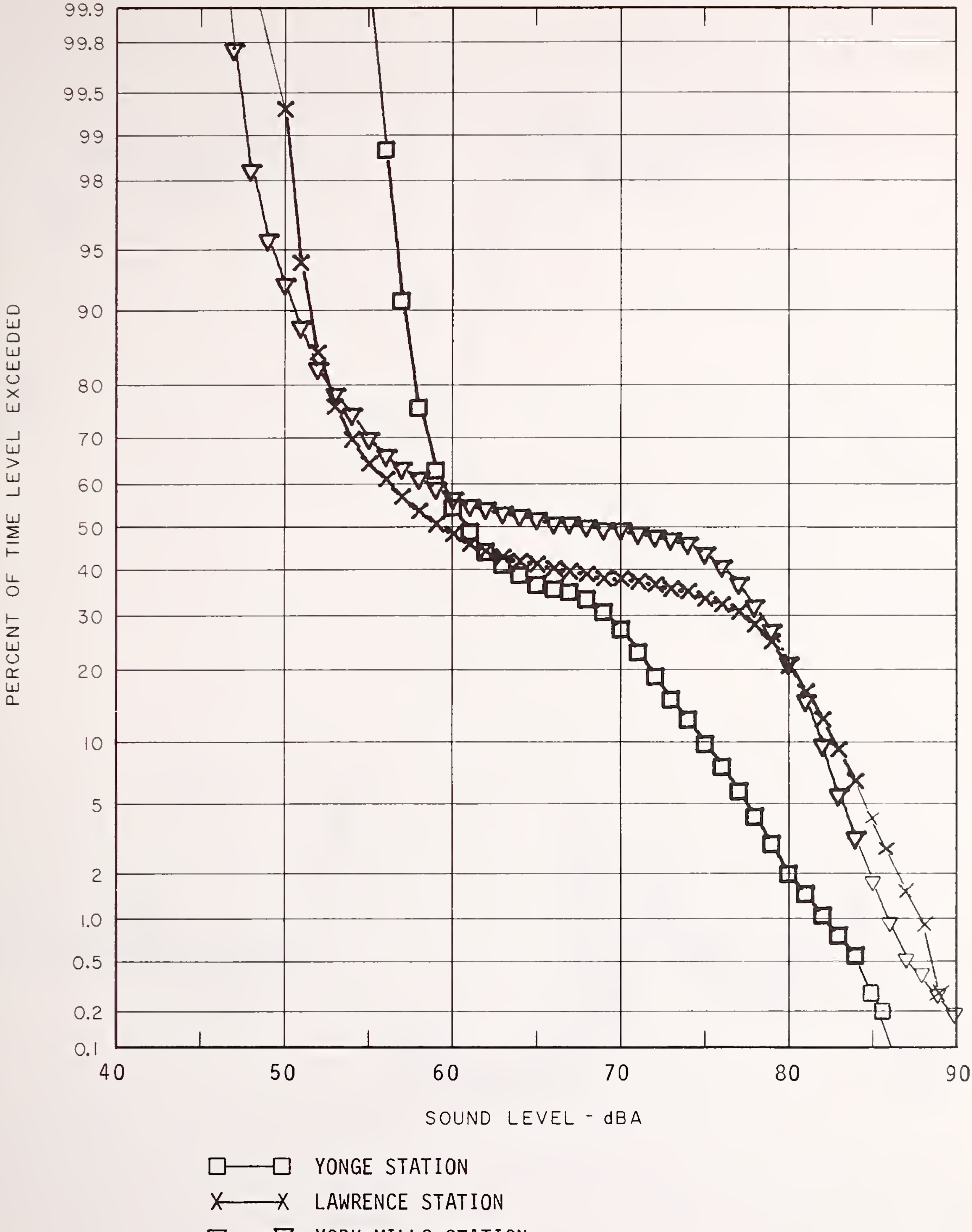
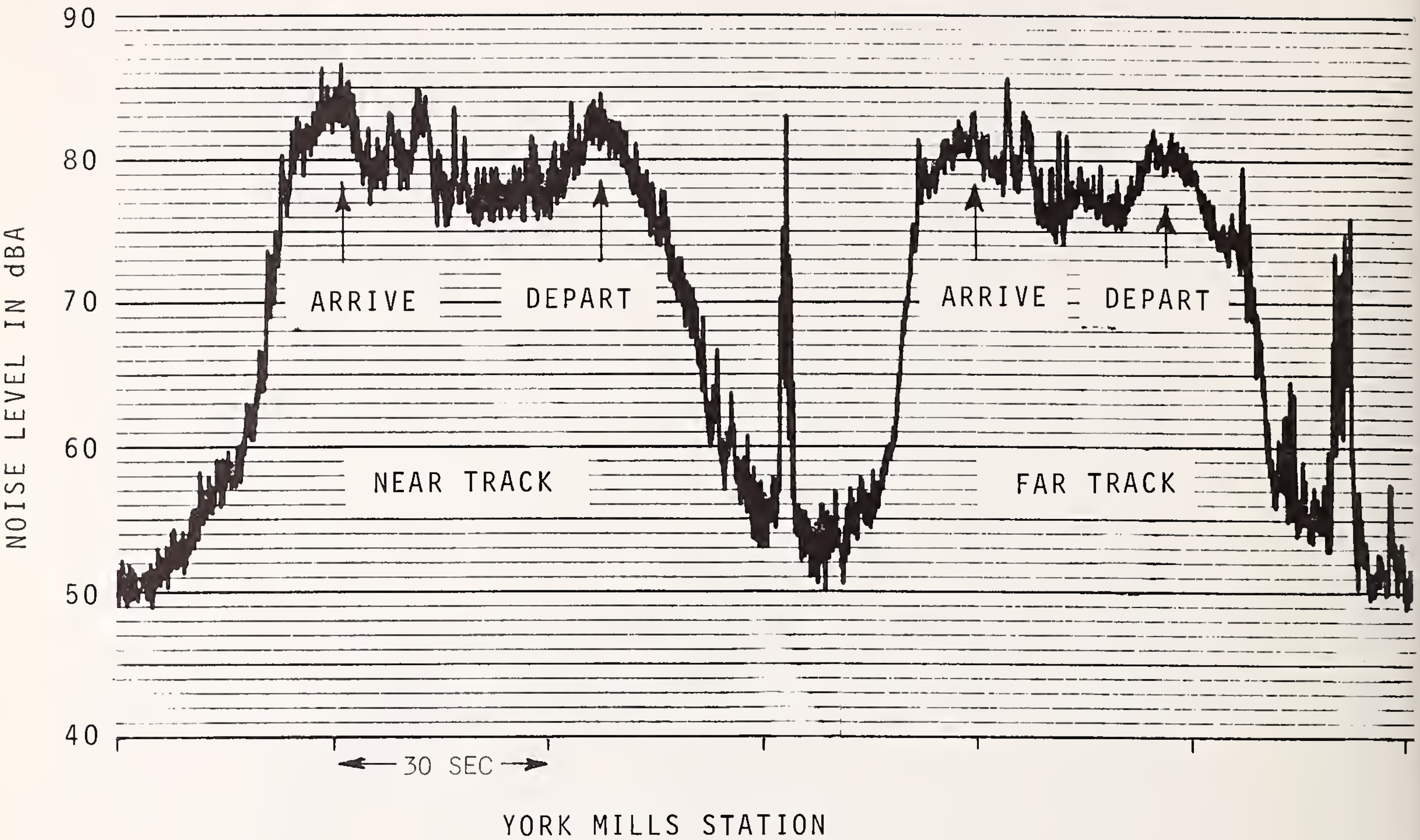


FIGURE 5.41b STATISTICAL DISTRIBUTIONS OF TORONTO TRANSIT COMMISSION SUBWAY STATION PLATFORMS WITH ACOUSTICAL TREATMENT



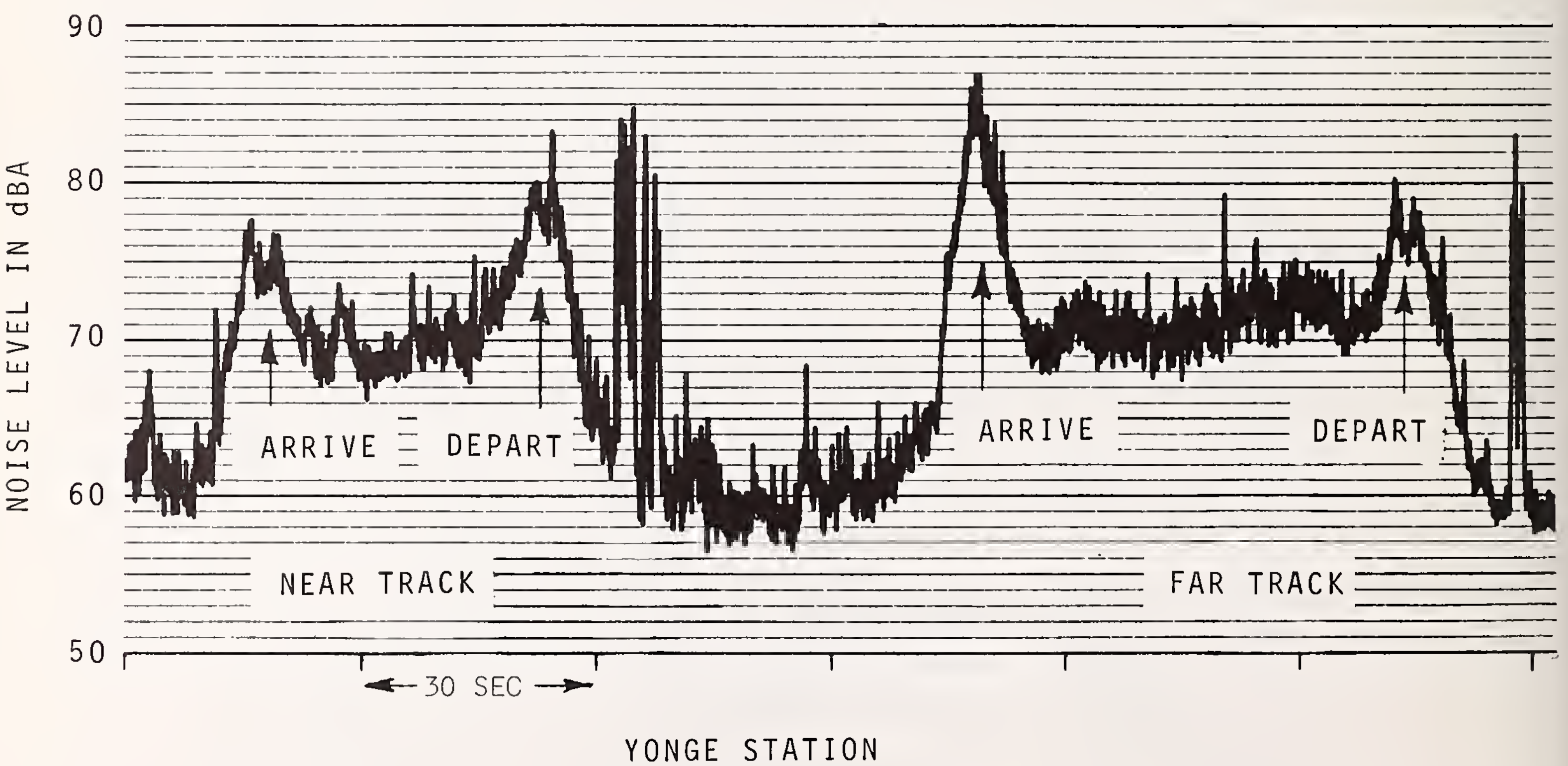


FIGURE 5.41c TYPICAL TRACES OF TRAIN ARRIVAL AND DEPARTURE AT YORK MILLS AND YONGE STATION PLATFORMS.

NOISE MEASUREMENTS INSIDE STATION AGENT'S BOOTH

The following data are provided for each station information booth:

[1] Statistical distribution curves for the 30 minute noise samples.

[2] A sample strip chart trace showing typical noise exposure.

[3] A summary table of the statistical measures of each noise sample [L_1, L_{10}, L_{50}, L_{90} and L_{99}, L_{EQ}].

[4] A short description of the important features and identification of the major components of noise at each information booth.

SUMMARY OF NOISE MEASUREMENTS INSIDE STATION AGENT'S BOOTH

		Statistical Descriptors [dBA]					
Station	Booth Location	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
Rockridge	Concourse Level [Below Track Level]	50	51	60	64	72	62
Walnut Creek	Street Level [Below Track Level]	59	60	62	66	74	64
Richmond	Track Level	49	50	52	63	73	61
Lake Merritt	Concourse Level [Above Track Level]	57	58	61	71	79	68
19th Street	Concourse Level [Above Track Level]	56	57	59	68	77	66

ROCKRIDGE STATION INFORMATION BOOTH (See Figures 5.42a-b)

At the Rockridge Station the "station agent's" or information booth is located on the concourse level which is directly below the track and platform level. The escalator and stair openings to the platform level are good paths for the train noise to be transmitted to the information booth. The noise trace shows that the noise generated by the train arrivals and departures is audible and does contribute to the noise exposure of the agent. Announcements from the PA system constitute another prominent noise source.

WALNUT CREEK STATION INFORMATION BOOTH (See Figures 5.43a-b)

The information booth at the Walnut Creek Station is located in the concourse area which is at street level and below the tracks and platform. The escalators and stairs provide openings for the transmission of train noise. During the measurement, the booth door was open and a heater fan was turned on inside the booth. The noise trace indicates that the noise from the train arrivals and departures is audible. Other prominent noise sources include announcements from the PA system and occasional conversation between the agent and passengers.

RICHMOND STATION DISPATCHER'S BOOTH (See Figures 5.44a-b)

The "dispatcher's" booth at the Richmond Station is located on the platform of this at-grade station. The booth window was open and air-conditioning was on during the measurement. The measurement results indicate that during the measurement period, the dispatcher was constantly talking or announcing. Noises from train arrivals and departures are quite audible due to the open window. The noise exposure as indicated by the L_{EQ} level is, however, the lowest among all the station booths.

LAKE MERRITT STATION INFORMATION BOOTH (See Figures 5.45a-b)

The information booth at the Lake Merritt Station is located on the concourse level, directly above the track level. The heater fan was on during the measurement. The escalator and stair openings provide transmission paths for the train noise. The noise traces show that the noise of train arrivals and departures is audible. Furthermore, the conversation around the booth area is relatively constant during the measurement and contributes to the noise in the booth.

19TH STREET STATION INFORMATION BOOTH (See Figure 5.46a-b)

The information booth in the 19th Street Station is located on the concourse level which is above both track levels. There was no heater operating inside the booth during the measurement. The escalator and stair openings provide transmission paths for the train noise from both train platforms. Thus, the noise generated by the train arrivals and departures is audible. Other prominent noise sources include frequent conversation near the booth and announcements from the Station PA system.

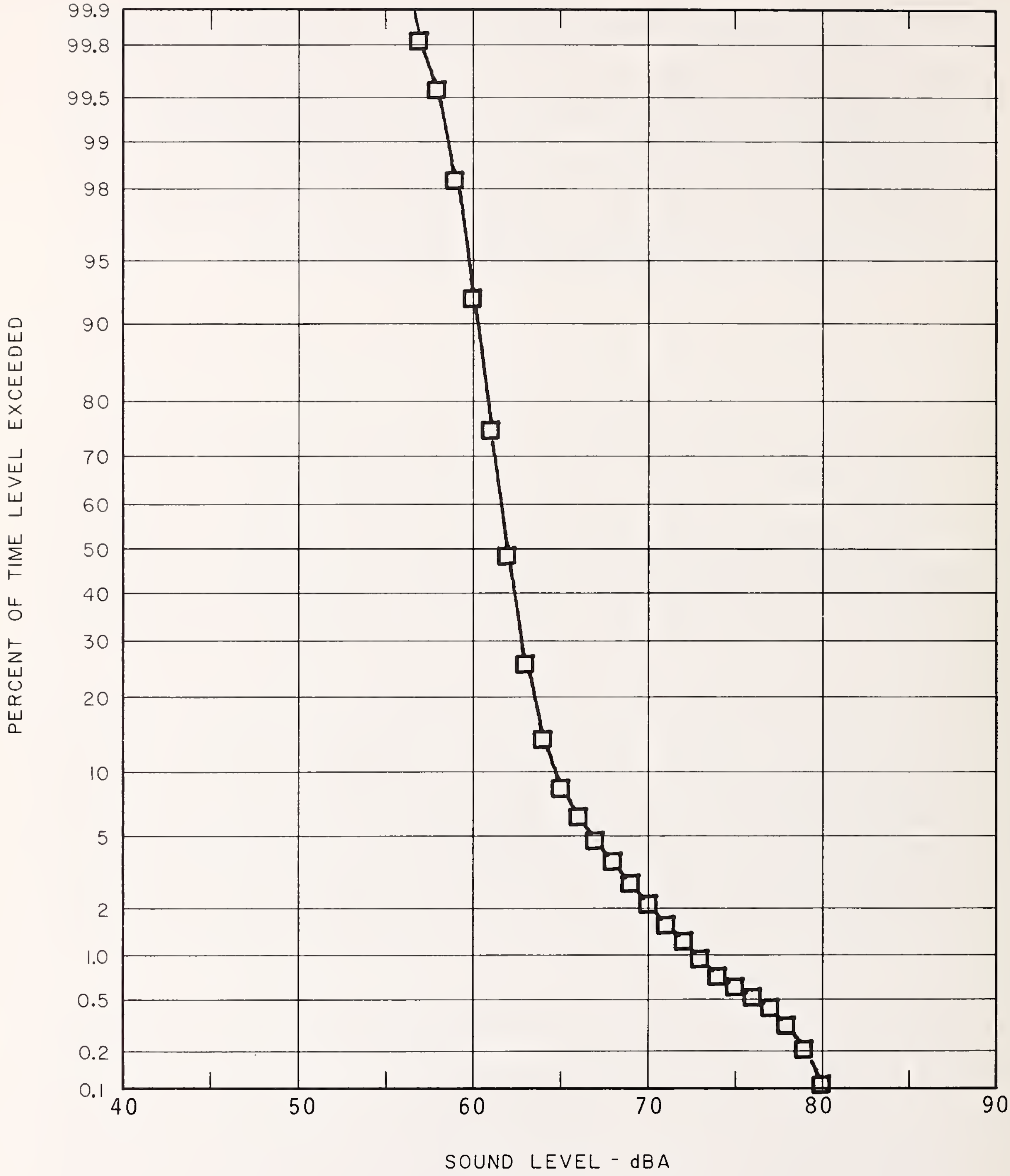


FIGURE 5.42a STATISTICAL DISTRIBUTION OF NOISE SAMPLE INSIDE INFORMATION BOOTH AT ROCKRIDGE STATION.

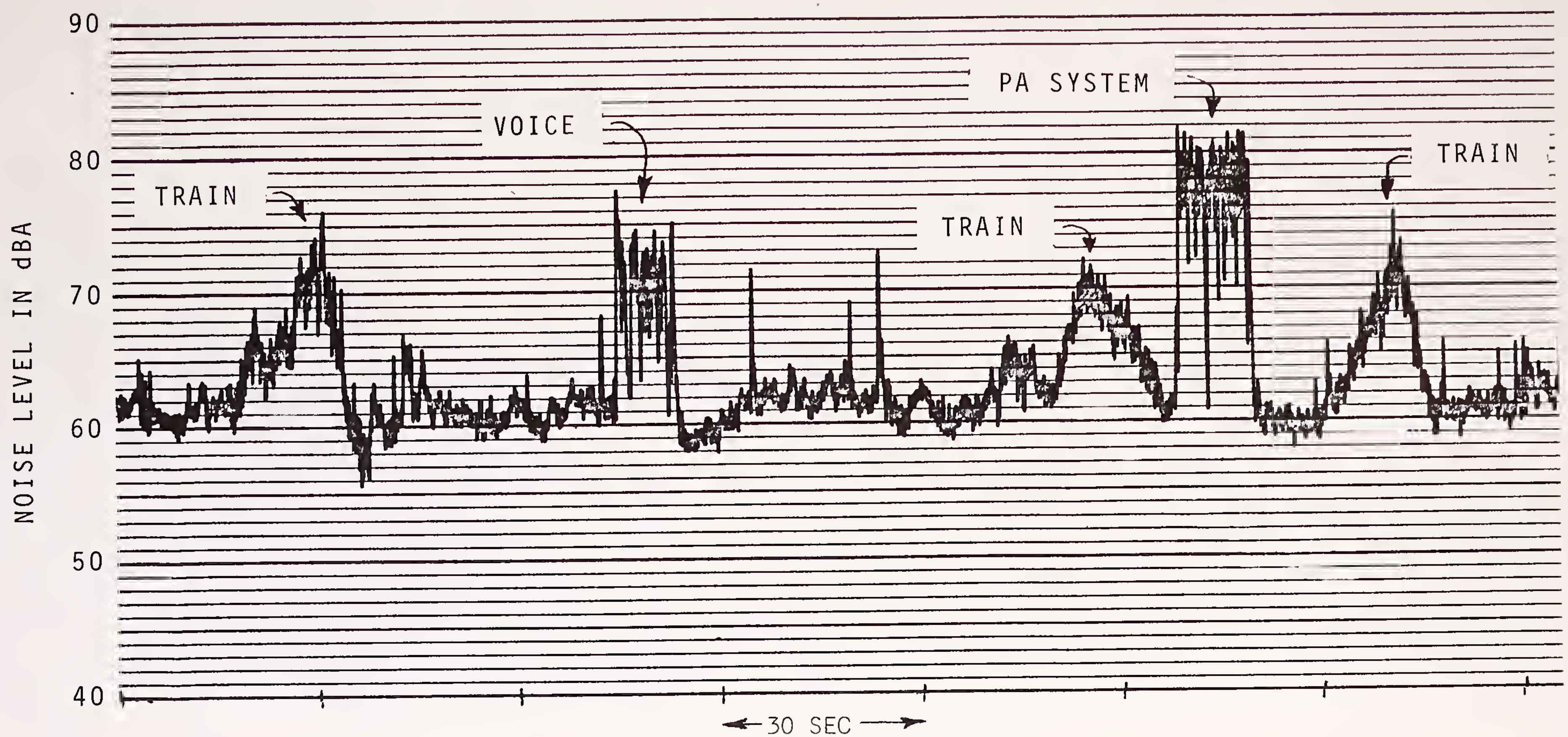


FIGURE 5.42b TYPICAL TRACE FROM NOISE SAMPLE INSIDE INFORMATION BOOTH AT ROCKRIDGE STATION.

