Department of Energy

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208-3621

In reply refer to: BPA-2025-03257-F

July 30, 2025

SENT VIA EMAIL ONLY TO: LangloisJM@BV.com

Jennifer Langlois, M.L.S.
Librarian
Global Library/Market Insights
Black & Veatch
11401 Lamar Avenue
Overland Park, KS 66211

Dear Ms. Langlois,

This communication concerns your request for Bonneville Power Administration (BPA) records submitted to the agency under the Freedom of Information Act, 5 U.S.C. § 552 (FOIA). BPA received your records request on June 2, 2025. BPA formally acknowledged your records request on June 24, 2025, via letter to you. This communication is the agency's final response to your FOIA request.

Original Request
You seek, "…the Bonneville Power Administration Substation Noise Study that was published by Beranek & Newman in 1976. Below is the information from the BPA Library catalog. There appears to be a main document, and it states that the Appendices B and D are published separately. I would like a copy of those also, if possible."

Clarification
Via email exchanges with the agency on June 11, 2025, you amended the scope of your FOIA request as follows: "…the Bonneville Power Administration Substation Noise Study that was published by Beranek & Newman in 1976. I seek the main document, and the appendices. BPA need not release facility maps or photos of facilities which might provide enough information to detail BPA infrastructure weaknesses or vulnerabilities – information BPA is required to protect from public release. BPA may withhold certain specific information describing where substations are located and where critical equipment is positioned within a substation, including the location of transformers."

Thank you for your willingness to work with the agency to protect sensitive infrastructure information from public release.

Response
Knowledgeable Technical Information Specialist personnel in BPA's Library located the records responsive to your request. That record is the 541 pages of the 1976 Substation Noise Study for BPA published by Bolt, Beranek & Newman (the Study). That record was reviewed by Information Security Specialists in Personnel & Information Security, and by Mechanical Engineer personnel in Laboratories & Field Services, and by Supervisory Electrical Engineer personnel in Diagnostics, Metrology & Laboratories.

Based upon that review, and in light of our mutually agreed upon clarifications to your original request, the Study you seek accompanies this communication. A total of 138 pages have been withheld/redacted from the Study as "non-responsive". Additionally, where a section in the Study refers to the number of transformers at a site, that information was redacted as "non-responsive"; where a section mentions plans of adding reactors or transformers, that information was redacted as "non-responsive". BPA is here releasing a truncated 403 pages version of the Study.

Fees
No fees are associated with processing your records request.

Certification
Pursuant to 10 C.F.R. § 1004.7(b)(2), I am the individual responsible for the records search and response described above. Your records request is now closed with the agency's responsive records provided.

Appeal
The records release certified above is final. Pursuant to 10 C.F.R. § 1004.8, you may appeal the adequacy of the records search, and the completeness of this final release, within 90 calendar days from the date of this communication. Appeals should be addressed to:

Director, Office of Hearings and Appeals
HG-1, L'Enfant Plaza
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585-1615

The written appeal, including the envelope, must clearly indicate that a FOIA appeal is being made. You may also submit your appeal by e-mail to OHA.filings@hq.doe.gov, including the phrase "Freedom of Information Appeal" in the subject line. (The Office of Hearings and Appeals prefers to receive appeals by email.) The appeal must contain all the elements required by 10 C.F.R. § 1004.8, including a copy of the determination letter. Thereafter, judicial review will be available to you in the Federal District Court either (1) in the district where you reside, (2) where you have your principal place of business, (3) where DOE's records are situated, or (4) in the District of Columbia.

Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire about the FOIA mediation services they offer. The contact information for OGIS is as follows:

Office of Government Information Services
National Archives and Records Administration
8601 Adelphi Road-OGIS
College Park, Maryland 20740-6001
E-mail: ogis@nara.gov
Phone: 202-741-5770
Toll-free: 1-877-684-6448
Fax: 202-741-5769

Questions about this communication may be directed to James King, FOIA Public Liaison, at jjking@bpa.gov or at 503-230-7621.

Sincerely,

Candice D. Palen
Freedom of Information/Privacy Act Officer

BOLT, BERANEK & NEWMAN

SUBSTATION NOISE STUDY
FOR
BONNEVILLE POWER ADMINISTRATION

BOLT BERANEK AND NEWMAN INC

CONSULTING · DEVELOPMENT · RESEARCH

Report No. 3296
Job No. 10908

BONNEVILLE POWER ADMINISTRATION SUBSTATION NOISE STUDY

BPA Contract No. 14-03-6020N

Roger J. Sawley
Colin G. Gordon
Michael A. Porter

30 September 1976

Submitted to
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Submitted by
Bolt Beranek and Newman Inc.
21120 Vanowen Street
Canoga Park, California 91303

TABLE OF CONTENTS

Table of Contents (Concluded)

1.0 INTRODUCTION

There are approximately 300 substations in the Bonneville Power Administration (BPA) system in the States of Oregon and Washington. The BPA is concerned that the sound levels emanating from these substations be in compliance with the noise control regulations of these states and, towards this end, has issued Contract No. 14-03-6020N for an acoustical engineering study of 34 of these substations. Eighteen of the substations are located in Oregon and 16 in Washington. These selected substations are located primarily west of the Cascade Mountains although several are located in the eastern portions of both states. In addition, several substations are in the planning or early construction stages.

The study has been concerned entirely with the noise generated by transformers and shunt reactors. Impulsive and other intermittent noise sources have not been considered.

The objective of the acoustical engineering study has been twofold.

- First, the substations have been investigated to determine whether they are in compliance with the appropriate noise control regulations. Where the substations presently exist, noise measurements have served as the basis for the evaluation. Where they do not presently exist or expansion is planned, predicted behavior has been used as the basis.

- Second, for those substations found or predicted to be in violation of the regulations, recommendations have been developed for the correction of the problem in each case.

This report describes the results of the investigation of 33 of the substations. The other substation -- McLoughlin substation -- is the subject of a separate BBN Report, No. 3172, submitted to BPA in April 1976.

This report is organized in the following way.

- In Chapter 2 the findings and recommendations for each of the substations are summarized.
- In Chapter 3 the noise control regulations for the States of Oregon and Washington are presented and assessed in terms of reasonableness and the potential for change in the future.
- In Chapter 4 the methodology used in the field measurement program is discussed. Details of the instrumentation systems are given.
- In Chapter 5 the methods of analyzing and manipulating the field field data are described. Some basic results of the survey are presented and developed to provide a means for the prediction of transformer noise.
- In Chapter 6 the methods of transformer noise control are discussed. Computational techniques for the design of shielding barriers are presented. Information on material suppliers is provided.
- In Chapter 7 we provide a general summary of the terms, abbreviations and procedures used in preparing the individual substation reports.

The detailed reports for the substations are presented in Appendices A and C. Appendices B and D contain the computer printout sheets for the microsample data. Appendices A and B apply to substations in the State of Oregon; Appendices C and D apply to substations in the State of Washington.

2.0 SUMMARY OF FINDINGS

For substations in the State of Oregon, compliance testing has been based on the present State noise regulations. For substations in the State of Washington, we have used the present State regulations as the primary compliance standard. We have in addition tested for compliance against a secondary, stricter, standard which we feel might reasonably be introduced in future years.

Our findings as regards the need for noise control are as follows:

2.1 State of Oregon Substations

- Allston: The substation is currently in compliance with the noise regulations. Future residential developments could pose a 3 to 5 dB problem at 120 Hz.

- Alvey: The substation exceeds the regulations by 2 to 4 dB at 120 Hz. [redacted] to the problem. Noise control, however, may not be necessary in light of the high ambient levels generated by the nearby Interstate 5 Highway.

- Big Eddy: The substation is, and should remain, in compliance with the noise regulations.

- Chemawa: The substation is in compliance with the regulations. Future residential developments could pose a 9 dB problem at 120 Hz. Treatment would be required of [redacted].

- Clatskanie: The substation is, and should remain, in compliance with the regulations.

- DeMoss: The substation is in compliance with the regulations. No pressure for residential developments can be foreseen which would alter this situation.

- Gold Beach: A 5 dB compliance problem at 120 Hz is indicated. This is largely due to the Coos-Curry transformer however. Treatment of the BPA transformer would be warranted only as part of a collaboration program with the Coos-Curry Cooperative.

- Keeler: The substation (with treated shunt reactors) is currently only marginally in default of the noise regulations. A simple noise barrier on Bank 1 would remove the problem. Future residential developments are likely however. These could create compliance problems of up to 12 dB at 120 Hz, requiring (in the limit) treatment of [redacted]

- LaGrande: The BPA transformer by itself is in compliance with the regulations. In combination with the CALPAC and IPC transformers, a non-compliance situation of about 4 dB at 120 Hz is created. Future residential developments could create a problem requiring the collaboration of all three supply authorities in developing noise controls.

- Lane: The substation is in compliance with the regulations. Future residential development could create a 6 dB problem at 120 Hz. Treatment would then be required on [redacted]

- Lyons: The application of the non-degradation clause in the regulations could pose a 17 dBA problem at the closest existing residence. A total wall enclosure would be necessary. The problem would be substantially less severe if the non-degradation clause were to be waived. In this case a simple L-shaped barrier would provide an adequate solution.

- <u>Marion:</u> It is predicted that the substation will be in compliance with the regulations [redacted] Future residential developments which would change this situation are not anticipated.

- <u>McNary:</u> The substation is currently in compliance with the regulations. A future problem of 5 dB at 120 Hz could arise in the event of residential developments on the closest privately owned land. Treatment would be required of [redacted]

- <u>Oregon City:</u> Based on an ordering specification of 84 dBA (NEMA), we anticipate a 6 dB problem at 120 Hz for present and future residential properties. The problem could increase to 10 dB at 120 Hz given the worst future development situation. A full height barrier should be planned.

- <u>Santiam:</u> The substation is in compliance with the regulations. Future residential developments which would change this situation are not anticipated.

- <u>Toledo:</u> The substation is in compliance with the regulations. Future residential developments which would change this situation are not anticipated.

- <u>Walnut City:</u> The substation is in compliance with the noise regulations but only when the cooling fans are not operating. It is not anticipated that tonal noise [redacted] will alter the compliance situation. However, given the possibility that the transformer could be noisier than anticipated or that future residential developments could occur directly to the east of the BPA property line, a compliance problem could arise.

2.2 State of Washington Substations

- Aberdeen: The substation is in compliance with the present noise regulations. It could be in default of the secondary standard by 10 dBA. Future compliance would require treatment [redacted]

- Covington: This substation is currently in compliance with the State Regulations. When tested for compliance with the secondary standard, a default condition of 5 dBA is indicated. A solution would require treatment [redacted]

- Custer: This substation is, and should remain in compliance with the present regulations. An 8 dBA problem would arise given the secondary standard. [redacted].

- Fidalgo: The substation is in compliance with both primary and secondary noise standards. It should remain in compliance [redacted].

- Fishers Road: The substation is in default of the present noise regulations by 3 dBA. A 13 dBA problem would occur given the secondary noise standard. Future residential developments are likely which would exacerbate the problem.

- Four Lakes: The substation is in compliance with the present noise regulations, and also with the secondary noise standard. Future residential developments could pose problems, but these are considered unlikely in the foreseeable future.

- Maple Valley: Even when judged on the basis of the secondary standard, no problem arises. [redacted] However, a compliance problem of 4 dBA could arise in the event of future residential developments.

- Mill Plain: The substation is in compliance with the present noise regulations. However it is in default of the secondary compliance standard to the extent of 10 dB at 120 Hz. A three-sided barrier would be required to achieve compliance.

- Olympia: The substation is in compliance with the present noise regulations. Future developments are considered unlikely to occur which would alter this finding. Judged on the basis of the secondary compliance standard, a problem of 6 dBA is foreseen. This would be resolved by treatment [redacted]

- Port Angeles: The substation is in compliance with the present noise regulations. It should remain so when the new Bank 4 is energized. Based on the secondary noise standard, a compliance problem of 6 dBA is anticipated. Treatment [redacted]

- Ritzville: The substation is in compliance with the present noise regulations. A 6 dBA problem arises with regard to the secondary standard. The Washington Water and Power Company is also a significant contributor to the noise environment.

- J. D. Ross: The substation is in compliance with the present noise regulations. Judged on the basis of the secondary standard a 10 dBA problem arises. Future residential developments are unlikely which would change this situation.

- Sifton: The substation should be in compliance with the existing State regulations and with the secondary compliance standard when the new transformer is energized. A 10 dBA problem with respect to the secondary standard could arise in the event of future residential developments close to the BPA property line.

- Snohomish: The substation is in compliance with the present noise regulations. An 8 dBA problem arises with respect to the secondary standard. [redacted]

- Sno-King: The substation is in compliance with the present noise regulations. A marginal default situation arises (3 dBA) when the substation is judged by the secondary standard. It is considered unlikely that there will be a need for noise control.

- Thayer Drive: The substation is in compliance with the present noise regulations. A reduction of 8 dBA would be required to produce compliance with the secondary standard, however. Treatment would probably be required on [redacted].

3.0 NOISE REGULATIONS AND SPECIFICATIONS

The States of Oregon and Washington have both enacted noise control regulations pertaining to industry and commerce. Although the regulations enacted by the two states differ substantially, both in the allowable noise level limits and in the complexity of procedure to demonstrate compliance, neither regulation establishes limits on the level of noise that may be generated at the source. The regulatory limits apply only to the noise levels received at identified nearby noise sensitive locations. These limits are described and interpreted in that which follows.

3.1 State of Oregon Noise Control Regulations

In September 1974, the Environmental Quality Commission of the State of Oregon, adopted Noise Control Regulations. These regulations appear as Sections 35-005 through 35-100 of the Oregon Administrative Rules Compilation. These rules, as they would apply to transformer noise in substations, can be summarized as follows.

The regulations recognize the time variability of environmental noise situations and use statistical noise levels,--levels which may be exceeded for a stated percentage of the time--as the basis for control. Control is exerted at the one, ten, and fifty percentile levels. The regulations are applicable to industrial and commercial noise sources in their influence on "Noise Sensitive Properties". Noise level limits are defined which apply to a position 25 feet towards the source from the noise sensitive *building*, or to a position on the building property line nearest the source, whichever position is furthest from the noise source.

In the case of a designated "Quiet Area" noise level limits are assigned to the boundaries of the area. However, if the noise source lies within the "Quiet Area" the limits are then assigned to a distance of 400 feet from the noise source.

To the best of our knowledge none of the substations studied lies close to designated "Quiet Areas". The applicable rules therefore are these assigned to "Noise Sensitive Properties" (buildings).

The basic limitation for existing or new noise sources is in terms of the A-weighted sound pressure level (dBA) of the source, at the one, ten, and fifty percentile levels. However there is also a "nondegradation clause" which applies to new sources on property previously unoccupied by noise sources; this clause limits the noise increase caused by the new source to no more than 10 dBA at the ten and fifty percentile levels. It is our interpretation that this clause would not apply to an existing substation switchyard upon the introduction of a transformer bank (e.g., Marion), but that it would be applicable to a new substation such as Lyons where no electrical equipment existed previously.

Furthermore, the regulations allow the Director of the Department of Environmental Quality to set limits on the octave band spectrum levels and on the intensity of tonal components using the one-third octave band spectrum generated by a noise source, when he has cause to believe that the defined A-weighted noise level limits will not adequately protect the health, safety, or welfare of the public. It is our belief that the Director will apply these additional rules to substation transformers because of the discrete frequency nature of the noise generated by them. These rules apply at the ten percentile level of noise only.

The limits on tonal components are defined in terms of the one-third octave band spectrum, again at the ten percentile level. As applied to transformers, the sound pressure level in the 125 Hz band should not exceed the average of the ambient levels in the adjacent bands (centered on 100 Hz and 160 Hz) by more than 15 dB unless the level in the 125 Hz band is ten decibels or more below the allowable 125 Hz octave band level. In the frequency range encompassing the 240 Hz and 360 Hz components of transformer noise, the limits on the extent to which the appropriate one-third octave band frequency can exceed the average of the two adjacent bands is 8 dB unless, as before, the peak frequency component level lies 10 dB or more below the allowable octave band level. For frequencies of 500 Hz and above, the allowed excess is reduced to 5 dB.

These regulations, as they apply to transformer discrete frequency noise at nighttime, are summarized in Table I.

We understand that it is the policy of the Department of Environmental Quality of the State of Oregon to apply these regulations only in situations where complaints are received. Exceptions or variances to the noise regulations may be granted under certain conditions, but for a limited period of time only.

3.2 State of Washington Maximum Environmental Noise Levels

Maximum environmental noise levels were adopted by the Department of Ecology of the State of Washington in April 1975, as Chapter 173-60 of the Washington Administrative Code.

TABLE I. NOISE REQUIREMENTS--USED IN SUBSTATION COMPLIANCE ANALYSES (Applicable to tonal noise from transformers operating at nighttime)

Function	Percentile	Level	Washington (Primary)	Washington[1] (Secondary)	Oregon
Nondegradation (total noise)	50	L(A)$\leq$	-	-	L_{50} + 10 dBA
	10	L(A)$\leq$	-	-	L_{50} + 10 dBA
Noise Level Limits (substation noise)	1	L(A)$\leq$	-	-	60 dBA
	10	L(A)$\leq$	-	-	55 dBA
	50	L(A)$\leq$	57 dBA	42 to 47 dBA[3]	50 dBA
Octave-Band Limits (substation noise)	10	L(125)$\leq$	-	-	46 to 56 dB[3]
	10	L(250)$\leq$	-	-	40 to 50 dB[3]
	10	L(500)$\leq$	-	-	36 to 46 dB[3]
1/3 Octave-Band Limits (total noise)	50/10[2]	L(125)<	-	15 + [L(100) + L(160)]/2	
	50/10	L(250)<	-	8 + [L(200) + L(315)]/2	
	50/10	L(400)<	-	8 + [L(315) + L(500)]/2	
	50/10	L(500)<	-	5 + [L(400) + L(630)]/2	

(1) Derived from Seattle/King County Draft Ordinance.

(2) 50% levels assumed for Washington; 10% levels specified by Oregon.

(3) Dependent upon compliance with one-third octave band limits.

The allowable levels in any instance are defined in terms of what is termed the "Environmental Designation of Noise Abatement" (EDNA) for the type of source and for the type of receiving property. The requirements on residential-type sources as they affect residential-type receivers are the most severe. Based on discussions with the State Department of Ecology, it would seem to be their view that substations should be categorized as commercial-type sources (EDNA Class B), the noise level limitation on the influence of such a source on residential properties being simply 57 dBA. BPA is seeking permission from the State to classify their substations as industrial (EDNA Class C) sources. This would increase the noise limitation to 60 dBA. In this report however we will use the lower (commercial source) limitation as the primary standard in assessing compliance with noise regulations. Electrical substations are *specifically exempted* from a 10 dBA reduction in allowable level imposed on sources which operate between 10 p.m. and 7 a.m.

The Washington Code does not use the normal convention of statistical levels in allowing for time varying environmental conditions. The code does have a clause which allows noncontinuous sources to exceed the "base" level by a specified number of decibels for a specified number of minutes in any one hour. The implication is that the noise level changes covered by this clause are not statistically random in nature but, rather, reflect discrete changes in the levels generated by the noise source. It is not possible to express the level variation allowed by this clause in terms of conventional statistical levels without involving the "zero percentile" level (i.e., the level which is never exceeded), and this level has no meaning statistically.

Fortunately, in the case of substation transformers, the standard deviation of the level fluctuations are small. Therefore the problem of statistical definition can be neglected. Since the code is obviously designed to be implemented using "average" meter readings, the limiting level of 57 dBA can be interpreted simply as the fifty percentile level of the measured noise.

The Washington Code does not contain a nondegradation clause.

In spite of the nighttime exemption, the code does not "... preclude the Department from requiring installation of the best available noise abatement technology consistent with economic feasibility. ...". We understand from the Department that, in this context, Puget Sound Power and Light Company have agreed to base their future substation designs on a limiting level of 45 dBA; this level corresponds to that allowed from a "domestic" source as it influences "domestic" receivers, with the nighttime penalty applied.

The noise limits defined in the code are intended to apply *at all points on and within the boundary of the receiving property.* It is the State's policy that the code shall be applied only upon receiving a complaint. The granting of variances is for a limited period only and the encroachment of residential properties upon land adjacent to an existing substation is unlikely to be accepted as a reason for noncompliance. The Code does not preempt existing local government "nuisance regulations". Neither does the Code preempt local government from imposing its own (more stringent) noise control regulations *as long as these are approved by the State.*

In spite of the views to the contrary expressed by the State Department of Ecology, we are of the opinion that the Washington State Regulations will be made more stringent in the future. Already the Seattle City and King County Departments of Public Health have jointly put forward proposals to the State of Washington for a City/County Noise Ordinance.

The draft Noise Ordinance proposed by the joint councils differs from the State of Washington Code in several important aspects -- insofar as it is likely to affect substation transformer noise.

First, the proposed noise ordinance introduces a "suburban" category which requires levels of noise lower than those covered under the "residential" category. Thus, if the substation were to be accepted as a commercial zone within a general area zoned as suburban, the maximum noise level allowed would be 55 dBA as opposed to the 57 dBA level imposed by the State. The draft ordinance does not exempt electrical substations from the nighttime reduction of 10 dBA and imposes a further 5 dBA reduction in level upon sources having a "pure tone" character. The definition of "pure tone" character is the same as that used in the Oregon Noise Control Regulations, although the percentile level at which it should be evaluated is not specified. We shall assume the fifty percentile level. The draft ordinance is similar to the State Ordinance in its treatment of noncontinuous sources.

It is our opinion that the State will not accept without some modification, the draft version of the Seattle/King County Ordinance that was made available to us--dated May 29, 1975. (We understand in fact, that a revised final draft has been presented to the State for its approval.) For example, it seems unlikely that the State will accept the need for the suburban classification. At the same time, it seems reasonable that the removal of the nighttime exemption for substations should be approved. The imposition of a "pure tone" penalty would also appear reasonable on the basis of current environmental evaluation practices; thus, this may also be accepted by the State.

The Seattle/King County Ordinance is likely, therefore, to impose a limit ranging from 42 to 47 dBA depending upon the compliance of a one-third octave band spectrum with the "pure tone" definition.

The Seattle/King County Ordinance allows the full force of the noise regulations to be imposed even in the absence of complaints. Since the ordinance will be administered by the combined councils and not by the State, it seems reasonable to assume that the State will approve this change. Variances may be granted, but only temporarily.

Only two substations included in the BPA survey lie within the jurisdiction of the Seattle City/King County Councils. However we are of the opinion (in spite of the views expressed by personnel in the State Department of Ecology) that the State Regulations will be made more exacting in the future. The draft ordinance of the Joint Councils would seem to indicate the form that these changes might take. We shall therefore use the levels of 42 dBA and 47 dBA, *in addition to the current State level of 57 dBA*, in evaluating all those substations in the State of Washington.

The levels and requirements used by us for compliance testing in the State of Washington are summarized in Table 1.

3.3 General Comments on Regulations

An important part of BBN's task in this study is to provide BPA with guidance as regards the present form and likely future trends of State and Local Government regulations for the control of environmental noise. In addition, of course, we must take into account the desirability of not only satisfying the law but also of maintaining good relationships with individuals and communities who might be annoyed by substation noise.

In the two previous sections of this chapter we have outlined the major provisions of the State of Oregon and State of Washington noise regulations, and have arrived at modifications to the State of Washington regulations which we feel might reasonably be introduced within the next few years. We have proposed, therefore, in the case of those substations in the State of Washington to make our compliance analyses at the present regulation level and also at a secondary (more stringent) level.

In fact the limits proposed as a secondary compliance test for the State of Washington are not inconsistent with current practice in environmental noise regulation; nor are they inconsistent with those limits currently in use in the adjacent State of Oregon.

For instance, we understand from the Washington State Department of Ecology that a limit of 45 dBA has been agreed informally between them and the Puget Sound Power and Light Company for future PSPL substations. This level is consistent with the 42 to 47 dBA range selected as the secondary compliance standard.

Evident from our substation analyses is the fact that the controlling clause in the State of Oregon regulation is that restricting the octave band spectrum at the ten percentile level. As applied to the primary tonal components at nighttime, this effectively imposes a limit in the range 40 to 45 dBA depending upon the tonal composition. In an environment dominated by transformer noise, the ten percentile level lies within one or or two decibels of the fifty percentile level; thus the limit at the fifty percentile (or average) level becomes effectively 38 to 43 dBA. Thus the secondary compliance standard selected for the State of Washington is consistent with the State of Oregon regulations also.

Finally, a review of the general literature on environmental standards shows substantial agreement in setting an upper limit at nighttime, to achieve a normally acceptable environmental situation, of 50 dBA at the fifty percentile level; this is for broadband noise with no singularly annoying characteristics. Moreover, practice would suggest that this level should be dropped to 45 dBA for a noise situation containing significant tonal components. These design levels would appear to be suited to suburban-residential situations. Rather higher levels could be permitted in urban situations; somewhat lower levels would be desirable in rural areas.

4.0 FIELD MEASUREMENT PROGRAM

The main field measurement program was carried out over the period of 26 February to 1 April 1976. Two further visits were made in May to collect additional data on certain substations. The main schedule of substation visits is shown in Table 2.

The schedule typically involved visiting two substations each day and recording the microsample data at each during the subsequent night. We were fortunate in that the weather conditions during the field measurements were generally good. There were only a few occasions on which the schedule had to be modified because of weather. On one occasion (Covington) the theft of a microsampler system required program revision.

The purpose of the field measurement program, as it applied to each substation, was to acquire sufficient data:

a) To allow the substation to be tested for compliance with the relevant noise regulations from the point of view of both present and future developments, and

b) To allow the individual source contributions to be quantified so that, in the event of noncompliance, the necessary noise control treatments could be determined.

The principal elements of each field survey were as follows:

a) On each bank of transformers, "direct read" data were acquired of the levels of the first four transformer harmonics (120 Hz, 240 Hz, 360 Hz and 480 Hz) at a

TABLE 2. SCHEDULE OF PRINCIPAL FIELD VISITS TO SUBSTATIONS

SITE \ DAY	Feb. 25	Feb. 26	Feb. 27	Feb. 28	Feb. 29	Mar. 1	Mar. 2	Mar. 3	Mar. 4	Mar. 5	Mar. 6	Mar. 7	Mar. 8	Mar. 9	Mar. 10	Mar. 11	Mar. 12	Mar. 13	Mar. 14	Mar. 15	Mar. 16	Mar. 17	Mar. 18	Mar. 19	Mar. 20	Mar. 21	Mar. 22	Mar. 23	Mar. 24	Mar. 25	Mar. 26	Mar. 27	Mar. 28	Mar. 29	Mar. 30	Mar. 31	Apr. 1
J.D.Ross									—	—																											
Mill Plain																												—	—								
Sifton																											—	—									
Fishers Rd.									—	—																											
Keeler	—	—																																			
Mc Loughlin										—	—																										
Oregon City										—	—																										
Walnut City													—	—																							
Allston											—	—																									
Clatskanie											—	—																									
Chemawa														—	—																						
Marion												—	—																								
Lyons												—	—																								
Santiam														—	—																						
Toledo													—	—																							
Lane															—	—																					
Alvey															—	—																					
Gold Beach																—	—																				
Big Eddy																				—	—																
De Moss																				—	—																
La Grande																					—	—															
Mc Nary																					—	—															
Thayer Dr.																						—	—														
Ritzville																							—	—													
Four Lakes																							—	—													
Olympia																																				—	—
Aberdeen																																				—	—
Pt. Angeles																																			—	—	
Covington																														—							
Maple Valley																														—	—						
Sno - King																															—						
Snohomish																																—	—				
Fidalgo																																		—	—		
Custer																																		—	—		

distance of 10 ft from the hypothetical line encompassing the tank (or tanks, in the case of three, single phase units) of the transformer. In most instances, between 5 and 7 measurement "areas" were selected. Within each measurement area, the maximum level obtained by moving the microphone "back and forth" along the hypothetical line of measurement was the level recorded. In this way the recording of local pressure nodes (due to phase cancellation) was avoided. All measurements were taken at a height of 4 to 5 ft above ground level. A typical data sheet is shown as Fig. 1.

b) Short tape recorded samples (about 10 seconds duration) were acquired at positions around the perimeter fence of each substation containing one or more transformers. Depending upon the size of the substation, these samples were taken at spatial intervals of between 50 and 200 ft. For each sample, the microphone position was fixed at a height above ground level of about 4 ft. These perimeter data were analyzed in the laboratory in terms of the first four harmonic components of the transformer noise.

c) Magnetic tape samples varying in duration from 5 to 15 minutes were taken at positions outside the substation representative of present and future residential developments. These tape samples were subsequently analyzed in the laboratory to obtain the levels of the principal tonal components of the transformer noise, and, if necessary, other characteristics of the noise environment. The major purpose of these data was to quantify the typical levels of transformer noise in the areas of potential complaint. In some instances "direct read" data in one-third octave bands of frequency were taken also. A typical data sheet is shown as Fig. 2 .

d) A long term "microsample" recording* was obtained at a "typical" position, generally outside the substation, for the prime purpose of establishing the nature of the normal nighttime noise ambient in the vicinity of the substation. The microsample record was analyzed statistically in terms of its one-third octave band and A-weighted overall sound pressure level characteristics for each hour of the time period 1800 to 0600 hours. A typical computer output sheet presenting these results is shown as Fig. 3.

Additional data, over and above the data elements described above, were obtained at certain substations--dependent upon the circumstances. In several instances, "live read" data in one-third octave bands were taken at perimeter and external positions to augment the tape recorded data. In some instances, data were acquired at a number of different distances from a spatially isolated transformer bank in order to study the typical rate of sound level reduction with distance from the bank.

The instrumentation systems used for data acquisition in the field and for laboratory analyses are shown schematically in Figs. 4 and 5.

---

* Microsample refers to a temporal sampling technique of analogue data acquisition. The method records 1.5 seconds of data every 30 seconds of real time.

5.0 DATA MANIPULATION TECHNIQUES, ANALYSES, AND PREDICTIONS

We have found in this study that in almost all instances the compliance of a substation with existing or projected noise regulations depends solely upon the tonal noise components produced by the transformer core and radiated from the transformer tank and from its fittings. We have found, also, that the problem is usually controlled by the 120 Hz (fundamental) component; certainly the problem can be adequately defined by examining the tonal components at 120 Hz, 240 Hz, 360 Hz and 480 Hz.

It was not possible in the field survey to acquire data at all positions representing existing or future residential properties. Thus, in interpreting the field data it has been necessary to manipulate these data to provide a basis for extrapolation (or interpolation) to other distances. In situations involving multiple banks of transformers it has been necessary to use such techniques also to provide a basis for identifying the particular source (or sources) requiring noise control treatments.

Manipulation of the field survey data has been desirable for yet a further reason. Tonal (discrete frequency) noise, generated by a spatially distributed source or by a multiplicity of sources, can exhibit substantial variations of level with spatial position due to phase cancellation and augmentation effects. Our field survey techniques around and outside each substation did not allow maximum tonal levels to be searched out and recorded, as they were in the case of the close-in measurements. Data manipulation has therefore provided us with a basis on which to check the validity of the community measurement data.

Finally, the study has involved the prediction of community noise levels arising from transformers which are yet to be installed and energized. The NEMA TRI Standard does not provide a basis on which to predict tonal components. We have therefore processed the data gathered in our studies to provide a method for estimating the noise of new installations.

5.1 Data Normalization Techniques

In processing the field data we have chosen to "normalize" the data to a distance from the source (or sources in the case of widely separated transformer banks) of 500 ft.

5.1.1 Close-in data

We have assumed that the "walls" of the transformer are the major source--i.e., that the lid can be neglected (see Section 6.3). The results are normalized using the expression,

$$SPL_N = SPL_c + 10 \log [S_W] - 10 \log [2\pi(500^2)] ,$$

where SPL_c is the average sound pressure level measured at each of the tonal frequencies and S_W is the wall measured area (in sq ft) given by the measurement perimeter multiplied by the tank height. We assume that in the far-field (i.e., at 500 ft), the radiation may be represented by the hemispherical area. The "equivalent" A-weighted levels, at the close-in distance and at the 500 ft distance are computed from the tonal levels.

Since the close-in levels are a measure of the maximum levels recorded around the transformer, we would expect that the normalizations would overestimate the average far-field performance, especially at the higher frequencies where a pronounced "lobal" pattern occurs close to the tank.

5.1.2. Perimeter data

In situations involving a well-defined source center, normalization of the perimeter data is straightforward. In situations involving well-separated sources, it has been necessary to separate the perimeter data into groups that can definitely be associated with one or other of the sources. Normalizations are made using the relation

$$SPL_N = SPL_p + 10 \log [2\pi d^2] - 10 \log [2\pi(500)^2]$$

where d is the distance (in ft) between the perimeter position and the dominant source. The normalizations are based therefore on hemispherical spreading. We have averaged the normalized perimeter levels (SPL_p) associated with each identified source. The A-weighted levels are compiled from the tonal levels. Those perimeter positions shielded from direct view of the source have been omitted from the analyses.

5.1.3 Community data

The community data are normalized in the same way as are the perimeter data.

5.2 Data Analyses and Correlations

In analyzing the combined normalized field data we have made no attempt to use other than the simplest statistical techniques.

5.2.1 Close-in transformer noise

Close-in data have been acquired on thirty-three, three phase transformers and on twenty-nine single phase transformers. The "equivalent" normalized A-weighted noise levels are shown in Fig. 6 plotted as a function of the *maximum MVA rating for each transformer bank* (see Section 5.4). Thus, some of the transformers at the lower ratings are "naturally" cooled whilst at the upper ratings most of the transformers are two stage "forced oil and air" cooled.

Three transformers in the population are much quieter than the rest. One of these is the partially enclosed unit at Walnut City. The other two are Big Eddy Bank 8 and the Clatskanie transformer. These three have been neglected in a regression analysis of the data.

We find, somewhat unexpectedly, that the population of three phase transformers, the population of single phase transformers, and the total combined population, have the same "best fit" regression line and that this is given by the expression

$$L_{(500)} = 29.7 + 8.2 \log (\mathrm{MVA}) \quad .$$

The fact that the "exponent" of the MVA rating is less than unity (0.82) is probably explained by the increased cooling capacity used on the larger power transformers. Our calculations show that the standard deviation on the regression line at the mean rating is about 3 dB.

5.2.2 Relative strength of pure tones

It is convenient to express the sound pressure level of each of the first four transformer tones in relation to the combined A-weighted noise level in the form,

$$\mathrm{SPL}(f) = \mathrm{dBA} + K(f)$$

Based on the close-in measurement data we have arrived at the values of K(f) for different categories of transformer. These values are given in Table 3. The values of standard deviations (based on a Gaussian distribution) are also given. Certain transformers which are substantially different from the "norm" are excluded from these analyses.

By using sub-categories, rather than treating the whole population as one category, the standard deviations are significantly reduced. These results suggest a greater degree of tonal spectrum variation in the single tank three phase transformers than in the three tank single phase banks.

5.2.3 Correlation with far-field data

The analyses presented above are based entirely on the normalization of the results of the close-in measurements on each transformer. The question remains as to whether the A-weighted noise levels and tonal spectra discussed above are representative of those that would be found at a greater distance from each transformer bank. The measurement methodology used in the close-in-survey in which the maximum levels at each tonal frequency were measured, leads one to suspect that the close-in data might overestimate the more distant levels especially at the higher frequencies where the lobal structure close to the transformer is pronounced.

We have compared the normalized close-in data and the normalized perimeter data for a number of substations in which a single source center can be reasonably defined. We find the following differences, *on average*

Three Phase Banks

HV(kV)	Rating(MVA)	No.	K_f	120	240	360	450(Hz)
230	15 to 280	11[(1)]	Av.	+5.9	+2.3	+1.2	-2.8
			s	3.6	3.8	2.5	2.6
115	6 to 83	19[(2)]	Av.	+11	+2.5	-3	-5
			s	4.0	3.6	3.5	4.0

Single Phase Banks

HV(kV)	Rating(MVA)	No.	K_f	120	240	360	480(Hz)
500	900 to 1600	9[(3)]	Av.	+10.5	+4	-1.6	-3
			s	2.6	1.6	2.5	2.1
345	600	5	Av.	+ 9.5	+7.3	-3.8	-3
			s	3.9	1.3	2.2	1.0
230	75 to 250	11	Av.	12.8	+1.6	-0.5	-4.7
			s	1.9	4.0	2.8	2.0
115	40 to 125	3	Av.	+14	+4	-5.3	-9.2
			s	1.5	1.7	2.5	3.0

(1) Excluding Sno-King #1, Lane #2
(2) Excluding Walnut City #1.
(3) Excluding Alvey #5.

TABLE 3. TONAL COMPOSITION OF TRANSFORMER NOISE FROM CLOSE-IN MEASUREMENTS (Average and Standard Deviation of K_f, see text)

dBA	120 Hz	240 Hz	360 Hz	480 Hz
-4	0	-4	-9	-11

The standard deviation on these differences is about 3 dB. The negative sign indicates that the far-field data are less than would be supposed based on extrapolation of the close-in measurements.

These results suggest that *on average* the correlation between close-in and more distant measurements is good at 120 Hz, but that the close-in data increasingly overestimate the more distant situation at the higher tonal frequencies. Since these generally contribute to the A-weighted level of the core noise, the dBA level is also overestimated.

5.2.4 Spatial variation of level

The tonal nature of transformer noise is such that considerable variations can occur in level as the spatial position of measurement is varied whilst maintaining a fixed distance from the source. The effect is the combined result of directivity influences and of wave interference effects; the tonal radiation from a transformer is strongly coherent. Based on analysis of a few perimeter surveys, we find typically a standard deviation of about 6.0 dB for each of the four lowest tonal components.

5.2.5 Comparison with other studies

The Empire State Electric Energy Research Corporation (ESEERCO) has recently completed a study in which the tonal radiation characteristics of three-phase transformers (20 to 400 MVA) were studied in great detail. It is our understanding that our findings in this study are fairly consistent with the ESEERCO results, notwithstanding the relatively low degree of sophistication used in our measurement techniques and in our data analyses methods.

It must be cautioned that the findings presented above are by no means rigorously developed. We feel however that these analyses may serve as a useful guide to BPA in the prediction of the tonal noise radiation from substation transformers.

5.3 New Transformer Predictions

In this study we have considered the consequences of new transformer installations at five substations. The procedure that we have chosen to adopt is as follows.

In the case of transformers for which no specific noise level guarantees, other than NEMA TRI values, are to be given we derive 500 ft levels in accordance with the regression curve of Fig 6 and the tonal composition of Table 3. -- using the appropriate high voltage rating. In the case of the new bank at Lyons Substation we have assumed that it will perform like a 500 kv unit.

In the case of transformers for which a low guaranteed noise level is to be given (e.g., Maple Valley Bank 2) we have normalized this level to a distance of 500 ft -- using the approximate NEMA measurement area -- and assigned a tonal spectrum in accordance with Table 3.

We have in no instance made use of the "far-field" correction values discussed in Section 5.2.3 on the basis that these are not well proven. As a consequence we may overestimate the higher frequency tonal components - but these rarely play a significant part in the compliance analyses anyway.

Usually, in the case of substations in which an additional transformer is to be introduced we have based our impact assessment upon comparison of the close-in normalized levels for the existing units and for the new unit. Thus any influence of far-field correction effects should be accounted for -- assuming that these effects are similar for the existing and for the new transformer. We have not used this technique however in the case of the Walnut City Substation since we consider the existing bank to be very untypical.

We have based our assessment for the new shunt reactor bank at Marion Substation on the NEMA standard level and upon the average tonal characteristics for the shunt reactors at Covington and Keeler Substations (prior to the fitting of the wall enclosures) and at Alvey Substation. Since the Marion shunt reactor bank will be a three tank unit these estimates may well be in error.

As an example let us consider the various methods of predicting the noise generated by the 1600 MVA, 500 kV three-tank bank due to be energized at Maple Valley substation.

Figure 6 suggests that, on average, this transformer will generate close-in levels consistent with a normalized level (at 500 ft distance) of 56 dBA. Applying the corrections for tonal composition given in Table 3 we arrive at the levels in Row (a) below. To more truly reflect far-field levels, we should probably apply the corrections given in Section 5.2.2. The result is given in Row (b) below.

The Maple Valley transformer, however, has been ordered at a specification level 8 dBA below the NEMA standard level (which is taken to be 92 dBA for this unit). According to the manufacturer, the transformer has been measured in his facility at a level close to 80 dBA which is even lower than specification.

The average NEMA measurement surface area, per phase, for this bank is estimated to be about 1000 sq ft (neglecting the lid area). Thus, levels measured according to the NEMA standard should be adjusted by a constant

$$10 \log[2\pi(500)^2/3 \times 1000] = 27 \text{ dB}$$

to give the appropriate levels at the 500 ft normalization distance. If we now apply the tonal composition factors given in Table 3 we arrive at the levels given in Row (c) corresponding to the 80 dBA NEMA measurement level.

	dBA	120 Hz	240 Hz	360 Hz	480 Hz
(a)	56	67	60	54	53
(b)	52	67	56	45	42
(c)	53	64	57	51	50

The Row (c) levels are the ones which we have elected to use in our analysis of the Maple Valley substation. However the agreement between these levels and the levels given in both

Rows (a) and (b) is good. This observation suggests that the Maple Valley transformer bank is not unusually quiet when compared with the transformer population currently in service in the BPA system.

5.4 Some Notes on Transformer Noise

The primary source of transformer noise is the vibration induced in the laminated core as a result of the interaction between the magnetostrictive properties of, and the alternating magnetic flux field in, the core material. Magnetostrictive distortion of the core material is sensitive to the amplitude of flux density within the core and is not dependent upon the flux direction. Thus distortion occurs at a fundamental frequency which is twice line frequency.

The peak flux density in a power transformer core is virtually constant throughout the total load range of the transformer (magnetizing current is normally independent of load current). Thus the strength of the primary source of noise is independent of the load carried. Changes in line voltage could produce changes in source strength, but such changes are normally insignificant in a power distribution sytem.

Electromagnetic forces within the primary and secondary (if any) windings form a secondary source of vibratory movement in a power transformer. This source is load (current) sensitive but general experience suggests that winding generated noise is insignificant when compared with the primary magnetstrictive source.

Power transformers are, typically, fairly rich in harmonic content. This is the combined result of the nonlinear magnetization characteristics of the core machinery, and also of the very complex mechanisms whereby the core vibrations are transmitted through the cooling/insulating oil to the core tank and, from there, radiated into the atmosphere as sound. Mechanical resonances of the core/oil/tank structure may be involved in this process. The frequencies of these resonances may be temperature sensitive; thus a transformer may on occasion appear to be load sensitive, especially insofar as the relative strength of the higher harmonics are concerned.

It is observed sometimes that the apparent character of the sound of a transformer will change when the tap-changer setting is changed. The effect may be due to either current changes in the coils or flux density changes in the core.

In connection with another study BBN has monitored the noise output from a 345/230 kV, 600 MVA transformer bank over a twenty-four hour period. Simultaneous measurements were made at fixed microphone positions at distances of 40 ft and 550 ft from the bank. Over the measurement period the load carried by the transformer varied between 240 MVA and 390 MVA. Sound pressure levels varied over a range of about ±2 dB. There was no time correlation between the load changes and the sound level changes. The data clearly indicated that the transformer noise was independent of load.

6.0 METHODS OF TRANSFORMER NOISE CONTROL

A number of methods are available by which attenuations can be achieved of transformer noise in a substation environment. These range from (a) replacing the existing transformer by one of similar rating which has been manufactured to meet lower than "normal" noise ratings, to (b) fitting a full enclosure around the transformer and applying the necessary silencing to the cooling fans.

Unfortunately the amount of definitive research carried out by the industry into developing some of these methods into reliable engineering designs has been limited. Thus, in producing recommendations for BPA in this study, we must restrict the methods we propose to those which we consider most likely to give reliable results. Indeed, some of the methods we put forward must be investigated by BPA before they can be committed safely to more general use within the Administration's overall power distribution system.

6.1 Quiet Transformers

The NEMA TRI Standard sets recommended limits on the noise levels radiated by the sides of a transformer when measured in a prescribed fashion under no-load conditions in the factory. The recommended standard levels for oil immersed power transformers are a function of MVA and BIL ratings and also of the type of cooling--the latter to take account of fan noise. They are expressed entirely in A-weighted decibels. The standard gives no information, therefore, on the relative intensities of the tonal components.

The neglect (admittedly unavoidable) of the transformer lid radiation by the Standard poses a problem also, especially in situations similar to those of the ASEA shunt reactors at Covington and Keeler. Here, in order to meet the NEMA standard levels, shielding panels have been manufactured and attached to the sides of the units. Measurements suggest that whilst a very substantial noise reduction has been achieved at the specified NEMA noise measurement positions, at considerably greater distances from the units the effective noise reduction is very much less--limited, it would seem, by the lid radiated sound power.

We have found in our substation survey that, in general, it is the tonal contribution rather than the fan noise (for transformers with fan augmented cooling) which poses the compliance problems. (The major observed exceptions to this finding are the enclosed transformer at Walnut City and the transformer by Industrie Elletrische Di Legnano at Sno-King.) The fact that the NEMA Standard noise levels on fan-cooled transformers may be influenced significantly by the fan generated sound power means that the purchase of a transformer at less than the NEMA standard level may not be accompanied by the appropriate reduction in level at the transformer tonal frequencies.

These limitations in the NEMA standard rating method must be borne in mind when ordering especially quiet transformers. We understand that NEMA may in the near future be improving the method of rating transformer noise generation. Hopefully this may provide a direct basis for level guarantees on the tonal components, as well as on the fan noise radiation.

The matter of tank lid radiation versus tank side radiation is discussed in Section 6.3 below.

We understand that currently the transformer manufacturers are able to offer transformers at levels up to 10 to 15 dB below the NEMA rating but at a substantial additional cost. The methods by which they achieve these reductions are well known and need not be discussed here. Level reductions in excess of 10 dB are unlikely to be achieved by design modifications within the tank alone; they will generally involve external wall shields or partial wall enclosures. They must therefore be treated with caution for the reasons expressed above.

6.2 External Noise Control Treatments

The major methods of external noise control which may be usefully used or explored by BPA are as follows. The anticipated performance at the 120 Hz tonal frequency for each of these is tabulated in Table 4 .

6.2.1 Attached resilient skins

This method is well known in certain engineering applications but has not been looked at extensively (as far as we know) as a means of reducing transformer noise.

The method consists in essence of applying a limp, impermeable, heavy sheet to the outside of the major radiating panels via a fibrous or porous resilient blanket. The system is illustrated in Fig. 7 . The method of predicting the noise reduction when applied to the entire surface of the radiating source is given in detail in Chapter 15.1.3 of Beranek's *Noise and Vibration Control* (McGraw-Hill, 1971). We predict that a 2 in. thick blanket of resilient material having an acoustic flow resistivity of about $2x10^4$ mks Rayls/m with a 3 lb/sq ft impervious skin, will provide an attenuation at 120 Hz of about 10 dB. In application to transformers it will never be possible to cover the

Method	Attenuation at 120 Hz
Attached Skin	3 to 7 dB
Noise Shell	7 to 13 dB
Barrier	8 to 15 dB
Wall Enclosure	15 to 22 dB
Full Enclosure	25 to 40 dB

TABLE 4. EXTERNALLY APPLIED METHODS FOR REDUCING TRANSFORMER NOISE (FOR DETAILS SEE TEXT)

entire radiating surface area. We are therefore of the opinion that this method can be considered only in situations requiring attenuations in the range 3 to 7 dB at 120 Hz.

6.2.2 Noise shell

The Advanced Technology Center (ATC) of Allis Chalmers Company is currently under contract to the Electrical Power Research Institute (EPRI) to develop design rules for the application of close fitting noise shells around power transformers. The likely form of the noise shell treatment is shown in Fig. 8. The theory behind this development takes into account the stiffness of the relatively thin air layer between the shell material and the transformer surface, the stiffness of the resilient isolator used to support the shell and the mass and stiffness of the shell material itself. The program appears to be directed towards achieving a 25 dBA reduction in radiated noise--but this (we think) presupposes its application to transformers which are particularly rich in the higher tonal harmonics. It is unlikely that, using the proposed design constraints, *theoretical* attenuations in excess of 20 dB could be achieved-- and this only with complete coverage of the transformer walls. Two items in the second quarter progress report on this contract are of interest.

ATC has found as a result of vibration and acoustic monitoring on *one particular transformer*, that:

a) The cooling radiators form a source of acoustic intensity approximately equal to the combined intensity of the four tank walls, and

b) The lid radiation lies some 22 dBA below the combined noise intensity of the four tank walls.

We suspect that the transformer used in this study is naturally cooled with large radiator banks. In most instances involving large power transformers with relatively small radiator banks, the contribution of the radiators to the tonal noise radiation will be substantially smaller. Nevertheless the matter of radiator noise must be considered in any noise control design in which the radiators are not included physically within the treatment.

The conclusion as regards the role of lid radiation confirms our own predictions discussed later in this chapter.

The success of the noise shell concept as a "retrofit" treatment for in-service transformers will depend to a great extent upon the percentage of coverage of the radiating surfaces which can be obtained and upon the integrity of acoustic sealing and of mechanical isolation that can be maintained around hardware (pipes, brackets, etc.) which necessarily must penetrate the shell. For example, in many instances it may not be practicable to include tap changers and control switching boxes within the shell; conservators would not generally be enclosed either.

It is our opinion at the present time that this form of treatment applied as a practicable retrofit measure will permit attenuation of the 120 Hz tonal component by between 7 and 13 dB and that the attainment of the higher attenuations may require the introduction of liquid silencers and flexible pipe sections between the transformer and radiators.

6.2.3 Barriers

The most conventional method of in-field noise control is a barrier which interrupts the passage of sound between the source and the receiver.

An effective barrier has no holes or air gaps. It has an impervious outer surface with a total weight including sound absorbent material of at least 6 lbs/sq ft constructed as shown in Fig. 9. The sketch in Fig. 10 shows the typical geometric configuration. The important parameters determining the performance of a barrier are δ (representing the difference in path length of a sound wave in traveling from source to receiver with and without the barrier in place) and λ, the wavelength of sound. Thus the performance of a barrier is frequency dependent. The calculation procedure is included in Fig. 10.

The relationship between the Fresnel number, given by $N = 2\delta/\lambda$ and the attenuation provided by the barrier is given in Chapter 7.6.1 of Beranek's *Noise and Vibration Control* (McGraw-Hill, 1971). As applied to the four principle tonal components the relationship between δ and attenuation is that given in Table 5.

It should be noted that in the case of a finite width barrier sound may propagate not only over but also around the barrier. Accordingly, in calculating δ one must use the orientation for which the barrier is least effective. In the event that the paths are approximately equal, the summation of the different paths should be used in arriving at the final attenuation performance.

It should be noted also that because of atmospheric refraction effects caused by wind and temperature gradients, we find for frequencies in the range of the first four tonal components of transformer noise that a practical upper limit of barrier performance lies in the range 15 to 20 dB.

In the substation situations which we have studies, it is the 120 Hz tonal component which most frequently requires noise control. We have calculated the performance at 120 Hz

Path Length Diff. δ (ft)	Tonal Component (Hz)			
	120	240	360	480
.012 - .025	5	5	5	6
.025 - .05	5	6	6	6
.05 - .1	6	6	6	7
.1 - .2	6	7	7	8
.2 - .4	7	8	8	9
.4 - .8	8	9	10	11
.8 - 1.6	9	11	12	13
1.6 - 3.2	11	13	14	-------- 16
3.2 - 6.4	13	-------- 16	-------- 17	19
6.4 - 12.8	-------- 16	19	20	22

Note: Those levels below the dashed lines lie within the upper practical limits of barrier performance.

TABLE 5. BARRIER PERFORMANCE VERSUS PATH LENGTH DIFFERENCE FOR TRANSFORMER TONAL COMPONENTS

of barriers of different height (of effectively infinite width) placed 7 ft from a transformer tank of height 12 ft. The performance has been calculated by dividing the face of the transformer into four horizontal strips of equal width--each radiating one quarter of the power radiated by the whole side. The observer is assumed to be located 5 ft above transformer base datum at a distance in excess of 200 ft from the transformer. By expressing the results of these calculations in terms of the ratio of the barrier height to the transformer height, we have developed the curve of Fig. 11. We feel that this curve can be used to assess barrier performance for transformers within the 10 to 16 ft lid flange height range encountered in this study.

We see from Fig. 11 that a barrier of height equal to about two times the transformer height would be required to achieve a 15 dB attenuation at 120 Hz. This must be considered an upper practical limit for barrier performance. The 8 dB limit in Table 4 assumes that the performance of a full height barrier could be limited by the finite width of the barrier and by radiation from unshielded lid components. We assume that it would not be economically worthwhile to consider a barrier height of less than lid height.

In all instances, that side of the barrier facing the transformer should be treated with a sound absorbent material; this is to avoid multiple reflections between the barrier and the transformer wall, which would degrade its performance, and also to avoid increasing the noise exposure at those locations not shielded by the barrier from the transformer. The target absorption coefficient for the liner should be 0.7 or greater at the 120 Hz tonal frequency.

The performance of a barrier is limited intrinsically because of the unobstructed passage that exists between the transformer and the perimeter of the barrier. Also, there are many problems in constructing barriers substantially higher than the transformer, not the least of these being associated with maintaining electrical clearances.

6.2.4 Wall enclosure

In instances requiring attenuation in excess of 15 dB at 120 Hz, the wall enclosure should provide an effective technique. The method, as it has been considered for one transformer, is illustrated in Figs. 12 and 13.

The minimum desirable weight of wall material including the weight of the sound absorbing treatment is 10 lbs/sq ft. The advised minimum absorption coefficient is about 0.7 at 120 Hz.

The adequacy of acoustic sealing and of the vibration isolation between the transformer and the wall enclosure is very important. The tank wall to enclosure wall spacing also plays a role. Multiples of one-quarter wavelength of sound at 120 Hz are preferred. A minimum spacing of 2 to 3 ft is therefore advised; spacing of 6 to 7 ft would be even better.

The estimated performance range given in Table 4 assumes adequate vibration isolation and acoustic sealing and presupposes that the lid, as a source, lies at least 25 dB below the acoustic intensity of the combined transformer walls. In some instances it may be possible to provide an extension parapet above the wall enclosure, as shown in Fig. 12 to provide some lid shielding.

To maintain adequate cooling it is generally necessary either to introduce secondary cooling fans into the wall enclosure design (with acoustically treated intake and exhaust ports), or to relocate the radiators outside the enclosure. In the latter case, if the radiators are a significant source of noise it may become necessary to shield these, or to provide flexible pipe connectors and/or fluid silencers within the interconnecting pipework.

The role of the tank wall in the overall cooling of the transformer must also be considered. We understand (from BPA) that some manufacturers place the total cooling requirement upon the radiator banks and place no reliance upon the wall cooling.

We feel that the basic concept of wall enclosure has application in situations requiring between 15 and 22 dB of attenuation at 120 Hz.

6.2.5 Complete enclosure

By providing a complete enclosure of the form shown in Fig. 14, it would be possible to obtain, reliably, noise reductions in the range 25 to 40 dB, at the 120 Hz tonal frequency.

To achieve the upper limit the wall weight would have to lie close to 30 lbs/sq ft. The enclosure would have to be lined with sound absorptive material and it would have to be well sealed and vibration isolated from the transformer. Openings for the passage of air into and out of the enclosure would have to be fitted with specially designed high performance, low frequency silencers.

Depending upon the intensity of the radiators as a source, and depending upon how successfully in-line fluid silencers and flexible couplings reduce this source, the radiators could possibly be located outside the enclosure. This would greatly simplify the design and cost.

The spacing between the enclosure and the transformer tank can be made quite small--certainly as small as one-quarter wavelength and possibly smaller without impairing seriously the acoustic performance. However, in the practical situation, access requirements would probably set rather larger clearances.

Total enclosure of a transformer would in most instances require the fitting of extension turrets to carry the primary, secondary, and tertiary bushings. The technique is therefore not attractive as a retrofit method to be applied to large, high voltage power transformers.

Hopefully, the need for complete unit enclosures can be voided in resolving BPA substation noise problems.

6.3 Lid Radiation

BPA has provided us with vibration displacement data taken on one of their shunt reactors. A brief analysis of these data shows the following:

1) Vibration amplitudes on the lid are about twice those on the sides,

2) There is good agreement between the measured NEMA levels quoted by the manufacturer and the predicted

levels based on the wall vibration--assuming a radiation efficiency of 100% and a dominant frequency of 120 Hz (the manufacturer did not provide a frequency spectrum).

3) A theoretical analysis of the directivity effects of the lid--acting as a simple piston--shows that, at 120 Hz the far-field acoustic intensity at ground level due to the lid, should lie some 15 to 25 dB below the intensity from the reactor sides, given equal vibration amplitudes on lid and sides.

4) In the case of this particular reactor then, the analyses would suggest a lid contribution some 10 to 20 dB below the contribution from the sides of the unit.

We have mentioned earlier the analysis carried out on one transformer by the Advanced Technology Center of Allis Chalmers.

We are of the opinion that the importance of the lid as a radiator will vary substantially from transformer to transformer. Not only will it depend upon the lid structure itself, and upon the way that this is driven by the tank and core coil structure (mechanically or via the cooling coil), but lid appendages such as turrets and conservators can be significant radiators of noise themselves. In general, however, we are inclined to believe that lid radiation will lie at least 15 dB below the combined wall radiation.

In the event that the lid limits the available noise reduction when using a barrier or wall enclosure design, we recommend that further attenuation be sought by applying an "attached skin" (as described earlier) to the major lid panels.

6.4 Cooling Radiators

One experience of the Allis Chalmers Company Advanced Technology Center (ATC) in assessing the contribution by the radiators on one particular transformer is noted in Section 6.2.2 above. It was found that the radiators were as important acoustically as the tank walls. By way of contrast, their preliminary experience on another transformer suggests that here, the radiator contribution lies some 15 dBA below the intensity of the tank wall radiation.

As in the case of lid radiation it is clear that substantial variability will arise in the extent to which the radiators on a transformer contribute to the noise intensity at a distance from it. We suspect, however, that on those transformers using FOA cooling, the radiators are sufficiently small in surface area relative to the sound wavelength, that their contribution to 120 Hz tonal noise is probably some 15 to 20 dB below the levels radiating from the tank wall. As we progress from FOA rated transformers to FA and to OA rated units, the contribution from the radiators may increase. It is likely, for instance, that the radiators on the ASEA shunt reactors at Covington and Keeler are comparatively energetic noise sources.

In some instances it may be necessary therefore to reduce radiator noise as well. When using barriers as a means of transformer noise reduction, the barrier will normally shield the radiators also. The performance of attached skins, of close-mounted noise shells and of wall (or full) enclosures may well be limited if the radiators are not shielded. In such cases it may prove necessary either to provide local shielding around the radiators or to connect the radiators to the transformer via flexible piping connectors and/or in-line liquid silencers.

6.5 Materials

Materials for the noise control treatments described in Section 6.2 and some potential suppliers of those materials are described below.

a) Sound Absorbing Material

Sound absorbing material for use with the barrier, wall enclosure and complete enclosure noise control treatments should have a minimum sound absorption coefficient in the 125 Hz octave band of frequency equal to 0.7 as measured with the material placed against a solid backing. This requirement is satisfied by material equal to 4 inch thick, Type 703, 3 lb/ft^3 fiber glass (≈\$0.70 per ft^2 f.o.b.) obtainable from:

Owens-Corning Fiberglas Corporation
Fiberglas Tower
Toledo, Ohio 43659.

An alternative material is open cell polyurethane foam (\$4 per ft^2 for two 2" layers, f.o.b) obtainable from:

Soundcoat Company, Inc.
175 Pearl Street
Brooklyn, New York 11201

or

Scott Paper Company
Foam Division
1500 East 2nd Street
Chester, Pennsylvania 19013.

b) Resilient Material

Resilient material called for in the resilient skin noise control treatment should be 2 inches thick (≈\$0.30 per ft^2 f.o.b.) either fiber glass or foam as noted above for sound absorbing materials.

c) Polyethylene Sheet Material

This material provides weather protection to the fiber glass or foam sound absorbing material. It also enhances the low frequency sound absorption characteristic of a sound absorbing material when used in conjunction with it. The polyethelene sheet material should be 0.002 inch thick (\$0.025 per ft^2 f.o.b.) and equal to Mylar film obtainable from:

Dupont-Film Department
5500 Union Pacific Avenue
City of Commerce, California 90022

d) Open Metal Protective Facing Material

Minimum 30% open area equal to "Armorweave", (\$0.57 per ft^2 f.o.b.) obtainable from:

U.S. Gypsum Company
9306 Sorensen Street
Santa Fe Springs, California 90670

e) Claddings or Outer Surfaces of Treatments

- Resilient skin - 3 lb/ft^2
  This skin must be impervious. Ideally, it should be a limp, impermeable, heavy sheet. Possible materials are:

  Thin sheet metal - aluminum or steel
  Lead - loaded vinyl plastic (\$4.27 per ft^2) obtainable from:

  Ferro Composites
  34 Smith Street
  Norwalk, Connecticut 06852

- Noise shell - 5 lb/ft^2
  Thin sheet metal - aluminum or steel

- Barrier - 6 lb/ft^2

  This weight represents the all-up surface weight of the barrier panel construction including the sound absorbent material and protective facing, assuming the sound absorbent material is installed under 5% compression. However, since the sound absorbent material and protective facing do not account for a large portion of the barrier surface weight, it is advisable to select the outer cladding to meet 6 lb/ft^2.

  One possible material is sheet steel. An alternative approach is to select one of a number of commercially available panels which are designed to provide a sound transmission loss in escess of that possible with a flat plate of the same surface weight. Materials and suppliers for the latter category are:

  Steel panel type UKX18-18 ($2.90 per ft^2 f.o.b.)

  H. H. Robertson Company
  Two Gateway Center
  Pittsburgh, Pennsylvania 15222

  Noishield Galvanized Steel Composite Panel ($6.00 per ft^2 f.o.b.)

  Industrial Acoustics Company
  1160 Commerce Avenue
  Bronx, New York 10462.

  It should be noted that this panel is made up as an acoustical panel and thus includes a sound absorbent material and protective facing. It is available with galvanized steel for outdoor applications.

Schoeller Noise Protection Wall (\$5.50 per ft^2 f.o.b.) obtainable from:

Sound Fighter Systems Inc.
6135 Linwood Avenue
Shreveport, Louisiana 71106

It should be noted that this composite panel is made up as an acoustical panel and thus includes a sound absorbent material and protective facing. It should be noted further that the surface weight requirement is met in general by the addition of gypsum board to the inner surface of the composite panel. The basic panel is made from high density polyethylene, dyed and UV-stabilized and is claimed to be suitable for outdoor applications.

ECD Galvanized Steel, Composite panel type A-46 (\$5.90 per ft^2 f.o.b.) obtainable from:

E. C. DeYoung, Inc.
633 West State Street
Ontario, California 91761

It should be noted that this composite panel is made up as an acoustical panel and thus includes a sound absorbent material and protective facing. It is available with galvanized steel for outdoor applications.

It should be noted that the three above-noted commercially available composite acoustical panels are made up in a modular form so that they can be assembled or dissembled with comparative ease.

- Wall Enclosure - 10 lb/ft^2

  The materials used for barrier construction can be used in up-graded form as the basic building block for a wall enclosure. The alternatives can be summarized as follows with reference to the above discussion on barriers.

Steel plate, 1/4 in. thick. Steel panel type NKX-18 (\$3.10 per ft^2 f.o.b.) obtainable from M. H. Robertson Company.

Noise-Lock galvanized steel composite panel (\$6.90 per ft^2 f.o.b.) obtainable from Industrial Acoustics Company.

Schoeller Noise Protection Wall (\$4.50 per ft^2 f.o.b.) obtainable from Sound Fighter Systems Inc.

ECD galvanized steel composite panel type B-32 (\$6.40 per ft^2 f.o.b.) obtainable from E. C. DeYoung, Inc.

Complete Enclosure - 30 lb/ft^2
A complete enclosure is called for where an attenuation in excess of 25 dB is called for at 120 Hz. Because of the potential for compromise via air intakes in the enclosure wall and via vibration transmission through the ground from the transformer to the enclosure wall and the like, an upper limit of 40 dB attenuation is considered appropriate.

The lower limit can be achieved marginally using the materials specified for the wall enclosure as the basic building blocks. Achievement of higher attenuations will require the use of materials such as concrete block or special acoustic blocks such as "Sound bloc" manufactured by:

The Proudfoot Comapny Inc.
P.O. Box 9
Greenwich, Connecticut 06830

It is recognized however, that poured concrete may be required in such instances because of the seismic requirements.

f) Neoprene Pad, Vibration Isolators equal to that obtainable from:

Mason Industries Inc.
3335 E. Pico Boulevard
Los Angeles, California 90023

or

Barry Controls
2323 Valley Street
Burbank, California 91505

g) Flexible Connectors

Flexible Connectors equal to that obtainable from:

Mason Industries Inc.
3335 E. Pico Boulevard
Los Angeles, California 90023

or

Thermo Tech Inc.
1400 S. Lifran Street
Denver, Colorado 80223

h) Silencers

Silencers are not called for except where openings are required in a barrier or enclosure wall to bring in air to cool the transformer. The performance requirements on the silencers are such that custom design will very likely be required in many cases to ensure that the basic design is not compromised.

Manufacturers of silencers include:

Industrial Acoustics Company
1160 Commerce Avenue
Bronx, New York 10462

Koppers Company, Inc.
P.O. Box 298
Baltimore, Maryland 21203

i) In-Line Liquid Silencers

Such silencers may be required where the cooling radiators are located remotely from a transformer tank which has been acoustically treated. The silencers control the transmission of oil borne sound energy from the tank to the radiators.

Manufacturers of such silencers include:

American Air Filter Co., Inc.
215 Central Avenue
Louisville, Kentucky 40201

Burgess Industries
(Burgess-Manning Division)
8101 Carpenter Freeway
Dallas, Texas 75247.

7.0 LAYOUT OF SUBSTATION REPORTS

The detailed reports on each of the thirty-three substations included in this survey are given in Appendices A and C. As far as possible we have attempted to standardize the layout of these reports. We have also made them as brief as possible. General information on the arrangement of, and abbreviations used in, these reports is as follows.

7.1 Introduction

Each report starts with an introduction describing the substation and its environs. The pertinent characteristics of the transformer(s) are tabulated. Much of the information in this section was gathered during the field visit. BPA provided aerial photographs and Geological Survey maps of each site. Information was also provided by them on the transformers. Information on residential development trends around each substation was gathered in conversations with Mr. L. Swenson (BPA Headquarters) and with BPA substation operating personnel.

The abbreviations used in listing transformer manufacturers are given in Table 6. Tabulated transformer loads are those at the time of the close-in and perimeter surveys. These were provided by the substation operating staff. The symbol "S" denotes that the transformer was ordered by BPA at the standard NEMA (TRI) rating. The tabulated dimensions of each transformer bank are approximate only--in some instances these were checked against the outline drawings provided by BPA.

7.2 Field Survey

The field methodology has been described in Chapter 4. The methods of data normalization have been described in Chapter 5.

TABLE 6. TRANSFORMER MANUFACTURER--SYMBOL DESIGNATION

A	-	ASEA
AC	-	Allis-Chalmers
AS	-	Alsthom Savoisienne
B	-	Brown Boveri
E	-	Elin
EE	-	English Electric
F	-	Fuji
G	-	General Electric
I	-	Italtrafo
L	-	Industrie Elletriche Di Legnano
M	-	Moloney
P	-	Pennsylvania
S	-	Standard Transformer Company
T	-	Toshiba
U	-	Uptegraff
WA	-	Wagner
W	-	Westinghouse

In most instances the quoted values of A-weighted noise level are those represented by the first four tonal components alone. Distances used in the normalizations are derived from substation plot plans provided by BPA and from the aerial photographs.

7.3 Data Interpretation and Compliance Analyses

The general methodology that we have used is discussed in Chapter 5. In some instances we have combined all of the field data to provide general *on average* estimates of noise conditions. In other cases we have relied in the main on the results of our community noise measurements and microsampling analyses.

7.4 Recommendations

For those substations for which a compliance problem exists or may be anticipated, we present recommendations for actions to be adopted by BPA. In some cases a number of options for action may exist. In recommending noise control treatments we have assumed, generally, that barriers will be the preferred treatment--until such time as field experience can be gained on alternative methods. In Chapter 6 we have presented some basic information on the procedures to be followed when designing barriers. We have, where possible, tried to define for each substation those sources requiring treatment. We have also tried to define the directions in which shielding is required or may be required in the future.

COUINGTON #2, 3-27-76, 03:00-04:00, 109091(B)
SAMPLE SIZE = 875

FREQ	LEQ	L1	L10	L50	L90
50	51	59	53	49	45
63	53	62	56	50	46
80	55	66	58	51	46
100	52	63	54	48	45
125	53	63	55	52	48
160	47	60	46	38	35
200	42	53	42	35	32
250	42	53	44	37	34
315	42	53	44	39	36
400	43	52	46	41	38
500	42	52	43	39	36
630	41	51	43	39	36
800	40	48	42	38	33
1000	39	48	42	37	31
1250	38	46	41	35	28
1600	36	45	39	32	25
2000	34	44	37	30	22
2500	30	41	34	25	19
3150	27	38	31	22	16
4000	23	34	27	19	14
5000	29	39	32	25	20
OA	61	71	63	58	54
DBA	49	59	51	46	42

FIGURE 3. MICROSAMPLE DATA - SAMPLE COMPUTER OUTPUT SHEET

OA = Overall (unweighted) sound pressure level in decibels.

dBA = A-Weighted Level in decibels.

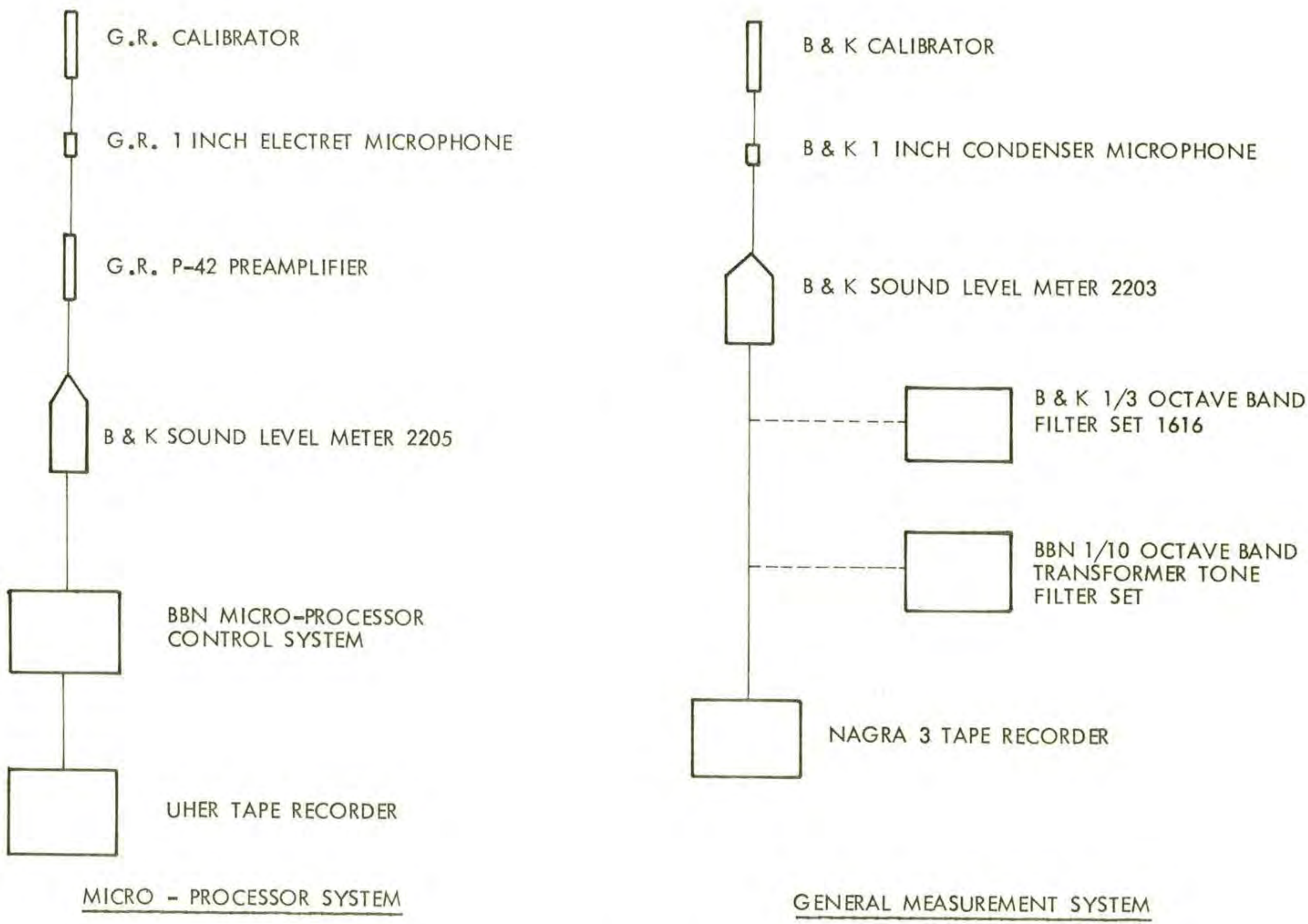


FIGURE 4. NOISE LEVEL DATA ACQUISITION SYSTEMS

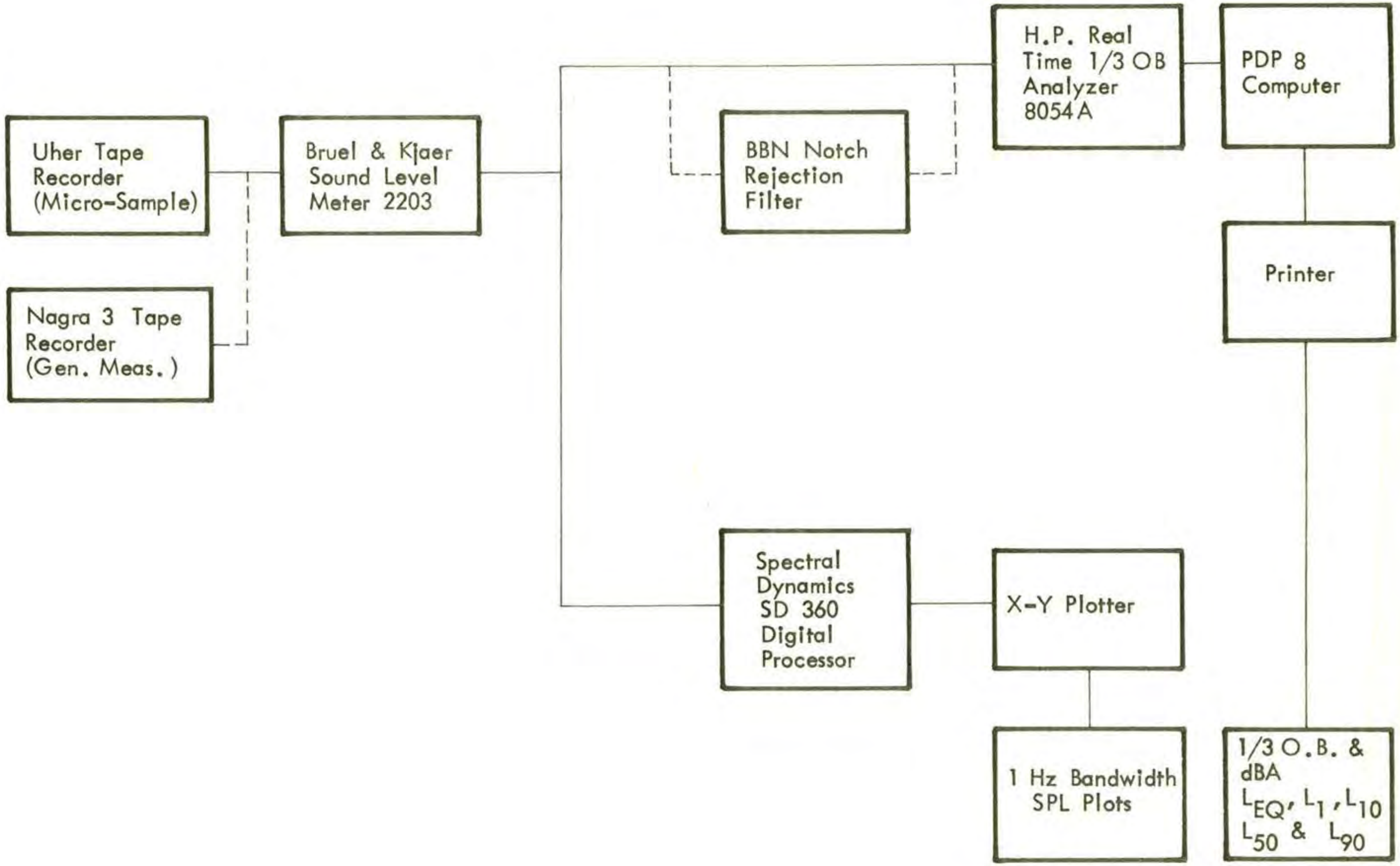


FIGURE 5. DATA REDUCTION SYSTEMS

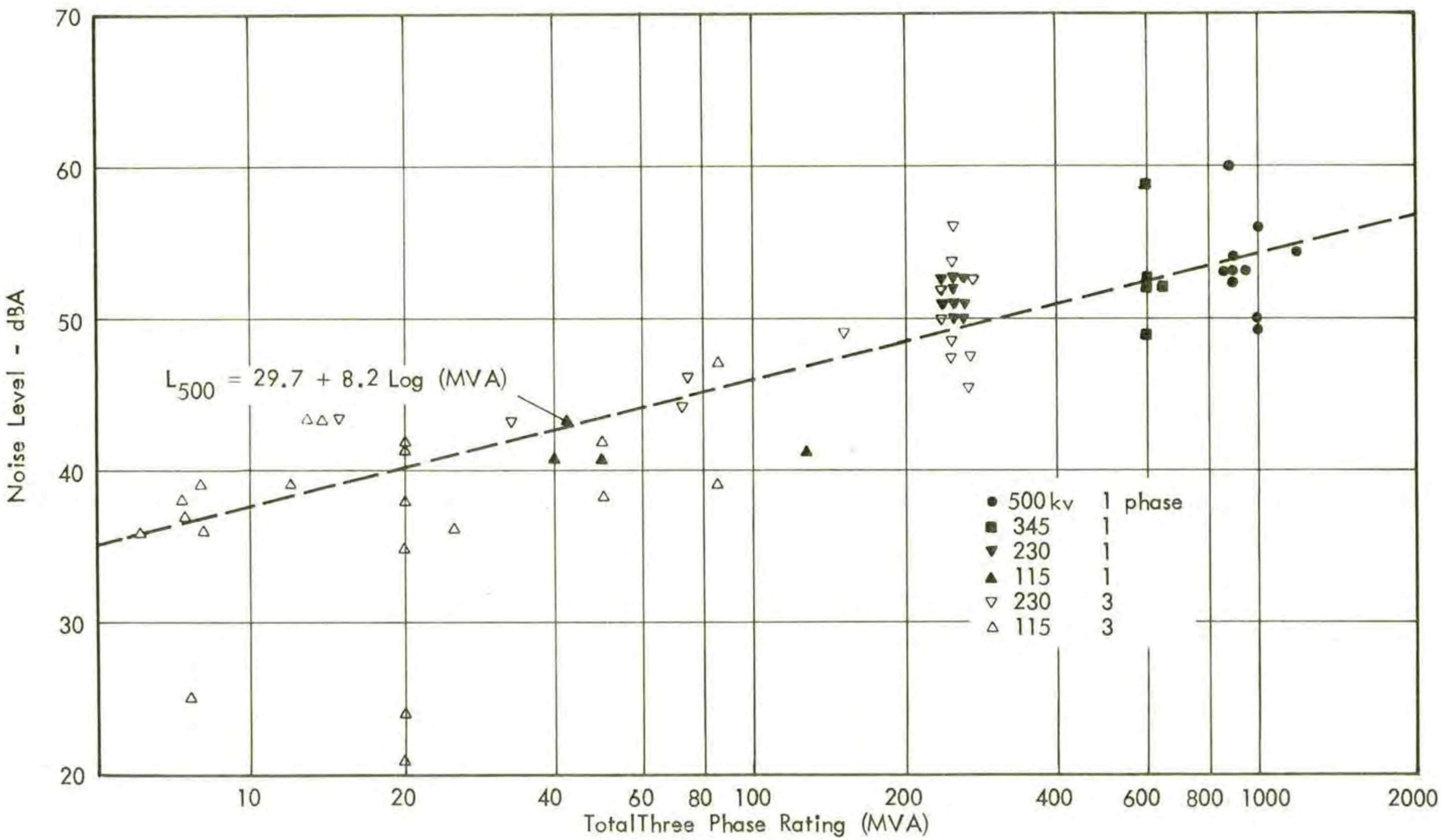
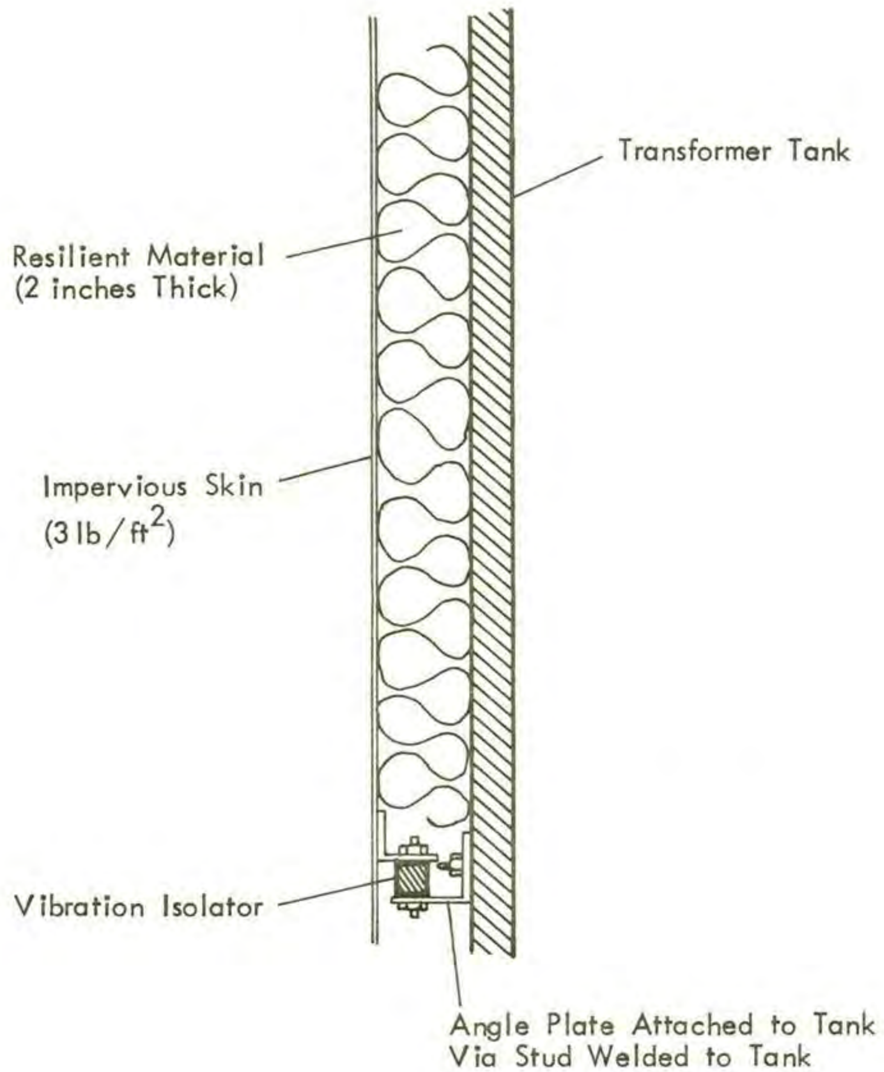
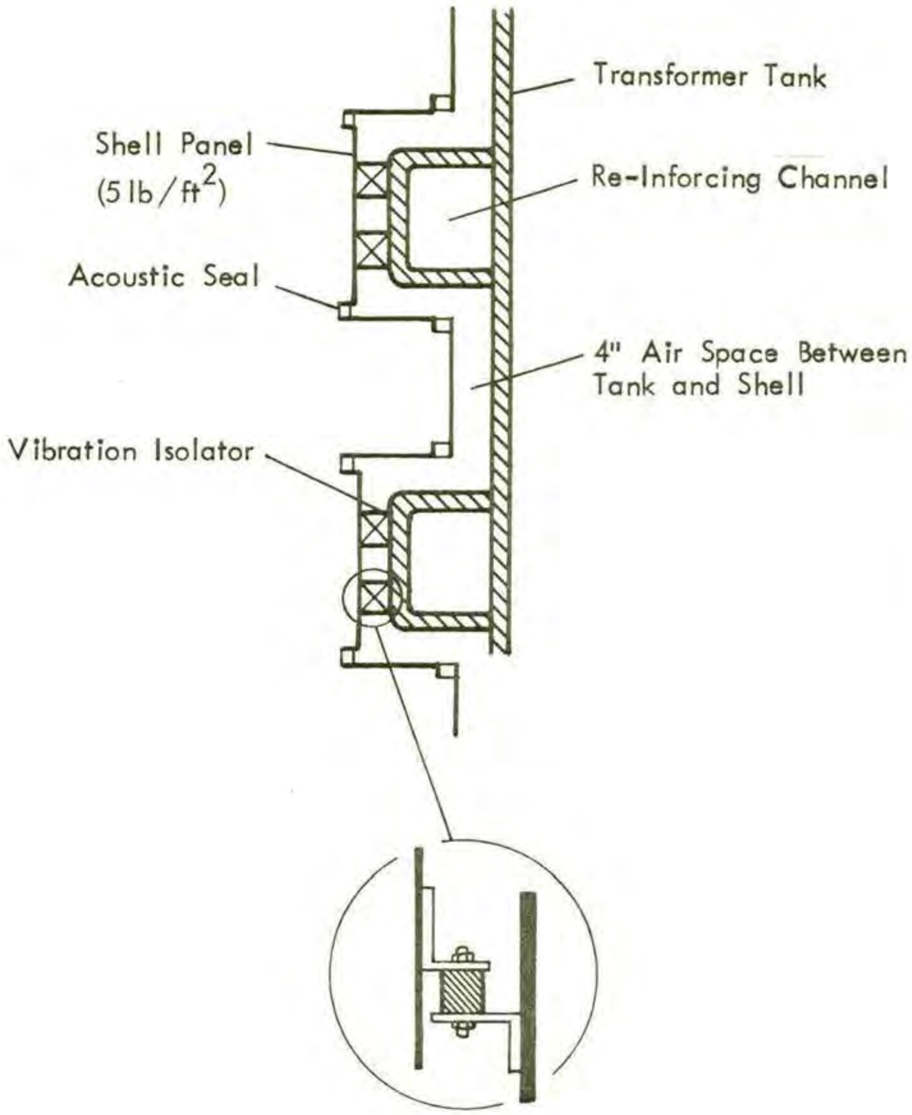


FIGURE 6. NOISE LEVELS AT 500 FT DISTANCE BASED ON NORMALIZATION OF TRANSFORMER CLOSE-IN DATA



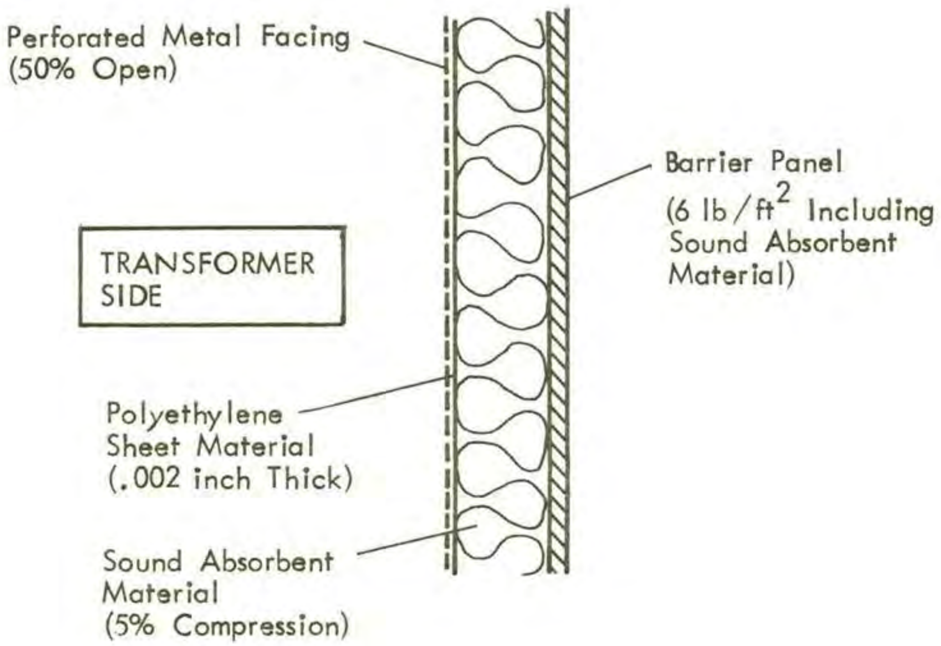
Note:
1. Expected noise reduction--between 3 and 7 dB at 120 Hz.
2. Refer Section 6.2 of text for description of treatment.
3. Refer Section 6.5 of text for information on materials.
4. All cracks, joints, etc. in skin should be packed with fiberglass and sealed with a nonhardening mastic compound.

FIGURE 7. TRANSFORMER NOISE CONTROL - RESILIENT SKIN



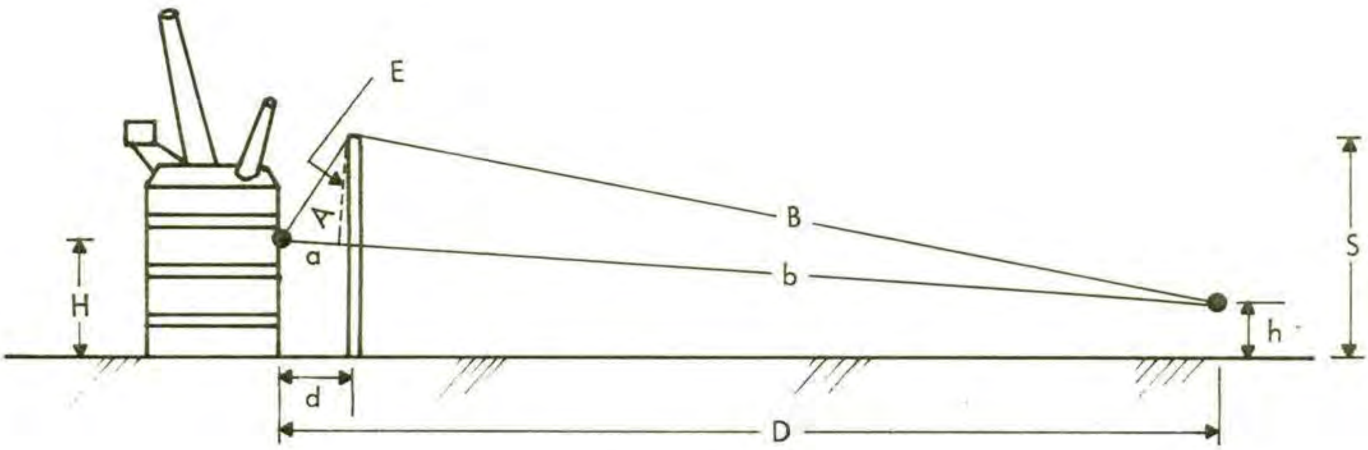
Note:
1. Expected noise reduction--between 7 and 13 dB at 120 Hz.
2. Refer Section 6.2 of text for description of treatment.
3. Refer Section 6.5 of text for information on materials.
4. All cracks should be packed with fiberglass and sealed with a nonhardening mastic compound.
5. All joints in the shell should be sealed with a nonhardening mastic compound or gasketed.
6. All access openings should be gasketed.

FIGURE 8. TRANSFORMER NOISE CONTROL - NOISE SHELL



Note:
1. Expected noise reduction--between 8 and 17 dB at 120 Hz.
2. Refer Section 6.2 of text for description of treatment.
3. Refer Section 6.5 of text for information on materials.
4. Refer Fig. 10 for geometric configuration.
5. All cracks, joints, etc. in barrier should be packed with fiberglass and sealed with a nonhardening mastic compound.
6. All access openings should be gasketed.

FIGURE 9. TRANSFORMER NOISE CONTROL - BARRIER



S = Height of Barrier

E = Effective Barrier Height

H = Effective Source Height = 2/3 transformer tank height

h = Observer Height--say 5 ft

d = Source Barrier Distance

D = Source Receiver Distance

a+b = Source/Observer Direct Path Distance = $[D^2 + (H-h)^2]^{\frac{1}{2}}$

A+B = Source/Observer Diffraction Path Distance:

$$A = [d^2 + (S-H)^2]^{\frac{1}{2}}$$

$$B = [(D-d)^2 + (S-h)^2]^{\frac{1}{2}}$$

δ = (A+B) - (a+b) -- see Table 5

Note:
1. For d>E and (D-d)>>E, δ is well approximated by $\delta = E^2/2d$
2. Side of barrier facing transformer should be treated with a sound absorbent material.
3. Refer Section 6.2 of text for description of treatment.
4. Refer Section 6.5 of text for information on materials.

FIGURE 10. ATTENUATION BY BARRIER

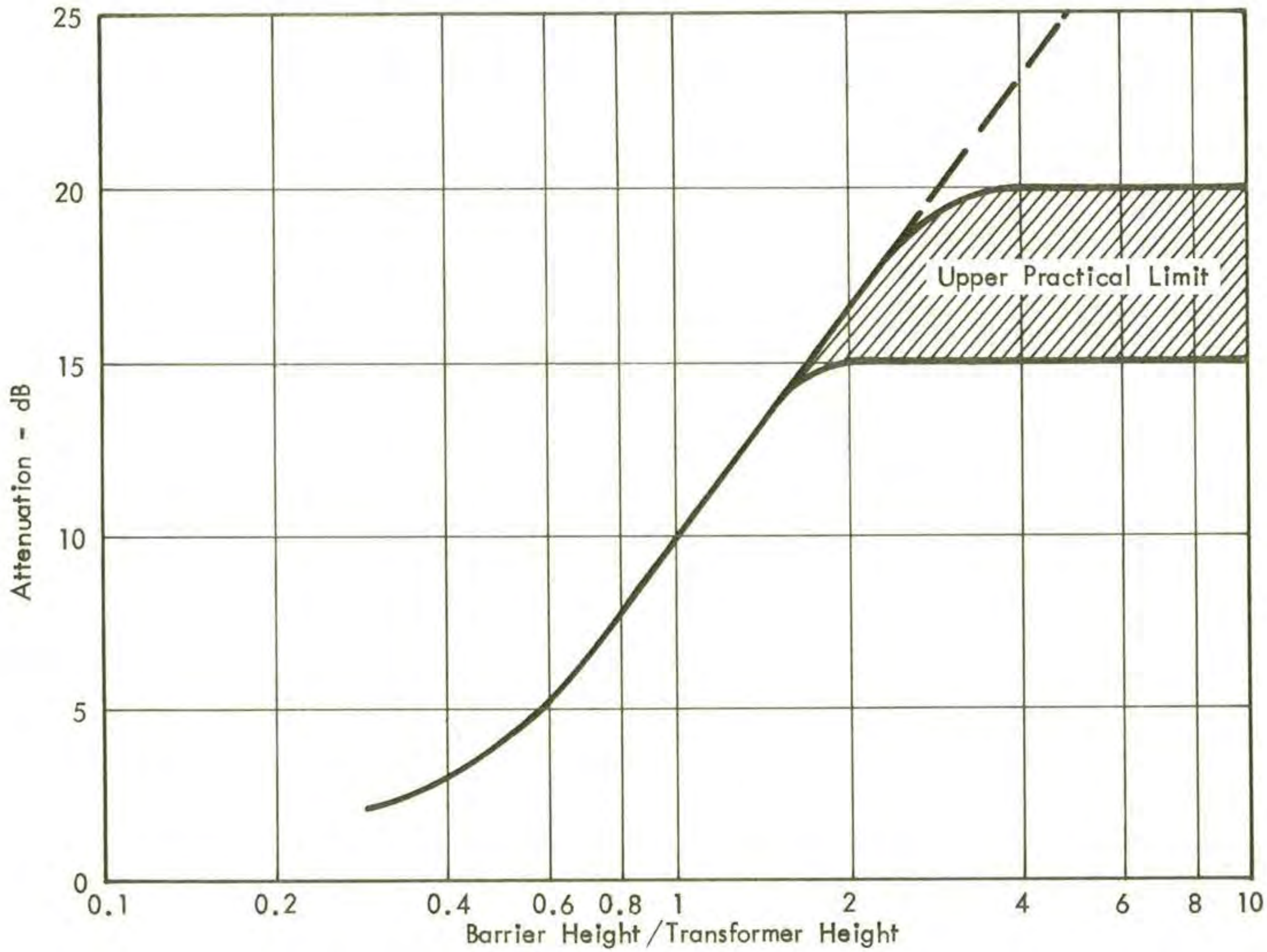


FIGURE 11. APPROXIMATE BARRIER ATTENUATION AT 120 Hz AS A FUNCTION OF THE RATIO BARRIER HEIGHT/TRANSFORMER WALL HEIGHT (FOR TRANSFORMER HEIGHT IN THE RANGE 10 TO 16 FT AND OBSERVER DISTANCES > 200 FT. BARRIER 7 FT FROM TRANSFORMER)

Note:
1. Expected noise reduction--between 15 and 22 dB at 120 Hz.
2. Refer Section 6.2 of text for description of treatment.
3. Refer Section 6.5 of text for information on materials.
4. All cracks, joints, etc. in enclosure should be packed with fiberglass and sealed with a nonhardening mastic compound.
5. All access openings should be gasketed.

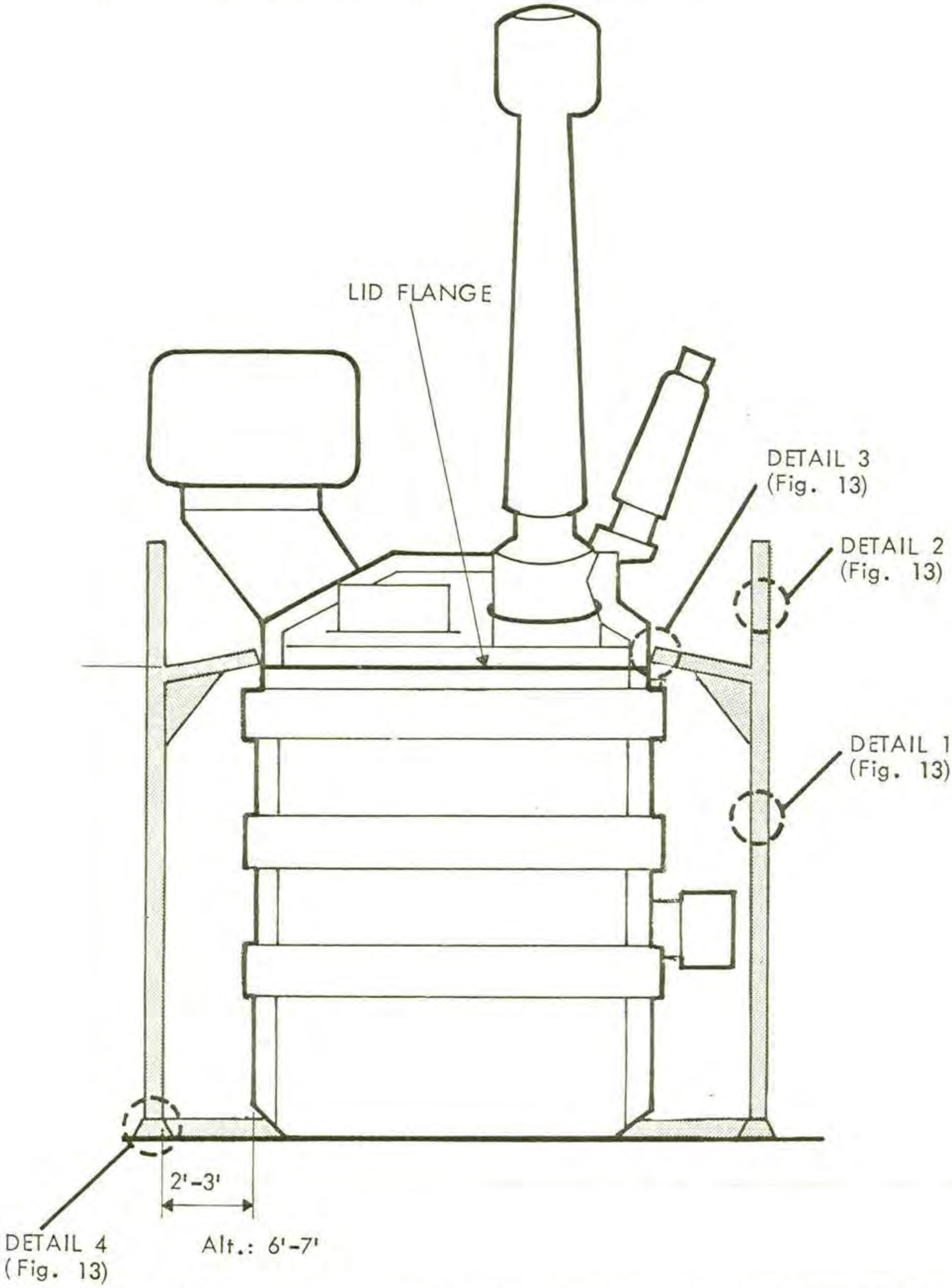
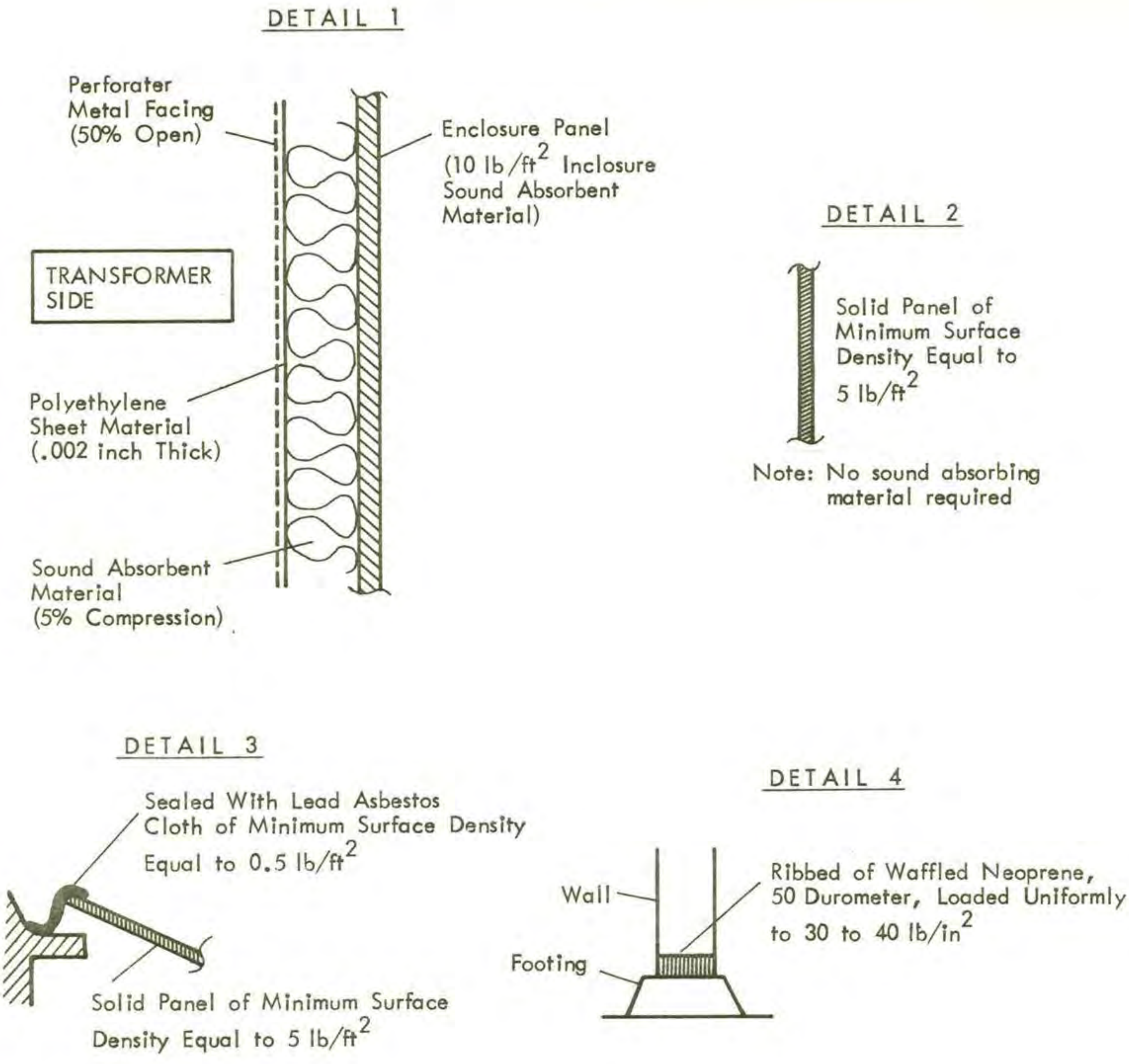
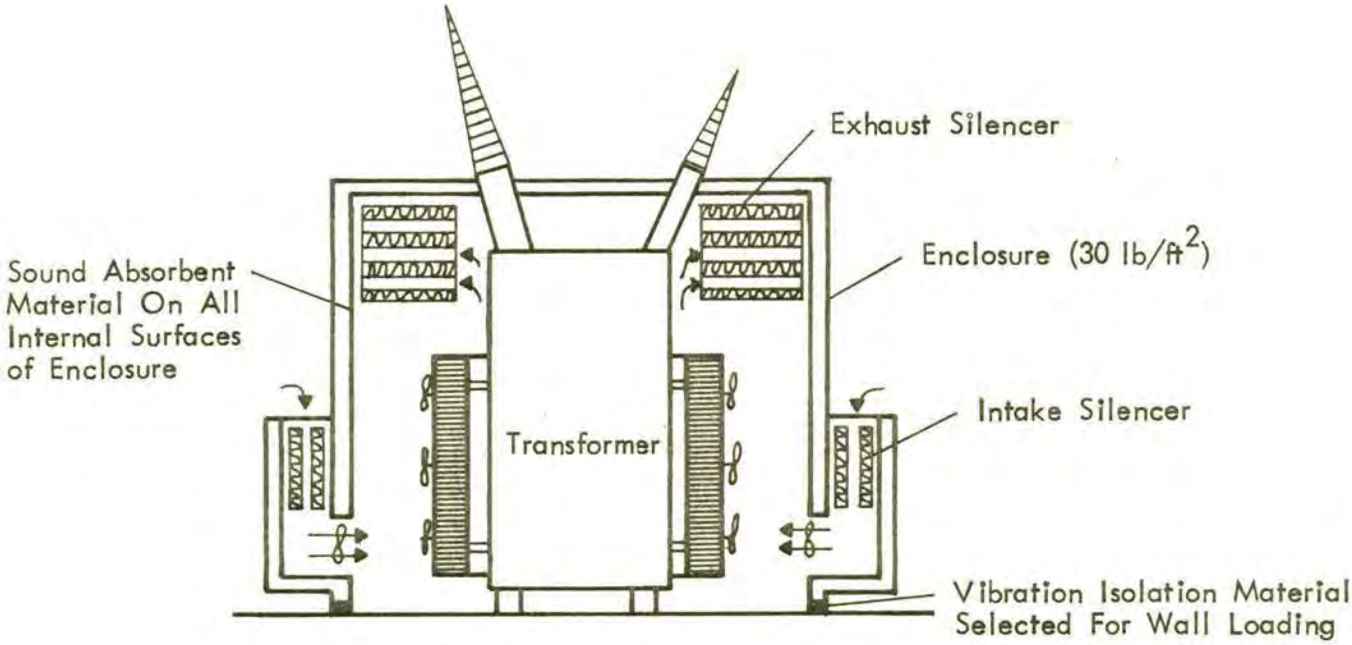


FIGURE 12. TRANSFORMER NOISE CONTROL - SECTIONAL VIEW OF WALL ENCLOSURE



Note: Refer Section 6.5 of text for information on materials.

FIGURE 13. TRANSFORMER NOISE CONTROL - WALL ENCLOSURE DETAILS



Note:
1. Expected noise reduction--between 20 and 40 dB at 120 Hz.
2. Refer Section 6.2 of text for description of treatment.
3. Refer Section 6.5 of text for information on materials.
4. All cracks, joints, etc. in enclosure should be sealed with a nonhardening mastic compound.
5. All access openings should be gasketed.

FIGURE 14. TRANSFORMER NOISE CONTROL - COMPLETE ENCLOSURE

BOLT BERANEK AND NEWMAN INC

CONSULTING · DEVELOPMENT · RESEARCH

Report No. 3296
Job No. 10908

BONNEVILLE POWER ADMINISTRATION
SUBSTATION NOISE STUDY

APPENDIX A
OREGON SUBSTATIONS – ANALYSIS AND RECOMMENDATIONS

BPA Contract No. 14-03-6020N

Roger J. Sawley
Colin G. Gordon
Michael A. Porter

30 September 1976

Submitted to:

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Submitted by:

Bolt Beranek and Newman Inc.
21120 Vanowen Street
Canoga Park, California 91303

APPENDIX A – OREGON SUBSTATIONS

FOREWORD

This appendix contains detailed information on the results of our evaluation of the seventeen (17) substations of concern in the State of Oregon. The substations are listed alphabetically in accordance with the table of contents presented over.

In each case, a description is first presented of the substation and its environs. Next, information is presented on the results of the field noise survey. The obtained noise level data are then analyzed and assessed for compliance with the State Regulations. Finally, recommendations are provided, where necessary, to bring the substation into compliance.

TABLE OF CONTENTS

A1. ALLSTON SUBSTATION

Allston Substation is located in Columbia County, Oregon, between U.S. Highway 30 and the Columbia River. It lies about four miles west of the township of Rainier.

The layout of the substation and its location with respect to residential properties are shown in Fig. A1.1. [redacted]

Details of the substation environs and of land uses are as follows.

The substation is remotely situated. There are few residential properties in the area, and none within 1000 ft of the perimeter fence. The land is heavily wooded on all sides of the station and the terrain is generally flat.

Transmission line easements to the north and south of the substation will limit future residential developments in these areas. However, future residential developments could arise both to the east and west of the substation. In this event properties could be as close as 900 ft to the transformer bank. This is not significantly closer than the closest property at present.

FIELD SURVEY

The field measurements were carried out over the period 6th to 7th March 1976. We were accompanied within the substation by the operator.

The weather during the measurements was clear and sunny. The wind was from the north at 4 mph. Air temperature on the afternoon of 6th March was 51°F. The relative humidity was 75%.

• Close-In Measurements

The results of the measurements at 10 ft from the transformer bank are given in Table A1.2.

• Perimeter Measurements

The results of the perimeter measurements at the first two tonal frequencies are included in Fig. A1.1. These data normalize to average levels at 500 ft of 63 dB at 120 Hz and 53 dB at 240 Hz. Agreement with the close-in normalized levels is especially good at 120 Hz.

• Community Measurements

Data were acquired at the junction of Heath Road and the Substation access road (Position (a) on Fig. A1.1). [redacted] A typical 1 Hz bandwidth spectrum at this position is shown in Fig. A1.2. The tonal components are summarized in Table A1.3.

The levels are lower than those predicted from the close-in measurements--substantially so at the higher frequencies. Ground attenuation may be partially responsible.

• Microsample Data

The microsample data were acquired at the northeast corner of the substation as shown in Fig. A1.1. The data are summarized in Figs. A1.3, 4 and 5. The full computer output sheets are included in Appendix B. [redacted]. The first two tonal components (see Fig. A1.5) normalize to 500 ft levels of 65 dB at 120 Hz and 54 dB at 240 Hz. This is in good agreement with the close-in data.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

[redacted] Levels here will (in the absence of shielding or losses) lie 8 dB below the normalized 500 ft levels. Thus we would predict levels of about 56 dB at 120 Hz, 46 dB at 240 Hz, and substantially lower levels at the higher tonal frequencies. We conclude on this basis that the substation is currently in compliance with the Oregon Noise Regulations--but barely so.

[redacted] would pose a 3 to 5 dB problem at the 120 Hz tonal frequency.

RECOMMENDATIONS

No noise control is required at present at the Allston Substation. In the event of future residential developments on, or close, to the west or east property lines of the substation, a requirement for noise control will probably arise. We recommend that BPA remain cognizant of development plans and land transactions in these areas. We recommend also that the BPA plan for the provision of a shielding barrier on that side of the transformer on which future residential development is most likely to occur. At the present this would seem to be on the east side, i.e., on that land to the east of Heath Road. Guidelines for the design of such a barrier are given in the main report.

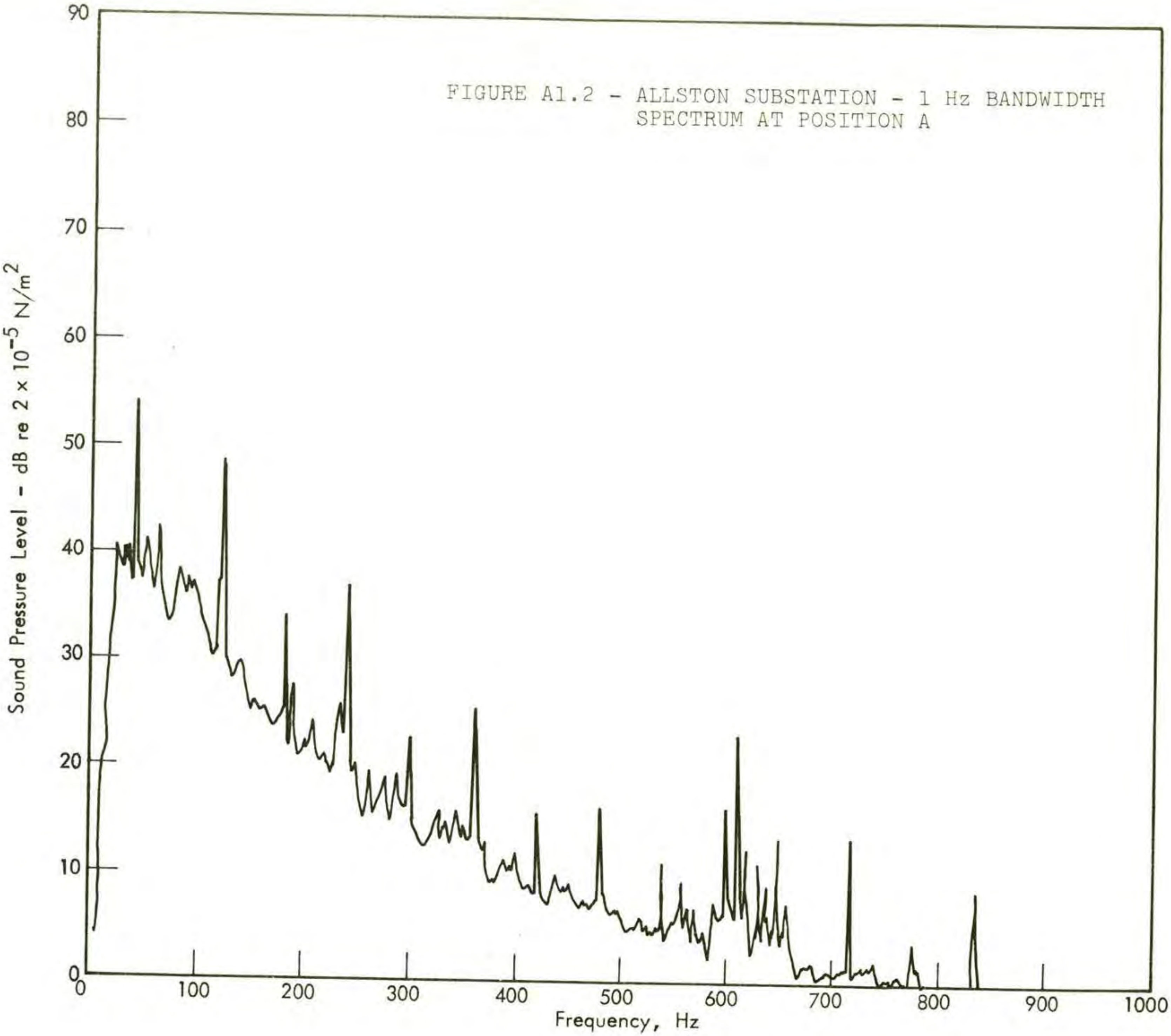


FIGURE A1.2 - ALLSTON SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POSITION A

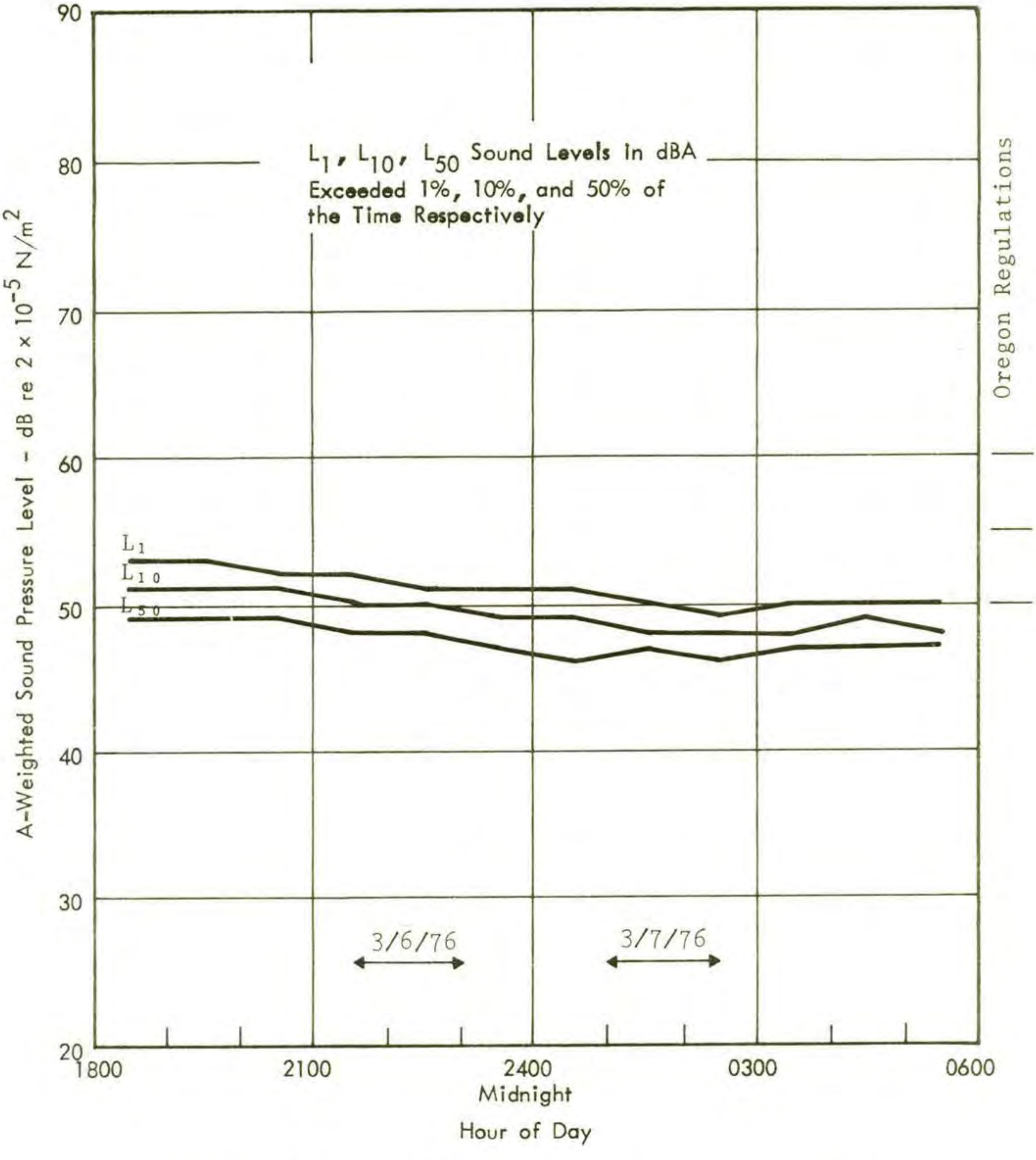


FIGURE A1.3 - ALLSTON SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

FIGURE A1.4 - ALLSTON SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS

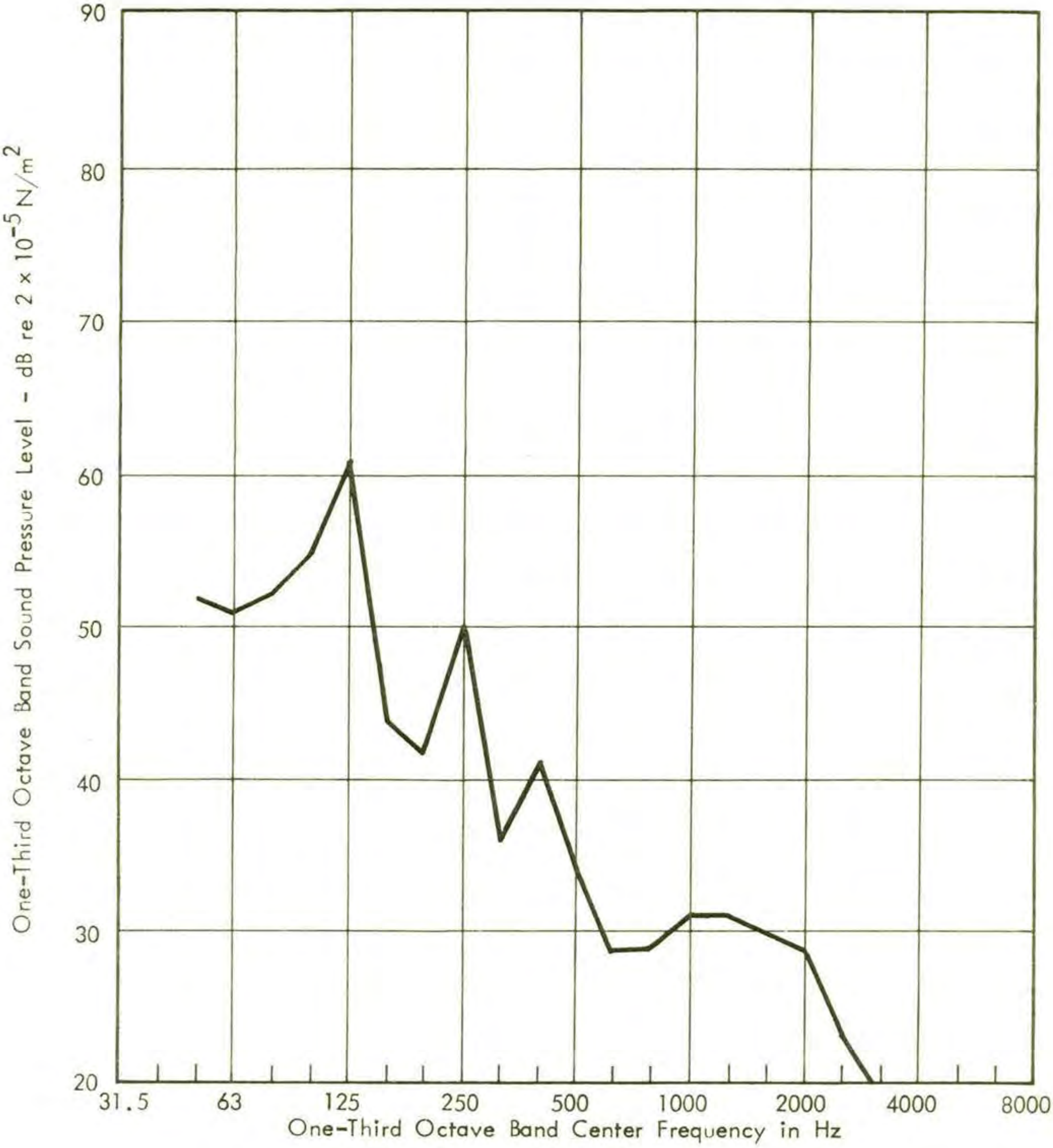


FIGURE A1.5 - ALLSTON SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS

A2. ALVEY SUBSTATION

Alvey Substation lies immediately northeast of the township of Goshen located southeast from Eugene. A layout of the substation and of its environs is shown in Fig. A2.1. [redacted]. Details of these units are given in Table A2.1.

Interstate 5 (I-5) lies to the north and west of the substation, running (over this portion) in a northwest/southeast direction. The BPA land holding and easements around the substation are substantial. To the north of the substation there are BPA maintenance and operations workshops and facilities. To the west and east the land is virtually secured against development by power line easements. The tree-covered hill directly to the south of the station is (we understand) owned by BPA. The only two areas in which the substation is likely to present a noise problem are those areas directly to the southeast and to the southwest. Goshen, which lies to the southeast, is primarily a lumber town. The noise environment in Goshen Center is dominated day and night by traffic on the I-5. The Transport Cafe in Goshen Center is open 24 hours per day, which is a good indication of the volume of nighttime truck traffic on this interstate route. The only property in Goshen which may be adversely affected by the substation is a house which lies 250 ft from the southeast corner perimeter fence.

There is farmland which would be suitable for future residential development to the southwest of the substation (to the west and to the south of the cooling tower). Because of the remoteness of this site from the I-5 and because of the extent to which the terrain shields this area from the I-5 and from the lumber yards, it must be presumed that this area could be particularly noise sensitive should it ever be developed. It is therefore this position which was used for microsampling. We understand, however, that no further residential development is scheduled in this area in the foreseeable future.

FIELD SURVEY

The major field study was carried out over the period 10th to 11th March 1976. Some further data on the shunt reactor were acquired on 12th May 1976.

We were accompanied within the substation by Mr. Les Farris (Chief Operator) and Mr. Dale Plunkett.

During the March visit the weather was fine with scattered clouds and sunny periods. The wind was from the northwest at 5 mph. The air temperature was 48°F and the relative humidity was 66%.

- Close-In Measurements

The results of the 10 ft measurements on each of the transformer banks are given in Table A2.2. The shunt reactor was energized briefly to allow us to acquire data on it.

- Perimeter Measurements

The levels at the first two tonal frequencies, recorded around the substation perimeter are included in Fig. A2.1. The shunt reactor was not operating during this time.

• Community Measurements

Data samples were acquired:

a) At a position close to the garage of the house, to the southeast of the substation, at a distance of about 350 ft from the shunt reactor, and

b) At a position close to the microsample position.

These data are summarized in Table A2.3. A typical spectrum at Position (a) is shown in Fig. A2.2. The shunt reactor was not operating during these measurements.

• Microsample Data

Microsampling was carried out at the location shown in Fig. A2.1. The results are presented in Figs. A2.3, 4 and 5. The full computer outputs are included in Appendix B.

According to the station records the shunt reactor was energized over the period 0010 hours until 0541 hours. The computer output records suggest that the shunt reactor has some slight influence on the 120 Hz tonal level at the microsampling position.

• Shunt Reactor Tests

Some further special tests were carried on the shunt reactor in May 1976. The purpose of these tests was to confirm the earlier close-in measurements and also to try to establish more precisely the influence of the shunt reactor at community position (a). These tests confirmed the levels given in Table A2.2 and allowed us to form the conclusions given in the next section.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

At the microsample location, the substation (with the shunt reactor operating) is in excess of the Oregon Regulations by about 4 dB in the 125 Hz octave band, although the substation is in compliance on the basis of the A-weighted level and pure tone requirements. Any residential developments in this area would appear to be very unlikely in the future, and so we must base our compliance analysis on the measured or expected conditions at the existing property to the southeast of the yard.

[redacted] By careful examination of the data quoted in this report, and of data and observations made during our two visits to the site, we are able to arrive at the following conclusions with regard to the environment at the selected noise sensitive property.

1) The nonsubstation environment is quite noisy during day *and* night because of the proximity of Interstate 5 *and* of the Transport Cafe. By itself, this environment is probably in excess of the Oregon Regulations.

2) The substation noise (with the shunt reactor energized) is in excess of the regulations in the 125 Hz octave band by 2 to 4 dB. The higher frequency components and the A-weighted sound pressure levels are in compliance with the regulations.

3) [redacted] Both will require some noise control to arrive at a satisfactory noise environment.

RECOMMENDATIONS

The noncompliance situation would best be resolved by the erection of a barrier along the perimeter fence starting at that corner to the [redacted] and extending to the northeast corner of the [redacted] [redacted] (that corner in Fig. A2.1 from which the location of Goshen Center is indicated). The height of this barrier should be such as to impose a 10 dB reduction on the 120 Hz tonal noise from the shunt reactor. The length of barrier treatment would be about 440 ft; the approximate height would be 12 ft. The perimeter line of course could be modified to allow a somewhat shorter wall length.

However, in view of the marginal nature of the substation noise excess--especially considering the high levels of nighttime environmental noise from road traffic sources--we recommend that BPA take no positive action at present, other than to make long range plans for the possible future erection of such a noise shielding wall.

BPA however should remain aware of the possible need in the future for noise corrective measures at Alvey. It would seem prudent to consider the possibility of carrying out some longer term monitoring in the vicinity of the "noise sensitive" property to define more precisely the relative contributions of the BPA substation and other non-BPA noise sources to the observed noise environment.

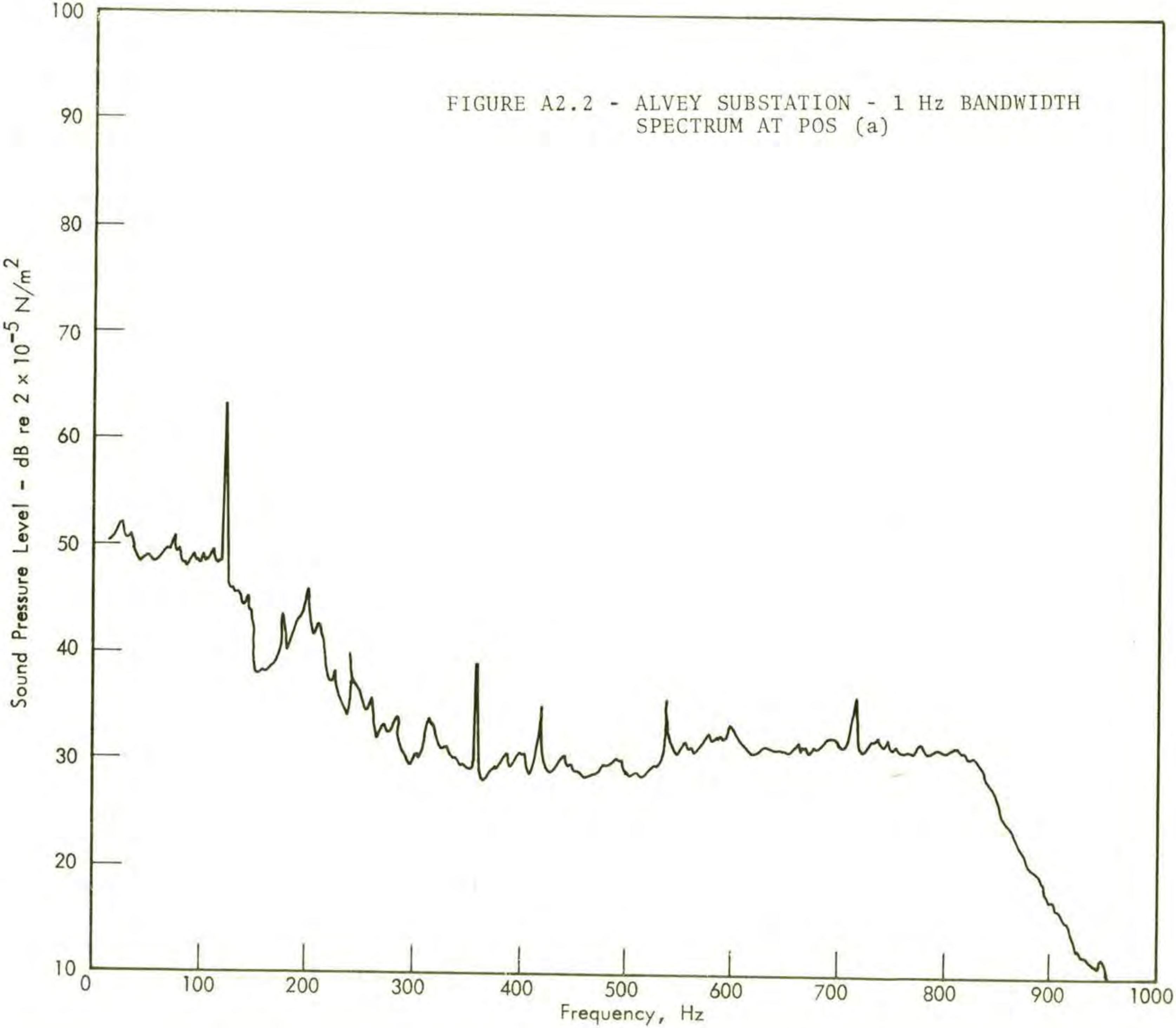


FIGURE A2.2 - ALVEY SUBSTATION - 1 Hz BANDWIDTH
SPECTRUM AT POS (a)
Sound Pressure Level - dB re 2 × 10^-5 N/m^2
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
Frequency, Hz

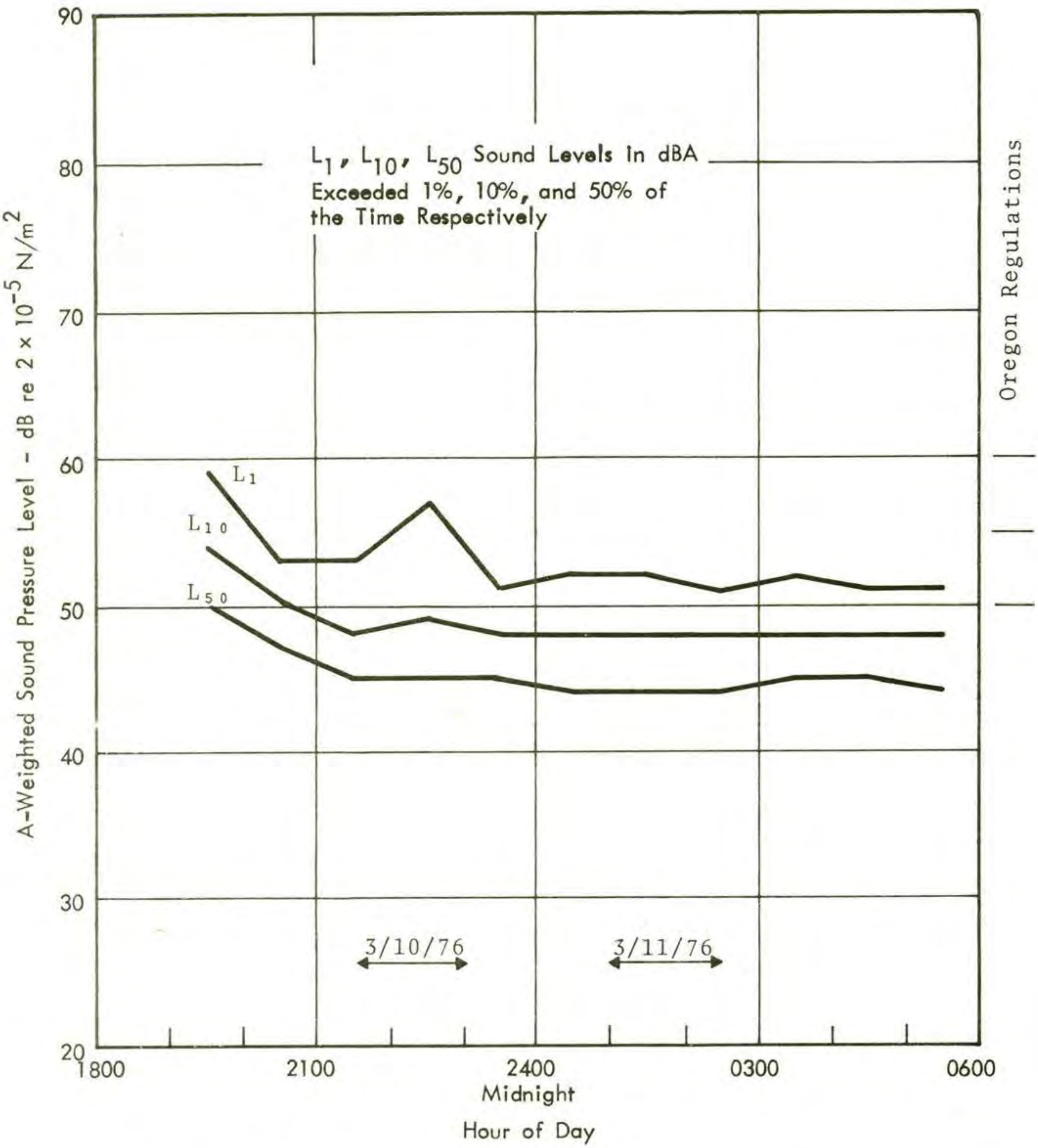


FIGURE A2.3 - ALVEY SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

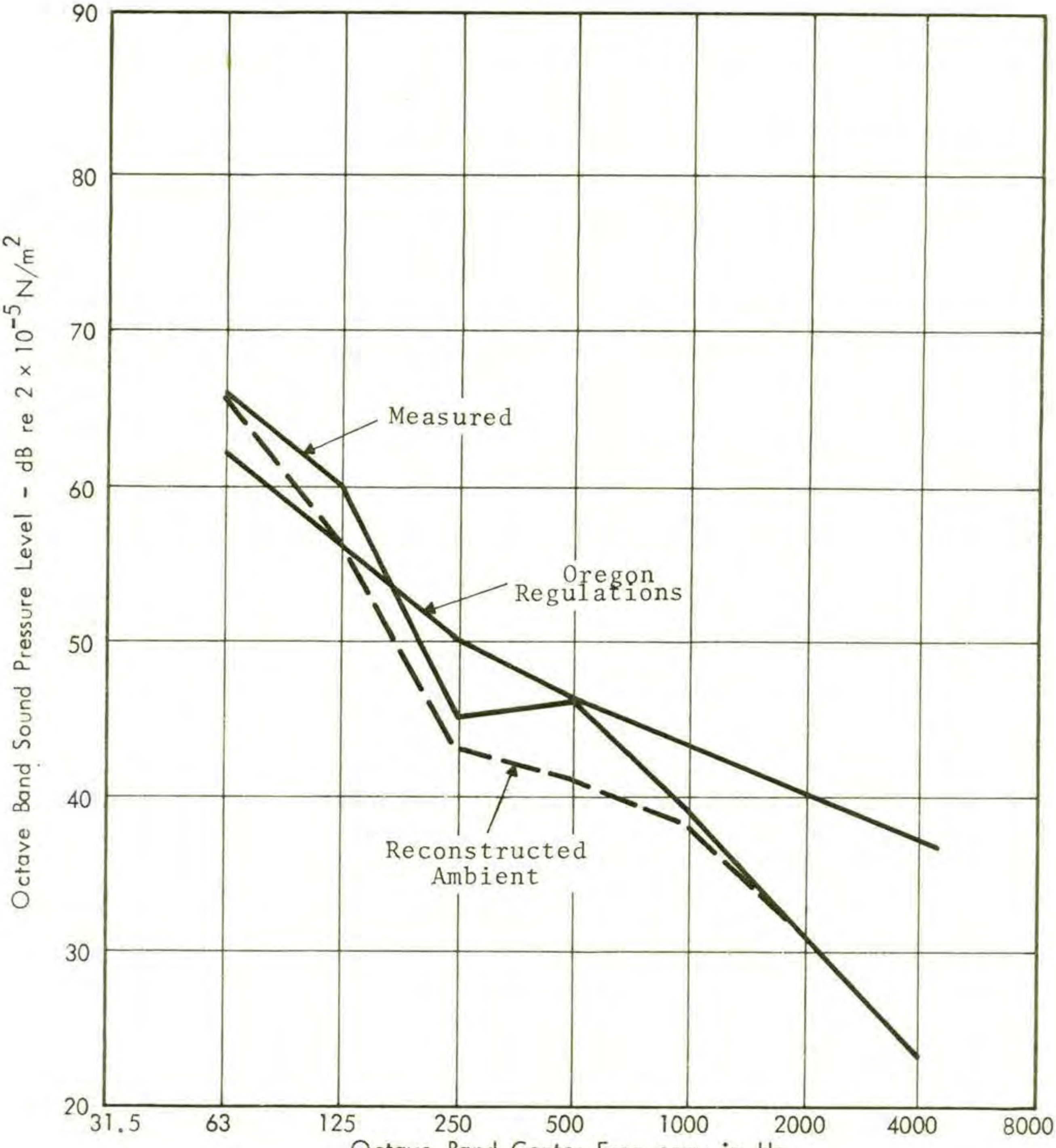


FIGURE A2.4 - ALVEY SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS

FIGURE A2.5 - ALVEY SUBSTATION - MICROSAMPLE (L_{10})
ONE-THIRD OCTAVE BAND LEVELS, 0300
TO 0400 HRS

A3. BIG EDDY SUBSTATION

Big Eddy substation lies 4 miles east of the Dalles in Wasco County, Oregon. The site lies some 250 ft above the Columbia River and U.S. Highway 30 (the Columbia River Highway).

The layout of the substation and the major pertinent features of its environs are shown in Fig. A3.1. Details of the four banks of transformers are given in Table A3.1.

The BPA property holding around Big Eddy Substation is very substantial. The site also "houses" the BPA "Celilo" dc power transmission station.

The two residential properties shown in Fig. A3.1, to the west and northwest of the substation, are the only properties at present that may be physically affected by the noise of the substation. The trailer park lies close to river level and so is well shielded by the terrain.

There are some properties visible from the substation which lie to the northeast, on the north side of the valley formed by Fifteen Mile Creek. These are at a distance in excess of 1500 ft from the perimeter fence.

No future developments would appear to be possible at distances which are closer than existing properties. The terrain is such, in fact, that future developments close to the BPA property line would almost certainly be shielded from direct view of the substation.

FIELD SURVEY

The field measurements were carried out over the period 15th to 16th March 1976. We were accompanied within the substation by Mr. Lefler (Operator-in-Charge) and Mr. Nicholson (Safety Officer).

The weather during the measurements was fine with light cloud cover and wind from the west at 3 mph. The temperature was 56°F; the relative humidity was 66%.

- Close-In Measurements

The results of measurements at 10 ft are summarized in Table A3.2.

- Perimeter Measurements

The results of perimeter measurements at the first two tonal frequencies are shown in Fig. A3.2. When normalized to a 500 ft distance from the [redacted] cluster, the approximate average levels are 64 dB at 120 Hz and 48 dB at 240 Hz. This is in reasonable agreement with the close-in normalizations given in Table A3.2.

- Community Measurements

Measurements were taken at the property to the west (Position (a) on Fig. A3.1) which was later used as the microsample location. The results of narrow (1 Hz) band analysis of these data are shown in Fig. A3.3. The results are summarized in Table A3.3.

- Microsample Data

The microsample location is shown in Fig. A3.1. The results are summarized in Figs. A3.4, 5 and 6. The full computer output sheets are included in Appendix B.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The Big Eddy substation is in compliance with the State of Oregon Noise Regulations. The apparent noise excess in Fig. A3.5 is not caused by the substation but is probably the result of water spillage noise from the nearby Dalles Dam. Traffic noise on the busy U.S. Highway 30 may also contribute to the nighttime environment.

Future residential development around the Big Eddy site is unlikely to alter the present compliance situation.

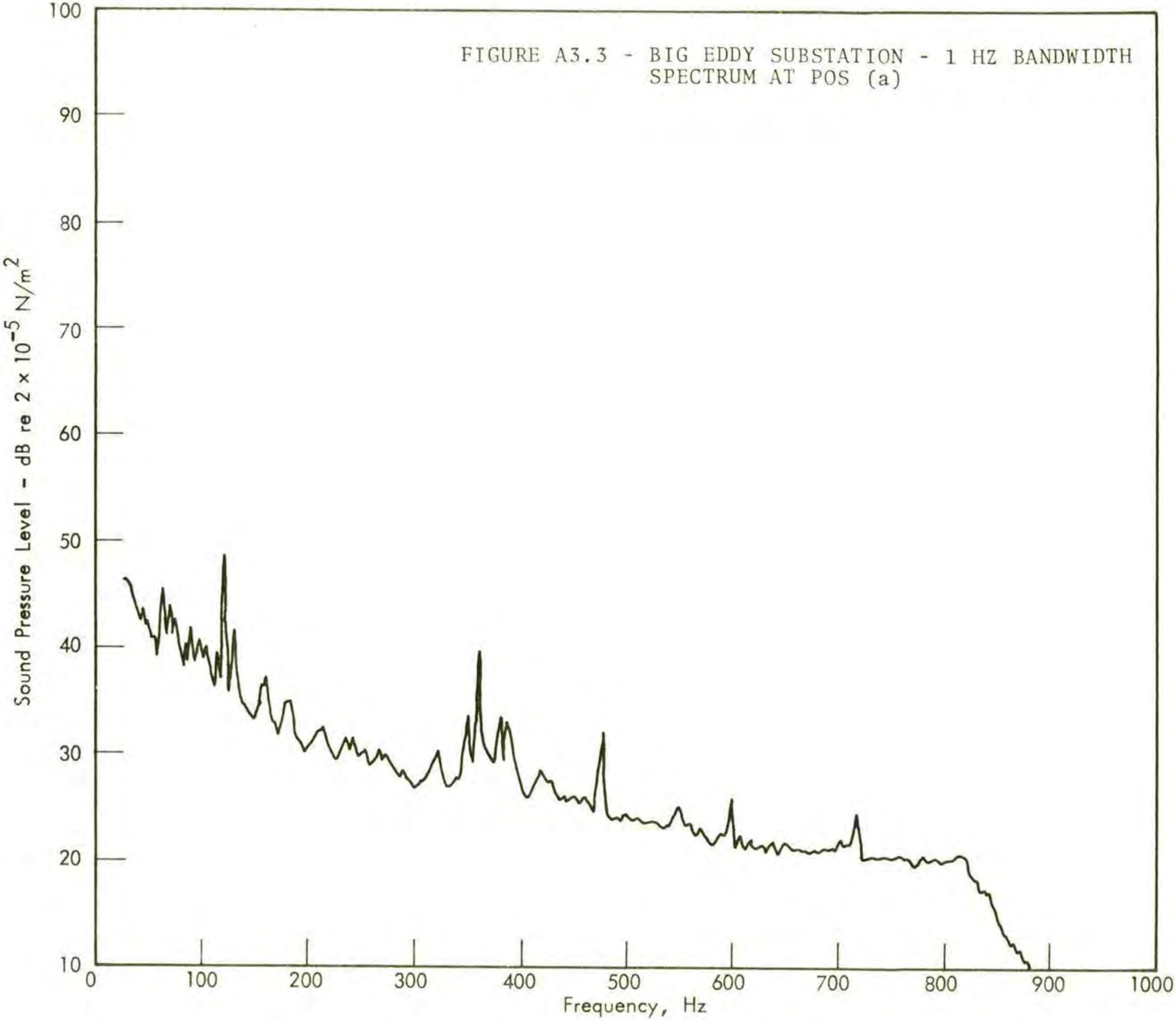


FIGURE A3.3 - BIG EDDY SUBSTATION - 1 HZ BANDWIDTH SPECTRUM AT POS (a)

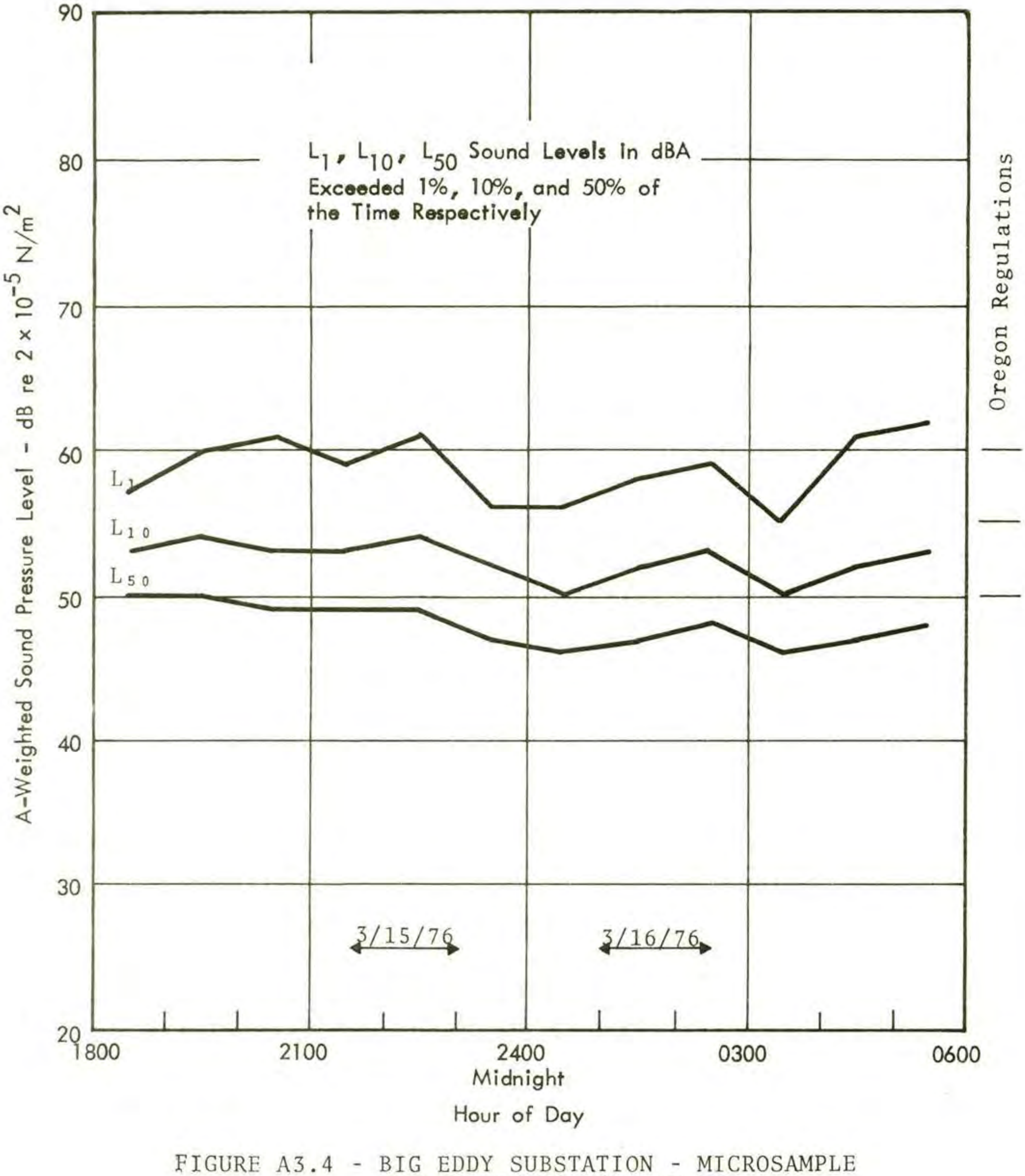


FIGURE A3.4 - BIG EDDY SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

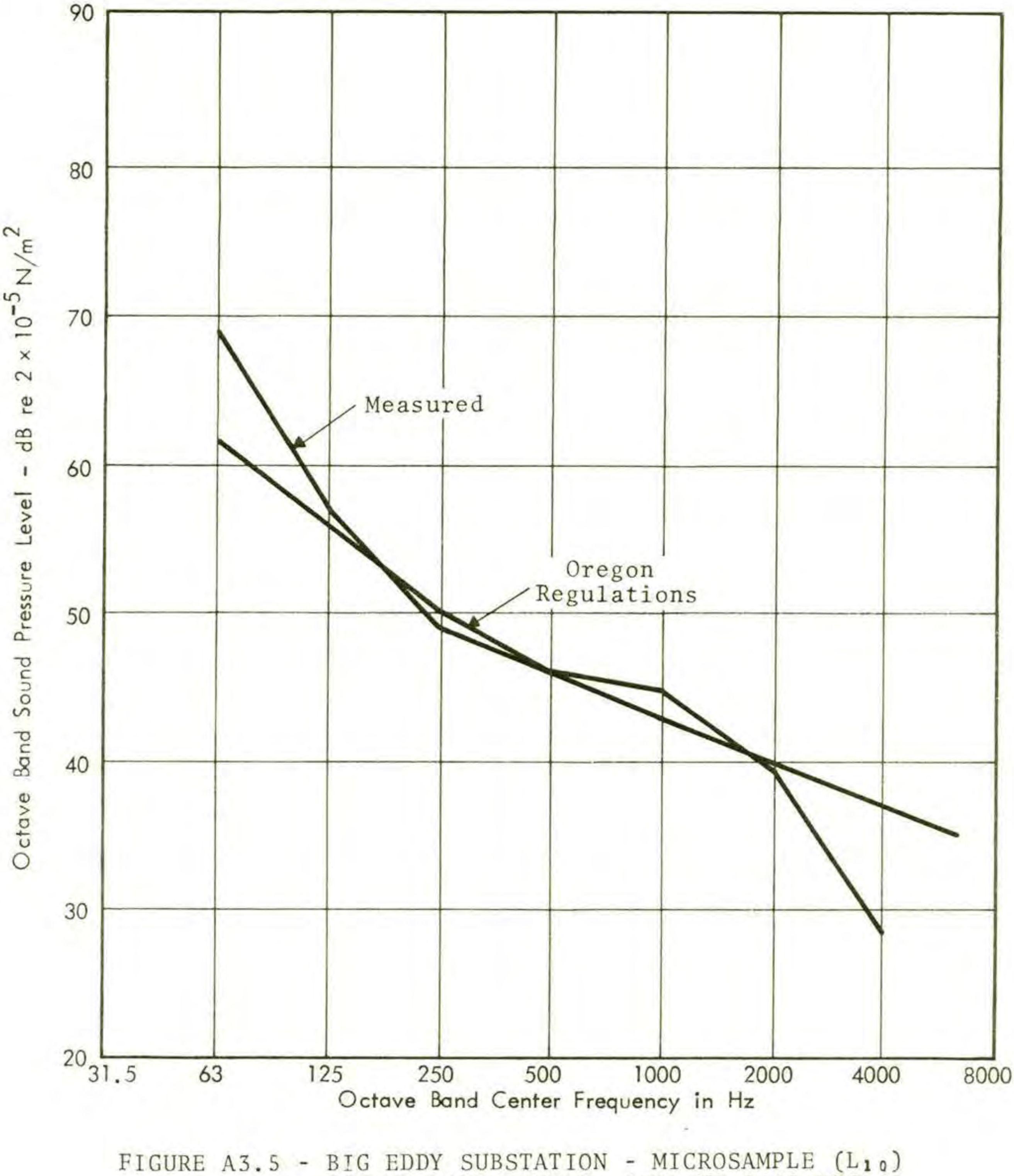


FIGURE A3.5 - BIG EDDY SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS

FIGURE A3.6 - BIG EDDY SUBSTATION - MICROSAMPLE (L_{10})
ONE-THIRD OCTAVE BAND LEVELS, 0300 TO
0400 HRS

A4. CHEMAWA SUBSTATION

Chemawa Substation is located to the west of Interstate Highway 5, 5 miles north of Salem Center, in Marion County, Oregon.

[redacted].

The terrain around the substation is flat and, at present, is largely agricultural in use. The closest residential buildings lie about [redacted]

It seems fairly clear that pressures from the Salem Metropolitan area to the south will bring further residential developments around the Chemawa site in the next ten to fifteen years. The BPA land holding around the site is fairly limited as can be seen from Fig. A4.1.

The most likely areas for future developments would seem to be to the west and south of the substation. Development to the east would be limited by the existence of transmission line easements; there is no ready access to the area to the north.

FIELD SURVEY

The field measurements were acquired over the period 9th to 10th March 1976. We were accompanied within the substation by Mr. W. Eimon (Operator) and Mr. Morales (Substation Design).

The weather during the measurements was clear and sunny with a 2 to 3 mph wind from the northeast. On the afternoon of 9th March the air temperature was 56°F and relative humidity 77%.

• Close-In Measurements

The data acquired at 10 ft from the transformer banks are summarized in Table A4.2.

• Perimeter Measurements

The results of the perimeter measurements at the first two tonal frequencies are included in Fig. A4.1.

These data normalize to average levels of 65 dB at 120 Hz and 50 dB at 240 Hz, at a distance of 500 ft. This compares well with the 500 ft predictions based on the Bank 2 close-in measurements (see Table A4.2).

• Community Measurements

Data were acquired for narrow band analysis at two positions:

a) At the farm to the northwest (close to the microsample position),

b) At the farm to the northeast.

These data are shown in Table A4.3. The agreement with the 500 ft predictions based on the close-in and perimeter measurements is reasonable at the 120 Hz frequency. At the higher component frequencies the community measurements are lower than predicted, perhaps due to ground attenuation effects.

• Microsample Data

Microsampling was carried out at the location shown in Fig. A4.1. The results of these measurements are shown in Figs. A4.2, 3, and 4. The complete computer printout sheets are included in Appendix B. The influence of the noise from Interstate Highway 5 is seen (in Fig. A4.2) in the relatively small changes in environmental levels that arise during the measurement period.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The apparent violation of the Oregon Noise Regulations in Fig. A4.3 is caused not by the substation but by nighttime traffic on Interstate Highway 5. At the present time the substation is not in violation of the Regulations.

Future developments to the west of the substation would bring residential properties as close as [redacted]. Developments to the south would be somewhat further away. The worst situation would arise if developments were to occur on the north boundary; here the distance would be about 400 ft. A distance of 400 ft would therefore seem to be a good figure on which to base our analysis.

In the event of future developments at this distance, our analyses suggest that the substation will be in violation of the Oregon Regulations by about 9 dB at 120 Hz; there will be little or no violation at the higher frequencies.

RECOMMENDATIONS

There is no need for noise control at the present time. We recommend, however, that BPA plan for the provision of shielding walls around Bank 2 at such time as residential developments around the site might make this necessary. There should be no need for treatment of Bank 1.

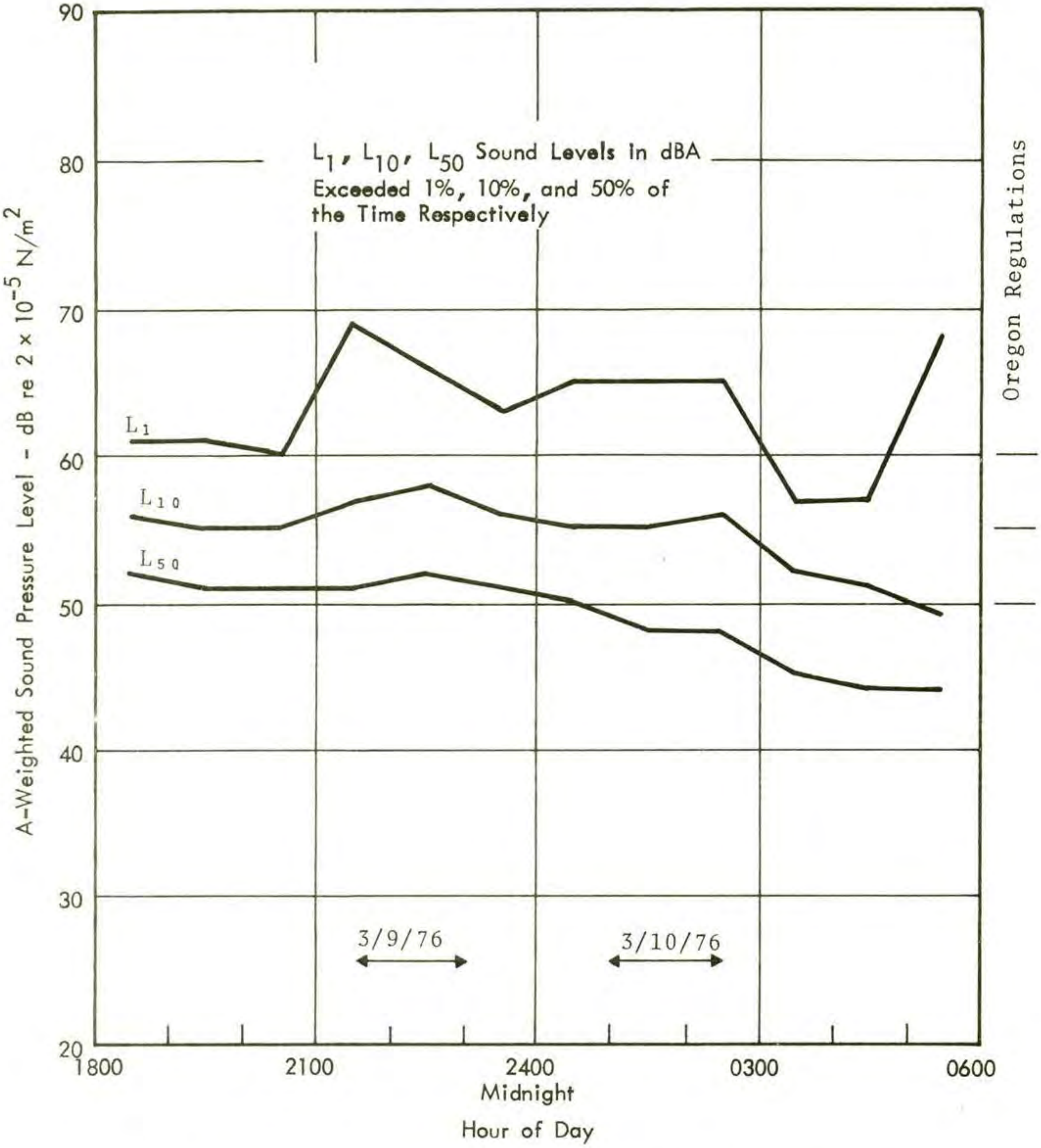


FIGURE A4.2 - CHEMAWA SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

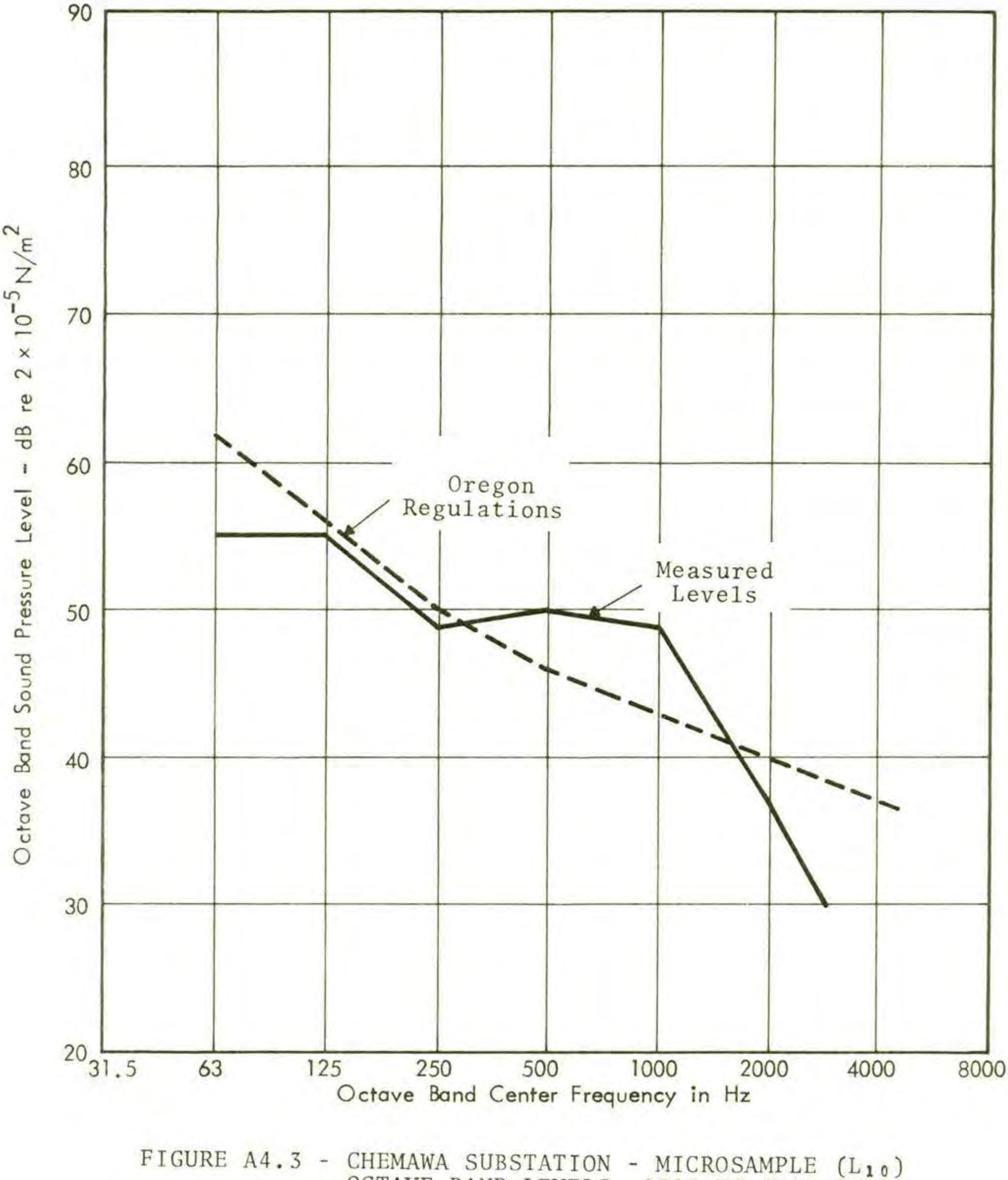


FIGURE A4.3 - CHEMAWA SUBSTATION - MICROSAMPLE (L_{10})
OCTAVE BAND LEVELS, 0300 TO 0400 HRS

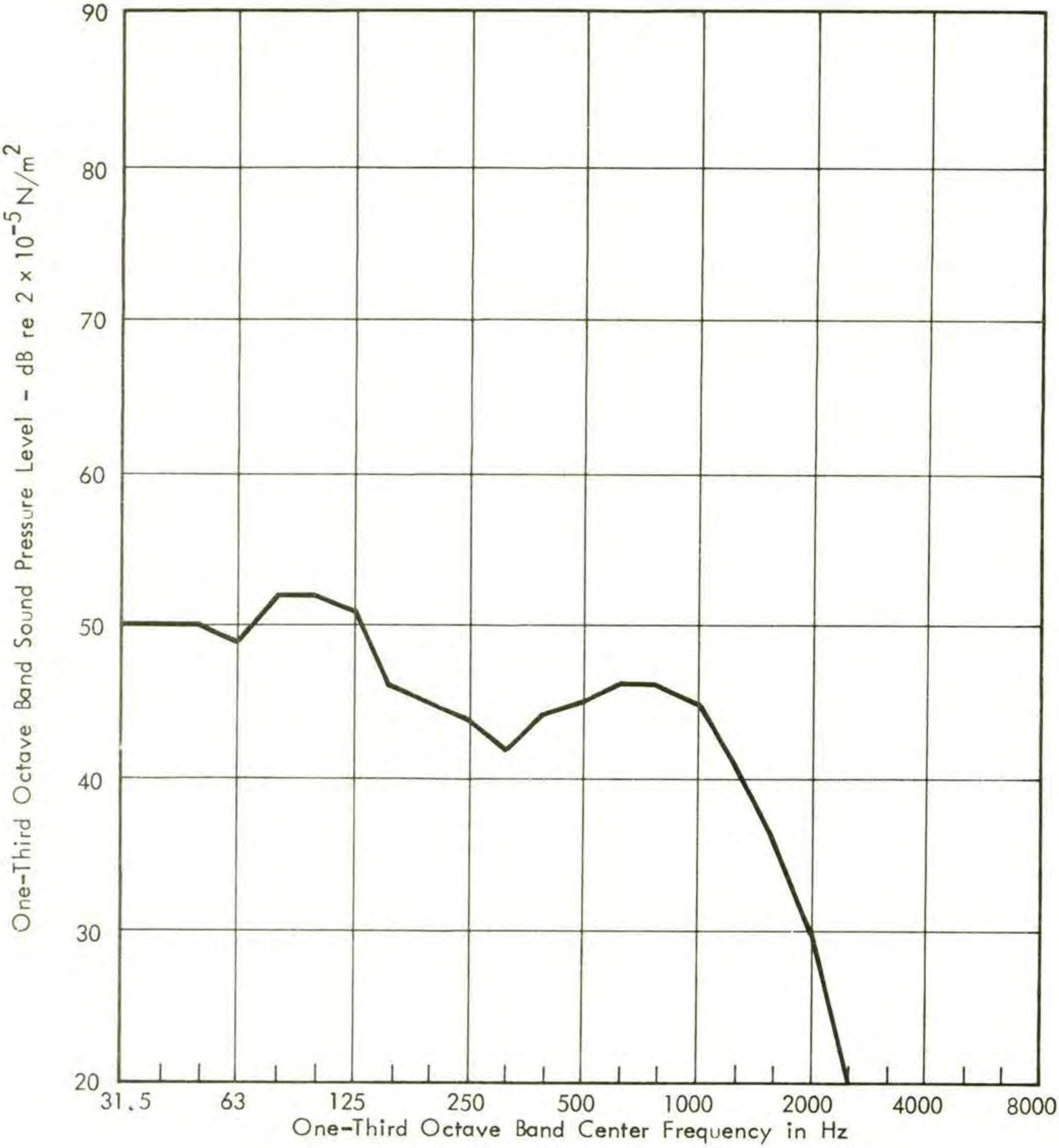


FIGURE A4.4 - CHEMAWA SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS

A5. CLATSKANIE SUBSTATION

Clatskanie Substation lies to the south of Clatskanie town in Columbia County, Oregon.

The layout of the substation is shown in Fig. A5.1.

Land rises steeply to the northwest and to the west. To the south and east the land drops sharply. The substation is effectively set on a level platform part way up a hill. There is a row of houses on Tichener Street. The closest of them shown in Fig. A5.1 lies only [redacted]. No closer residential development is possible and in fact the terrain is such that it would seem unlikely that any further development could occur within several hundred feet of the substation.

FIELD SURVEY

Measurements were carried out over the period 6th to 7th March 1976. We were accompanied within the substation by Mr. Lyle Howard (Substation Design). The weather was dry and calm.

• Close-In Measurements

The measurement data acquired 10 feet from the transformer are summarized in Table A5.2. Since it appeared likely that the Allis-Chalmers voltage regulators were noisier than the Toshiba transformer, these were included in the survey.

• Perimeter Measurements

The results of the perimeter measurements at the first two tonal frequencies are presented in Fig. A5.1. These data normalize to average levels at 500 ft of 34 dB at 120 Hz and 23 dB at 240 Hz.

• Community Measurements

Measurements were taken at the following positions outside the perimeter fence:

a) 25 ft to the north of the fence in line with the voltage regulators,

b) [redacted] [redacted] [redacted] [redacted],

c) In the center of the parking area 25 ft east of the fence,

d) At a position on the edge of the parking lot 25 ft south of the southeast corner of the house.

The results are summarized in Table A5.3. The distance used for normalization in each case is the distance to the BPA transformer from the measurement location.

• Microsample Data

The microsampler was located in the garden of the nearby house, as shown in Fig. A5.1. The results are given in Figs. A5.2, 3 and 4. The full computer output sheets are included in Appendix B.

COMPLIANCE ANALYSIS AND RECOMMENDATIONS

Clatskanie Substation is in compliance on all counts with the Oregon Regulations. No future development around the substation can be envisioned which would alter this finding. No noise control requirements are recommended, therefore.

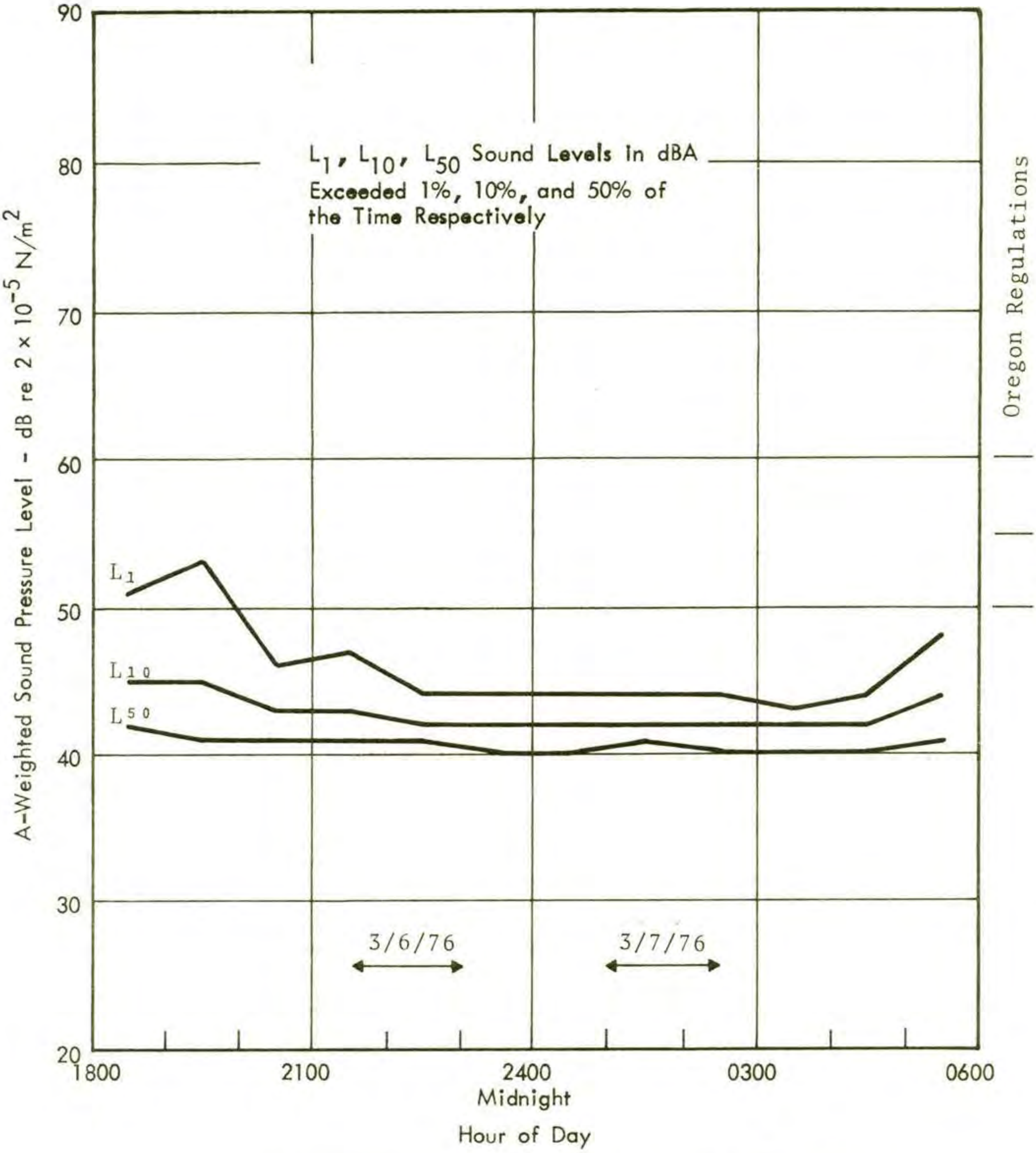


FIGURE A5.2 - CLATSKANIE SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

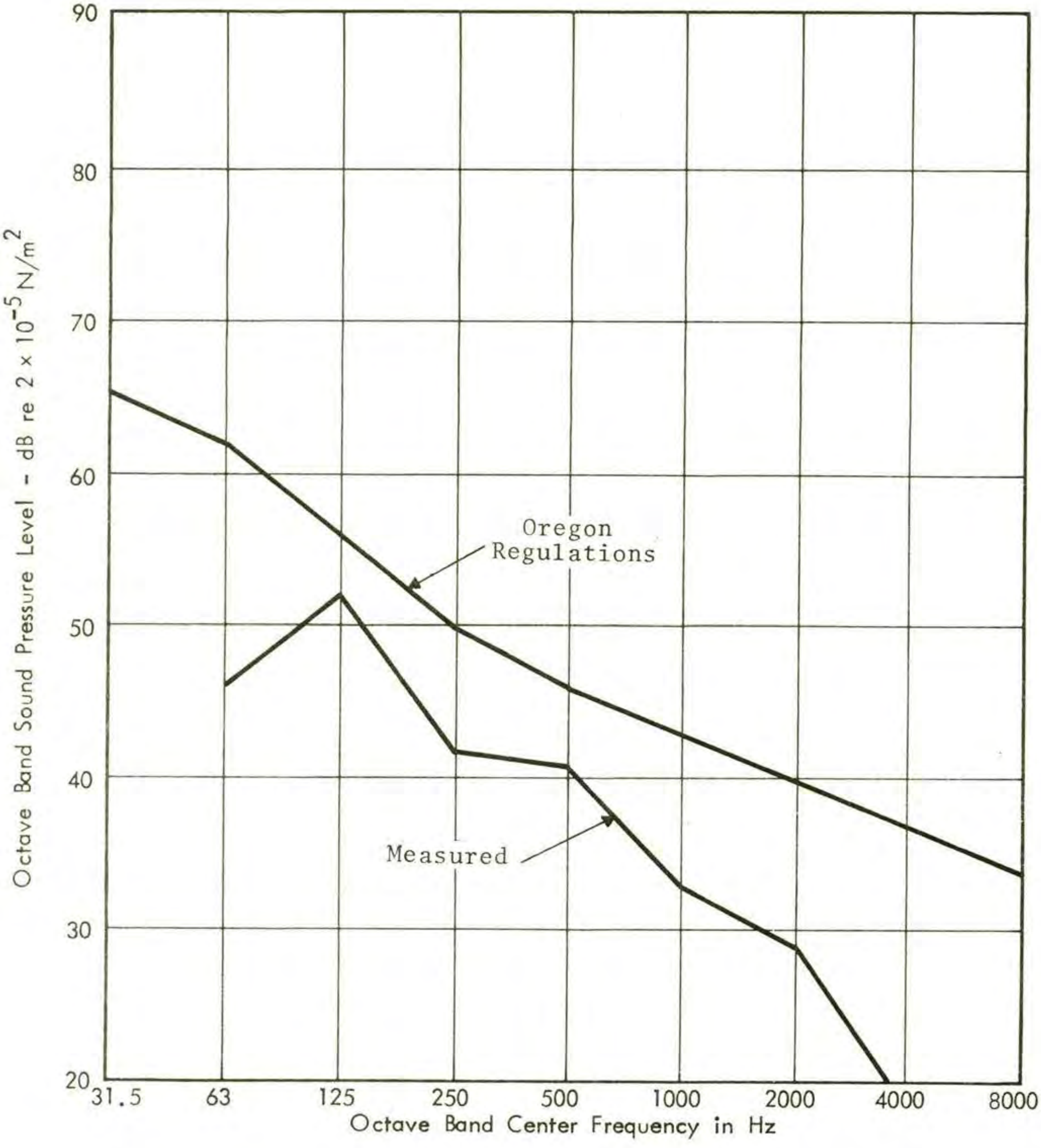


FIGURE A5.3 - CLATSKANIE SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS

FIGURE A5.4 - CLATSKANIE SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS.

A6. DE MOSS SUBSTATION

De Moss Substation is five miles south of Wasco, in Sherman County, Oregon. It lies one half mile west of U.S. Highway 97.

Details of the layout of the substation and of its environs are given in Fig. A6.1. The pertinent features of the [redacted] are given in Table A6.1.

A Pacific Power and Light substation lies some 350 ft to the northwest of the BPA yard. This substation has a bank of [redacted] which, subjectively, are substantially noisier than the BPA transformer.

The substation lies in a shallow valley (Gordon Hollow) which runs in a northwest to southeast direction. The land therefore rises towards the northeast and also towards the southwest. The main land use is agriculture. The terrain is treeless.

In recent years (since 1958) the path of the U.S. Highway 97 has been changed. The abandoned section of highway overlooks the substation at a distance of 240 ft to the northeast. The new highway is now some 2000 ft from the substation and is entirely shielded from it by the terrain.

There are no residential properties within sight of the substation. A grain elevator lies at the junction of Gordon Hollow Road and the main highway. This would appear to be the nearest building.

The situation of De Moss substation is therefore very remote. There would seem to be no reason for and, therefore, little likelihood of any residential development in the area in the foreseeable future.

FIELD SURVEY

The field survey was carried out over the period 15th to 16th March 1976. We were accompanied within the substation by Mr. John Richards (BPA Area Office).

The weather during our visit was overcast but dry. The wind was from the east at 5 mph. On the afternoon of 15th March the air temperature and relative humidity were 50°F and 67%, respectively.

- Close-In Measurements

The results of measurements at 10 ft from the transformer are given in Table A6.2.

- Perimeter Measurements

The tonal data obtained at the perimeter fence are given in Fig. A6.1. When normalized to a 500 ft distance from the transformer they give average levels of 52 dB at 120 Hz and 48 dB at 240 Hz.

More limited perimeter data were also taken at the Pacific Power and Light Substation, to determine its relative significance as a noise source. The levels recorded, normalized to 500 ft distance, averaged 43 dB at 120 Hz and 38 dB at 240 Hz. This source would therefore appear to be less significant than the BPA transformer.

- Community Measurements

Data were acquired at a position (Position (a)) on the old Highway 97, [redacted] NR
The tonal levels are given in Table A6.3.

· Microsample Data

Microsampling was carried out at a position to the southeast of the [redacted]. The data are summarized in Figs. A6.2, 3 and 4. The full computer output sheets are included in Appendix B.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

De Moss substation clearly complies with the Oregon Noise Regulations; the substation should be in compliance for residential properties lying as close as [redacted]. Since there would seem to be no pressures for the development of residential properties in this area, no problems are anticipated in the foreseeable future.

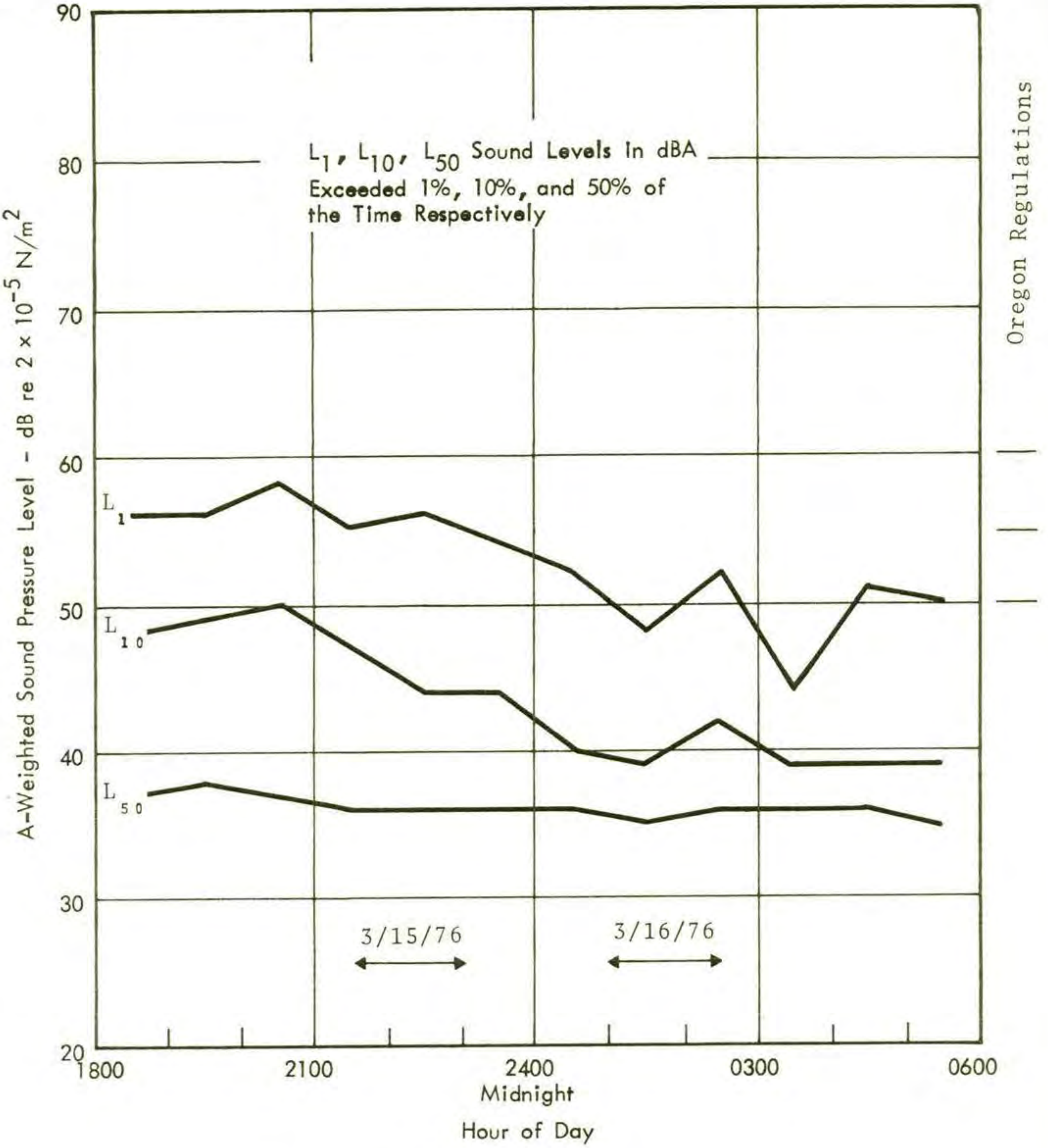


FIGURE A6.2 DE MOSS SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

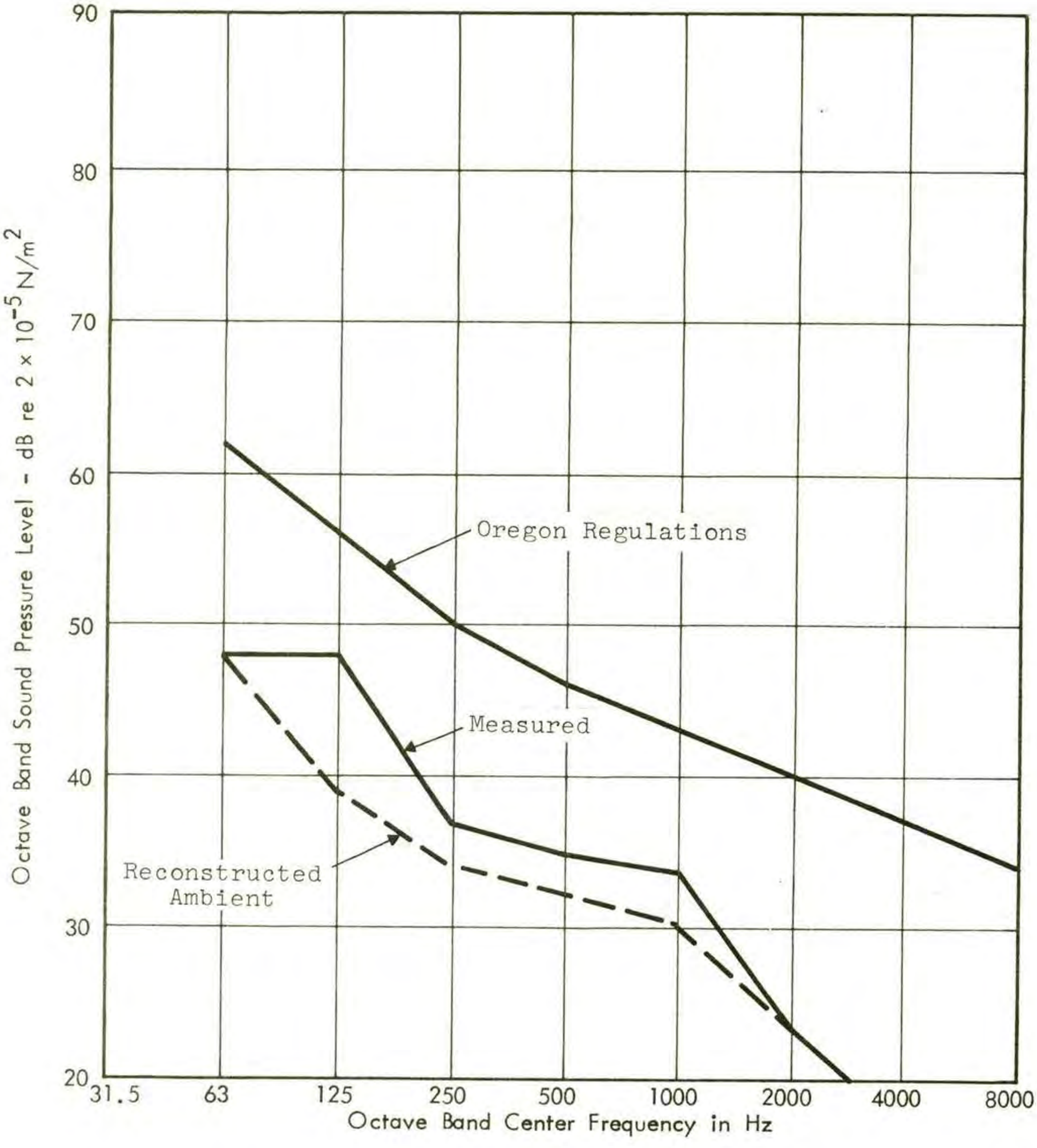


FIGURE A6.3 DE MOSS SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

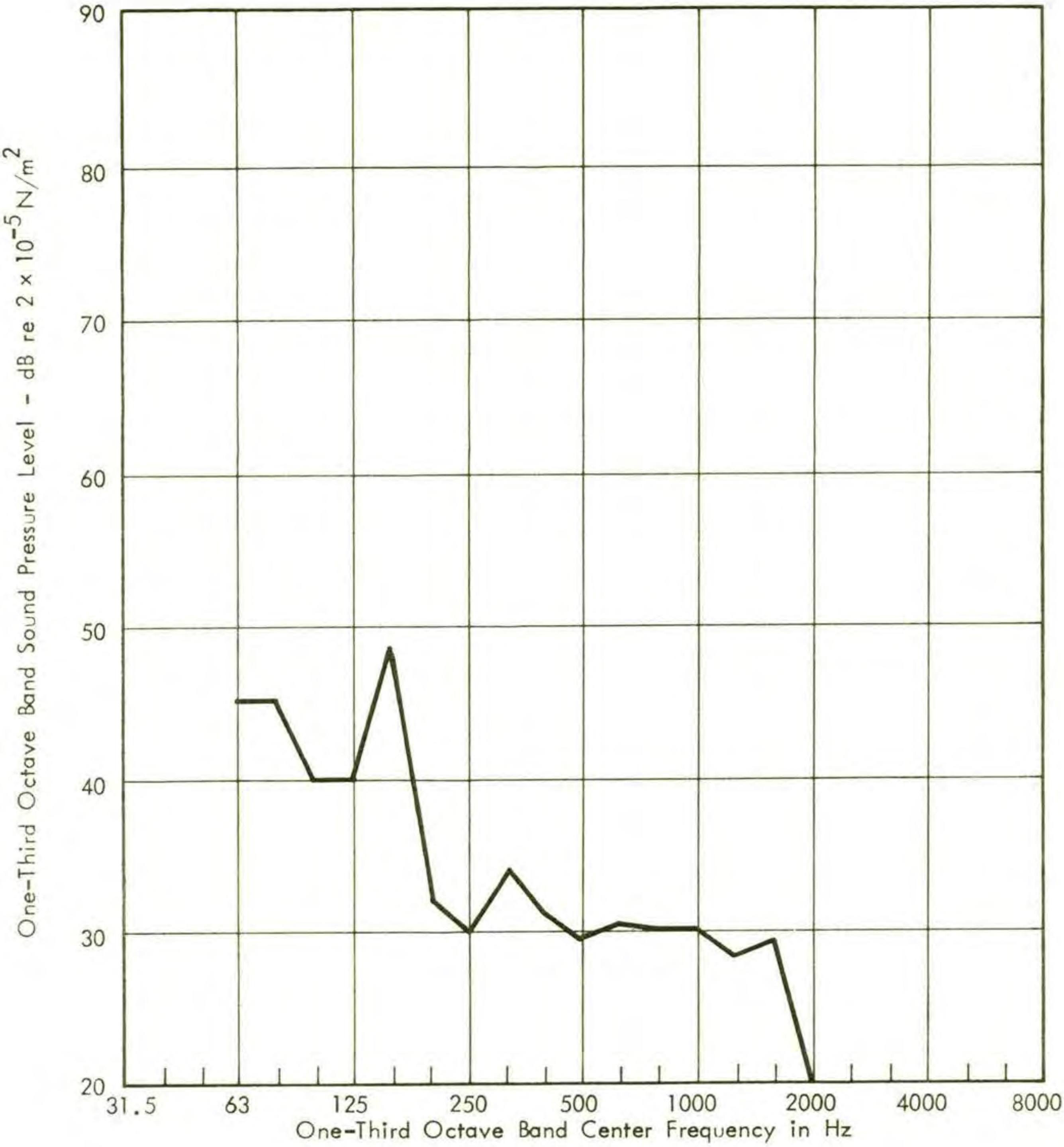


FIGURE A6.4 - DE MOSS SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS 0300 TO 0400 HRS

A7. GOLD BEACH SUBSTATION

Gold Beach Substation is located one mile southeast of the center of the township of Gold Beach, in Curry County, Oregon.

The layout of the substation and of its environs are given in Fig. A7.1. The substation adjoins a substation operated by the Coos-Curry Electric Cooperative. The characteristics of the BPA transformer bank and of the Coos-Curry bank are given in Table A7.1.

To the west and north of the substation, development is already complete. A school is located 500 ft to the northeast. There is a cable storage yard to the east. To the southeast and south of the substation the land rises steeply. A house is located on the hill to the south.

There would appear to be little land available for future development in the immediate vicinity of the substation.

FIELD SURVEY

The field survey was carried out over the period 11th to 12th March 1976. We were accompanied within the substation by Mr. George Rose (Operator).

During the survey the weather was clear and sunny. On the afternoon of 11th March wind velocities lay in the range 6 to 8 mph from the northwest. Wind velocities fell during the evening and night. On the morning of 12th March there was virtually no wind. On the afternoon of 11th March the air temperature and relative humidity were 52°F and 69%, respectively.

• Close-In Measurements

The results of measurements at 10 ft from the BPA and Coos-Curry transformer banks are given in Table A7.2.

• Perimeter Measurements

The results of the perimeter measurements at the first two tonal frequencies are given in Fig. A7.2. Taking the BPA transformer as the source, the southern perimeter data normalize to 500 ft levels of 42 dB at 120 Hz and 35 dB at 240 Hz. Taking the Coos-Curry transformer as the source, the northern perimeter data normalize to 500 ft levels of 41 dB at 120 Hz and 33 dB at 240 Hz. The agreement with the close-in normalizations is reasonable.

• Community Measurements

Data were acquired at the five positions shown in Fig. A7.1. The results of analyses are given in Table A7.3. Positions (a) to (d) are primarily influenced by the Coos-Curry transformer; therefore normalizations are based on their distance to this transformer. Position (e) lies about 50 ft above substation grade level, in full view of both transformer banks; therefore normalization is based on the distance to the center of the two-bank cluster.

• Microsample Data

The microsample data were collected at the location shown in Fig. A7.1. The results are summarized in Figs. A7.3 to A7.5. The full computer output sheets are given in Appendix B.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The microsample data show that at this location the situation is in compliance on the basis of the A-weighted noise level, but that the octave band requirement is exceeded by about 6 dB at 120 Hz. Of the other positions monitored, only Position (d) is in default--here to the extent of 5 dB at 120 Hz.

A detailed analysis of all the data acquired in the study suggest that the Coos-Curry transformer is marginally noisier than the BPA transformer. The problem at Position (d) is generated entirely by the Coos-Curry bank. At the microsample location the problem would appear to be shared equally by the Coos-Curry and the BPA banks. Thus in itself the BPA bank would be about 2 dB in default (at 120 Hz) of the Oregon Noise Regulations.

Since the regulations apply to a noise source owned or controlled by a corporation or agency or municipality (etc.), it must be presumed that BPA *in itself* is only marginally in default of the noise regulations. Noise control action by BPA alone would not change the present situation significantly.

RECOMMENDATIONS

We recommend that BPA explore with Coos-Curry the possibility of joint noise control measures at the Gold Beach site. The BPA contribution to the problem could probably be eliminated by the use of a resilient skin applied to their transformer bank. However, given the willingness of Coos-Curry to incorporate noise control measures themselves, we recommend that BPA consider the use of a simple barrier to the west of their transformer bank. Similar action by Coos-Curry would ensure a very adequate solution of the present problem.

In the absence of Coos-Curry collaboration on this project, we would advise no noise control action (other than planning) at the present time.

We recommend, further, that BPA remain cognizant of land transactions and planning applications in this area.

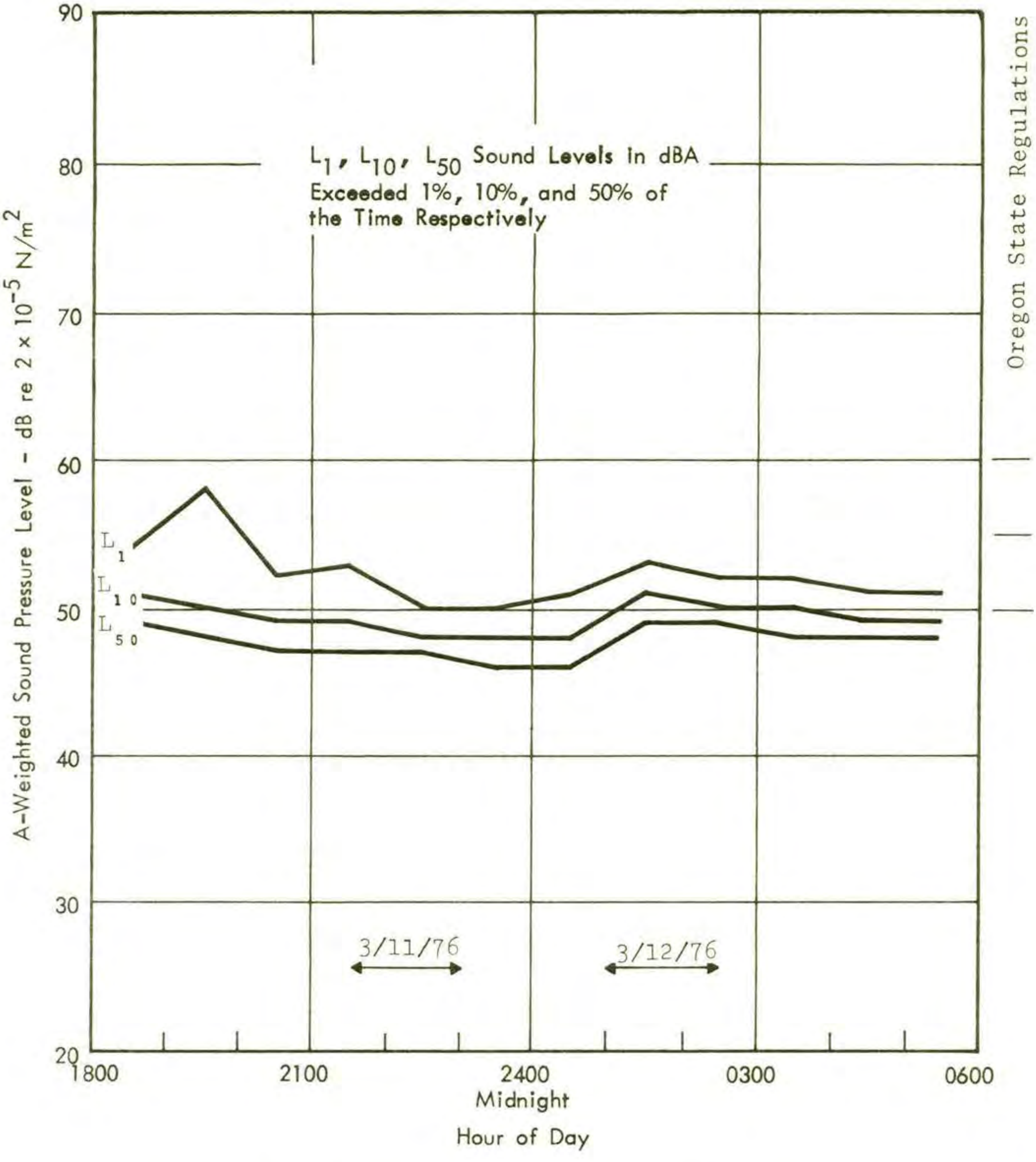


FIGURE A7.3 - GOLD BEACH SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

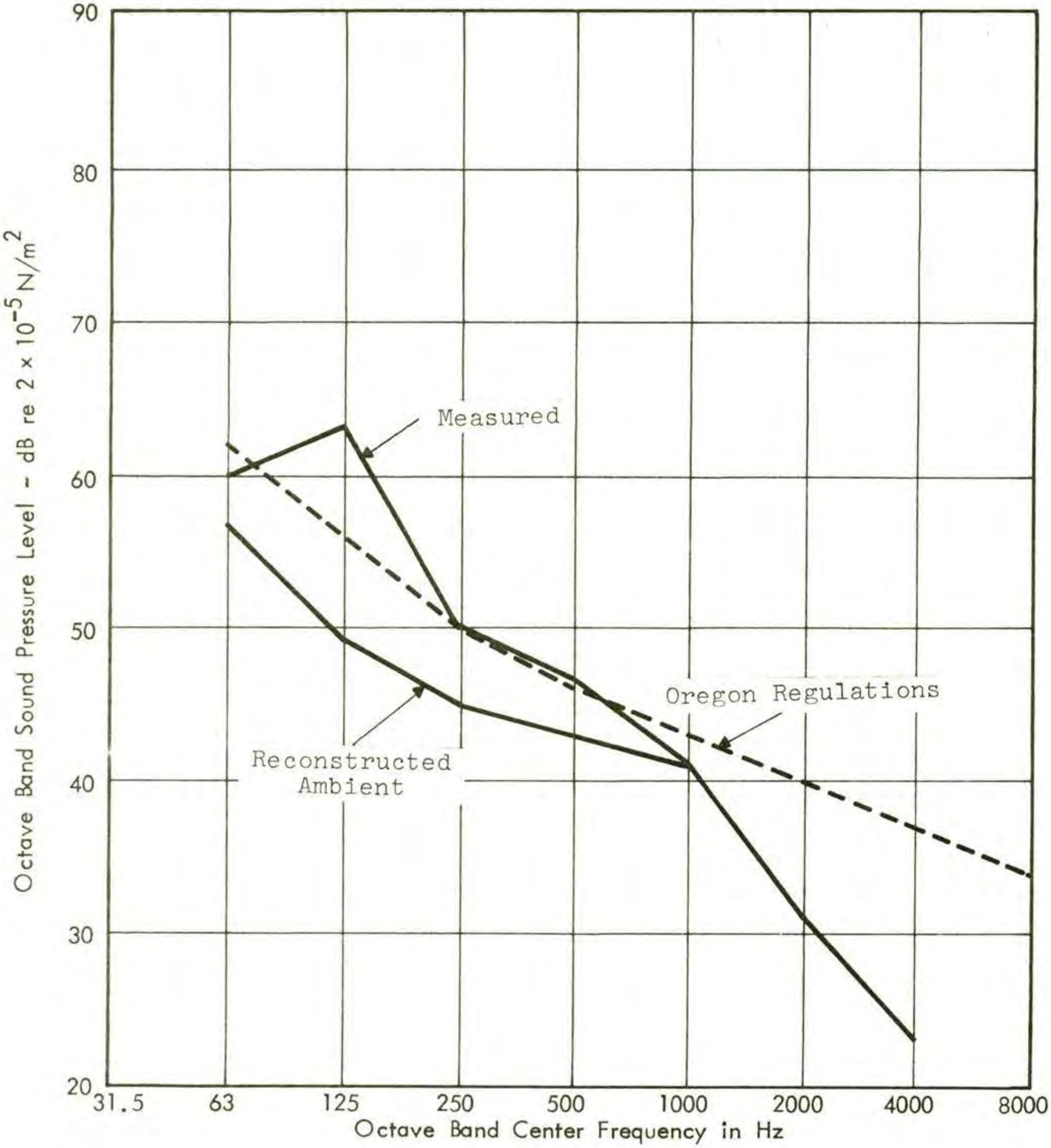


FIGURE A7.4 - GOLD BEACH SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS.

FIGURE A7.5 - GOLD BEACH SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS.

A8. KEELER SUBSTATION

Keeler Substation is located 13 miles northwest of Portland, on the south side of U.S. Highway 26, in Washington County, Oregon.

The layout of the station and its location with respect to surrounding properties are shown in Fig. A8.1.

Details of each of the [redacted] in the substation are given in Table A8.1. [redacted] is identical to that at Covington Substation.

Most of the terrain around the substation is flat and at present is farmed.

The small area of existing development on the north side of Highway 26 is shown in Fig. A8.1. This development will in the near future spread westwards by up to 1000 ft. The land is already surveyed and staked out in residential lots.

A cottage and several outbuildings lie close to the southeast corner of the substation. Under wet weather conditions this property is exposed to corona noise from the 500 kV transmission lines which lie 300 ft to the west. A farmhouse is located on the west side of Cornelius Pass Road close to its intersection with the substation access road.

FIELD SURVEY

The major part of the field survey was carried out over the period 25th to 26th February 1976. Because of weather and instrumentation problems, the microsampling was carried out on the night of 22nd March 1976.

During much of the study, the sky was overcast and there were occasional showers.

• Close-In Measurements

The results of the measurements at 10 ft from the transformers and the shunt reactor are summarized in Table A8.2. The accuracy of the measurements on the shunt reactor are limited by the presence of a temporary barrier on the north and east sides of the reactor.

• Perimeter Measurements

The results of the perimeter survey are included in Fig. A8.1. During the survey the shunt reactor was not energized. The normalization of these data to a 500 ft distance using Bank 2 as the source center, gives average levels of 69 dB at 120 Hz and 57 dB at 240 Hz. These values are in good agreement with the predictions in Table A8.2.

• Community Measurements

Measurements were taken at the following positions:

a) At the cottage to the south, close to the microsample location (see Fig. A8.1).

b) At the farmhouse to the southwest.

c) At the closest cul-de-sac on the north side of Highway 26.

d) At a position on the north side of Highway 26 representative of that land staked out for future development.

The results are summarized in Table A8.3. The shunt reactor was not energized during these measurements. Normalization is given with respect to the distance [redacted]r. A typical spectrum at Position (d) is presented in Figure A8.2.

- Microsample Data

The results of the microsample survey are summarized in Figs. A8.3, 4 and 5. The full computer output sheets are included in Appendix B. The shunt reactor was energized between the hours of midnight and 0600 hours.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The analysis at Keeler Substation is complicated by the fact that since the field survey the shunt reactor has been fitted with a wall enclosure identical to that fitted at Covington.

At the microsample location the results of analysis show that the substation was marginally in excess of the State of Oregon noise regulation to the extent of about 2 dB at 120 Hz and 1 dB at 240 Hz. A more detailed analysis suggests that this position benefits from some ground attenuation and that under the conditions at the time, the excess *in the absence of shielding* could have been 8 dB at 120 Hz and 4 dB at 360 Hz--the latter arising from the shunt reactor. Our analysis also shows that, under these conditions, degrees of noncompliance in the range 5 to 8 dB at 120 Hz, and 4 to 10 dB at 360 Hz, would be expected at those positions typical of existing or projected residential communities. The situation would have been closely resolved by treating Bank 1 to the extent of about 10 dB at 120 Hz and treating the shunt reactor to a similar extent at 300 Hz.

Given the present situation in which the shunt reactor is partially enclosed, we have reanalyzed the situation. Further, since the presence of the temporary barrier beside the shunt reactor created measurement difficulties, we have assumed that *now* the shunt reactor will be virtually identical in sound output to the one at Covington; we shall therefore use the Covington estimates.

We find the following:

1) At a distance of 500 ft from the [redacted].

	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

2) Using these values we find that at the microsample location--in the absence of shielding--an 8 dB noncompliance problem would be expected at 120 Hz. Taking into account the possibility of some ground shielding the problem would be resolved by attenuating Bank 1 by 10 dB.

3) Using the same procedure we predict that at the farmhouse to the southwest of the yard, a 5 dB problem at 120 Hz would occur. Our data suggest that this position is shielded; it is likely therefore that, as measured during the survey, the position is in compliance.

4) The properties around the cul-de-sac to the northeast are shielded by the terrain to the extent of 5 to 10 dB. Our calculations indicate that this area should be in compliance with the noise regulations. In the absence of shielding the noncompliance would be limited to about 4 dB at 120 Hz.

5) The area to the west of the cul-de-sac on which residential development is (we believe) planned is not shielded by the terrain. Here we anticipate an 8 to 10 dB noncompliance problem at 120 Hz. The situation should be just in compliance at the 360 Hz frequency. The lower limit attenuation could probably be achieved by attenuating [redacted] to the extent of 15 dB. To achieve the higher limit attenuation it would probably be necessary to apply some treatment to [redacted] also; in this latter case the treatment to [redacted] could be such as to achieve a 10 dB attenuation.

6) In the event that development could occur to the east of the substation, close to the BPA property line, the compliance problem would be 12 dB at 120 Hz, 9 dB at 240 Hz, and 3 dB at 360 Hz. A solution of this problem would require a 10 dB treatment (at 240 Hz) of [redacted] accompanied by attenuations of about 17 dB and 9 dB (at 120 Hz) for [redacted], respectively.

In presenting these estimates it is important to recognize the inherent difficulties in identifying and separating the noise effects of the different transformer banks. We have also made assumptions about the shunt reactor--based on our experience at Covington--which may not be borne out in practice.

RECOMMENDATIONS

At the present time the substation would seem to be in compliance at all residential positions except at the house to the south, which was used as the microsample location. The excess here would be removed by the erection of a simple shallow "C" shaped barrier to the south of [redacted] Such a barrier would also ensure against a potential problem at the farmhouse to the southwest in the event that ground shielding is not consistently present at this position.

We recommend that BPA make provisions for the erection of such a barrier.

We recommend also that BPA carry out some monitoring of the far-field effects of the shunt reactor in its partially enclosed form. Our analyses suggest that the shunt reactor problem has been solved for all areas of existing or potential development. This should be confirmed.

We recommend that BPA investigate the details of development plans around the substation--especially in that area to the north which is currently staked out. The potential for future residential developments in the field to the east of the substation should also be examined. Development in this latter area would pose the most severe compliance problem.

In the event that residential developments to the north of the substation are confirmed, it would be necessary to attenuate the [redacted] by 15 dB at 120 Hz *or* to reduce both [redacted] by about 10 dB at the same frequency. We recommend that BPA consider the latter solution involving therefore:

a) The erection of a full height three-sided barrier around Bank 1--to protect the south, west, and north exposures, and

b) The erection of a one-sided (or shallow "C") barrier to the north [redacted]

In the event that development eventually arises to the east of the substation, it may be necessary to convert the [redacted] treatment to a full wall enclosure and to extend the [redacted] treatment to a two-sided configuration. [redacted] [redacted] [redacted].

Many options have to be considered in arriving at a solution to the potential future problem at Keeler Substation. We recommend that these be carefully assessed when the decisions have been reached about those areas requiring protection.

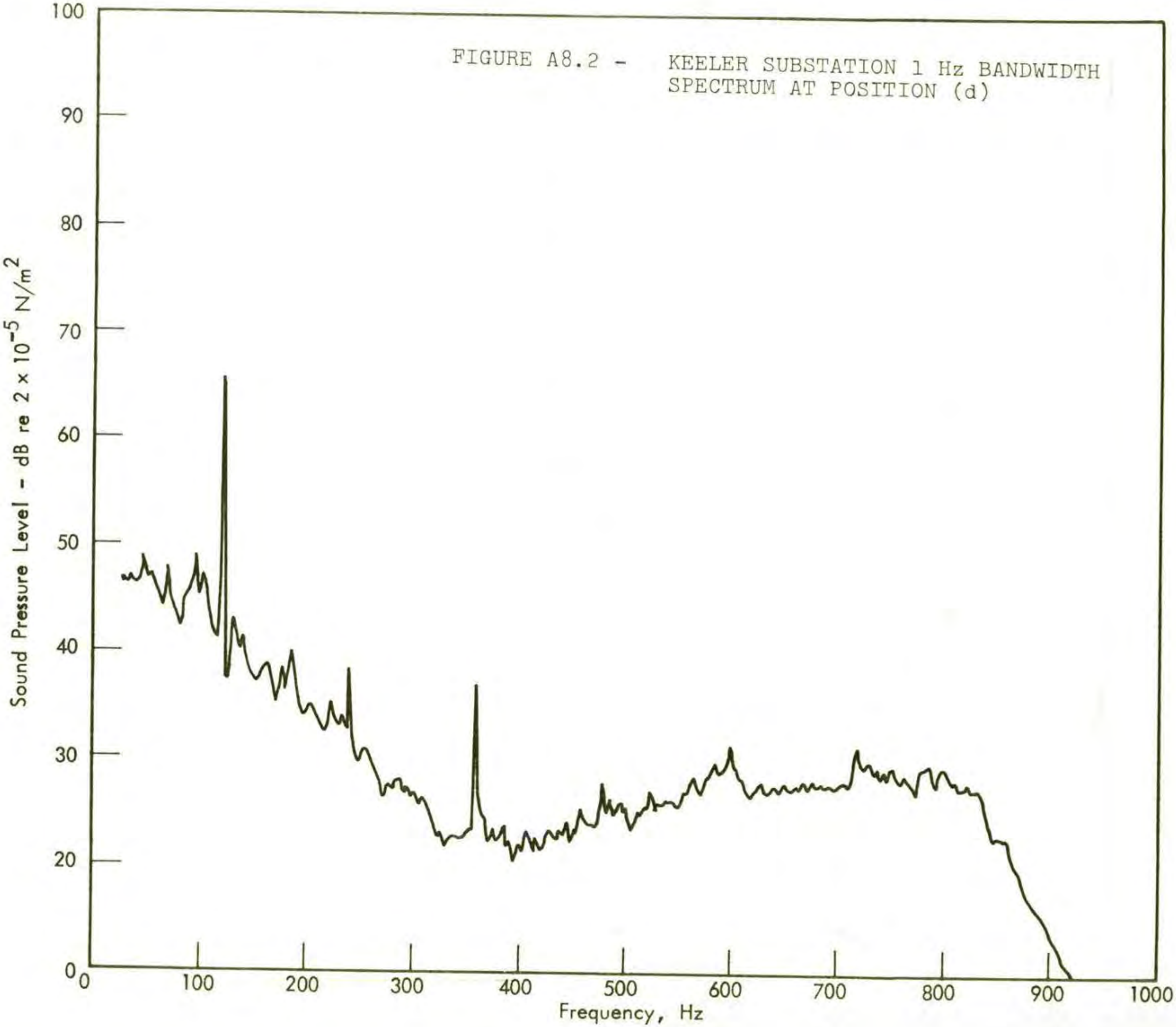


FIGURE A8.2 - KEELER SUBSTATION 1 Hz BANDWIDTH SPECTRUM AT POSITION (d)

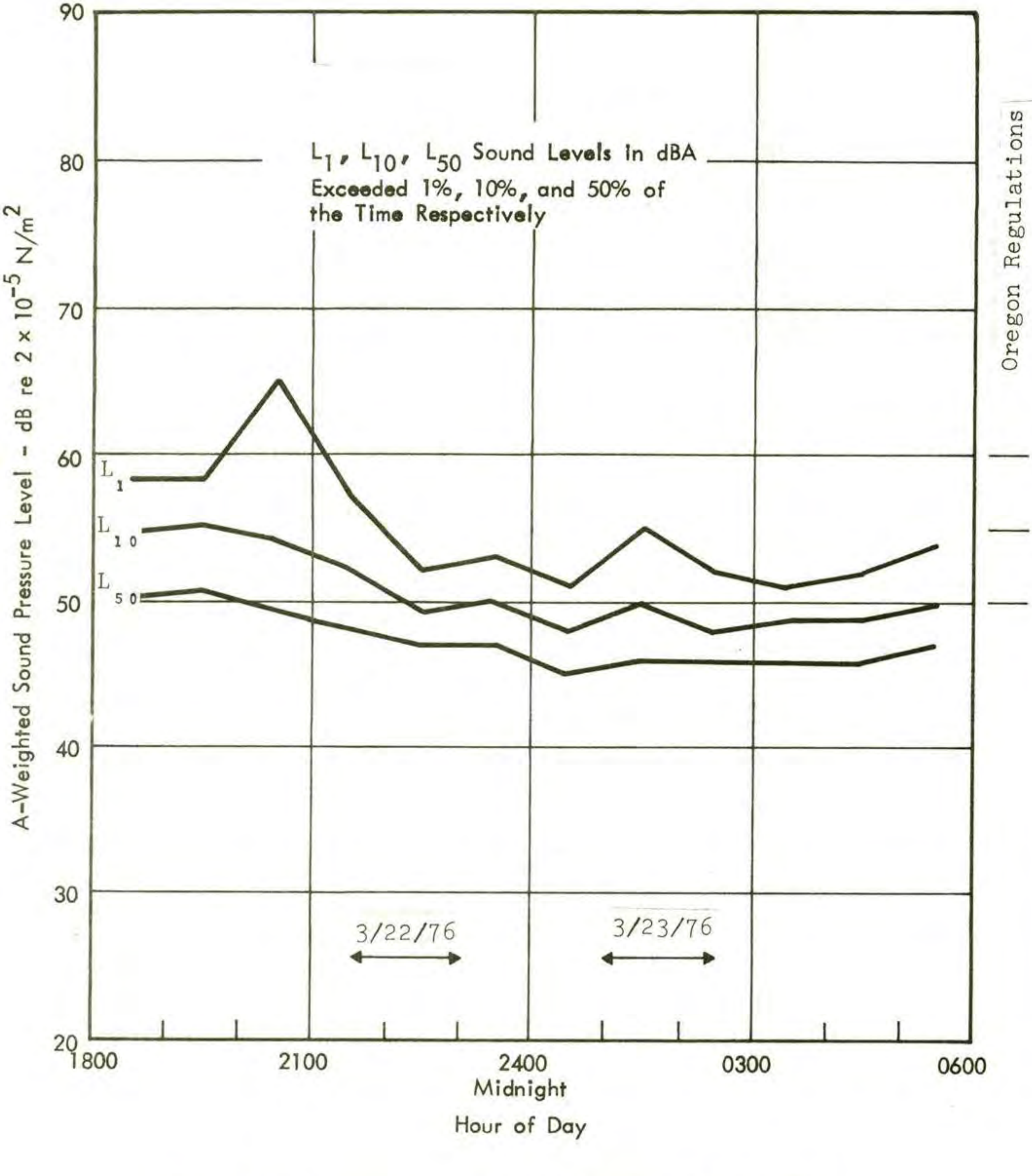


FIGURE A8.3 - KEELER SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

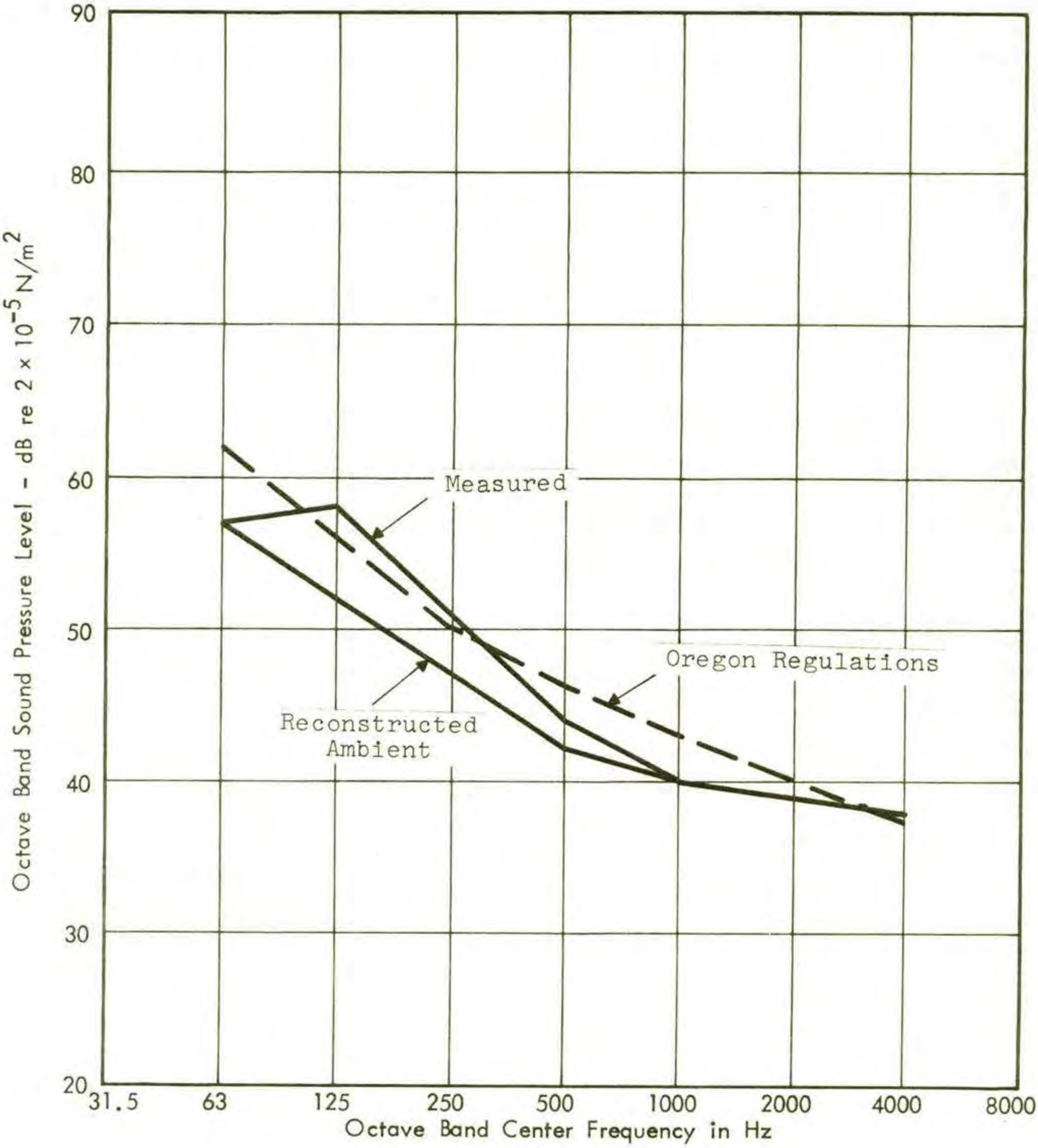


FIGURE A8.4 - KEELER SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS.

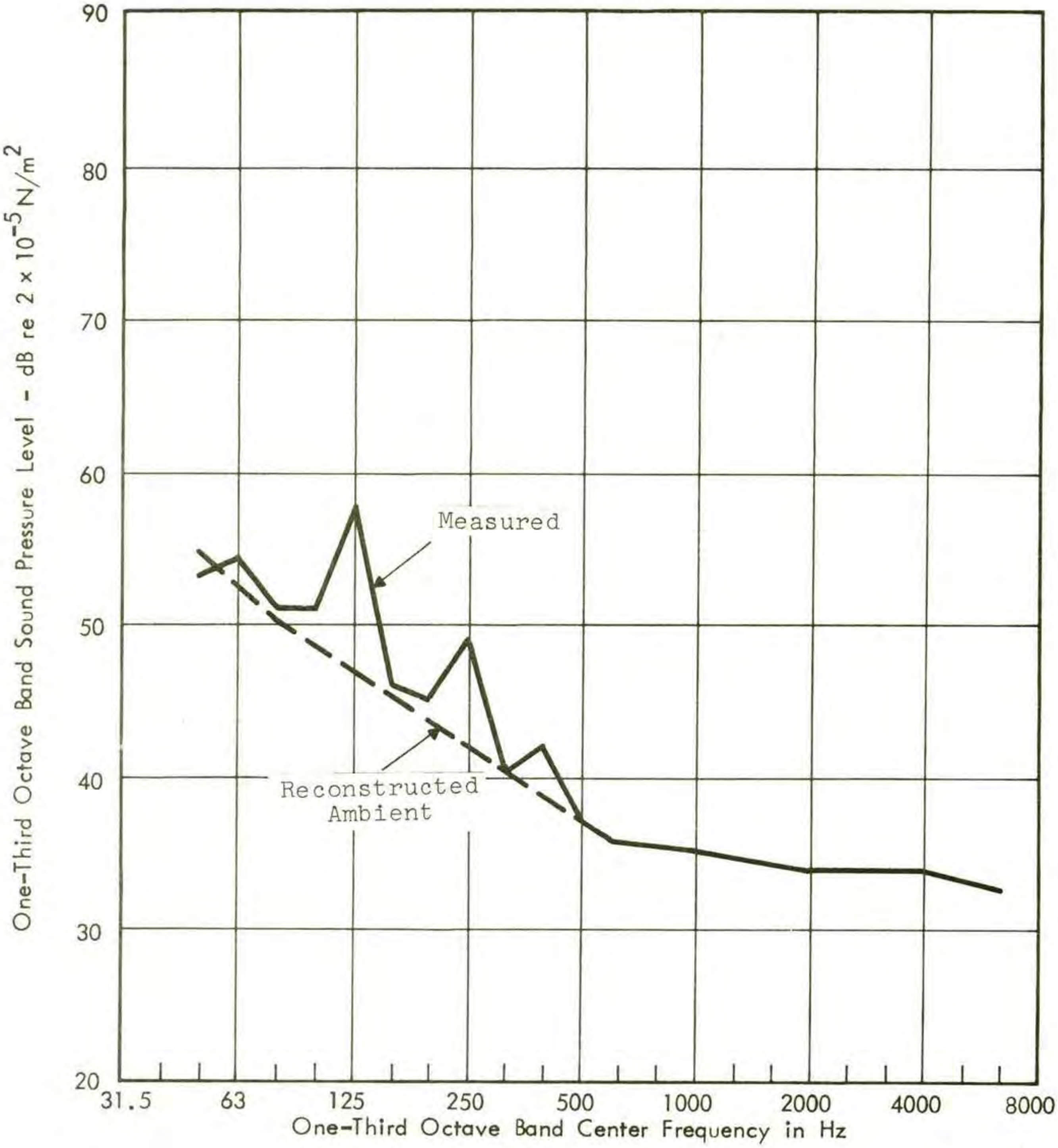


FIGURE A8.5 - KEELER SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HOURS.

A9. LA GRANDE SUBSTATION

La Grande Substation is located to the south of U.S. