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NOISE AND VIBRATION SURVEY
FOR THE
METRO RAIL PROJECT

FINAL REPORT

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1. INTRODUCTION

This report presents a study of the ambient noise and ground-borne vibration existing at the present time along the proposed alignment of the SCRTD Metro Rail Project.

Noise and vibration measurements were made outside representative buildings and in representative areas along the proposed Metro Rail alignment to provide information and documentation on the existing ambient levels and to provide assistance in determining the acceptable or allowable Metro Rail System noise and vibration levels in nearby buildings. These data used in conjunction with the noise and vibration design criteria provide a basis for determining those areas where special design features are needed to reduce the noise and vibration from transit train operations to acceptable levels.

This noise and vibration survey report discusses the survey locations and procedures, presents background information on noise and vibration measurements and descriptors, presents the results of the measurements and identifies community areas and some individual structures along the alignment that may require particular attention to assure acceptable noise and vibration levels once the plan and profile of the alignment are finalized.

2. SURVEY PROCEDURE AND BACKGROUND INFORMATION

Establishing the existing noise level or noise environment in a community requires measuring the noise at a large number of locations at several different times of day and, preferably, on several different days and times of the year. Community noise is a continually fluctuating entity dependent on many factors. Because the noise level does fluctuate over a relatively wide range, it is necessary to make measurements which are statistically significant and which can be analyzed on a statistical basis.

Establishing the existing vibration environment requires the same procedures and has the same general statistical variations as does the existing noise environment. Although reference is made throughout this section to ambient or community noise, this discussion for the most part is equally applicable to vibration.

The proposed 18.6 mile Metro Rail alignment is entirely underground, beginning at Union Station, continuing west along Macy Street and Broadway Street, then along Seventh Street and Wilshire Boulevard to Fairfax Avenue. The alignment then continues north along Fairfax Avenue and east along Fountain Avenue to Cahuenga Boulevard. The alignment again turns north along Cahuenga Boulevard, then northwest through the Santa Monica Mountains, west of Cahuenga Pass. The final section of the alignment continues north along Vineland Avenue then turns west along Chandler Boulevard and ends at a point east of the Hollywood Freeway.

The alignment passes through several different types of community areas. In the downtown area and along Wilshire Boulevard, the area is primarily commercial with office buildings and retail stores. There are also a significant number of multi-family residences (apartments and condominiums) along some sections of Wilshire Boulevard. Along Fairfax Avenue there are sections of commercial buildings and some multi- and single-family residences. Between Fountain Avenue and Vineland Avenue the area near the alignment is primarily residential with single- and multi-family residences. Along Vineland Avenue to the end of the alignment the area has some commercial as well as residential areas. A more detailed description of the land usage along the alignment is given in Table 2-1.

For the commercial areas, with principally daytime occupancy, the possibility of intrusion from transit train operations is primarily a daytime consideration. In residential areas, the community ambient or background noise level is generally the lowest during the evening and nighttime hours and the possibility of intrusion from transit train operations is greatest during this time period. Thus, in the commercial areas, the environmental measurements are accomplished mainly in the daytime and the transit system design criteria are based primarily on daytime operations and noise levels. In the residential areas, the measurements are performed at several different characteristic times of the day and the transit system design criteria are based primarily on evening and nighttime operations and noise levels.

Although community noise data for the daytime in commercial areas and noise data for the evening and nighttime in residential areas are sufficient to establish the design criteria and evaluate the potential impact of the transit system, such measurements are not sufficient for a complete assessment of the community area environment. Therefore, measurements are generally made to provide data on the existing noise levels for several different times of day. Complete 24-hour surveys of the noise level can be performed in order to obtain a complete statistical representation of the daily noise exposure in a community area. It has been found, however, that the noise in communities can be characterized adequately by making spot-check measurements during at least four characteristic times of day. Because of the purpose of the noise measurements reported herein, the spot-check type of survey with a measurement duration of 10 minutes was performed at all of the measurement locations during appropriate characteristic times of day. These data are supplemented by complete 24-hour noise surveys at several selected measurement locations.

A total of forty-five measurement locations were chosen as representative of areas along the proposed alignment. "Spot-check" or short-term noise and vibration measurements were made at all forty-five locations. Twenty-four hour or long term noise measurements were also performed at nine selected locations. The locations of the measurement sites are indicated in Figures 2-1 through 2-4, and a brief description of each measurement location and its relation to the alignment is given in Table 2-2. Table 2-3 gives a brief description of each of the 24-hour noise survey locations and their relation to the alignment. All of the noise and vibration data were obtained between September 21 through 25 and September 28 through October 1, 1981. Results of the noise and vibration survey are presented in Section 3, EXISTING NOISE LEVELS and Section 4, EXISTING VIBRATION LEVELS.

For the purpose of this study the day was divided into four characteristic measurement periods representing:

Daytime:	10:00 a.m. to 2:00 p.m.
Rush Hour:	4:00 p.m. to 6:00 p.m.
Evening:	7:00 p.m. to 10:00 p.m.
Nighttime:	11:00 p.m. to 2:00 a.m.

No data were taken during the morning rush hour because it is generally found that the noise level results are essentially the same as for the evening rush hour.

The results of the noise measurements and the description of the noise environments prevailing at each of the measurement locations in the community are based on a statistical analysis of the observed noise levels in decibels. The factors derived from the analysis are the levels exceeded 99% of the time, 90% of the time, 50% of the time, 10% of the time, and 1% of the time designated L_{99}, L_{90}, L_{50}, L_{10}, and L_1, respectively.

L_{99} and L_{90} are descriptors of the typical minimum or "residual" background noise level observed during a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual sound sources. The most prevalent source of this residual noise is distant street and highway traffic, but L_{99} and L_{90} are not strongly influenced by occasional local motor vehicle passbys. However, they can be influenced by nearby stationary sources such as air conditioning equipment.

L_{50} represents a long-term statistical average or median sound level over the measurement period and does reveal the long-term influence of local traffic. If the instantaneous sound level is sampled over a measurement period, the sound level will be above L_{50} 50% of the time and below L_{50} 50% of the time.

L_{10} describes the average peak or maximum sound level occurring for example, during nearby passbys of trucks, buses, automobiles, trains, or airplanes. Thus, while L_{10} does not describe the long-term noise prevailing it does describe the typical maximum noise levels observed at a point and is strongly influenced by the momentary maximum sound level occurring during vehicle passbys.

L_1, the sound level exceeded 1% of the time, is representative of the occasional maximum or peak sound level which occurs in an area.

Because of some inherent deficiencies of the simple percentile measures described above in evaluating the noise exposure effects of short duration, high level sounds (such as truck or bus passbys), the Energy Equivalent level, L_{eq}, has been developed and is widely used as a valid single-number descriptor of environmental noise. Because it is an energy integral over time, L_{eq} represents the constant or steady sound level which would give the same energy level as the fluctuating value integrated over the total time period. Because sound energy is proportional to the square of the sound pressure, L_{eq} places more emphasis on high noise level periods than does L_{50} or a straight arithmetic average of noise level over time. Some consider L_{eq} a more useful measure than L_{50} for the average or typical noise exposure in an area and most recent evaluation systems such as CNEL (Community Noise Equivalent Level) or L_{dn} (Day/Night Average Level) use the energy equivalent concept.

TABLE 2-1 LAND USAGE ALONG THE METRO RAIL ALIGNMENT

Station Number From Union Street Station	Description of Land Usage
00+00 to 30+70	Commercial office buildings from Union Street Station to Hollywood Freeway.
30+70 to 43+00	County and Federal Court Houses.
43+00 to 95+00	Commercial office buildings.
95+00 to 110+00	Several banks (California Commercial, Banco de Brasil S.A. etc.), commercial office buildings and Hilton Hotel.
110+00 to 124+00	Commercial office buildings.
124+00 to 130+00	Hospitals and commercial office buildings.
130+00 to 162+00	Commercial office buildings.
162+00 to 174+50	McArthur Park.
174+50 to 178+30	Art Gallery and commercial office building.
178+30 to 200+00	Commercial office buildings and Sheraton Hotel.
200+00 to 240+00	Mixed commercial, offices and apartments. Immanuel Presbyterian Church at station 223+00 and Wilshire Church at station 240+00.
240+00 to 280+00	Commercial offices and bank buildings. St. Basil Roman Catholic Church at station 249+00 and St. James Episcopal Church and St. James Episcopal School, at station 276+00.
280+00 to 312+00	Commercial office and residential buildings. Scottish Rite and Wilshire Methodist Church at stations 310+00.

TABLE 2-1 (Continued)

Station Number From Union Street Station	Description of Land Usage
312+00 to 340+00	Commercial, office and residential buildings.
340+00 to 357+00	Residential and office buildings. High School at station 350+00.
357+00 to 415+00	Commercial, office and residential buildings.
415+00 to 420+00	Commercial office buildings and Art Museum at station 417+00.
420+00 to 450+00	Commercial and residential buildings.
450+00 to 490+00	Residential buildings.
490+00 to 515+00	Residential and commercial buildings. CBS T.V. Studio at station 417+00.
515+00 to 570+00	Residential and commercial buildings. Fairfax High School at station 535+00 and a theater at station 534+50.
570+00 to 622+50	Apartments and isolated houses.
622+50 to 670+00	Apartments, isolated houses and some commercial buildings.
670+00 to 700+00	Commercial and office buildings.
700+00 to 710+00	Apartments, commercial and office buildings.
710+00 to 735+00	Residential area close to Hollywood Freeway.
735+00 to 745+00	Open land and Hollywood Bowl at station 743+00.
745+00 to 760+00	Open land.
760+00 to 833+00	Single-family residential dwellings.
833+00 to 874+00	Commercial and some office buildings.

TABLE 2-1 (Continued)

Station Number From Union Street Station	Description of Land Usage
874+00 to 905+00	Residential and office buildings.
905+00 to 925+00	Residential and office buildings, and isolated houses.
925+00 to 1008+00	Mixture of apartments, houses, commercial and office buildings.
1008+00 to 1020+00	Residential and some commercial buildings.

TABLE 2-2 LOCATIONS USED FOR EVALUATION OF THE NOISE AND VIBRATION ENVIRONMENT ALONG THE METRO RAIL ALIGNMENT

Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
1	16+00	640	Near the band stage platform area located within the El Pueblo State Historical Park Plaza on Olivera Street
2	34+00	30	On the west side of the intersection of North Broadway and Temple Street, near the Los Angeles County Hall of Records
3	59+40	25	On the west side of Broadway between 3rd and 4th Streets
4	99+50	340	On the north side of the intersection of Wilshire Boulevard and Flower Street, near the corner of Wells Fargo Bank
5	129+80	60	On the north side of Wilshire Boulevard and 165 ft southeast of the intersection of Wilshire Boulevard and Witmer, near the Hospital of the Good Samaritan
6	143+20	25	On the south side of Wilshire Boulevard and 60 ft west of the intersection of Wilshire Boulevard and Union Avenue

TABLE 2-2 (Continued)

Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
7	175+50	45	On the north side of the intersection of Wilshire Boulevard and Park View Street, near Otis/Parsons Art Gallery
8	195+80	65	On the northwest of the intersection of Wilshire Boulevard and Commonwealth Avenue, near the corner of Sheraton Hotel
9	222+80	30	On the south side of the intersection of Wilshire Boulevard and Berendo Street, near the steps to Immanual Presbyterian Church
10	240+20	35	On the north side of the intersection of Wilshire Boulevard and Normandie Avenue, near the Wilshire Christian Church
11	250+20	25	On the north side of Wilshire Boulevard between Kingsley Drive and Harvard Boulevard, near the corner of St. Basil Roman Catholic Church
12	276+60	45	On the north side of Wilshire Boulevard between St. Andrews and Gramercy Place, near the corner of St. James Episcopal School and an office building
13	310+90	45	On the south side of Wilshire Boulevard between Lucerne Boulevard and Plymouth Boulevard, near the corner of Wilshire Methodist Church and the parking area

TABLE 2-2 (Continued)

Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
14	337+30	20	On the north side of Wilshire Boulevard between Rimpau Boulevard and Hudson Avenue, near the Farmers' Insurance building and the parking area
15	352+50	65	On the east side of Longwood Avenue and 40 ft south of Wilshire Boulevard, near the Leona School
16	389+10	35	On the northeast corner of the intersection of Wilshire Boulevard and Burnside Avenue, near the office building
17	410+40	45	Near the La Brea Tar Fossil Pits located within Hancock Park, on the north side of the intersection of Wilshire Boulevard and Stanley Avenue
18	418+30	620	Near the observation pit located within the grounds of the Art Museum, 140 ft south of the intersection of Ogden Drive and 6th Street
19	425+30	850	Near the south end of Orangegrove Avenue
20	510+25	240	In the parking area of CBS T.V. Studio on Fairfax Avenue and Beverly Boulevard
21	534+40	25	On the west side of Fairfax Avenue and 100 ft north of the intersection of Fairfax Avenue and Clinton Street, near the Theater and King Solomon Home for the elderly

TABLE 2-2 (Continued)

Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
22	551+30	15	On the west side of Fairfax Avenue, 160 ft south of the intersection of Fairfax Avenue and Willoughby Avenue, near the driveway to the underground parking area of the County Villa Convalescent Home
23	587+70	295	On the northeast corner of the intersection of Spaulding Avenue and Hampton Avenue
24	598+80	25	On the northwest corner of the intersection of Fountain Avenue and Gardner Street
25	616+00	20	On the northwest corner of the intersection of Fountain Avenue and Alta Vista Boulevard
26	625+30	20	On the northwest corner of the intersection of Fountain Avenue and La Brea Avenue
27	648+90	10	On the northwest corner of the intersection of Fountain Avenue and Las Palmas Avenue
28	663+30	295	On the south side of Fountain Avenue and 50 ft west of the intersection of Fountain Avenue and Wilcox Avenue, near the Orchard Gables Convalescent Hospital
29	673+60	1060	On the southeast corner of the intersection of Vine Street and De Longpre Avenue

TABLE 2-2 (Continued)

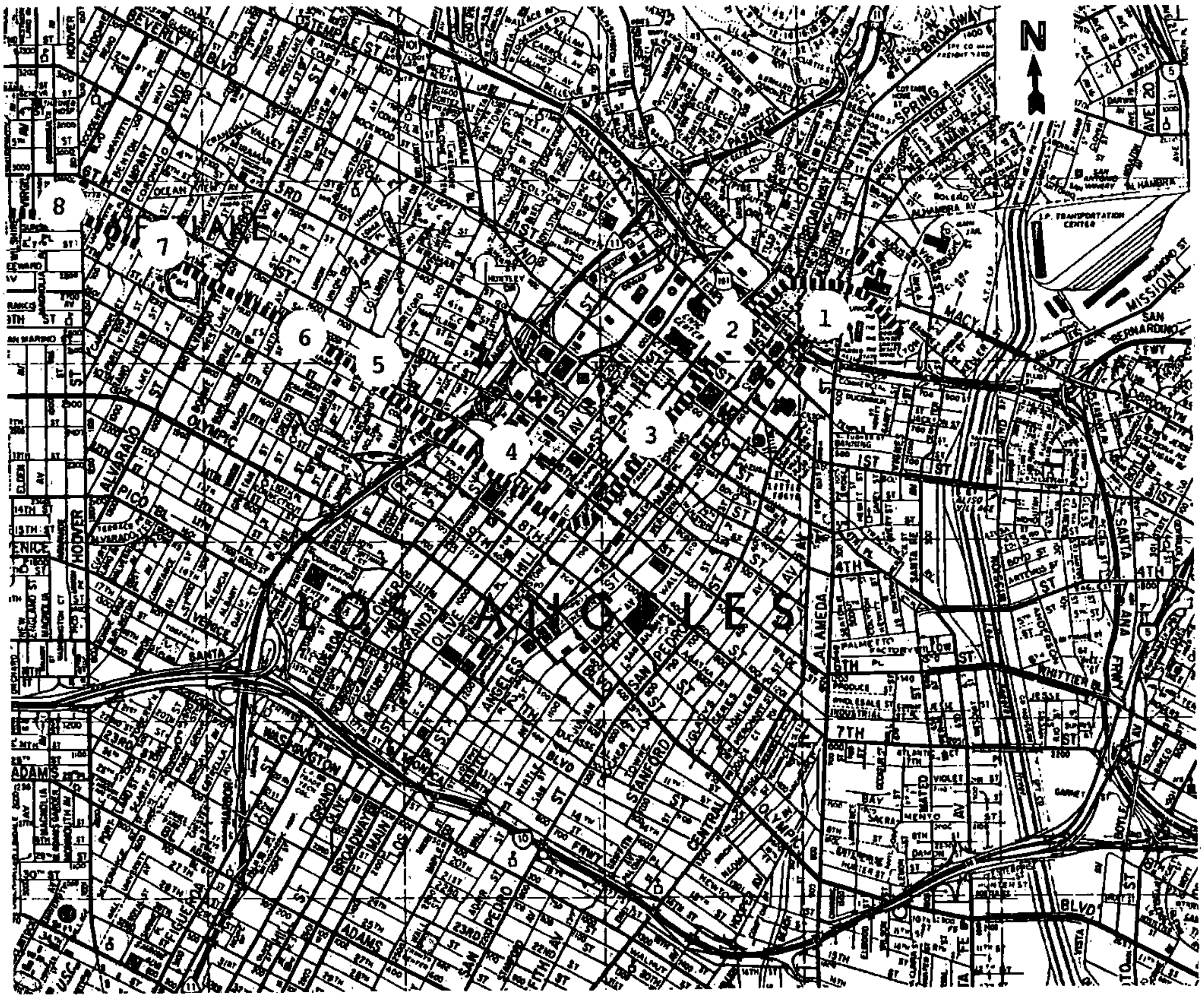
Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
30	695+00	890	On the west side of Vine Street, 330 ft north of the intersection of Vine Street and Hollywood Boulevard, near the Capitol Records Building
31	714+90	45	On the south corner of Cerritos Place and Holly Hill Terrace
32	724+80	755	On the west side of the intersection of Las Palmas Avenue and Milner Terrace
33	740+60	20	Within the Hollywood Bowl parking area on Hollywood Bowl Drive
34	760+80	750	Outside the apartments at 6720 Parkhill Drive off Cahuenga Boulevard
35	779+80	185	Outside the house at 7010 Pacific View Drive
36	812+70	335	Outside the house at 3149 Oakshire Drive near Adina Drive
37	821+50	690	At the front of the garage of 3340 Bonnie Hill Drive
38	834+20	290	Outside the house at 3827 Broadlawn Drive off Cahuenga Boulevard

TABLE 2-2 (Continued)

Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
39	847+20	190	Outside a commercial building at 3623 Cahuenga Boulevard, located between Fredonia Drive and Regal Place
40	896+90	95	In the parking area of Howard Johnson's Inn, 70 ft east of the intersection of Vineland Avenue and Aqua Vista Street
41	911+90	55	On the southeast corner of the intersection of Vineland Avenue and Bloomfield Street
42	931+20	60	On the southwest corner of the intersection of Vineland Avenue and Hortense Street
43	964+30	50	On the southeast corner of the intersection of Vineland Avenue and Hartsock Street
44	987+70	565	On the northwest corner of the intersection of Cumpston Street and Fulcher Avenue
45	1014+90	60	On the northeast corner of the intersection of Chandler Boulevard and Camellia Avenue

TABLE 2-3 24-HOUR NOISE SURVEY LOCATIONS ALONG THE METRO RAIL ALIGNMENT

Location Number	Station Number	Approximate Perpendicular Horizontal Distance From Near Track Centerline (ft)	Description of Site
5	129+80	60	On the north side of Wilshire Boulevard, 165 ft southeast of the intersection of Wilshire Boulevard and Witmer, near the Hospital of the Good Samaritan
11	250+20	25	On the north side of Wilshire Boulevard between Kingsley Drive and Harvard Boulevard, near the corner of St. Basil Roman Catholic Church
19	425+30	850	Near the south end of Orangegrove Avenue
21	533+50	25	On the northwest corner of the intersection of Fairfax Avenue and Clinton Street
23	587+70	295	On the northeast corner of the intersection of Spaulding Avenue and Hampton Avenue
25	616+60	15	Outside the apartments at 7228 Fountain Avenue near Alta Vista Boulevard
28	663+30	295	On the south side of Fountain Avenue, 50 ft west of the intersection of Fountain Avenue and Wilcox Avenue, near the Orchard Gables Convalescent Hospital
32A	727+40	705	At the intersection of Highland Avenue and Rockledge Road near Las Palmas Avenue
42	931+20	60	On the southwest corner of the intersection of Vineland Avenue and Hortense Street



(SCALE: 1 INCH = 2800 FT)

FIGURE 2-1 LOCATION OF NOISE AND VIBRATION MEASUREMENT SITES ALONG THE METRO RAIL ALIGNMENT

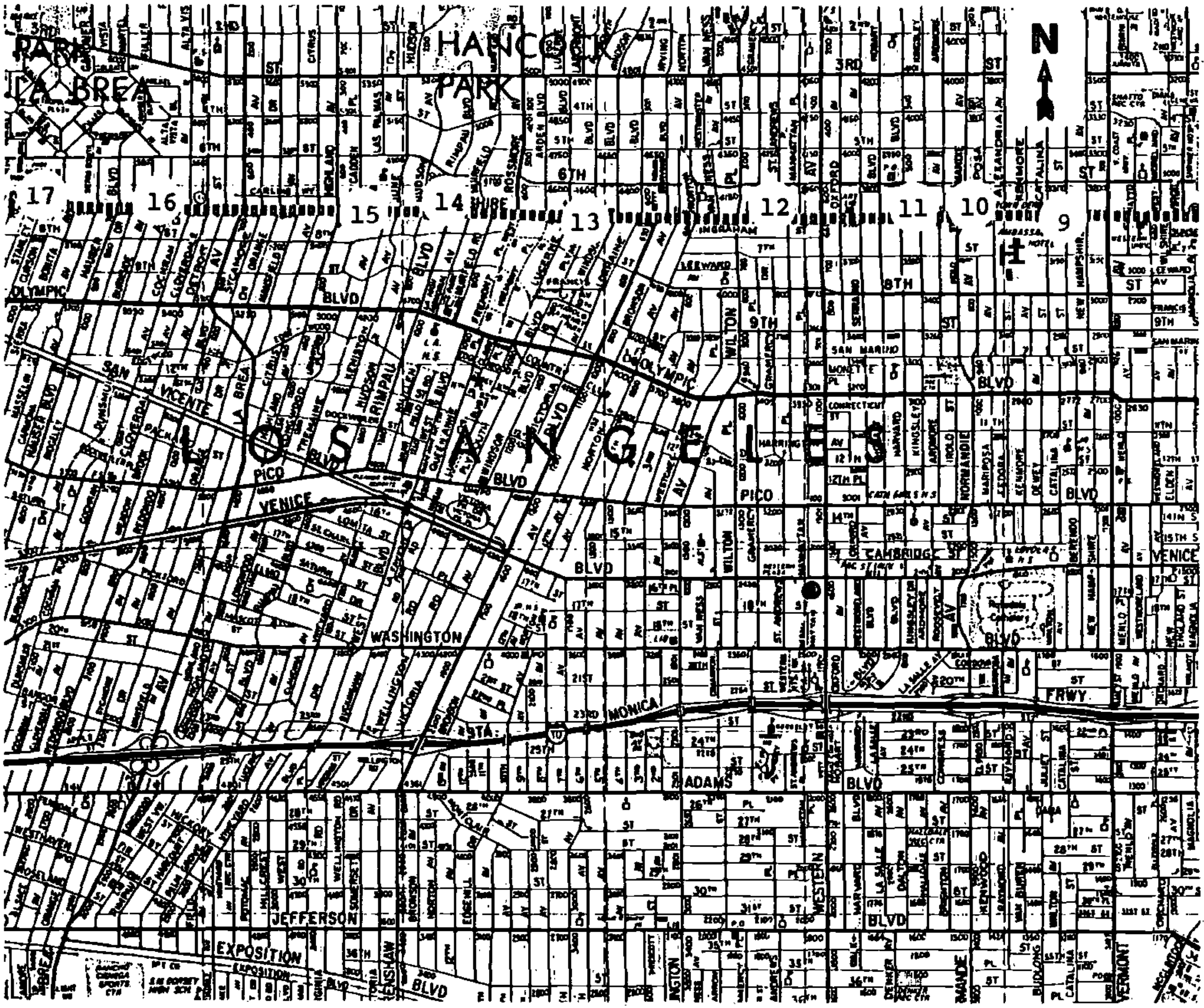


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FIGURE 2-2 LOCATION OF NOISE AND VIBRATION MEASUREMENT SITES ALONG THE METRO RAIL ALIGNMENT

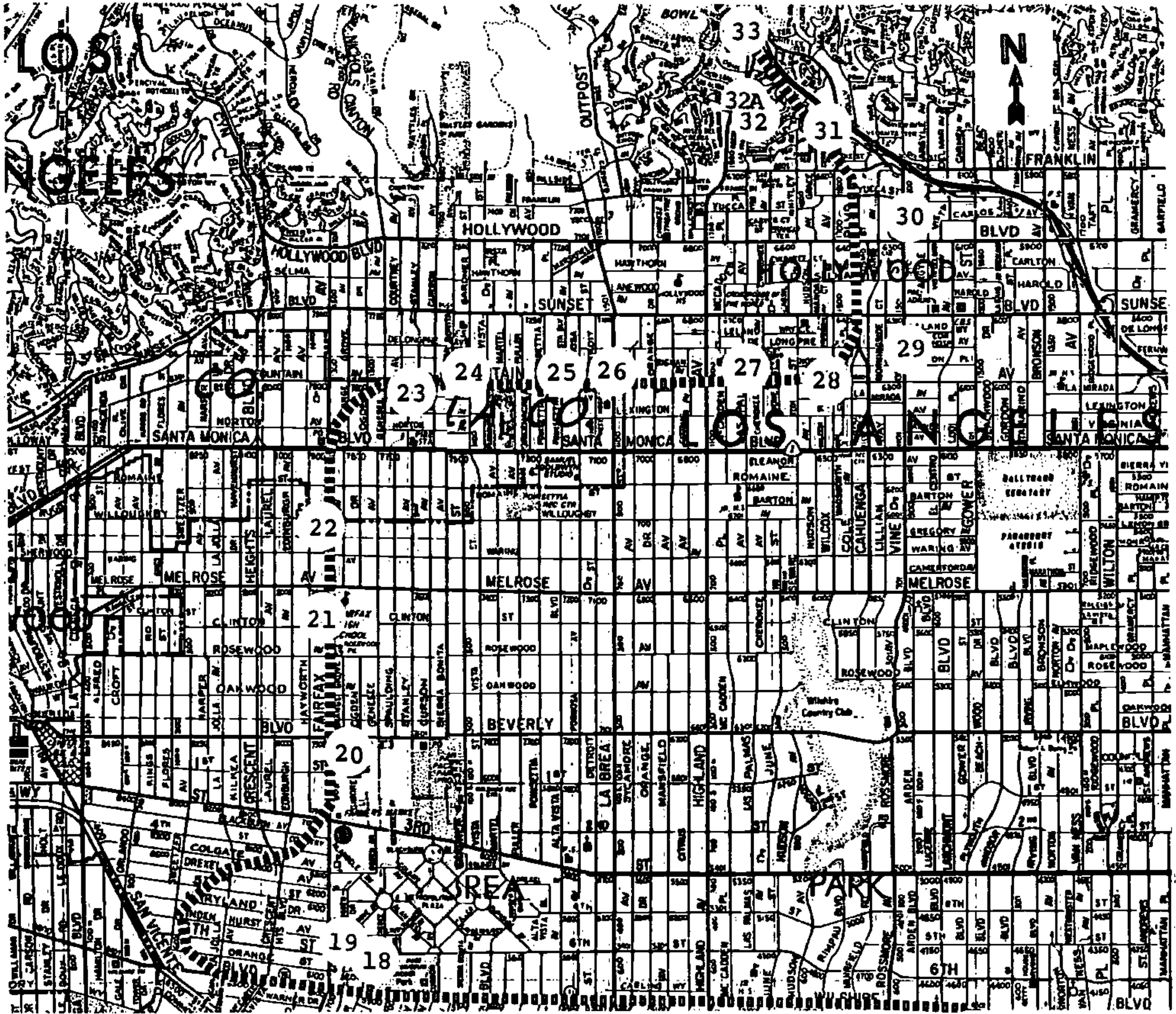

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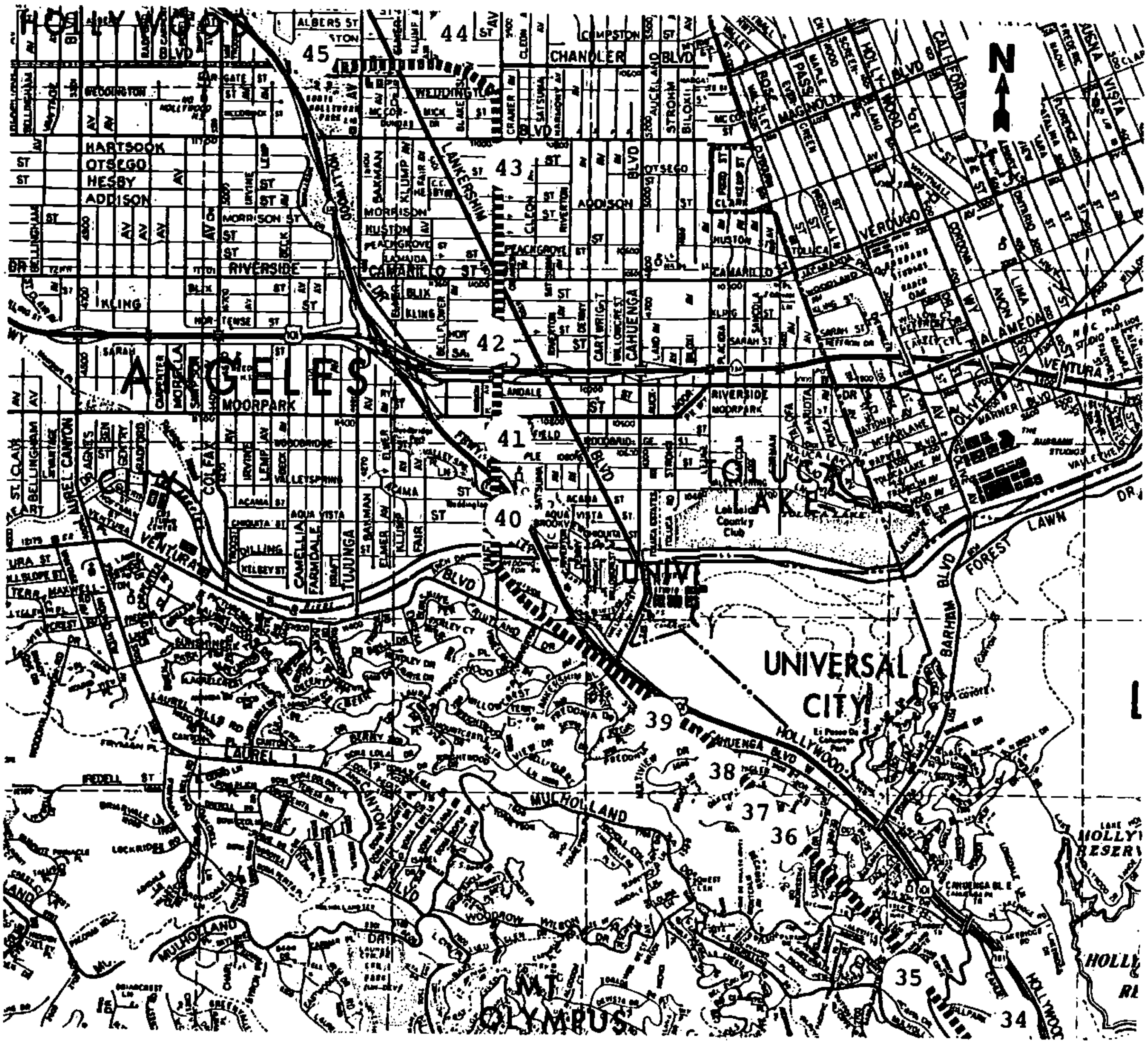
FIGURE 2-3 LOCATION OF NOISE AND VIBRATION MEASUREMENT SITES ALONG THE METRO RAIL ALIGNMENT



(SCALE: 1 INCH = 2800 FT)

FIGURE 2-4 LOCATION OF NOISE AND VIBRATION MEASUREMENT SITES ALONG THE METRO RAIL ALIGNMENT

3. EXISTING NOISE LEVELS

Table 3-1 presents a tabulation of the statistical analysis of the noise observed at each of the 45 noise measurement locations. All of the noise levels are presented in terms of A-weighted sound level in decibels, abbreviated dBA. This measurement scale is used because it has become accepted as the best compromise scale, using frequency weighting which approximates the hearing characteristics of the average human ear. The A-weighted sound level shows good correlation of the subjective response of people and communities with measured noise levels. Also, most noise ordinances, standards and specifications are written in terms of A-weighted sound level. Figure 3-1 indicates the typical A-weighted sound levels for some common noises.

Each measurement to determine the noise data in Table 3-1 consisted of a ten minute long continuous sample of noise at the site, recorded by means of a calibrated multi-channel precision magnetic tape recorder equipped with a sound level meter microphone. The recordings obtained were later analyzed to obtain the statistical distribution and other descriptors of the noise levels. The tape recordings can be used in the future to obtain spectral analysis of the noise at the sites (such as octave band or 1/3 octave band analyses) and are permanently retained as a record of the noise environment existing at the time of the measurements.

Each measurement location was chosen to obtain the noise levels characteristic of an area or near a potentially noise sensitive building. Wherever possible the measuring microphone was located at the set back line of the nearby buildings.

Review of the sound level data obtained during the spot-check or 10-minute measurements indicates that the residual background noise levels, L_{99} and L_{90}, range from 37 to 69 dBA during the rush hour and day, and 34 to 64 dBA during the evening and nighttime hours. At most locations the noise levels do show a significant decrease during the evening and nighttime hours when compared with the rush hour and daytime noise levels.

The median or L_{50} noise level for the different sites ranges from 40 to 72 dBA during the rush hour, 39 to 72 dBA during the day, 43 to 69 dBA during the evening and 38 to 64 dBA during the night. As with the residual background noise levels, the L_{50} noise level generally shows a significant decrease during the evening and nighttime hours.

At many measurement locations, the data for L_{10} and L_1 show typical levels for a high volume of vehicular traffic on city streets. This results in L_{10} and L_1 noise levels greater than 70 dBA, and at some locations, greater than 80 dBA. An L_1 noise level of 80 dBA or greater is generally considered a high noise level for commercial and residential developed areas. At several of the measurement locations there was only a slight decrease in the L_1 and L_{10} noise levels during the evening and nighttime hours which indicates that there is a significant volume of nearby vehicular traffic at night.

The Energy Equivalent Level, L_{eq}, ranges from 48 to 76 dBA during the rush hour, 47 to 74 dBA during the daytime, 48 to 70 dBA during the evening and 45 to 67 dBA during the nighttime. As with the noise levels characterized by the other statistical descriptors, the noise levels represented by the upper bound of the range for each time period are quite high and are due primarily to vehicular traffic on the nearby streets.

Since most of the noise impact is from local activities and local traffic, different areas along the proposed alignment have different noise environments as is shown by the wide range of noise levels represented by each statistical descriptor when examining all of the measurement locations over the entire length of the route. The range of noise levels encountered during a particular time period over the entire length of the alignment is 20 to 30 dB which indicates that very different noise environments were observed. Despite this wide range of observed noise levels, the noise data indicate a high level of ambient noise along most of the alignment which is primarily due to vehicular traffic.

The use of digital analysis equipment to derive the statistics of the ambient noise level at each of the measurement locations permits calculation and plotting of continuous graphs or charts giving a complete graphical description of the noise level distribution at each measurement location. Since this information is a supplement to the noise level information given in tabular form for the specific descriptors such as L_{90}, L_{50}, and L_{10}, a series of graphs of the statistical analyses has been prepared as part of the noise data analysis and the graphs are presented in Appendix A. These charts present data similar to that given in Table 3-1 except that the complete distribution is shown with a resolution of 1 dBA. A separate chart for each measurement location is included. At those locations where repeat measurements were made, the statistical distribution charts present an average of the data obtained for each visit during a specific time period.

These charts provide a means of graphically comparing the noise distribution along different sections of the route. In addition, since each chart is devoted to one measurement location, the influence of the time of day on the noise levels can be readily discerned.

As stated previously, 24-hour or long-term noise measurements were made at 9 of the 45 noise measurement locations. These measurements were made in order to obtain a complete statistical representation of the daily noise exposure in a community area and to show that the short-term or spot-check sample data correlate well with the variation of noise levels characteristic of the four time periods used. As with the spot-check measurements, the 24-hour or long-term noise measurements are reported in terms of A-weighted sound level in decibels, abbreviated dBA.

The equipment used for the long-term noise evaluation consisted of calibrated, precision, digital acoustical data acquisition systems with a sampling rate of 60 measurements per minute. These digital data acquisition systems digitize the A-weighted noise level each second, and then store these digitized data on tape cassettes for subsequent laboratory statistical analysis of the noise levels observed. Although the digital data acquisition systems can provide information on the noise levels over a long period of time, since these units digitize the A-weighted noise level, they cannot provide information on the spectrum of noise, i.e., octave band or 1/3 octave band analyses are not possible.

Since these digital data acquisition systems operate unattended, they were generally secured to a telephone or street light-pole which usually located the measuring microphone closer to nearby vehicular traffic but higher above the ground than the microphone of the spot-check measuring system. Thus the peak noise levels measured by the digital data acquisition system are often greater than that observed by the spot-check measurement system. However, these data do show good correlation with that obtained with the spot-check measuring system.

With the long-term measurement system, single number descriptors of the noise environment over a 24-hour time period can be obtained. The descriptors, CNEL and L_{dn} are by definition, based on a 24-hour time period and are minor variations of L_{eq}. These descriptors take into consideration the fact that people are generally more annoyed by a given sound level at night than during the day. They are determined in the same manner as L_{eq}, except that both have a 10 dB adjustment factor added to the noise levels between 10 p.m. and 7 a.m. In addition, CNEL has a 5 dB penalty applied to the noise levels between 7 p.m. and 10 p.m. Thus, depending on the noise levels occurring in a community during the evening and nighttime, CNEL and L_{dn} are often several decibels greater than $L_{eq}(24)$, the energy equivalent level over a 24-hour period.

CNEL is the noise descriptor specified in the California State Aeronautic Code for evaluation of noise impact of aircraft operations. CNEL is also specified in the California State Noise Insulation Standards for new multi-family residential dwellings. Hence, local compliance with these standards often necessitates that community noise be specified in terms of CNEL. L_{dn} represents a slight simplification of CNEL and is the noise descriptor preferred by the US EPA. For most environmental noise, L_{dn} and CNEL seldom differ by more than 1 dB. Although no long term noise descriptor levels are specified by any legislative body for operation or construction of the Metro Rail System, CNEL, L_{dn} and $L_{eq}(24)$ are reported for each long-term measurement location. The CNEL ranges from a low of 62 dBA at Location 19 to a high of 78 dBA at Location 32A, while the $L_{eq}(24)$ ranges from a low of 58 dBA at Location 19 to a high of 73 dBA at Location 32A.

Figures 3-2 through 3-10 are plots of the time history of the noise levels at the long-term measurement locations. These figures also show the date and time each survey began, as well as the values for CNEL, L_{dn} and $L_{eq}(24)$. These surveys are representative of weekday activities and show the decrease in noise levels during the nighttime and early morning hours which is characteristic of urban noise dominated by transportation activities. The survey at Location 42 was not a complete 24-hour survey since the measuring microphone was stolen between 10 and 11 p.m. on the night of Thursday, October 1. However the data obtained between 11 a.m. and 10 p.m. are reported on Figure 3-10.

As previously stated, at each of the long-term measurement locations, the time history of the noise levels show the characteristic pattern of urban noise dominated by transportation activities. Thus the noise levels are the greatest during the rush hour period, the same or somewhat lower during the daytime, still somewhat lower during the evening and considerably lower during the nighttime. This characteristic pattern of the variation of noise level over a full day was shown at each of the locations where a long-term measurement was made, thus the correlation between the short and long term measurements can be drawn at those locations where both types of measurements were made. This noise level variation over a full day has been shown to be characteristic of noise environments in a large number of urban areas in the U.S.A. and Canada. This correlation of noise measurements during different times of the day can be logically extended to the short term noise measurements, thus validating them as characteristic for the appropriate time of day and accurately characterizing the noise environment at a particular location without the need for a complete 24-hour survey.

TABLE 3-1 ENVIRONMENTAL NOISE LEVELS MEASURED AT LOCATIONS ALONG THE METRO RAIL ALIGNMENT - SEPTEMBER 21 THROUGH OCTOBER 1, 1981

Location Number	Time of Day	Date (1981)	Noise Levels - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
1	Rush Hour	9/28	62	63	64	66	72	65
	Day	9/28	57	58	61	64	68	62
	Evening	9/28	53	54	56	60	66	58
	Night	9/28	52	53	54	57	60	55
2	Rush Hour	9/22	65	67	70	74	81	72
	Day	9/21	65	67	71	75	82	72
	Evening	9/22	63	64	67	71	76	68
3	Rush Hour	9/22	62	65	70	77	84	73
	Day	9/21	64	66	69	74	81	72
	Evening	9/22	54	57	63	71	79	68
4	Rush Hour	9/22	66	68	71	77	83	74
	Rush Hour*	9/28	68	69	72	78	85	75
	Day	9/21	66	68	72	77	83	74
	Day*	9/28	66	68	71	76	83	73
	Evening	9/22	59	61	64	71	79	68
	Evening*	9/28	58	60	64	70	79	68
5	Rush Hour	9/23	56	60	66	73	80	71
	Rush Hour*	9/28	57	60	68	74	81	71
	Day	9/21	56	60	64	69	77	67
	Day*	9/28	54	57	63	70	75	66
	Evening	9/21	51	53	58	65	76	63
	Evening*	9/28	52	55	63	70	79	68
	Night	9/22	50	51	55	64	70	60

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
6	Rush Hour	9/21	57	60	66	74	82	71
	Day	9/21	56	60	65	73	82	70
	Evening	9/21	54	57	63	71	80	68
7	Rush Hour	9/21	56	59	66	74	81	70
	Rush Hour*	10/1	58	60	66	73	79	69
	Day	9/21	56	59	66	73	80	70
	Day*	9/29	56	59	65	71	78	68
	Evening	9/21	51	53	59	69	77	66
	Night	9/21	49	50	53	62	66	57
8	Rush Hour	9/21	61	64	68	74	81	71
	Rush Hour*	10/1	61	63	67	72	78	69
	Day	9/21	60	63	67	72	78	69
	Day*	9/29	58	61	66	72	79	69
	Evening	9/21	55	57	64	70	79	67
	Night	9/21	50	51	57	65	72	61
9	Rush Hour	9/21	63	65	69	77	83	73
	Day	9/22	59	62	67	74	80	70
	Evening	9/21	56	57	69	69	77	66
	Night	9/21	54	55	61	68	75	66
10	Rush Hour	9/21	64	67	71	76	82	74
	Rush Hour*	10/1	63	66	71	82	84	76
	Day	9/22	62	65	70	75	82	72
	Day*	9/29	61	64	69	78	83	73
	Evening	9/21	57	60	65	71	78	68
	Night	9/21	55	58	64	70	76	67

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA					
			L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{eq}
11	Rush Hour	9/21	59	61	69	74	80	71
	Rush Hour*	10/1	61	64	69	74	82	72
	Day	9/22	62	64	70	76	79	72
	Day*	9/29	63	64	68	72	77	70
	Evening	9/21	56	59	65	71	74	67
	Night	9/22	49	51	58	68	75	64
12	Rush Hour	9/23	56	59	70	74	82	72
	Day	9/22	56	58	67	74	80	70
	Evening	9/23	51	55	65	71	75	67
13	Rush Hour	9/23	57	61	68	73	77	70
	Day	9/22	56	61	70	76	82	72
	Evening	9/22	52	56	66	71	76	68
	Night	9/23	44	47	57	68	74	63
14	Rush Hour	10/1	54	57	66	72	76	68
	Day	9/29	58	60	66	72	81	71
15	Rush Hour	9/23	57	60	65	69	76	67
	Day	9/23	50	53	63	69	78	67
	Day*	9/29	51	54	60	66	75	63
	Evening	9/23	47	50	59	67	71	63
	Night	9/25	40	42	47	63	69	58
16	Rush Hour	9/24	59	62	68	74	83	72
	Day	9/23	56	59	68	75	84	72
	Evening	9/23	53	58	66	71	75	67

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
17	Rush Hour	9/24	54	58	63	68	73	65
	Day	9/23	54	58	63	67	73	64
	Evening	9/23	47	51	58	64	69	61
	Night	9/23	45	47	57	64	69	60
18	Rush Hour	9/23	50	52	56	59	63	56
	Day	9/23	49	51	54	58	63	55
	Day*	9/23	48	50	53	56	60	54
	Day*	9/30	52	53	55	57	63	55
19	Rush Hour	9/22	52	54	57	60	64	58
	Rush Hour*	9/30	51	54	57	61	65	58
	Day	9/22	50	53	57	60	63	57
	Day*	9/30	48	52	55	60	66	57
	Evening	9/22	48	51	55	59	64	56
	Night	9/23	39	41	45	52	60	49
20	Rush Hour	9/23	50	51	53	57	69	57
	Day	9/23	51	52	55	59	64	57
	Day*	9/29	48	50	52	55	60	53
	Evening	9/23	50	51	54	58	64	55
21	Rush Hour	9/22	57	62	68	72	76	69
	Day	9/22	54	59	66	71	76	67
	Day*	9/30	52	59	67	73	78	70
	Evening	9/22	50	58	65	71	77	68
	Night	9/25	44	50	60	71	78	67

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
22	Rush Hour	9/22	52	56	64	71	78	68
	Day	9/22	51	54	63	71	82	69
	Evening	9/22	48	51	59	69	74	64
	Night	9/24	44	46	53	64	70	59
23	Rush Hour	9/24	46	49	53	60	67	57
	Rush Hour*	9/30	46	47	58	60	67	56
	Day	9/23	42	44	48	57	65	54
	Day*	9/30	43	44	48	58	67	55
	Evening	9/23	39	41	47	54	63	51
	Night	9/24	34	35	38	49	60	47
24	Rush Hour	9/24	56	62	68	72	79	70
	Day	9/24	59	62	68	72	78	70
	Evening	9/24	49	54	62	69	72	65
	Night	9/24	46	49	61	69	75	65
25	Rush Hour	9/24	49	57	66	72	74	68
	Rush Hour*	9/30	50	55	64	69	72	66
	Day	9/24	50	56	66	72	76	68
	Day*	9/30	46	49	63	69	73	66
	Evening	9/24	43	48	61	69	73	65
	Night	9/24	44	47	59	69	73	64
26	Rush Hour	9/24	66	68	72	75	82	73
	Day	9/24	63	68	72	76	81	73
	Evening	9/24	59	62	68	73	78	70

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{eq}
27	Rush Hour	9/24	59	62	66	70	75	67
	Day	9/24	55	61	66	71	78	68
	Evening	9/24	50	55	63	69	76	66
	Night	9/24	45	49	60	67	72	63
28	Rush Hour	9/28	57	60	65	70	76	67
	Day	9/28	54	57	64	69	74	66
	Evening	9/28	54	57	63	69	76	66
	Night	9/28	45	48	55	63	71	60
29	Rush Hour	9/24	62	65	70	75	80	72
	Day	9/24	58	62	66	72	77	68
	Day*	9/24	56	63	68	74	80	70
	Evening	9/24	57	60	66	73	79	69
30	Rush Hour	9/29	59	62	67	71	78	69
	Day	9/24	61	62	66	72	77	68
	Evening	9/24	56	58	62	68	72	64
	Evening*	9/24	55	57	62	67	75	65
31	Rush Hour	9/24	54	56	58	61	65	59
	Day	9/24	52	54	56	59	62	56
	Evening	9/24	50	53	56	58	62	56
	Night	9/24	44	47	52	58	62	54
32	Rush Hour	9/29	51	55	59	63	67	60
	Day	9/25	46	49	53	57	65	55
	Evening	9/29	49	53	58	63	68	61
	Night	9/29	46	48	54	58	63	55

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
33	Rush Hour	9/29	52	53	55	59	64	57
	Day	9/25	55	57	59	63	71	62
	Evening	9/29	49	50	52	58	73	59
34	Rush Hour	9/29	53	54	56	60	72	60
	Day	9/25	49	51	53	55	68	57
	Evening	9/29	51	52	54	57	66	57
	Night	9/30	49	50	52	56	67	56
35	Rush Hour	9/29	42	44	46	58	67	56
	Day	9/25	42	43	45	48	60	48
	Evening	9/29	41	42	44	58	68	55
	Night	9/29	39	44	45	47	53	46
36	Rush Hour	9/29	40	43	52	63	70	59
	Day	9/29	41	42	46	59	70	57
	Evening	9/29	41	42	43	53	69	55
	Night	9/29	42	43	44	52	62	52
37	Rush Hour	9/29	38	38	40	46	59	48
	Day	9/29	37	38	39	42	62	47
	Evening	9/29	44	44	45	46	62	49
	Night	9/29	42	42	43	46	52	46
38	Rush Hour	9/28	45	47	49	55	68	55
	Evening	9/28	45	46	48	50	54	48
	Night	9/29	43	44	46	48	55	48

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
39	Rush Hour	9/28	64	66	70	75	79	72
	Day	9/28	61	63	67	73	78	70
	Evening	9/28	59	61	65	71	79	69
40	Rush Hour	9/28	56	57	60	66	72	63
	Day	9/28	56	57	60	65	71	62
	Day*	9/30	55	57	60	64	72	62
	Evening	9/28	52	54	57	61	66	58
	Evening*	9/29	54	55	58	65	70	61
	Night	9/30	49	51	55	60	64	56
41	Rush Hour	9/28	55	58	63	68	79	68
	Day	9/28	55	57	63	69	75	66
	Evening	9/28	52	54	58	65	73	62
	Night	9/29	41	43	48	56	66	56
42	Rush Hour	9/28	56	58	63	69	75	66
	Day	9/28	59	61	64	68	75	65
	Evening	9/28	55	57	60	65	70	62
	Night	9/29	43	46	50	58	62	54
43	Rush Hour	9/28	52	56	65	71	76	67
	Day	9/28	50	54	64	72	79	68
	Evening	9/28	49	52	61	69	77	66
	Night	9/29	42	44	50	63	70	59

*Repeat Measurements

TABLE 3-1 (Continued)

Location Number	Time of Day	Date (1981)	Noise Levels - dBA					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
44	Rush Hour	9/28	48	49	54	64	69	59
	Day	9/28	44	45	53	64	72	61
	Evening	9/28	44	45	48	54	63	52
	Night	9/29	42	42	45	46	51	45
45	Rush Hour	9/28	56	58	62	70	80	68
	Day	9/28	53	55	59	68	77	66
	Evening	9/28	53	54	57	68	76	64
	Night	9/28	48	49	52	56	68	57

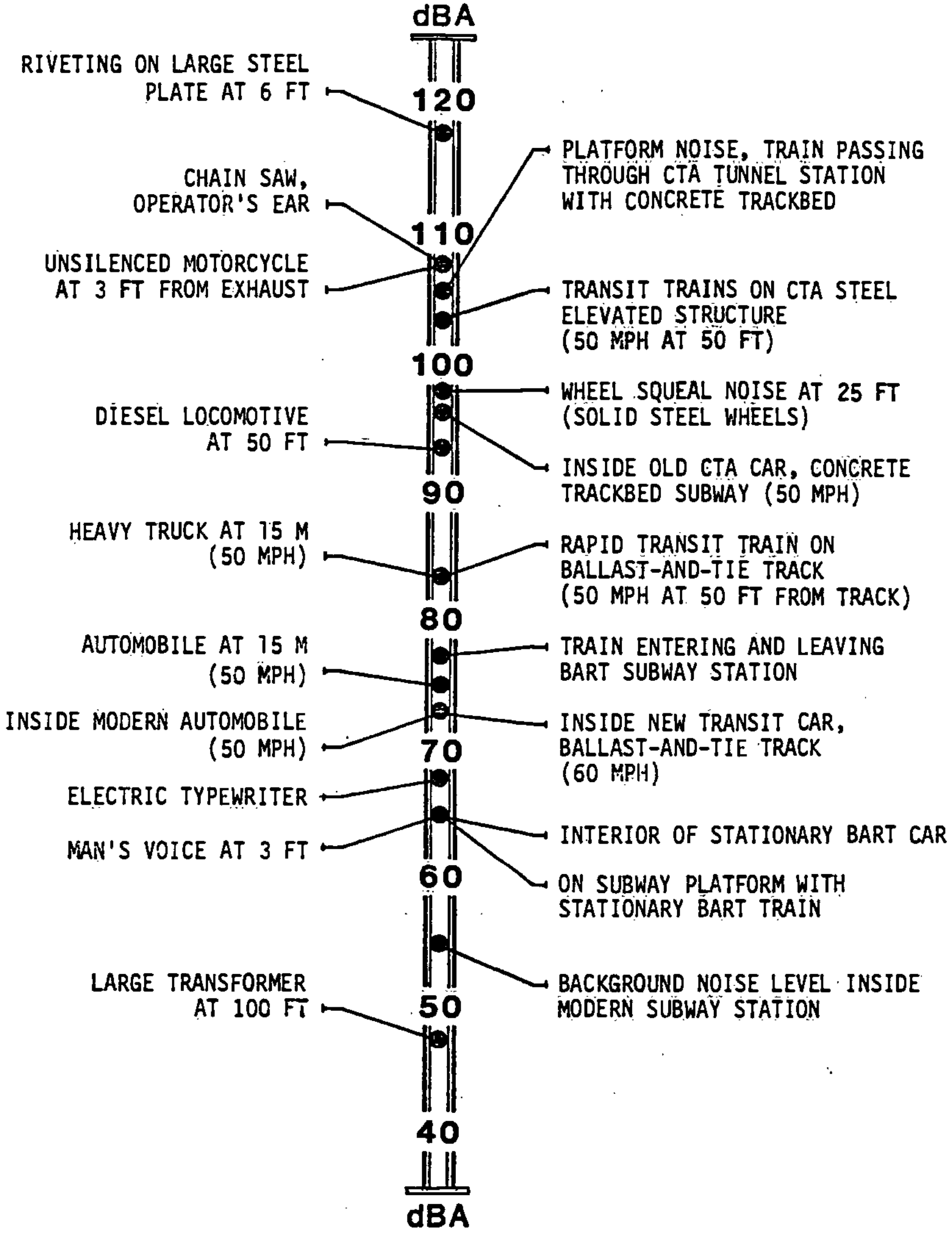


FIGURE 3-1 TYPICAL NOISE LEVELS

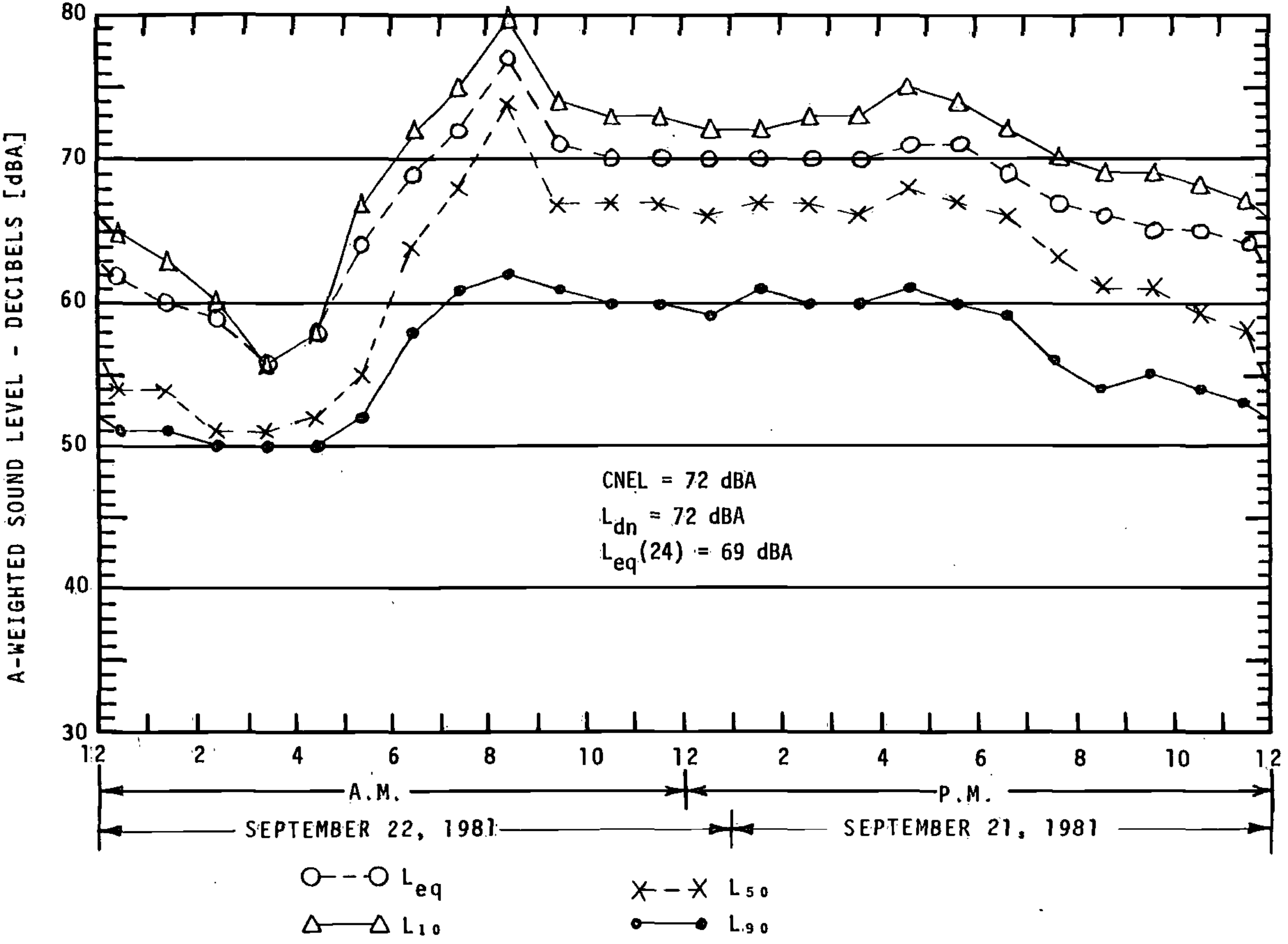


FIGURE 3-2 TIME HISTORY OF THE NOISE LEVEL MEASUREO AT LOCATION 5, OVER THE 24-HOUR PERIOD BEGINNING 1PM, MONOAY SEPTEMBER 21, 1981

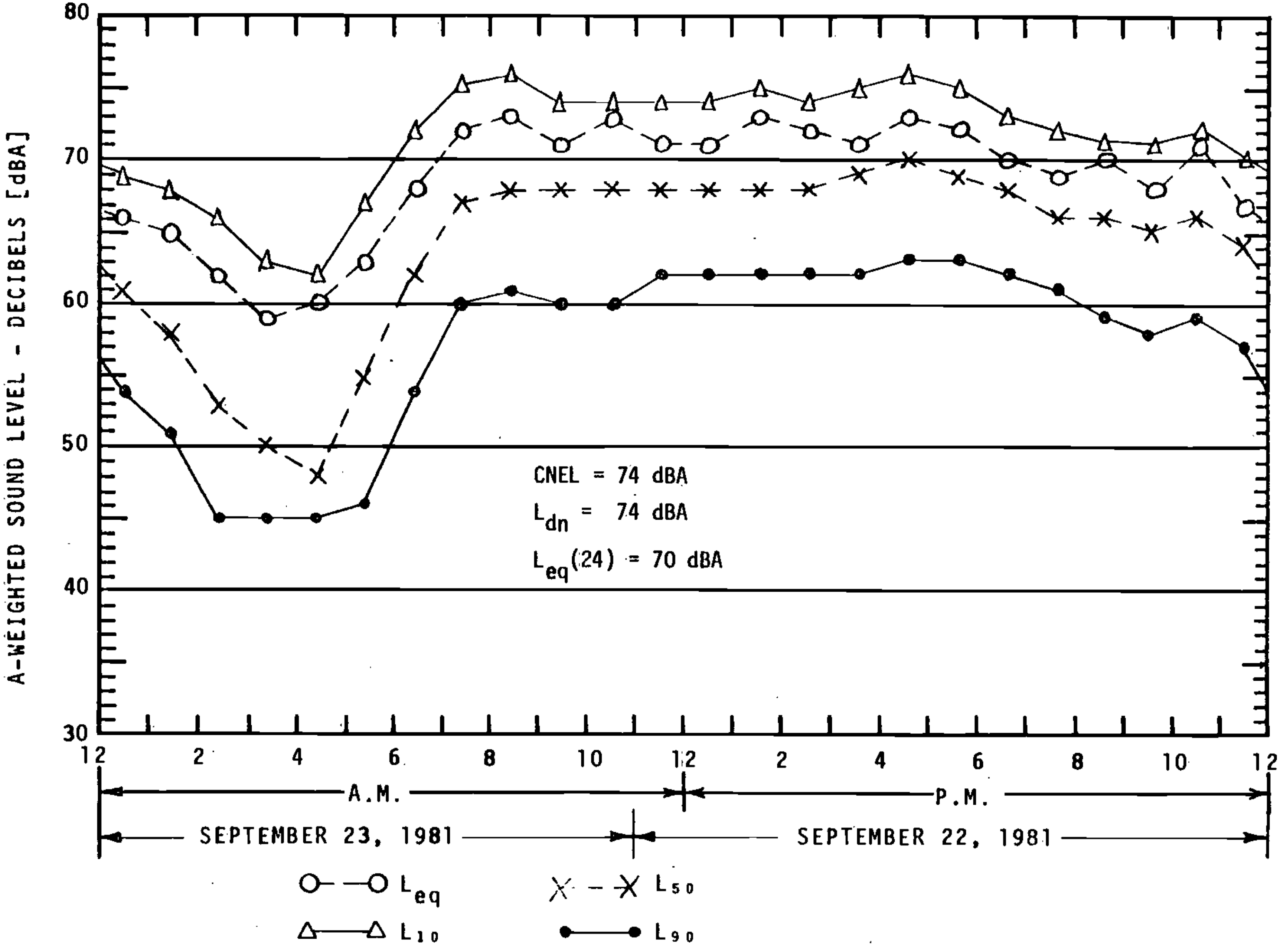


FIGURE 3-3 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 11, OVER THE 24-HOUR PERIOD BEGINNING 11AM, TUESDAY, SEPTEMBER 22, 1981

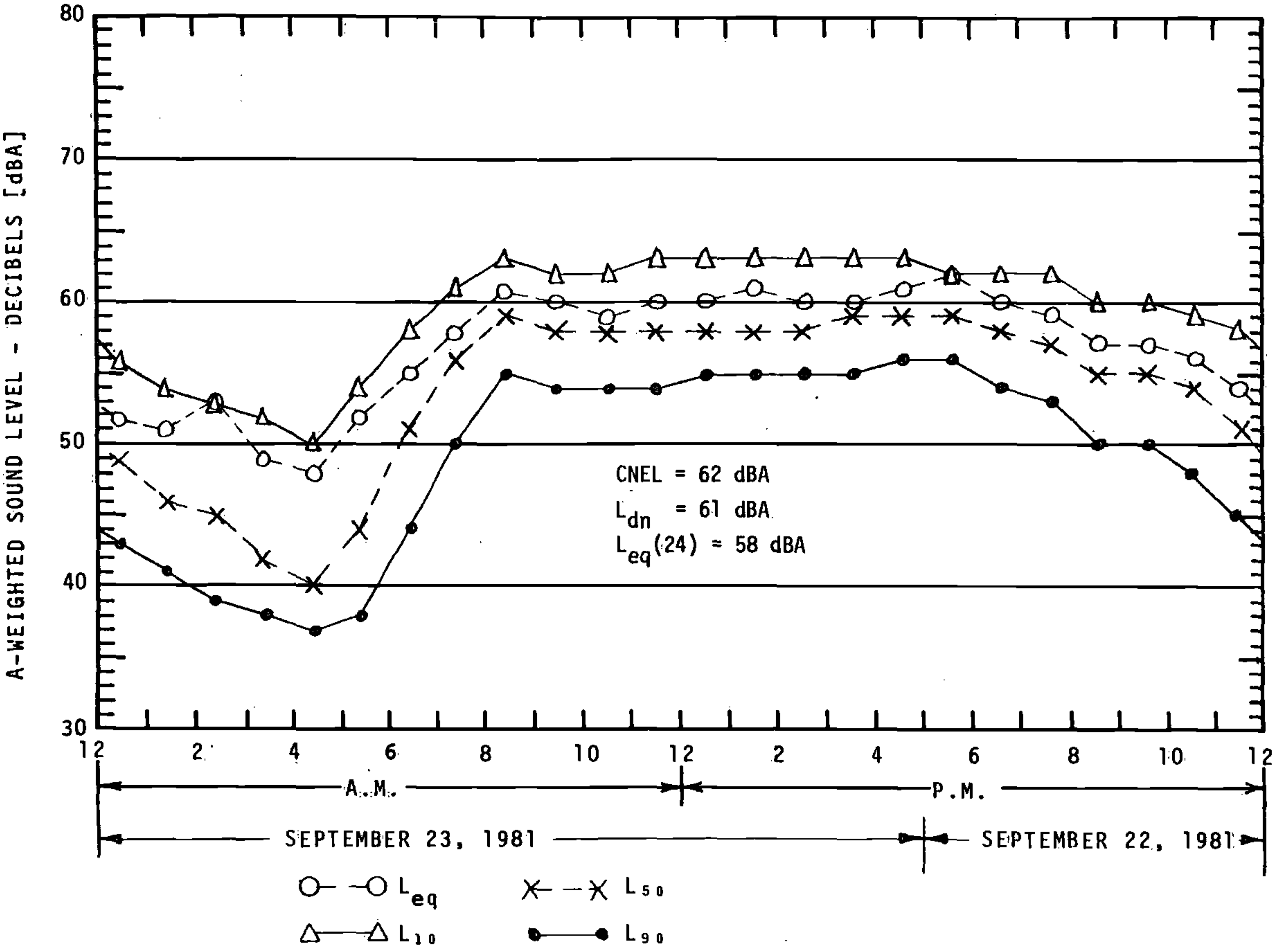


FIGURE 3-4 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 19, OVER THE 24-HOUR PERIOD BEGINNING 5PM, TUESDAY SEPTEMBER 22, 1981

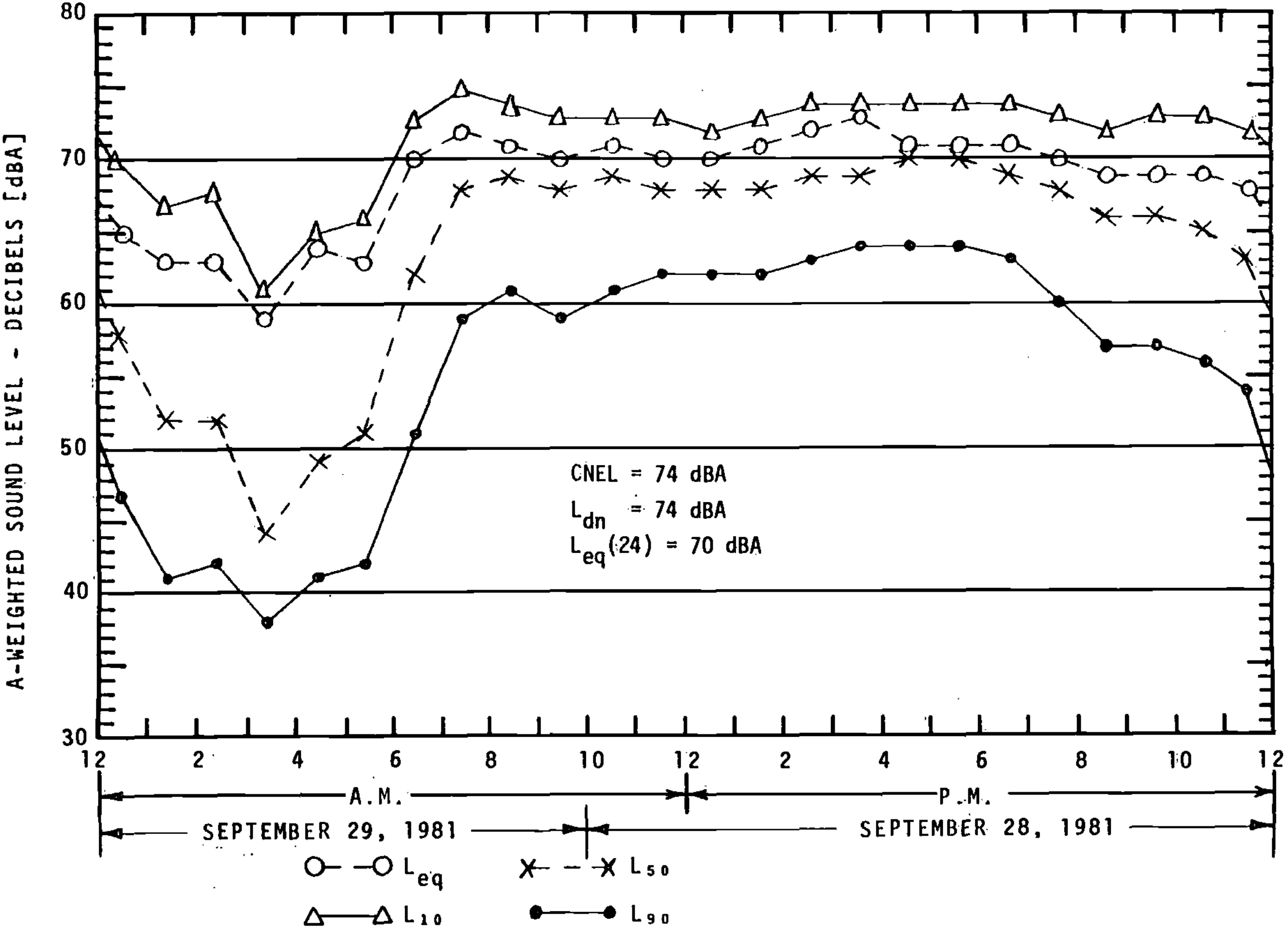


FIGURE 3-5 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 21, OVER THE 24-HOUR PERIOD BEGINNING 10AM, MONDAY SEPTEMBER 28, 1981

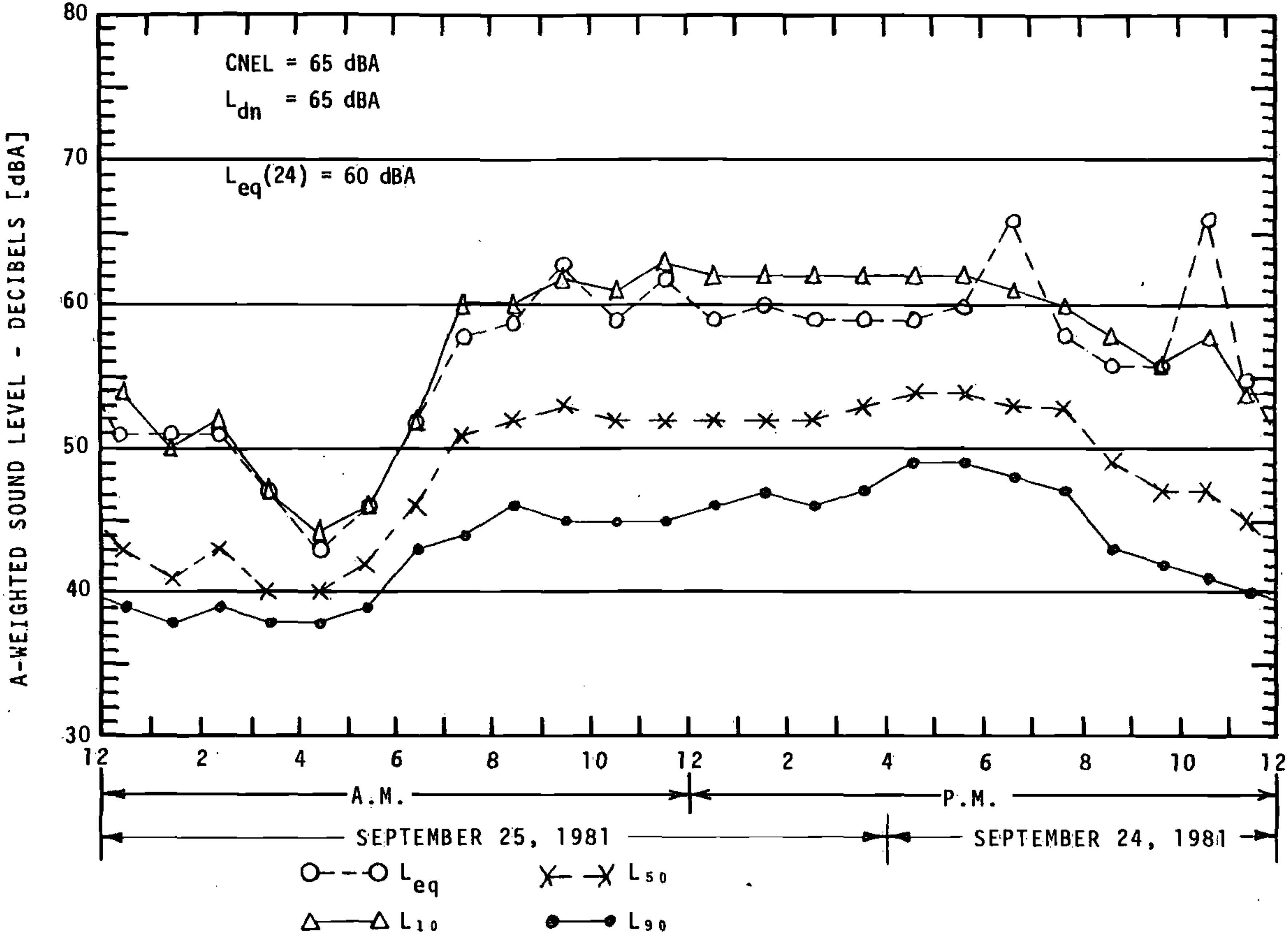
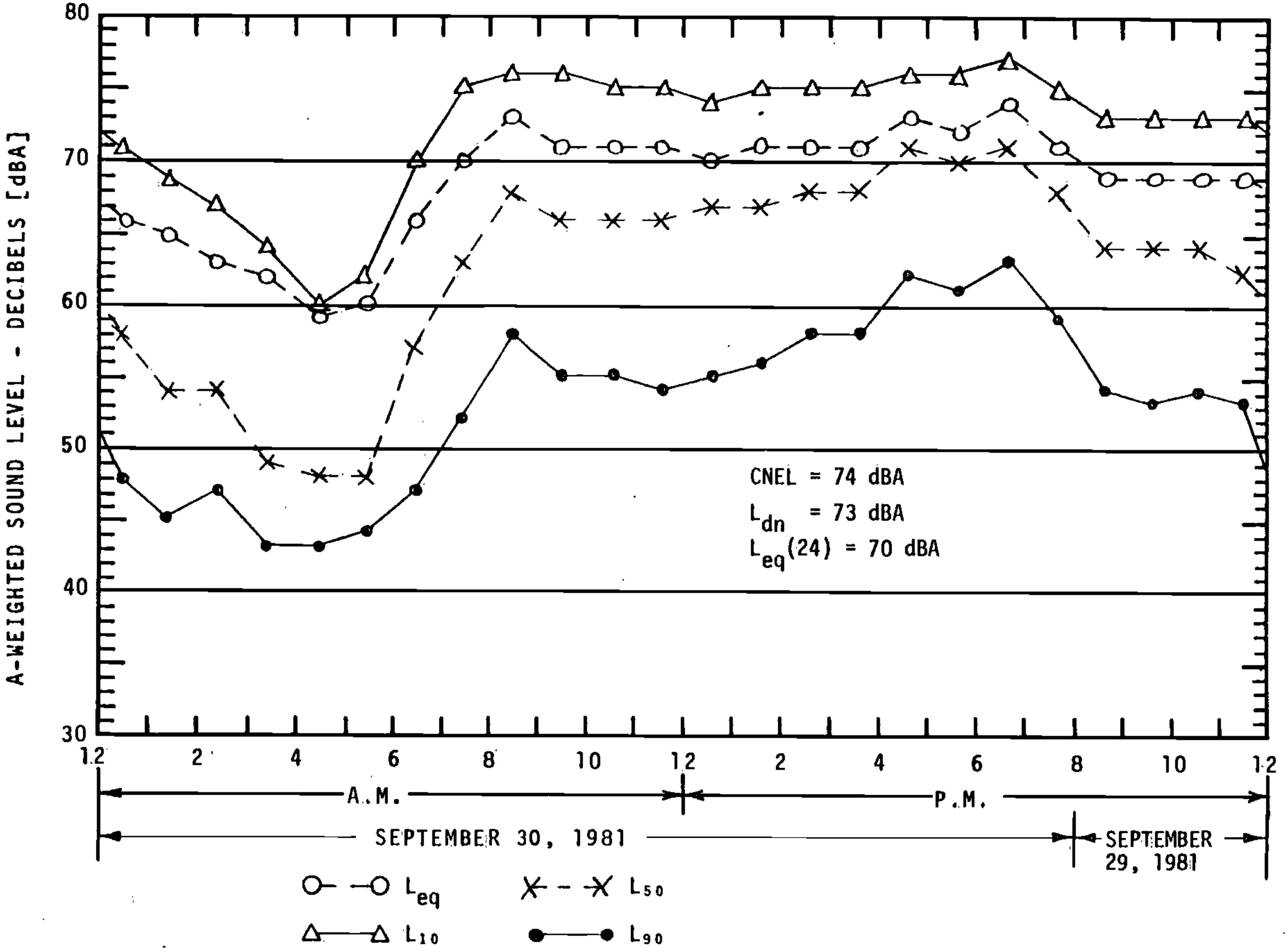


FIGURE 3-6 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 23, OVER THE 24-HOUR PERIOD BEGINNING 4PM, THURSDAY, SEPTEMBER 24, 1981



CNEL = 74 dBA

L_{dn} = 73 dBA

$L_{eq}(24)$ = 70 dBA

FIGURE 3-7 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 25, OVER THE 24-HOUR PERIOD BEGINNING 8PM, TUESDAY, SEPTEMBER 29, 1981.

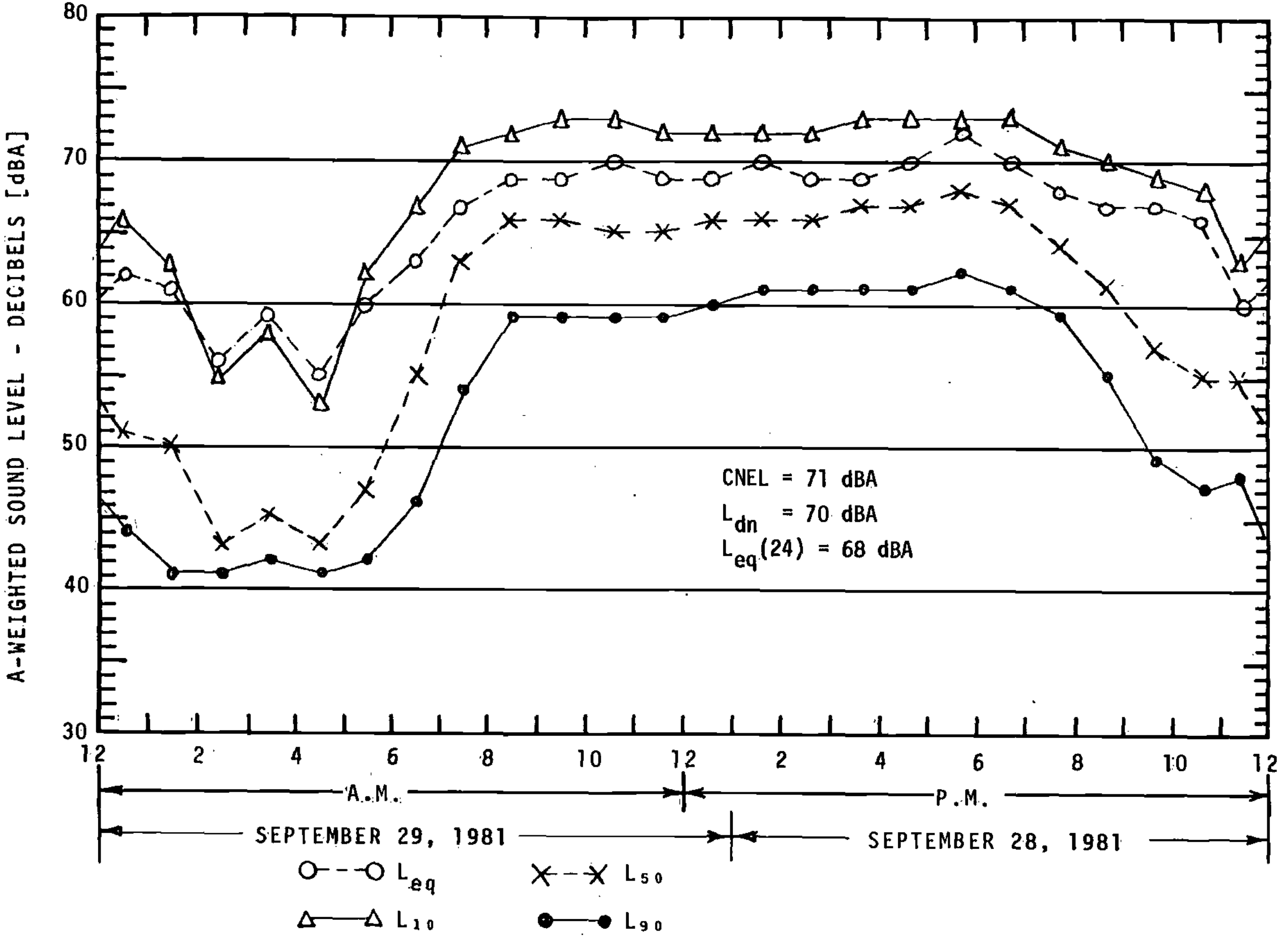
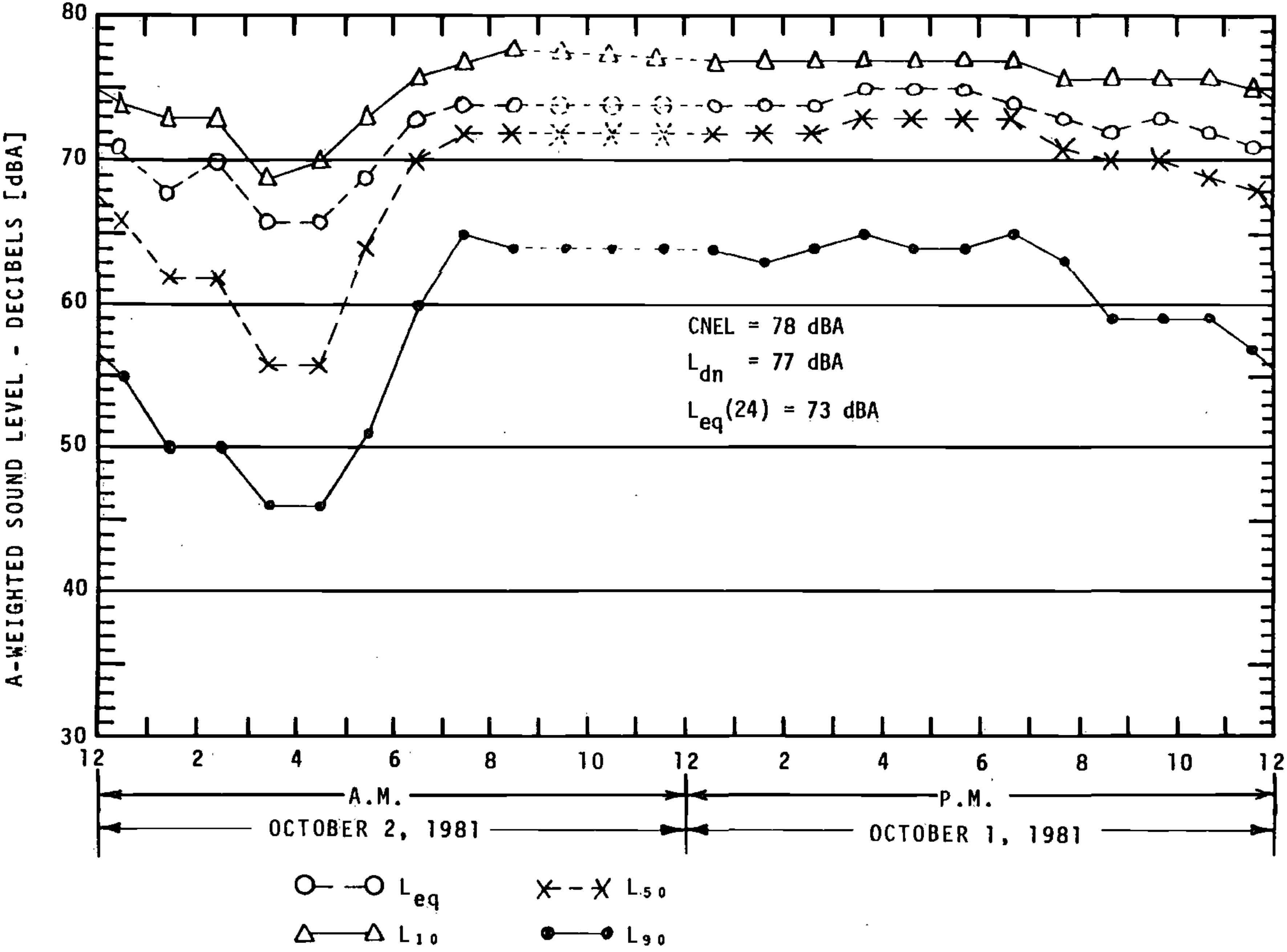


FIGURE 3-8 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 28, OVER THE 24-HOUR PERIOD BEGINNING 1PM, MONDAY SEPTEMBER 28, 1981



CNEL = 78 dBA

L_{dn} = 77 dBA

$L_{eq}(24)$ = 73 dBA

FIGURE 3-9 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 32a, OVER THE 21-HOUR PERIOD BEGINNING 12NOON, THURSDAY, OCTOBER 1, 1981

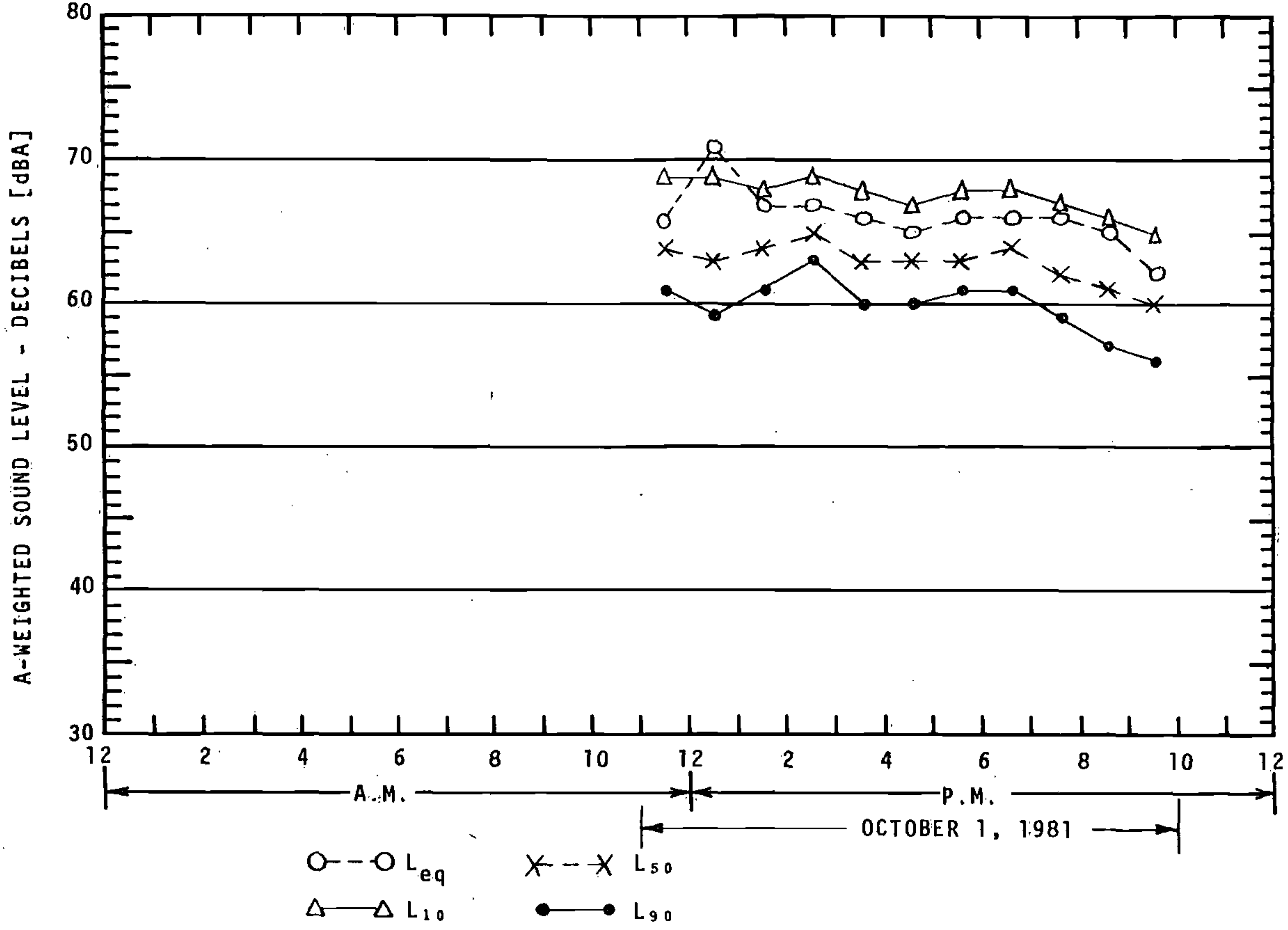


FIGURE 3-10 TIME HISTORY OF THE NOISE LEVEL MEASURED AT LOCATION 42, OVER THE 11-HOUR PERIOD BEGINNING 11AM, THURSDAY, OCTOBER 1, 1981

4. EXISTING VIBRATION LEVELS

The perception of vibration by people has been discussed extensively in the literature, however, most of the criteria are based on the results obtained from steady-state sinusoidal vibration excitation in laboratory environments. Relatively little information is available on the response of humans to low level random vibration or to transient vibration levels. Recently more information on this type of vibration has been obtained from the results of measurements and subjective evaluations of transit train vibration in Toronto, Washington, D.C., San Francisco and Atlanta.

A number of scales for evaluating the effect of vibration on man have been devised. Units such as Pal and Trem have been presented for establishing scales of response to vibration similar to the A-weighted sound level or the various loudness scales which have been used for the determination of subjective response to noise levels. None of the scales have been widely accepted in evaluating human response to vibration levels and, in general, the criteria for response are presented as charts with ranges of response as a function of vibration frequency. As for the subjective response to noise, the human sensitivity to vibration varies with frequency. Therefore, the frequency must be taken into consideration in assessing annoyance due to vibration. A number of studies have indicated that at frequencies above approximately 12 to 16 Hz, sensitivity to vibration is primarily determined by the velocity amplitude and is relatively independent of frequency. Since the frequency range over which human sensitivity is approximately proportional to velocity amplitude covers the range of principal vibration components from transit trains and since the noise level generated by the vibration of buildings' surfaces is approximately proportional to vibration velocity level, it is appropriate to present vibration criteria and data in terms of velocity level.

A curve of human response to vibration has evolved from the studies which have been done and has been documented in the International Standards Organization document 2631 and Draft ANSI Standard S3.29-198X. Additional information on human sensitivity to vibration is contained in the CHABA Publication, "Guidelines for Preparing Environmental Impact Statements on Noise" which has utilized much of the information contained in the ISO Standard. These standards and publications do indicate that below about 12 to 16 Hz the sensitivity to vibration velocity is somewhat lower. This is characterized in Figure 4-1 which indicates human response to building vibration. The curve shape is based on information in the CHABA publication and in this report will be know as CHABA weighting. These curves show the vibration perception level ranges in decibels, dB, re 1.0 micro in/sec, as a function of frequency in Hertz, Hz.

The existing exterior vibration sources include automobiles, trucks, buses, underground mechanical equipment, and on a local scale, pedestrians. Most of the vibration sources, except stationary mechanical equipment operating continuously, create transient vibration levels. The observed level of vibration at a particular location is the summation of the vibrations created by all the various sources, near and far. This is analogous to ambient community noise which represents the summation of many noise sources.

For this survey, the vibration level data were taken simultaneously with, and at the same locations as, the sound level data. Vibration acceleration was measured using a piezoelectric accelerometer, with a signal recorded on one channel of the data tape recorder.

The data were analyzed to obtain a single-number velocity level weighted in such a way to approximate the CHABA weighting shown in Figure 4-1. To obtain the weighted velocity level from the acceleration data, an electronic integrator and filter with approximately the inverse of the CHABA weighting were used.

Although the CHABA weighting is not a standardized measurement, the resultant weighted velocity level is a good single-number indication of the human response to vibration. Figure 4-1 indicates that weighted vibration velocity levels below about 69 dB overall level are generally imperceptible or just perceptible as vibration to the average person under normal conditions.

The weighted vibration velocity levels obtained in this manner were statistically analyzed to obtain the same statistical parameters used to describe the existing noise levels; L_{99}, L_{90}, L_{50}, L_{10}, L_1, and L_{EQ}.

Table 4-1 presents a complete tabulation of the statistical analysis of the weighted vibration velocity levels observed at each measurement site. In general those locations with the highest noise levels also have the highest vibration levels and vice versa, since in most cases, trucks and buses which produce high noise levels also produce high vibration levels. However, this correlation is not always true since airplanes, motorcycles, and some cars can produce high noise levels but not necessarily high vibration levels.

Review of the vibration data indicates that as for the noise data there is a considerable range of levels at different locations over the length of the alignment. The lowest vibration levels were observed at Locations 32, 33, 34, 35 and 37 which are located away from nearby vibration producing activities, especially during the evening and nighttime measurement periods. These locations are located on or near the Santa Monica Mountains which in addition to having few nearby vibration producing activities may also be on or near rock. Although rock transmits vibration more efficiently than soil, it takes a greater vibration energy level at the source to produce the same vibration amplitude at the receiver.

There are a number of locations where the L_1 vibration velocity level exceeds 69 dB. This means that for approximately 6 seconds in 10 minutes the vibration from passing vehicles was at least barely perceptible at the measurement location. Vibration at other locations with the L_1 vibration velocity level less than 69 dB should not be perceptible as mechanical motion. Excluding Locations 32, 33, 34, 35 and 37, the weighted vibration velocity L_{eq} ranges from 38 to 61 dB which is typical of commercial and residential areas near heavily traveled streets and boulevards. Comparing these data with that obtained during previous environmental vibration studies performed by WIA indicates that the vibration levels are typical of other large cities (such as Baltimore and Chicago).

Appendix B presents statistical distribution plots showing the detailed statistical distribution in terms of the weighted vibration velocity level exceedance as a percentage of time for all of the measurement locations along the alignment. These plots are analogous to those plotted for noise level exceedance in Appendix A. As with the noise plots, these charts allow graphic comparison of the vibration velocity statistical distributions along different sections of the Metro Rail alignment.

To provide some indication of the frequency content of the measured ground-borne vibration, five representative examples of the vibration levels were statistically analyzed by 1/3 octave bands. For the statistical analysis the unweighted vibration velocity level as a function of time was analyzed in each of the 1/3 octave bands from 3.15 Hz through 1000 Hz. The results of these are shown on Figures 4-2 through 4-6. Although several analyses indicate somewhat similar overall vibration velocity levels, each of the charts show a somewhat different shape for the frequency spectrum.

TABLE 4-1 WEIGHTED OVERALL VIBRATION VELOCITY LEVELS[1] MEASURED AT LOCATIONS ALONG THE METRO RAIL ALIGNMENT - SEPTEMBER 21 THROUGH OCTOBER 1, 1981

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec)					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
1	Rush Hour	9/28	41	44	48	52	57	49
	Day	9/28	45	48	51	54	58	52
	Evening	9/28	37	39	42	48	52	44
	Night	9/28	34	37	40	46	52	43
2	Rush Hour	9/22	46	49	54	60	66	56
	Day	9/21	48	51	54	60	67	57
	Evening	9/22	47	48	52	58	66	55
3	Rush Hour	9/22	44	47	52	59	68	57
	Day	9/21	44	48	52	61	69	57
	Evening	9/22	38	41	46	55	68	54
4	Rush Hour	9/22	40	42	46	51	57	48
	Rush Hour*	9/28	40	42	46	51	56	48
	Day	9/21	42	44	48	52	58	51
	Day*	9/28	41	43	46	50	56	47
	Evening	9/22	34	36	39	44	54	43
	Evening*	9/28	33	36	39	45	52	42
5	Rush Hour	9/23	42	44	49	57	64	54
	Rush Hour*	9/28	41	43	49	56	60	52
	Day	9/21	43	45	49	53	58	50
	Evening	9/21	34	36	38	43	52	41
	Evening*	9/28	38	40	44	50	57	47
	Night	9/22	39	41	44	47	52	45

[1] Corrected for Human Perception Curve (see text)

*Repeat Measurements

TABLE 4-1 (Continued)

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec)					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
6	Rush Hour	9/21	49	52	58	64	70	61
	Day	9/21	49	53	56	62	69	59
	Evening	9/21	44	48	53	58	68	58
7	Rush Hour	9/21	44	46	54	62	71	59
	Rush Hour*	10/1	44	47	54	60	69	58
	Day	9/21	46	49	54	60	66	57
	Day*	9/29	44	47	53	60	68	57
	Evening	9/21	40	42	46	56	66	53
	Night	9/21	38	39	42	49	58	48
8	Rush Hour	9/21	51	53	57	62	73	61
	Rush Hour*	10/1	52	54	58	64	70	60
	Day	9/21	49	50	54	60	65	56
	Day*	9/29	50	53	56	62	70	59
	Evening	9/21	44	46	50	54	64	53
	Night	9/21	46	48	50	56	67	55
9	Rush Hour	9/21	44	46	49	55	60	52
	Day	9/22	40	41	45	51	58	48
	Evening	9/21	40	41	45	51	55	47
	Night	9/21	39	42	46	51	61	50
10	Rush Hour	9/21	50	52	56	62	67	58
	Rush Hour*	10/1	44	48	54	61	67	57
	Day	9/22	44	46	50	56	61	53
	Day*	9/29	43	46	50	57	61	53
	Evening	9/21	42	45	50	56	59	52
	Night	9/21	42	44	48	54	61	51

*Repeat Measurements

TABLE 4-1 (Continued)

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec) L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{eq}
11	Rush Hour	9/21	41	43	47	51	59	49
	Rush Hour*	10/1	38	40	45	56	67	54
	Day	9/22	37	39	42	46	52	44
	Day*	9/29	40	43	47	51	56	48
	Evening	9/21	40	41	45	52	60	50
	Night	9/22	37	39	42	46	51	44
12	Rush Hour	9/23	42	44	49	54	62	52
	Day	9/22	40	44	47	51	56	48
	Evening	9/23	42	46	50	56	62	52
13	Rush Hour	9/23	40	43	47	54	59	50
	Day	9/22	33	36	42	50	56	46
	Evening	9/23	31	33	40	46	56	44
	Night	9/23	37	40	43	48	58	47
14	Rush Hour	10/1	35	38	43	51	60	49
	Day	9/29	36	39	44	51	59	49
15	Rush Hour	9/23	38	42	46	52	61	50
	Day	9/23	38	42	46	52	62	50
	Day*	9/29	31	34	42	50	61	48
	Evening	9/23	26	30	37	45	54	44
	Night	9/25	22	24	28	39	50	38
16	Rush Hour	9/24	43	45	49	56	64	53
	Day	9/23	43	46	50	56	62	53
	Evening	9/23	35	39	45	52	62	50

*Repeat Measurements

TABLE 4-1 (Continued)

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec)					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
17	Rush Hour	9/24	39	43	49	58	68	55
	Day	9/23	38	42	47	54	68	55
	Evening	9/23	38	41	46	52	59	49
	Night	9/23	32	35	44	55	67	53
18	Rush Hour	9/23	38	40	44	49	55	46
	Day	9/23	35	40	44	50	55	47
	Day*	9/30	28	33	38	43	46	39
19	Rush Hour	9/22	38	41	44	49	54	46
	Rush Hour*	9/30	36	40	44	50	58	48
	Day	9/22	39	42	46	52	59	49
	Day*	9/30	32	37	41	45	53	44
	Evening	9/22	37	39	43	47	54	45
	Night	9/23	36	39	42	46	54	44
20	Rush Hour	9/23	40	42	46	49	54	47
	Day	9/23	42	45	50	54	57	51
	Day*	9/29	38	40	44	48	53	45
	Evening	9/23	39	42	44	50	54	49
21	Rush Hour	9/22	42	46	52	57	62	54
	Day	9/30	34	40	52	59	65	55
	Evening	9/22	39	42	49	57	65	54
	Night	9/25	30	32	39	57	68	55
22	Rush Hour	9/22	44	46	48	51	55	49
	Day	9/22	41	43	45	49	54	47
	Evening	9/22	42	44	46	50	56	48
	Night	9/24	40	42	44	48	53	46

*Repeat Measurements

TABLE 4-1 (Continued)

			Weighted Vibration Velocity Levels (dB re 1 micro in/sec)					
Location Number	Time of Day	Date (1981)	L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{eq}
23	Rush Hour	9/24	36	41	46	50	54	48
	Rush Hour*	9/30	31	34	37	43	53	42
	Day	9/23	39	42	45	48	54	46
	Day*	9/30	32	36	40	44	49	41
	Evening	9/23	35	37	40	44	54	43
	Night	9/24	35	38	41	45	51	43
24	Rush Hour	9/24	44	47	53	59	64	56
	Day	9/24	39	43	50	58	68	55
	Evening	9/24	38	41	49	58	64	54
	Night	9/24	31	34	43	54	60	50
25	Rush Hour	9/24	38	42	47	52	56	49
	Rush Hour*	9/30	32	37	44	50	54	46
	Day	9/24	39	42	47	52	58	49
	Day*	9/30	34	38	44	50	55	47
	Evening	9/24	30	34	41	49	54	45
	Night	9/24	36	39	44	51	55	47
26	Rush Hour	9/24	42	45	49	53	56	50
	Day	9/24	42	45	50	54	59	51
	Evening	9/24	35	39	45	52	57	48
27	Rush Hour	9/24	41	44	49	55	62	52
	Day	9/24	42	45	50	56	62	53
	Evening	9/24	35	40	46	53	57	49
	Night	9/24	29	33	42	52	59	48

*Repeat Measurements

TABLE 4-1 (Continued)

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec) L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
28	Rush Hour	9/28	38	43	49	54	58	50
	Day	9/28	38	42	49	54	58	51
	Evening	9/28	32	38	46	54	61	50
	Night	9/28	26	29	36	49	55	44
29	Rush Hour	9/24	42	47	55	64	70	60
	Day	9/24	44	47	53	59	64	56
	Day*	9/24	41	46	53	61	67	57
	Evening	9/24	40	43	50	61	67	57
30	Rush Hour	9/29	42	45	50	56	62	53
	Day	9/24	46	48	53	58	67	59
	Evening	9/24	41	43	47	56	63	52
	Evening*	9/24	38	40	45	53	61	51
31	Rush Hour	9/24	36	38	41	44	48	42
	Day	9/24	36	39	42	47	53	44
	Evening	9/24	35	37	41	46	53	43
	Night	9/24	34	37	41	46	53	44
32	Rush Hour	9/29	36	38	41	44	48	41
	Day	9/25	32	34	37	41	45	38
	Evening	9/29	25	27	32	38	45	35
	Night	9/29	22	24	29	34	46	34
33	Rush Hour	9/29	36	37	40	43	46	41
	Day	9/25	32	35	38	45	56	44
	Evening	9/29	27	29	32	35	38	33

*Repeat Measurements

TABLE 4-1 (Continued)

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec)					
			L_{99}	L_{90}	L_{50}	L_{10}	L_1	L_{eq}
34	Rush Hour	9/29	34	37	40	44	47	41
	Day	9/25	25	28	32	38	45	35
	Evening	9/29	20	22	26	32	39	29
	Night	9/30	18	20	24	29	35	26
35	Rush Hour	9/29	22	24	29	36	49	36
	Day	9/25	24	26	32	42	44	39
	Evening	9/29	21	24	28	34	44	33
	Night	9/29	18	20	24	28	31	25
36	Rush Hour	9/29	30	32	35	47	55	43
	Day	9/29	36	38	41	46	54	44
	Evening	9/29	32	33	35	40	55	42
	Night	9/29	32	33	35	40	55	43
37	Rush Hour	9/29	22	25	29	34	41	32
	Day	9/29	22	24	27	30	43	31
	Evening	9/29	20	21	23	26	45	35
	Night	9/29	20	22	24	27	32	27
38	Rush Hour	9/28	37	39	42	46	50	43
	Evening	9/28	33	36	39	44	52	42
	Night	9/29	30	32	35	40	54	41
39	Rush Hour	9/28	39	42	48	53	60	50
	Day	9/28	36	41	47	54	63	52
	Evening	9/28	29	32	40	48	61	48

TABLE 4-1 (Continued)

Location Number	Time of Day	Date (1981)	Weighted Vibration Velocity Levels (dB re 1 micro in/sec) L_{99}	L_{90}	L_{50}	L_{10}	L_{1}	L_{eq}
40	Rush Hour	9/28	42	44	46	50	56	48
	Day	9/28	44	46	50	57	67	55
	Day*	9/30	42	44	48	53	58	50
	Evening	9/28	39	41	44	48	56	46
	Evening*	9/29	39	41	44	50	58	49
	Night	9/30	36	37	41	46	51	43
41	Rush Hour	9/28	48	52	57	64	72	61
	Day	9/28	47	51	56	64	74	62
	Evening	9/28	40	44	51	59	67	56
	Night	9/29	38	40	46	58	71	56
42	Rush Hour	9/28	44	46	51	58	67	55
	Day	9/28	46	48	52	57	64	55
	Evening	9/28	42	46	50	57	64	54
	Night	9/29	39	41	46	52	58	49
43	Rush Hour	9/28	47	50	54	60	66	57
	Day	9/28	43	46	53	60	67	57
	Evening	9/28	45	48	54	63	69	59
	Night	9/29	41	43	48	58	66	55
44	Rush Hour	9/28	45	47	49	56	63	53
	Day	9/28	43	45	49	56	62	52
	Evening	9/28	50	51	52	56	64	54
	Night	9/29	46	48	50	53	55	51
45	Rush Hour	9/28	46	48	52	56	61	54
	Day	9/28	48	49	50	54	58	52
	Evening	9/28	36	39	43	49	57	47
	Night	9/28	35	38	42	48	56	45

*Repeat Measurements

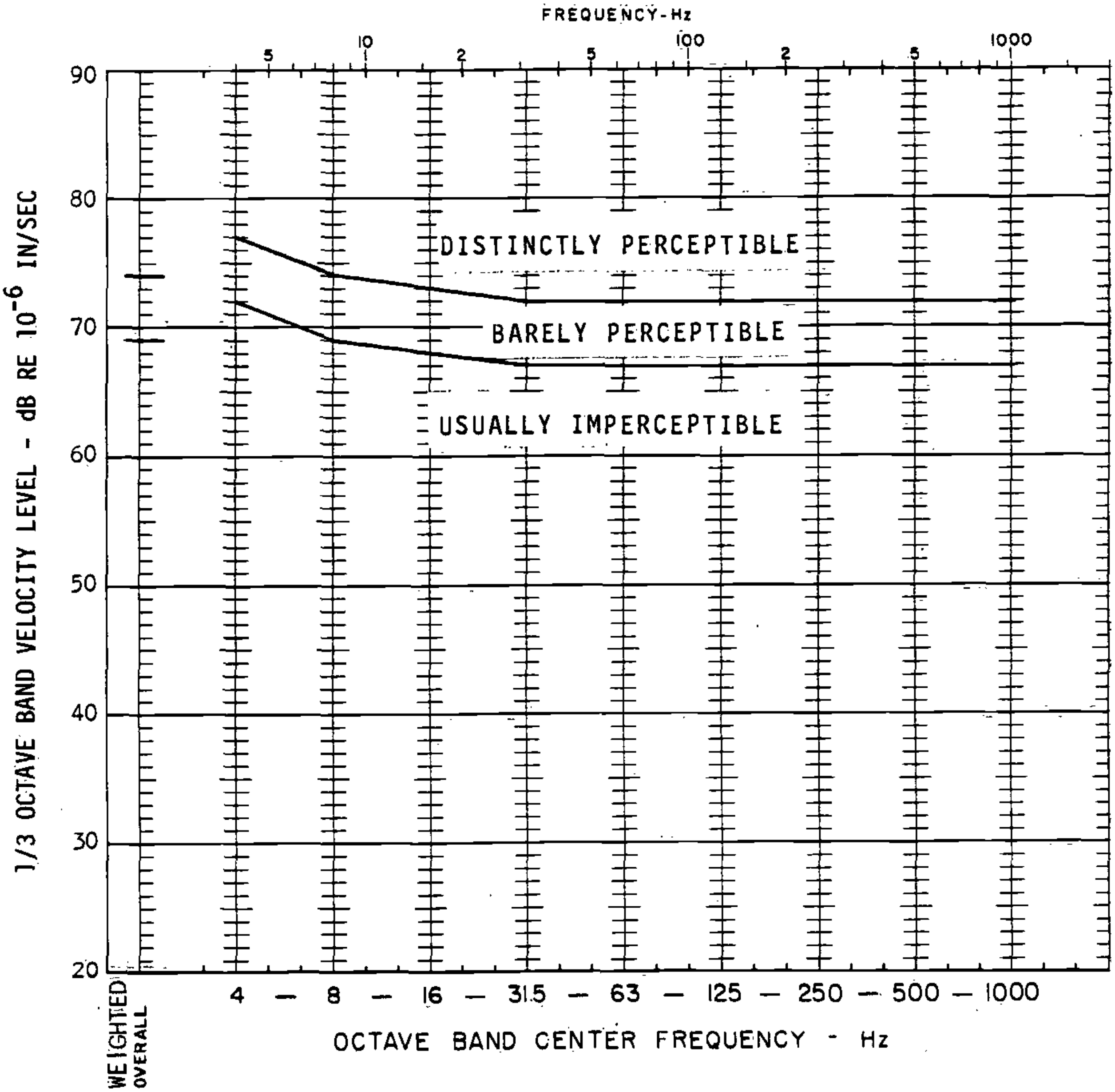


FIGURE 4-1 RESPONSE OF PERSONS SEATED OR STANDING TO BUILDING VIBRATION

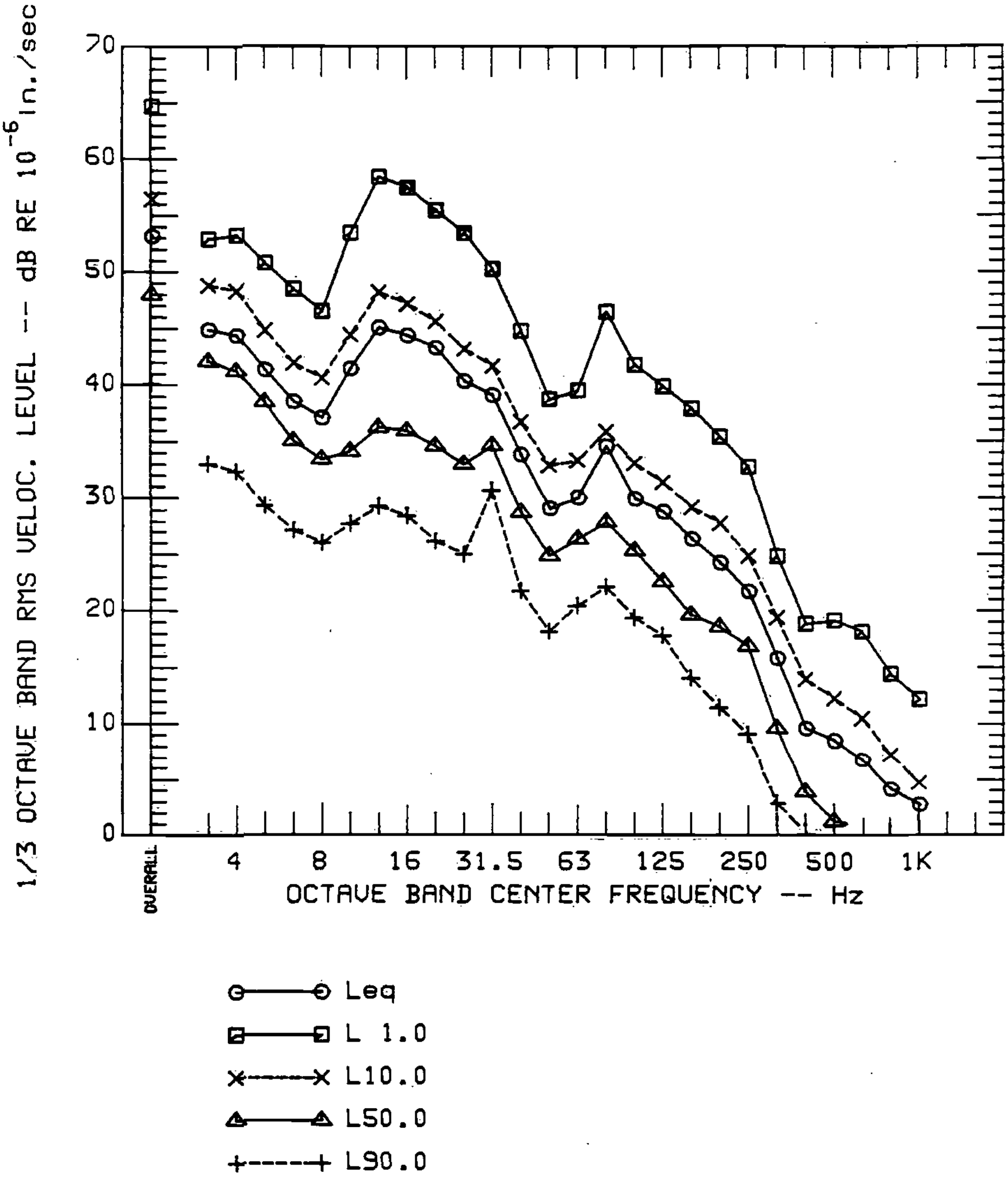


FIGURE 4-2 ONE-THIRD OCTAVE BAND VIBRATION VELOCITY LEVEL STATISTICS DURING RUSH HOUR AT LOCATION 5 ON SEPTEMBER 23, 1981

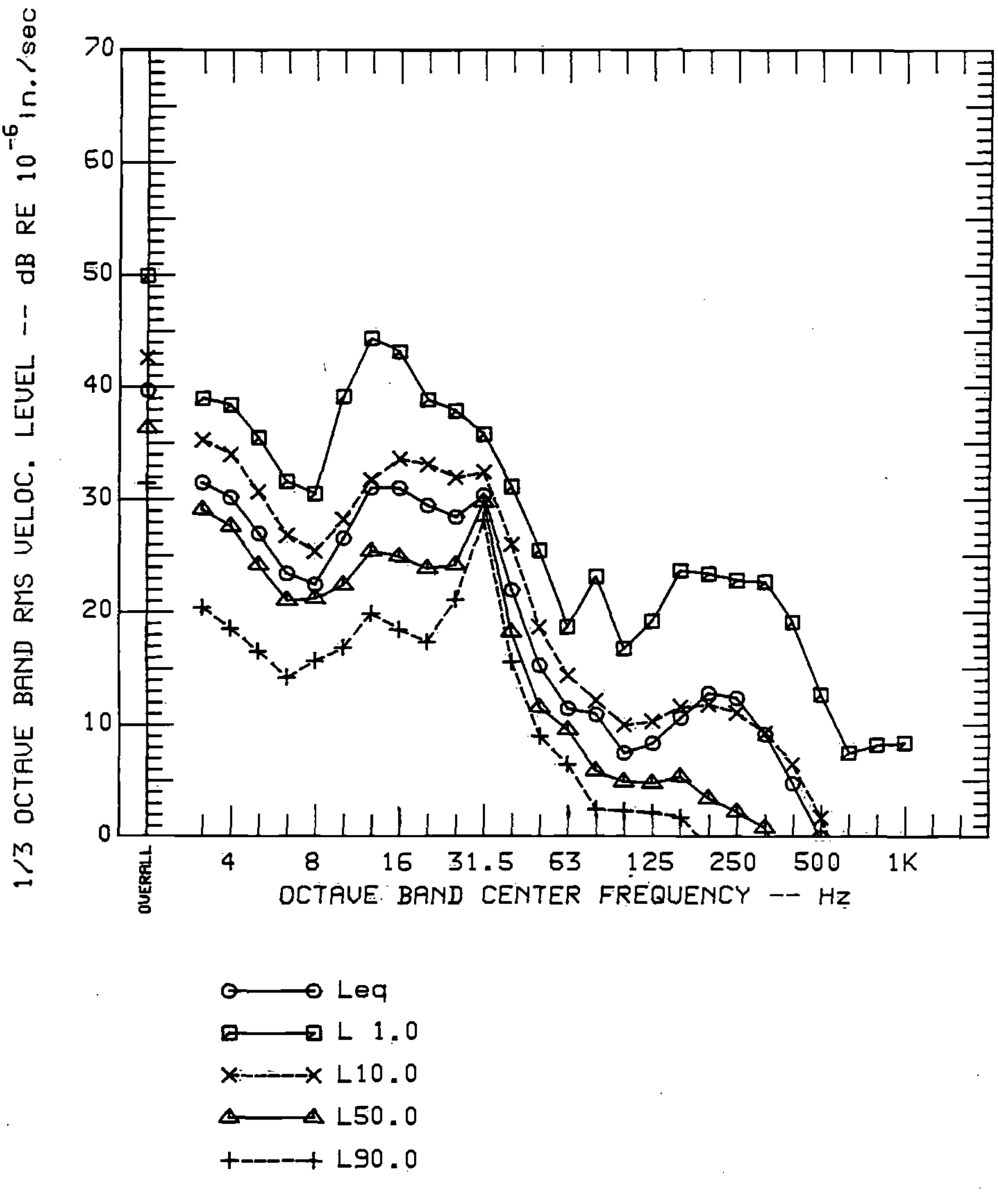


FIGURE 4-3 ONE-THIRD OCTAVE BAND VIBRATION VELOCITY LEVEL STATISTICS DURING THE EVENING AT LOCATION 5 ON SEPTEMBER 21, 1981