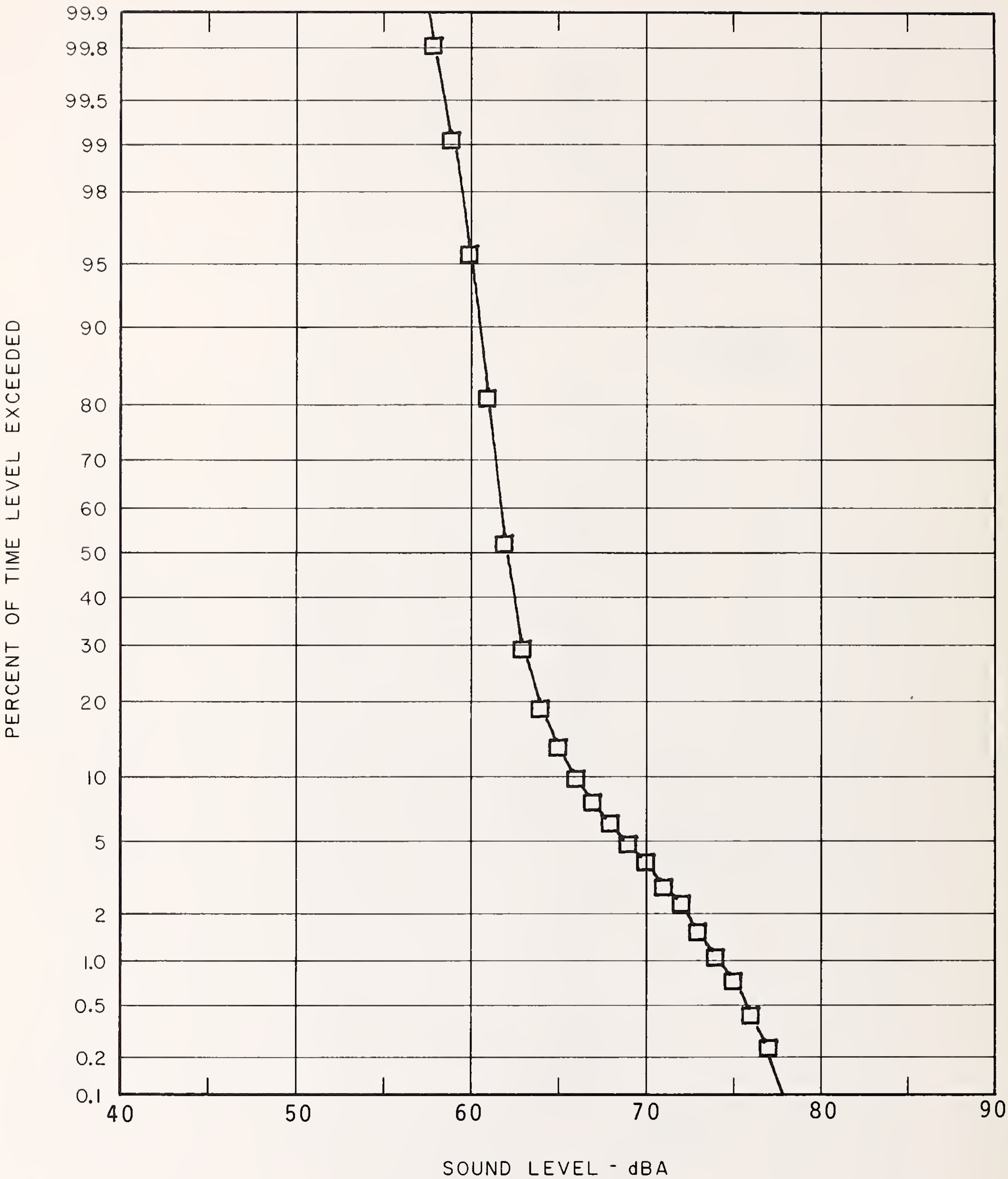


FIGURE 5.43a STATISTICAL DISTRIBUTION OF NOISE SAMPLE INSIDE INFORMATION BOOTH AT WALNUT CREEK STATION.

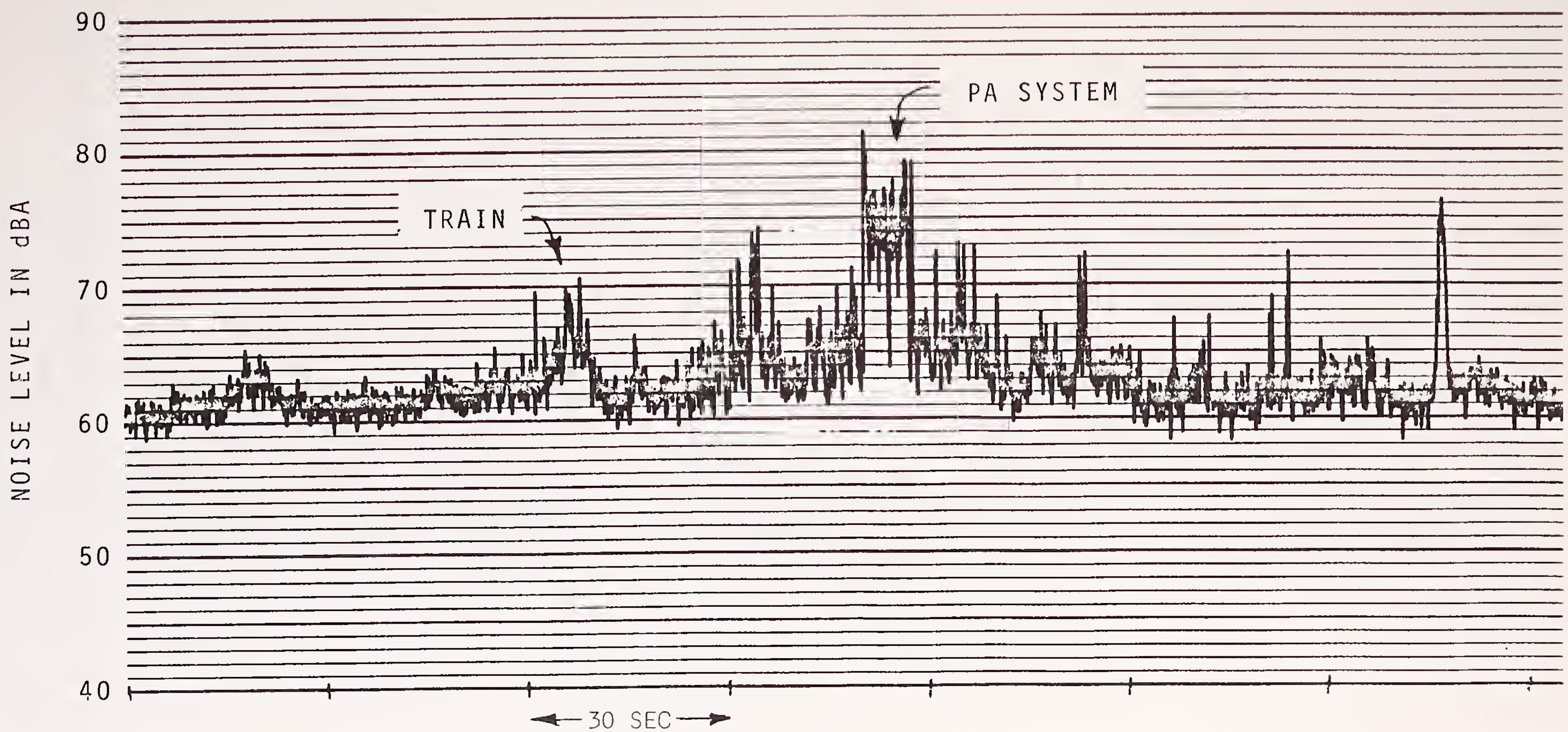


FIGURE 5.43b TYPICAL TRACE FROM NOISE SAMPLE INSIDE INFORMATION BOOTH AT WALNUT CREEK STATION.

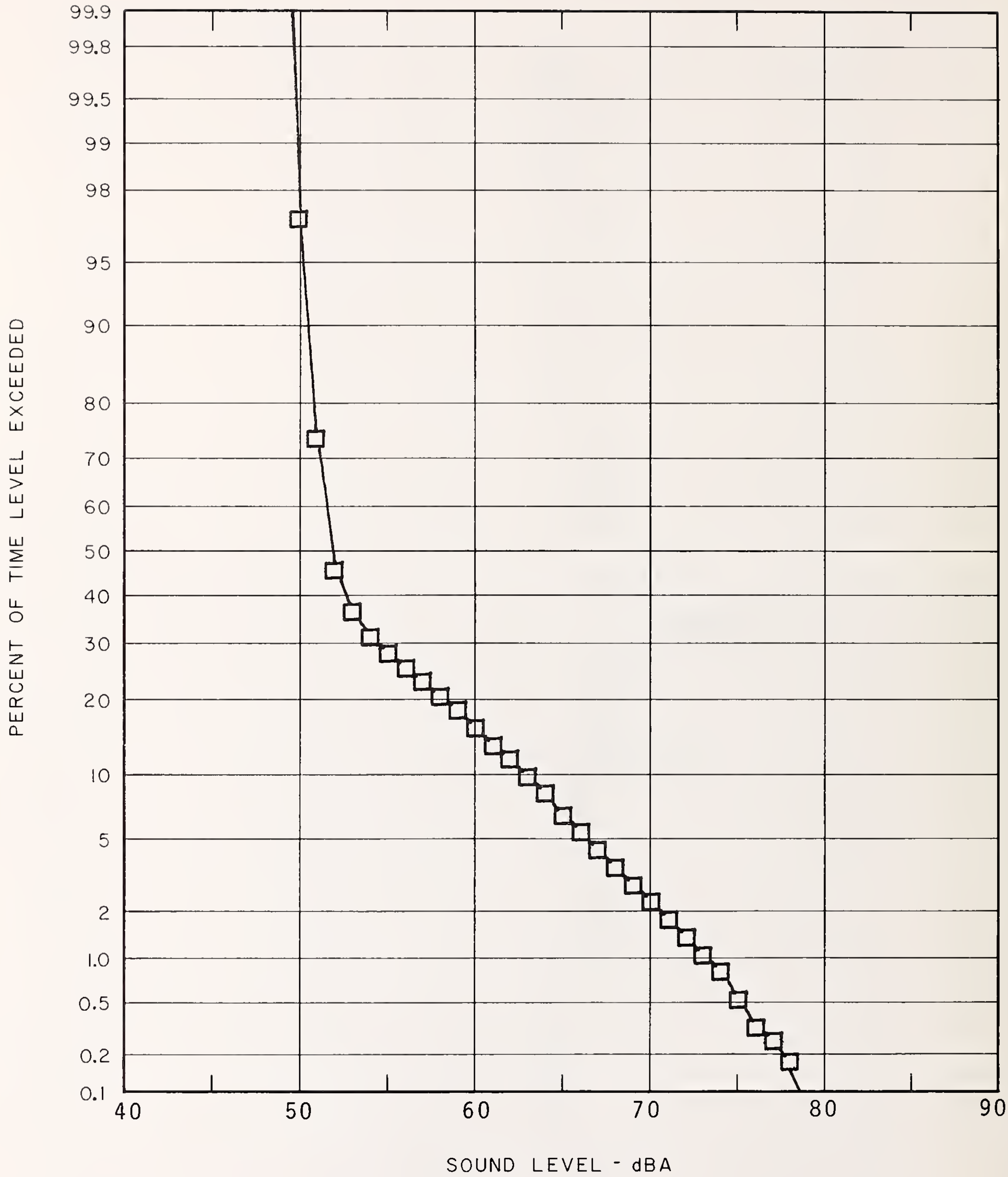


FIGURE 5.44a STATISTICAL DISTRIBUTION OF NOISE SAMPLE INSIDE DISPATCHER'S BOOTH AT RICHMOND STATION.

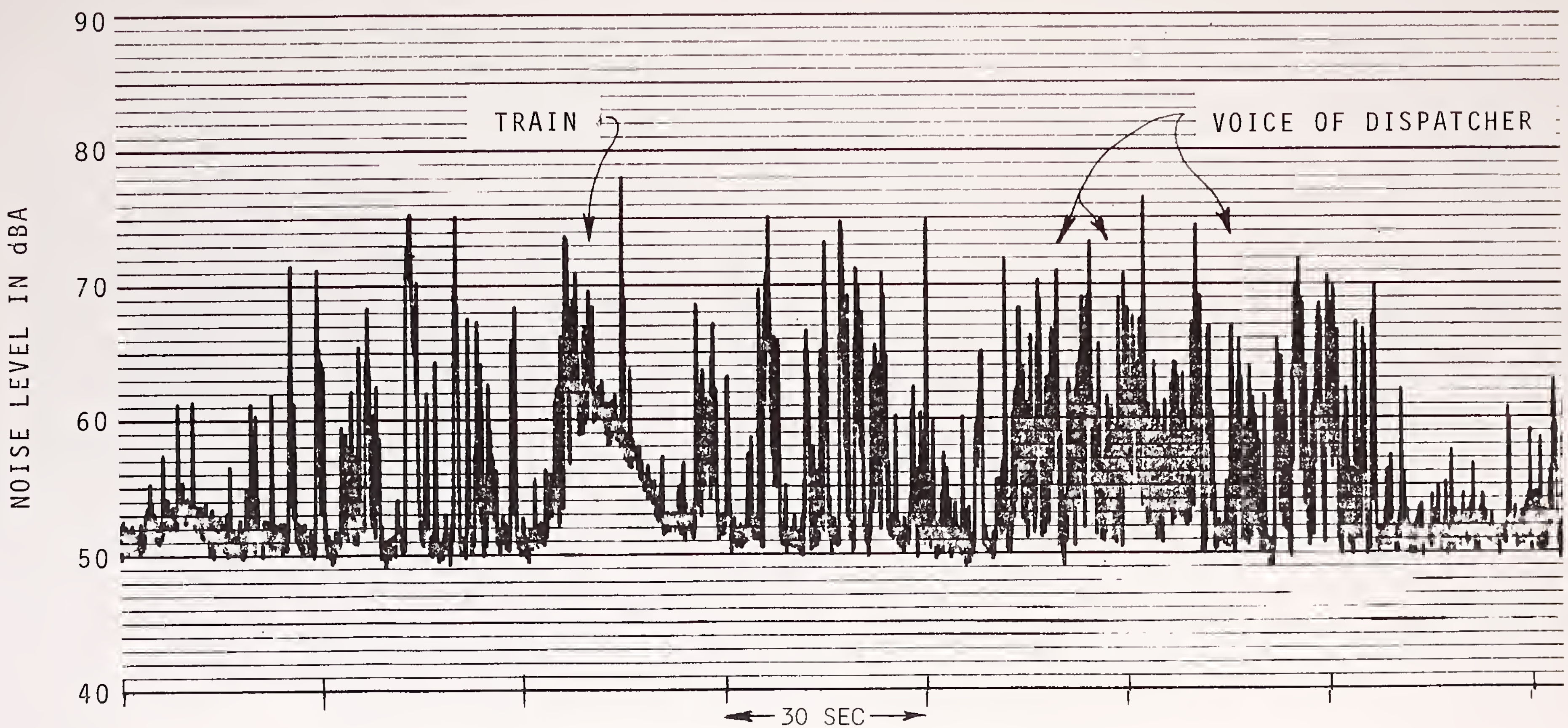


FIGURE 5.44b TYPICAL TRACE FROM NOISE SAMPLE INSIDE DISPATCHERS BOOTH AT RICHMOND STATION.

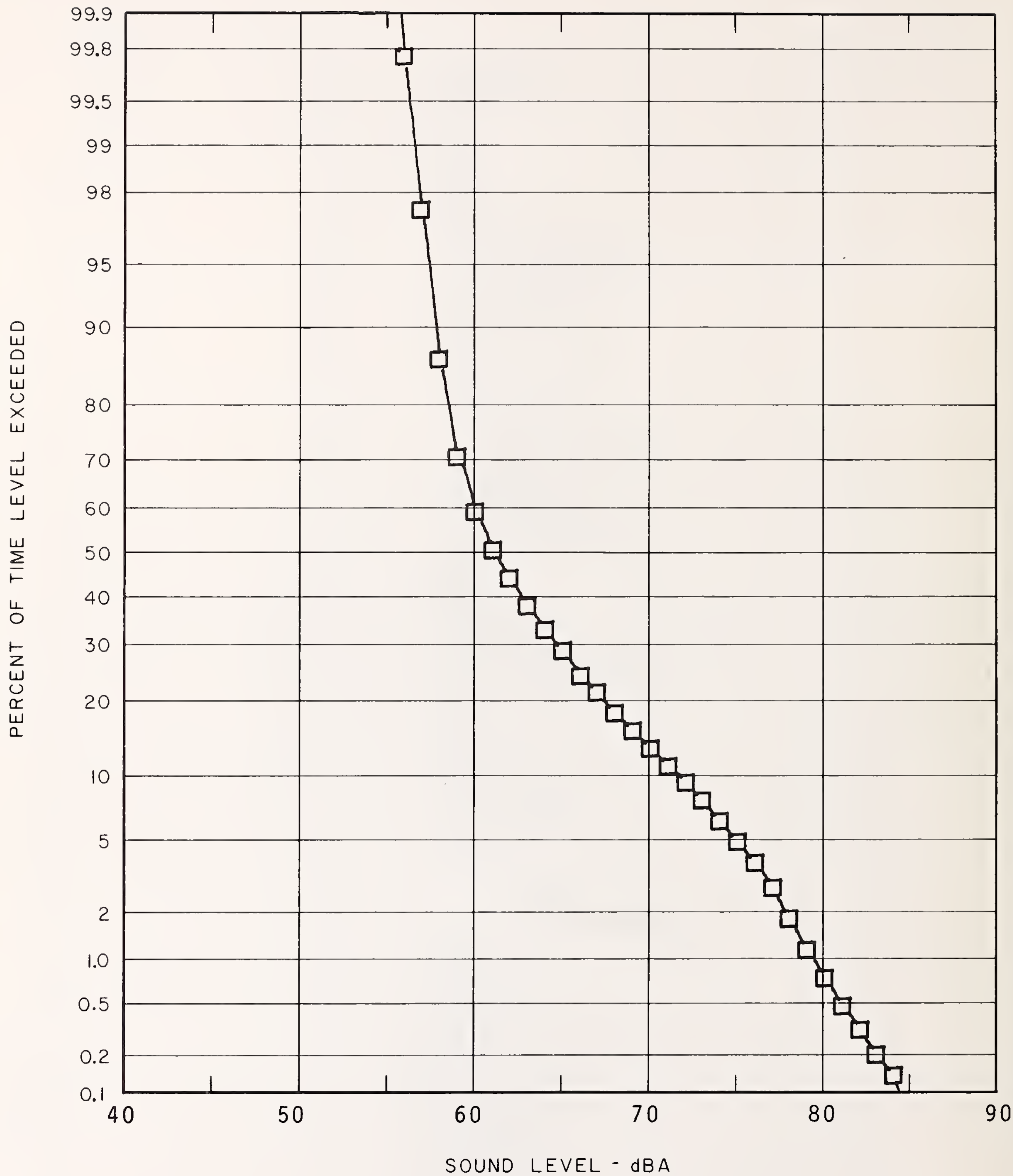


FIGURE 5.45a STATISTICAL DISTRIBUTION OF NOISE SAMPLE INSIDE INFORMATION BOOTH AT LAKE MERRITT STATION.

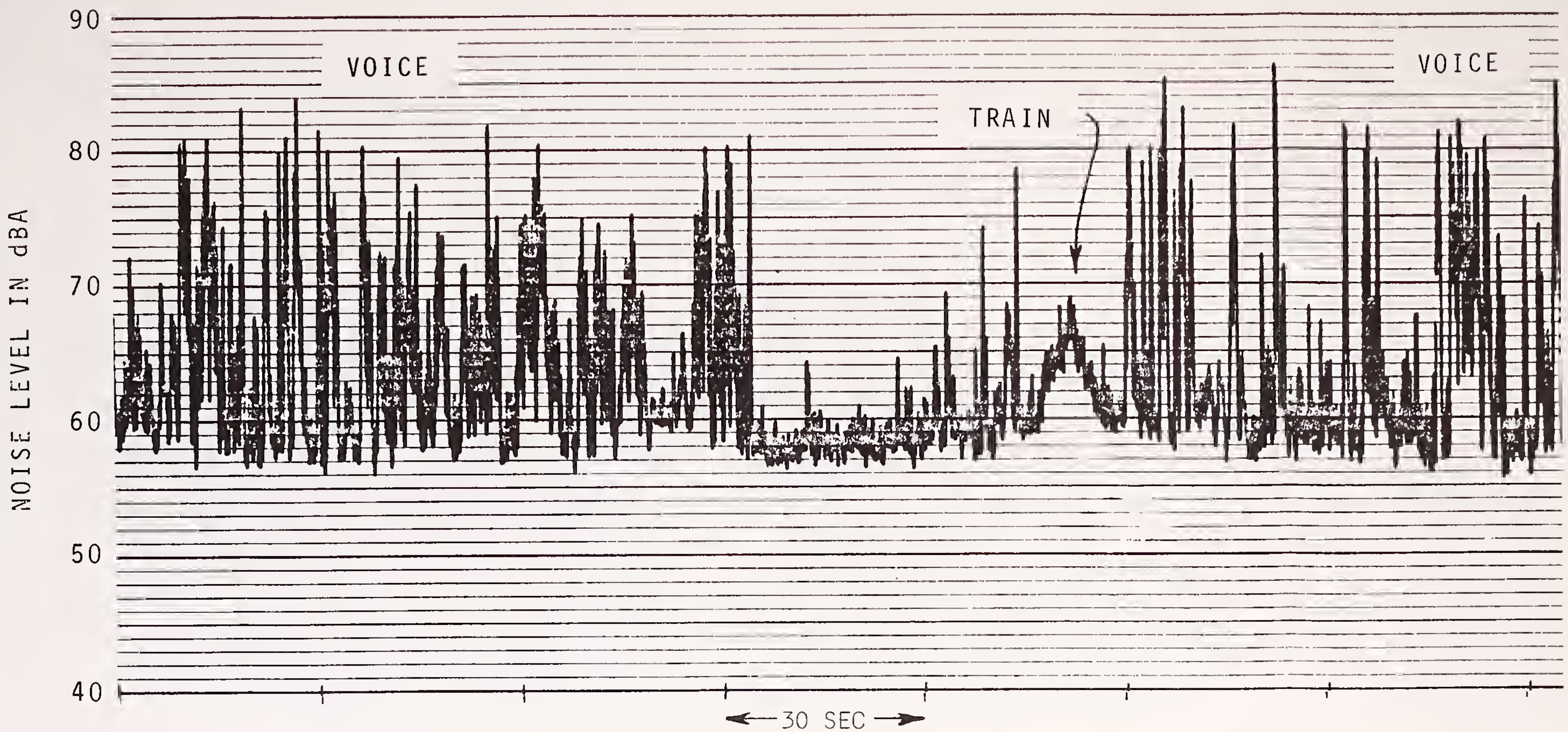


FIGURE 5.45b TYPICAL TRACE FROM NOISE SAMPLE INSIDE INFORMATION BOOTH AT LAKE MERRITT STATION.

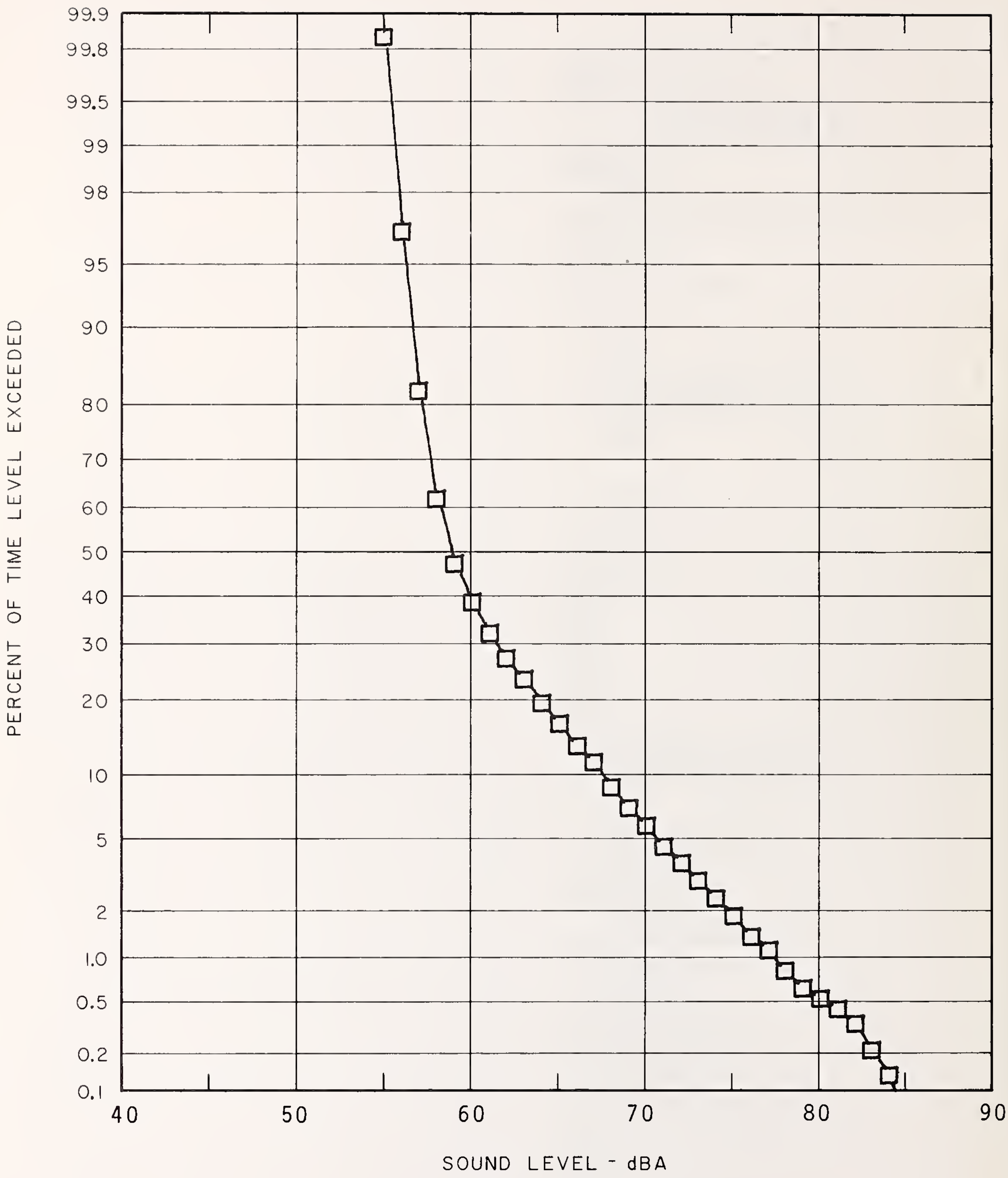


FIGURE 5.46a STATISTICAL DISTRIBUTION OF NOISE SAMPLE INSIDE INFORMATION BOOTH AT 19TH STREET STATION.

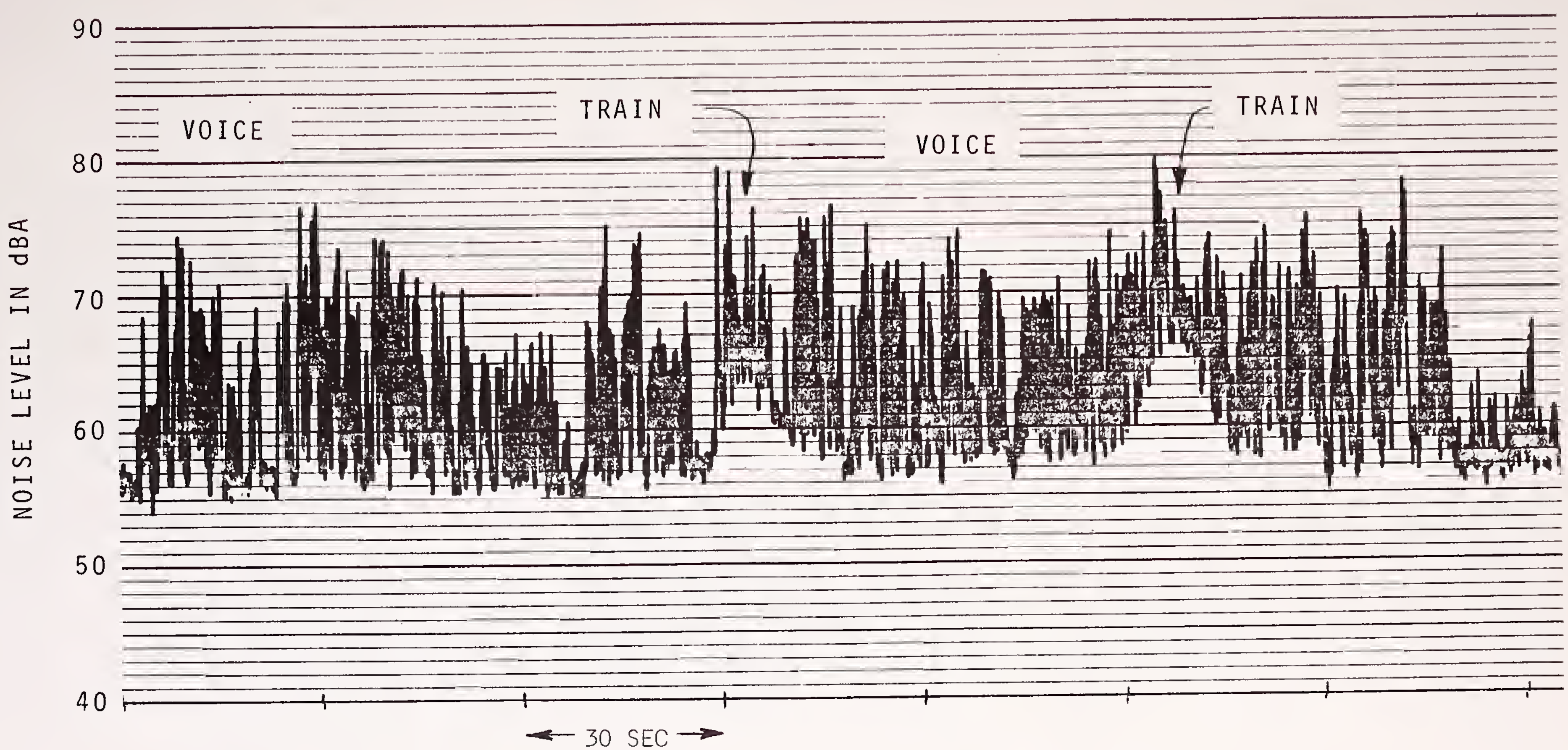


FIGURE 5.46b TYPICAL TRACE FROM NOISE SAMPLE INSIDE INFORMATION BOOTH AT 19TH STREET STATION.

5.2.5 Interior Noise Measurements - Discussion and Summary

In order to document the acoustic environment which patrons and operating personnel experience under normal operating conditions, two types of interior noise measurements were made.

The first type of interior noise measurements consisted of the commute trip. Five commute trips, simulating a typical commuter's trip on BART were made with noise instrumentation to assess the noise exposure during a typical trip.

The other type of interior noise measurement consisted of two end-to-end trips with microphones at standard locations, documenting the noise between Concord and Daly City, and Richmond and Fremont. The results from the end-to-end measurements which also consisted of speed data, allow for correlation between noise level and train speed, and for a comparison between the interior noise at BART and that in the trains of the other systems studied as part of this project.

A detailed summary of the data collected for each test along with descriptions of each test are contained in Section 5.2.6. This section is intended to highlight the important results and trends observed.

Table 5.37 gives a summary of the overall results for each test. Some of the general factors observed from the data are:

(1) The interior noise levels between cars on identical track structure are consistent for measurements made at the same speed and microphone position.

(2) For the end-to-end tests the microphone location over the lead bogie averaged a maximum of 4 to 5 dBA greater than the microphone location at the center of the car.

(3) The average maximum interior noise levels in subway are from 4 to 7 dBA higher than those on aerial structure.

(4) The average maximum interior noise levels on aerial structure are from 3 to 5 dBA higher than those for at-grade ballast and tie track.

(5) Despite the different trip lengths and track structure encountered, the trip L_{EQ} for all of the commute trips were either 75 or 76 dBA.

Most of the above observations are not unexpected when the noise characteristics of the track structure and car are considered. The first observation indicates consistancy between the construction and maintenance of the transit vehicles. The second observation indicates that the noise level in the transit vehicle is greater at the ends. This is due both to being closer to the bogie and the increase in noise transmission through the doors.

The third and fourth observations are due to the noise characteristics of the track structures. Subway structure with concrete trackbed is more reverberant due to its hard and enclosed surfaces than aerial structure with concrete trackbed, thus producing higher interior noise levels. Interior noise levels are lower for trains on ballast and tie track than on aerial structure with concrete trackbed due to the absorbing properties of the ballast. A full discussion of the noise characteristics of various track structures is contained in the report "Noise Abatement for Minimum Cost" as part of this project.

The fifth observation indicates that even with the high noise levels experienced by some patrons waiting on a station platform in a freeway median, or traveling predominantly through subway structure where the noise levels are relatively higher, the overall noise exposure when measured in terms of L_{EQ} is essentially the same.

TABLE 5.37 SUMMARY OF INTERIOR NOISE MEASUREMENTS

COMMUTE TRIPS	Sample Length [mins]	Maximum Noise Level [dBA] [Excluding Transients]				Trip L_{EQ} [dBA]
		Platform	Subway	At-Grade	Aerial	
Trip:						
Concord Station to Montgomery Street Station	53.5	65	85	77	81	76
Fremont Station to Berkeley Station	54.5	65	82	75	79	75
Rockridge Station to Glen Park Station (1)	46.6	85	84	73	78	76
El Cerrito Plaza Station to Lafayette Station	44.3	57 [El Cerrito] 80 [MacArthur]	86	74	76	75
Powell Street Station to North Berkeley Station	38.4	65 [Powell Street] 80 [MacArthur]	83	71	77	76

END-TO-END TESTS	Sample Length [mins]	Microphone Location	Maximum Noise Level [dBA] [Excluding Transients]			Trip L_{EQ} [dBA]
			Subway	At-grade	Aerial	
Trip:						
Concord Station to Daly City Station	63.1	Mic #1 (2)	88	79	83	79
		Mic #2 (3)	83	74	79	74

(1) Average of three trips

(2) Microphone #1 over lead bogie

(3) Microphone #2 at center of car

TABLE 5.37 [cont.]

END-TO-END TESTS	Sample Length [mins]	Microphone Location	Maximum Noise Level [dBA] [Excluding Transients]			Trip L_{EQ} [dBA]
			Subway	At-grade	Aerial	
Trip:						
Daly City Station to Concord Station	58.3	Mic #1	88	79	83	80
		Mic #2	83	74	78	75
Richmond Station to Fremont Station	56.4	Mic #1	87	80	81	77
		Mic #2	83	75	76	73
Fremont Station to Richmond Station	57.7	Mic #1	84	75	79	76
		Mic #2	80	70	75	72

5.2.6 Descriptions and Data for Commute Trips and End-to-End Interior Noise Samples

This section provides descriptions and data for each commute trip and for the end-to-end interior noise samples. The following data are provided for each test:

(1) A short description of each test.

(2) Sketch of BART car showing microphone location.

(3) A summary table giving the date, time started and length of trip for each test. This table also includes the maximum noise level (excluding transients): (a) on the station platform while waiting for the BART train to arrive (for commute trips only), (b) for subway, (c) at-grade and (d) aerial operation. The statistical measures obtained for each test are also included in the summary table.

(4) Statistical distribution curves for all interior noise tests.

(5) Representative strip chart traces for portions of the end-to-end interior noise tests.

(6) Photographs indicating microphone locations for the end-to-end interior noise tests.

COMMUTE TRIPS

Concord Station to Montgomery Street Station (See Table 5.38, Figure 5.47)

This commute trip started in the parking lot of the Concord Station where there was relatively little activity having a noise level less than 60 dBA. Once on the platform, the noise level increased to a maximum of 65 dBA. There were relatively few passengers in the car before the MacArthur Station. After the MacArthur Station, the passenger load increased, but the car was never completely full for the remainder of the trip. Upon exiting at the Montgomery Street Station the noise level was in the range of 60 to 65 dBA in the Station and 65 to 80 dBA on the street level where there was considerable pedestrian and vehicular activity.

Fremont Station to Berkeley Station (See Table 5.39, Figure 5.48)

This commute trip started in the relatively inactive Fremont Station parking lot where the noise level was in the 55 to 65 dBA range. The trip started with only two other passengers in the car. The number of passengers steadily increased as the train traveled towards Oakland. After the Lake Merritt Station, there were no seats available for passengers, i.e., standing room only. This condition continued until the test concluded at the Berkeley Station. The noise level in the congested Berkeley Station ranged from 62 to 75 dBA. Once at the street [Shattuck Avenue], the noise level ranged from 65 to 72 dBA.

Rockridge Station to Glen Park Station (See Table 5.40a-c, Figure 5.49)

Three commute trips were made between the Rockridge and Glen Park Stations in an attempt to obtain what could be considered a typical commute trip with the BART trains operating on their regular schedule. Commute trip #1 was a typical commute trip after boarding the train. However, the 19 minute wait on the Station platform before boarding the train cannot be considered typical as the typical headway between trains on the Concord Line is 12 minutes. Thus the patron of this trip would have a considerably longer exposure to the freeway traffic noise.

The second commute trip started out as a typical trip, however, there was a 2-1/2 minute stopover at the Oakland West Station and two stops in the Trans-Bay Tube totaling approximately two minutes. The typical Station dwell is 30 seconds. The trains normally travel non-stop at 80 mph through almost the entire length of the Trans-Bay Tube.

The third commute trip was typical, without any major delays, however, due to some previous problems earlier in the day, the train operated at slower than normal operating speed, with an estimated maximum speed on the order of 68 to 70 mph.

Figure 5.49 shows the statistical distribution for each of the three commute trips made between the Rockridge and Glen Park Stations. These distributions correlate well with the time spent waiting on the Rockridge Station platform as well as the train speed once on board the train. The high noise level above 85 dBA measured for approximately 1% of the time on commute trip #2 is from the train PA system announcements which were both louder and somewhat more distorted than that typically encountered.

<u>El Cerrito Plaza Station to Lafayette Station</u> (See 5.41, Figure 5.50)

This commute trip required a change of train at the MacArthur Station since there are no through trains that operated between the Richmond and Concord Stations. This trip began in the El Cerrito Plaza Station parking lot where the noise level was in the range of 60 to 70 dBA due principally to the vehicular traffic on nearby San Pablo Avenue and the activity in the El Cerrito Plaza Shopping Center parking lot. The maximum Station platform noise level was considerably lower [57 dBA] due to the shielding of the wall which supports the overhanging roof of the Station.

After leaving the first train at the MacArthur Station, a seven minute wait was required before a Concord bound train arrived. The noise level on the MacArthur Station platform ranged from 65 to 85 dBA [including transients]. The commute trip terminated in the Lafayette Station parking lot which had relatively little activity. However, the nearby freeway traffic noise kept the noise level in the 60 to 70 dBA range.

<u>Powell Street Station to North Berkeley Station</u> (See Table 5.42, Figure 5.51)

This commute trip, as with the El Cerrito Plaza Station to Lafayette Station trip, required a train transfer at the MacArthur Station as there are presently no through trains between Daly City Station and Richmond Station, although future plans call for through trains following this route. The trip began on Market Street outside the main entrance to the Powell Street Station where the noise level was in the range of 65 to 80 dBA. After leaving the Concord bound train at the MacArthur Station, a wait of 4-1/2 minutes was required before the arrival of a Richmond bound train. The noise level on the MacArthur Station platform ranged from 65 to 92 dBA including transients. The Richmond bound train was very crowded, requiring taking a position near the front of the leading "A" car. This trip was terminated in the North Berkeley Station parking lot, in a relatively quiet residential area where the noise level ranged from 52 to 56 dBA.

END-TO-END TESTS

Concord Station to Daly City Station - Interior Noise Sample
(See Tables 5.43, 5.44; Figures 5.52a-d, 5.53)

This end-to-end test was made in Car 606 from Concord to Daly City and in Car 666, part of an entirely different train on the return from Daly City back to Concord. The microphones were set up at the standard end-to-end test positions, one over the lead bogie [truck] and one in the center of the transit vehicle. The difference for the maximum noise level between the two microphone positions is 4 or 5 dBA for either subway, at-grade, or aerial structure. Although typical operating speeds were achieved for both directions of this test, the return trip from Daly City to Concord had somewhat shorter dwell times in the stations and no wait to get into the final station. The Daly City bound train on the trip from Concord waited outside the Daly City Station for several minutes waiting for a Fremont bound train to leave the station platform area. This made the return trip shorter by almost five minutes. Figures 5.52b, c, and d are strip charts indicating typical noise levels at both microphones for different types of transit structure.

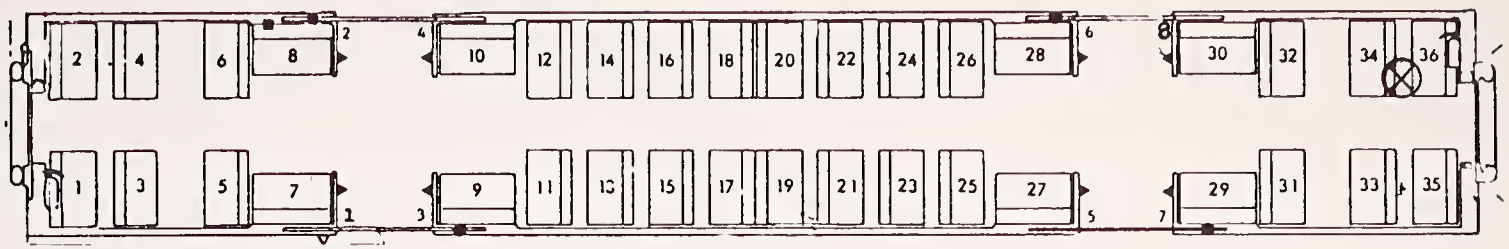
Richmond Station to Fremont Station - Interior Noise Sample
(See Tables 5.45, 5.46; Figures 5.54a-e, 5.55)

This end-to-end test was made in Car 741 from Richmond to Fremont and in Car 660, part of an entirely different train for the return from Fremont to Richmond. Again, the two microphones were set up at the standard positions for this end-to-end test. As with the Concord to Daly City test, the difference between the maximum noise levels measured at each microphone was 4 or 5 dBA for subway, at-grade, or aerial structure. Although the trip time between the end stations was within approximately one minute, thus indicating consistent operation, the maximum train speed rarely reached 80 mph. Generally the maximum train speed was on the order of 68 to 70 mph. Figures 5.54b and c are strip charts indicating typical noise levels at both microphones for different types of transit structure. Figures 5.54d and e are photographs showing the microphones set up for noise measurement between the Richmond and Fremont Stations.

Concord Station to Daly City Station Operator's Cab Noise Sample (See Table 5.47, Figure 5.56)

This sample was made with the measurement microphone hung just behind and above the operator's head. Although the train operation was consistent, the maximum train speed obtained in both the Berkeley Hills Tunnel and the Trans-Bay Tube was 70 mph.. Occasionally, 80 mph train speed was obtained on short sections of the system. The peak noise levels in the operator's cab were from the closing of the cab window and messages on the operator's intercom.

TABLE 5.38 CONCORD STATION TO MONTGOMERY STREET STATION COMMUTE TRIP - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATION

LOCATION OF MICROPHONE: At last seat of Y-end of Car #660, third car in 7-car train

DATE: 2/21/75 ; STARTING TIME: 3:16 p.m.; LENGTH OF TRIP [SAMPLE LENGTH]: 53.5 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
65	85	77	81

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
57	62	71	81	85	76

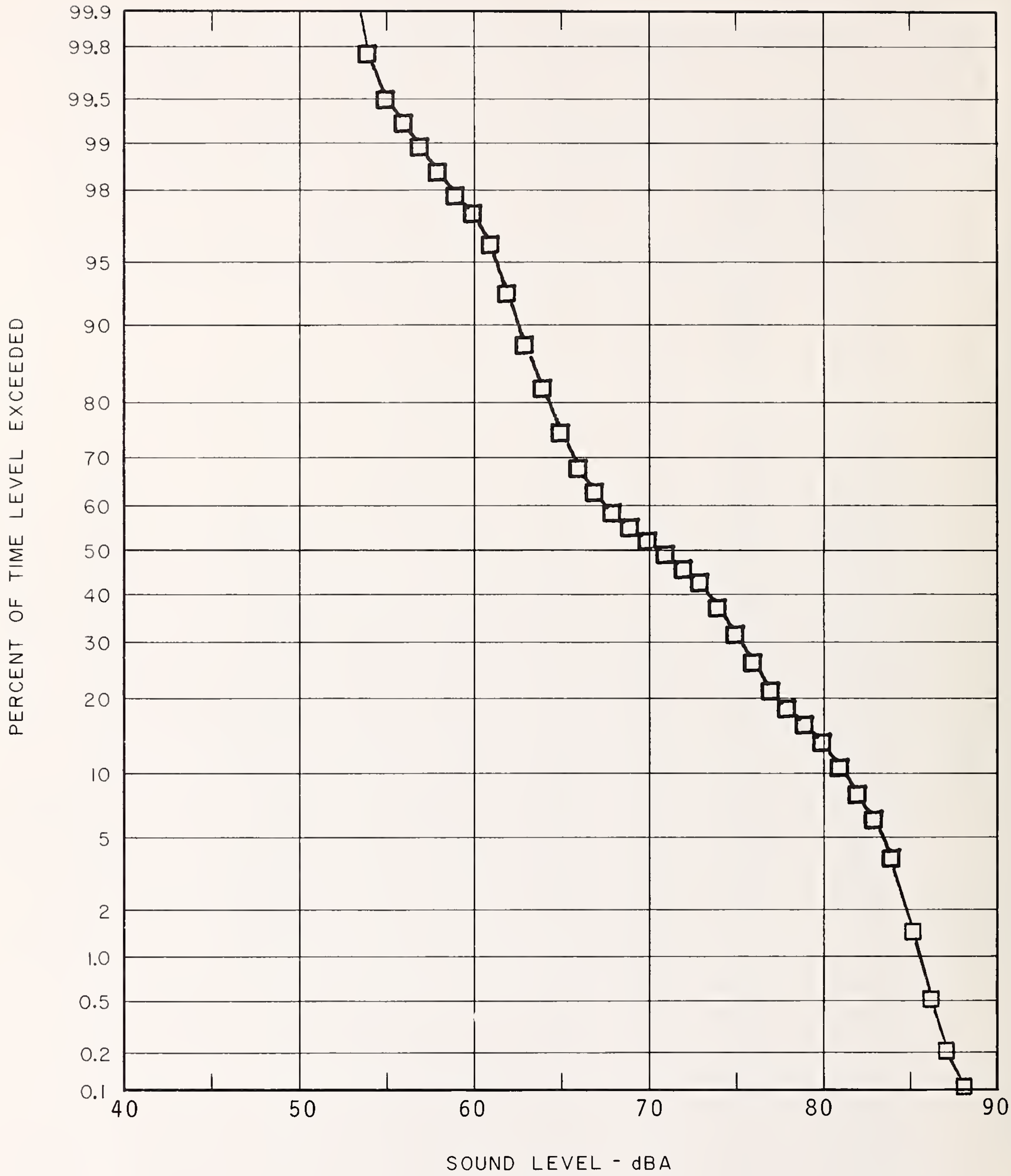
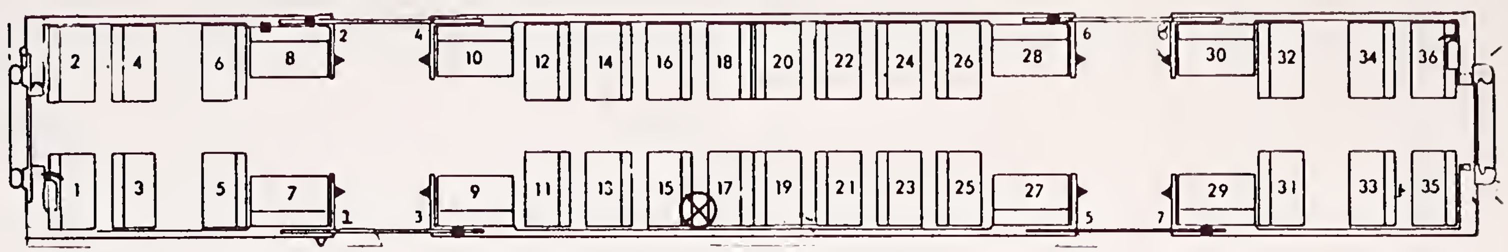


FIGURE 5.47 STATISTICAL DISTRIBUTION OF CONCORD STATION TO MONTGOMERY STREET STATION COMMUTE TRIP

TABLE 5.39 FREMONT STATION TO BERKELEY STATION COMMUTE TRIP - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATION

LOCATION OF MICROPHONE: In middle of Car #589, second car in 4-car train

DATE: 2/18/75 ; STARTING TIME: 2:06 p.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 54.4 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
65	82	75	79

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
54	64	70	78	83	75

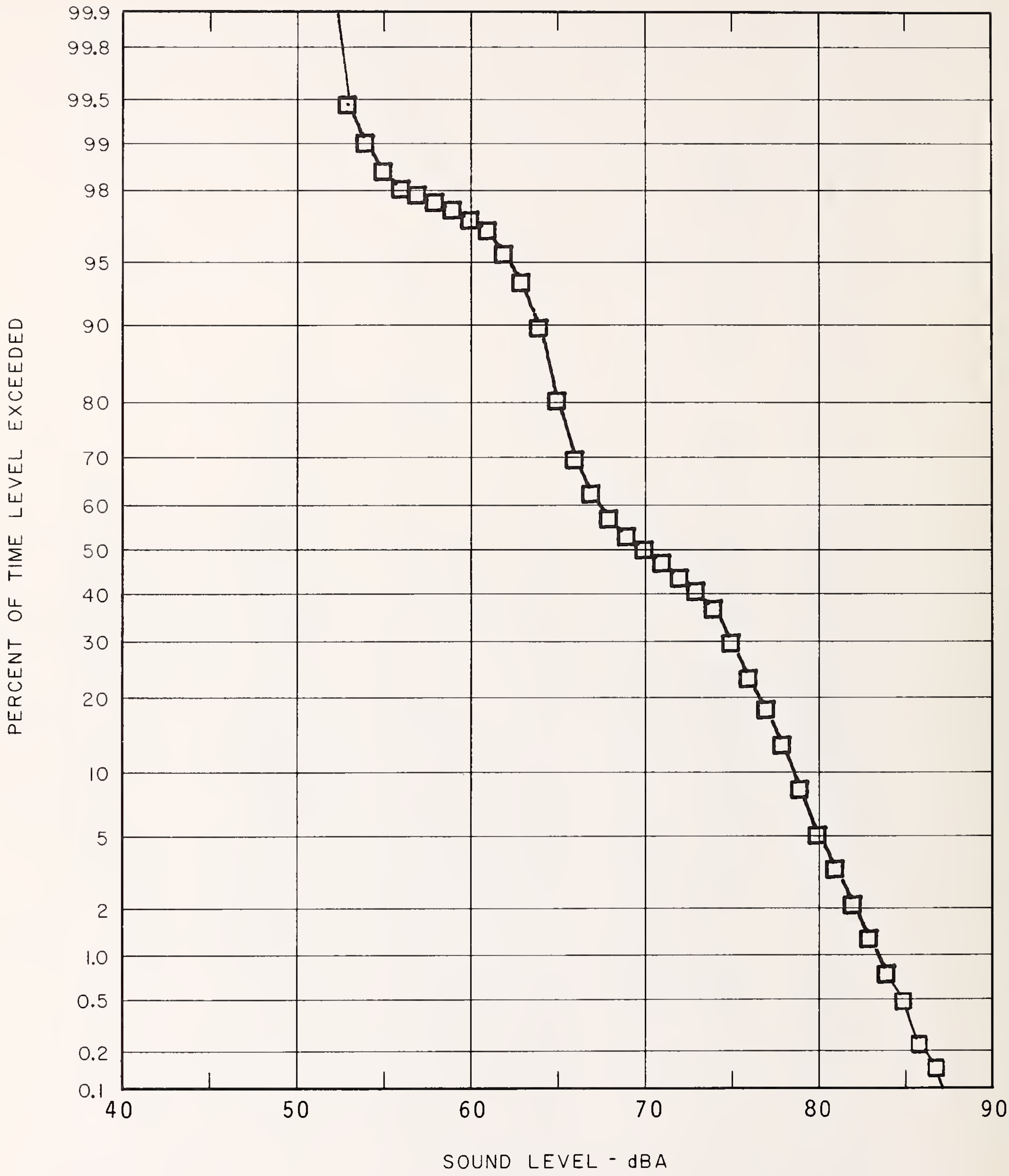
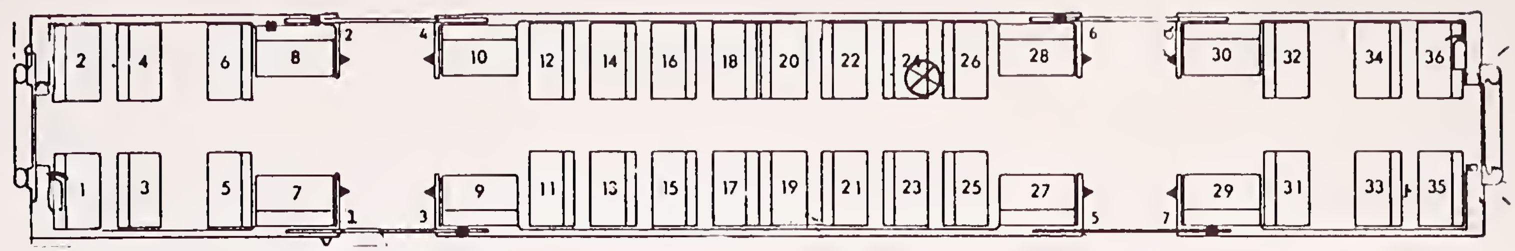


FIGURE 5.48 STATISTICAL DISTRIBUTION OF FREMONT STATION TO BERKELEY STATION COMMUTE TRIP

TABLE 5.40a ROCKRIDGE STATION TO GLEN PARK STATION COMMUTE TRIP #1 - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATION

LOCATION OF MICROPHONE: Near middle of Car #660, third car in 7-car train

DATE: 2/14/75 ; STARTING TIME: 3:00 p.m.; LENGTH OF TRIP [SAMPLE LENGTH]: 51.4 mins

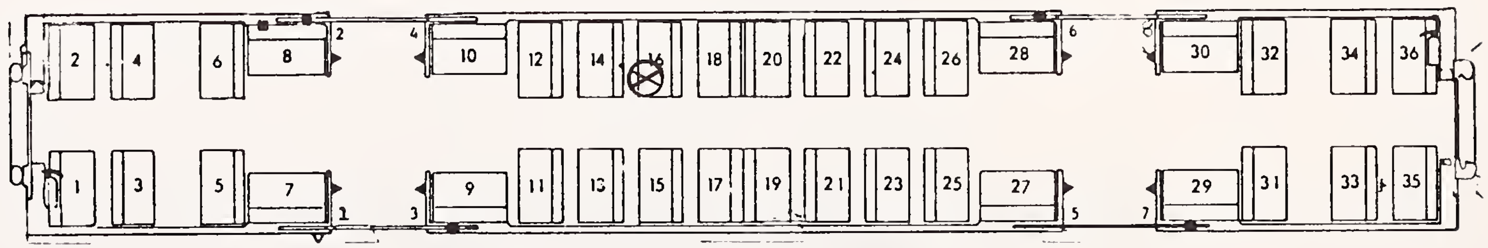
MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
86 (avg peak)	85	76	79

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
62	66	76	82	84	78

TABLE 5.40b ROCKRIDGE STATION TO GLEN PARK STATION COMMUTE TRIP #2
SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATION

LOCATION OF MICROPHONE: In middle of Car #566, second car in 5-car train

DATE: 2/20/75 ; STARTING TIME: 2:08 p.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 43.3 mins

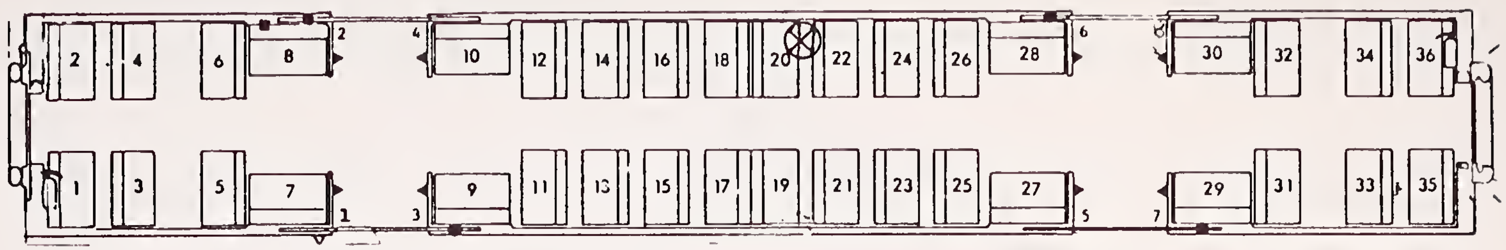
MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
83 (avg peak)	86	74	78

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
61	63	72	82	86	77

TABLE 5.40c ROCKRIDGE STATION TO GLEN PARK STATION COMMUTE TRIP #3
SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATION

LOCATION OF MICROPHONE: In middle of Car #715, third car in 6-car train

DATE: 2/21/75 ; STARTING TIME: 10:50 a.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 45 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
86 (avg peak)	81	67	76

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
61	62	69	78	81	74

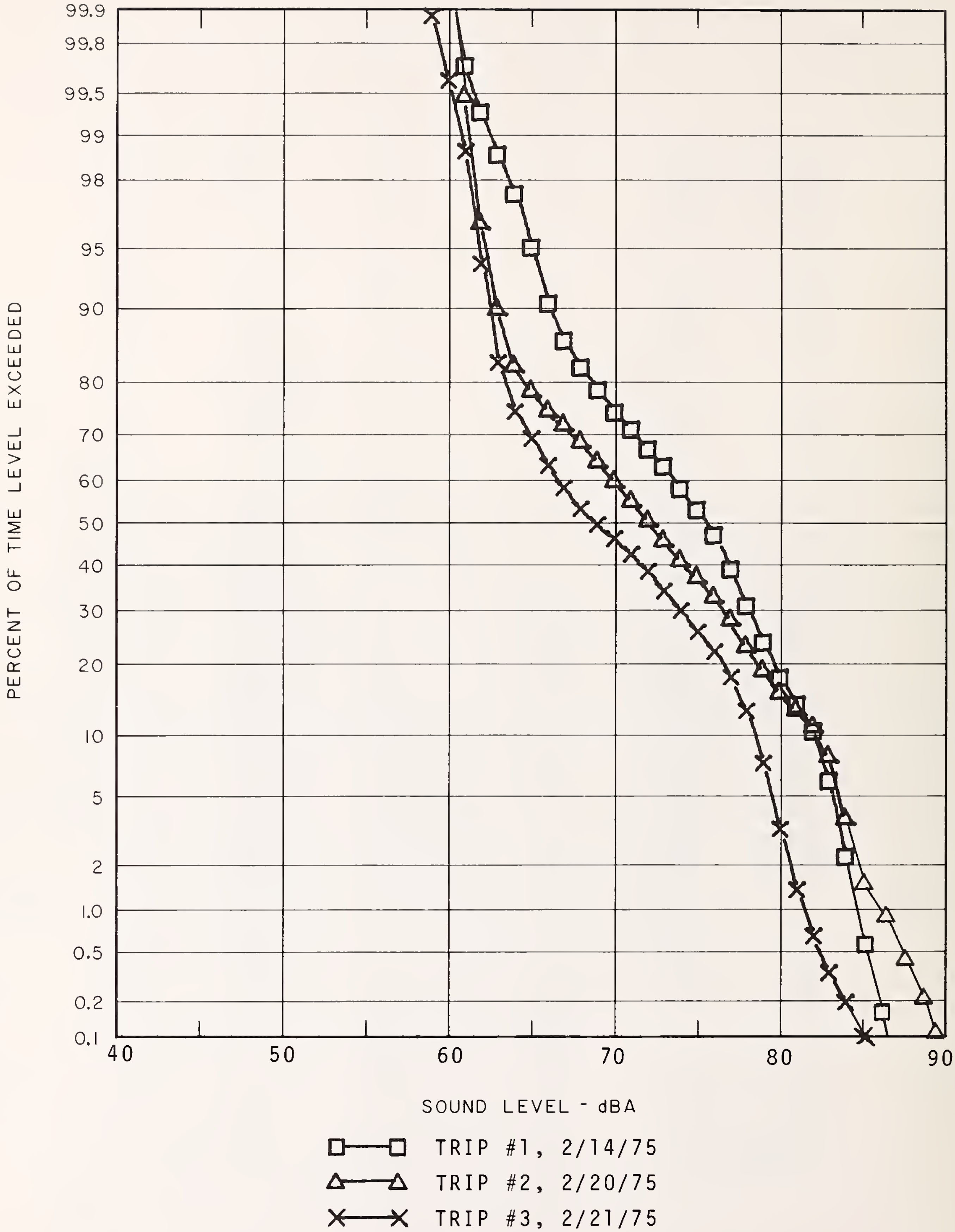
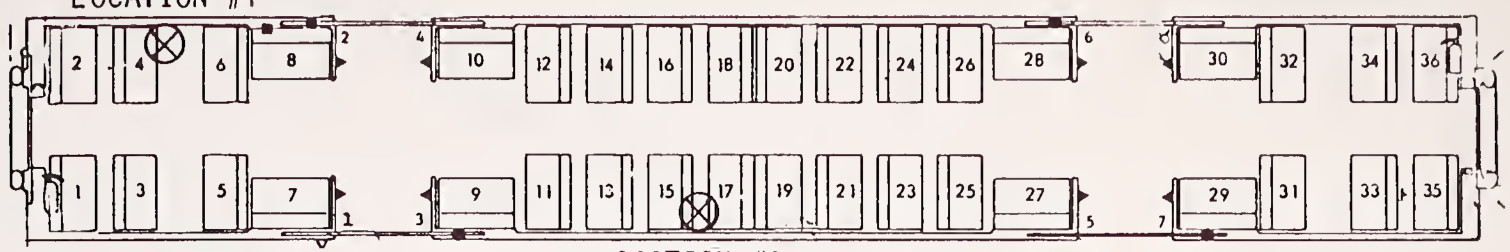


FIGURE 5.49 STATISTICAL DISTRIBUTIONS OF ROCKRIDGE STATION TO GLEN PARK STATION COMMUTE TRIP

TABLE 5.41 EL CERRITO PLAZA STATION TO LAFAYETTE STATION COMMUTE TRIP - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATIONS

LOCATION OF MICROPHONE: First Portion of Trip [El Cerrito Plaza to MacArthur Station]: At end of Car #624, third car in 4-car train.

Second Portion of Trip [MacArthur Station to Lafayette Station]: In middle of Car #209, first car in 5-car train.

DATE: 2/18/75 ; STARTING TIME: 3:27 p.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 44.3 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
57 (El Cerrito)	86	74	76
80 (Mac Arthur)			

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
56	63	71	80	84	75

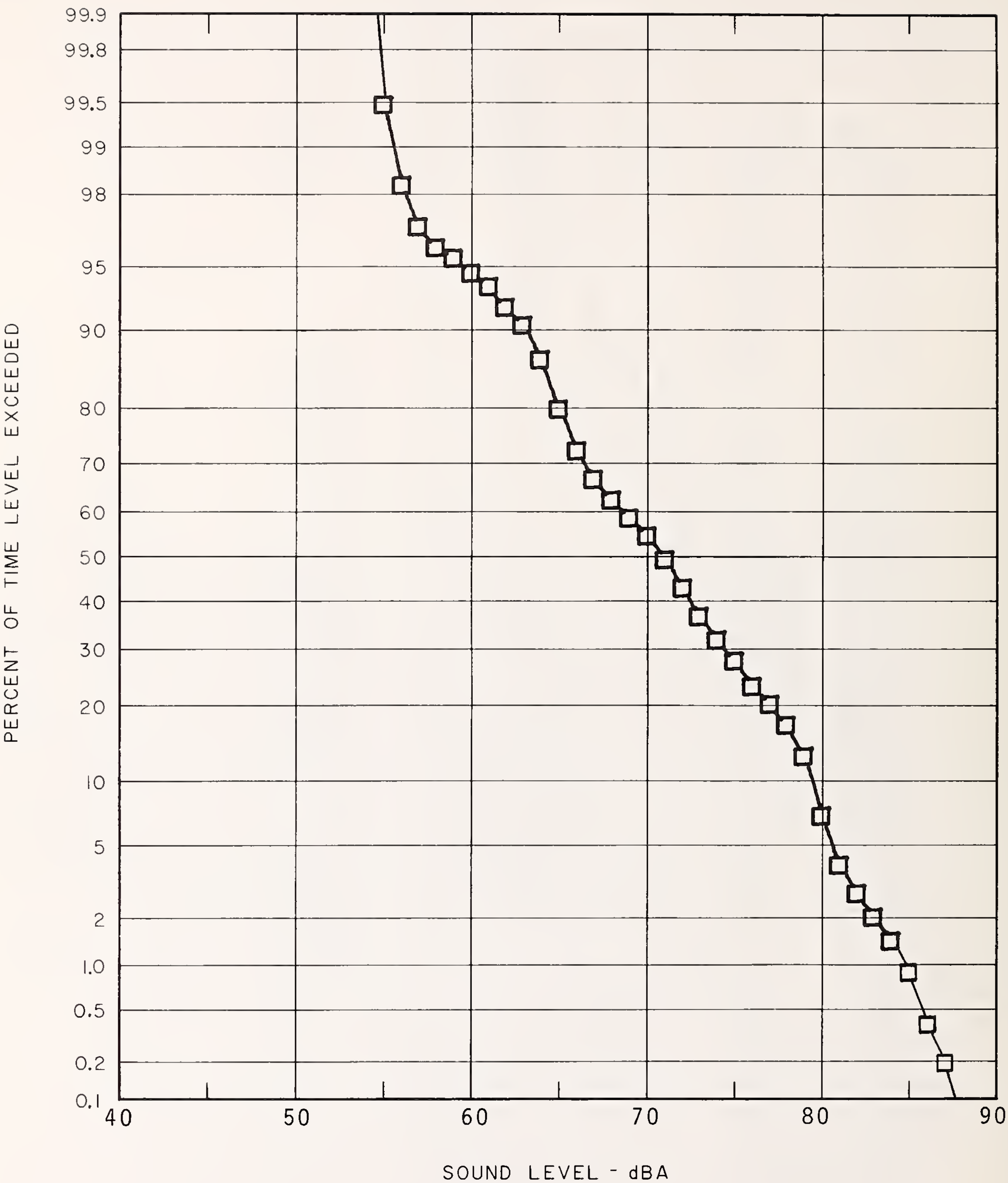
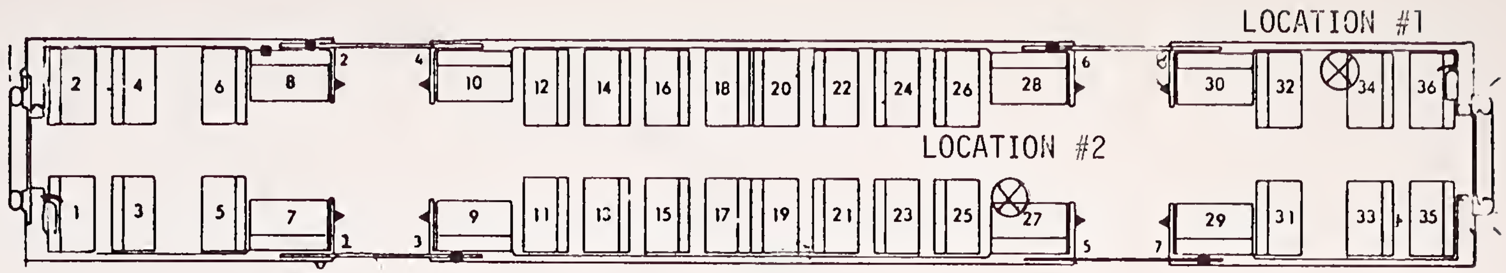


FIGURE 5.50 STATISTICAL DISTRIBUTION OF EL CERRITO PLAZA STATION TO LAFAYETTE STATION COMMUTE TRIP

TABLE 5.42 POWELL STREET STATION TO NORTH BERKELEY STATION COMMUTE TRIP - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATIONS

LOCATION OF MICROPHONE: First Portion of Trip [Powell Street Station to MacArthur Station]: At front of Car #240, last car of 4-car train.

Second Portion of Trip [MacArthur Station to North Berkeley Station]: Near first doors of Car #217, first car of 5-car train.

DATE: 2/21/75 ; STARTING TIME: 12:08 p.m.; LENGTH OF TRIP [SAMPLE LENGTH]: 38.4 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Platform	Subway	At-Grade	Aerial
65 (Powell St)	83	71	77
80 (Mac Arthur)			

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
54	65	70	80	86	76

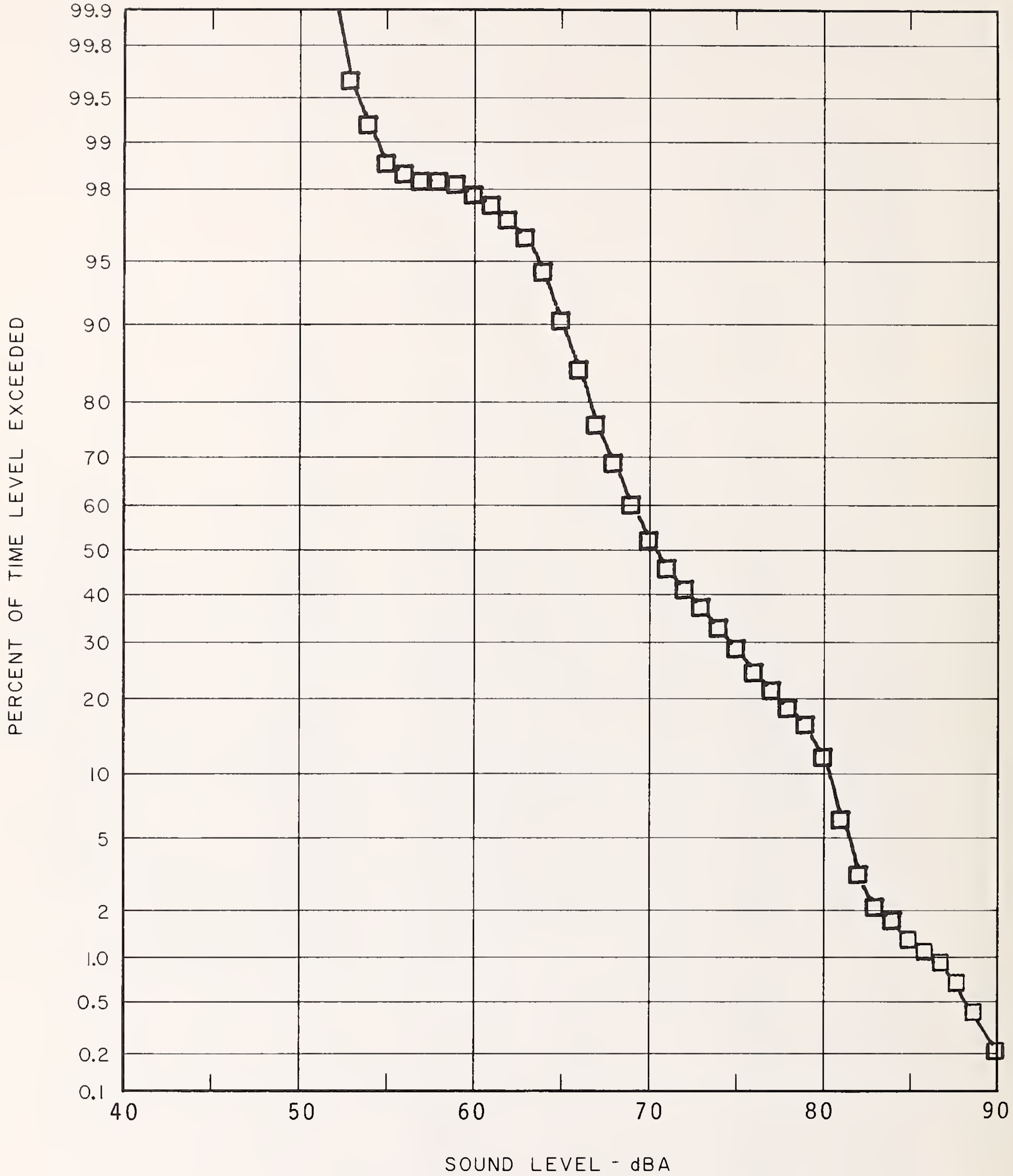
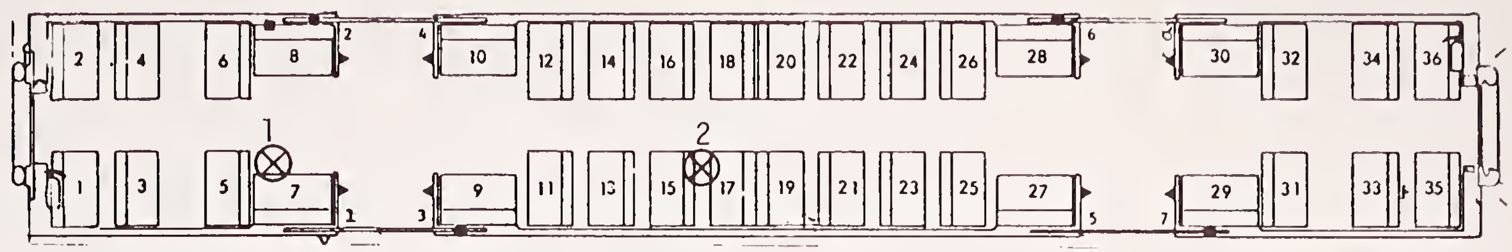


FIGURE 5.51 STATISTICAL DISTRIBUTION OF POWELL STREET STATION TO NORTH BERKELEY STATION COMMUTE TRIP

TABLE 5.43 CONCORD STATION TO DALY CITY STATION INTERIOR NOISE SAMPLE - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATIONS

LOCATION OF MICROPHONE: In Car #606, second car of 5-car train.
Microphone #1 over bogie
Microphone #2 at center of car

DATE: 2/27/75 ; STARTING TIME: 9:58 a.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 63.1 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

	Subway	At-Grade	Aerial
MICROPHONE #1	88	79	83
MICROPHONE #2	83	74	79

STATISTICAL DESCRIPTORS [dBA]

	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
MICROPHONE #1	61	63	74	84	88	79
MICROPHONE #2	62	64	70	79	83	74

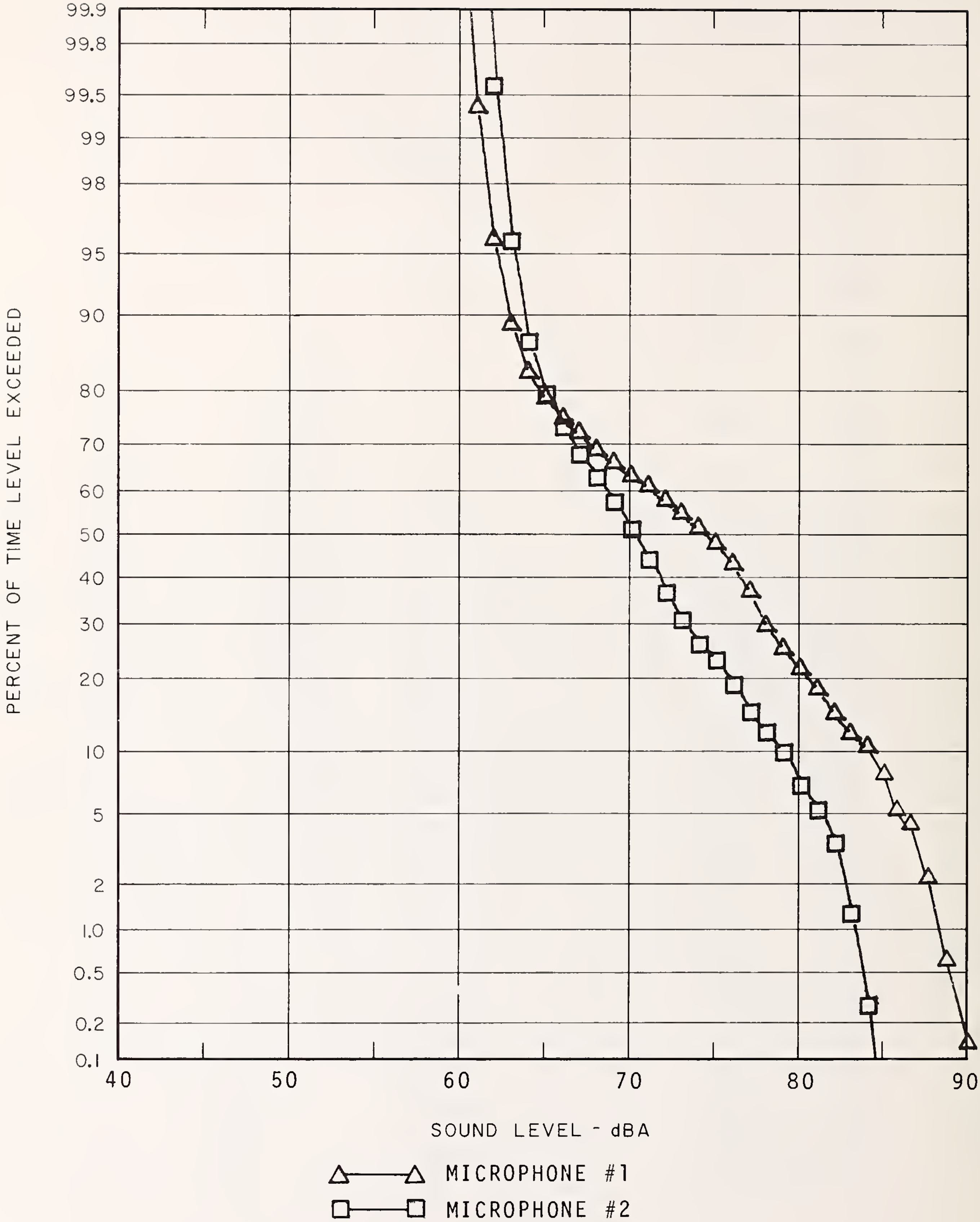


FIGURE 5.52a STATISTICAL DISTRIBUTION OF CONCORD STATION TO DALY CITY STATION INTERIOR NOISE SAMPLE

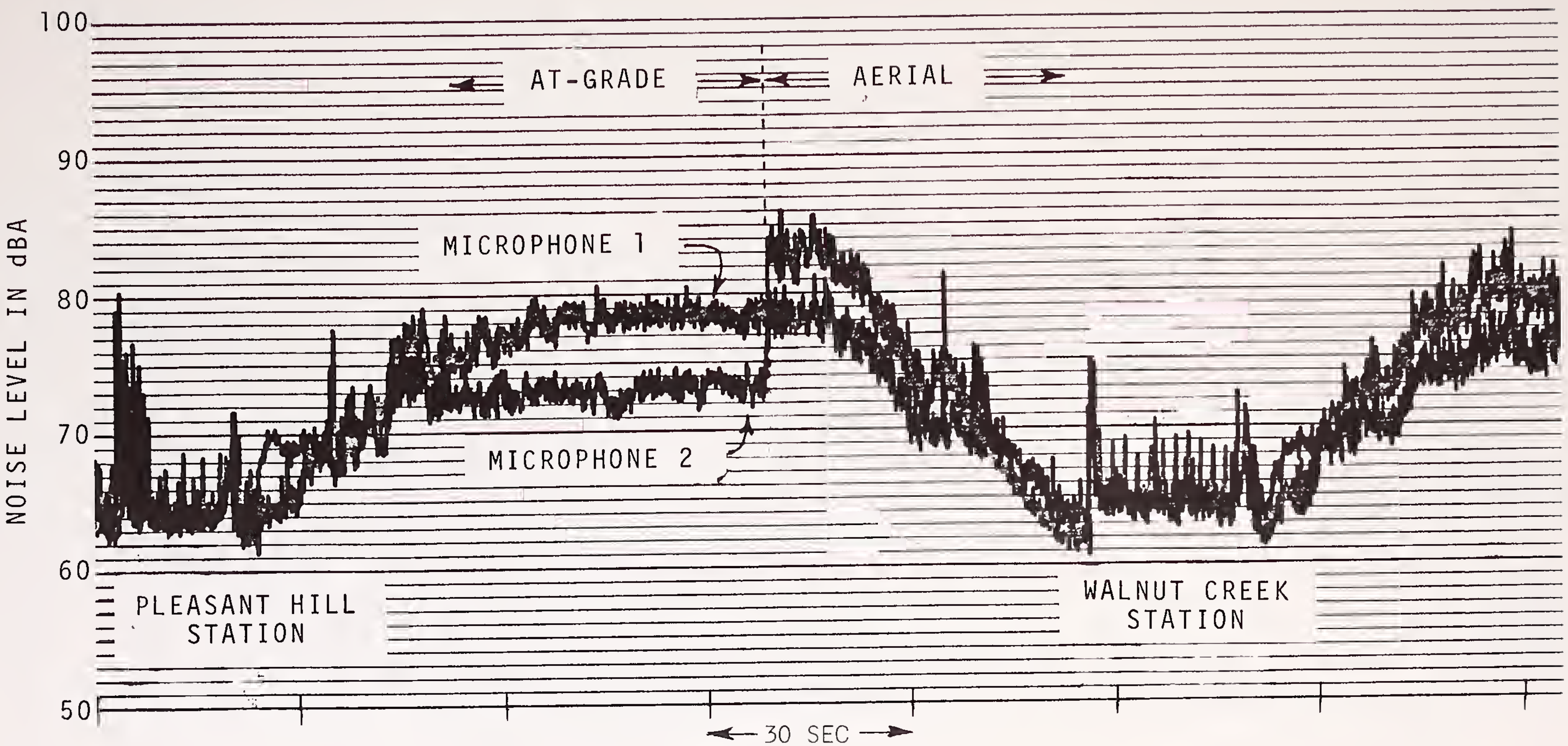


FIGURE 5.52b TRACE OF INTERIOR NOISE IN CAR #606 BETWEEN PLEASANT HILL AND WALNUT CREEK STATIONS. TRAIN SPEED AT AT-GRADE/AERIAL TRANSITION: 80 MPH.

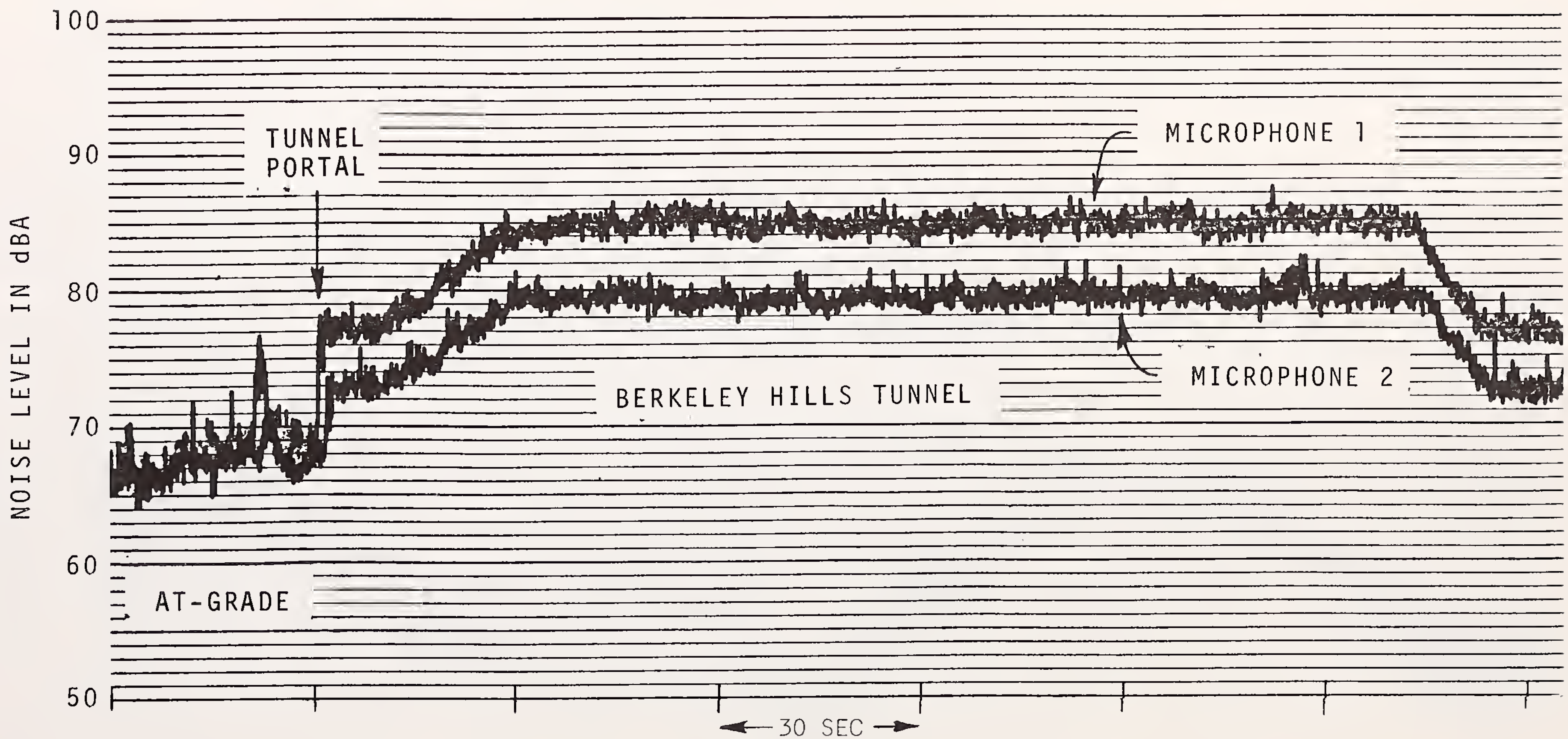


FIGURE 5.52c TRACE OF INTERIOR NOISE IN CAR #606 BETWEEN ORINDA AND ROCKRIDGE STATIONS. MAXIMUM TRAIN SPEED IN BERKELEY HILLS TUNNEL: 70 MPH.

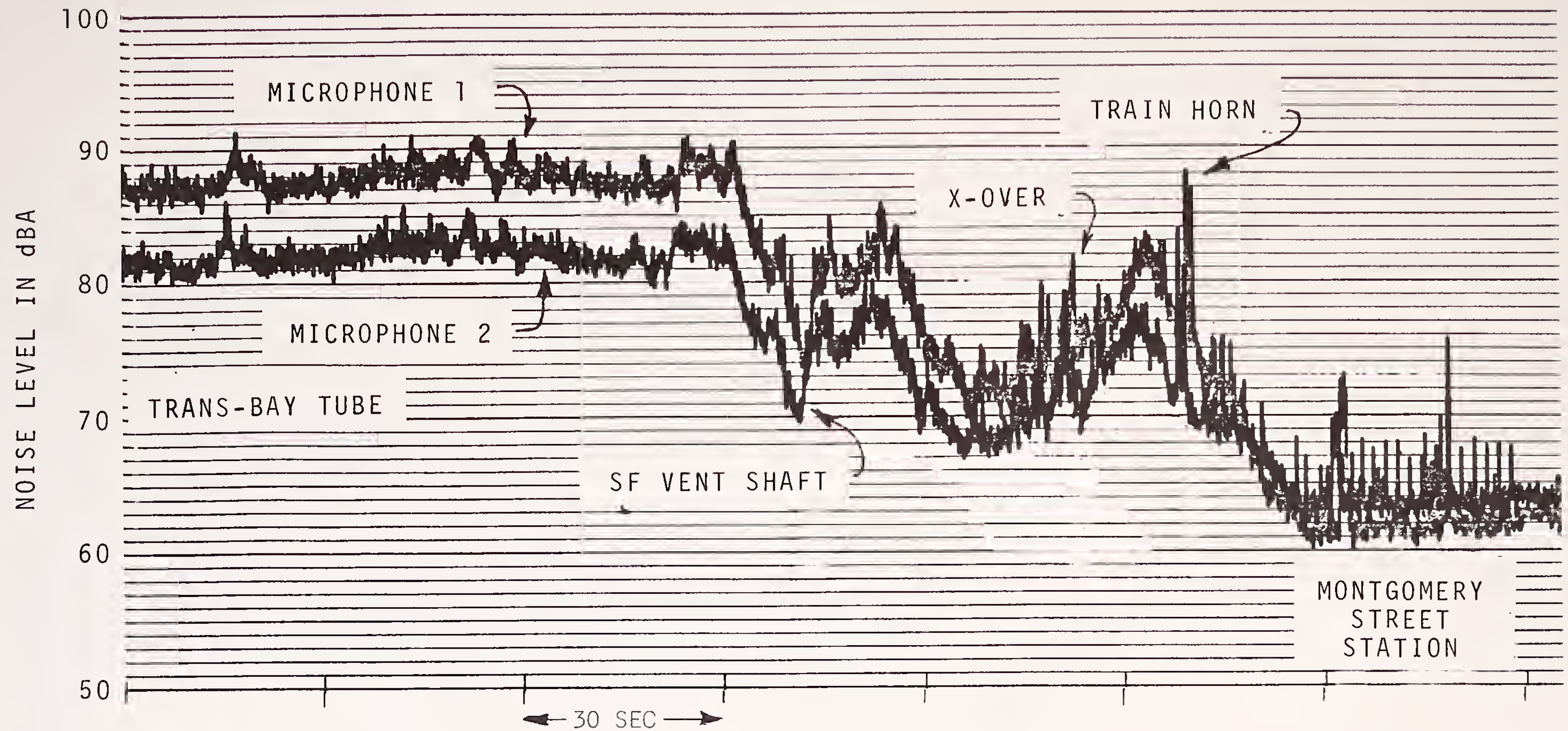
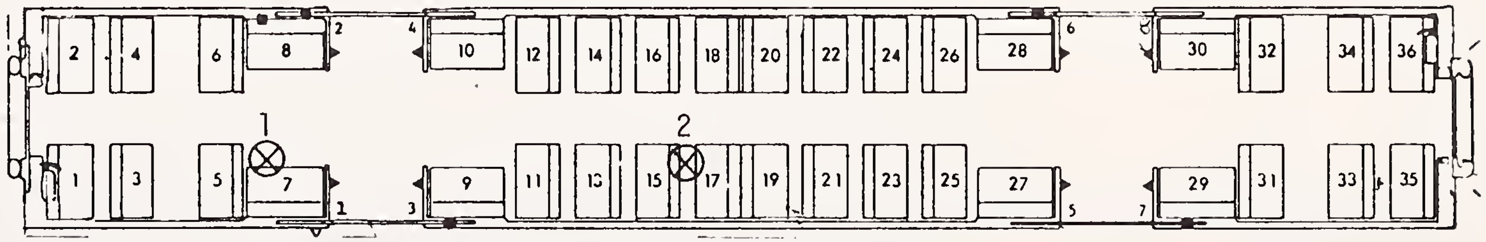


FIGURE 5.52d TRACE OF INTERIOR NOISE IN CAR #606 LEAVING THE TRANS-BAY TUBE AND ENTERING MONTGOMERY STREET STATION. MAXIMUM TRAIN SPEED IN TRANS-BAY TUBE: 80 MPH.

TABLE 5.44 DALY CITY STATION TO CONCORD STATION INTERIOR NOISE SAMPLE - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATIONS

LOCATION OF MICROPHONE: In Car #666, second car of 5-car train.
Microphone #1 over bogie
Microphone #2 at center of car

DATE: 2/27/75 ; STARTING TIME: 11:18 a.m.; LENGTH OF TRIP [SAMPLE LENGTH]: 58.3 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

	Subway	At-Grade	Aerial
MICROPHONE #1	88	79	83
MICROPHONE #2	83	74	78

STATISTICAL DESCRIPTORS [dBA]

	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
MICROPHONE #1	64	66	75	84	89	80
MICROPHONE #2	61	63	72	80	84	75

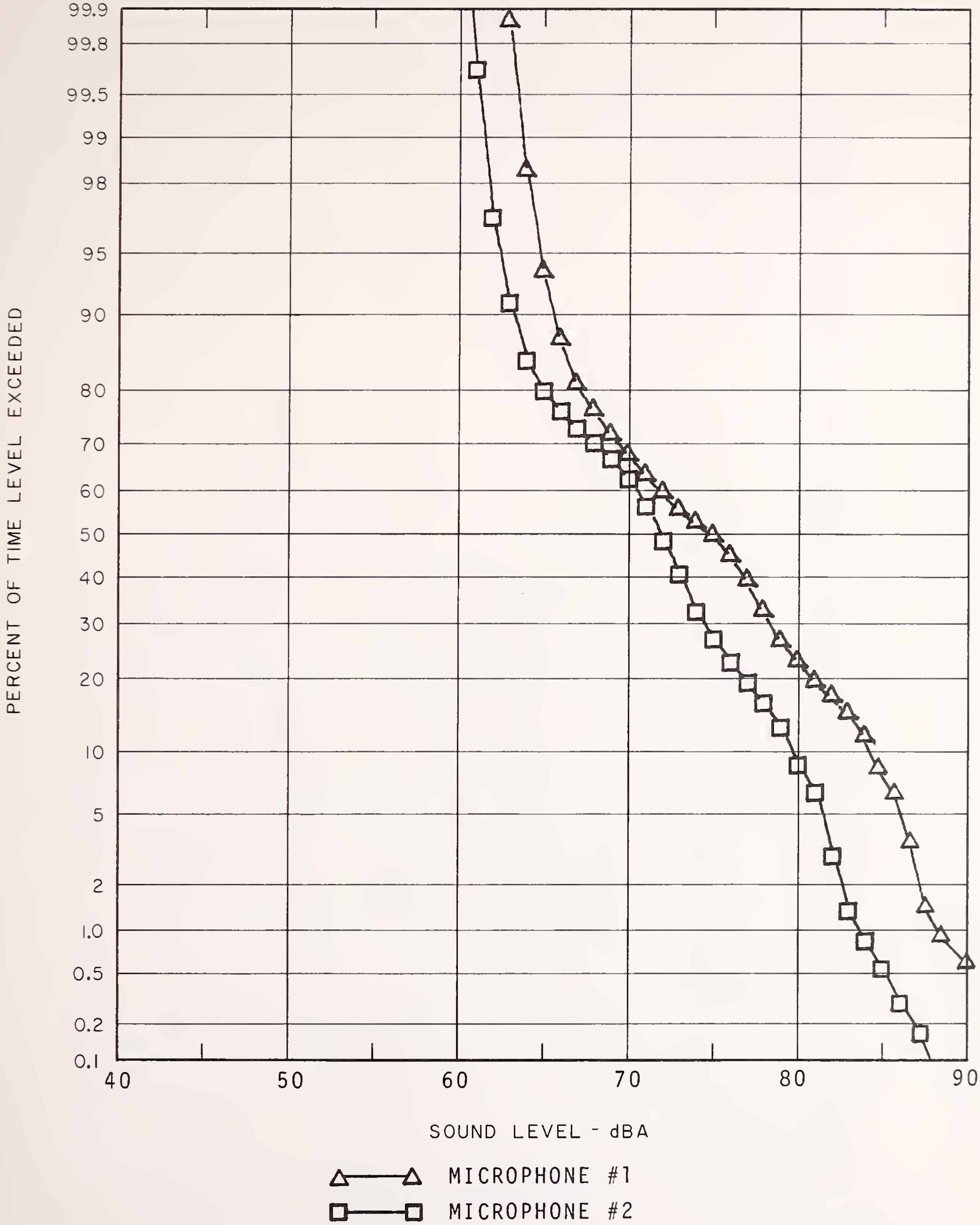
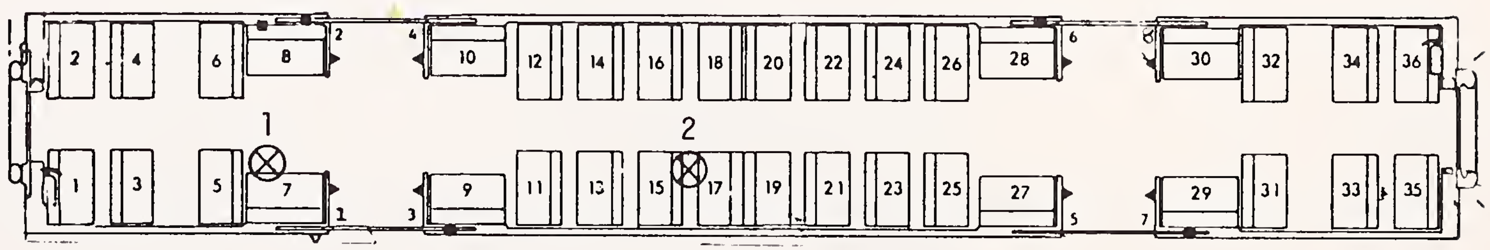


FIGURE 5.53 STATISTICAL DISTRIBUTION OF DALY CITY STATION TO CONCORD STATION INTERIOR NOISE SAMPLE

TABLE 5.45 RICHMOND STATION TO FREMONT STATION INTERIOR NOISE SAMPLE - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATIONS

LOCATION OF MICROPHONE: In Car #741, second car of 5-car train.
Microphone #1 over bogie
Microphone #2 at center of car

DATE: 4/7/75 ; STARTING TIME: 10:22 a.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 56.4 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

	Subway	At-Grade	Aerial
MICROPHONE #1	87	80	81
MICROPHONE #2	83	75	76

STATISTICAL DESCRIPTORS [dBA]

	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{EQ}
MICROPHONE #1	62	63	74	80	86	77
MICROPHONE #2	62	63	70	76	83	73

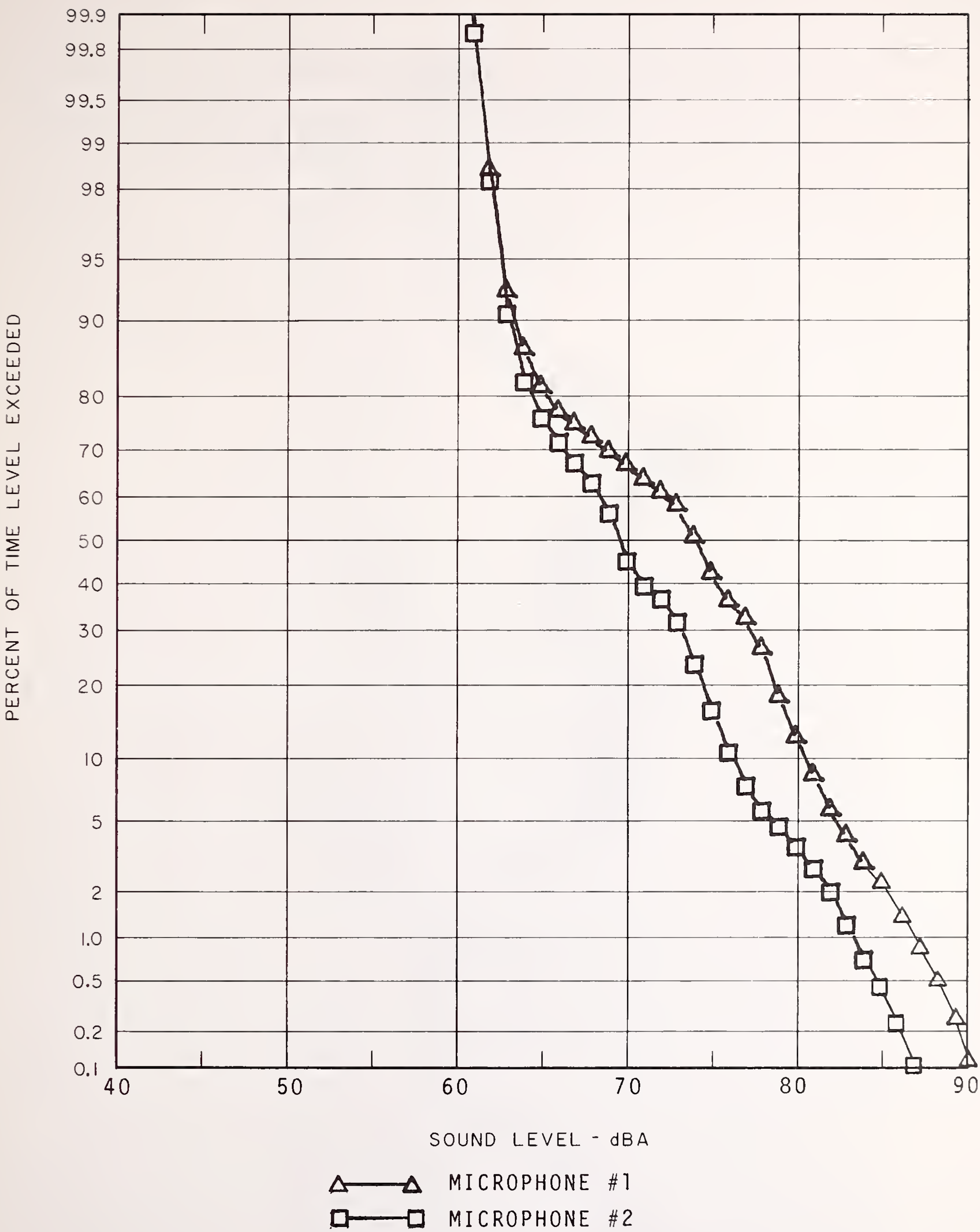


FIGURE 5.54a STATISTICAL DISTRIBUTIONS OF RICHMOND STATION TO FREMONT STATION INTERIOR NOISE SAMPLE

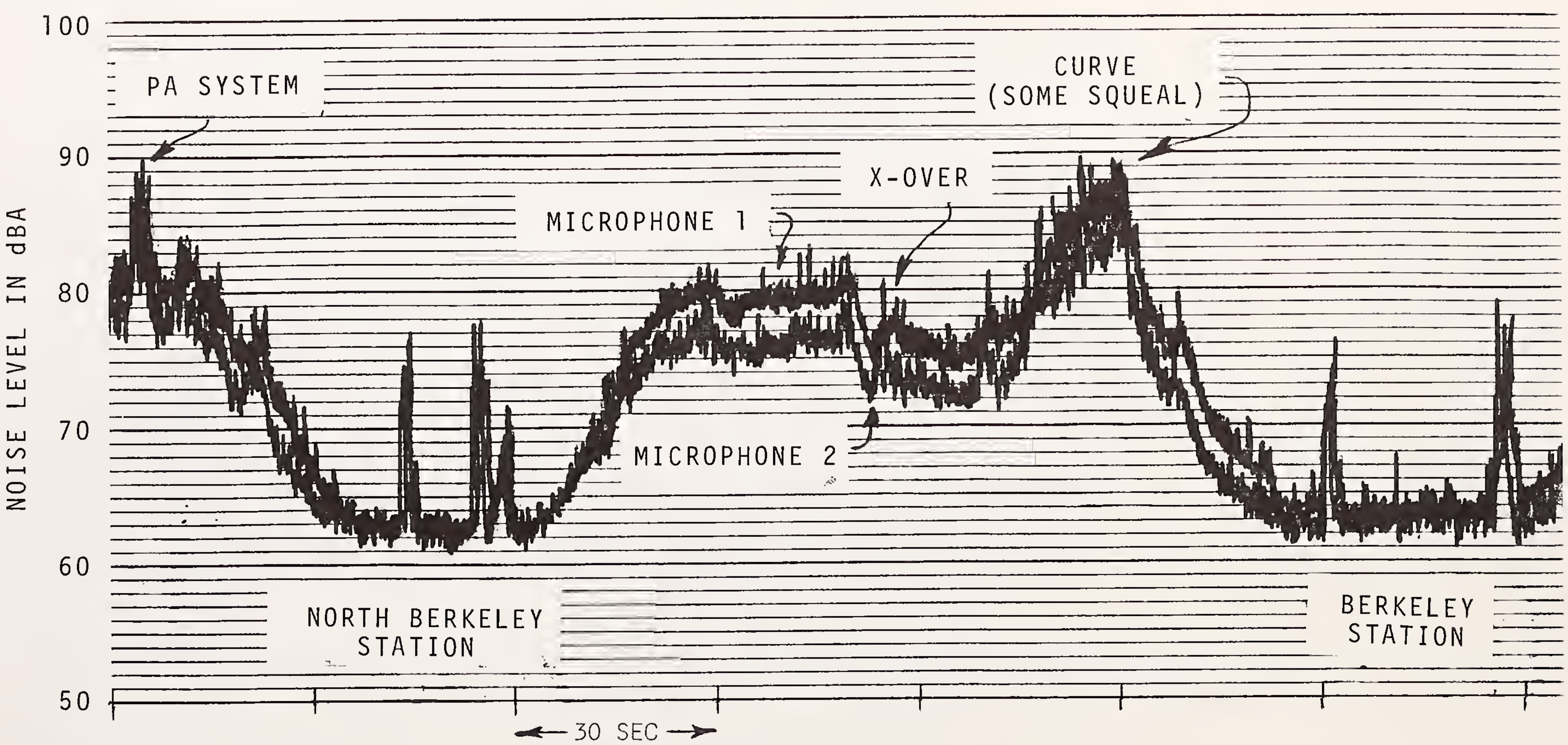


FIGURE 5.54b TRACE OF INTERIOR NOISE IN CAR #741 BETWEEN NORTH BERKELEY AND BERKELEY STATIONS. TRAIN SPEED AT X-OVER: 47 MPH. TRAIN SPEED ON CURVE: 33 MPH.

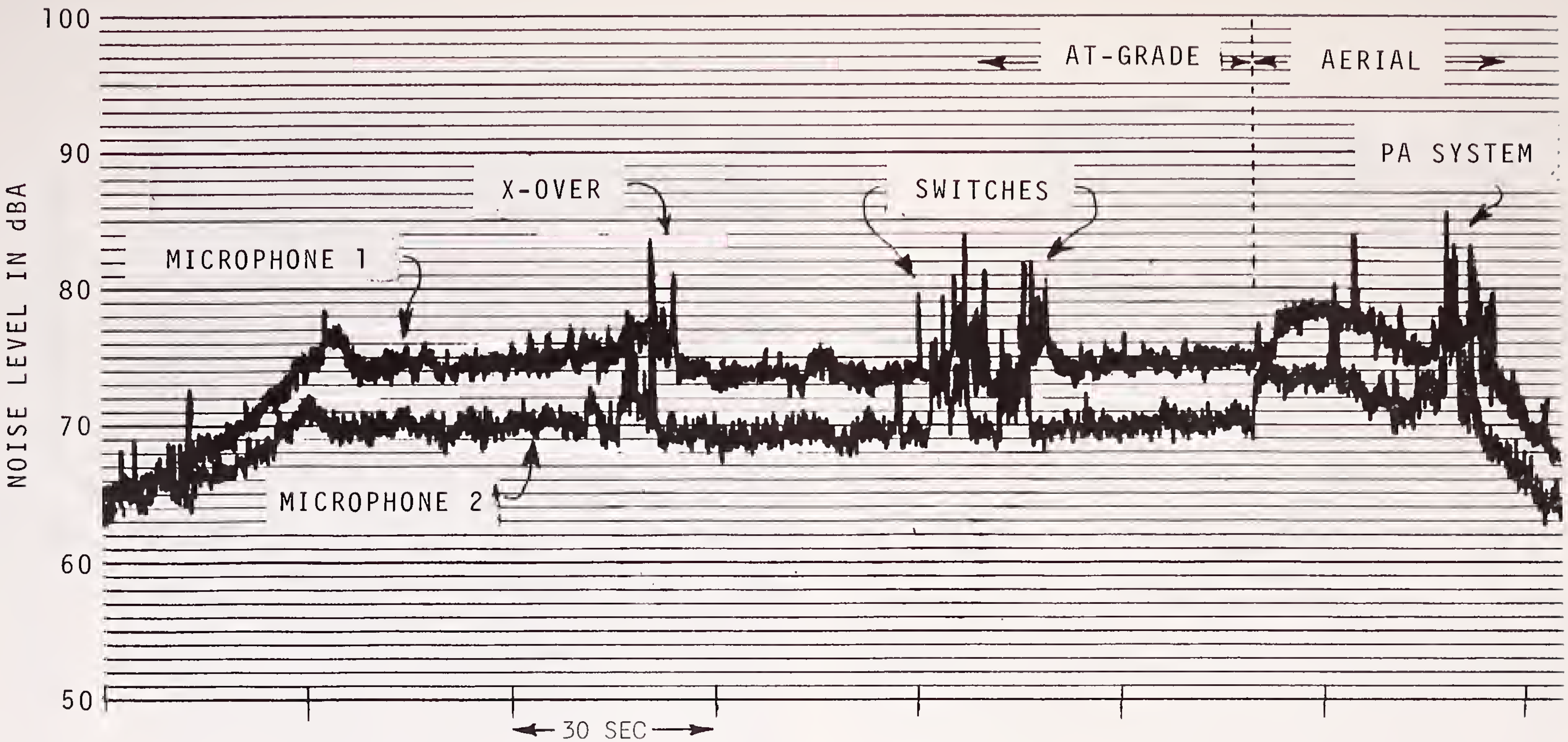


FIGURE 5.54c TRACE OF INTERIOR NOISE IN CAR #741 BETWEEN SOUTH HAYWARD AND UNION CITY STATIONS BY HAYWARD YARD. TRAIN SPEED AT X-OVER AND SWITCHES: 68 MPH.

VIEW LOOKING TOWARDS X-END OF CAR

VIEW LOOKING TOWARDS Y-END OF CAR

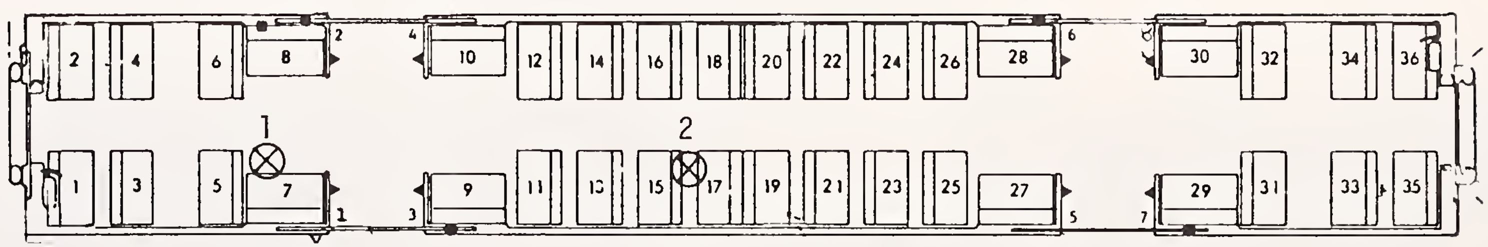
FIGURE 5.54d PHOTOGRAPHS SHOWING THE TWO MICROPHONES SET UP IN CAR 741

MICROPHONE #1

MICROPHONE #2

FIGURE 5.54e PHOTOGRAPHS SHOWING MICROPHONES SET UP IN CAR 741

TABLE 5.46 FREMONT STATION TO RICHMOND STATION NOISE SAMPLE - SUMMARY OF RESULTS



SKETCH OF BART CAR SHOWING MICROPHONE LOCATIONS

LOCATION OF MICROPHONE: In Car #660, second car of 5-car train
Microphone #1 over bogie
Microphone #2 at center of car

DATE: 4/7/75 ; STARTING TIME: 11:32 a.m.; LENGTH OF TRIP [SAMPLE LENGTH]: 57.7 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

	Subway	At-Grade	Aerial
MICROPHONE #1	84	75	79
MICROPHONE #2	80	70	75

STATISTICAL DESCRIPTORS [dBA]

	L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
MICROPHONE #1	61	63	73	78	85	76
MICROPHONE #2	61	63	69	75	82	72

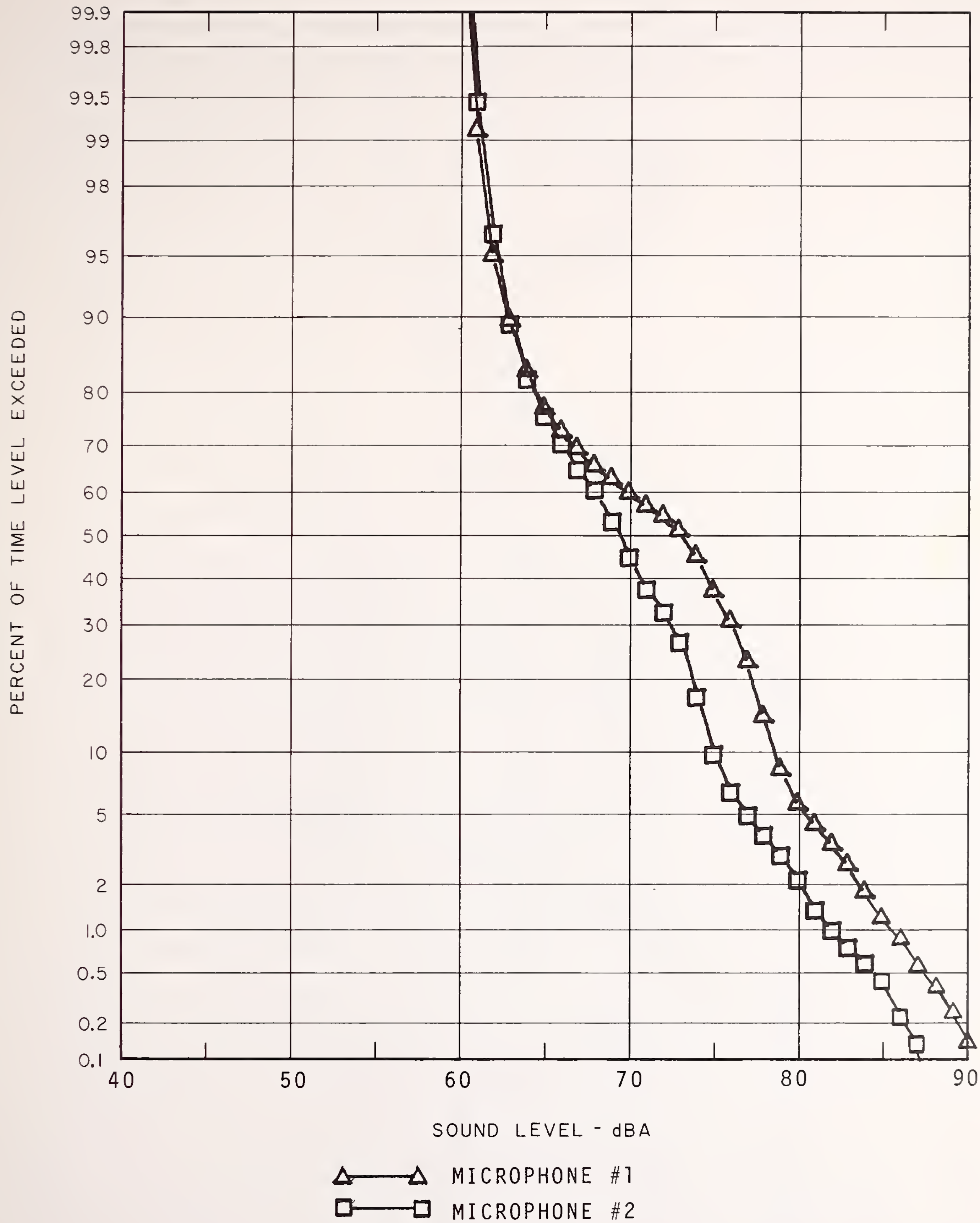


FIGURE 5.55 STATISTICAL DISTRIBUTION OF FREMONT STATION TO RICHMOND STATION INTERIOR NOISE SAMPLE

TABLE 5.47 CONCORD STATION TO DALY CITY STATION OPERATOR'S CAB NOISE SAMPLE - SUMMARY OF RESULTS

LOCATION OF MICROPHONE: In Operator's Cab hanging above and just behind Operator's head Car #212

DATE: 2/26/75 ; STARTING TIME: 10:21 a.m. ; LENGTH OF TRIP [SAMPLE LENGTH]: 59.1 mins

MAXIMUM LEVEL [dBA] [EXCLUDING TRANSIENTS]

Subway	At-Grade	Aerial
84	73	75

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
57	59	72	82	86	77

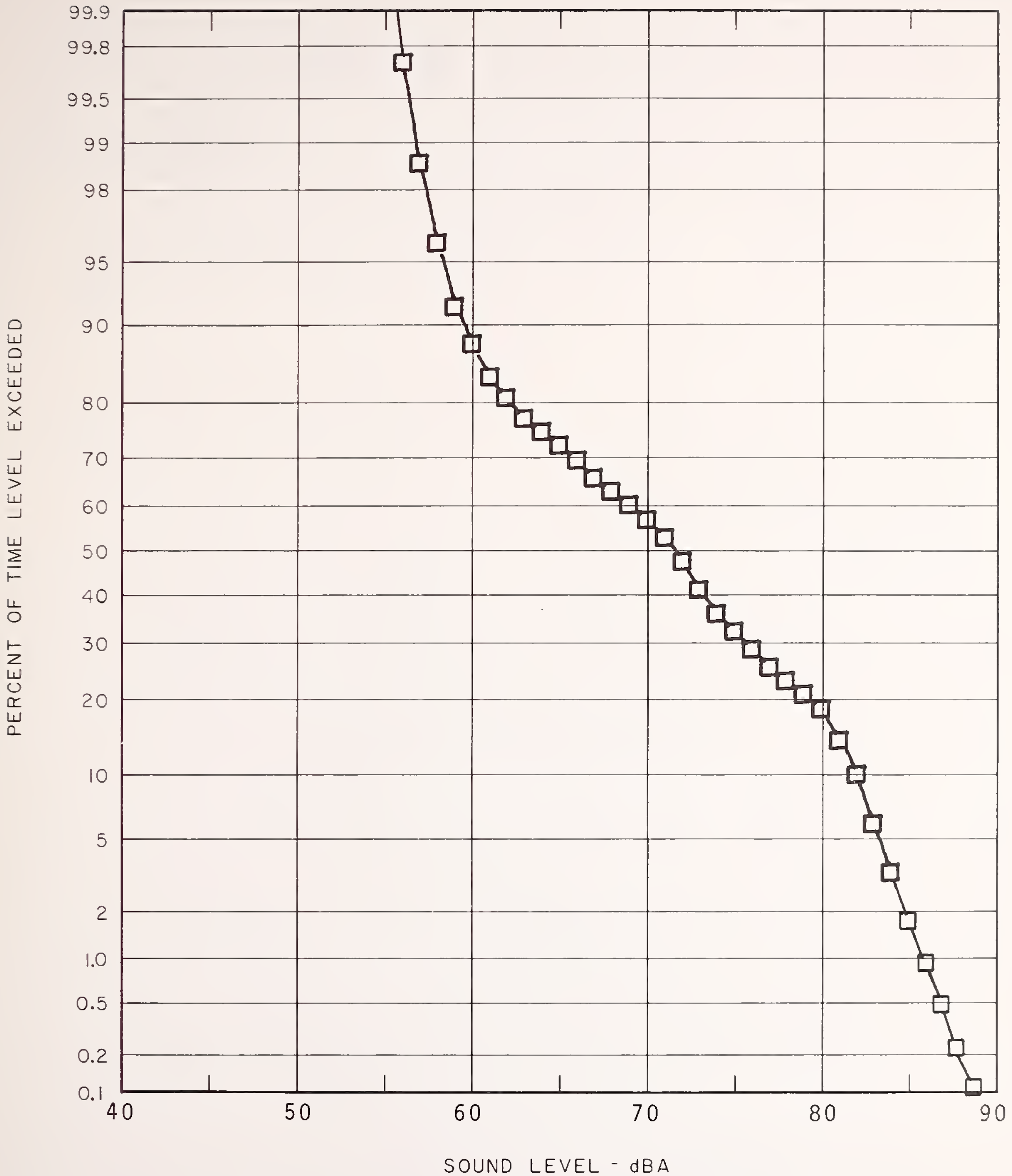


FIGURE 5.56 STATISTICAL DISTRIBUTION OF CONCORD STATION TO DALY CITY STATION OPERATOR'S CAB NOISE SAMPLE

INTERIOR NOISE TESTS AT TORONTO TRANSIT COMMISSION*

Two samples of interior noise were taken at the Toronto Transit Commission [TTC] for comparison with the interior noise data obtained on BART. The first sample was made in the center of an H-2 car which was the second car of the train. The sample was made between Warden Station and Bathurst Station, a distance of approximately 8.2 miles. The second sample was made in the center of the second car of another train. The sample was made between Finch Station and Union Station, a distance of approximately 9.9 miles See Table 5.48 for summary of results.

Although the statistical distribution shown on Figure 5.57a is comparable to some of the statistical distributions obtained on the BART trains, the maximum speed of a TTC train is approximately 45 mph while the maximum train speed for BART is 80 mph. Figure 5.57b shows typical traces of the interior noise for the two runs indicating the generally lower noise level observed on the second run between Finch and Union Stations.

*Source: Unpublished data from Wilson, Ihrig & Associates, 2/75.

TABLE 5.48 TTC INTERIOR NOISE SAMPLES - SUMMARY OF RESULTS

RUN #1 - Warden Station to Bathurst Station

Date: 2-5-75; Length of Sample: 20.4 mins

Maximum Level [Excluding Transients]: 88 dBA

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
69	71	76	84	88	80

RUN #2 - Finch Station to Union Station

Date: 2-5-75; Length of Sample: 25.8 mins

Maximum Level [Excluding Transients]: 86 dBA

STATISTICAL DESCRIPTORS [dBA]

L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{EQ}
66	68	74	81	86	78

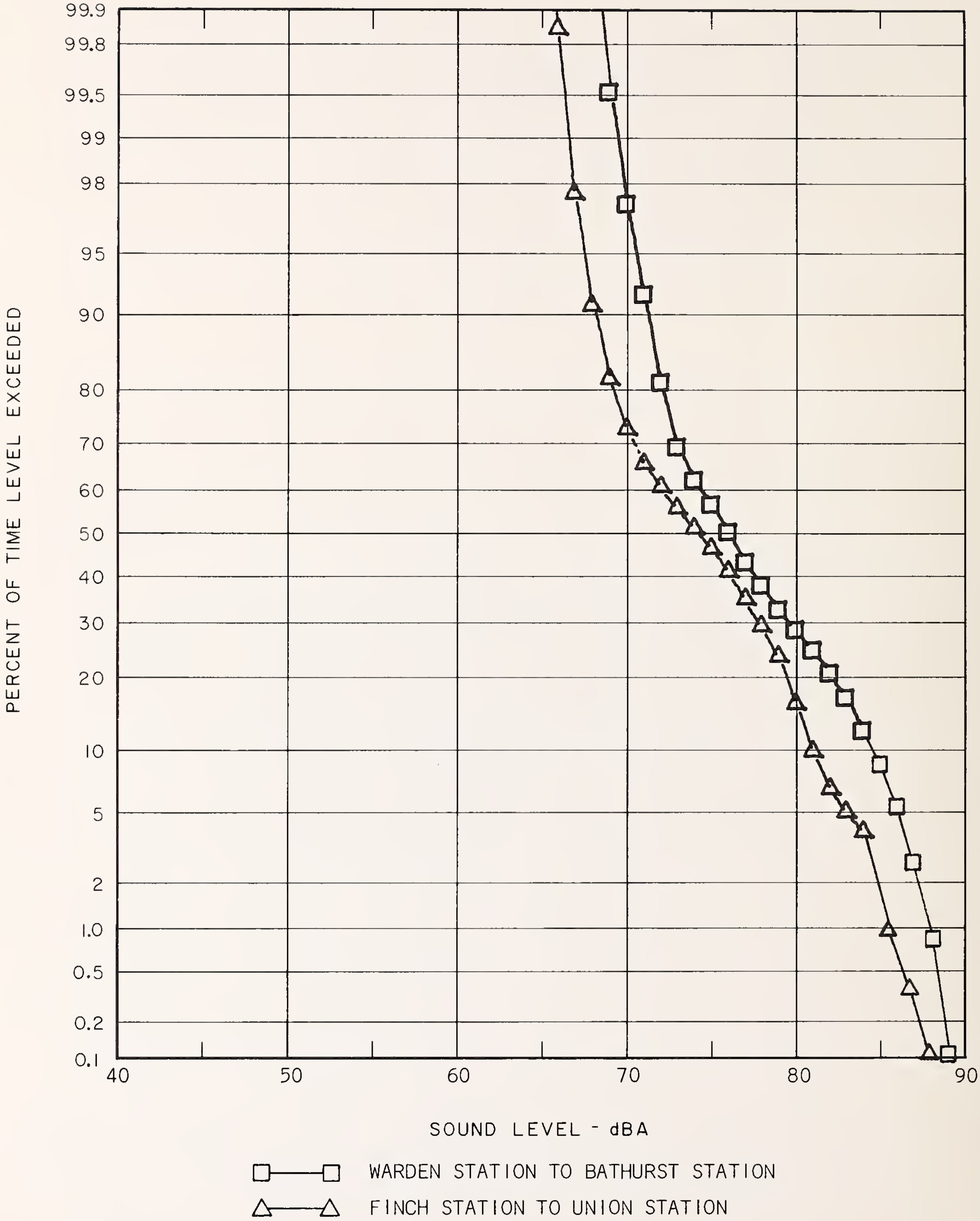
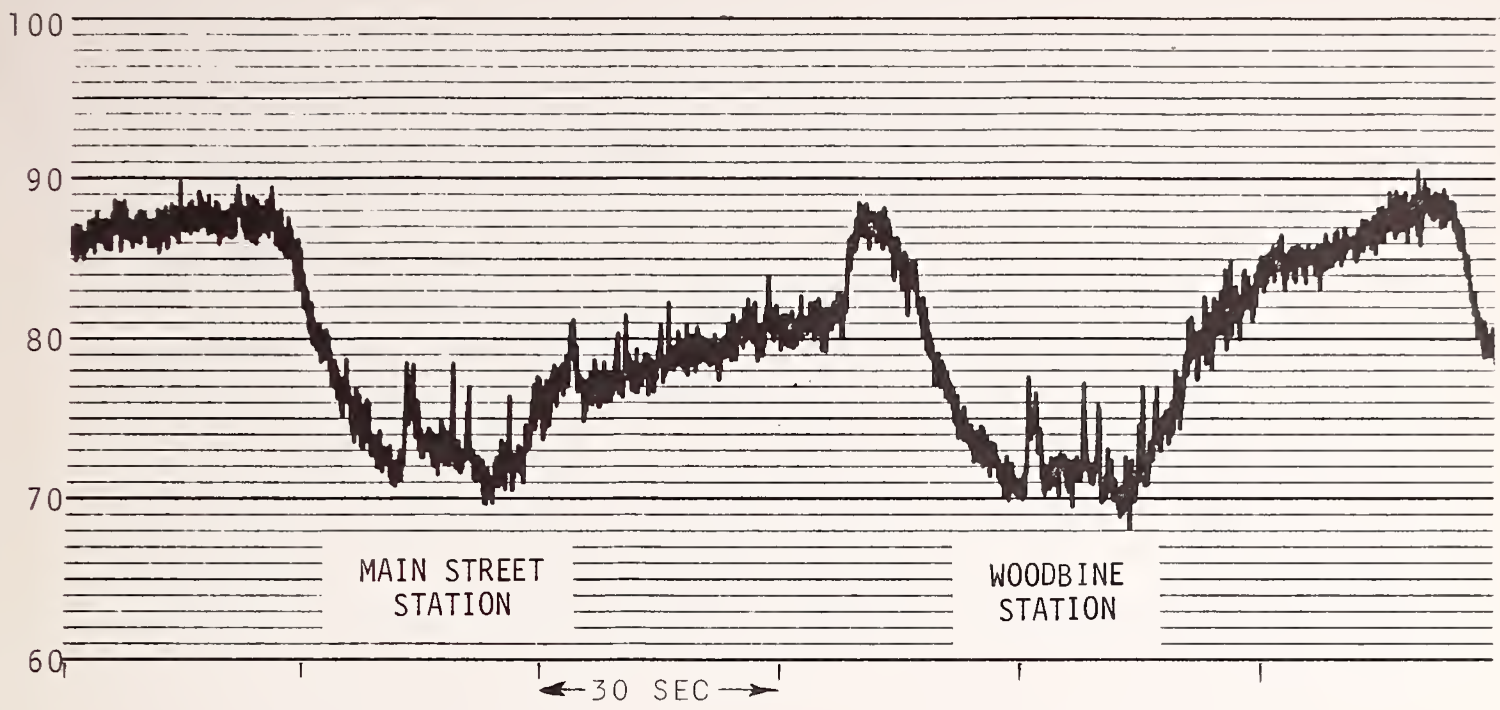
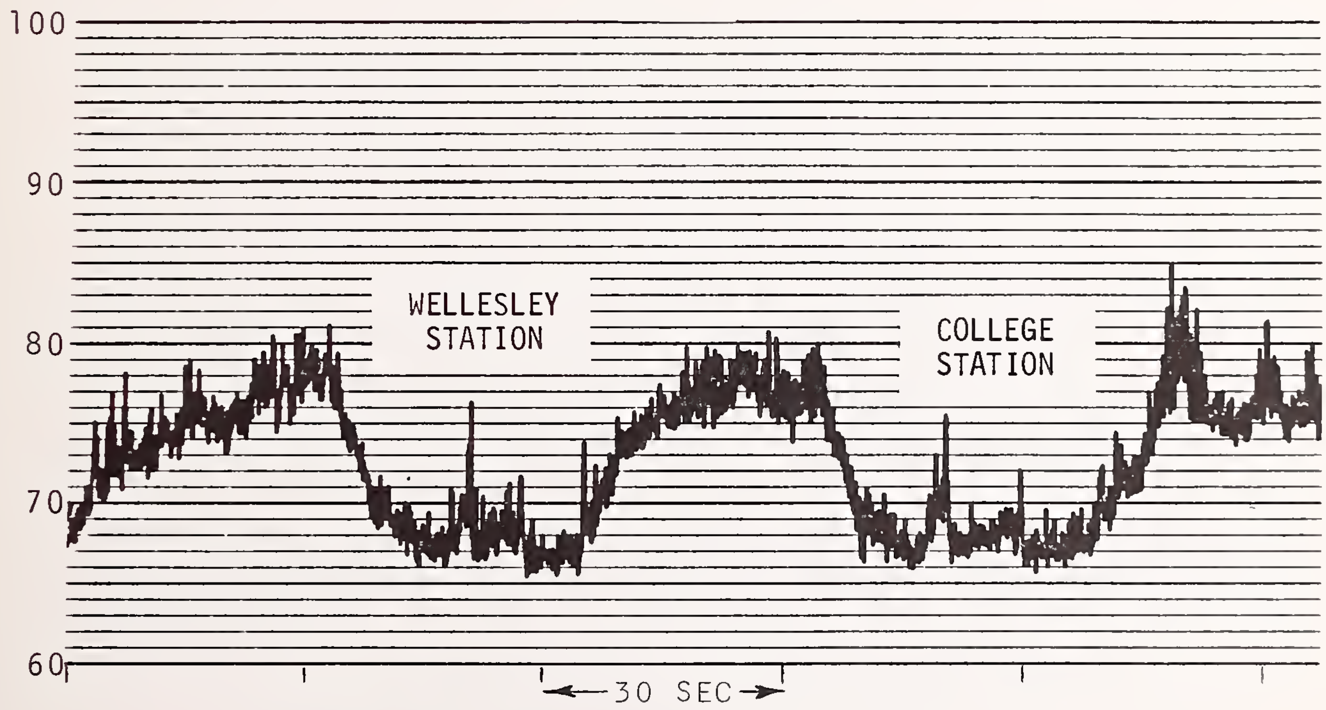


FIGURE 5.57a STATISTICAL DISTRIBUTIONS OF INTERIOR NOISE FOR TWO SAMPLES MADE AT THE TORONTO TRANSIT COMMISSION



TRACE FROM RUN #1 BETWEEN WARDEN AND BATHURST STATIONS



TRACE FROM RUN #2 BETWEEN FINCH AND UNION STATIONS

FIGURE 5.57b TYPICAL TRACES OF INTERIOR NOISE FOR TTC TRAINS

6. TRANSIT SYSTEM SUMMARY

6.1 General

The following summarizes the data reported in Section 5, obtained at selected community, station platform and in-car locations. Tables summarizing the results obtained from these measurements have been included.

The wayside noise reported is an average of the maximum noise levels [L_A(Max)] obtained for each near train passby at a distance of 50 ft from the near track centerline. The station platform noise reported is an average of the maximum level L_A(Max) obtained for each train's arrival and departure at a position in the center of the station platform 2 m from the platform edge. The interior noise data reported represents the maximum plateau noise level achieved at the car center for operation over a particular type of track structure.

For the wayside community noise, no attempt was made to calculate L_{DN} because BART did not operate at night at the time of the measurements. Thus noise measurements were made only during the daytime, rush hour and evening. It is felt that the calculation of an L_{DN} without the nighttime data would not be valid in light of operations during nighttime periods begun after the measurements.

6.2 Community Noise

Wayside community noise measurements were made at 13 representative locations as shown in Table 6.1. The locations were chosen to be representative of residential and commercial areas which contain the different types of track structures on which the BART trains operate. Measurements were made along different lines to assess the effects of operation frequency and train length.

Table 6.1 also summarizes the results obtained at each wayside location. The following general observations can be drawn from the noise data:

(1) The passby noise levels at each measurement location are consistent.

TABLE 6.1 SUMMARY OF WAYSIDE NOISE MEASUREMENTS

Location & Line	Community Type	Track Structure	Train Speed [MPH] Near	Far	Average Maximum Levels - dBA @ 50 Ft Near Track	Far Track
1 Richmond	Residential	Aerial	80	80	93	80
2 Richmond	Commercial	Aerial	80	80	93	81
3 Fremont	Residential	Aerial	80	80	89	79
4 Fremont	Commercial	Aerial	80	80	88	79
5 Richmond	Commercial	At-Grade	80	80	87	85
6 Concord	Residential	At-Grade	80	80	84	76
7 Fremont	Residential	At-Grade	80	80	85	77
8 Fremont	Commercial	At-Grade	70	80	87	79
9 Richmond	Residential	Vent Shaft	50	50	--	--
10 Richmond	Commercial	Vent Shaft	60	60	--	--
11 Concord	Residential	Walnut Creek Bridge	80	80	87	78
12 Fremont	Residential/ Commercial	Aerial Crossover	60	80	87	76
13 Fremont	Residential	At-Grade Crossover	80	80	78*	73*

*Noise level at 100 ft

(2) The maximum passby noise levels for trains on the BART concrete aerial structure are 3 to 6 dBA higher than for trains on ballast and tie at-grade tracks.

(3) The noise radiated from the two vent shafts was not a significant contributor to the noise climate during the samples.

6.3 Station Noise

Station platform noise measurements were made at 12 stations representative of the six different types of stations in use on the BART system. The six different types of stations are indicated on Table 6.2. Table 6.2 also presents the average of the maximum noise levels of both the entering and departing trains. The noise data obtained lead to the following general observations:

(1) The average maximum noise levels at the aerial and subway stations are generally higher than those at the at-grade stations by 4 to 8 dBA.

(2) The station platform configuration contributes only a small observable difference in the average maximum train noise levels on the platform from the near track.

(3) The subway station absorption material contributes to the reduction of the subway station platform noise to comparable or less than that on the aerial station platforms.

6.4 Interior Noise

Five commute trips, simulating a typical commuter's trip on BART were made with noise instrumentation to assess the noise exposure during a typical trip. Table 6.3 summarizes the results of these trips. End-to-end interior noise measurements were also made between Concord and Daly City, and Richmond and Fremont. These tests were made with the microphone located at the center of the car. Both noise and train speed data were obtained for correlation between the noise level and train speed. A summary of the results is shown in Table 6.3. From the interior noise data obtained, the following general observations can be made:

TABLE 6.2 SUMMARY OF STATION PLATFORM MEASUREMENTS

Station	Platform Type	Configuration	Average Maximum Levels - dBA for Near Track at Center of Platform 2 m From Edge: Train Entering	Train Departing
Rockridge [Daytime]	Center	Aerial - Concrete Trackbed	80	82
Rockridge [Rush Hour]	Center	Aerial - Concrete Trackbed	85	86
Coliseum	Center	Aerial - Concrete Trackbed	80	85
Bay Fair	Center	Aerial - Concrete Trackbed	80	85
Walnut Creek	Side	Aerial - Concrete Trackbed	75	84
El Cerrito Del Norte	Side	Aerial - Concrete Trackbed	84	82
Pleasant Hill	Side	Aerial - Concrete Trackbed	79	83
Richmond	Center	At-Grade - Ballast & Tie	75	80
Union City	Side	At-Grade - Ballast & Tie	78	79
South Hayward	Side	At-Grade - Ballast & Tie	74	77
Lake Merritt	Center	Subway - Concrete Trackbed	77	86
19th Street [Upper Level]	Side [Multi-Level]	Subway - Concrete Trackbed	83	85
19th Street [Lower Level]	Side [Multi-Level]	Subway - Concrete Trackbed	84	87
Civic Center	Center	Subway - Concrete Trackbed	81	82

TABLE 6.3 SUMMARY OF INTERIOR NOISE MEASUREMENTS

COMMUTE TRIPS:

Trip	Maximum Noise Level [dBA] [Excluding Transients] Platform	Subway	At-Grade	Aerial
Concord Station to Montgomery Street Station	65	85	77	81
Fremont Station to Berkeley Station	65	82	75	79
Rockridge Station to Glen Park Station[1]	85	84	73	78
El Cerrito Plaza Station to Lafayette Station	57 [El Cerrito] 80 [Mac Arthur]	86	74	76
Powell Street Station to North Berkeley Station	65 [Powell St] 80 [Mac Arthur]	83	71	77

END-TO-END TESTS:

Trip	Maximum Noise Level [dBA] [Excluding Transients] Subway	At-Grade	Aerial
Concord Station to Daly City Station and Return	83	74	79
Richmond Station to Fremont Station and Return	83	75	76

[1] Average of three trips

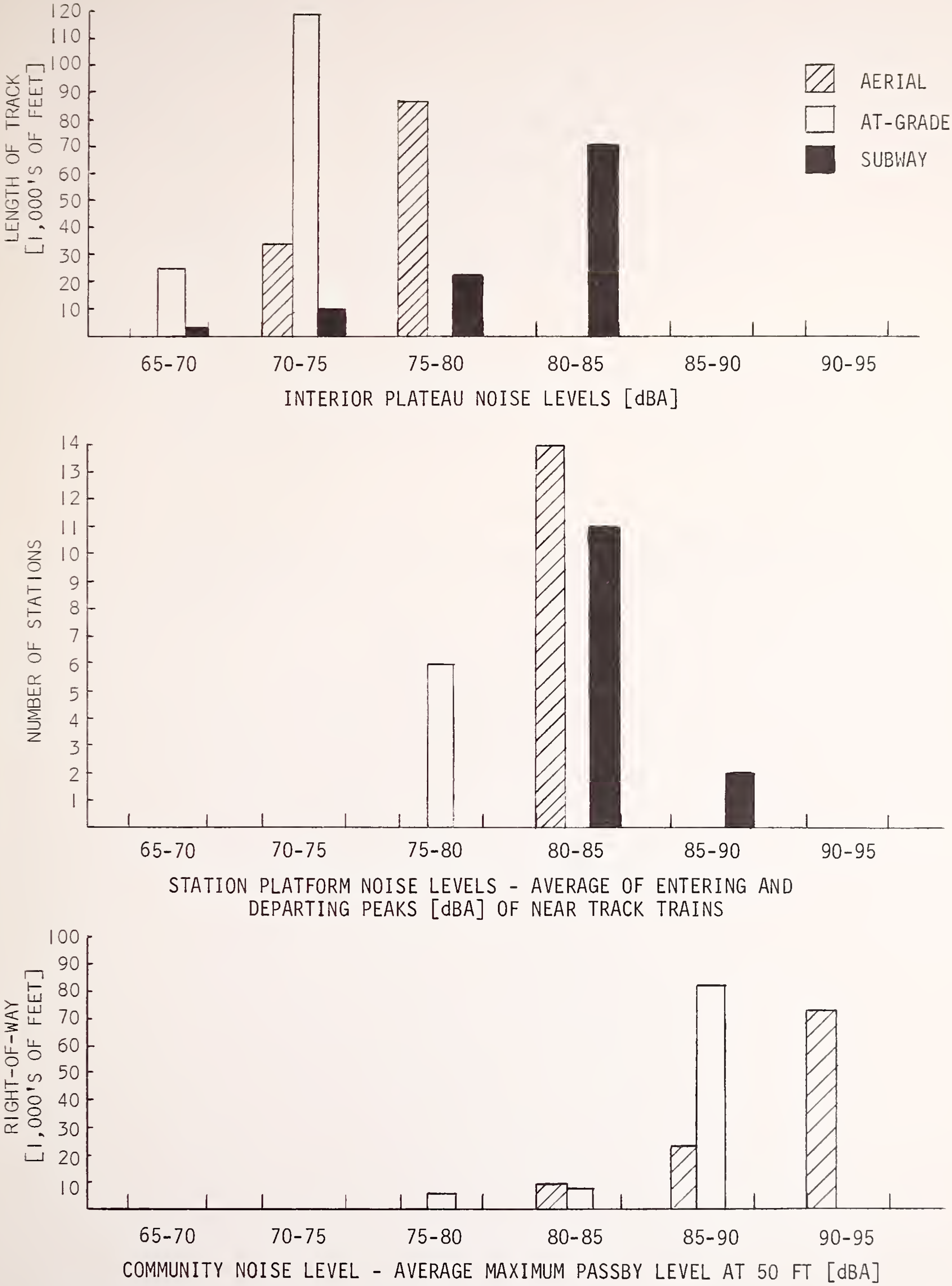
(1) The average maximum interior noise levels in subway are from 4 to 7 dBA higher than those on aerial structure.

(2) The average maximum interior noise levels on aerial structure are from 1 to 5 dBA higher than those for at-grade ballast and tie track.

(3) The noise levels inside different cars on identical track structures are relatively consistent for measurements made at the same speed with the same microphone position.

6.5 BART Noise Summary

A graphic summary of interior, station, and wayside noise is presented in Figure 6.1. The levels have been grouped into 5 dBA ranges: 65-70; 70-75; 75-80; 80-85; 85-90; and 90-95. The levels have been further broken down in terms of aerial, at-grade, and subway structure, as the noise levels are highly dependent upon the type of structure on which the trains operate.



NOTE: GROUPED SOUND LEVEL INTERVAL INCLUDES LOWER, BUT NOT UPPER END POINT

FIGURE 6.1 SUMMARY OF BART NOISE ENVIRONMENT

7. REFERENCES

1. Kurzweil, L.G.; Lotz, R.; and Apgar, E.G.; "Noise Assessment and Abatement in Rapid Transit Systems"; Report No. UMTA-MA-06-0025-74-8; September 1974.

2. Webster, W.J. and Farinacci, J.W., "Use of Graphic Level Recorders as Indicating Instruments, Part 1: Meeting the Specifications of a Sound Level Meter" Bureau of Noise, New York State Department of Environmental Conservation, Albany, New York, 1974.

3. Shultz, T.J., "Development of an Acoustic Rating Scale for Assessing Annoyance Caused by Wheel/Rail Noise in Urban Mass Transit", Report No. UMTA-MA-06-0025-74-2, February 1974.

APPENDIX

REPORT OF INVENTIONS

A detailed review of the work performed under this contract and the material contained in this report has not disclosed any discoveries or inventions. The work reported here represents a data base of noise measurements on a specific transit system, suitably extrapolated to all locations in and around the system as to provide an assessment of existing noise levels.

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE, CAMBRIDGE, MA. 02142