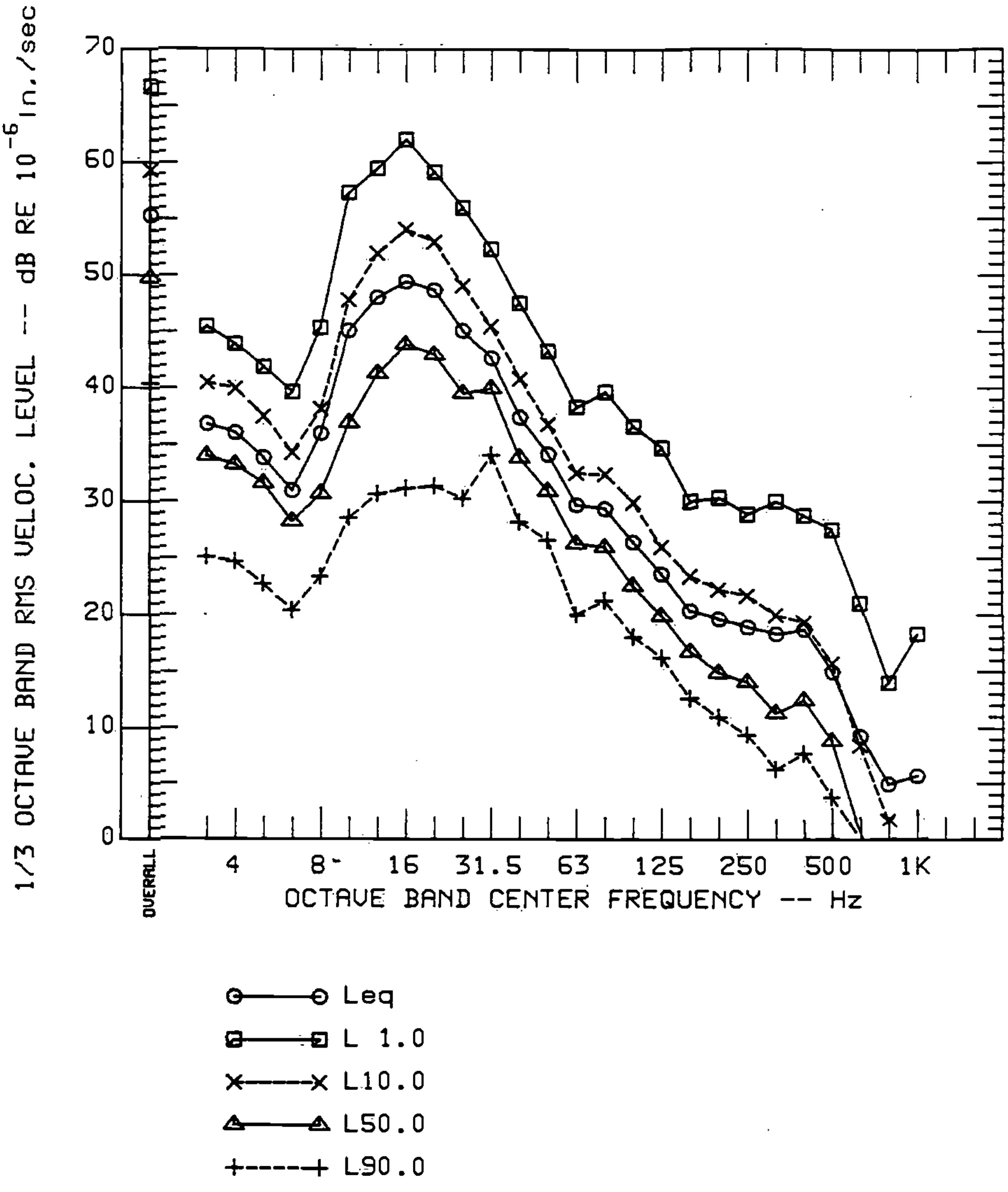


FIGURE 4-4 ONE-THIRD OCTAVE BAND VIBRATION VELOCITY LEVEL STATISTICS DURING RUSH HOUR AT LOCATION 7 ON SEPTEMBER 21, 1981

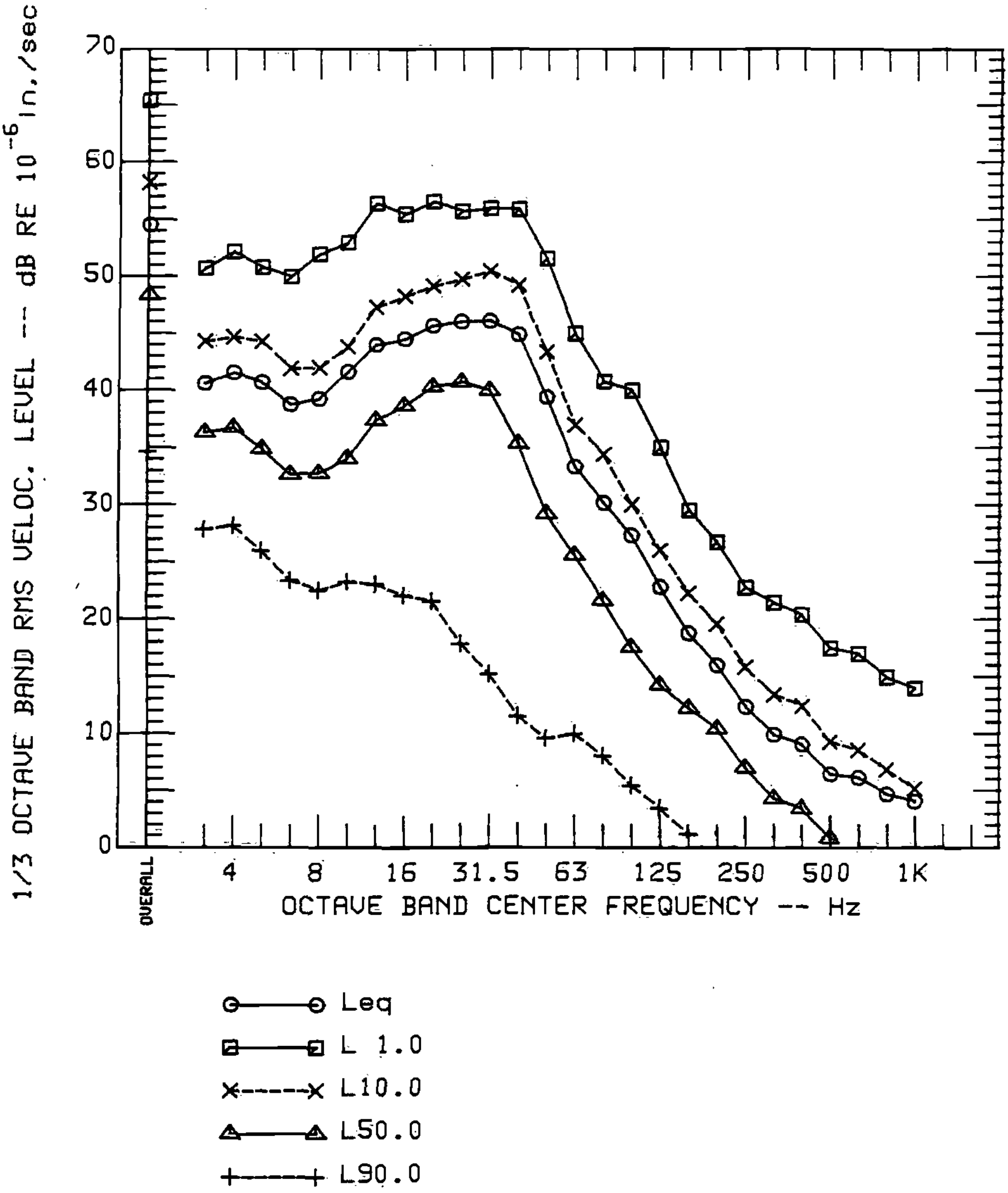


FIGURE 4-5 ONE-THIRD OCTAVE BAND VIBRATION VELOCITY LEVEL STATISTICS DURING THE DAY AT LOCATION 21 ON SEPTEMBER 30, 1981

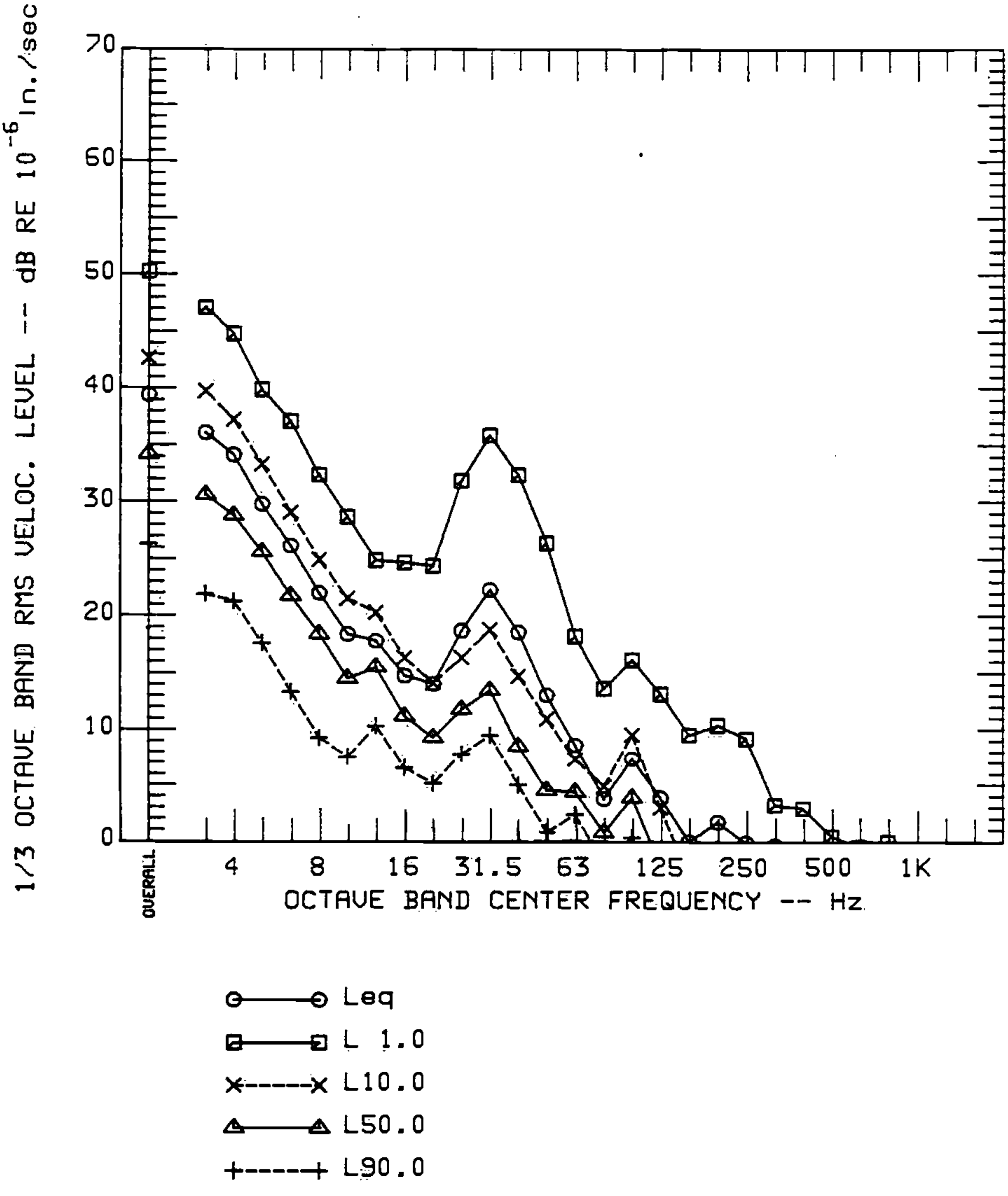


FIGURE 4-6 ONE-THIRD OCTAVE BAND VIBRATION VELOCITY LEVEL STATISTICS DURING THE DAY AT LOCATION 34 ON SEPTEMBER 29, 1981

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4. "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety", United States Environmental Protection Agency, EPA Technical Document 500/9-74-004, March 1974.

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6. "Guide for the Evaluation of Human Exposure to Whole-body Vibration", ISO 2631-1974(E), International Organization for Standardization, with Addendum 2, "Vibration and Shock Limits of Occupants in Buildings".

7. "Guide to the Evaluation of Human Exposure to Vibration in Buildings", December 1981, Draft ANSI Standard S3.29-198X.

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GLOSSARY AND SIGNIFICANCE OF ACOUSTICAL TERMS

1. Glossary of Terms

A-WEIGHTED SOUND LEVEL (dBA):
The sound pressure level in decibels as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

ACCELEROMETER:
A vibration sensitive transducer that responds to the vibration acceleration of a surface to which it is attached. The electronic signal generated by an accelerometer is directly proportional to the surface acceleration.

ACCELERATION LEVEL:
Also referred to as "vibration acceleration level." Vibration acceleration is the rate of change of speed and direction of a vibration. An accelerometer generates an electronic signal that is proportional to the vibration acceleration of the surface to which it is attached. The acceleration level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the acceleration to a reference acceleration. The generally accepted reference vibration acceleration is 10^{-6} g (10^{-5} m/sec).

AMBIENT NOISE:
The prevailing general noise existing at a location or in a space, which usually consists of a composite of sounds from many sources near and far.

BACKGROUND NOISE:
The general composite non-recognizable noise from all distant sources, not including nearby sources or the source of interest. Generally background noise consists of a large number of distant noise sources and can be characterized by L_{90} or L_{99}.

COMMUNITY NOISE EQUIVALENT LEVEL (CNEL):
The L_{eq} of the A-weighted noise level over a 24-hour period with a 5 dB penalty applied to noise levels between 7 p.m. and 10 p.m. and a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

DAY-NIGHT SOUND LEVEL (L_{dn}):
The L_{eq} of the A-weighted noise level over a 24-hour period with a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

DECIBEL (dB):
The decibel is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, sound intensity) with respect to a standardized reference quantity.

ENERGY EQUIVALENT LEVEL (L_{eq}):
The level of a steady noise which would have the same energy as the fluctuating noise level integrated over the time period of interest. L_{eq} is widely used as a

single-number descriptor of environmental noise. L_{eq} is based on the logarithmic or energy summation and it places more emphasis on high noise level periods than does L_{50} or a straight arithmetic average of noise level over time. This energy average is not the same as the average of sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

FREQUENCY (Hz):
The number of oscillations per second of a periodic noise (or vibration) expressed in Hertz (abbreviated Hz). Frequency in Hertz is the same as cycles per second.

L_1, L_{10}, L_{50}, L_{90} AND L_{99}:
The noise (or vibration) levels that are exceeded for 1%, 10%, 50%, 90% and 99% of a specified time period, respectively. Environmental noise and vibration data are often described in these terms. See section 2. for a more detailed discussion of the statistical distribution terms.

NOISE REDUCTION COEFFICIENT (NRC):
Noise reduction coefficient is a measure of the acoustical absorption performance of a material, calculated by averaging its sound absorption coefficients at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz.

OCTAVE BAND - 1/3 OCTAVE BAND:
One octave is an interval between two sound frequencies that have a ratio of two. For example, the frequency range of 200 Hz to 400 Hz is one octave, as is the frequency range of 2000 Hz to 4000 Hz. An octave band is a frequency range that is one octave wide. A standard

series of octaves is used in acoustics, and they are specified by their center frequencies. In acoustics, to increase resolution, the frequency content of a sound or vibration is often analyzed in terms of 1/3 octave bands, where each octave is divided into three 1/3 octave bands.

REVERBERANT FIELD:
The region in a room where the reflected sound dominates, as opposed to the region close to the noise source, where the direct sound dominates.

REVERBERATION:
The continuation of sound reflections within an enclosed space after the sound source has stopped.

REVERBERATION TIME (RT):
The time taken for the sound-pressure level in a room to decrease to one-millionth (60 dB) of its steady state value after the source of sound energy is suddenly interrupted. It is a measure of the persistence of a sound in a room and of the amount of acoustical absorption present inside the room.

SOUND ABSORPTION COEFFICIENT ( ):
The absorption coefficient of a material is the ratio of the sound absorbed by the material to that absorbed by an equivalent area of open window. The absorption coefficient of a perfectly absorbing surface would be 1.0 while that for concrete or marble slate is approximately 0.01 (a perfect reflector would have an absorption of 0.00).

SOUND PRESSURE LEVEL (SPL):
The sound pressure level of a sound in decibels is 20 times the logarithm to the base of 10 of the ratio of the RMS value of the sound pressure to the RMS value of a reference sound pressure. The standard reference sound pressure is 20 micro-pascals as indicated in ANSI S1.8-1969, "Preferred Reference Quantities for Acoustical Levels".

VELOCITY LEVEL:
Also referred to as the "vibration velocity level." Vibration velocity is the rate of change of displacement of a vibration. The velocity level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the velocity to the reference velocity. In this report the reported vibration velocity levels are all referenced to 10^{-6} in/sec. Above approximately 10 Hz, human response to vibration is more closely correlated to the velocity level than the acceleration level.

WEIGHTED VELOCITY LEVEL:
The vibration velocity level to which a weighting factor has been added. The weighting de-emphasizes the low frequencies in a manner similar to human response to vibration. The weighting used in this report is based on that proposed in Reference 8, however, there is no internationally recognized velocity weighting filter.

2. Statistical Distribution Terms

L_{99} and L_{90} are descriptors of the typical minimum or "residual" background noise (or vibration) levels observed during a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual noise sources. The most prevalent source of this residual noise is distant street traffic. L_{99} and L_{90} are not strongly influenced by occasional local motor vehicle pass-bys. However they can be influenced by stationary sources such as air conditioning equipment.

L_{50} represents a long-term statistical median noise level over the measurement period and does reveal the long-term influence of local traffic.

L_{10} describes typical levels or average for the maximum noise levels occurring, for example, during nearby pass-bys of trucks, buses and automobiles, when there is relatively steady traffic. Thus, while L_{10} does not necessarily describe the typical maximum noise levels observed at a point, it is strongly influenced by the momentary maximum noise level occurring during vehicle pass-bys at most locations.

L_1, the noise level exceeded for 1% of the time is representative of the occasional, isolated maximum or peak level which occurs in an area. L_1 is usually strongly influenced by the maximum short-duration noise level events which occur during the measurement time period and are often determined by aircraft or large vehicle passbys.

APPENDIX A

STATISTICAL DISTRIBUTION OF THE NOISE AT THE MEASUREMENT LOCATIONS

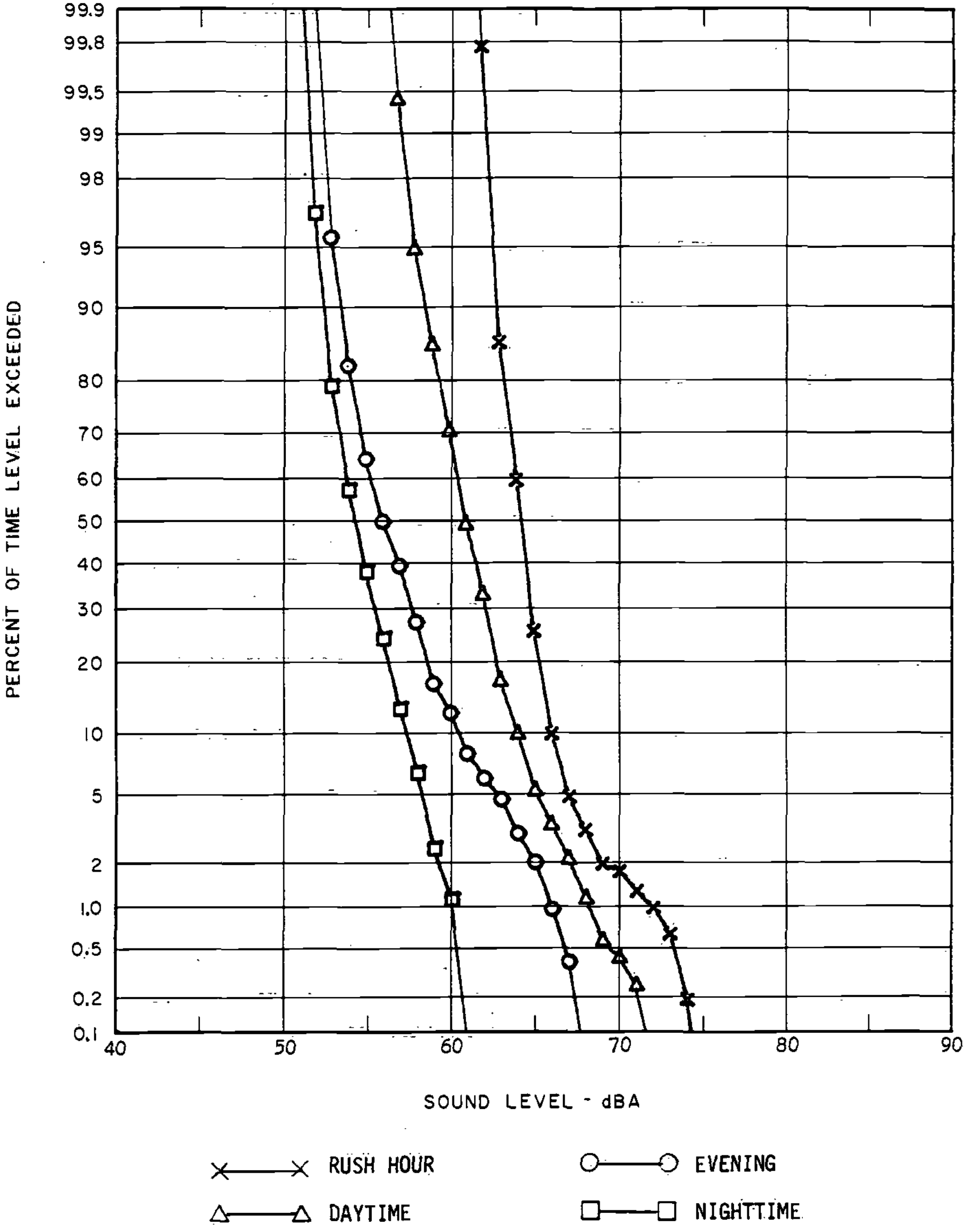


FIGURE A-1 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 1

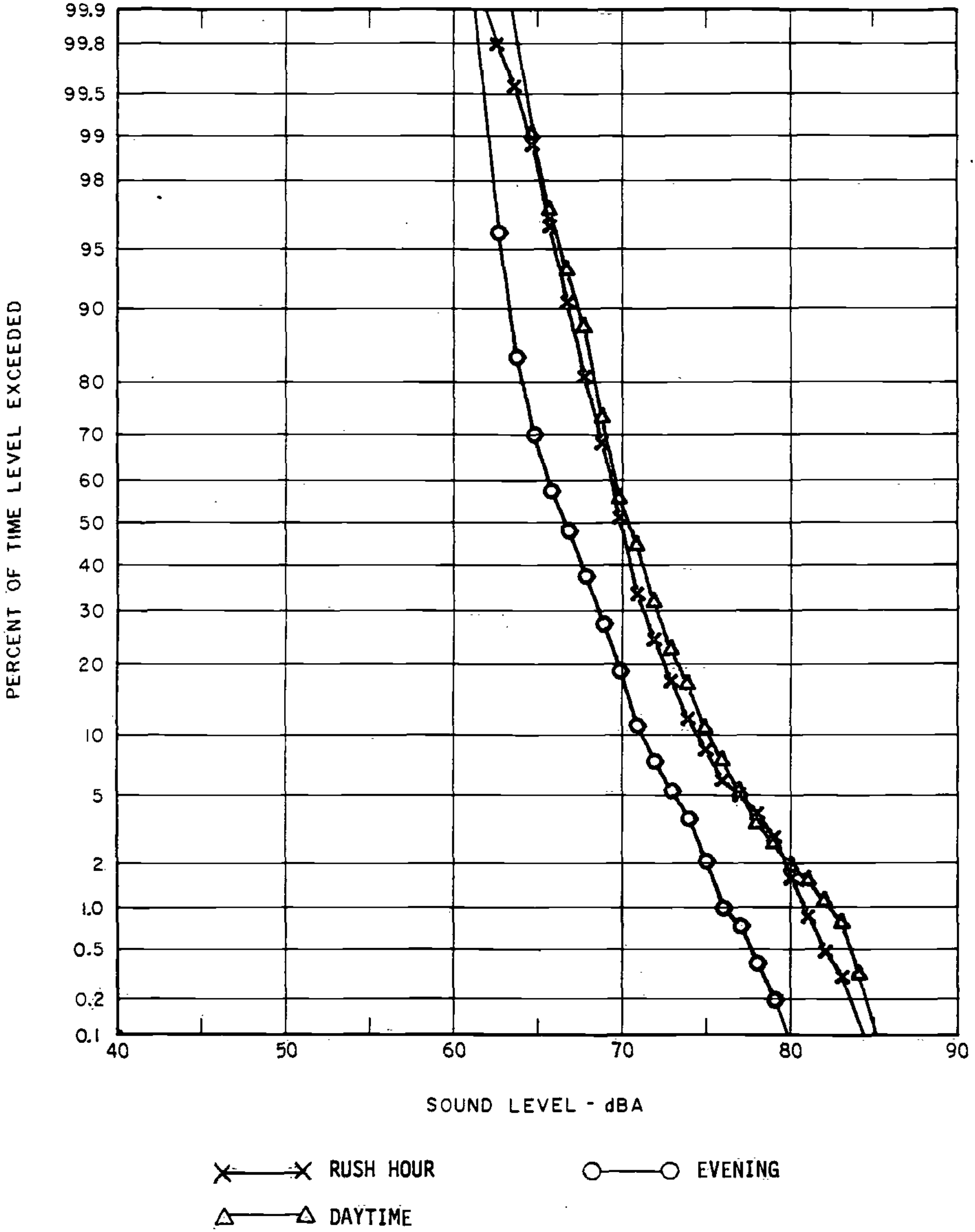


FIGURE A-2 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 2

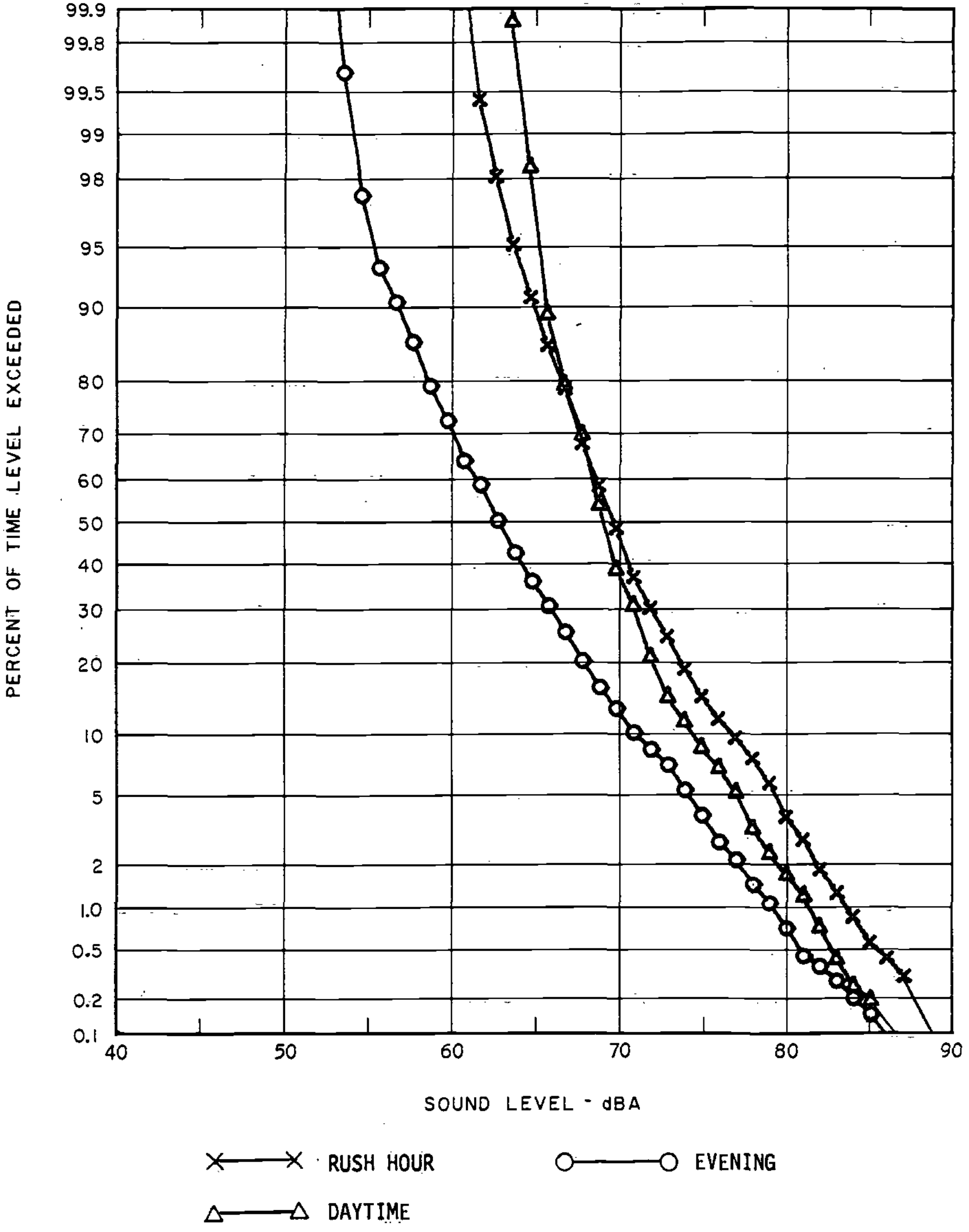


FIGURE A-3 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 3

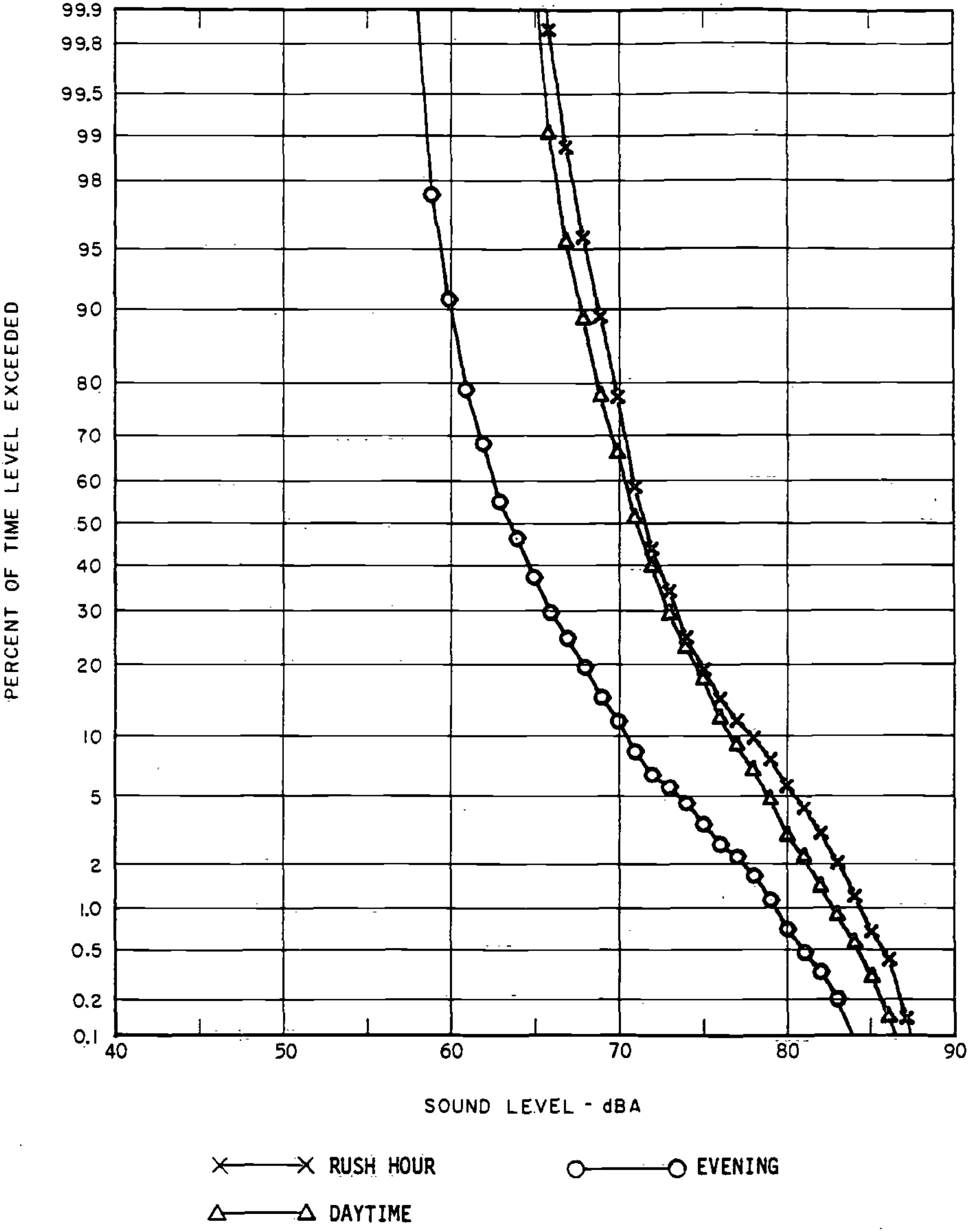


FIGURE A-4 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 4

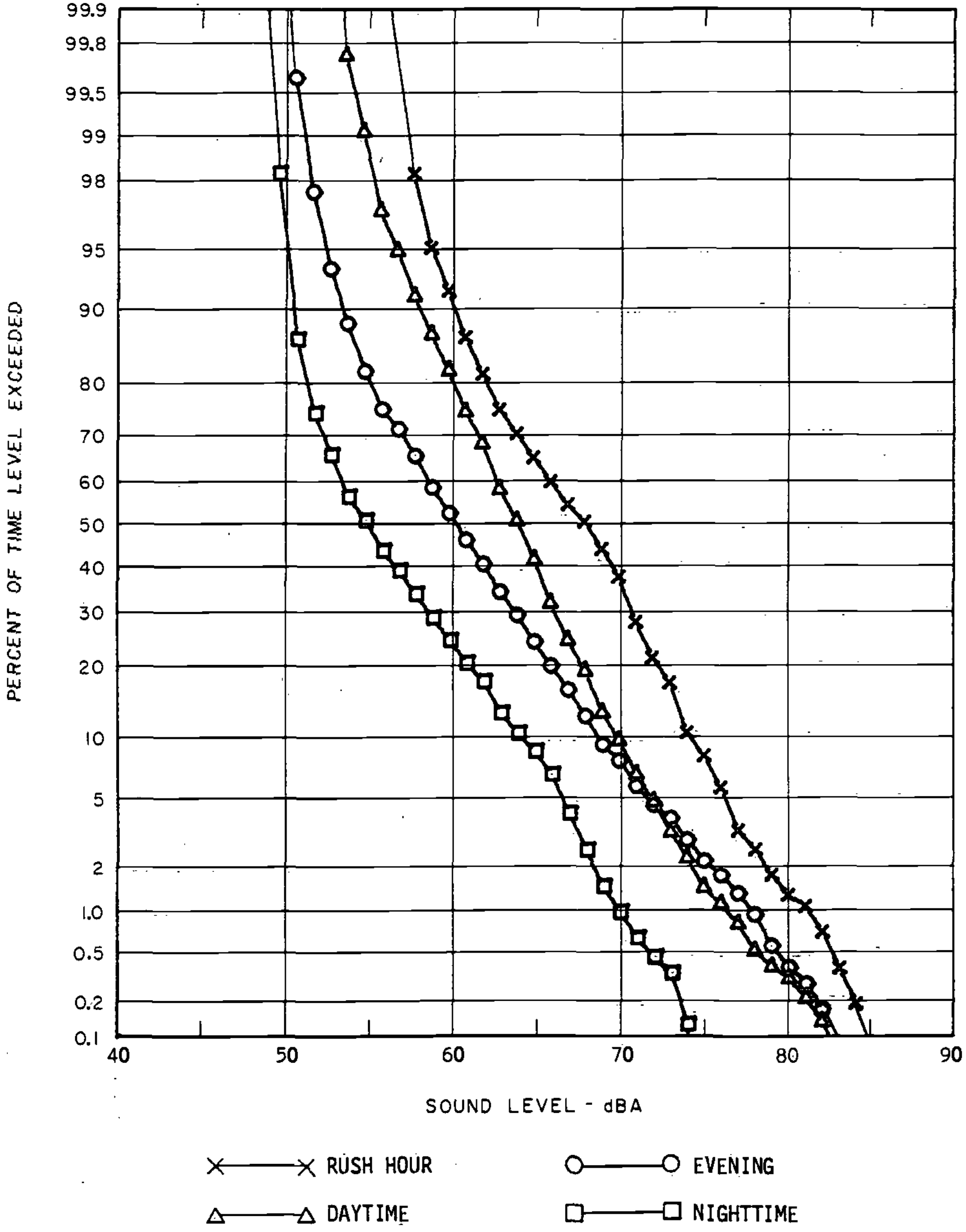


FIGURE A-5 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 5

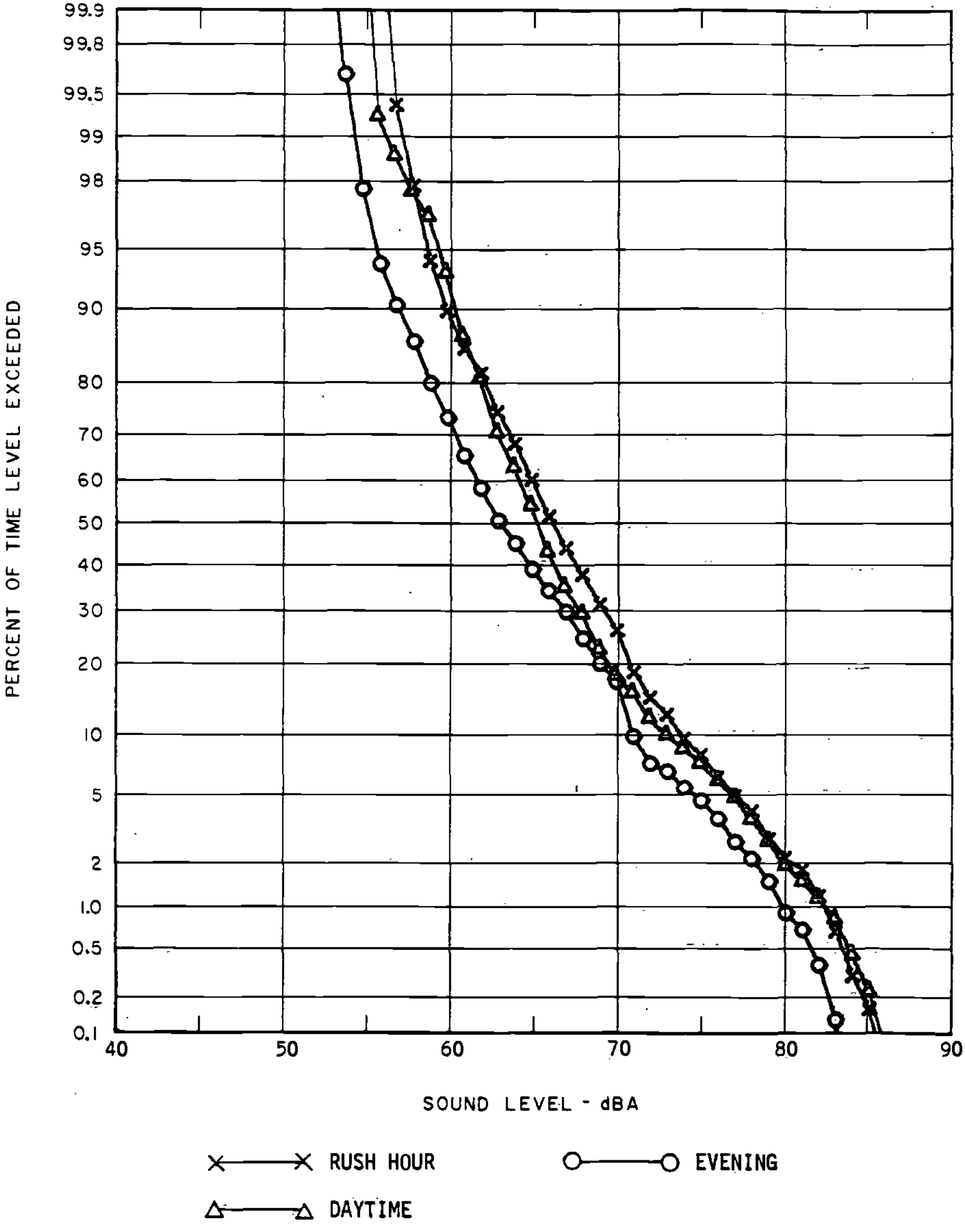


FIGURE A-6 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 6

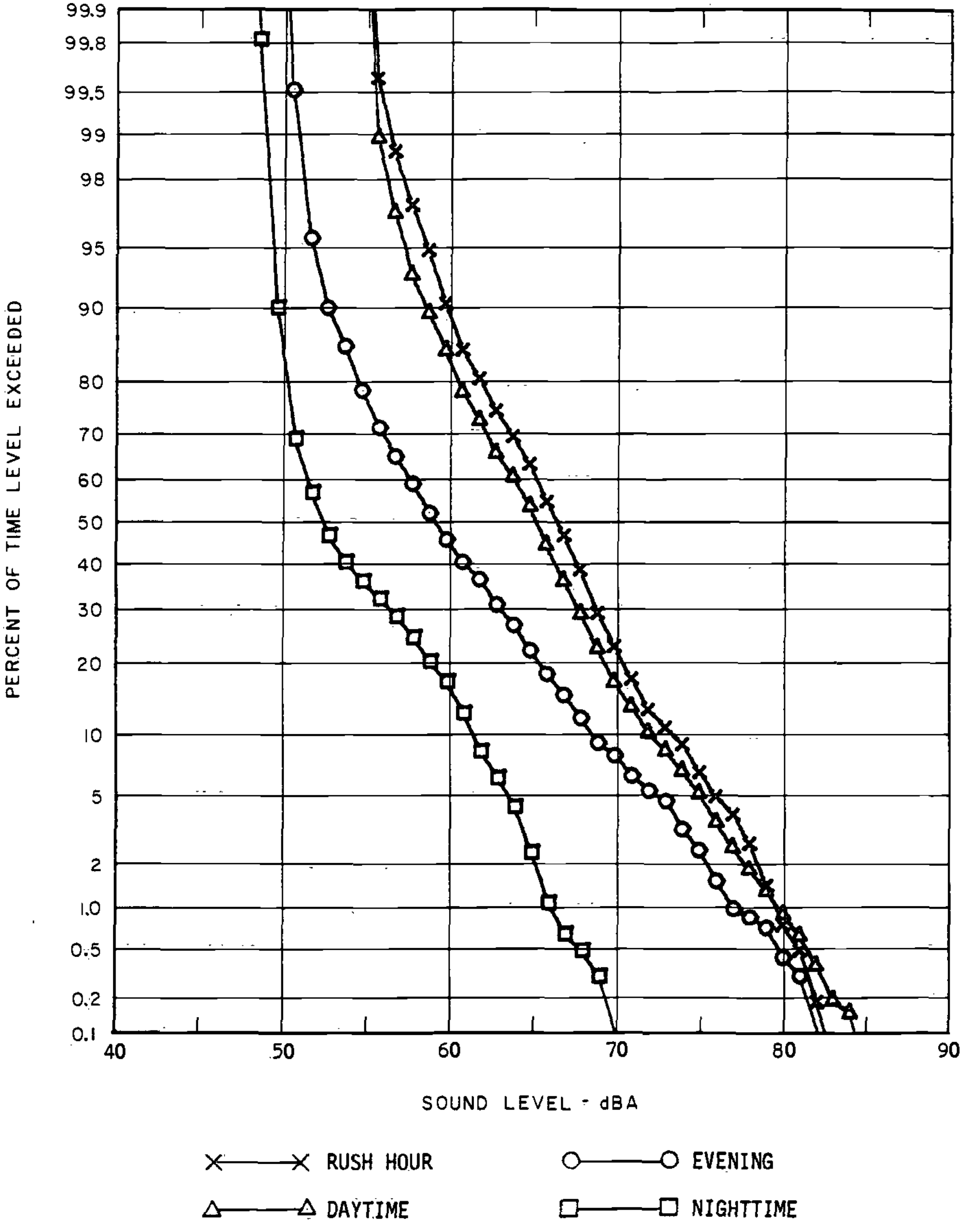


FIGURE A-7 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 7

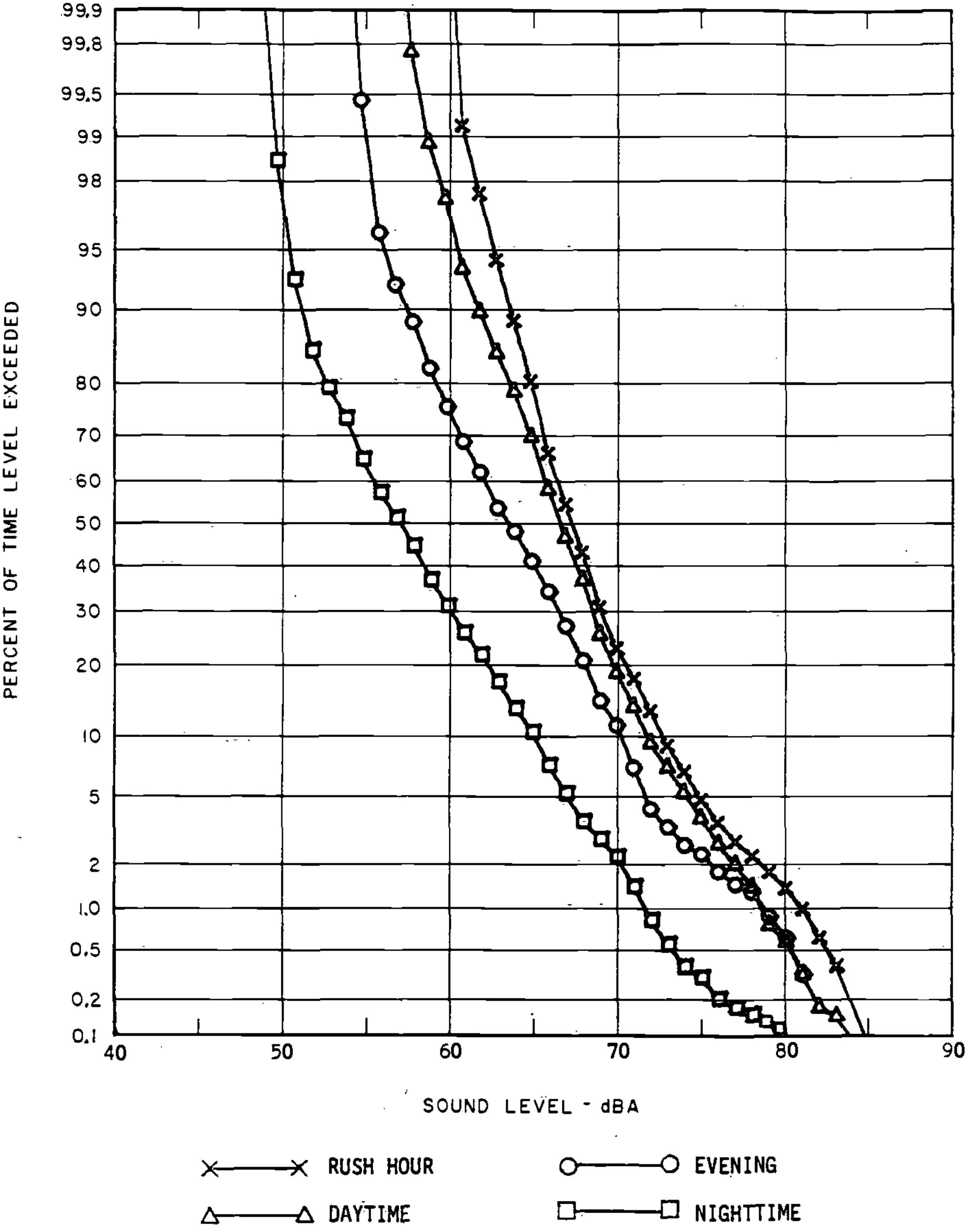


FIGURE A-8 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 8

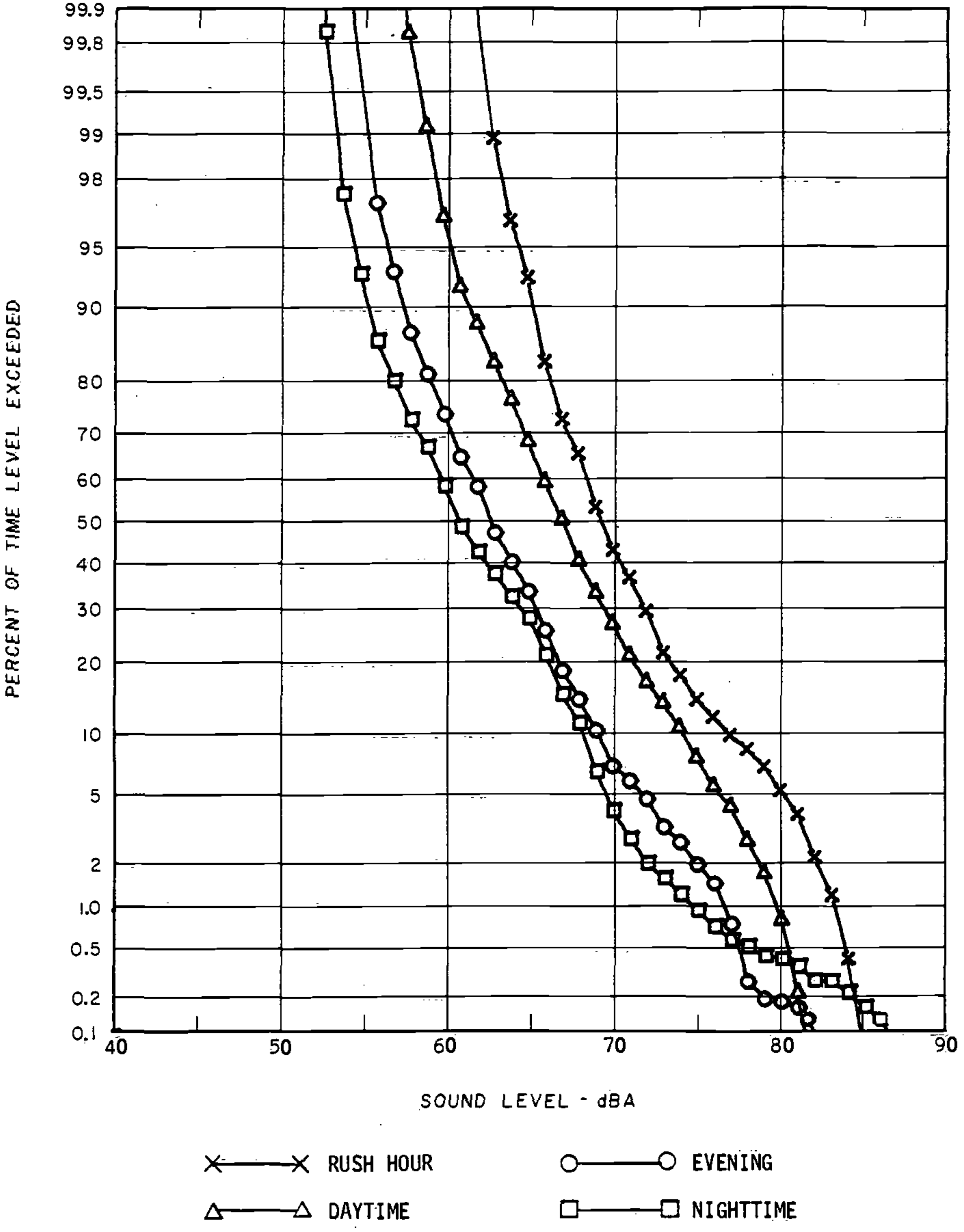


FIGURE A-9 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 9

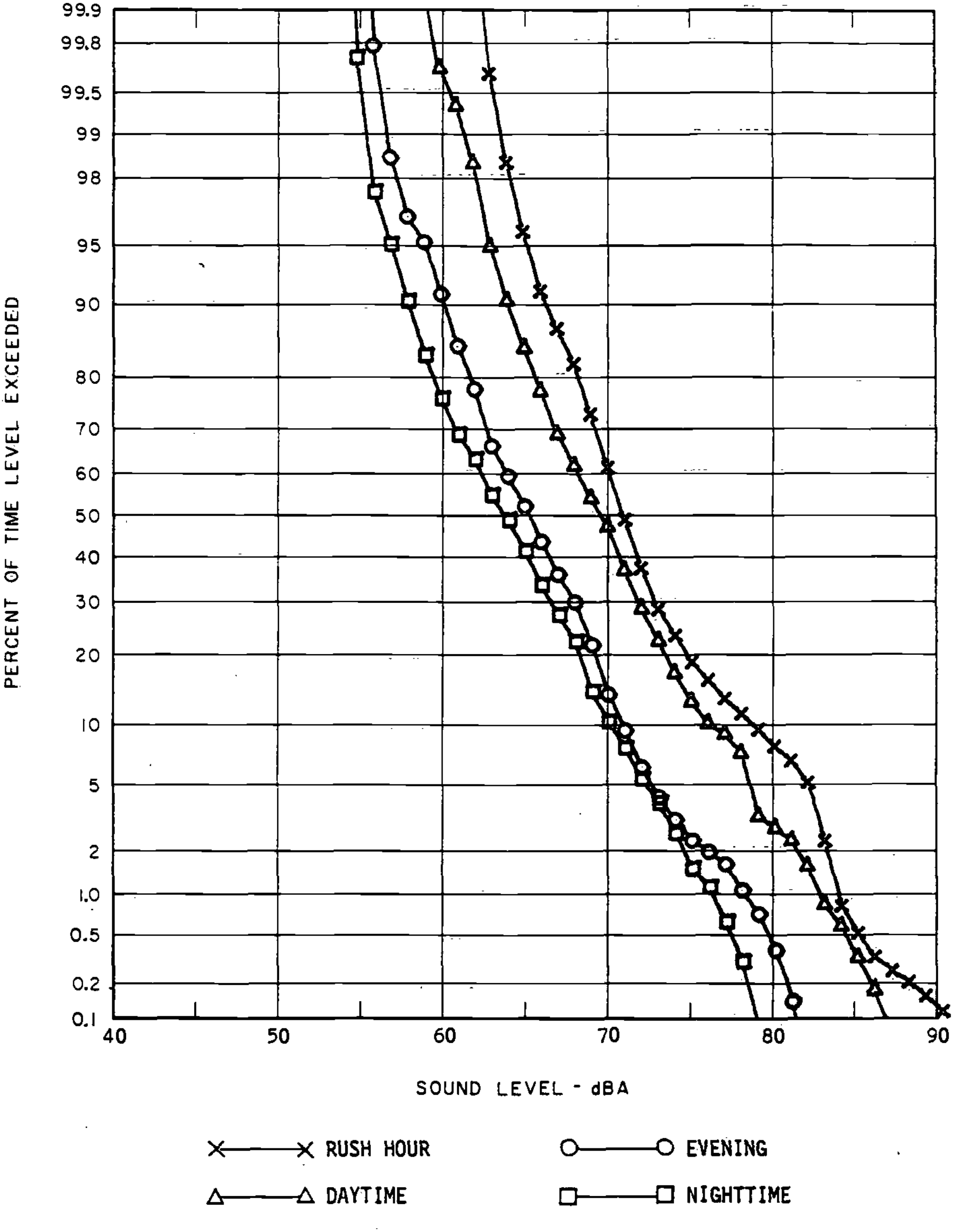


FIGURE A-10 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 10

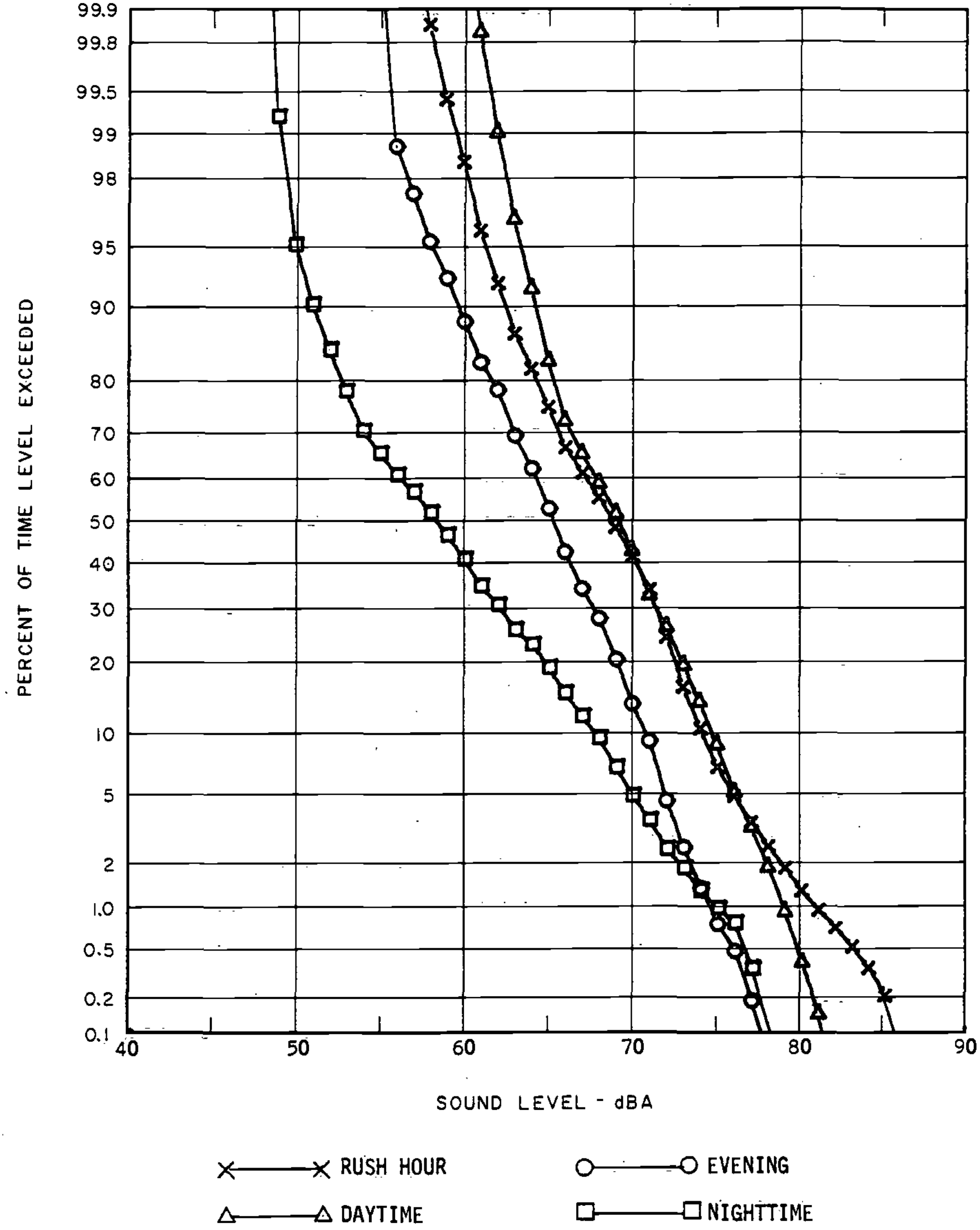


FIGURE A-11 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 11

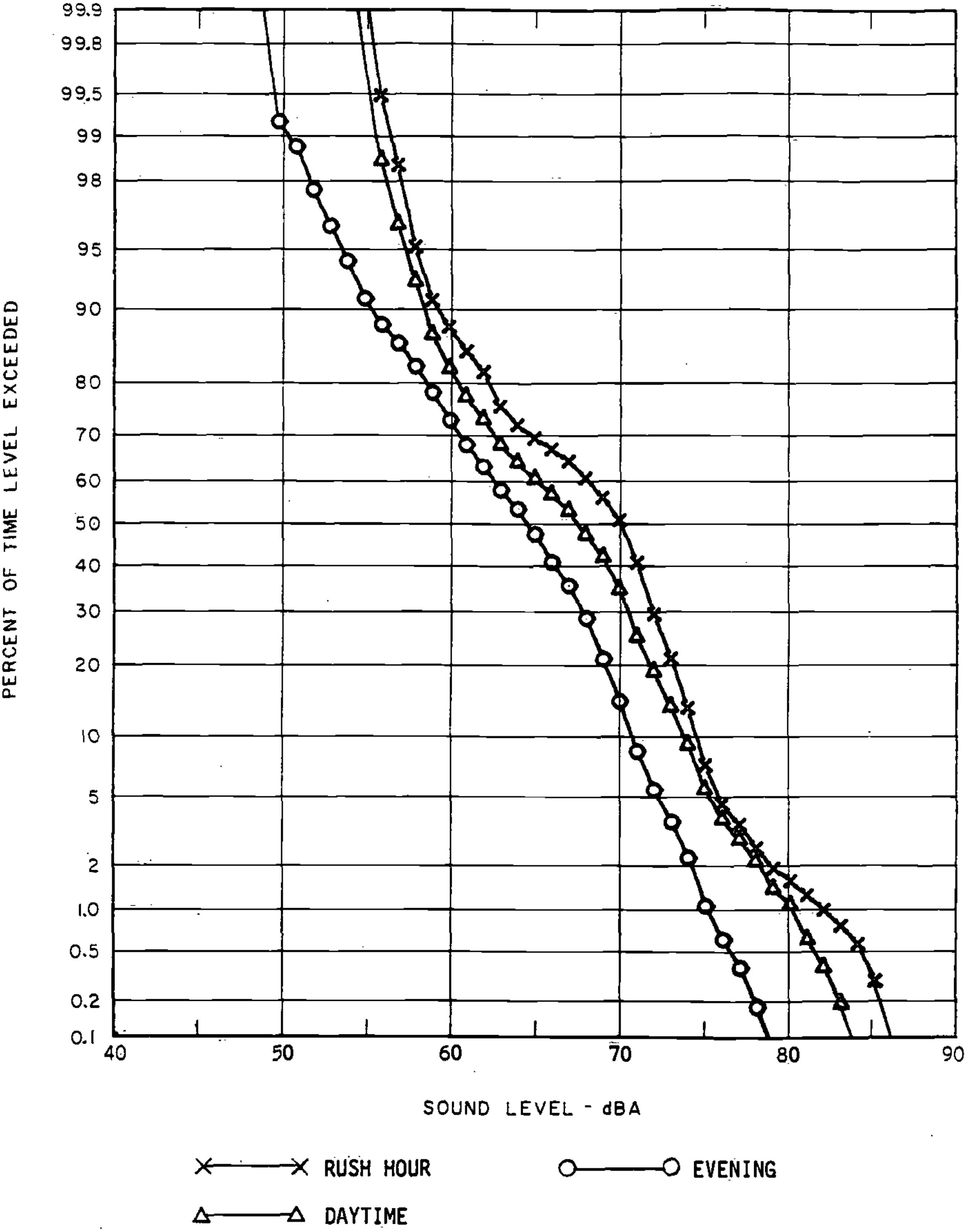
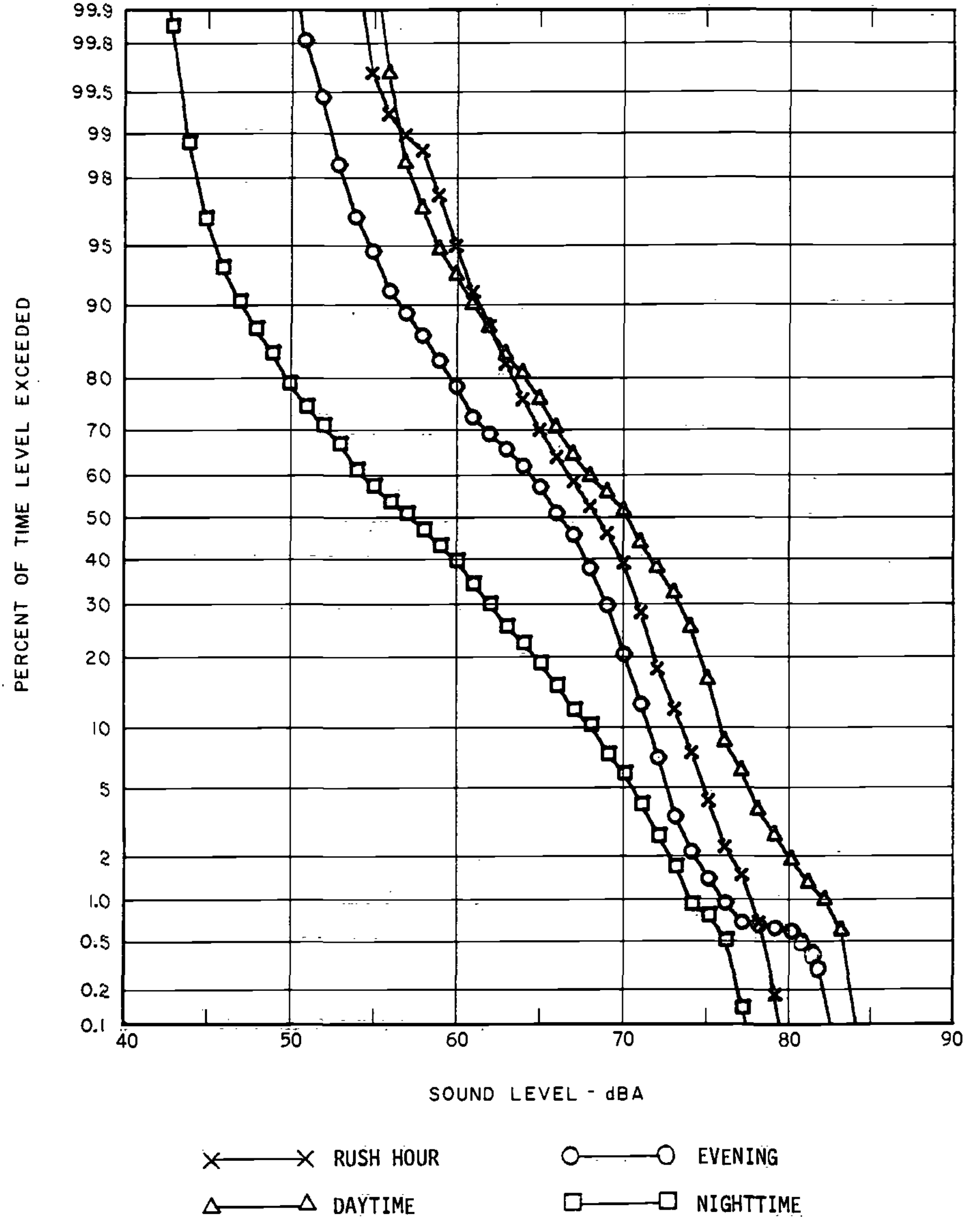


FIGURE A-12 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 12



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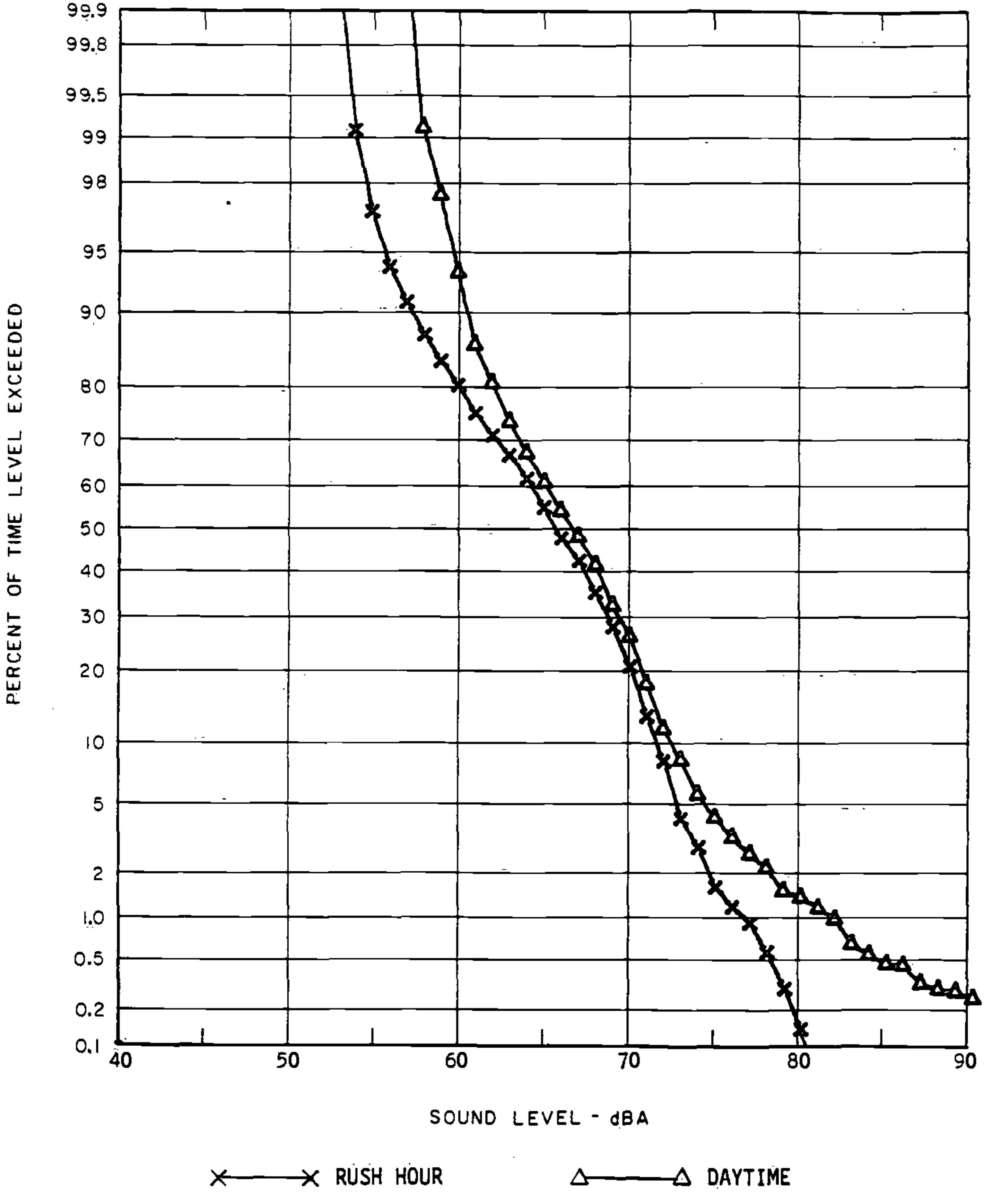
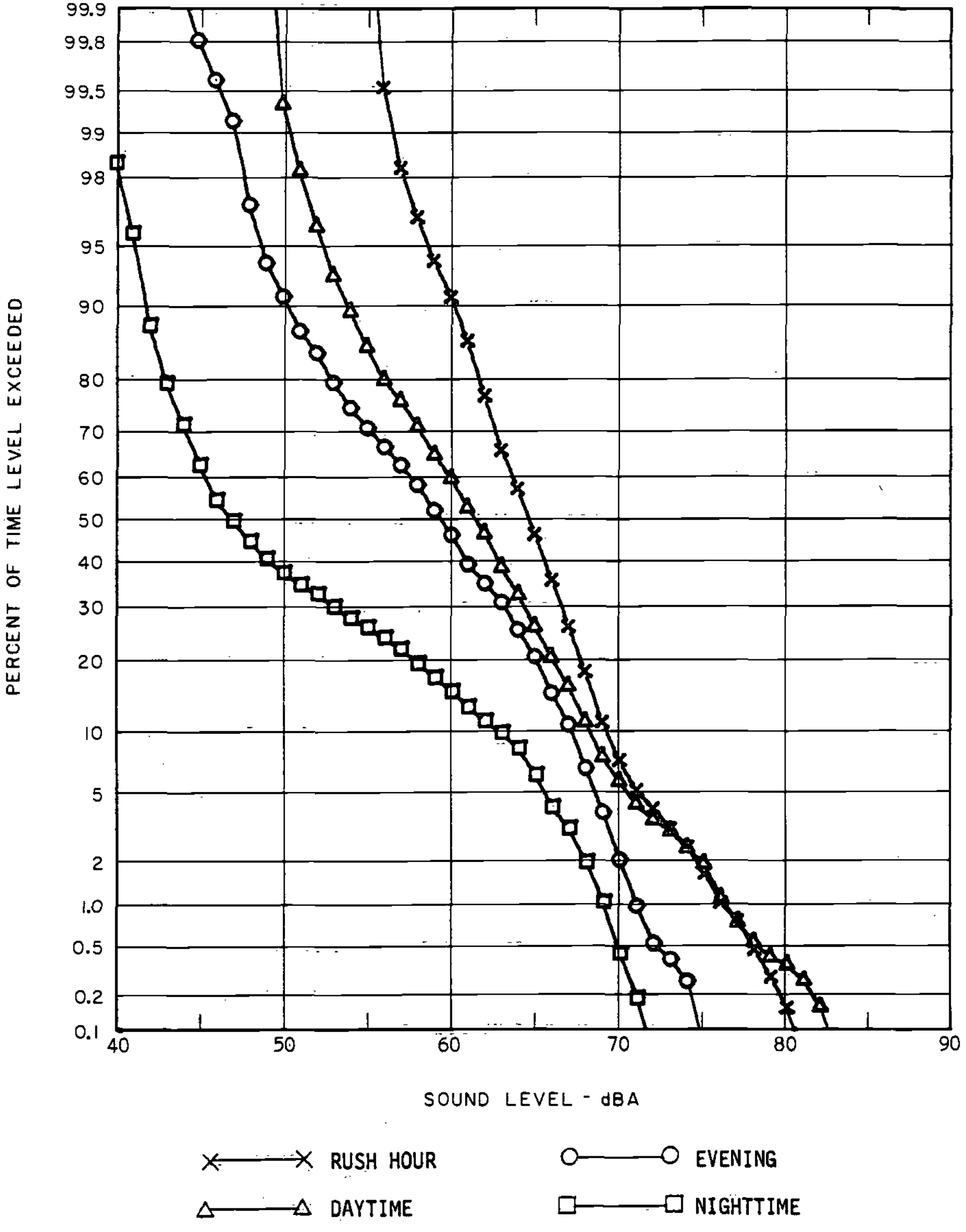


FIGURE A-14 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 14



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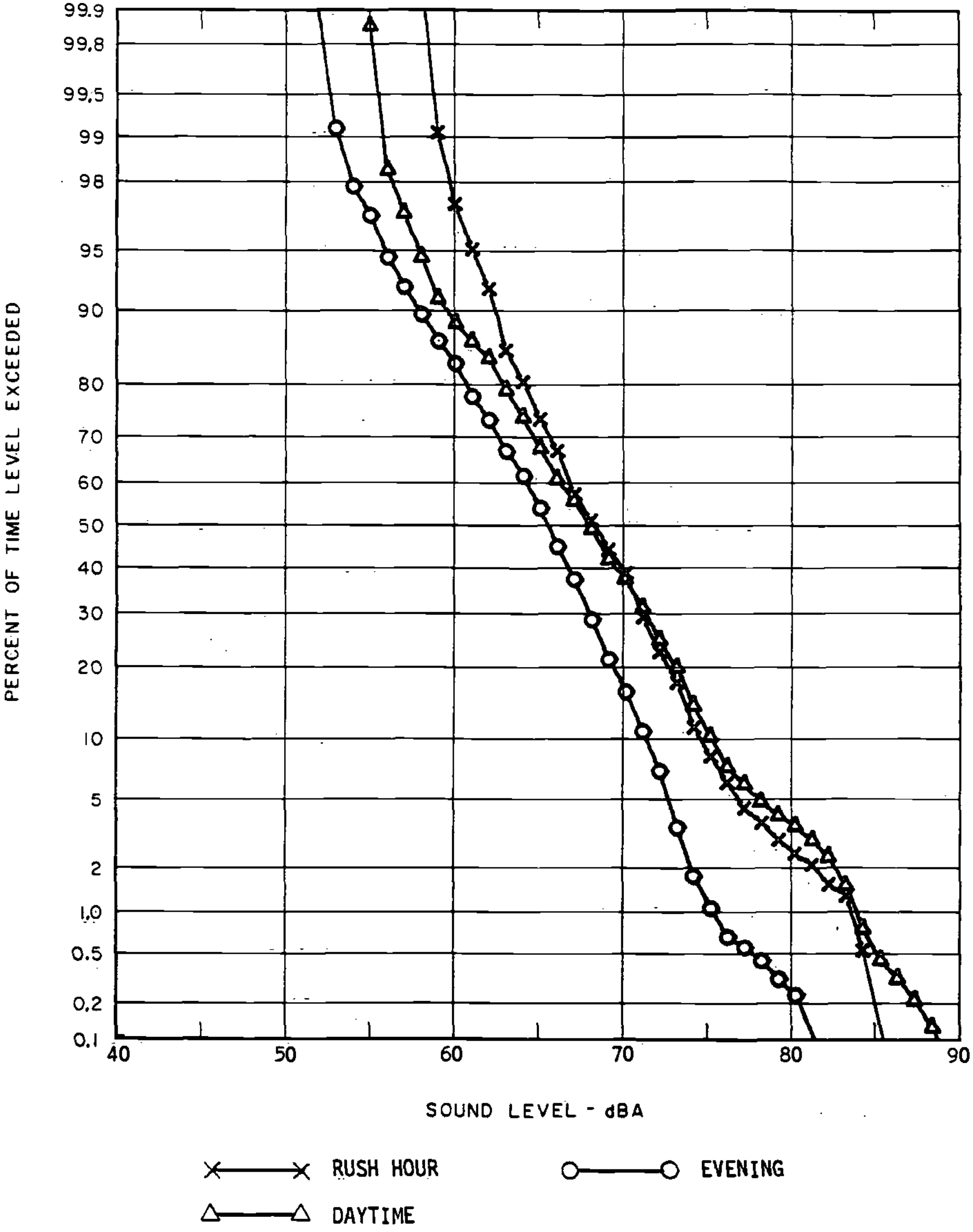

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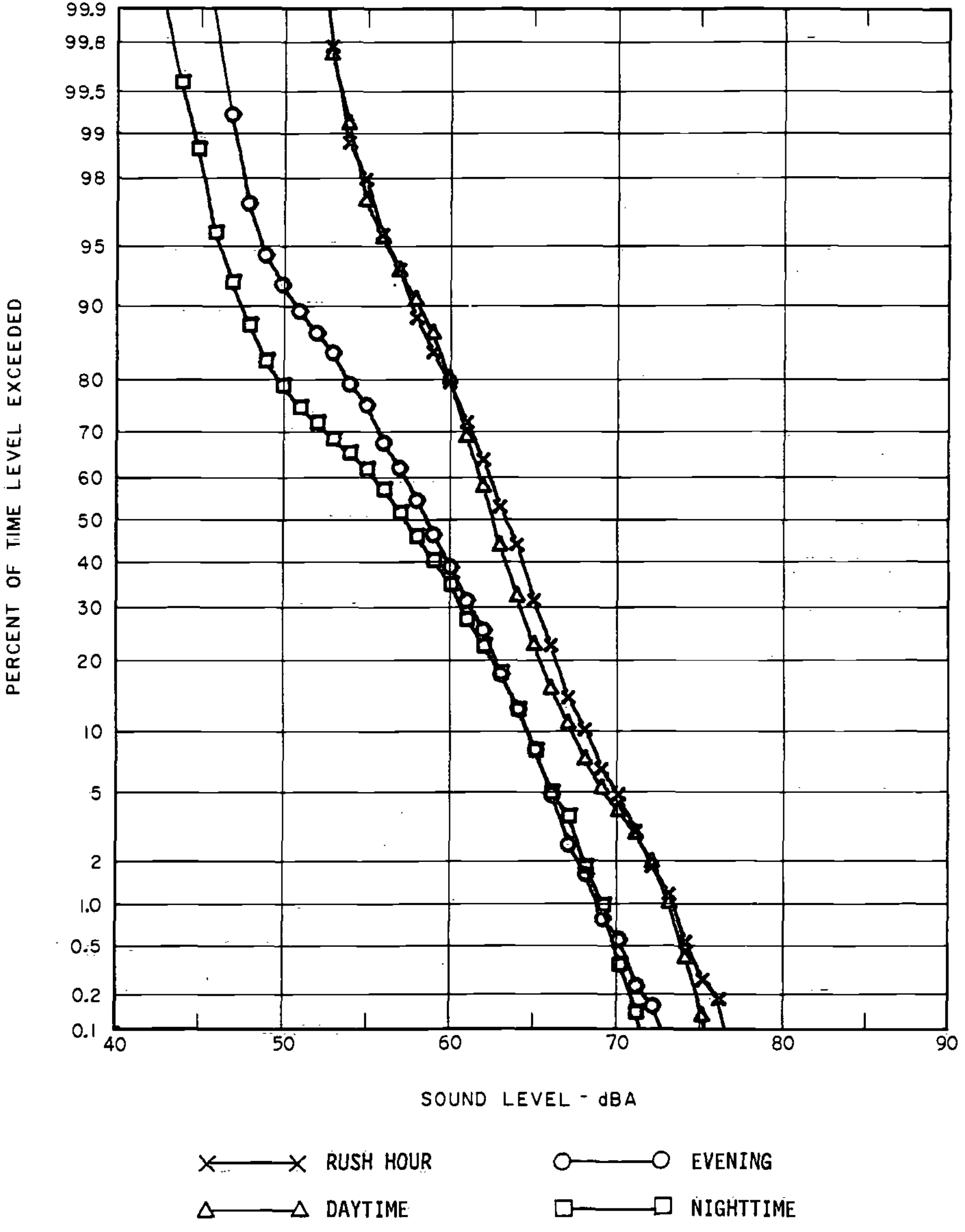

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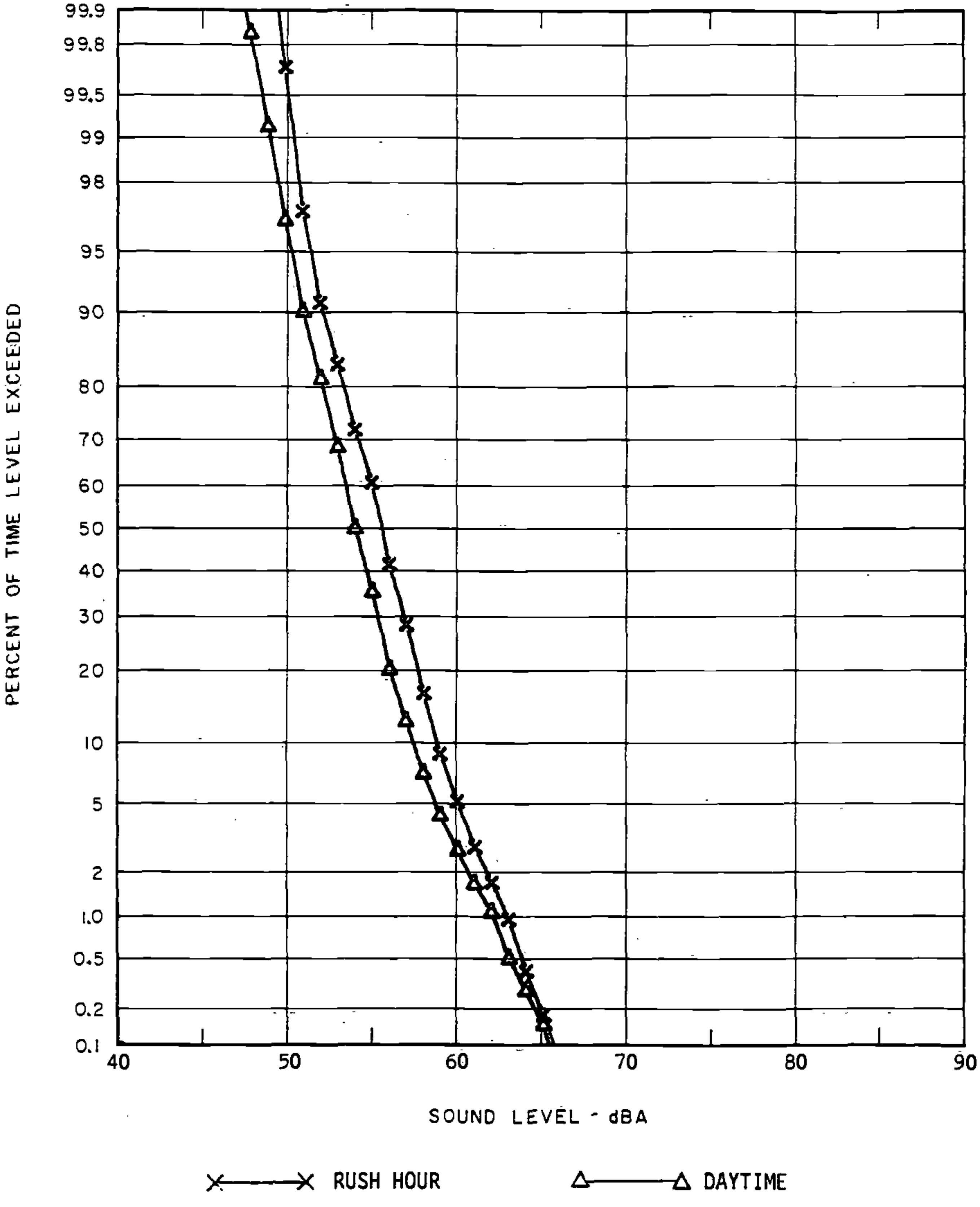

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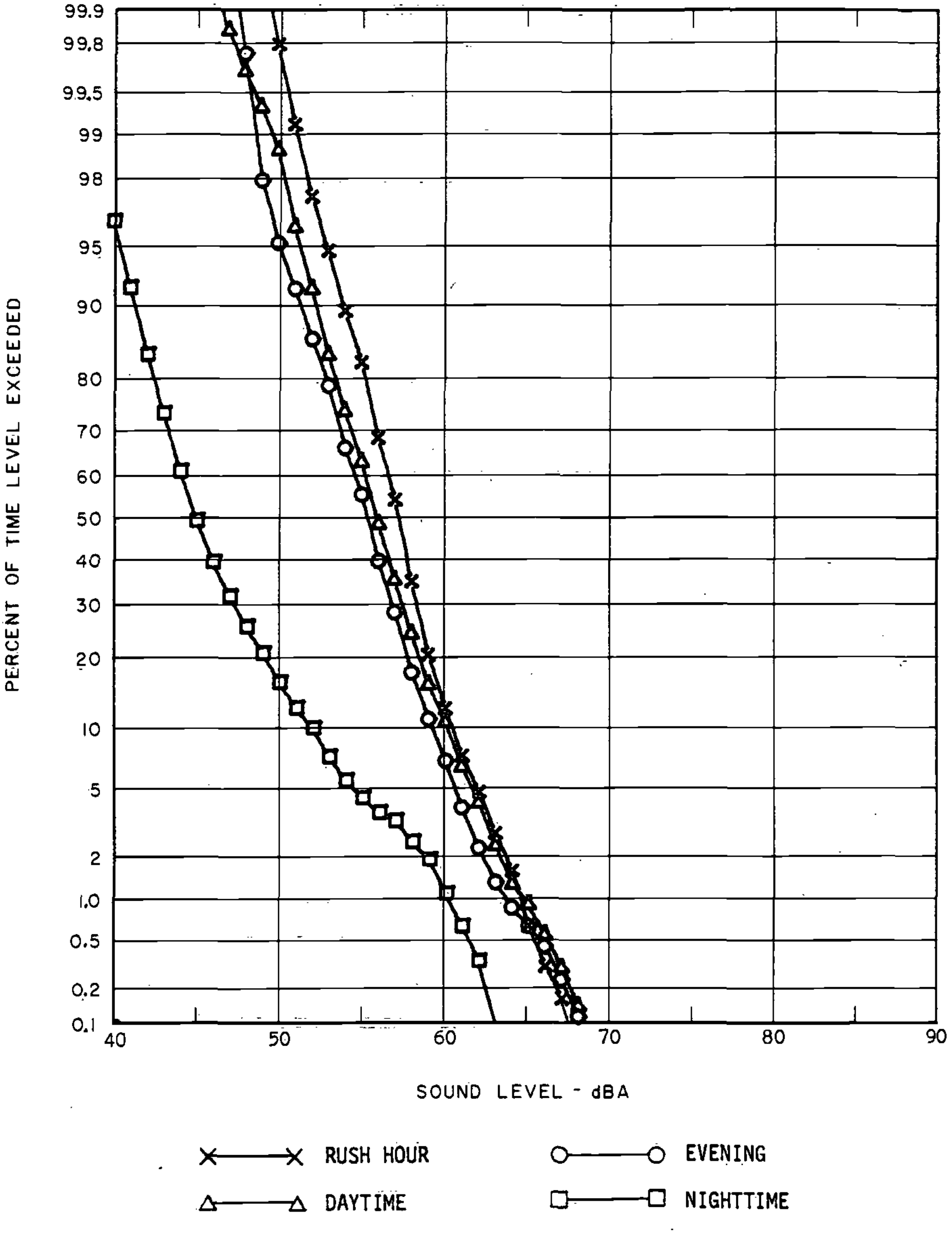

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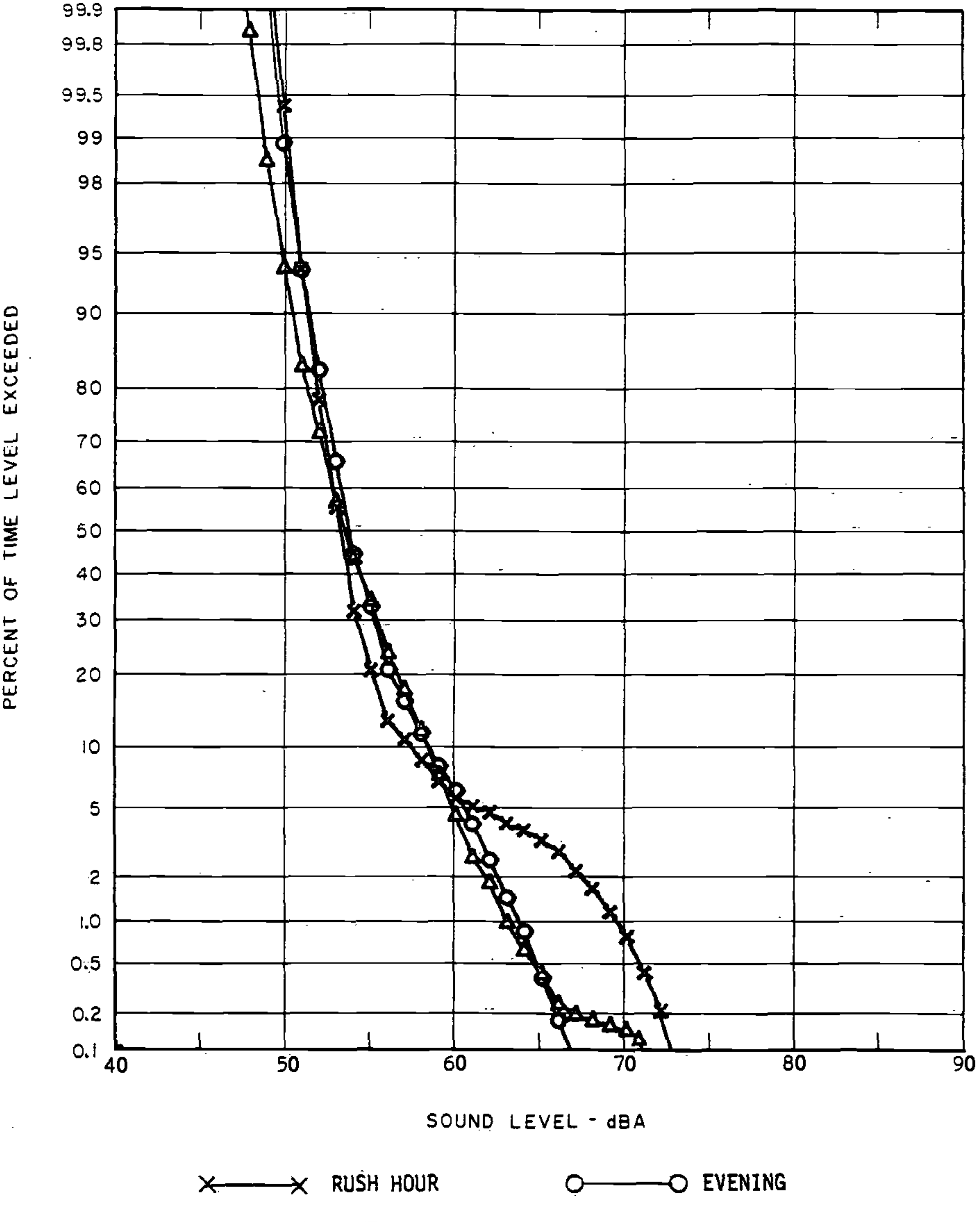

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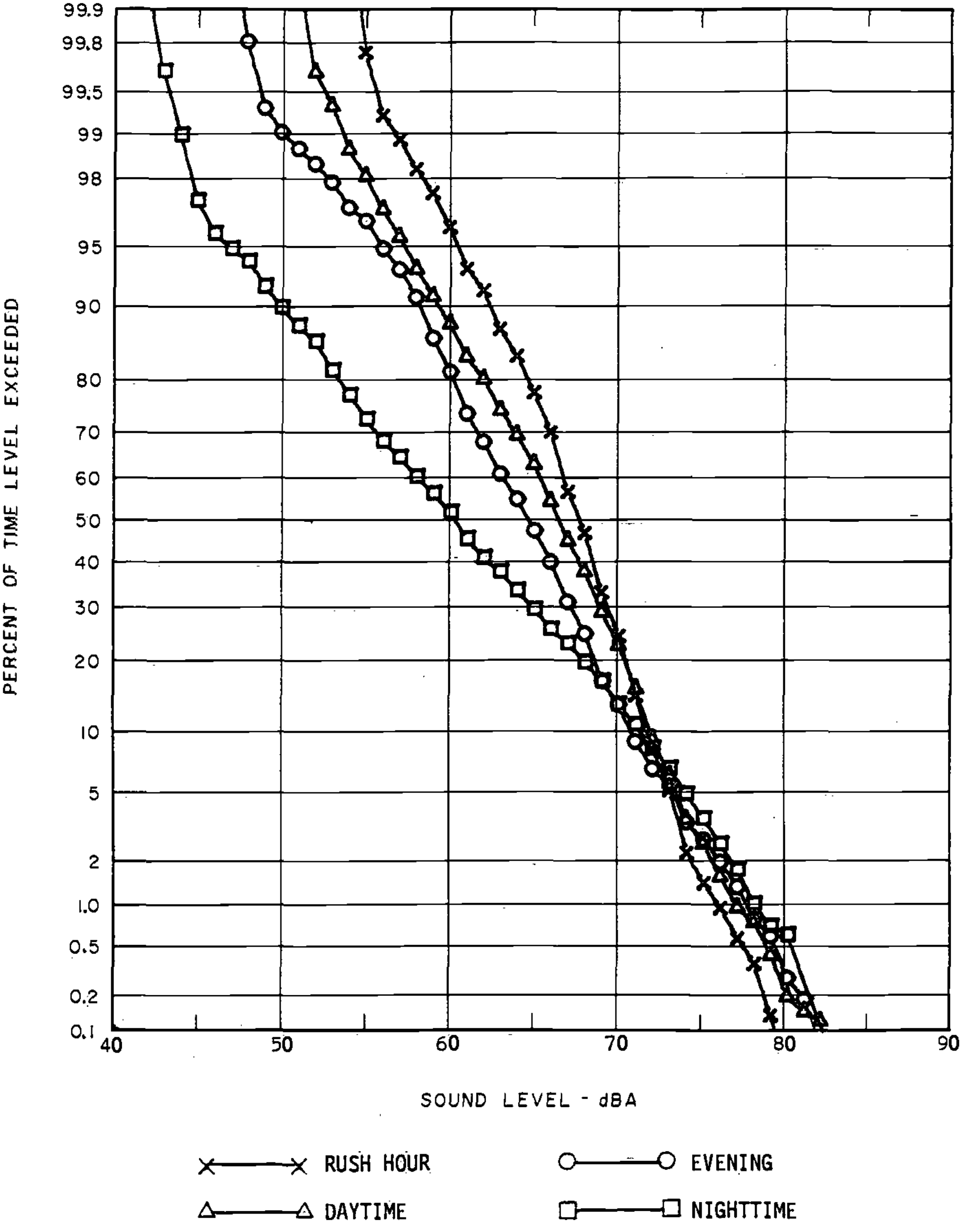

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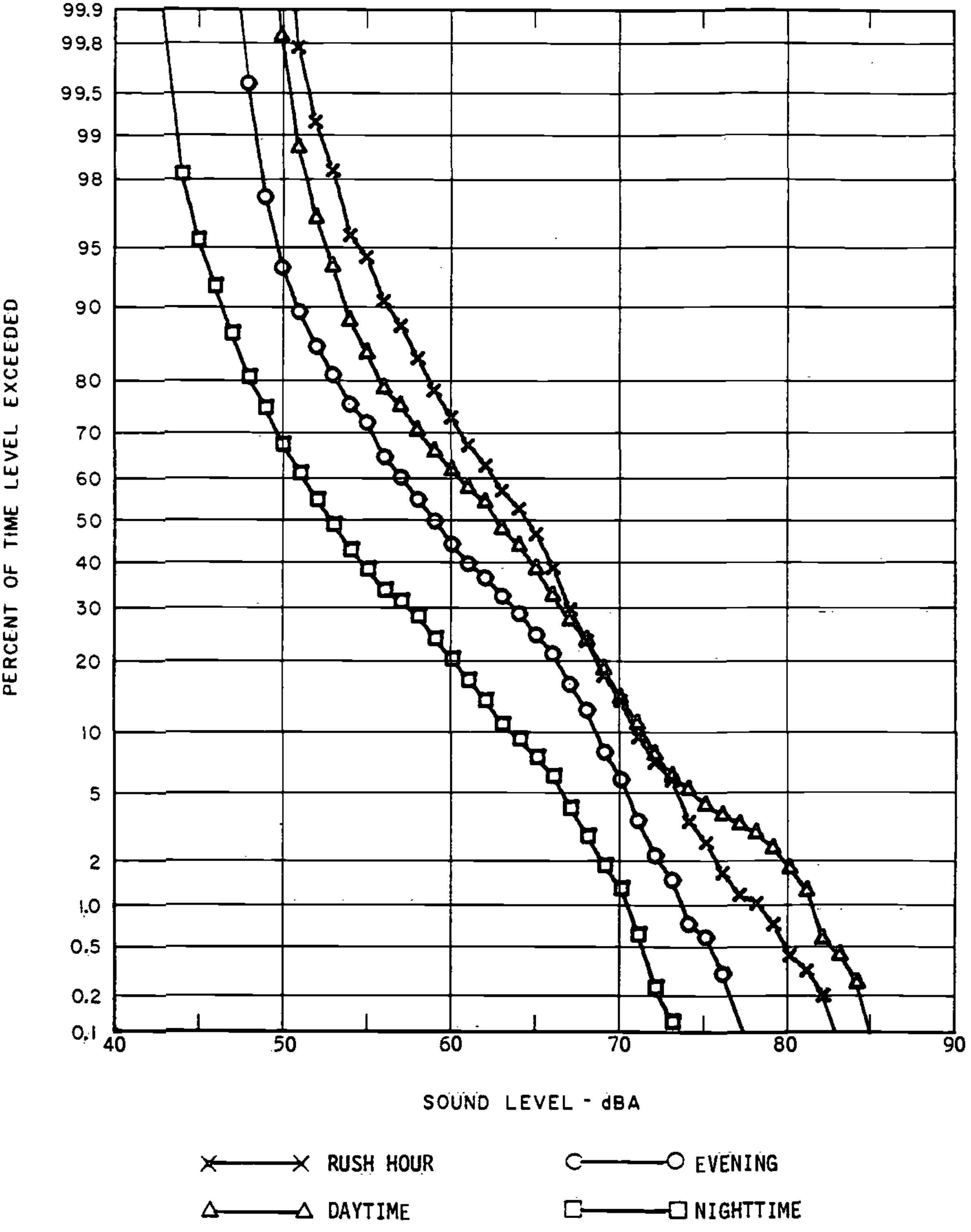

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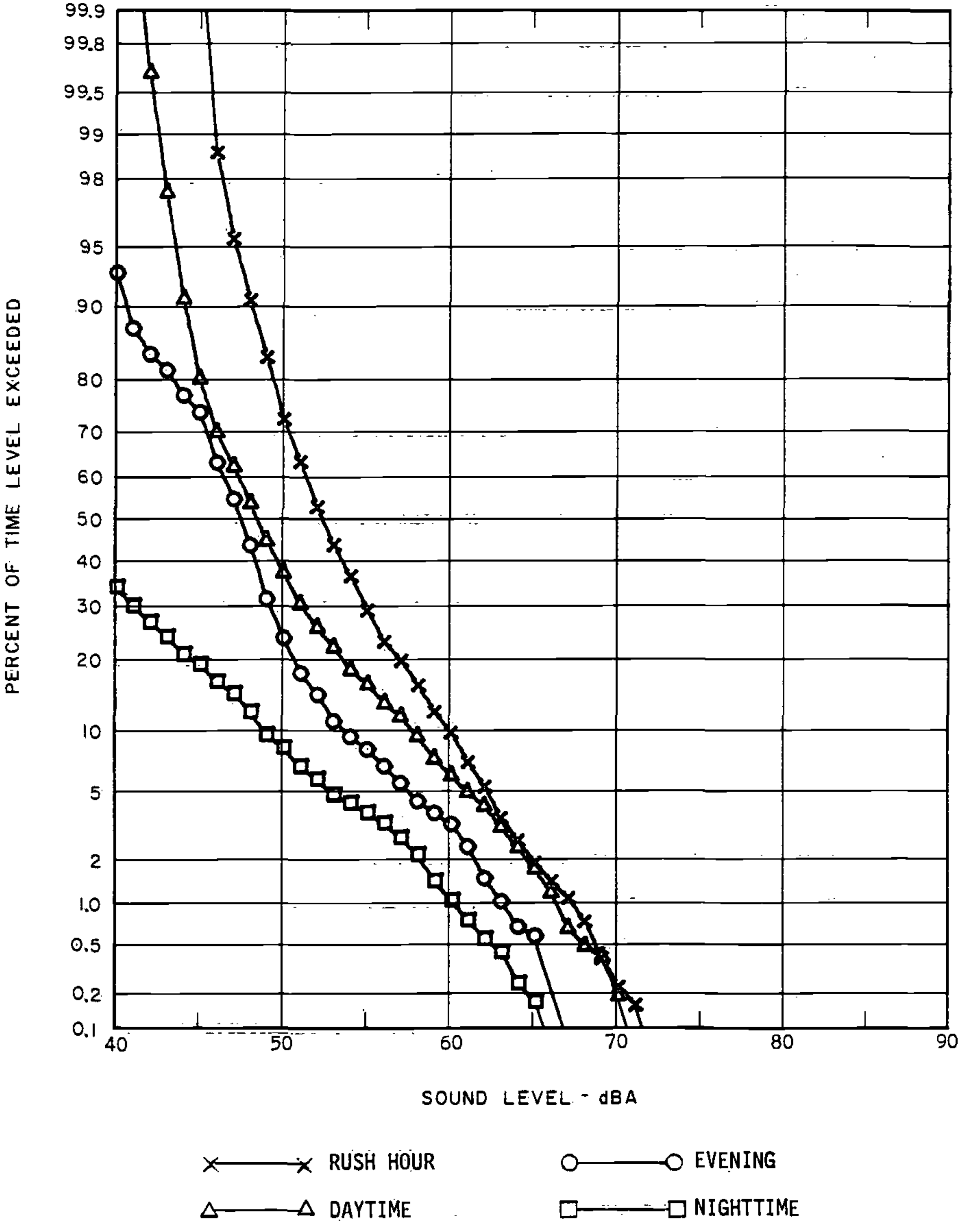

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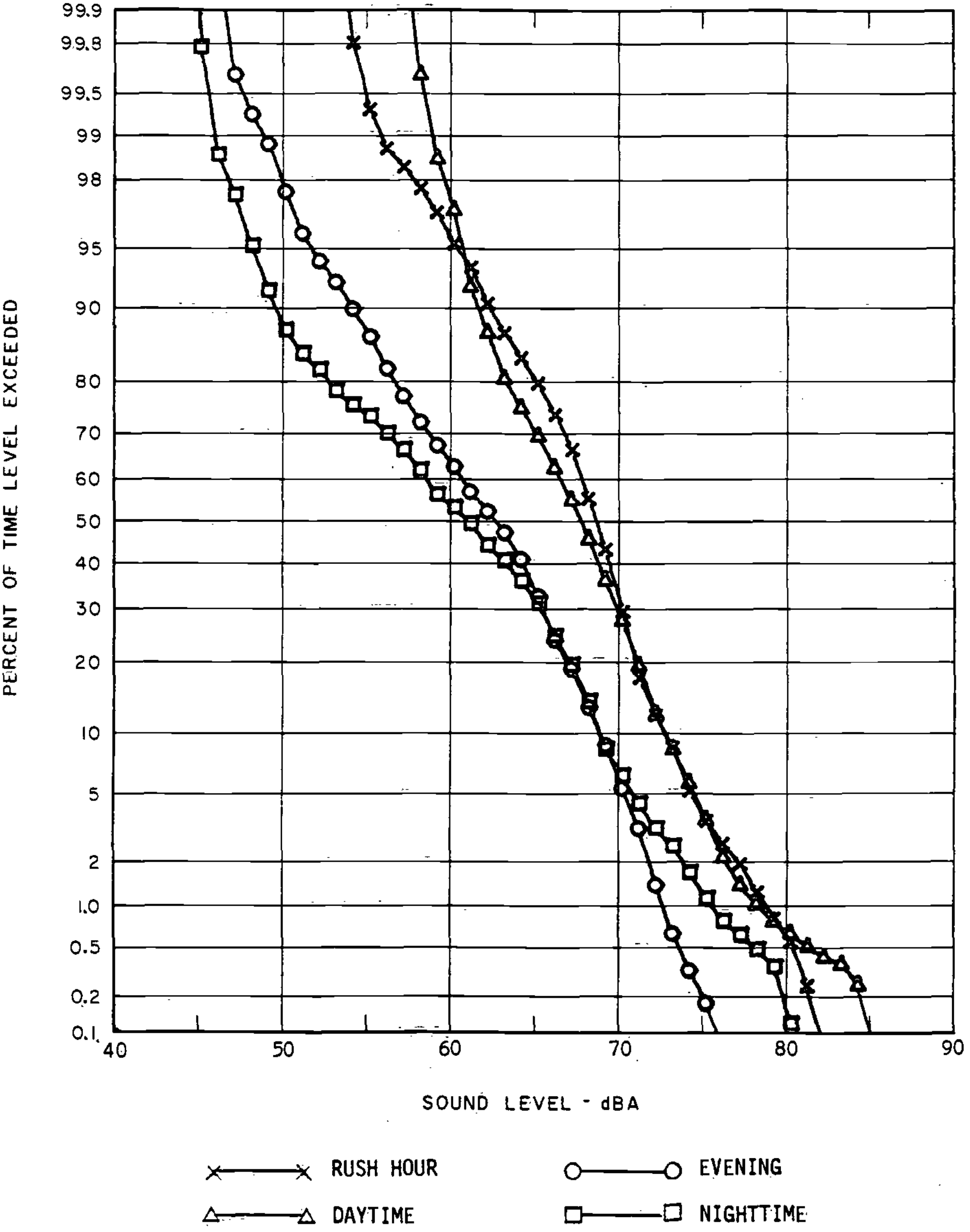

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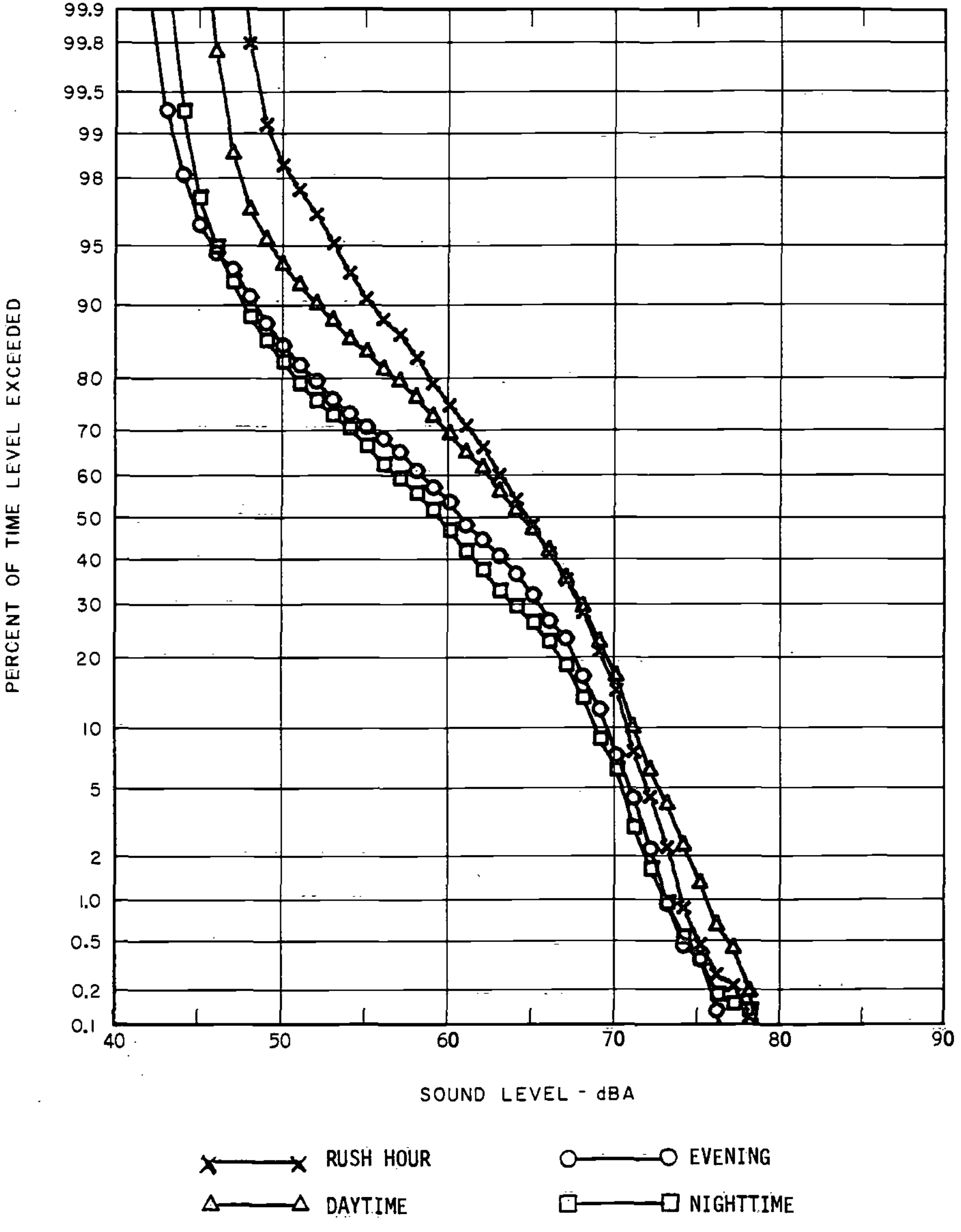

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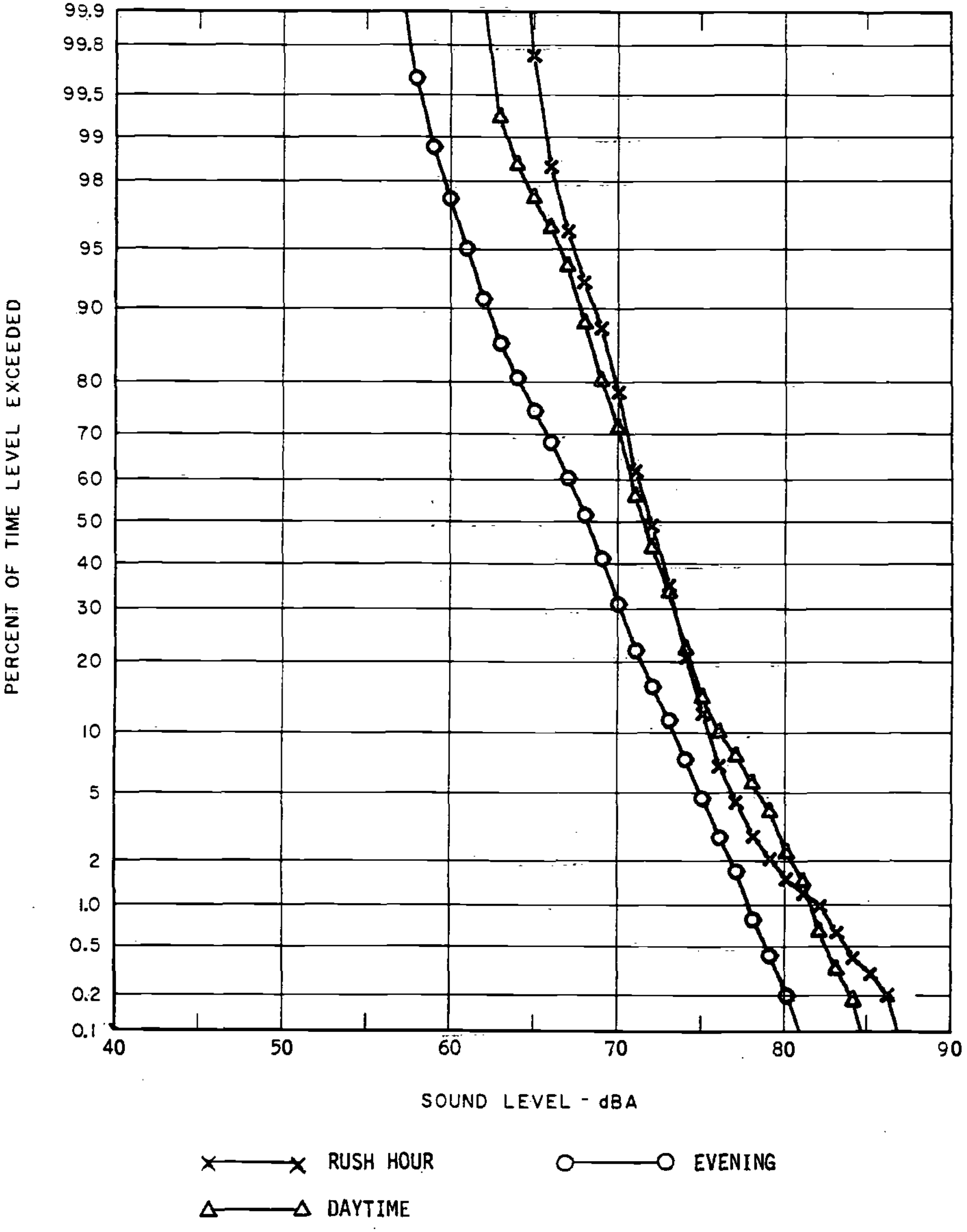

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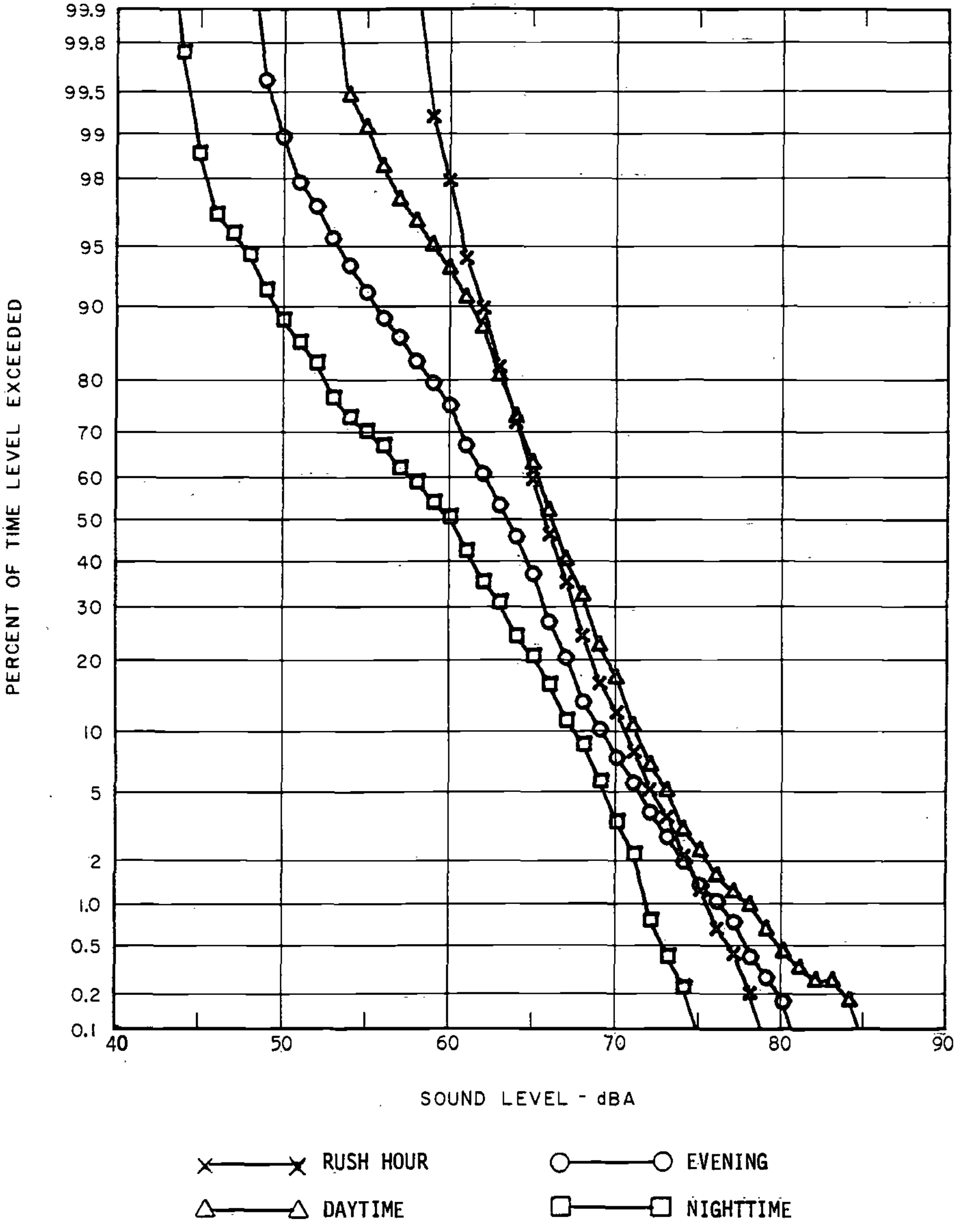

FIGURE A-27 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 27

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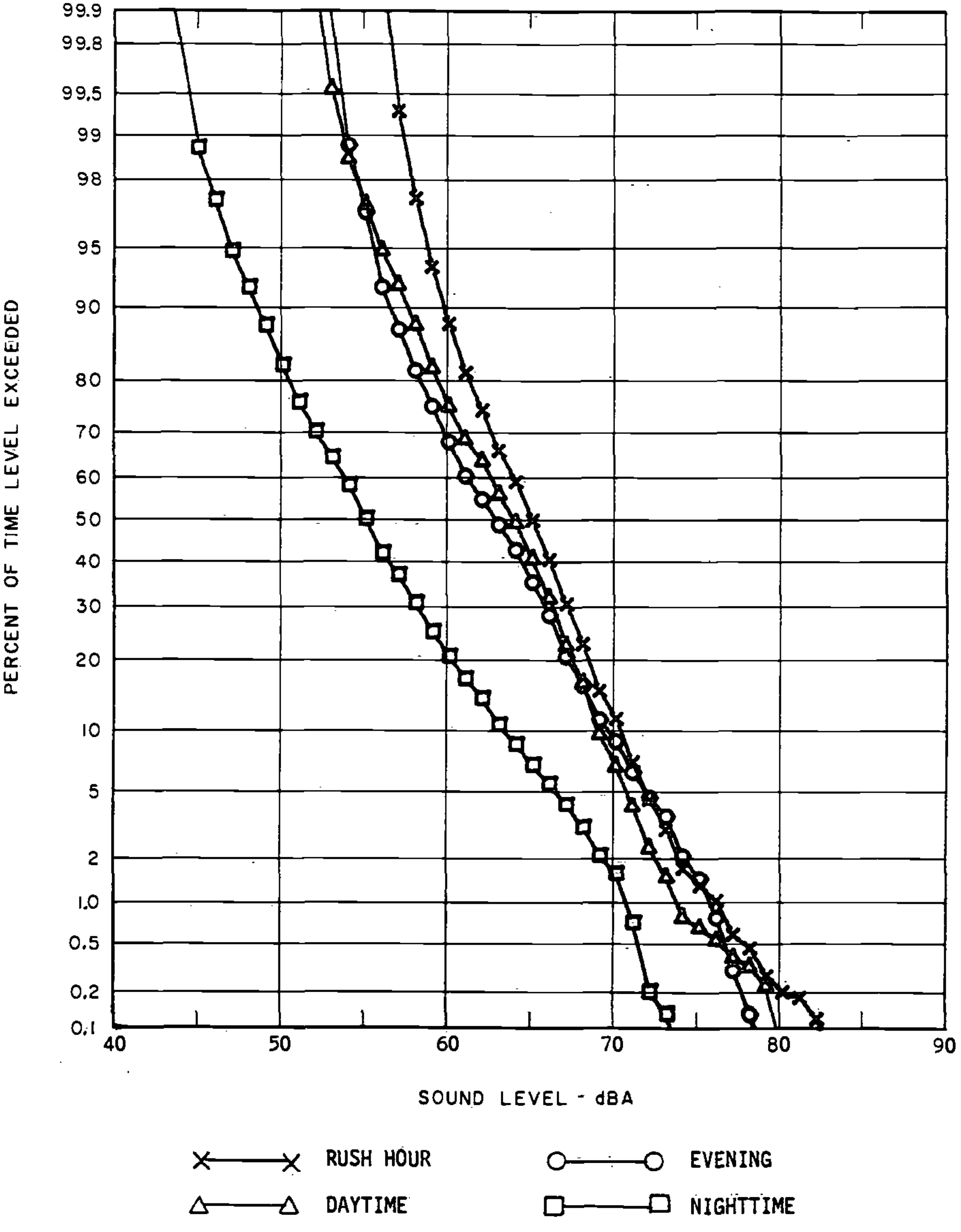
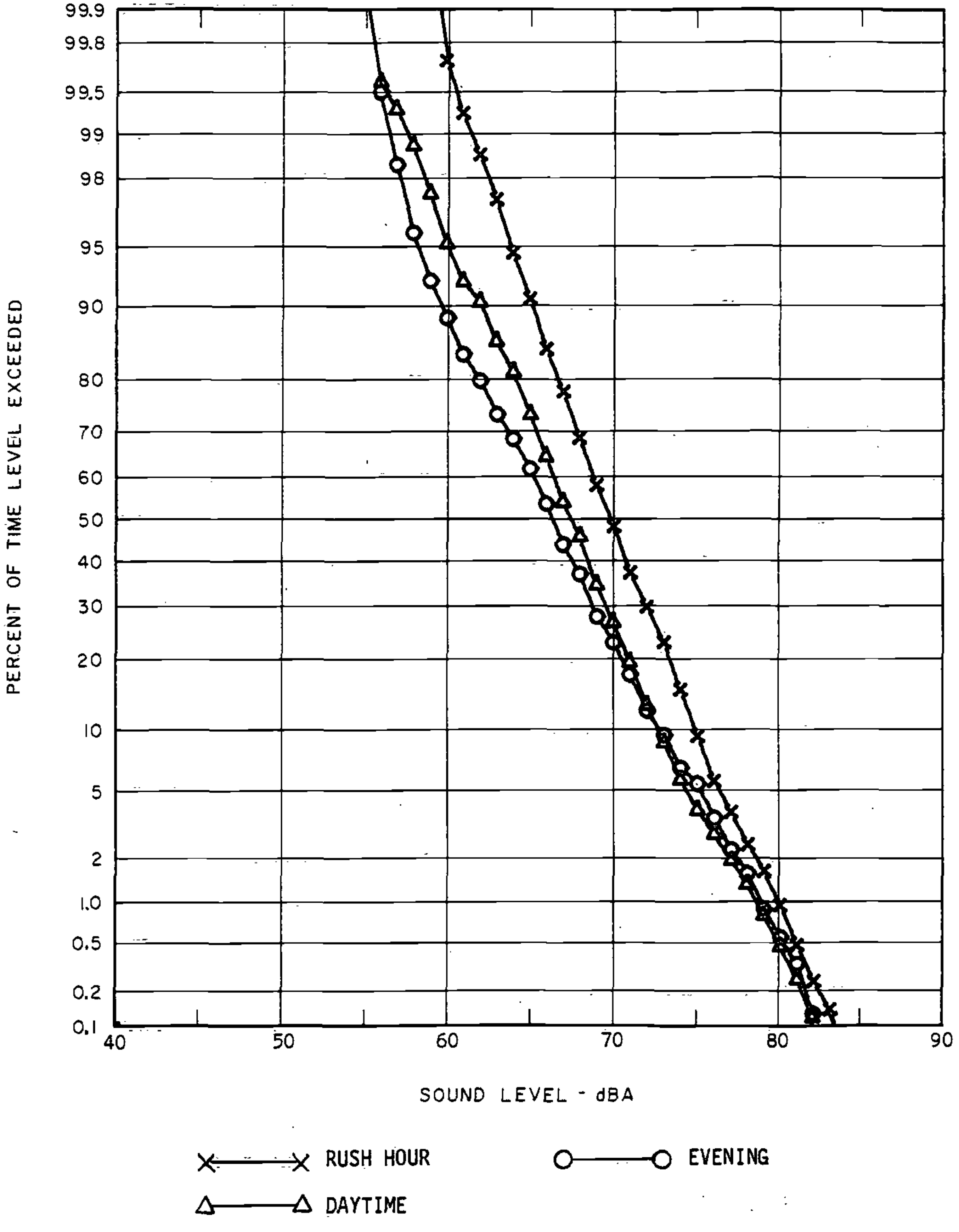


FIGURE A-28 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 28



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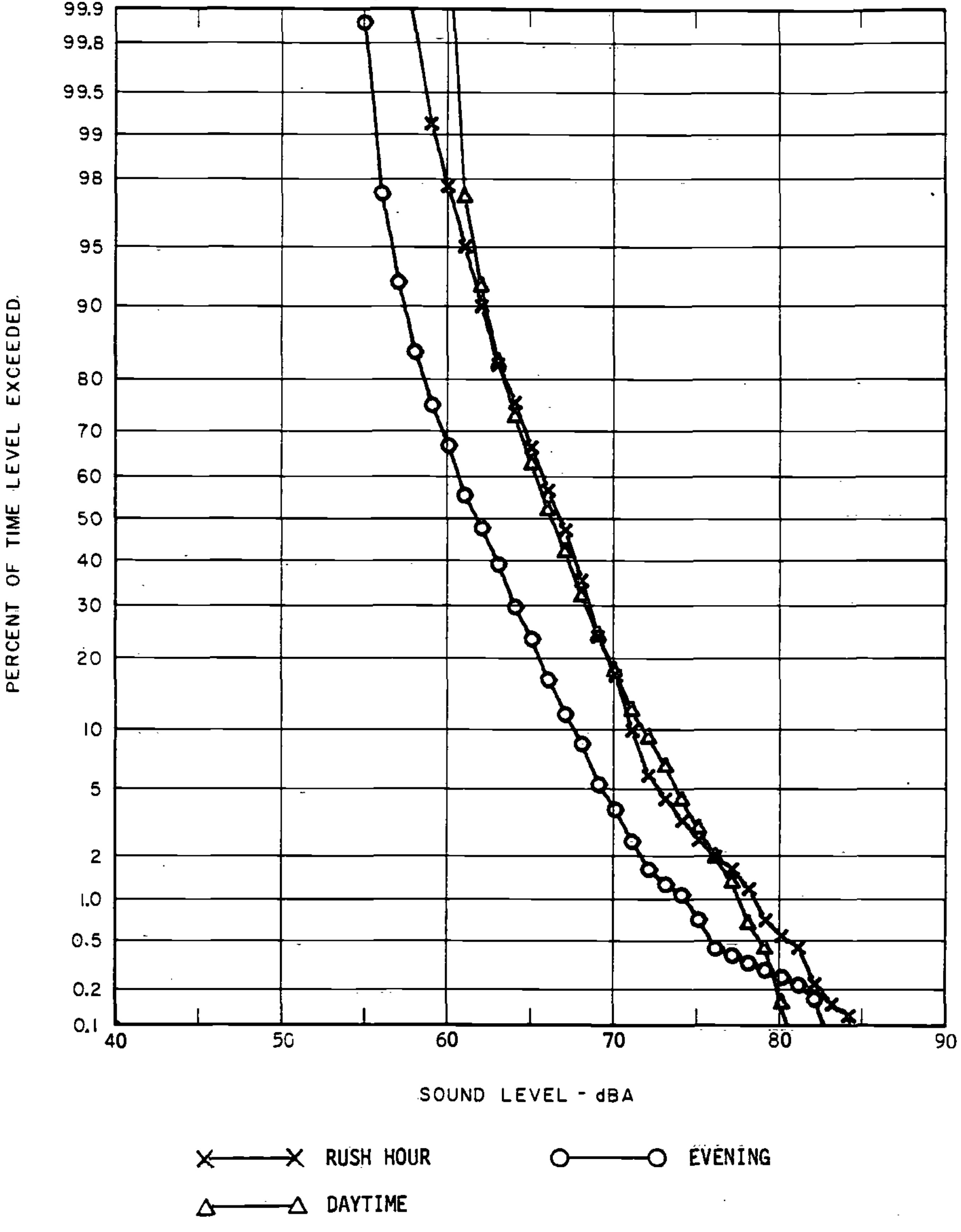
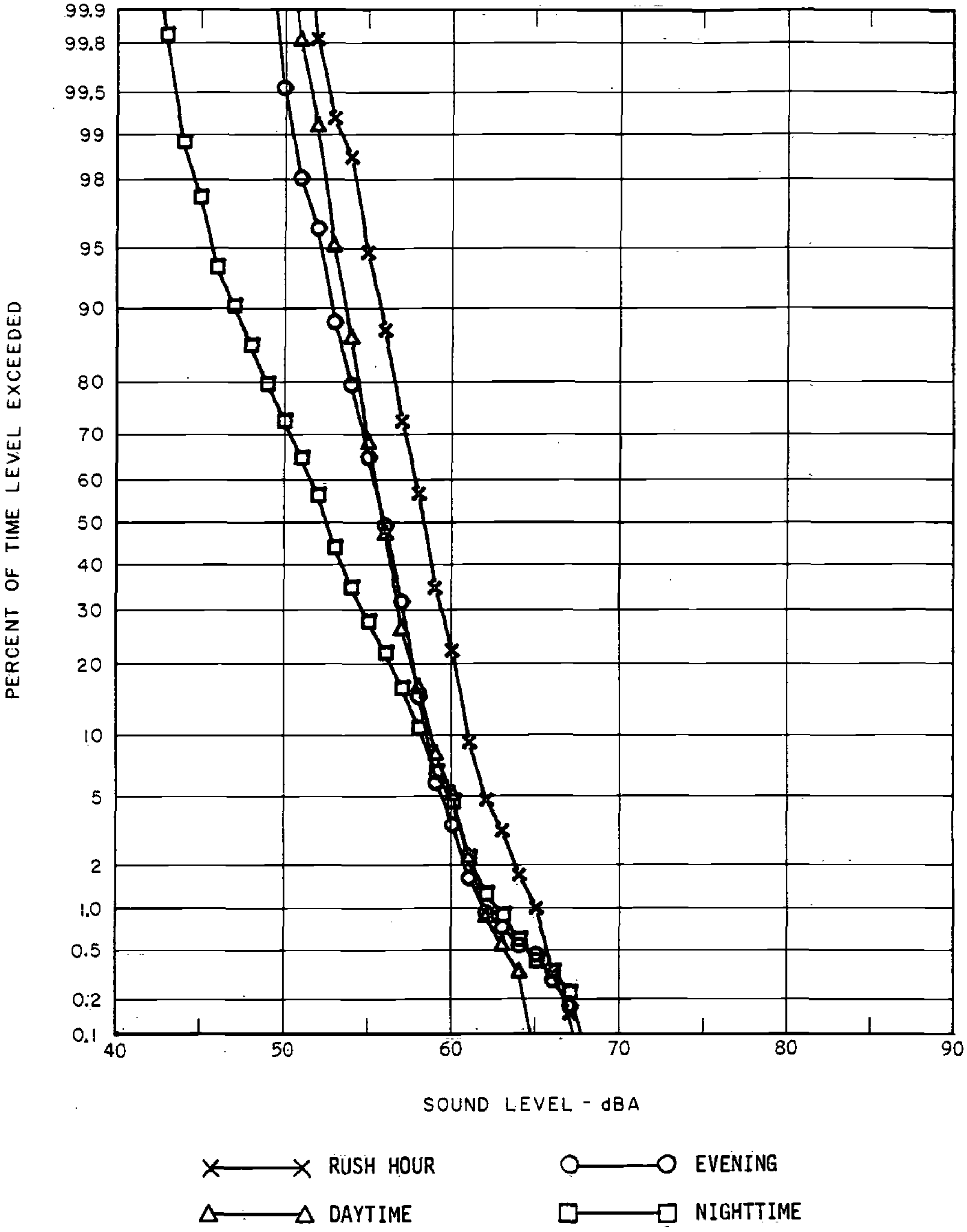


FIGURE A-30 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 30



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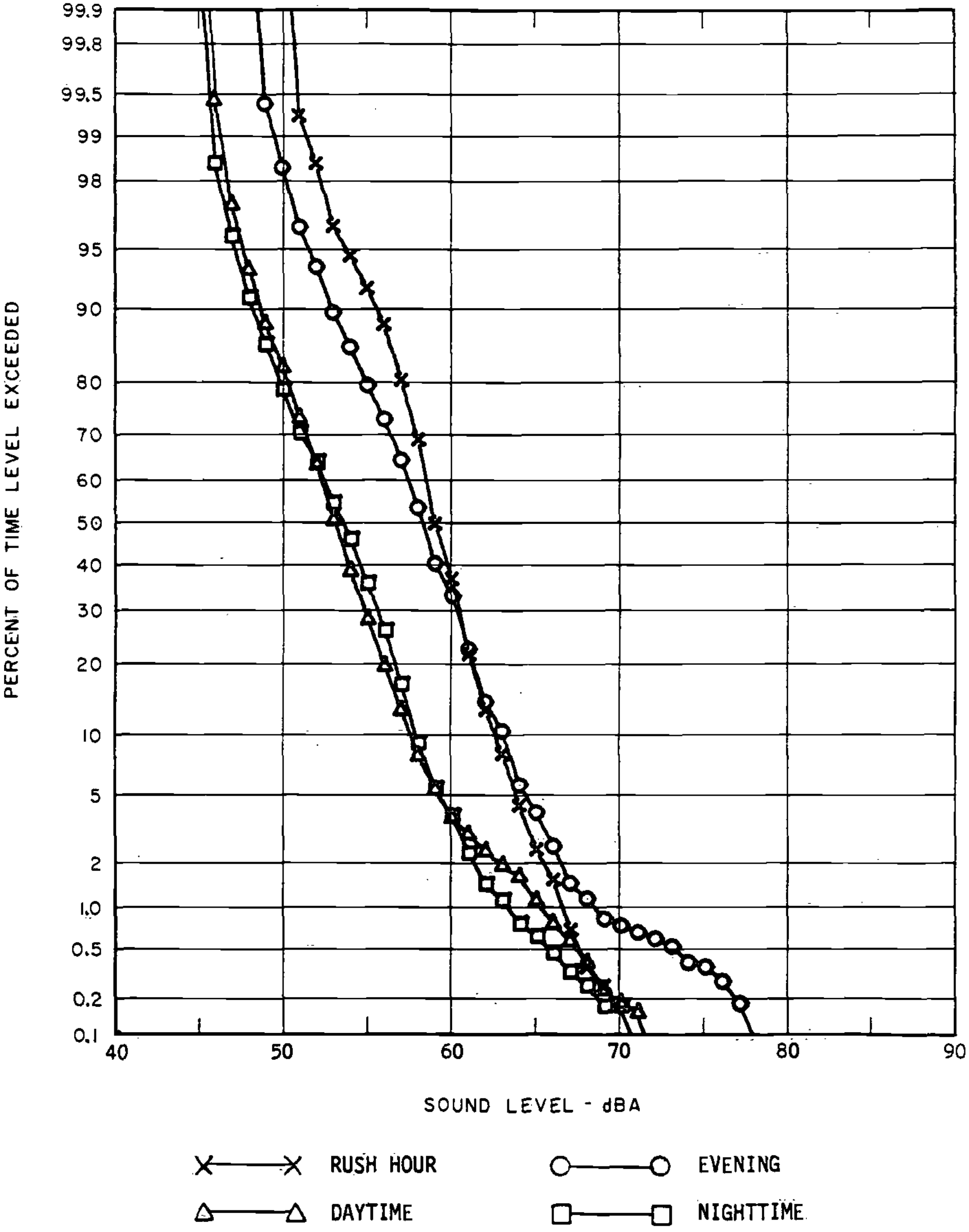

FIGURE A-32 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 32

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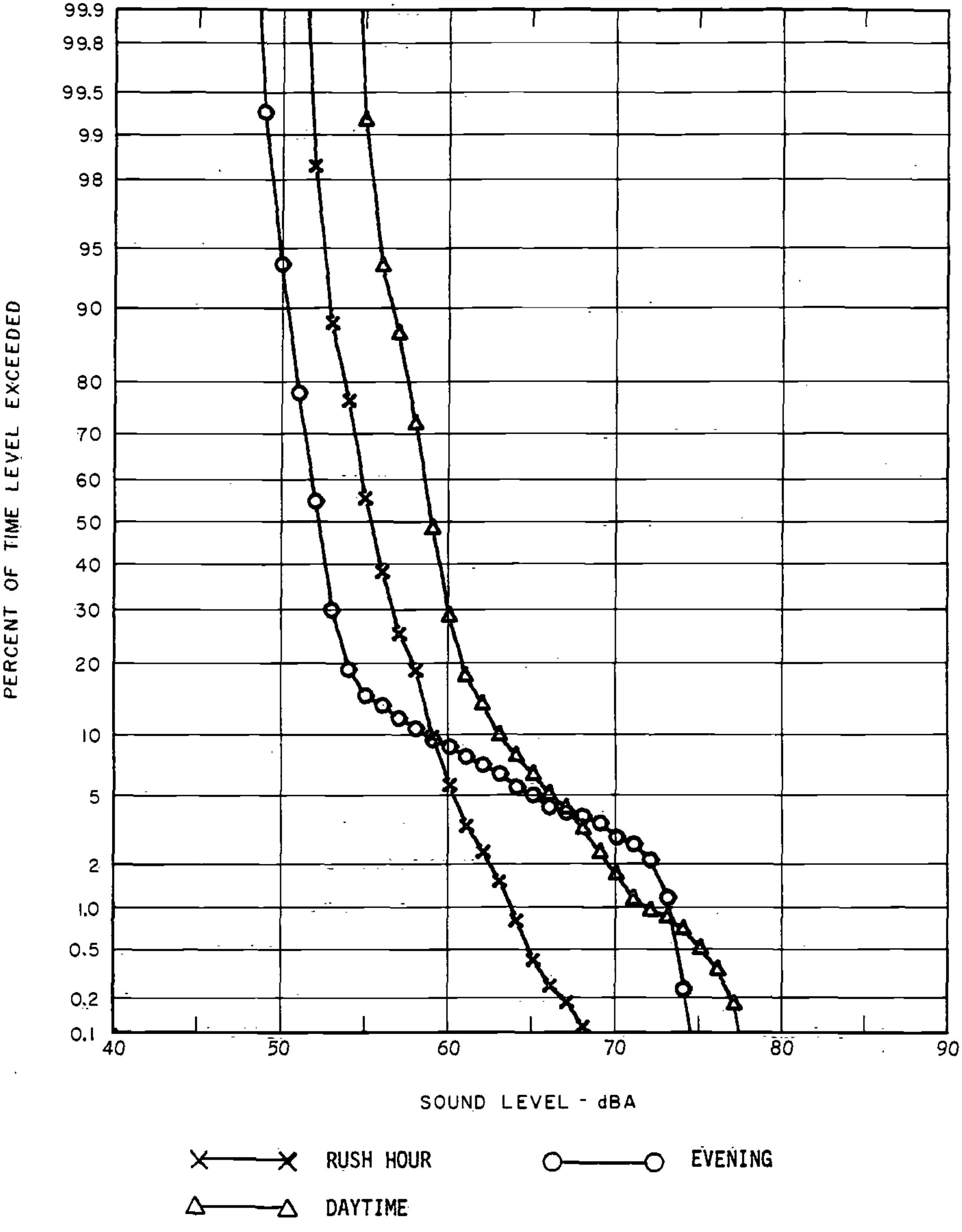

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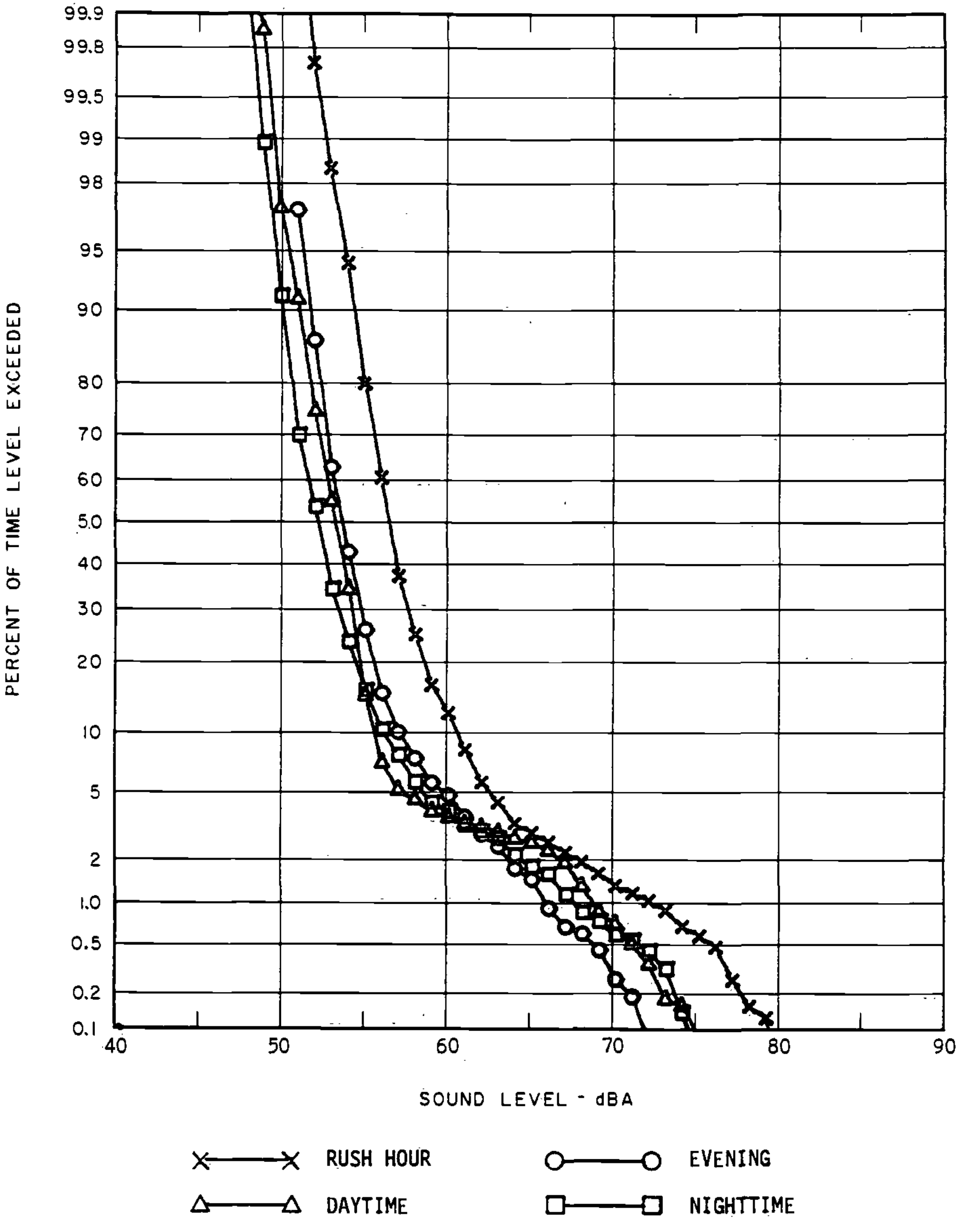

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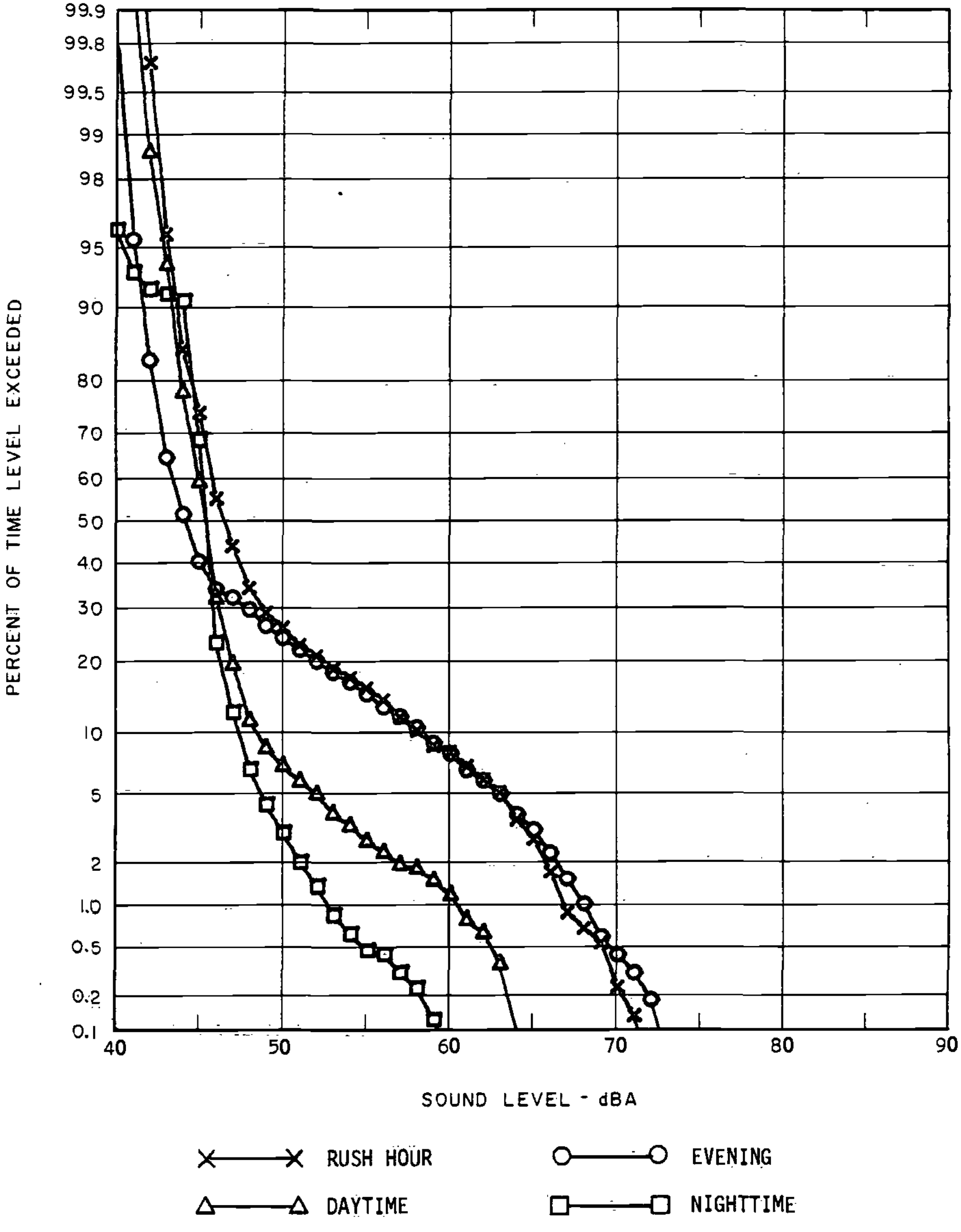

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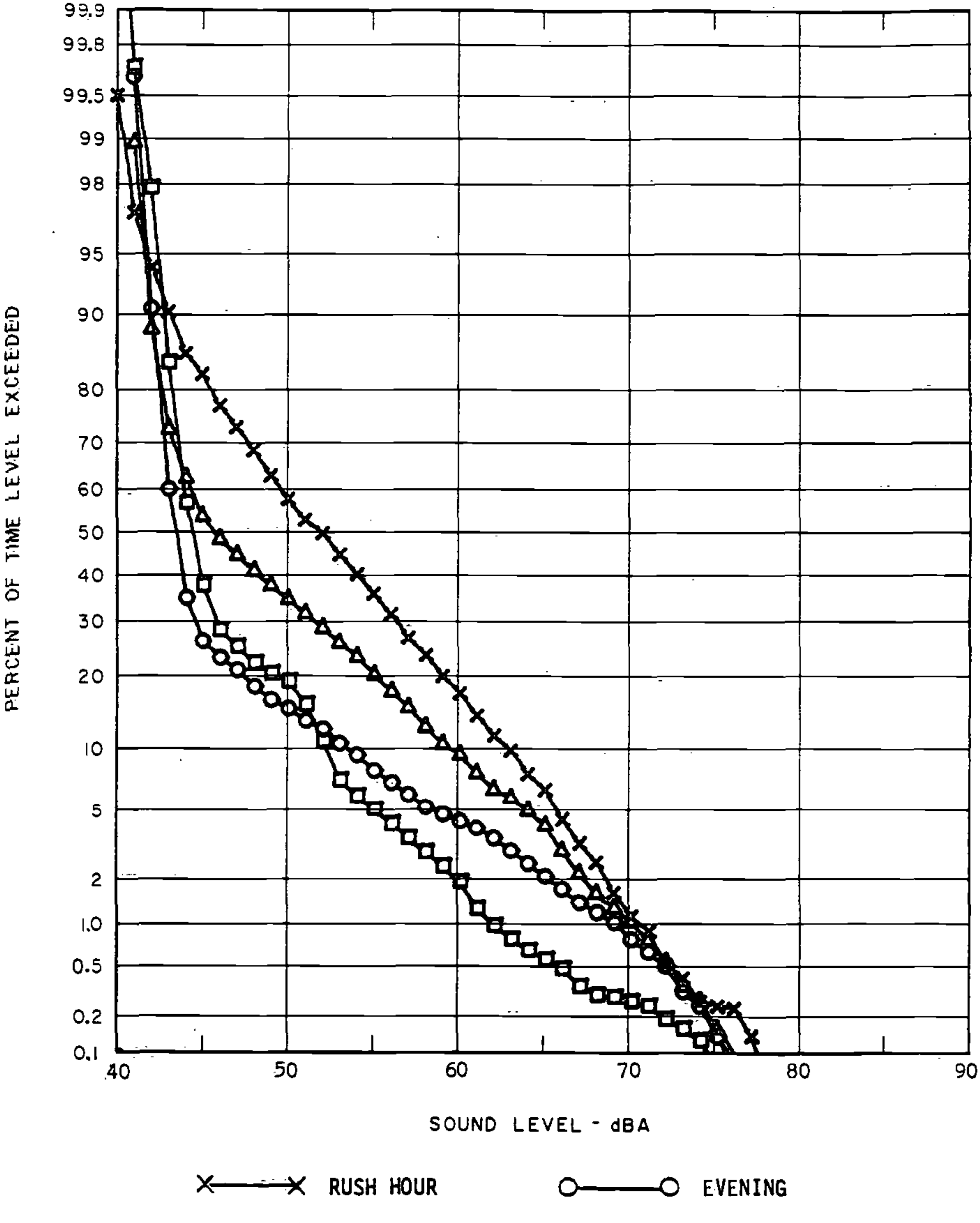

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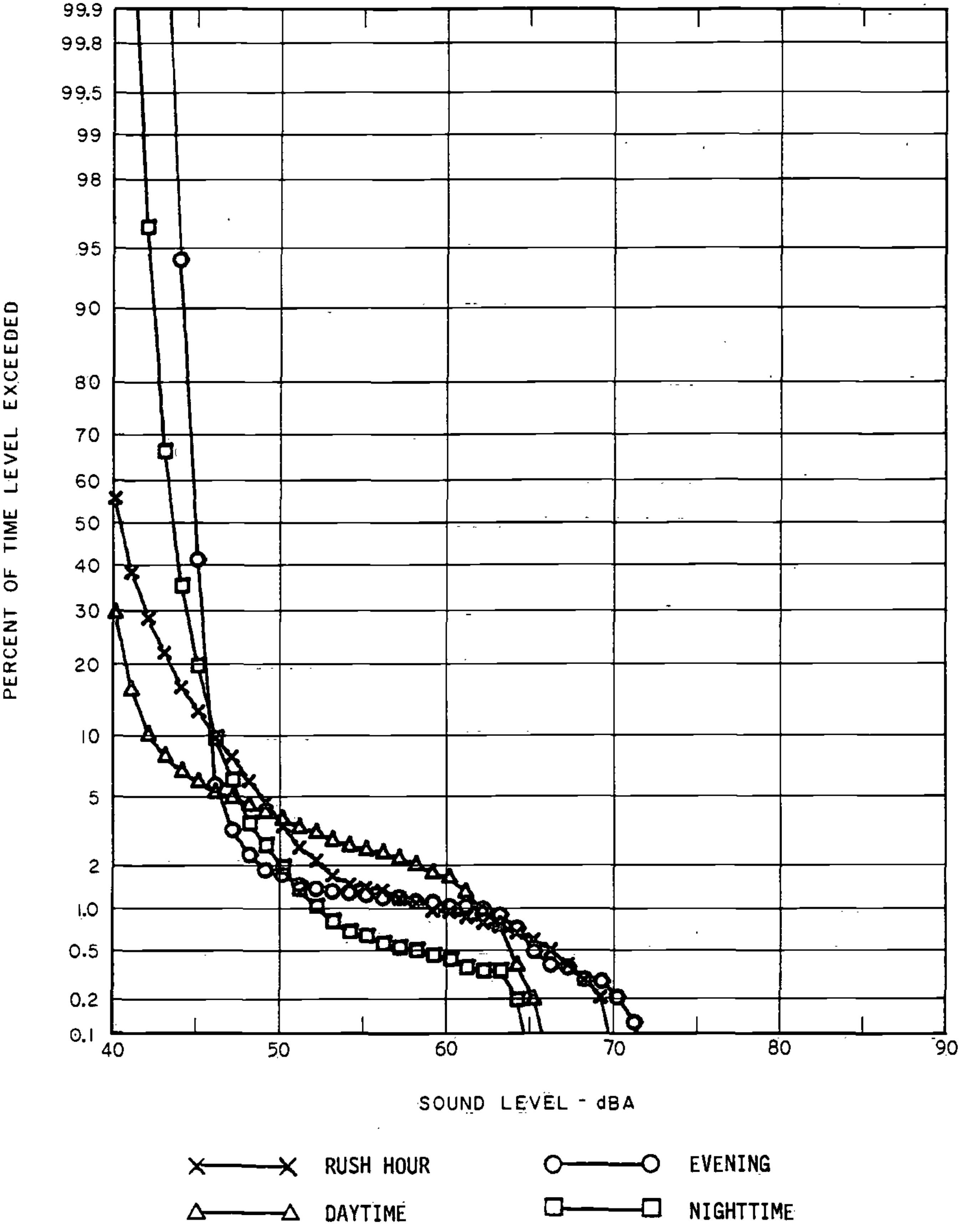
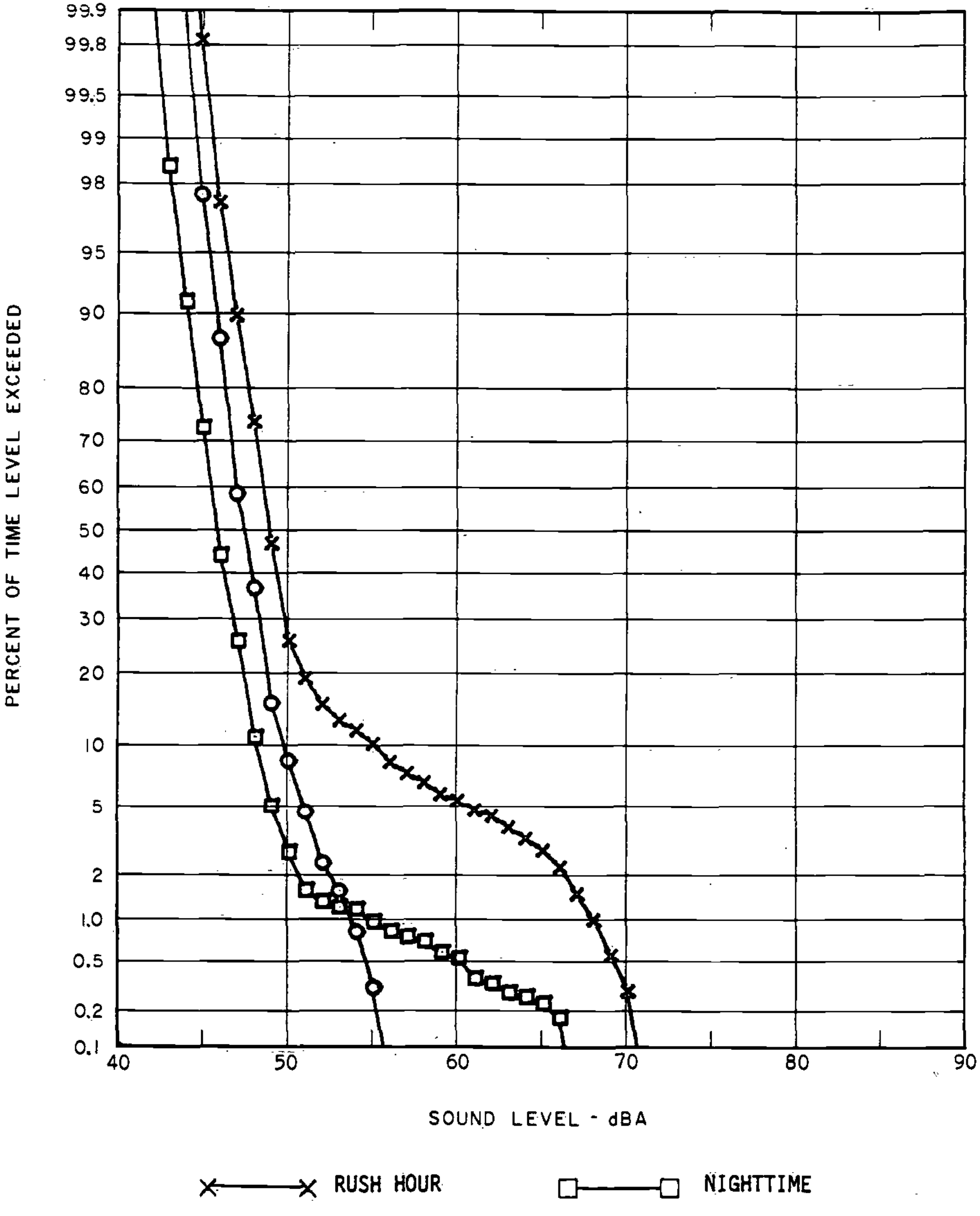


FIGURE A-37 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 37



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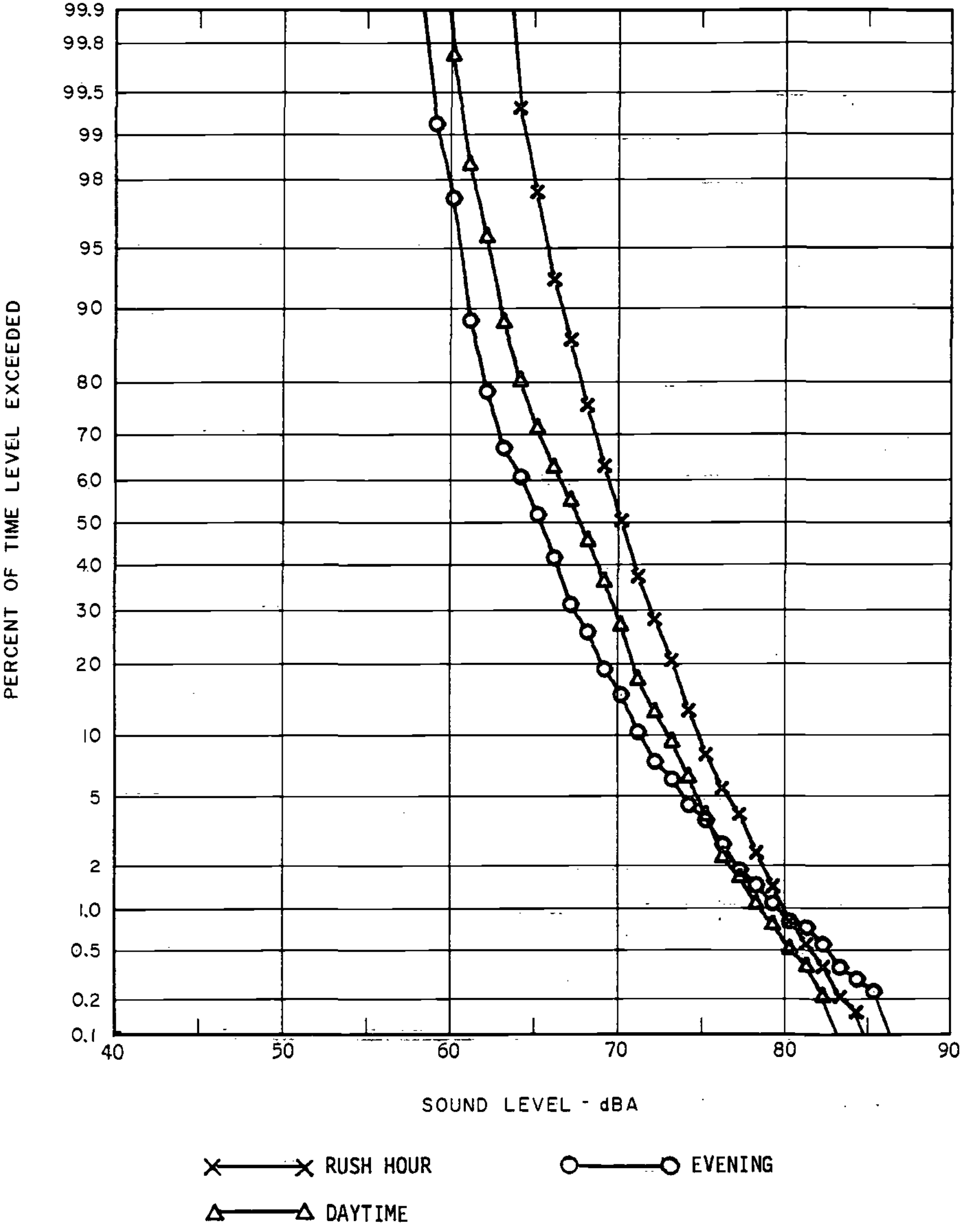


FIGURE A-39 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 39

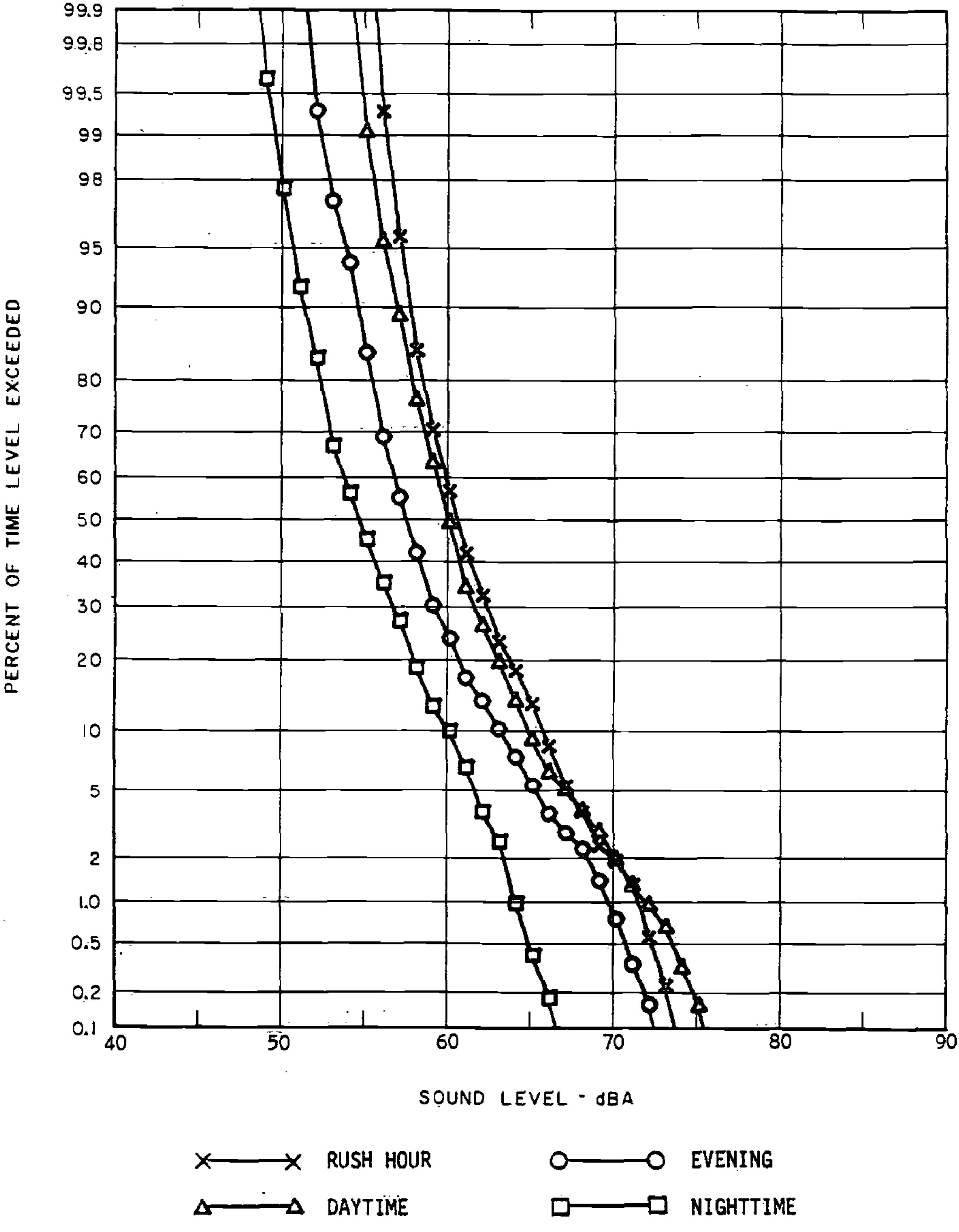


FIGURE A-40 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 40

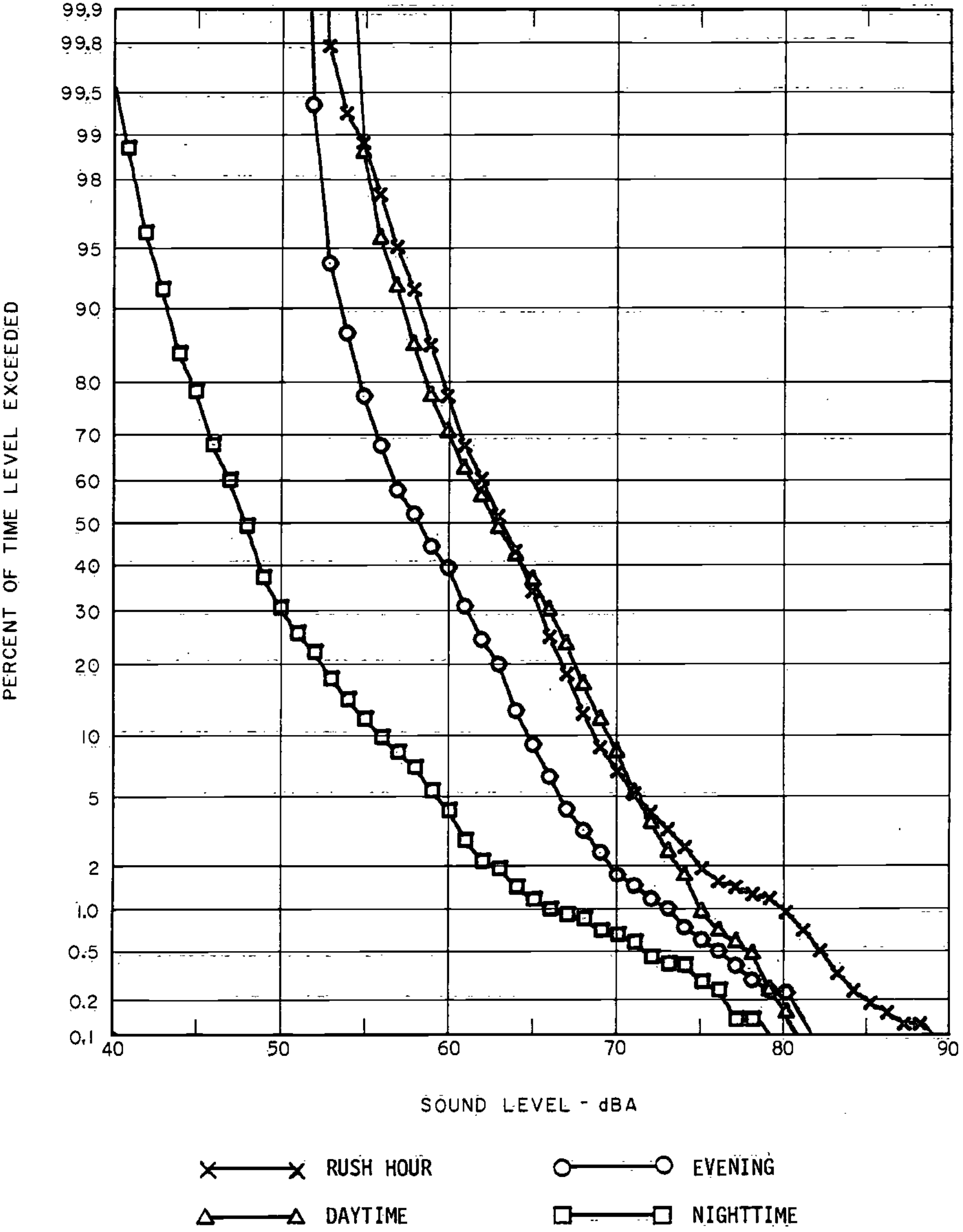
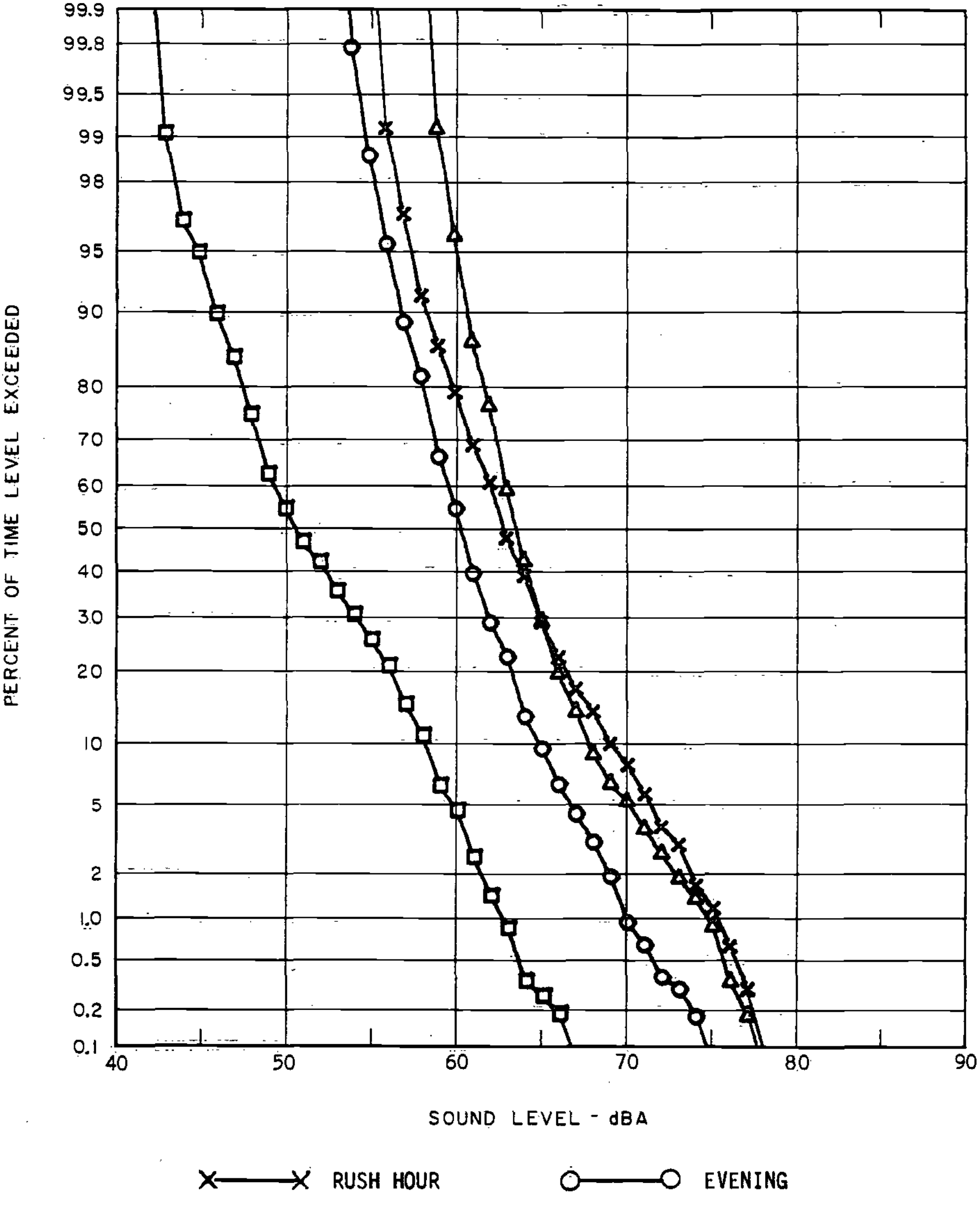


FIGURE A-41 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 41



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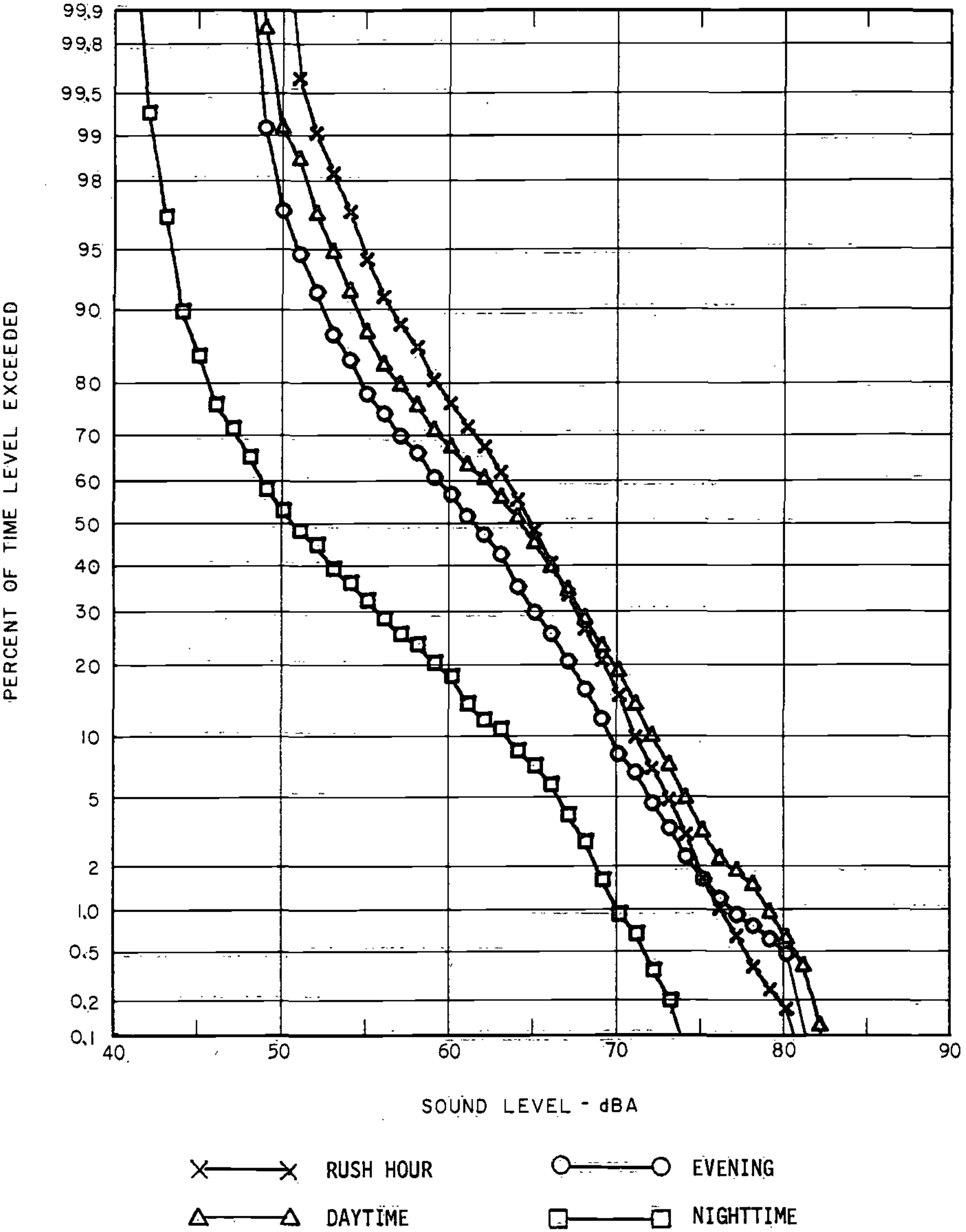

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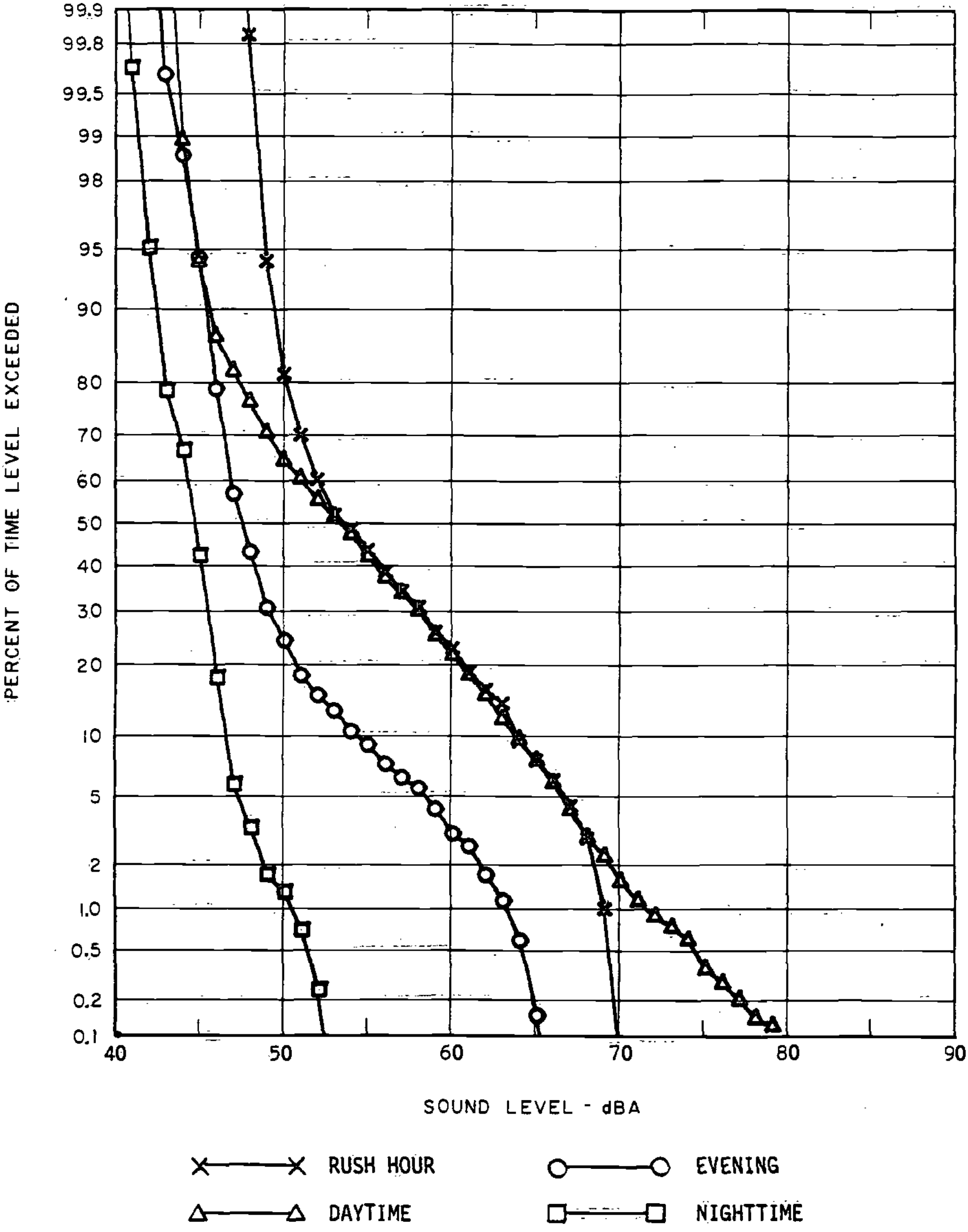

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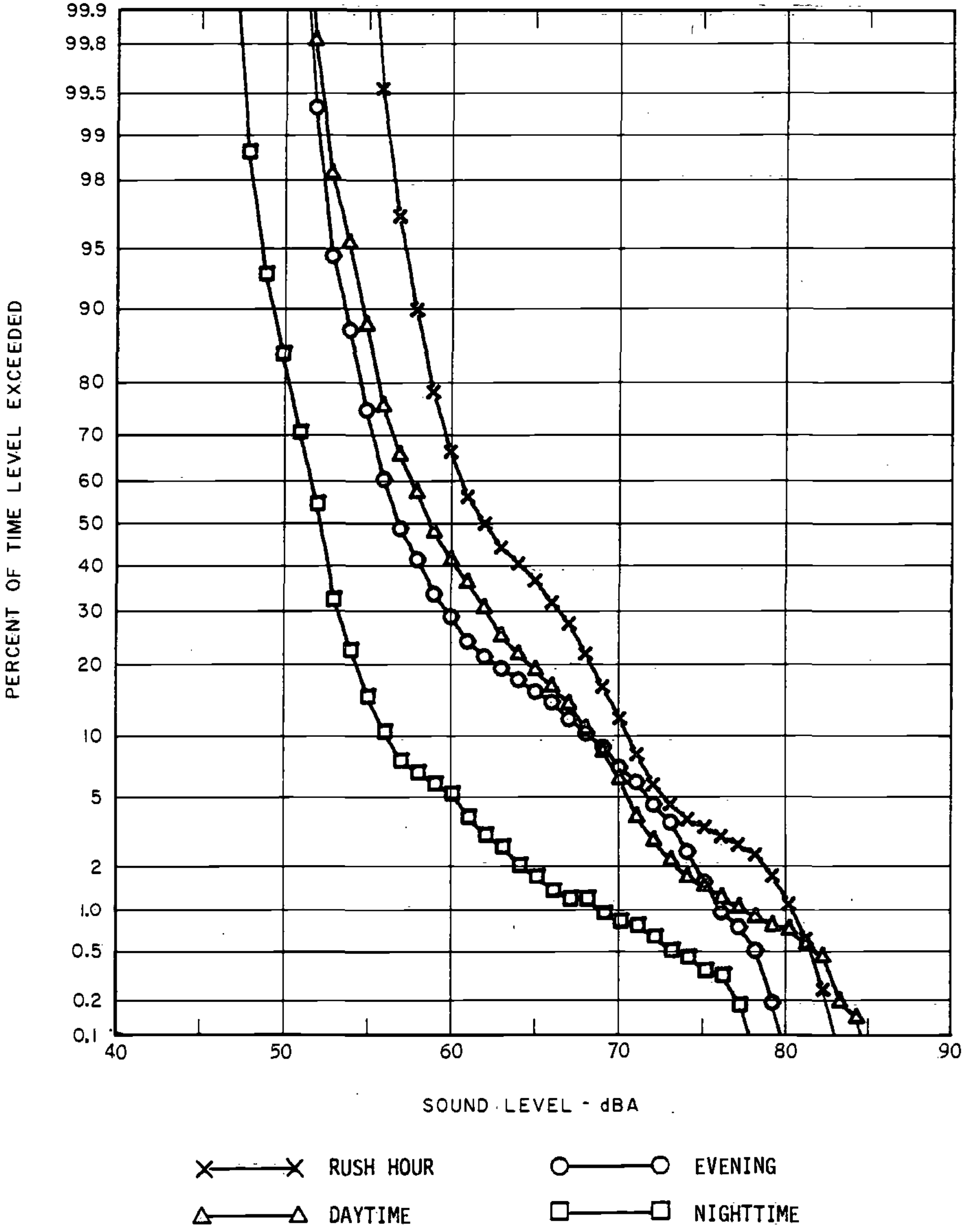


FIGURE A-45 STATISTICAL DISTRIBUTION OF THE NOISE AT LOCATION 45

APPENDIX B

STATISTICAL DISTRIBUTION OF THE VIBRATION AT THE MEASUREMENT LOCATIONS

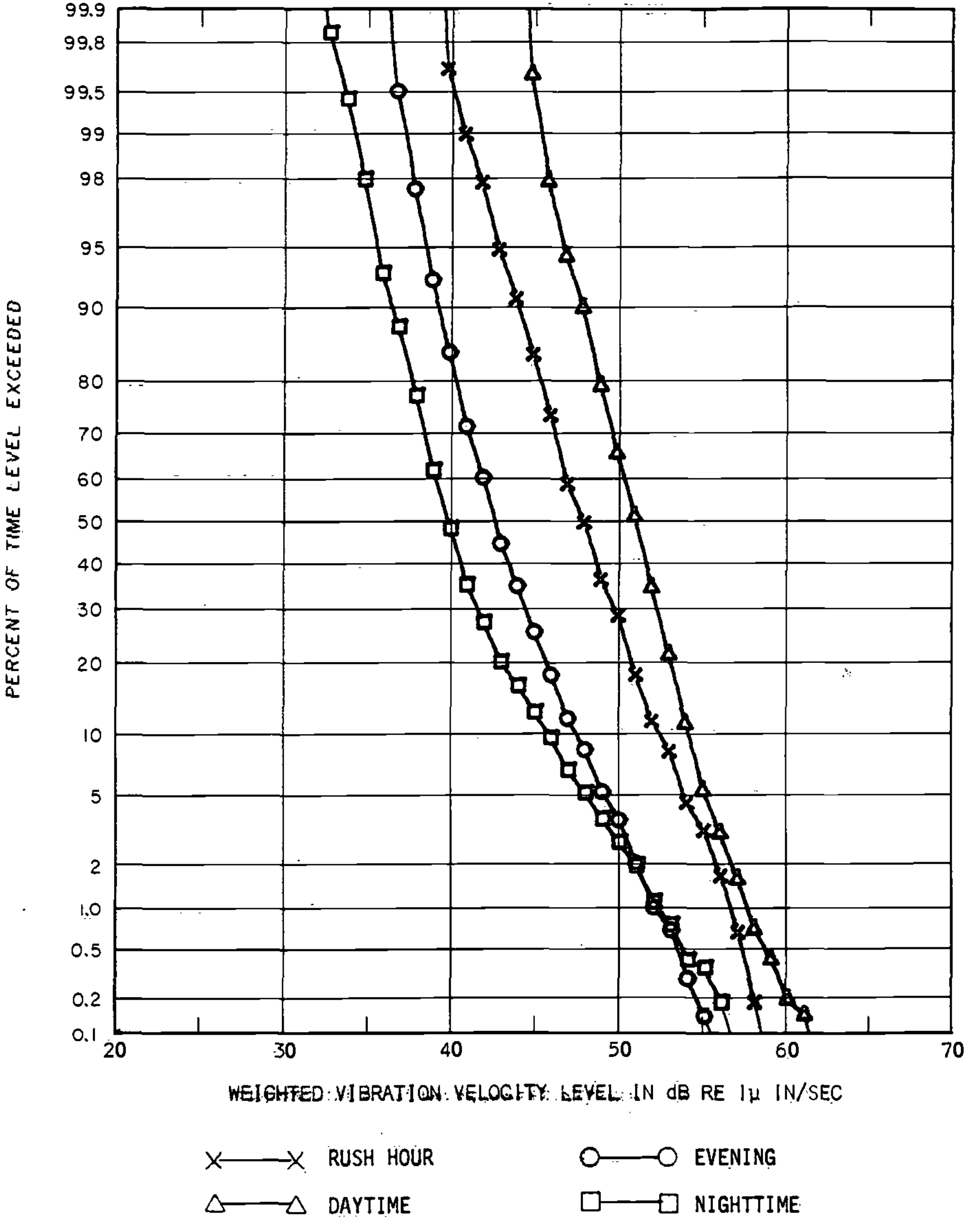


FIGURE B-1 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 1

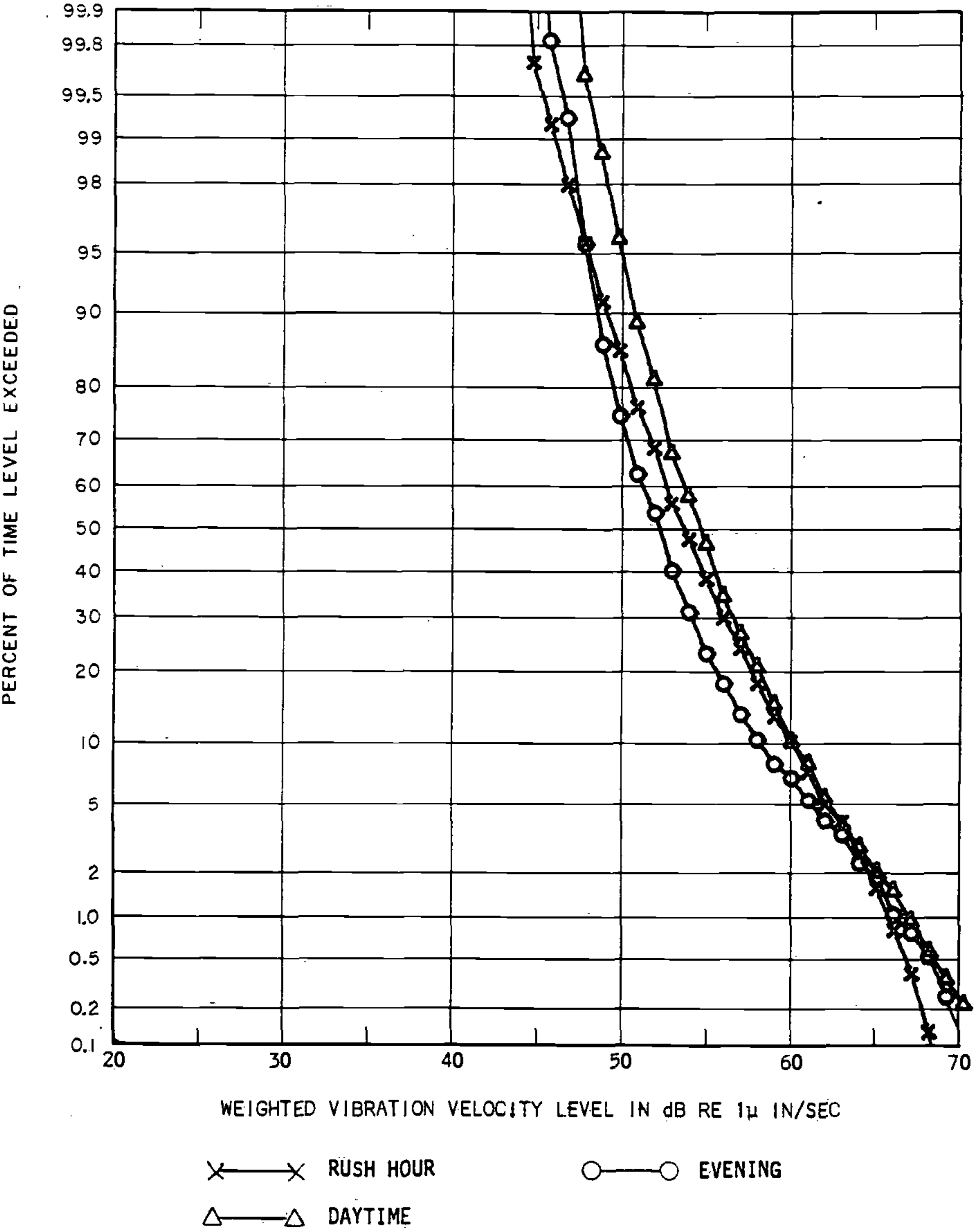


FIGURE B-2 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 2

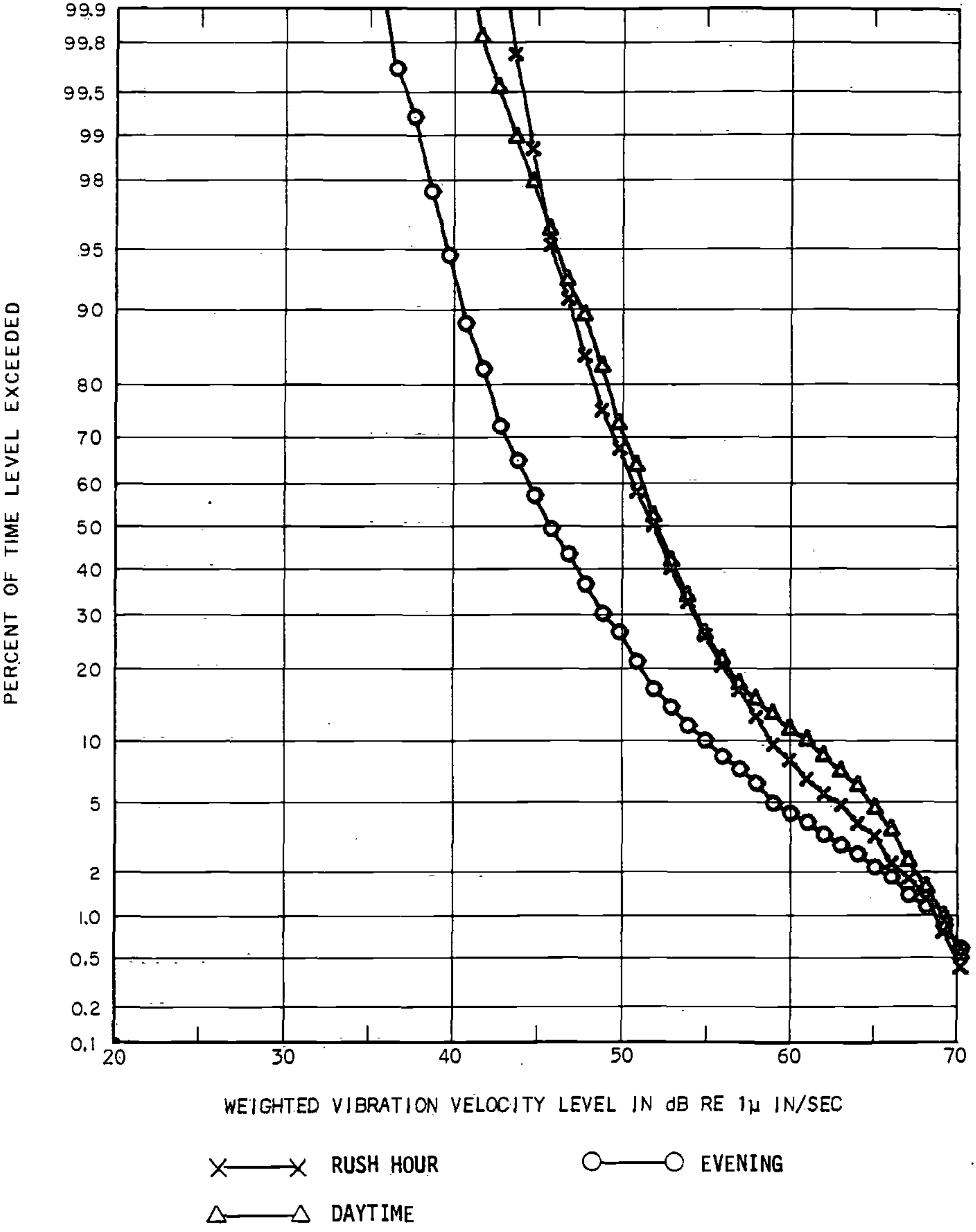


FIGURE B-3 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 3

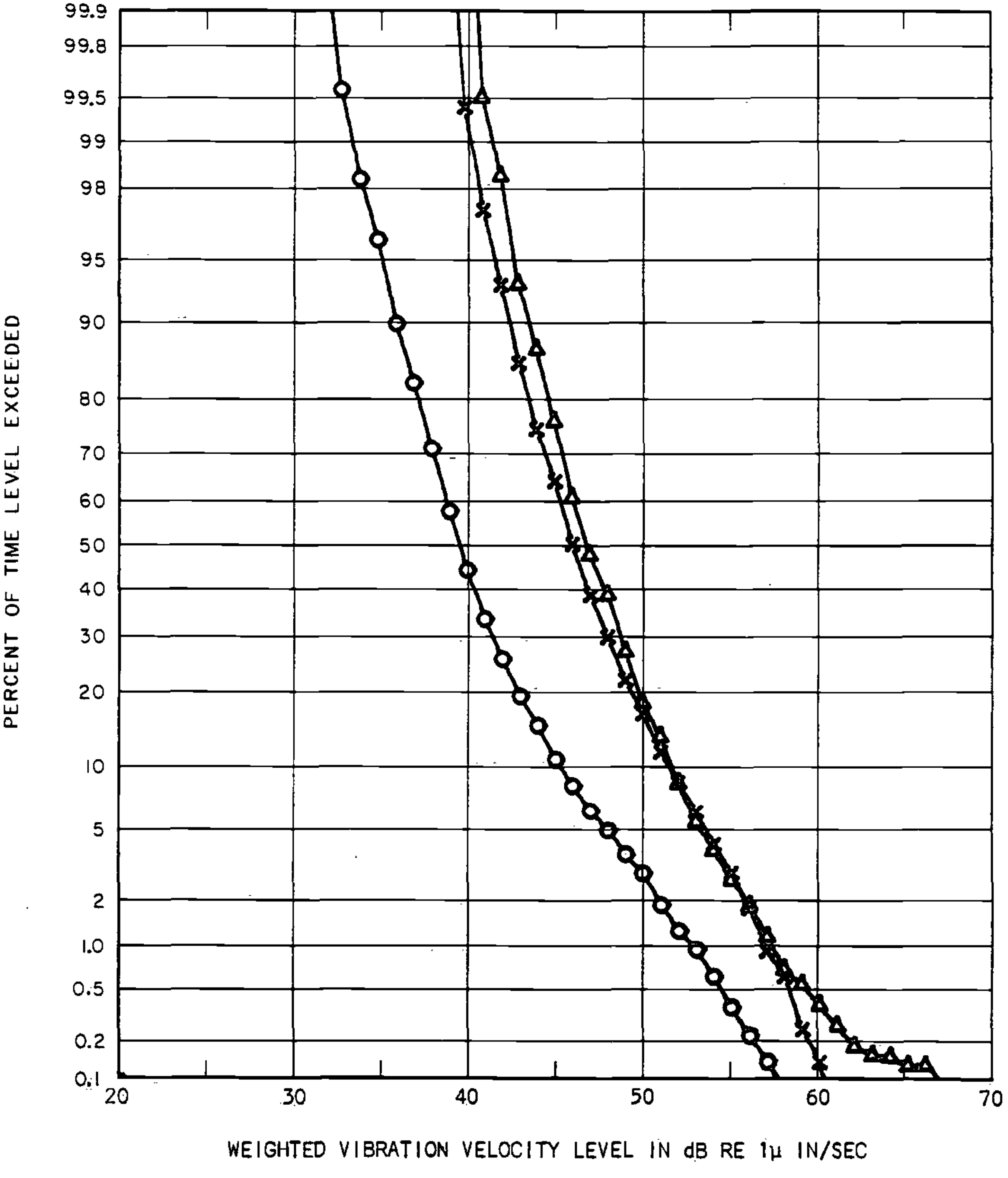


FIGURE B-4 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 4

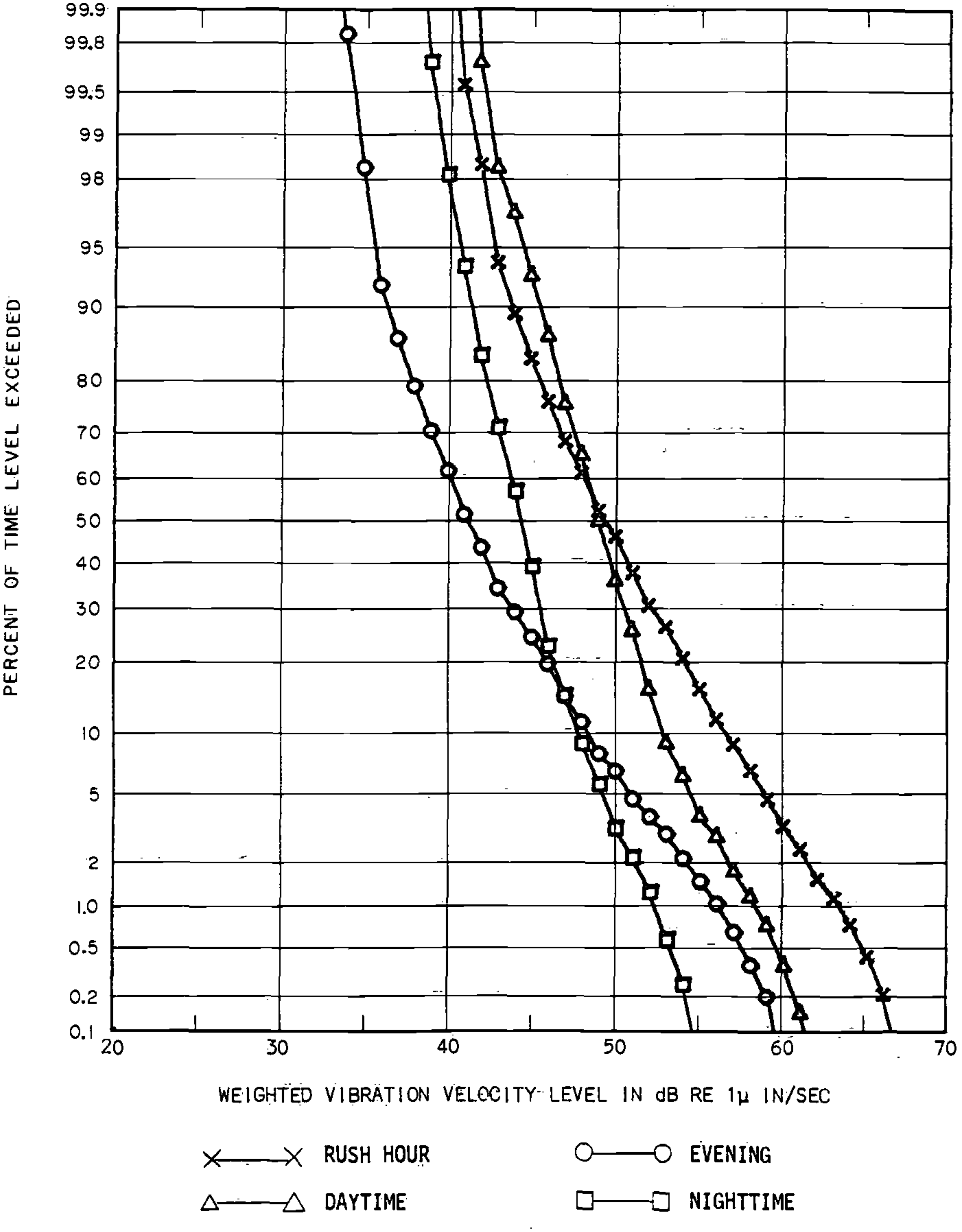


FIGURE B-5 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 5

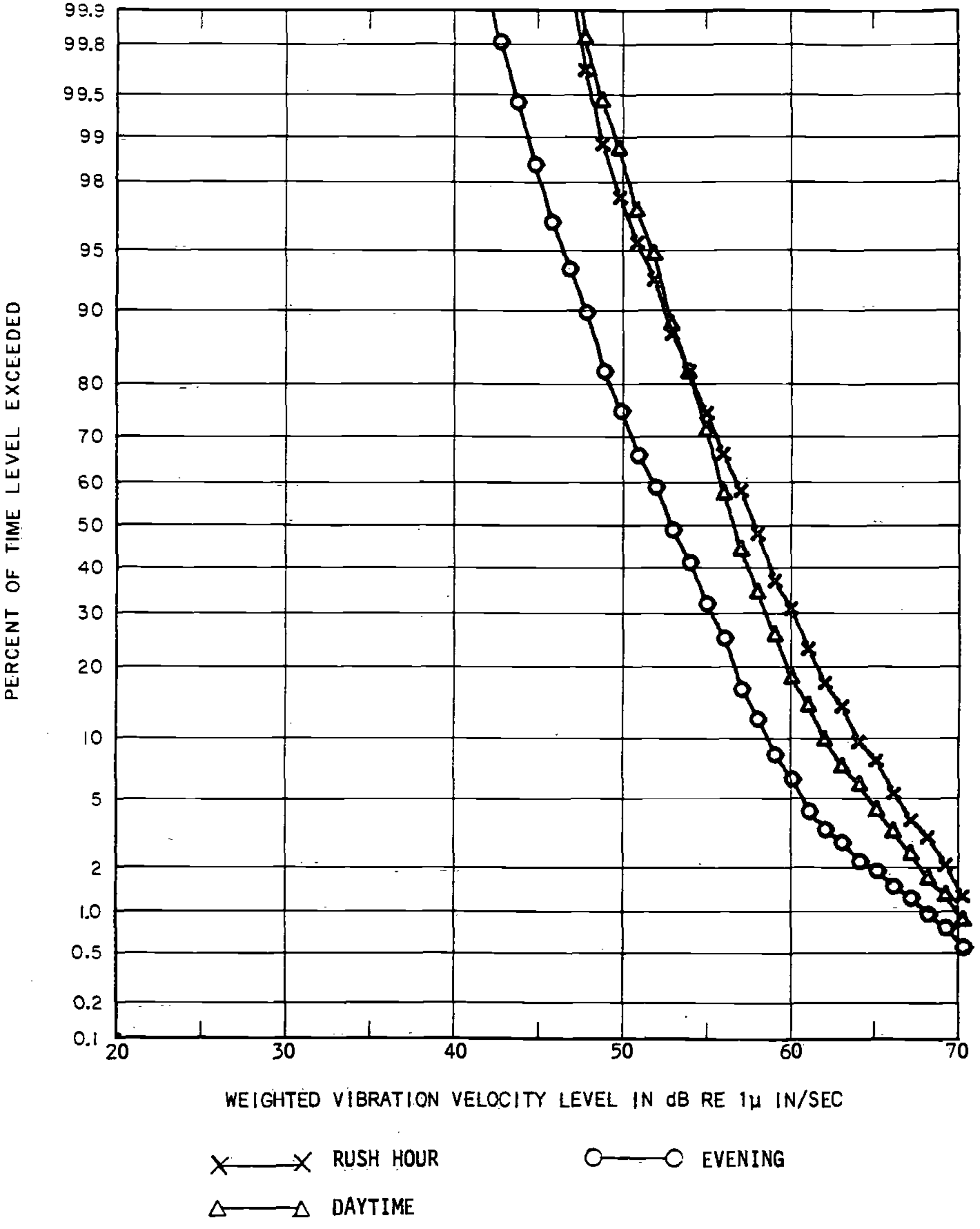


FIGURE B-6 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 6

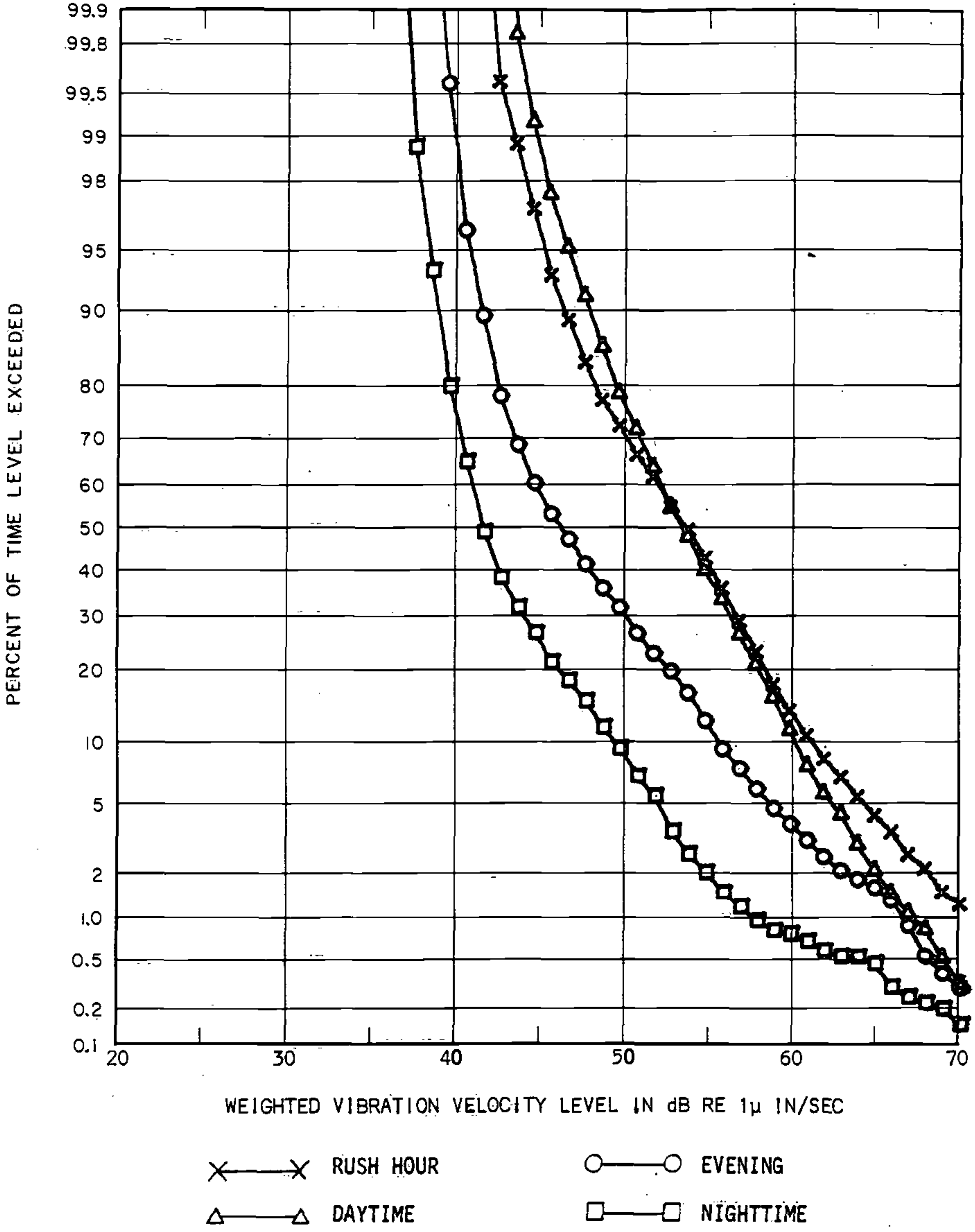


FIGURE B-7 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 7

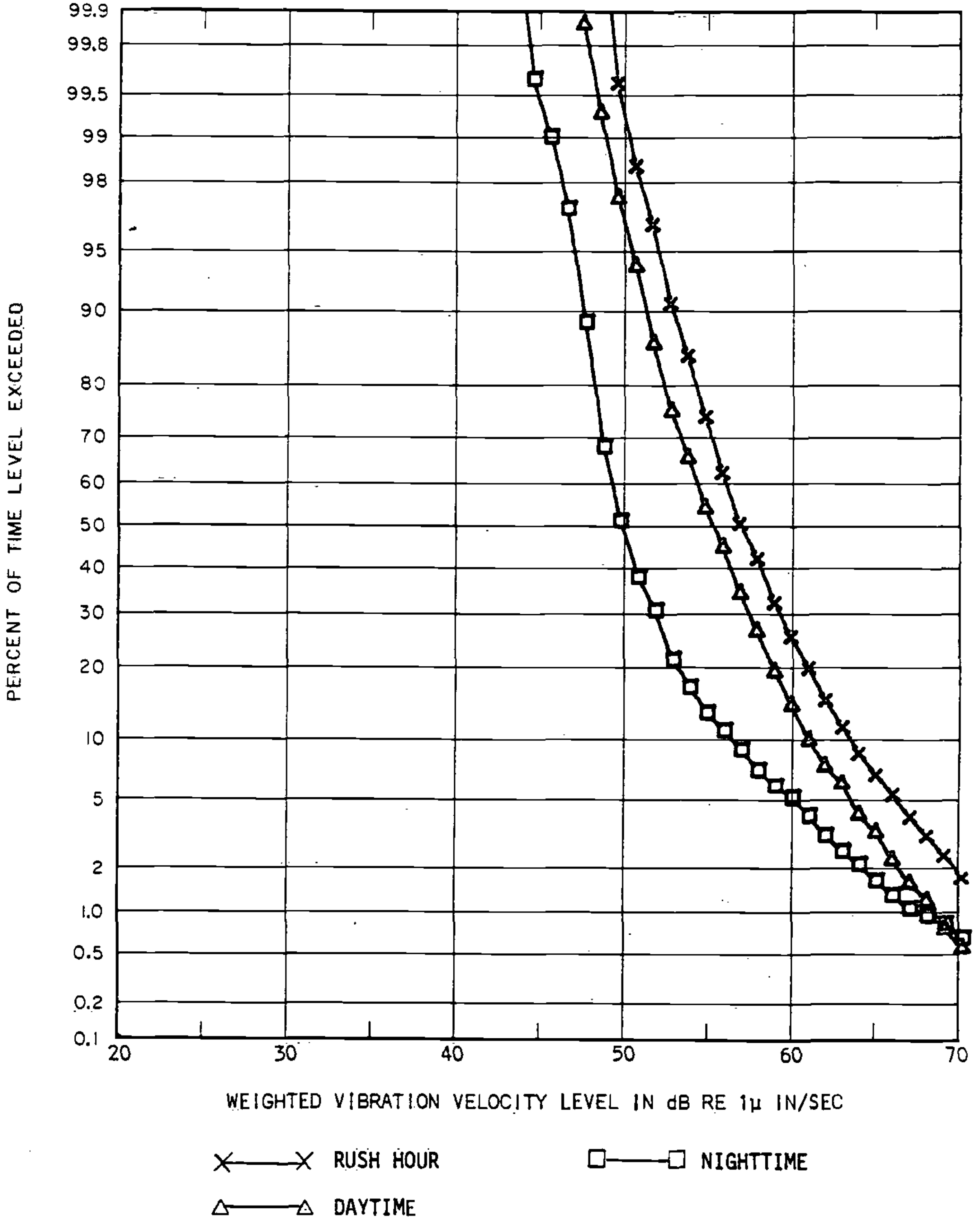


FIGURE B-8 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 8

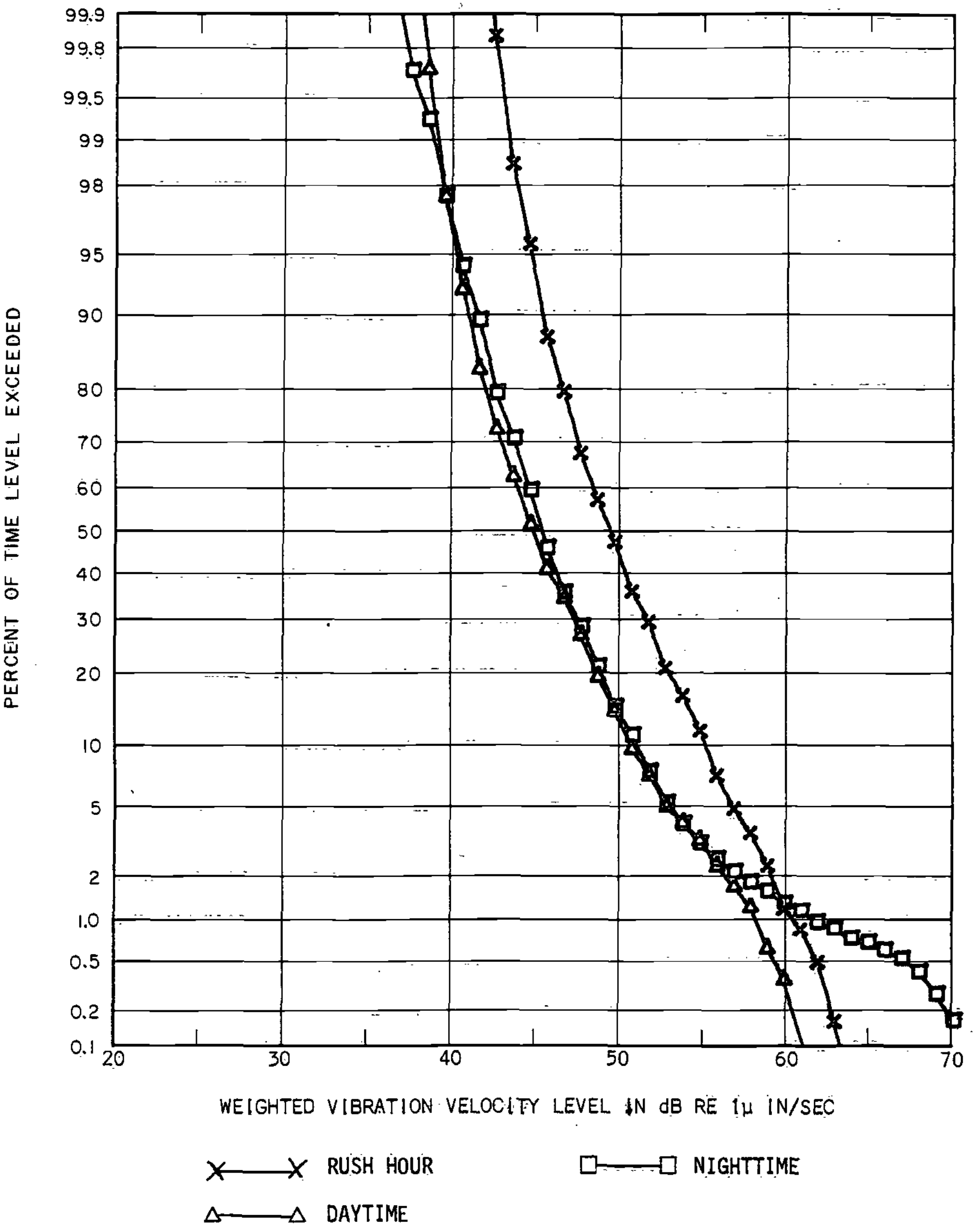


FIGURE B-9 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 9

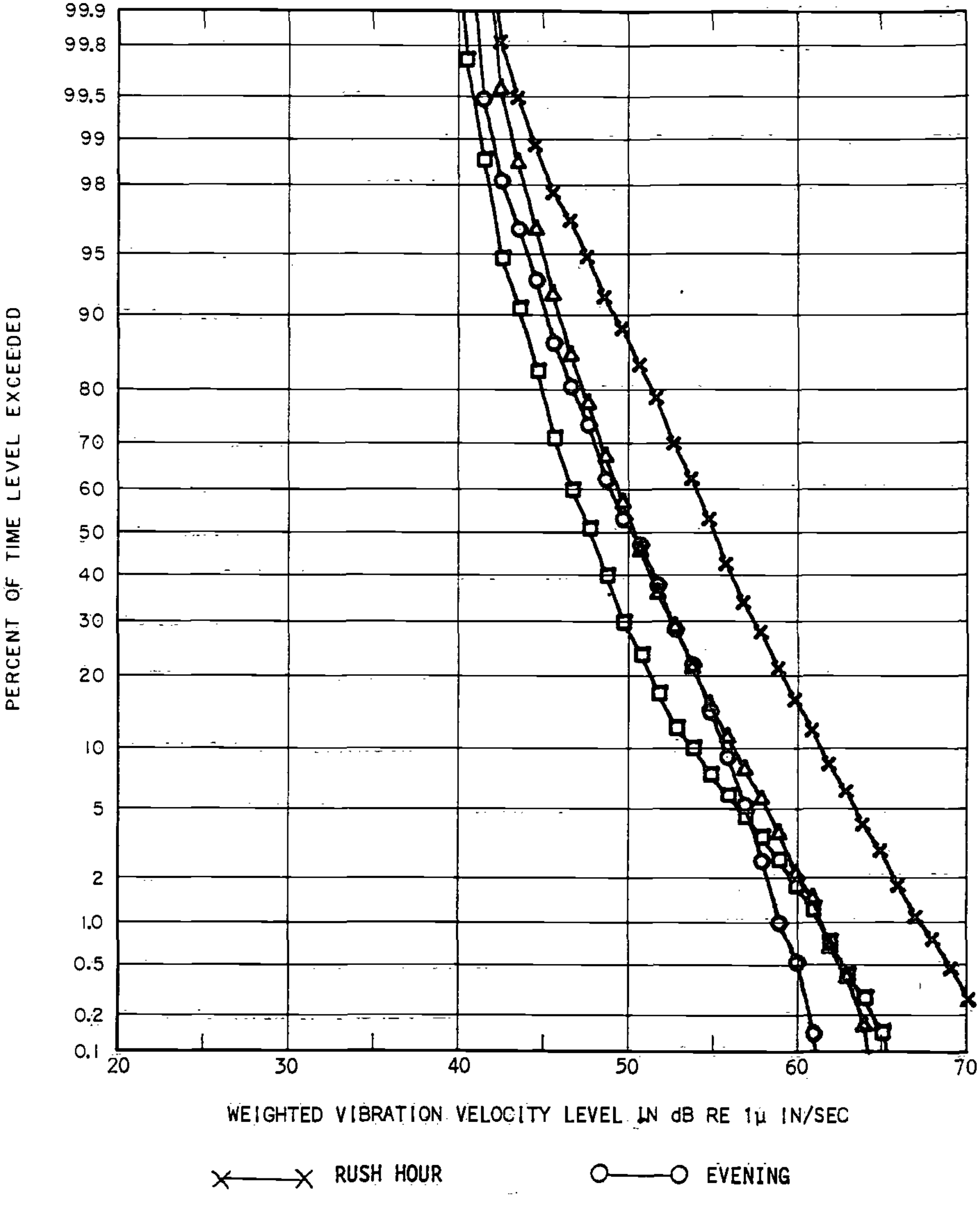


FIGURE B-10 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 10

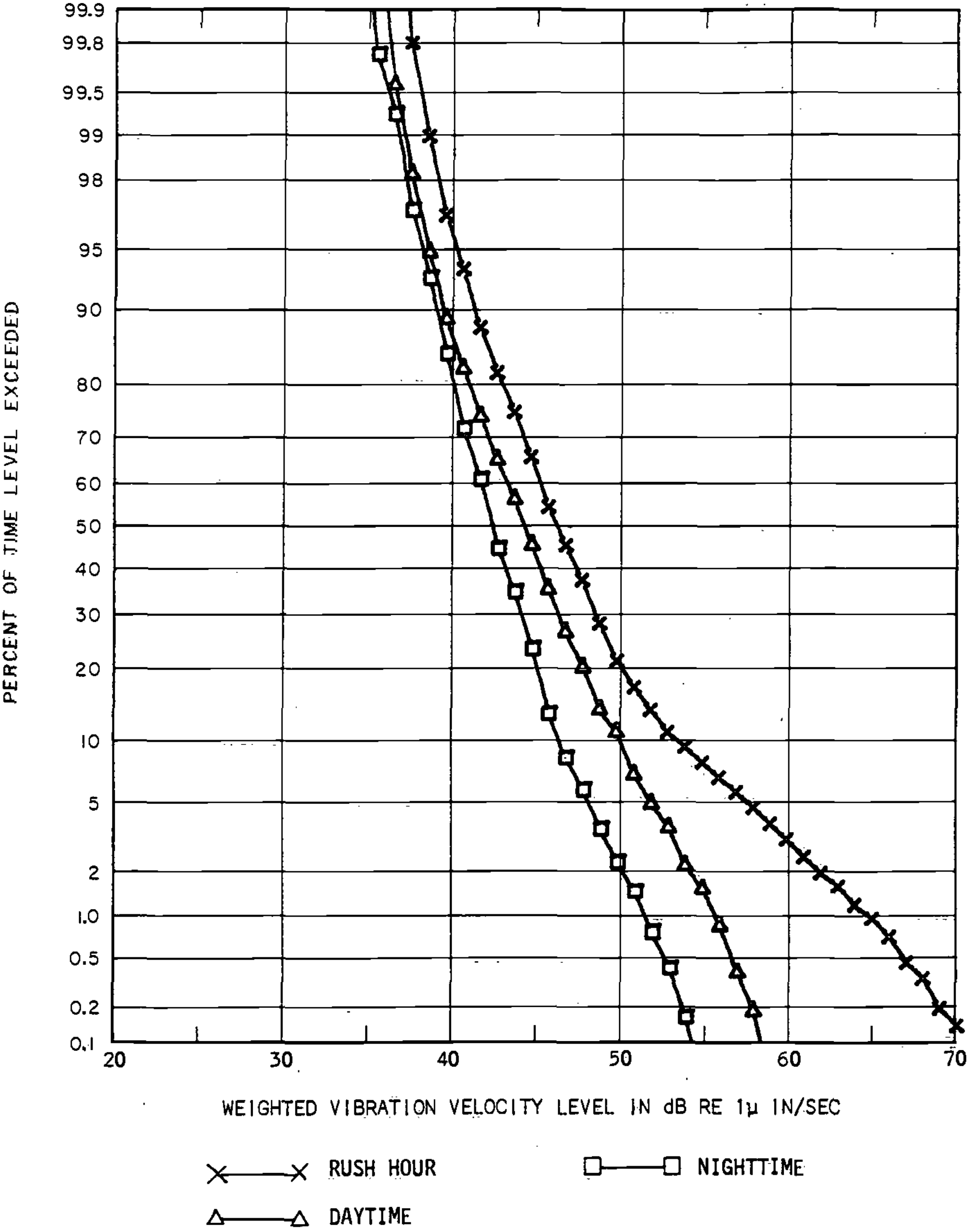


FIGURE B-11 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 11

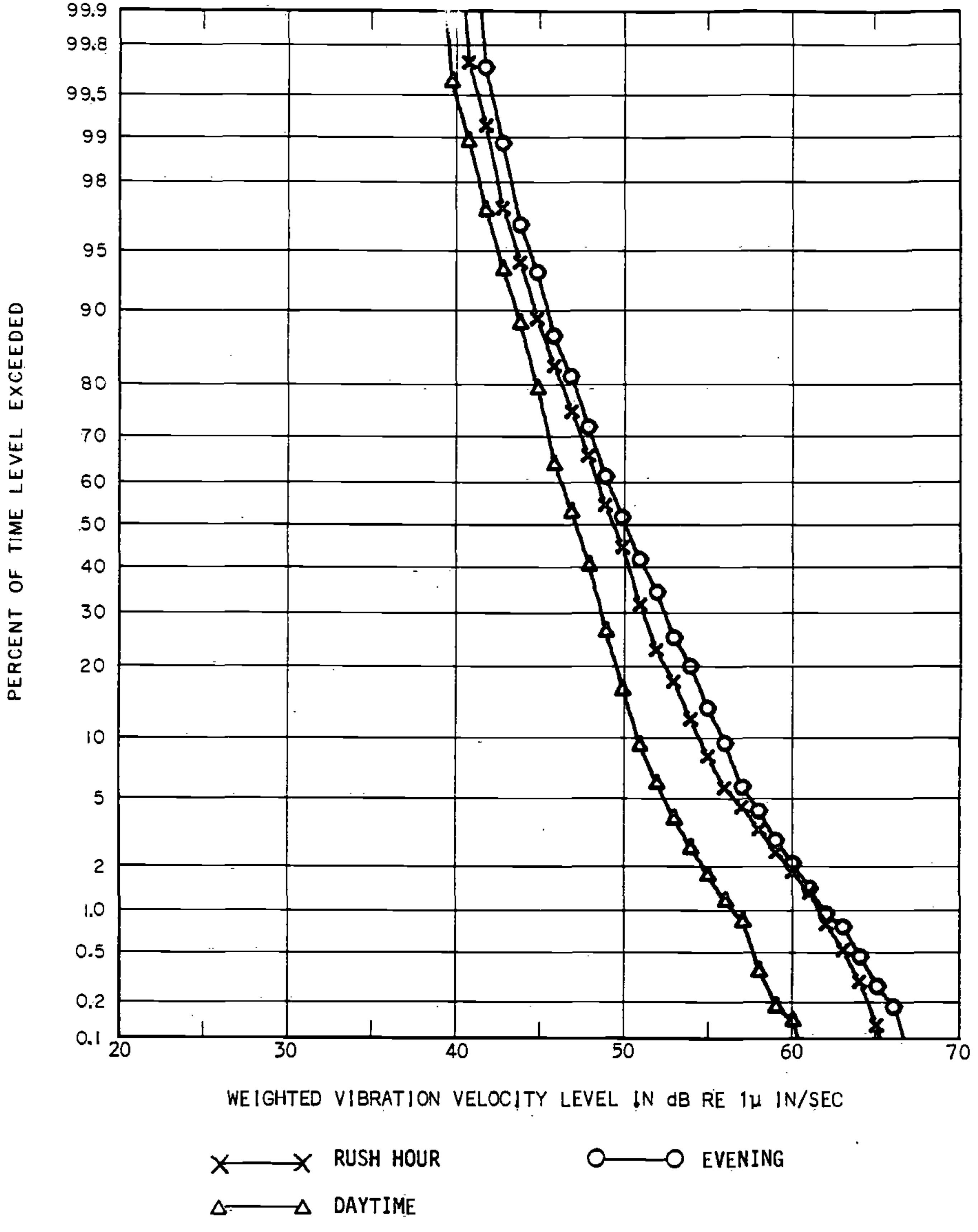


FIGURE B-12 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 12

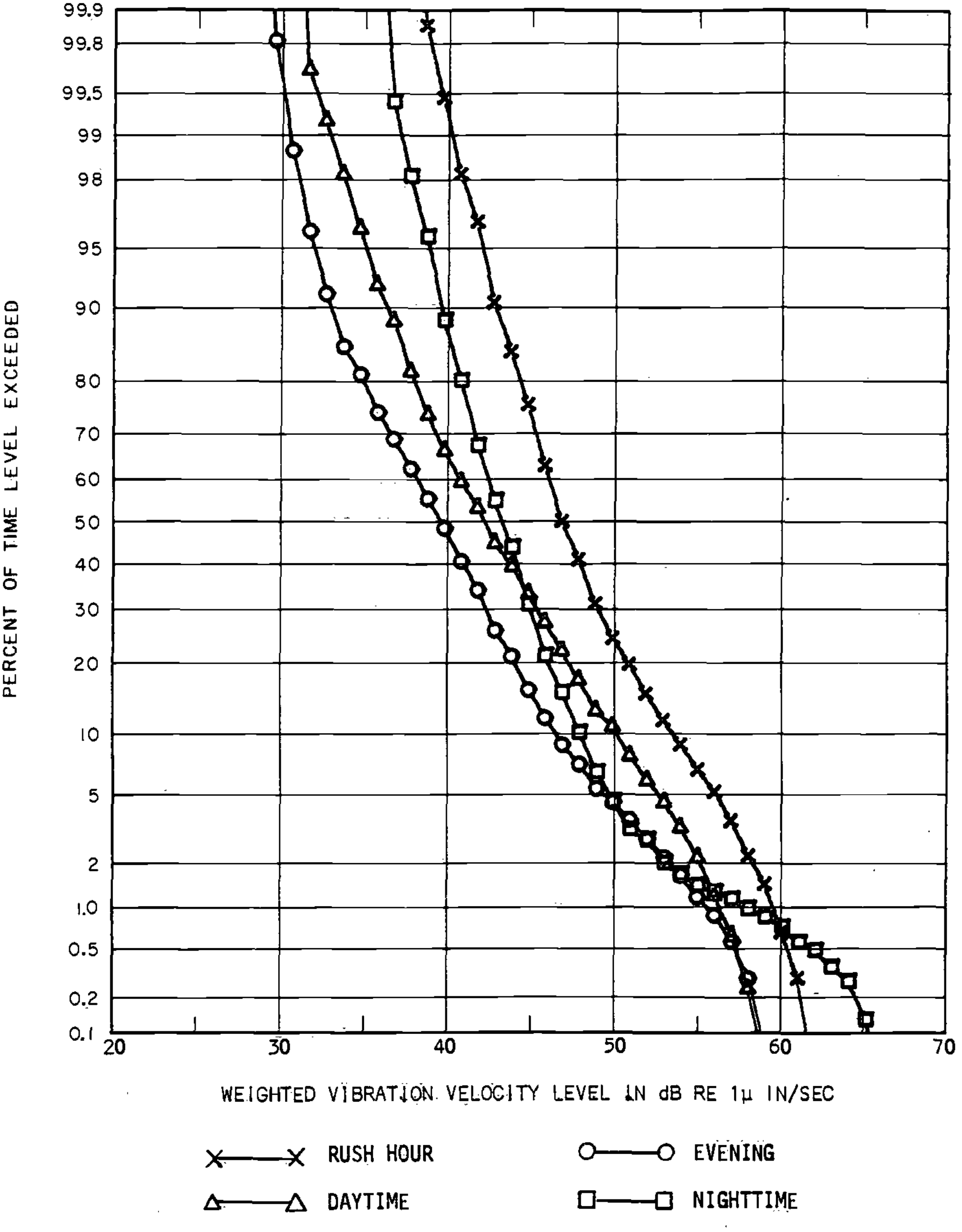


FIGURE B-13 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 13

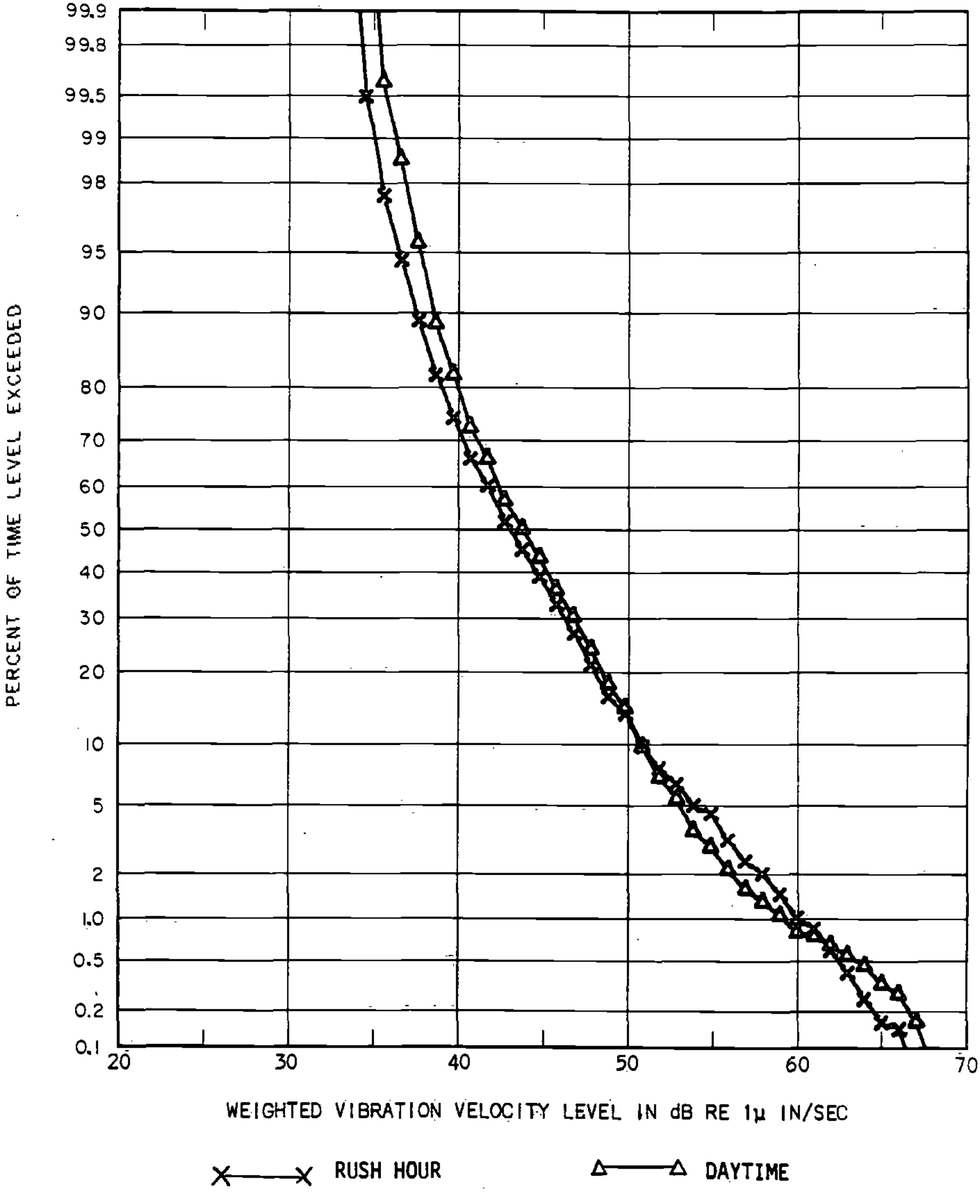


FIGURE B-14 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 14

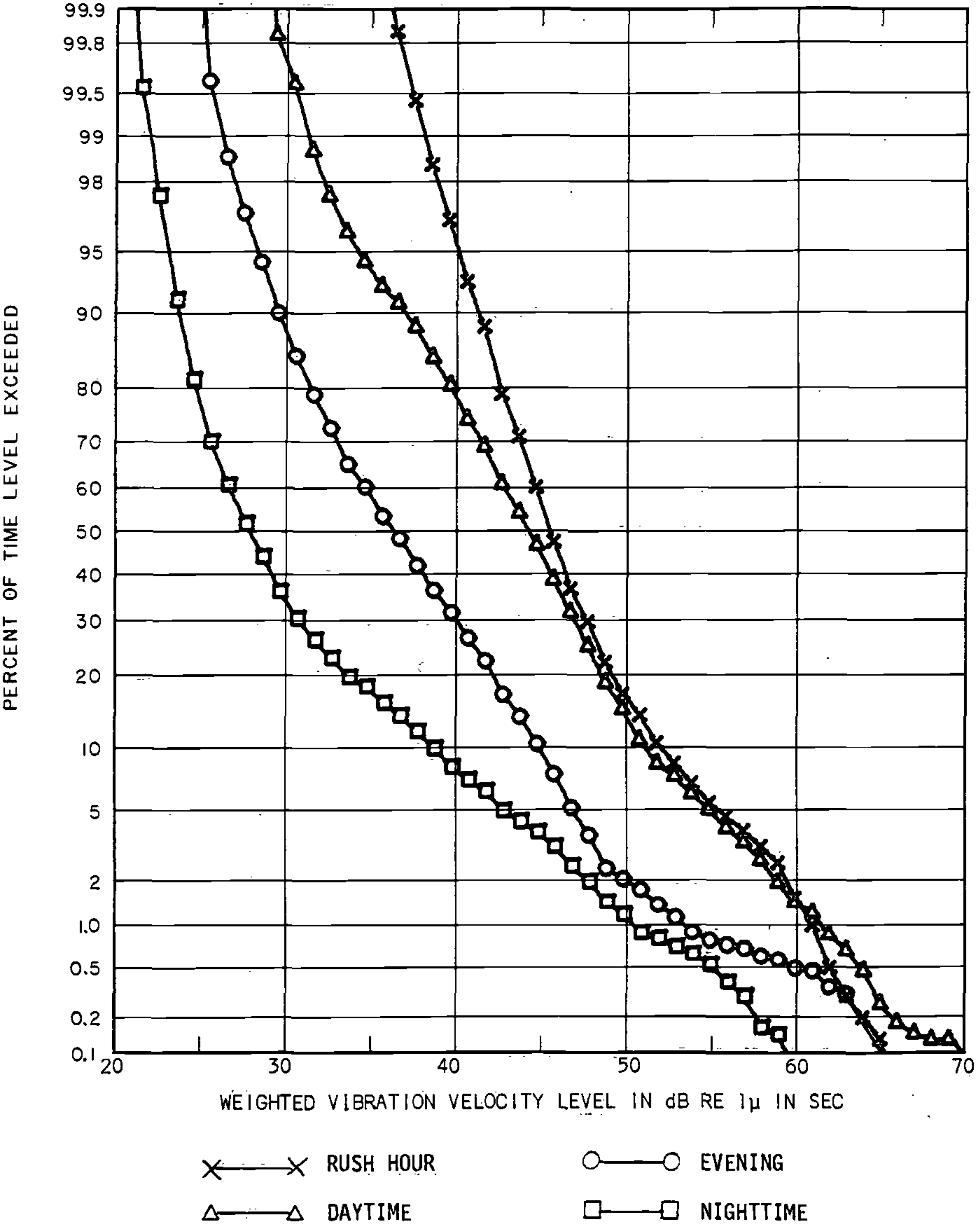


FIGURE B-15 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 15

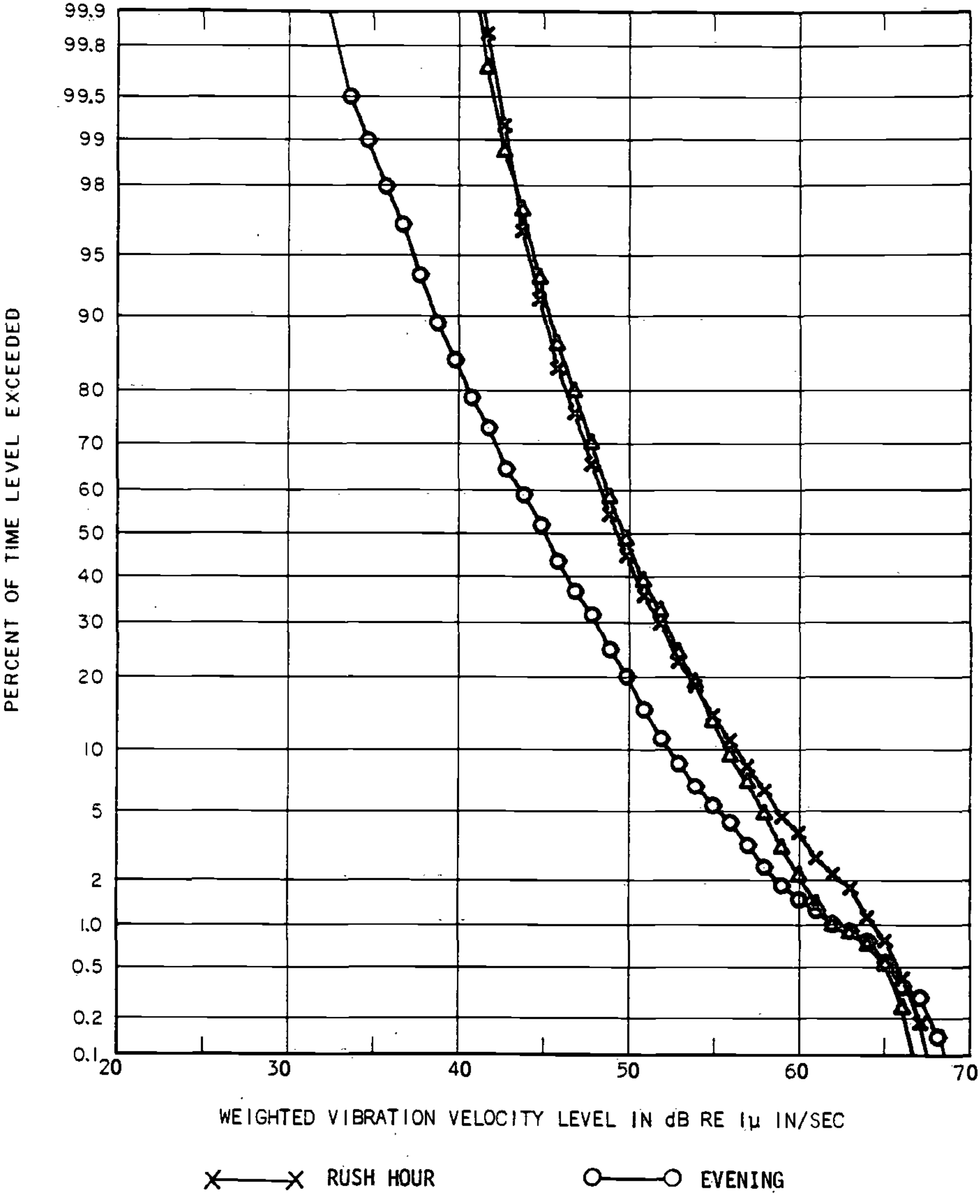


FIGURE B-16 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 16

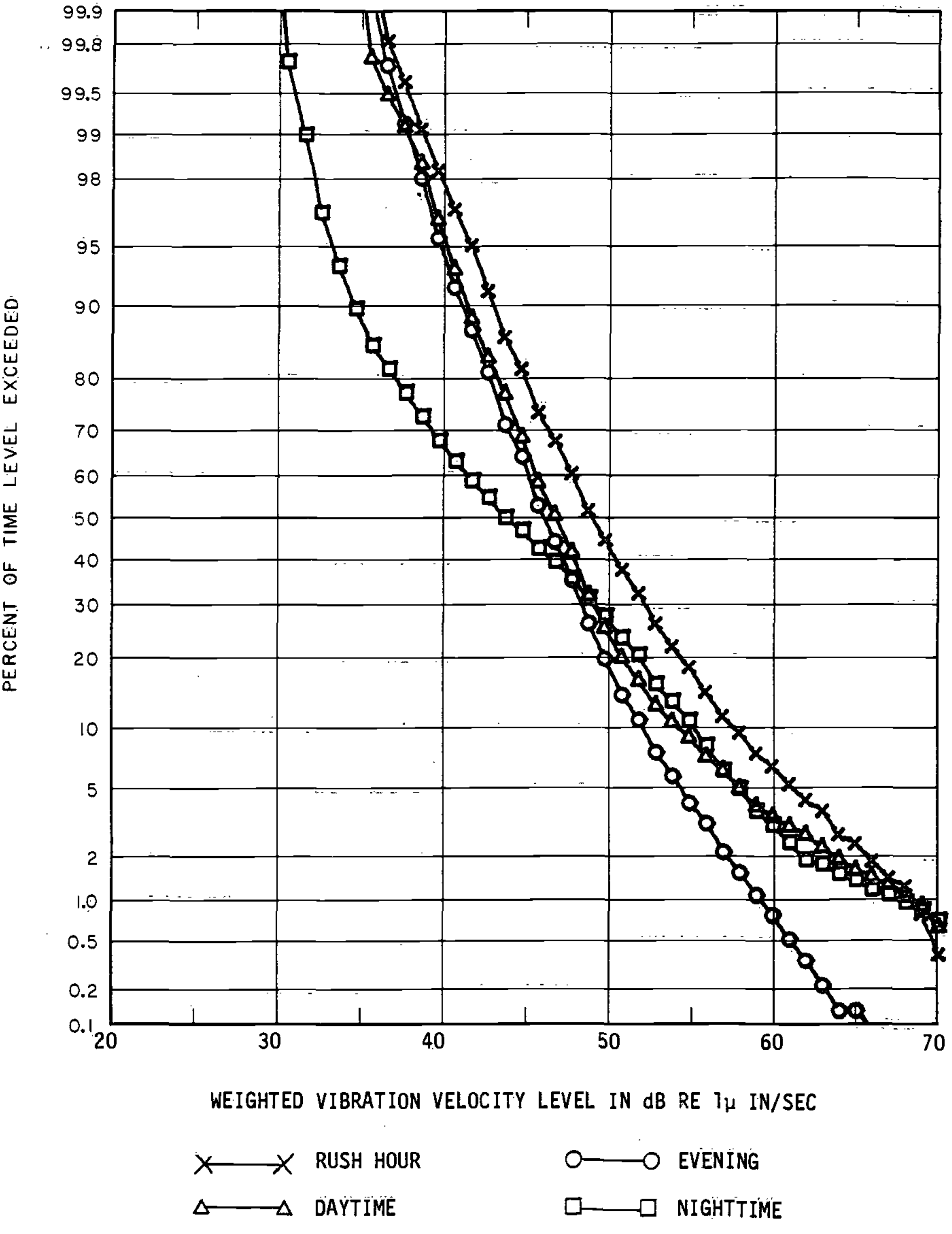


FIGURE B-17 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 17

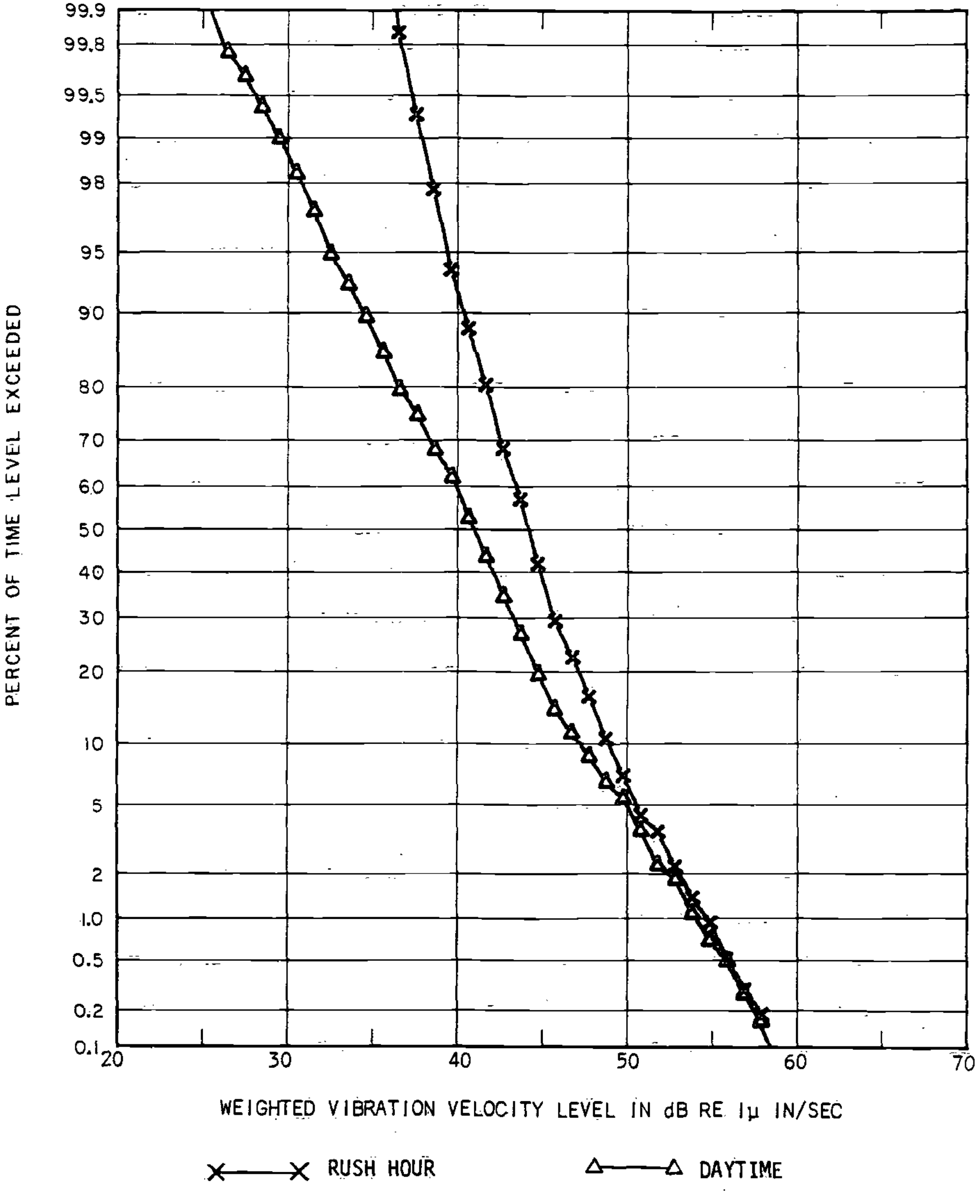


FIGURE B-18 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 18

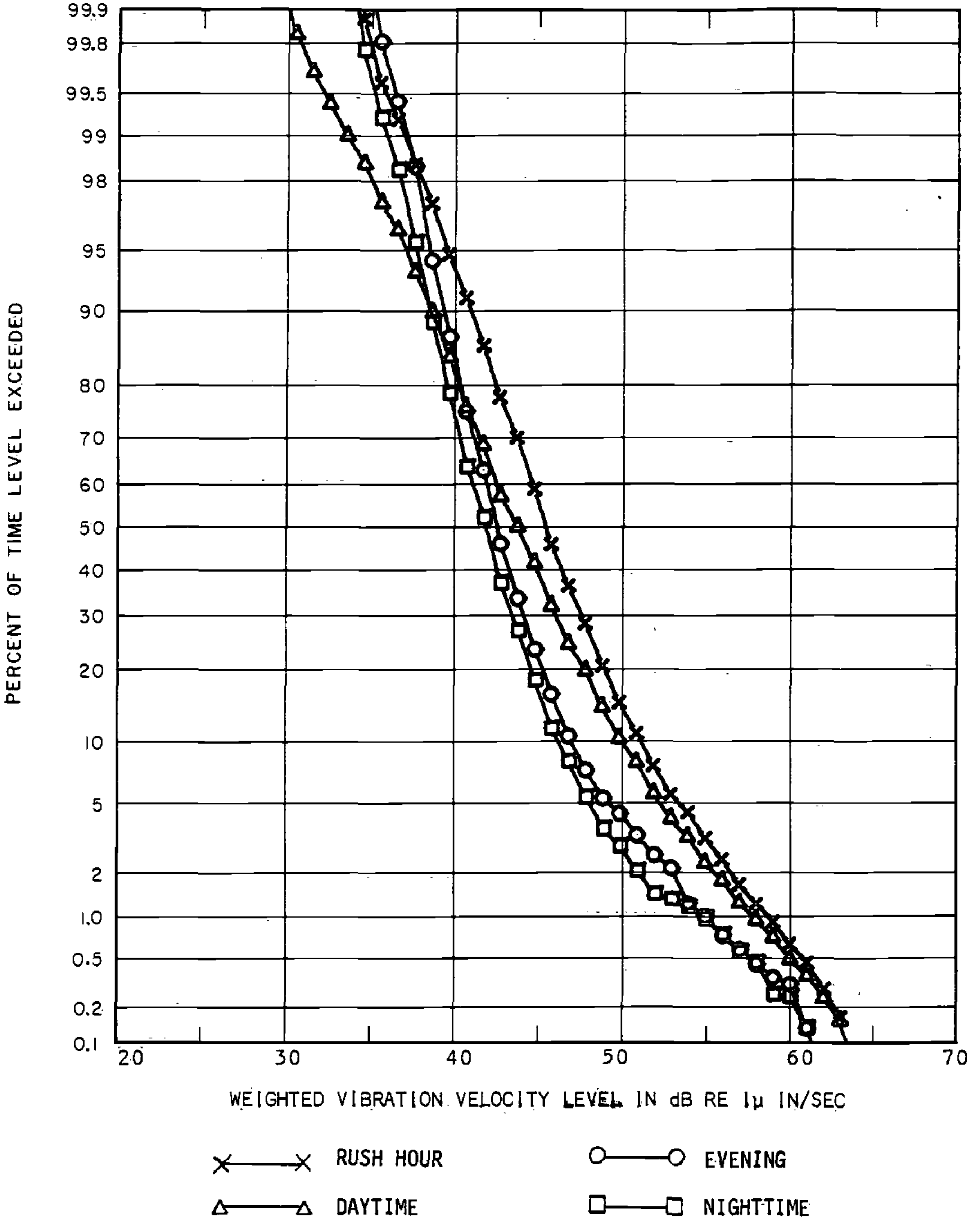


FIGURE B-19 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 19

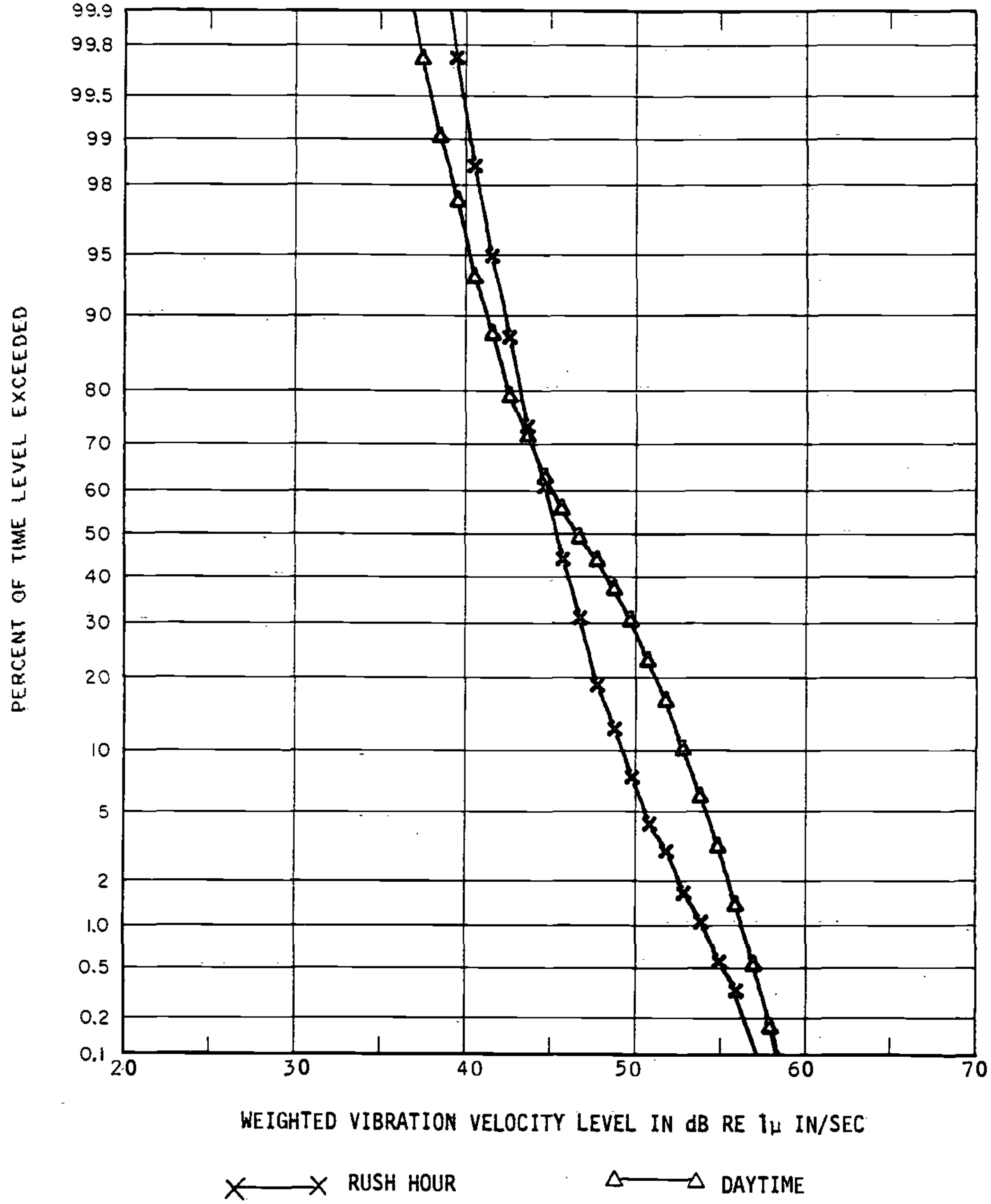
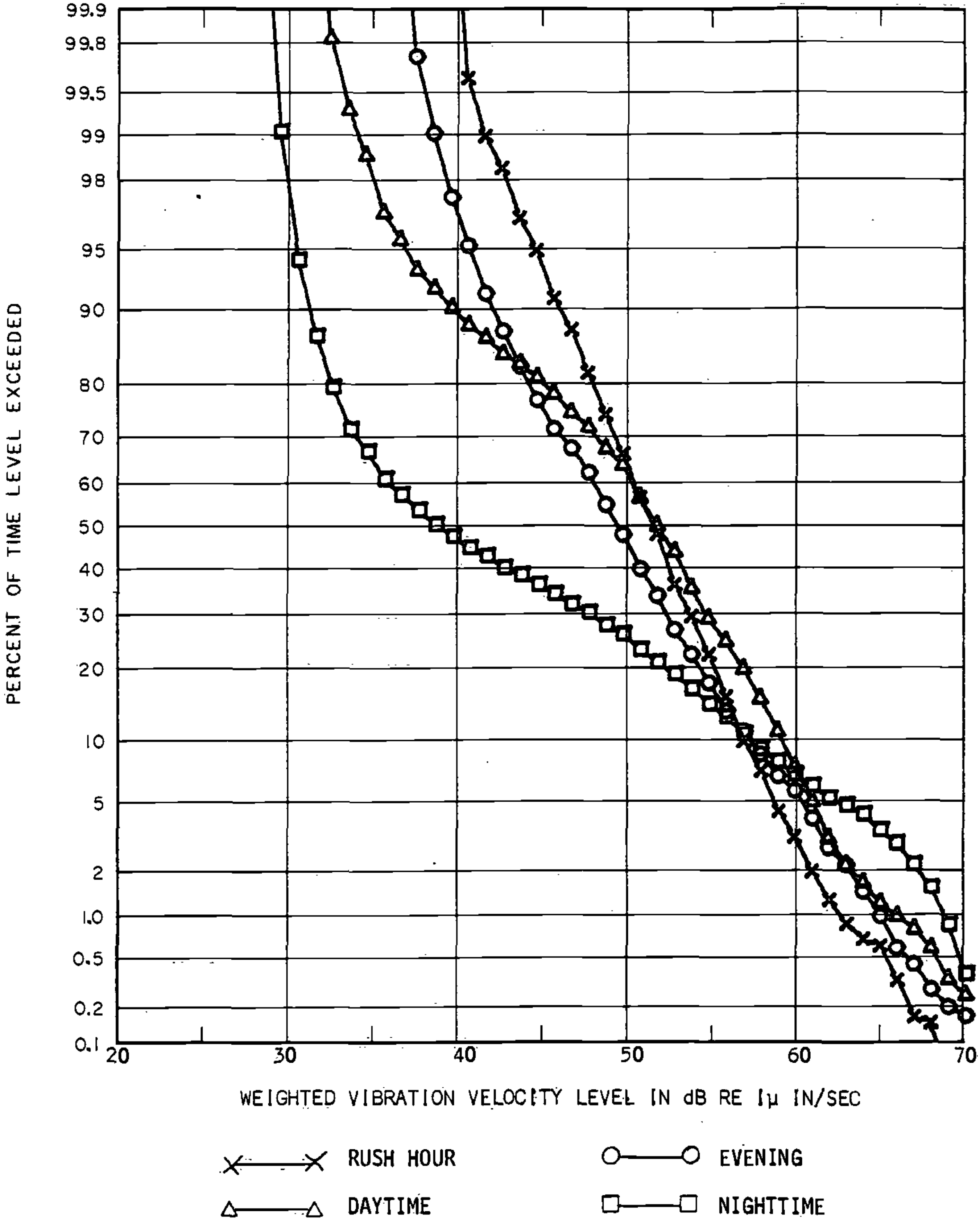


FIGURE B-20 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 20



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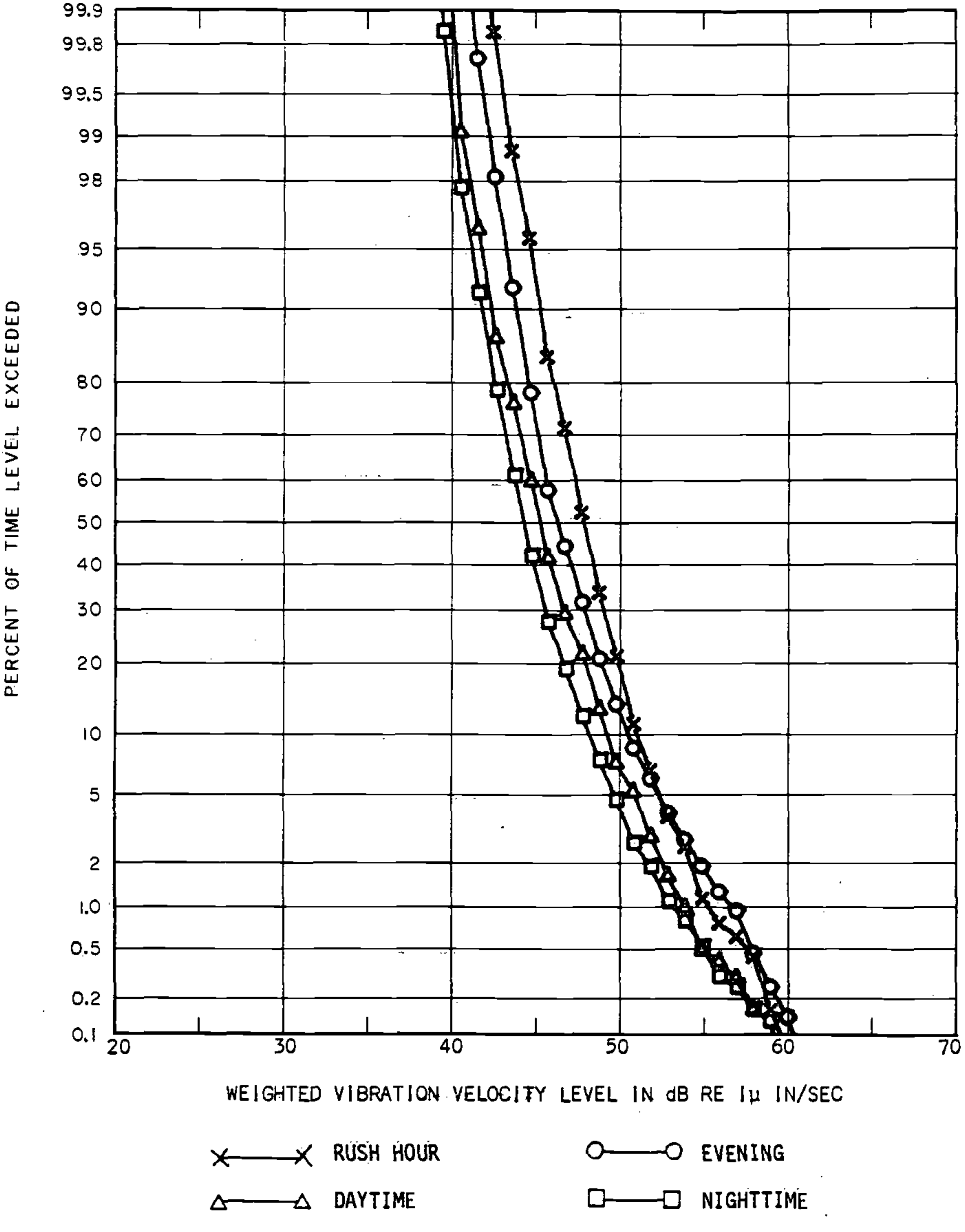

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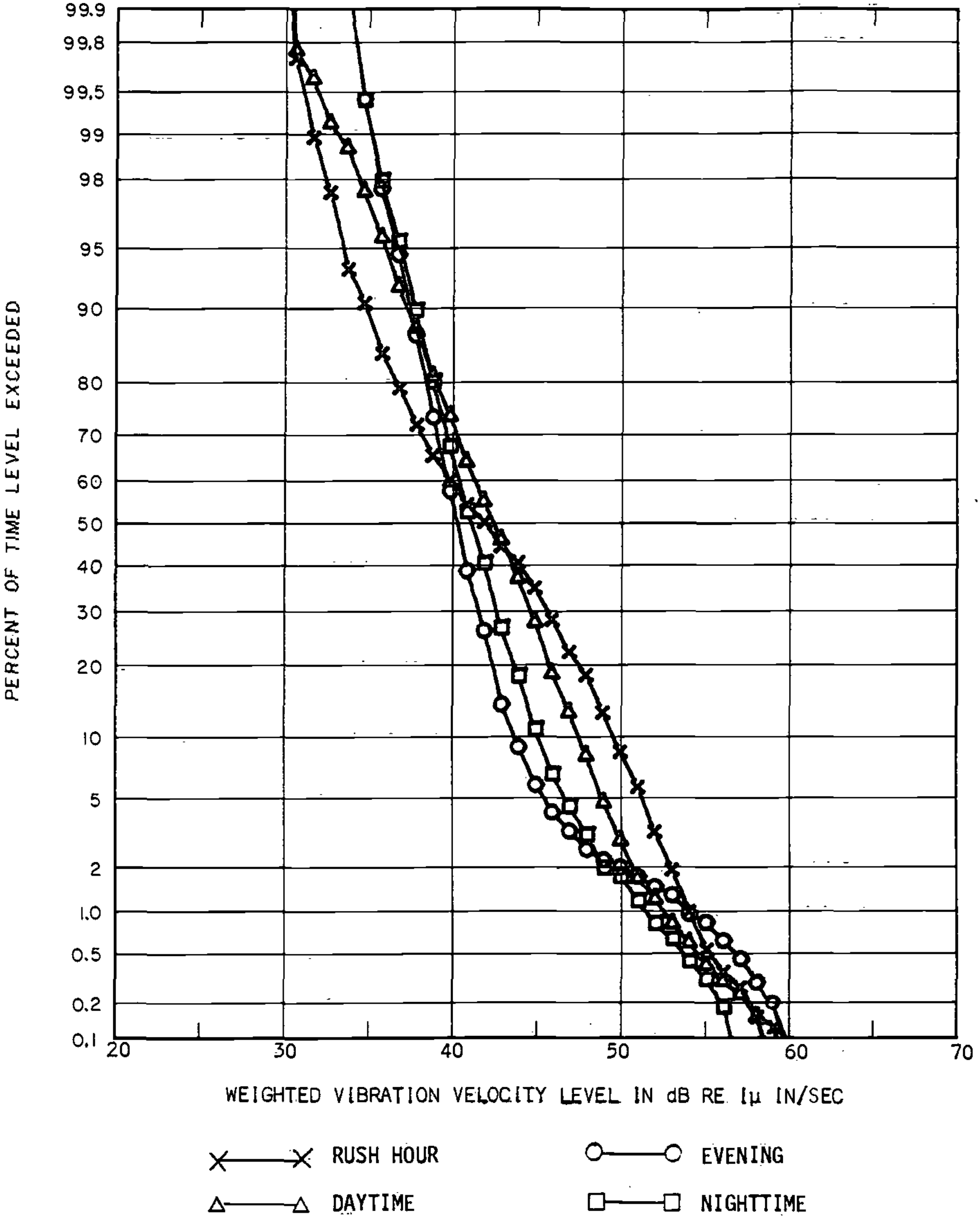

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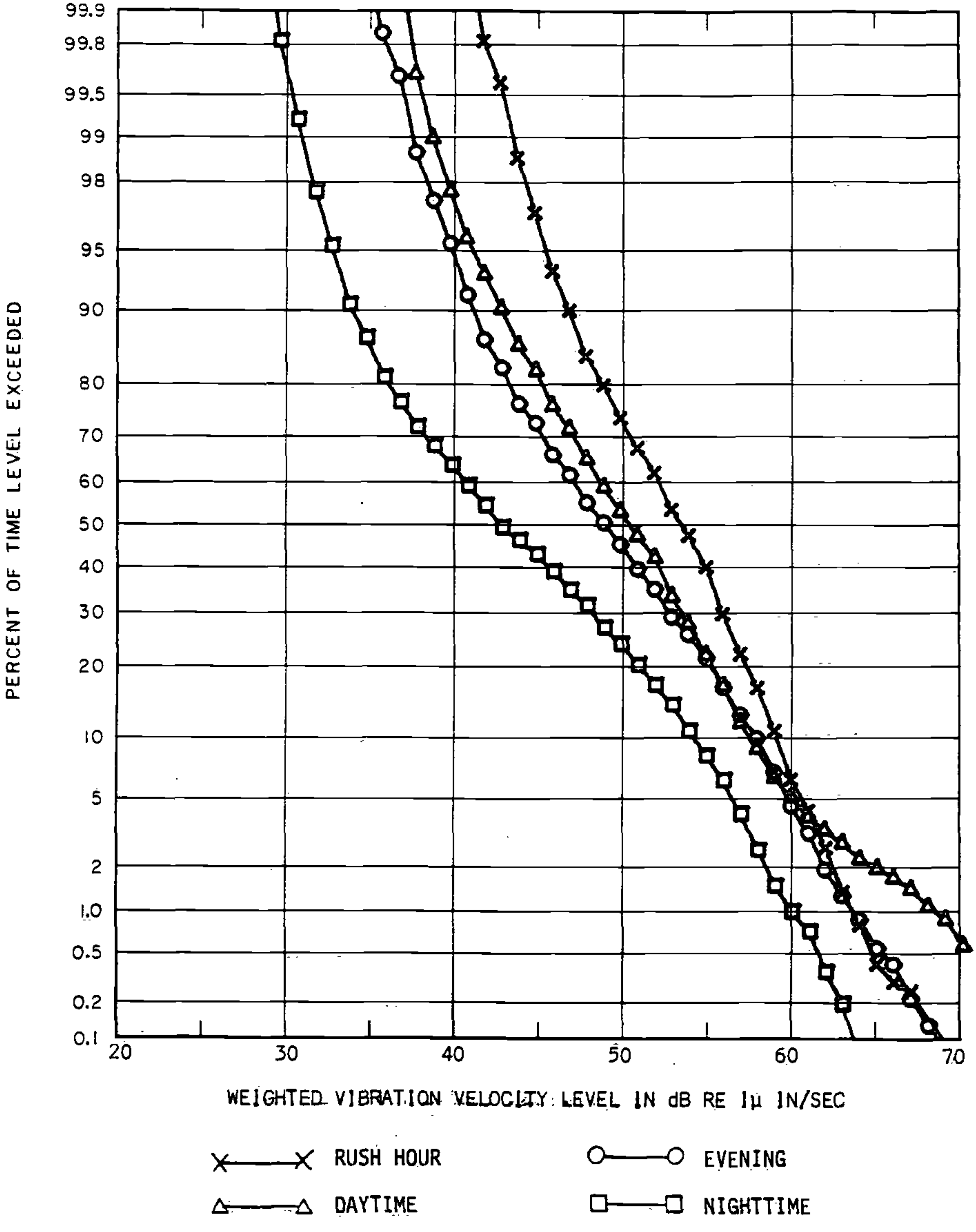

FIGURE B-24 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 24

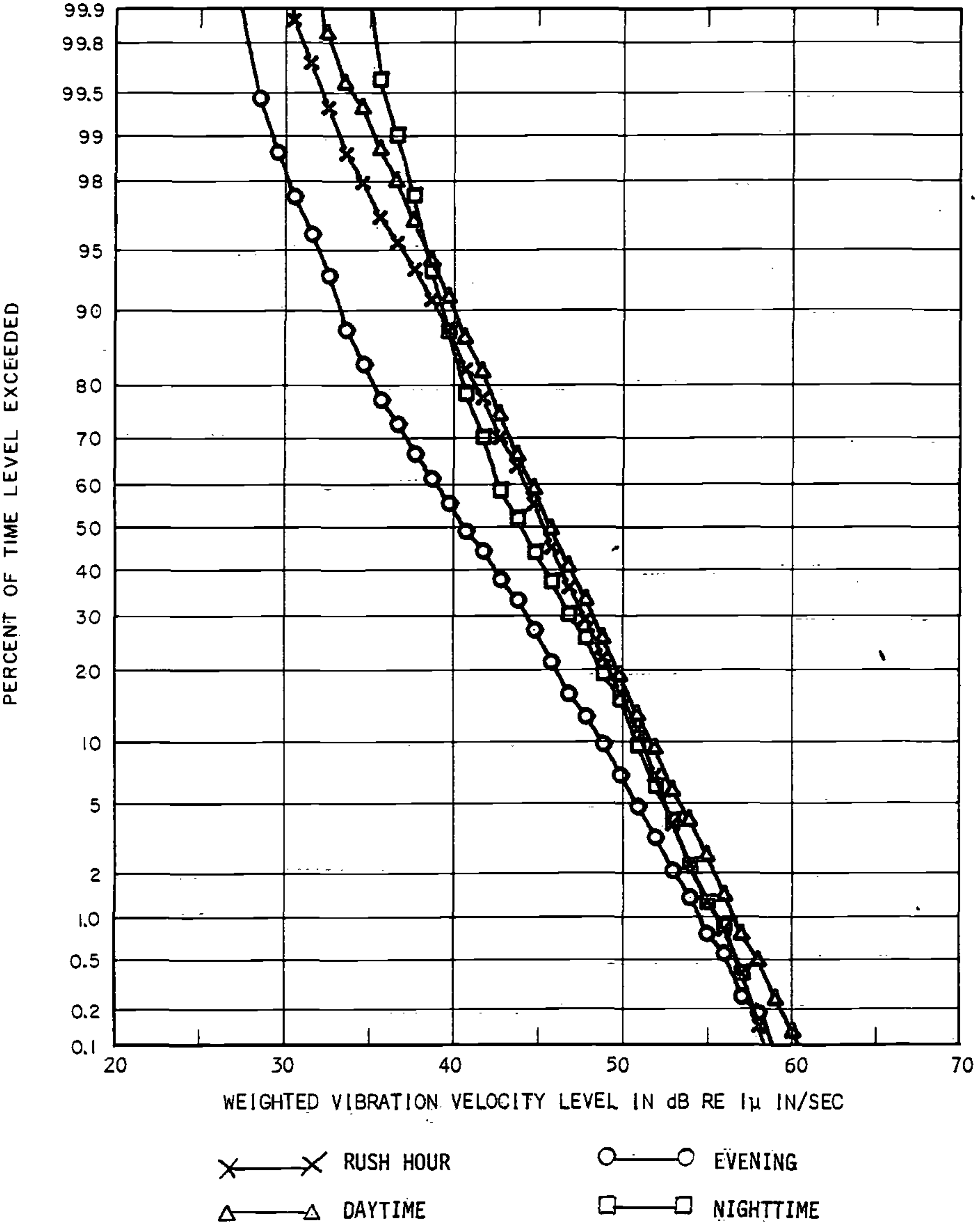

FIGURE B-25 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 25

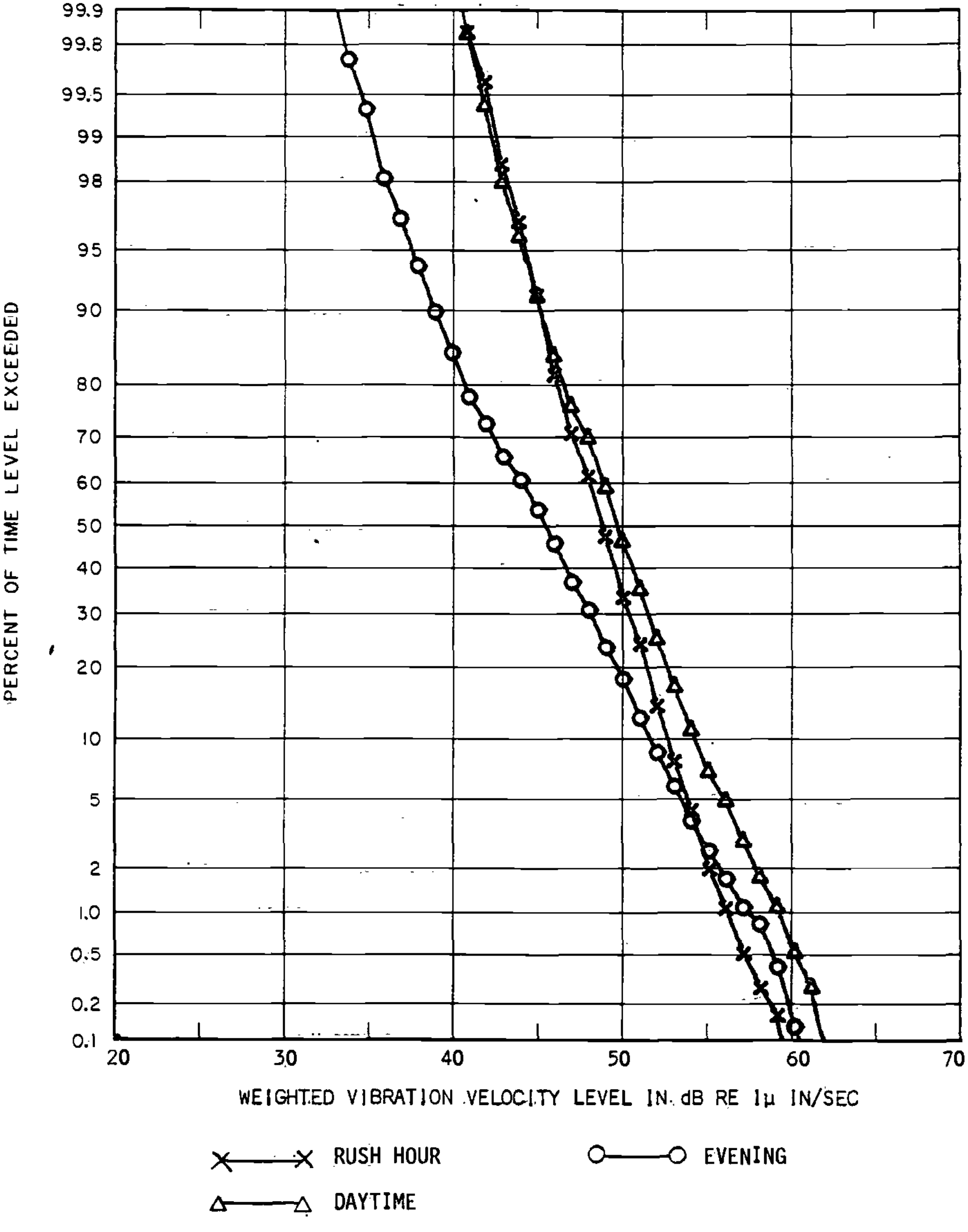

FIGURE B-26 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 26

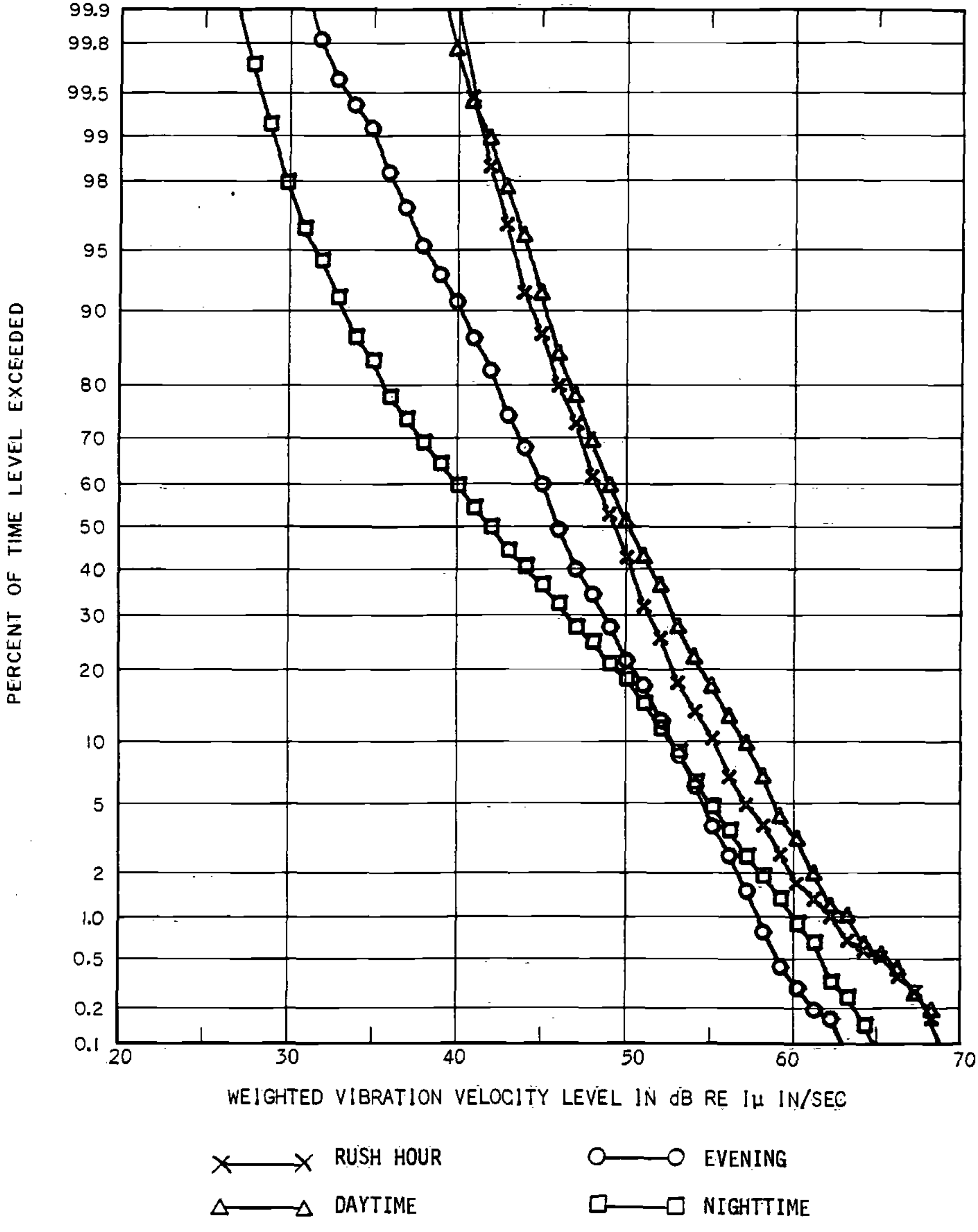

FIGURE B-27 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 27

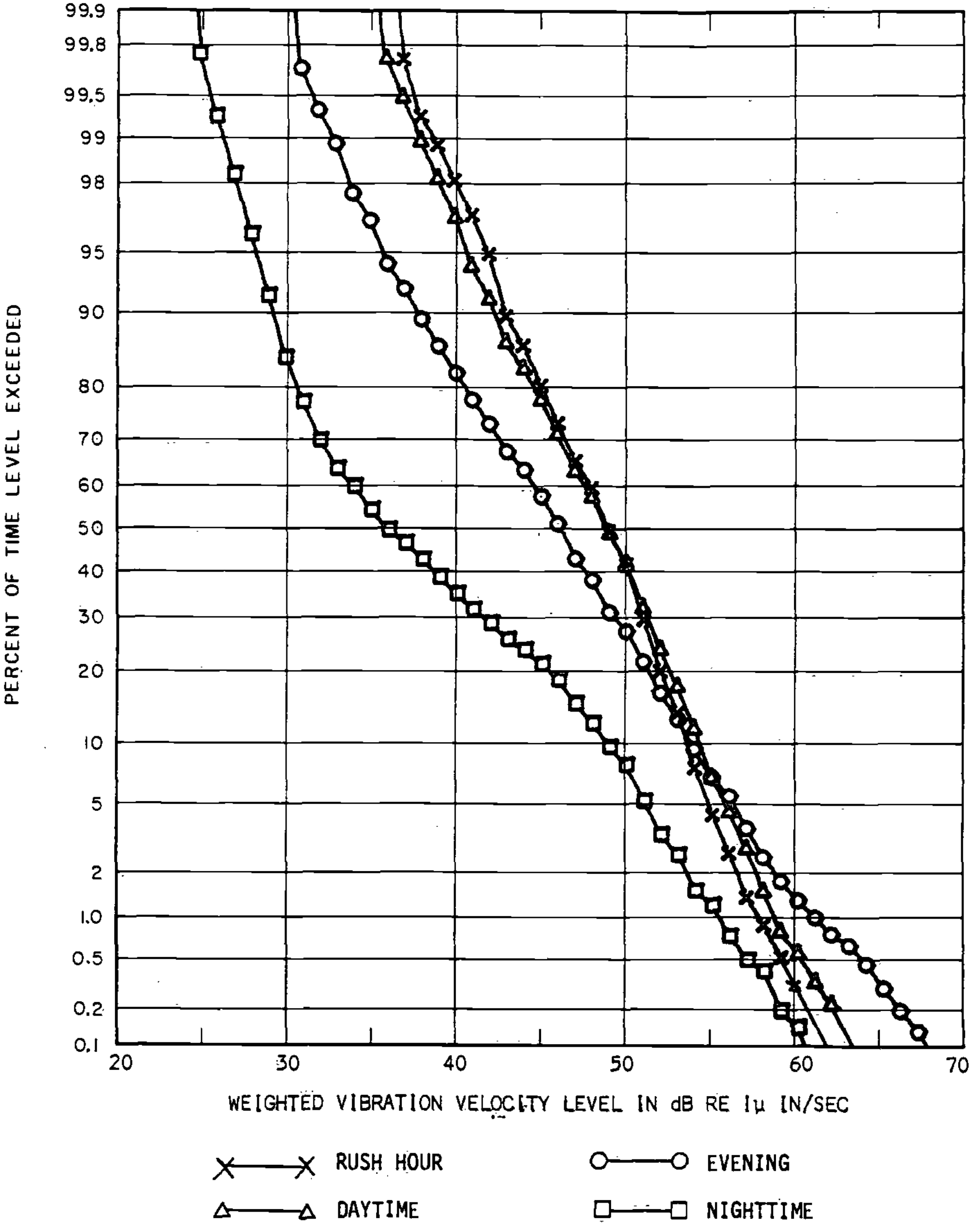

FIGURE B-28 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 28

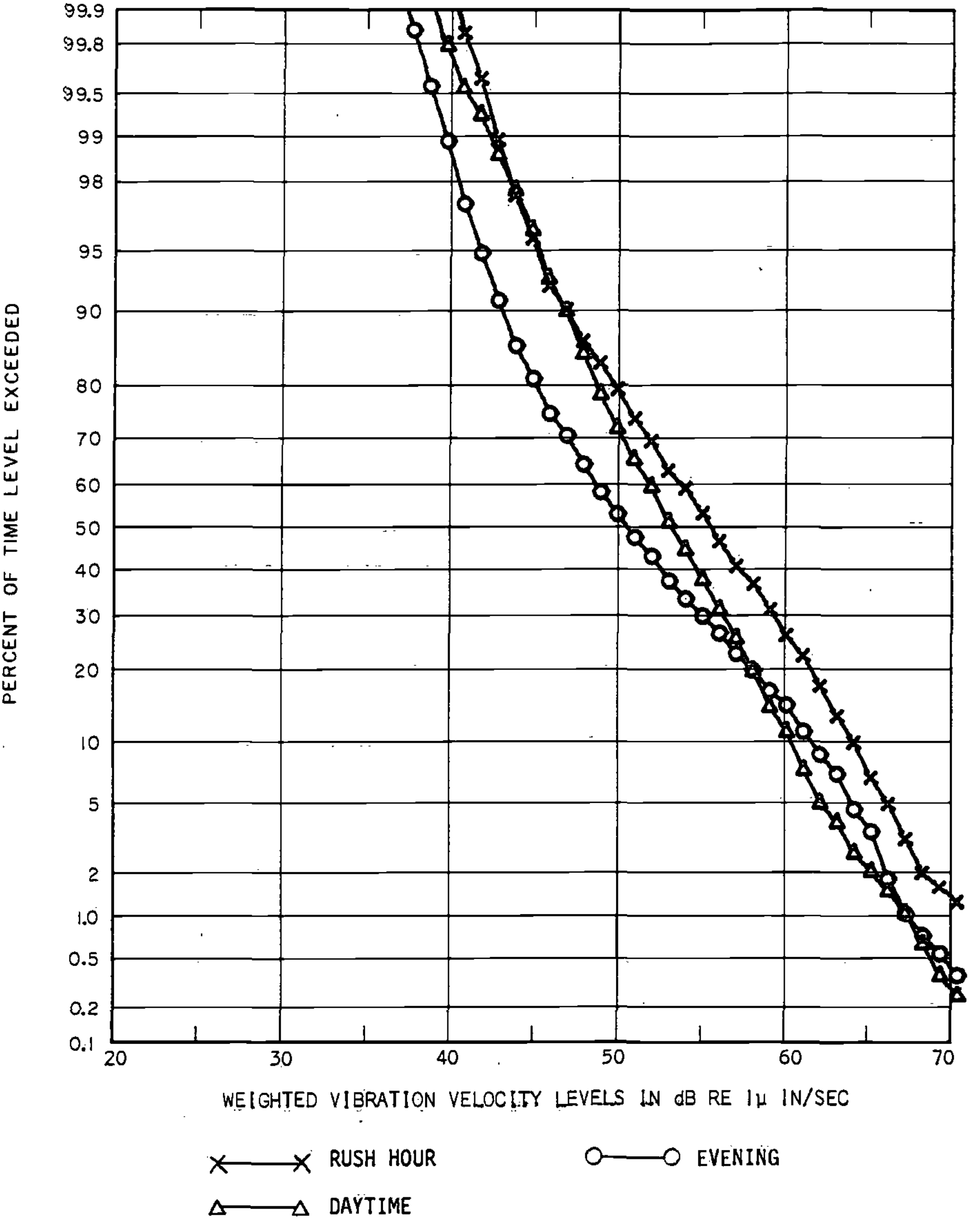

FIGURE B-29 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 29

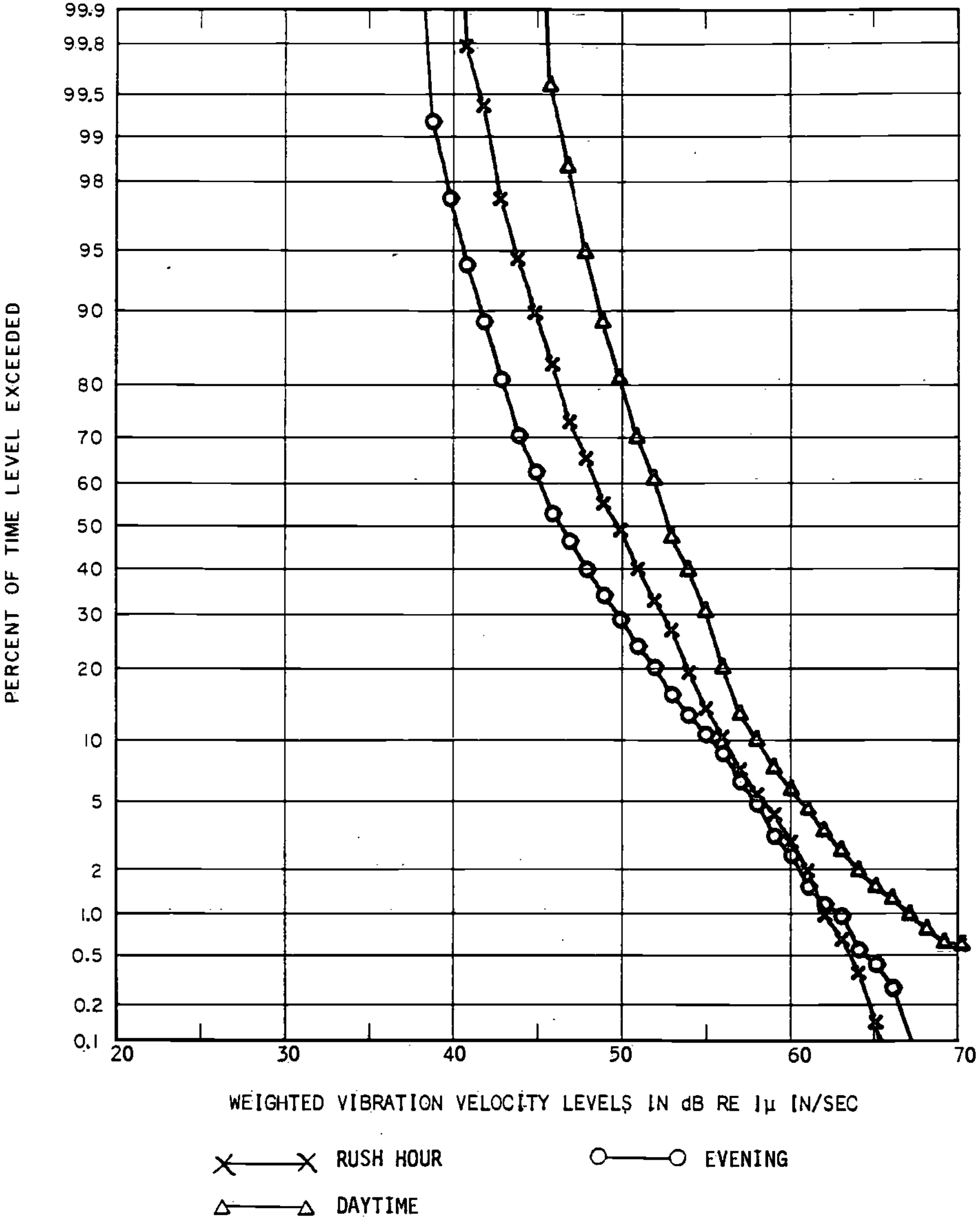

FIGURE B-30 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 30

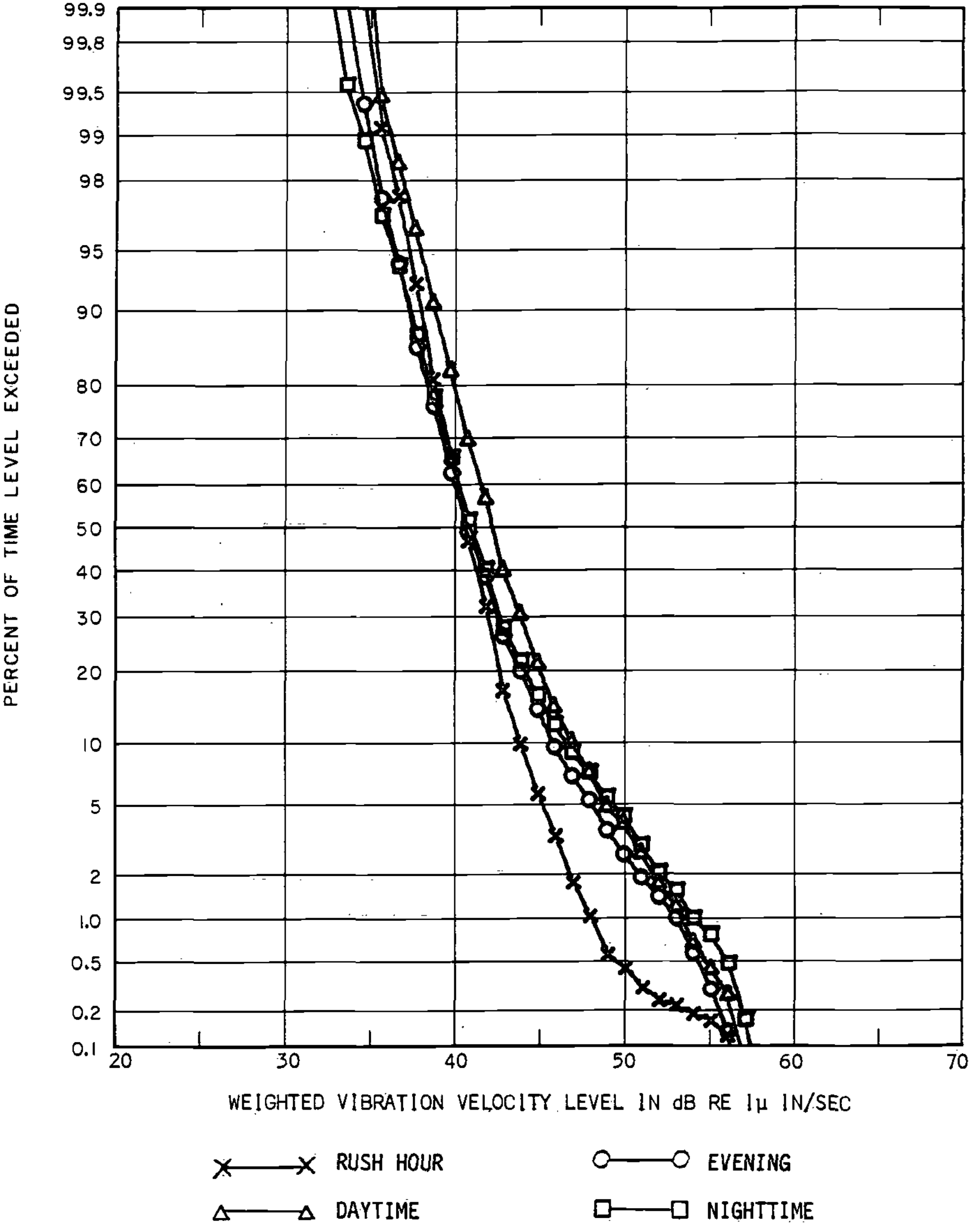

FIGURE B-31 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 31

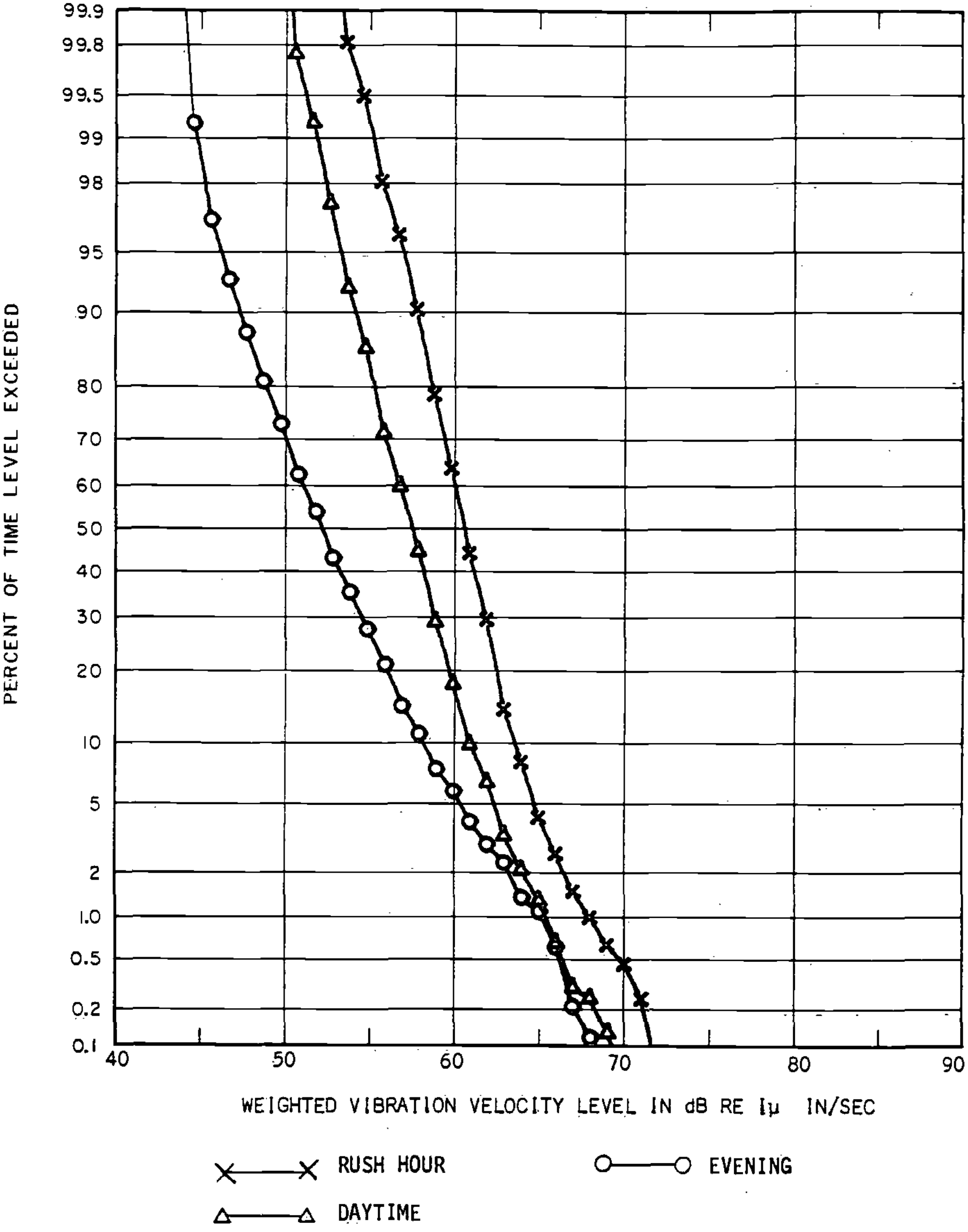

FIGURE B-32 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 32

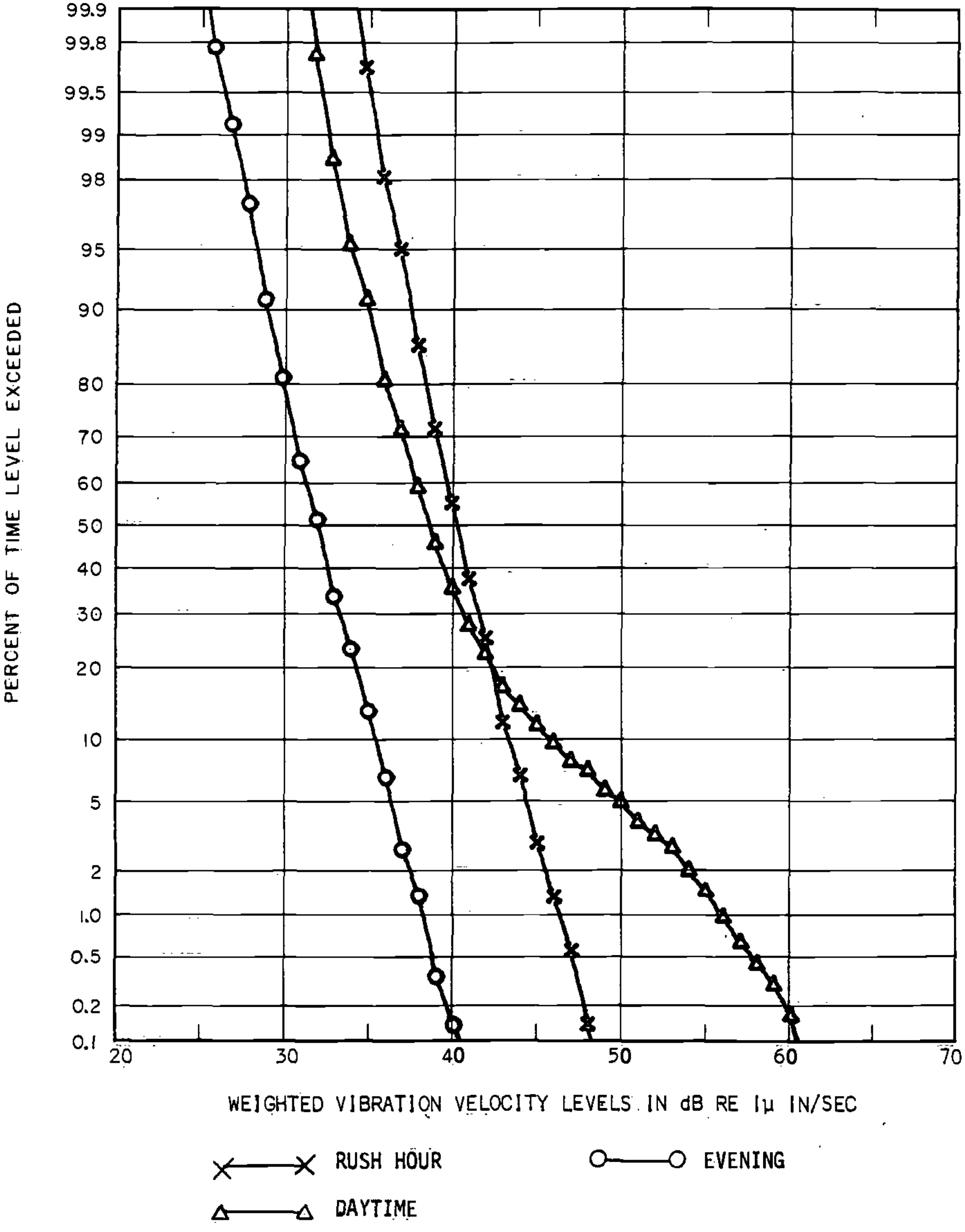

FIGURE B-33 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 33

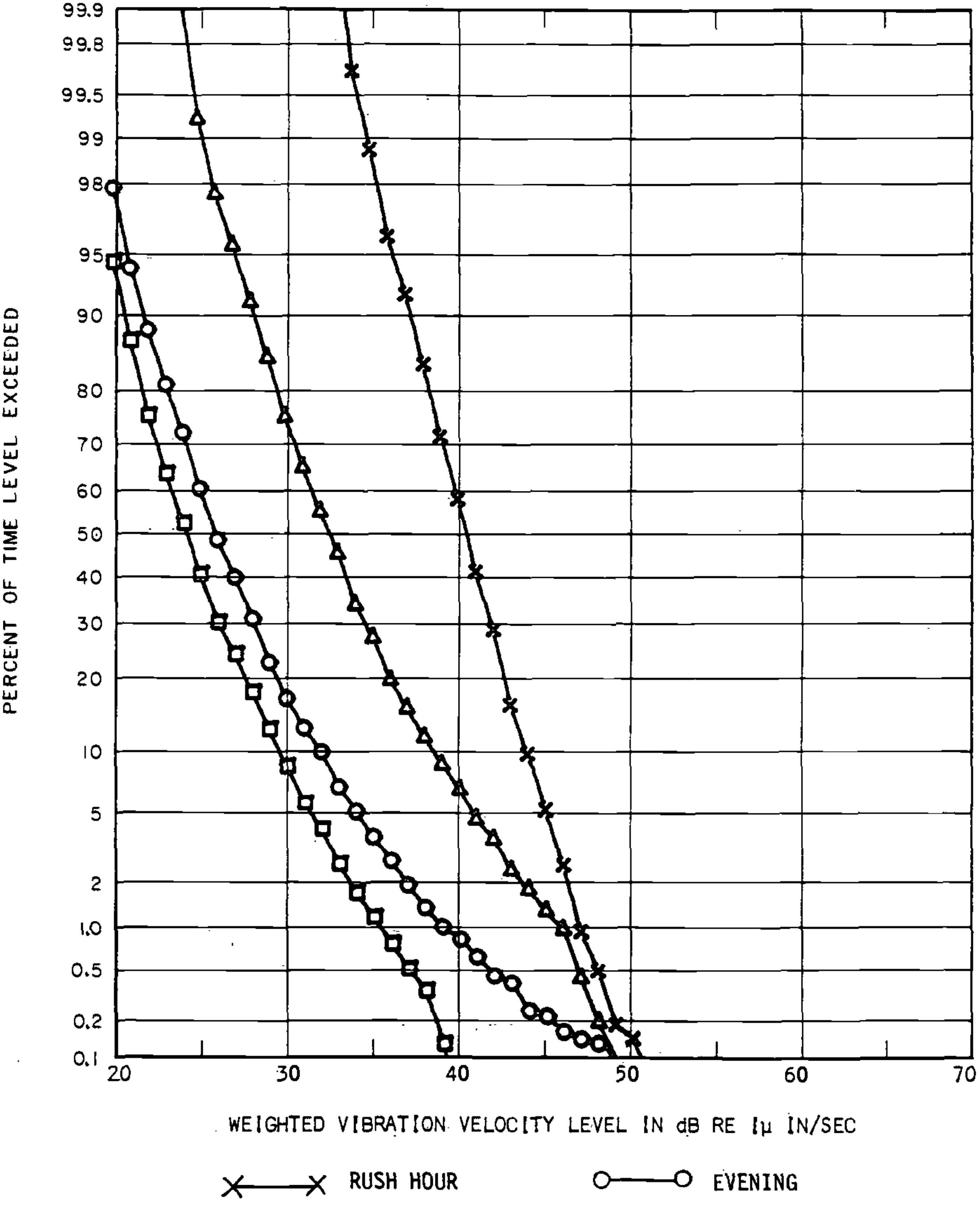

FIGURE B-34 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 34

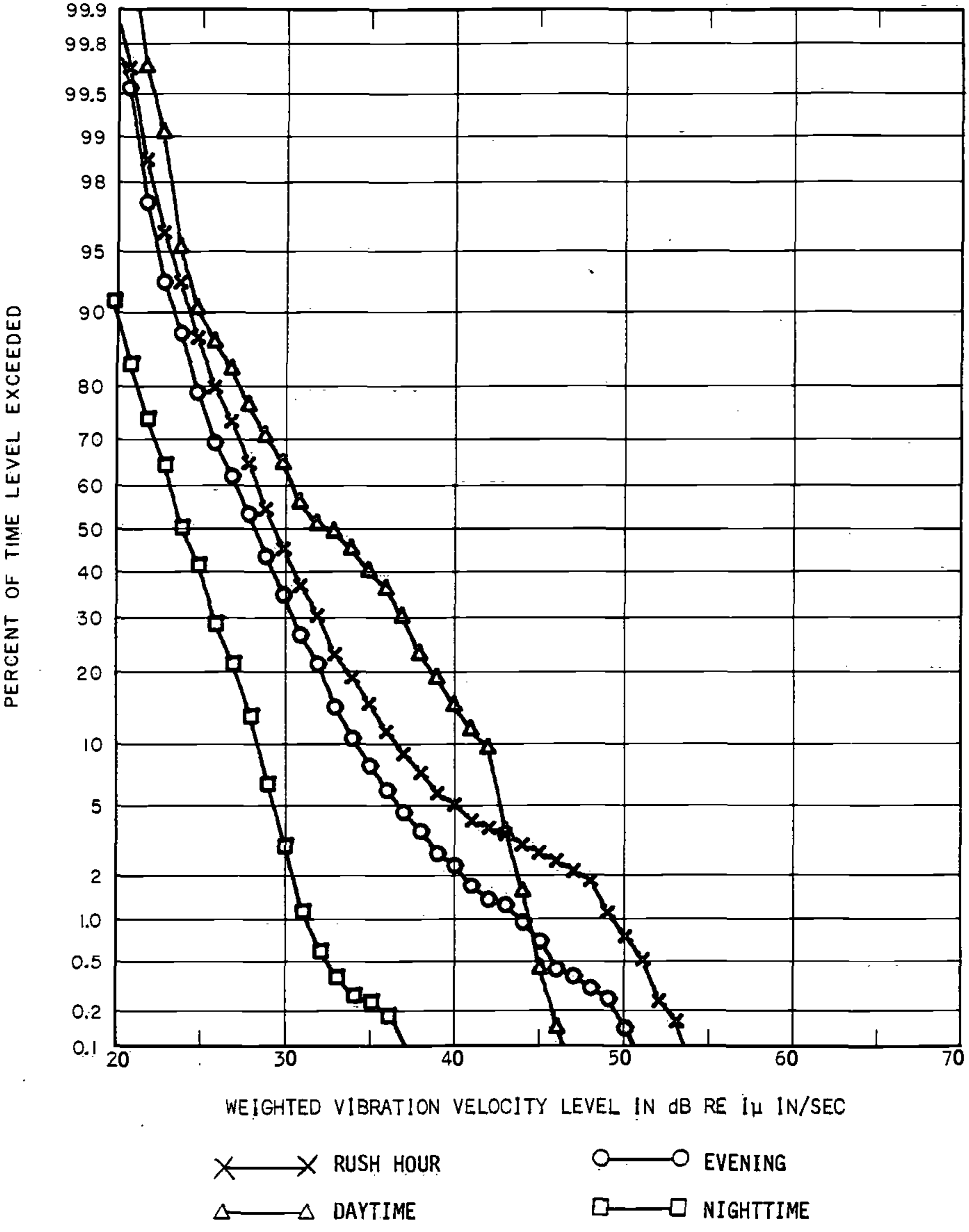

FIGURE B-35 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 35

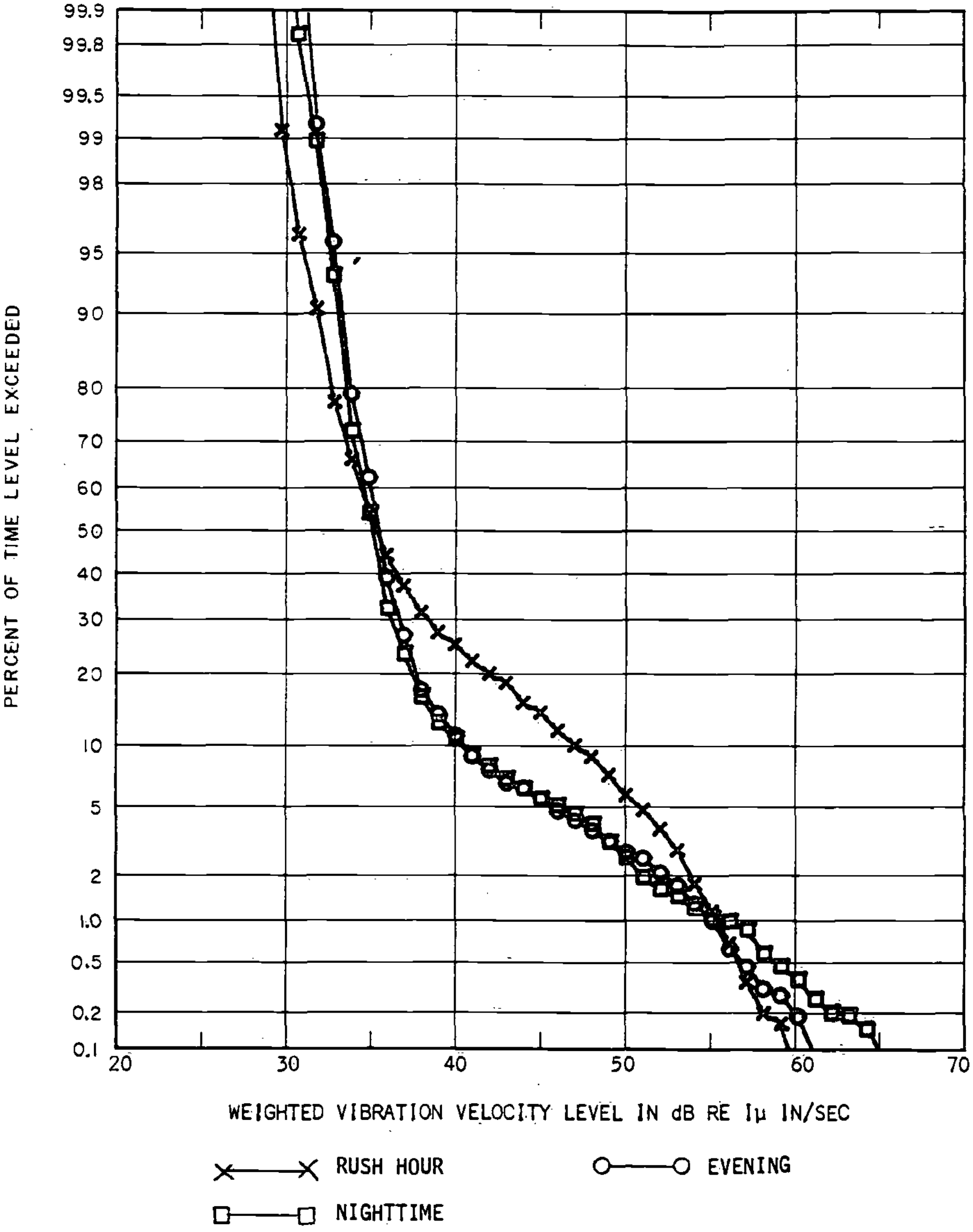

FIGURE B-36 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 36

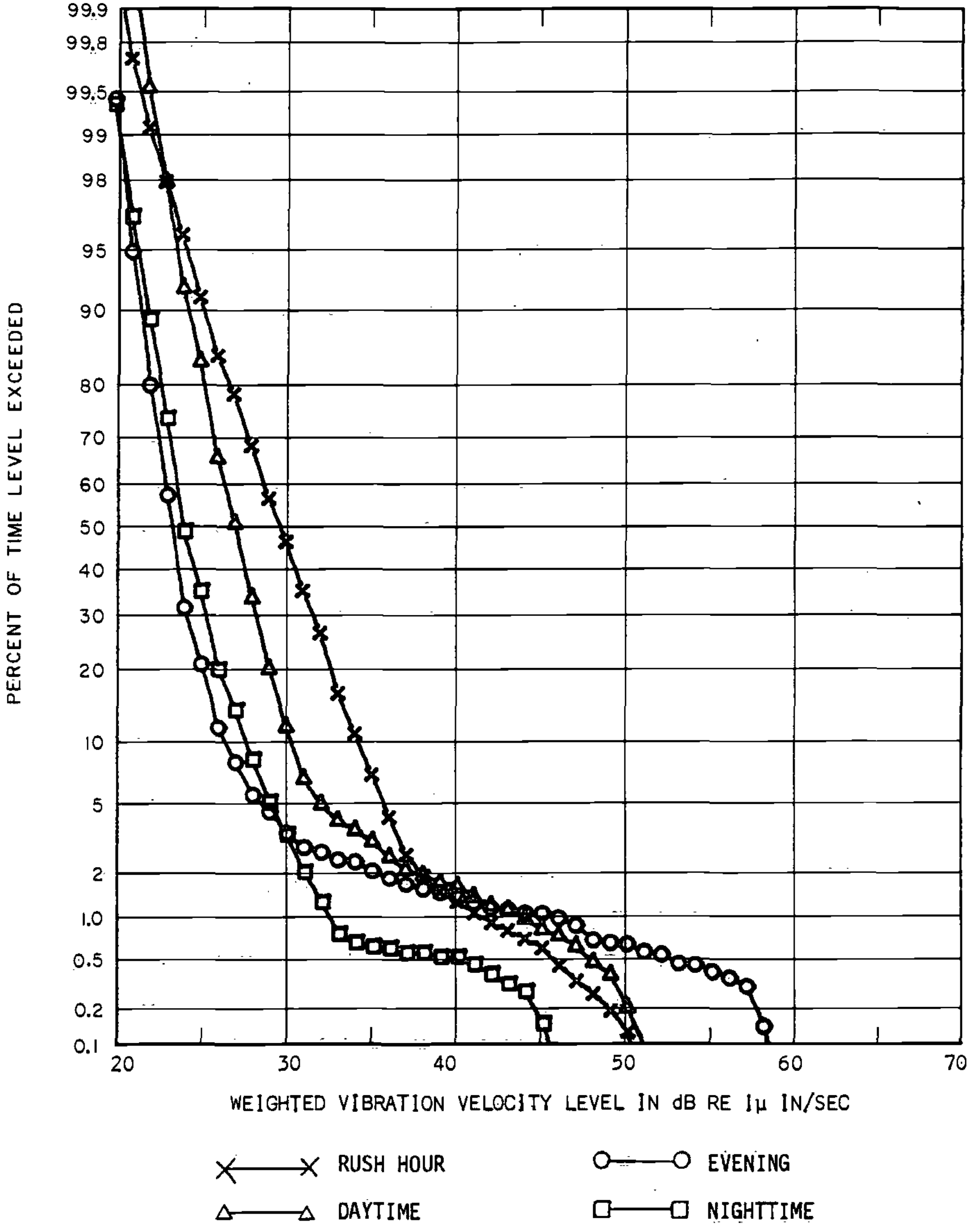

FIGURE B-37 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 37

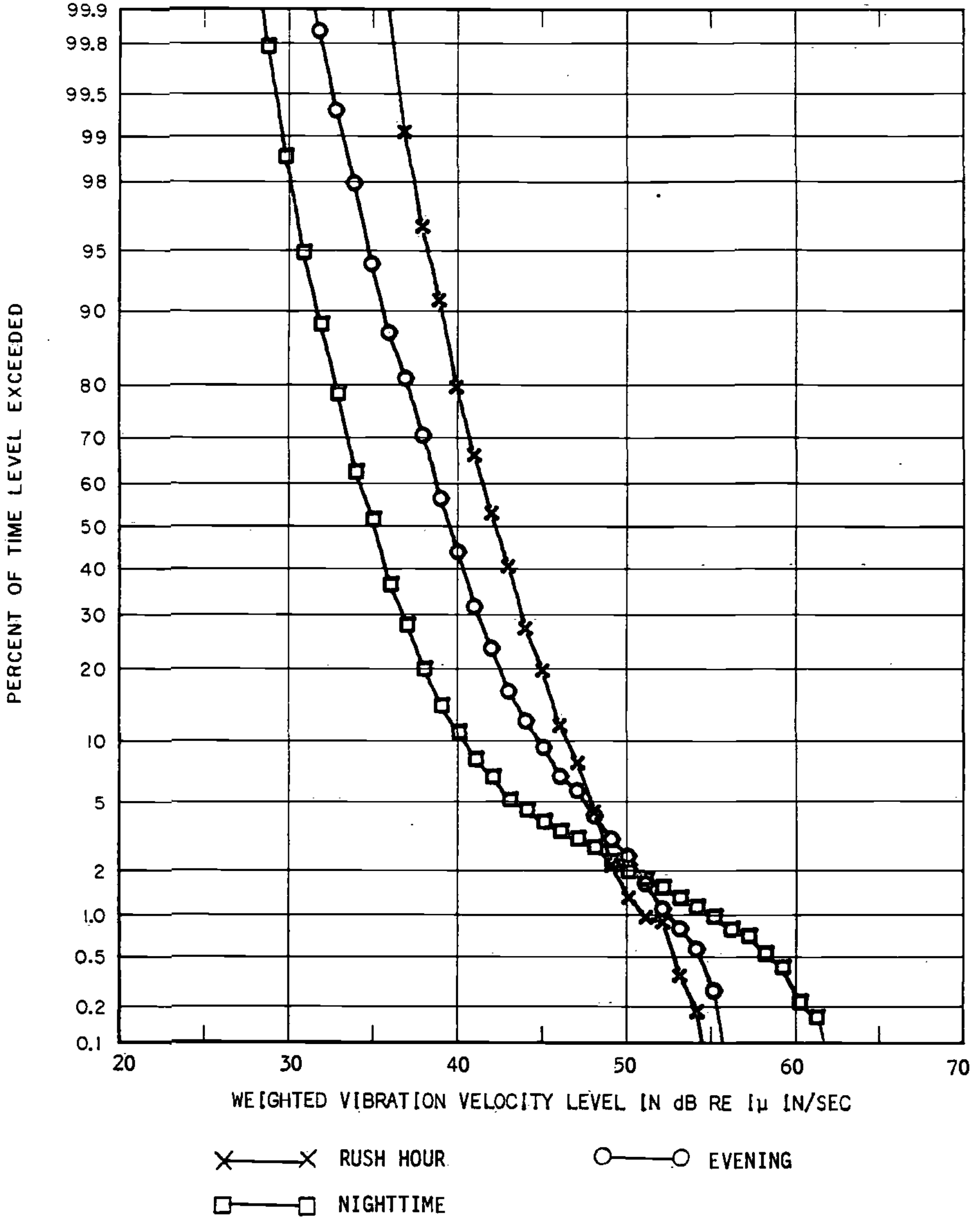

FIGURE B-38 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 38

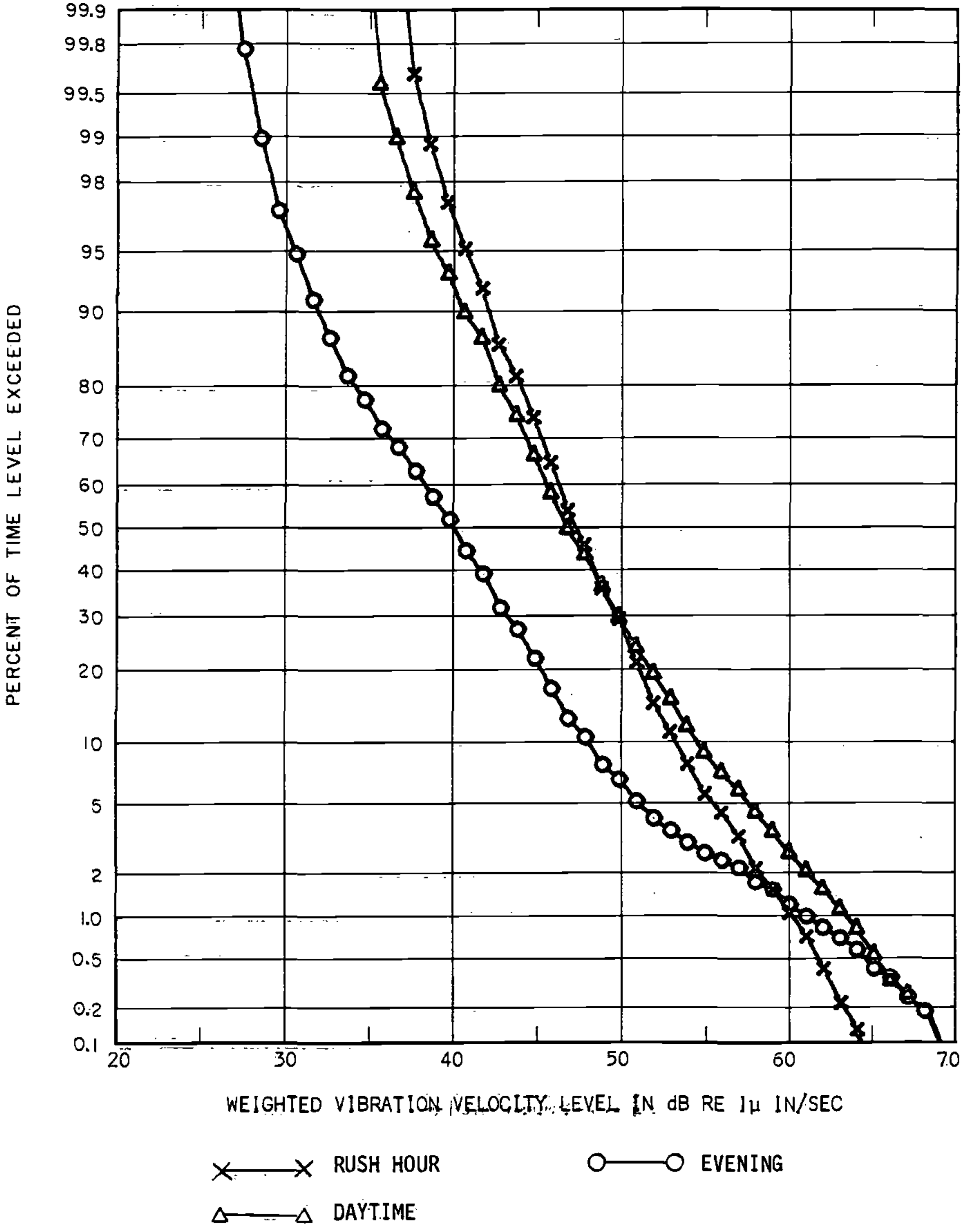

FIGURE B-39 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 39

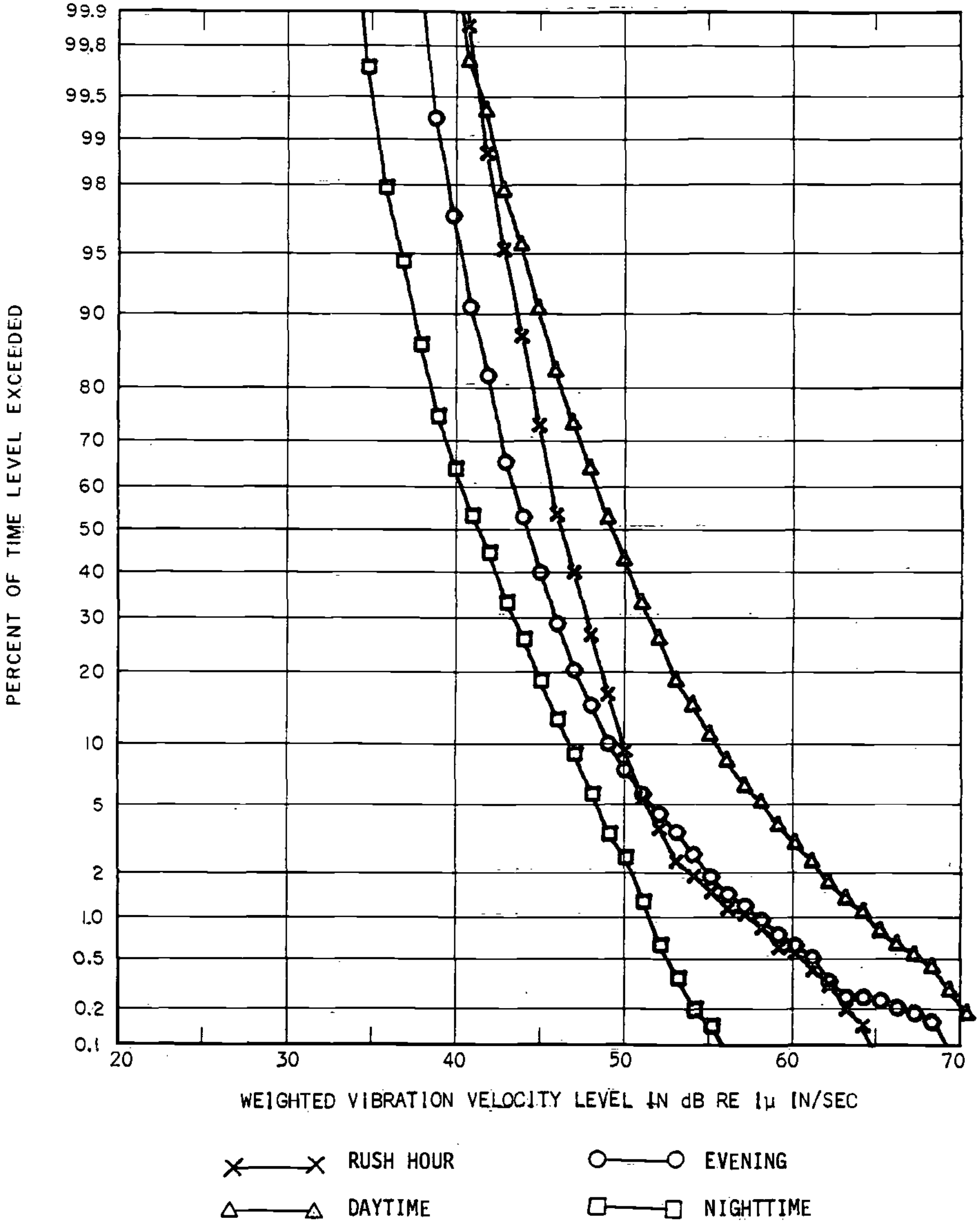

FIGURE B-40 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 40

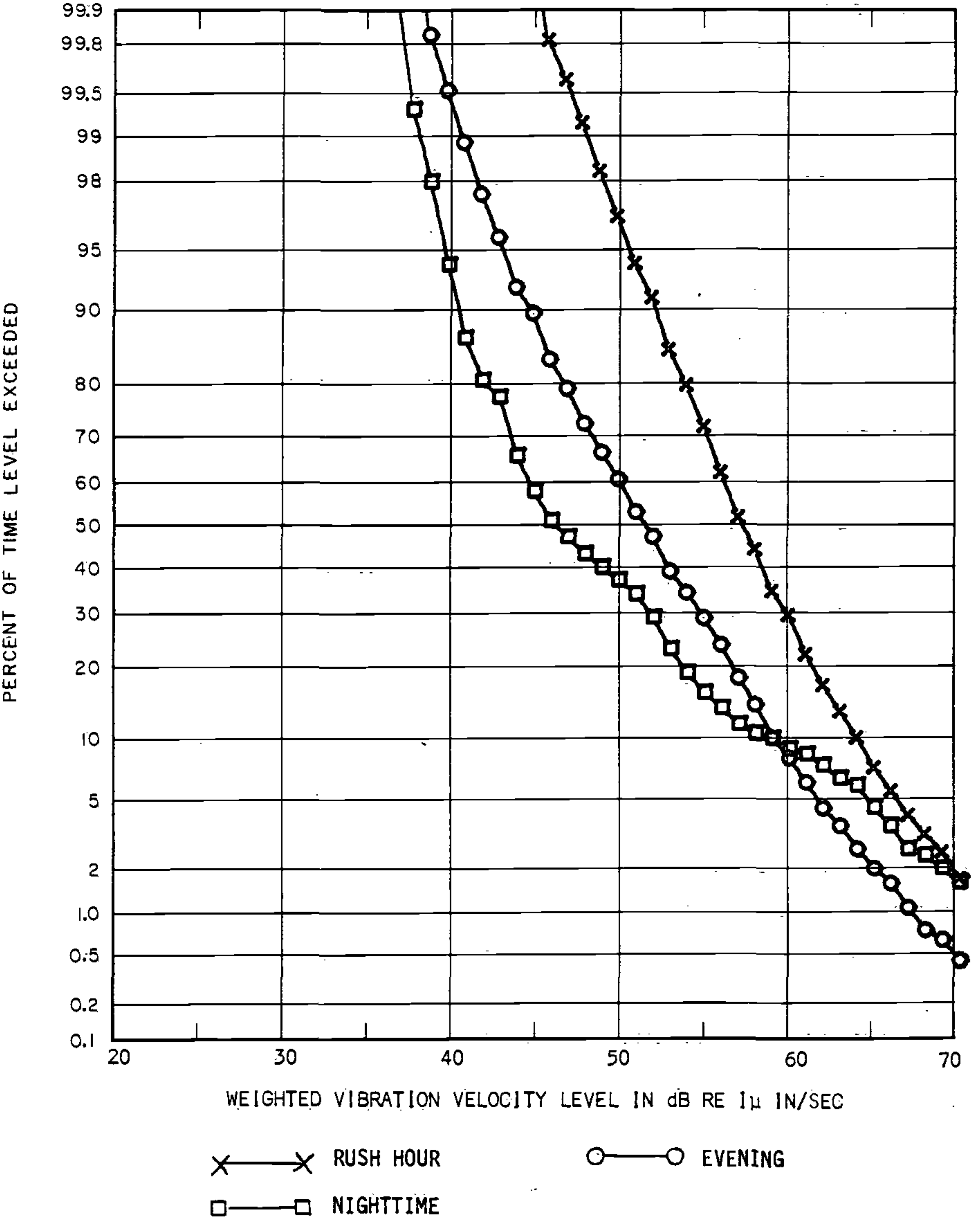

FIGURE B-41 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 41

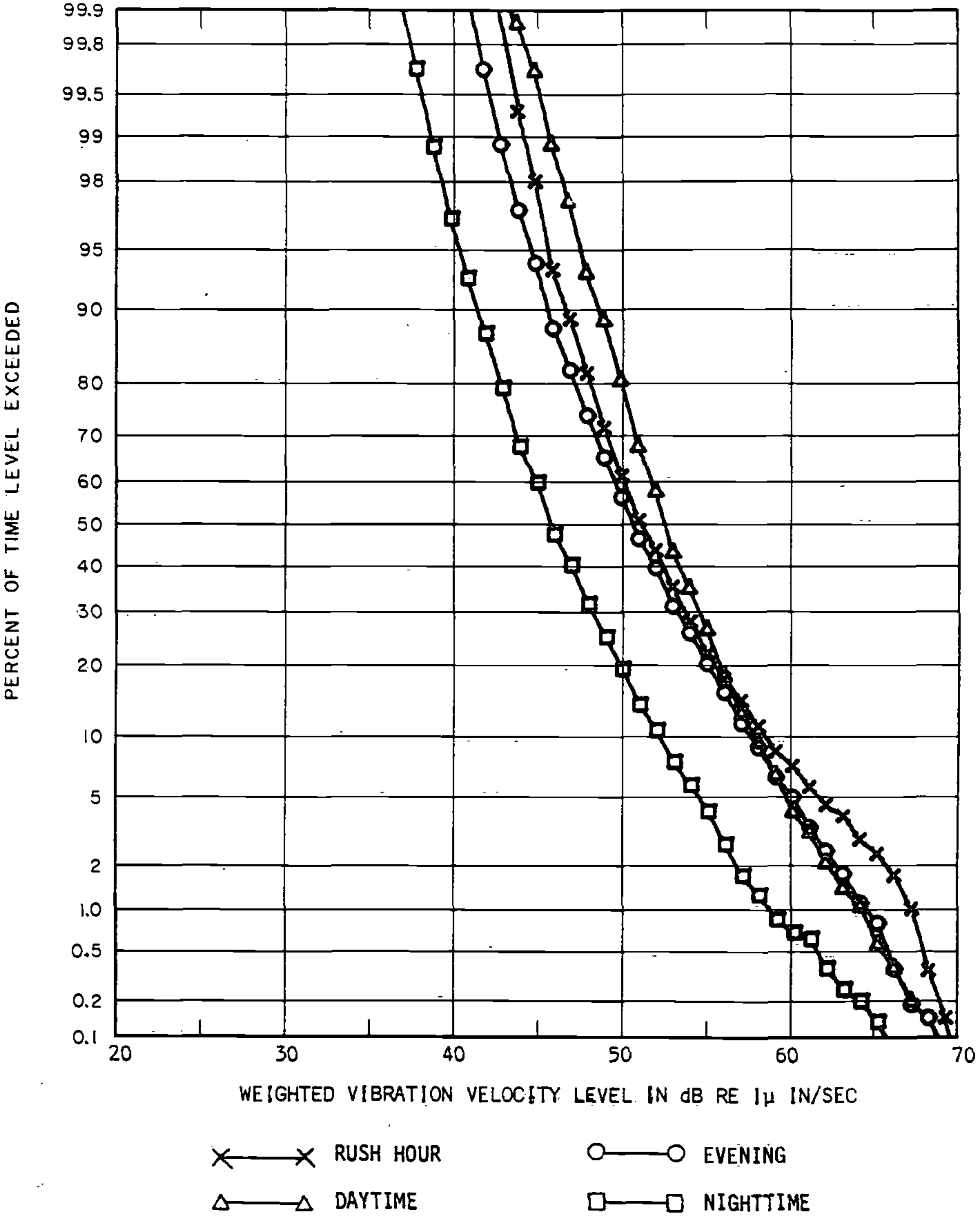

FIGURE B-42 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 42

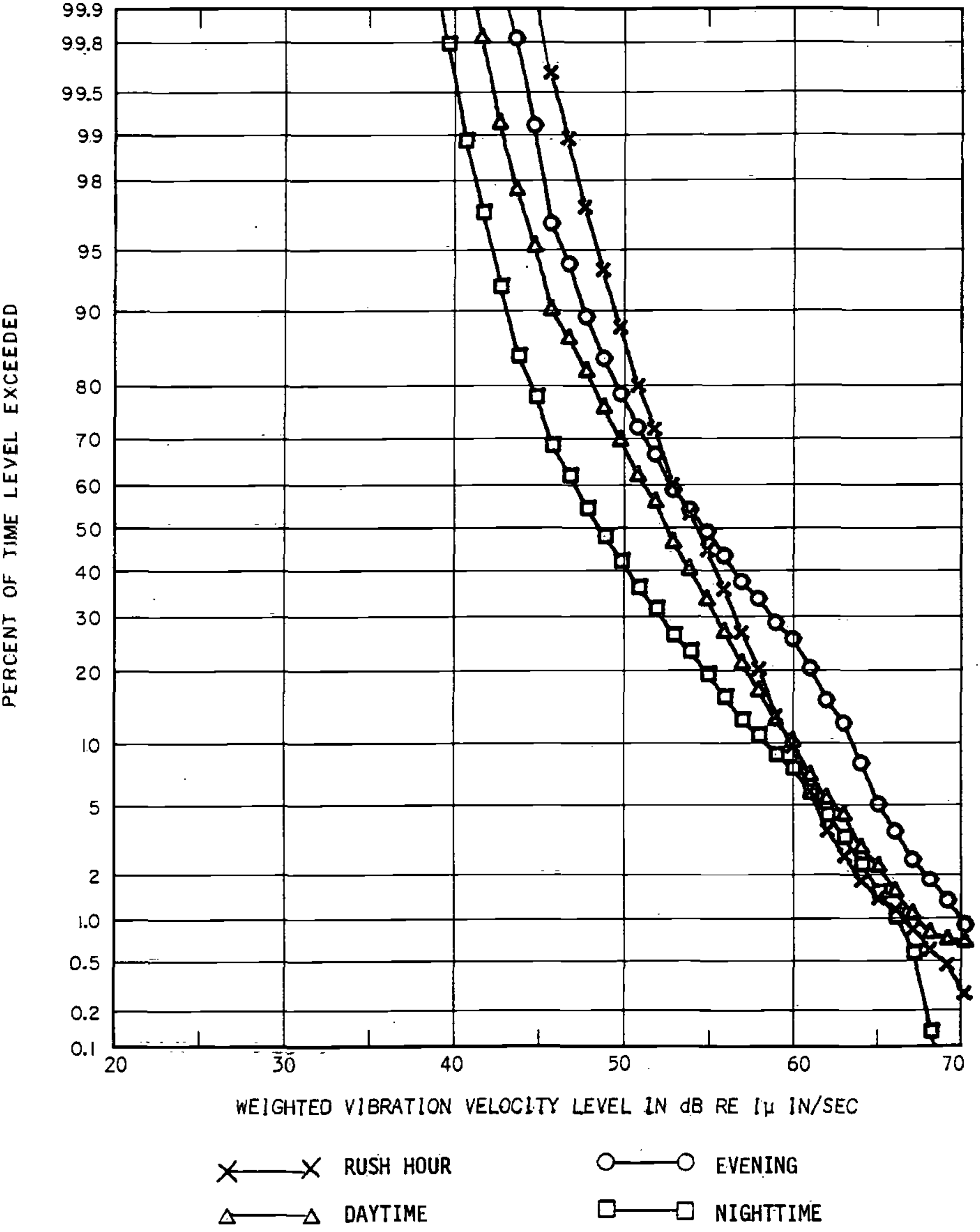

FIGURE B-43 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 43

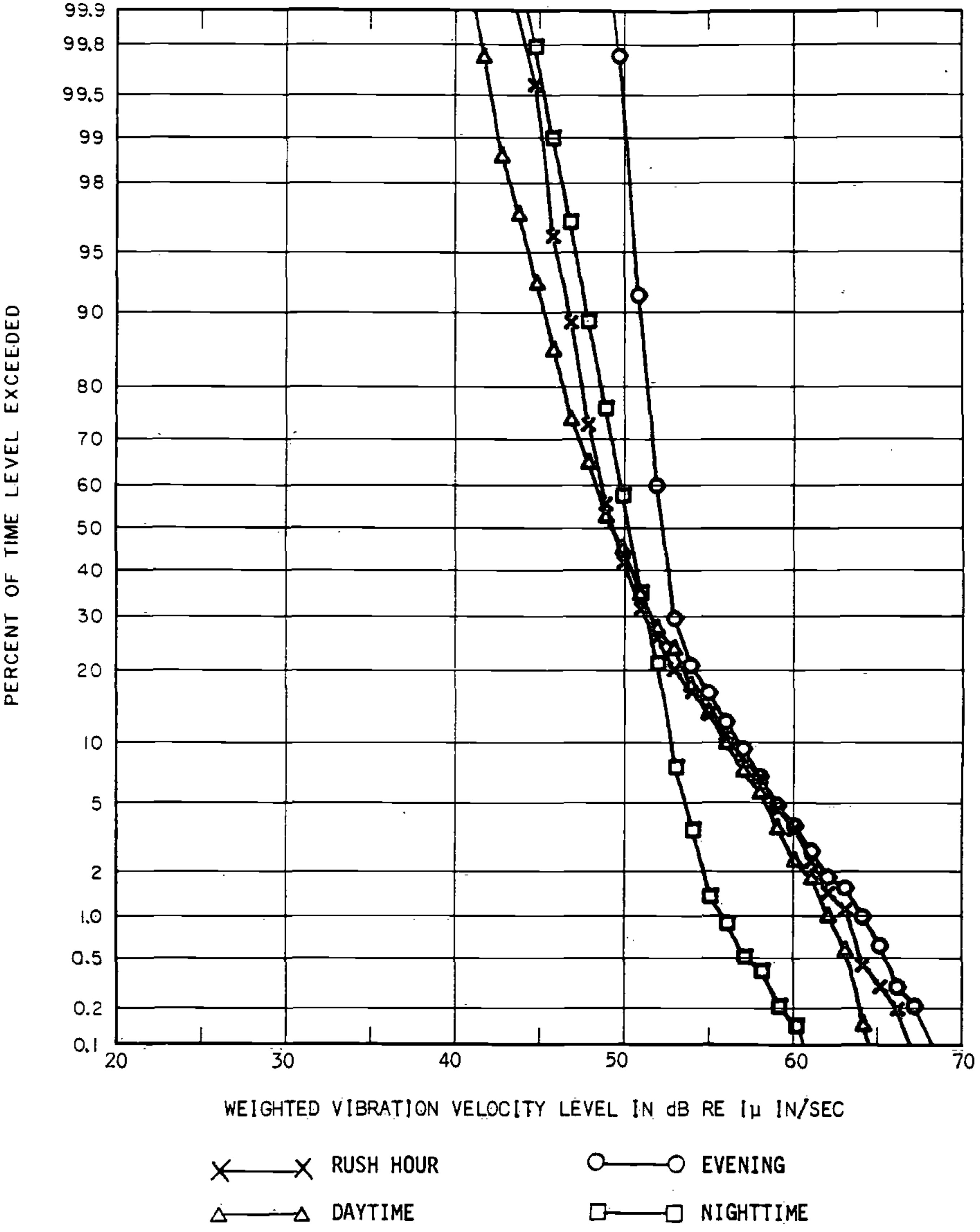

FIGURE B-44 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 44

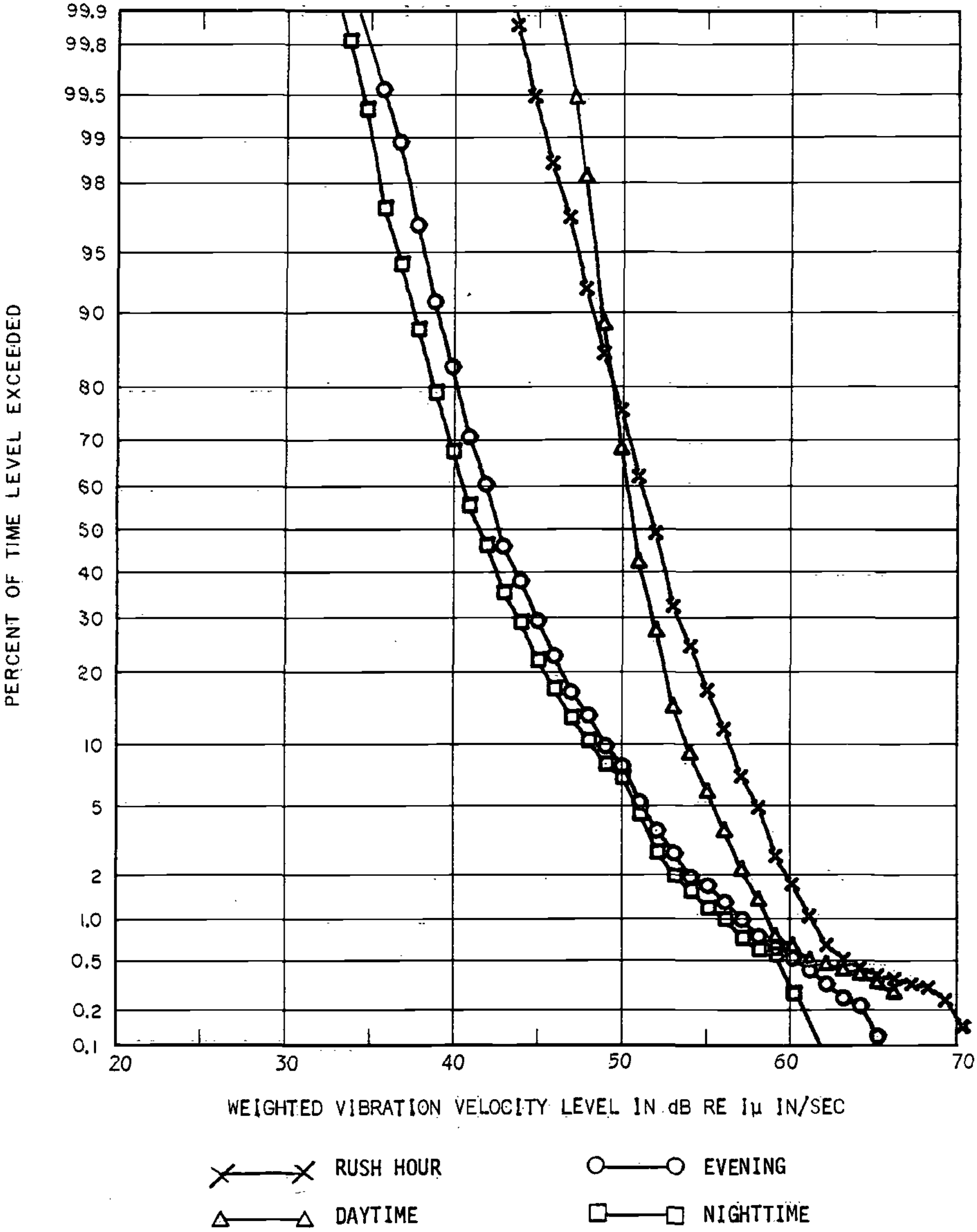

FIGURE B-45 STATISTICAL DISTRIBUTION OF THE WEIGHTED VIBRATION VELOCITY LEVELS AT LOCATION 45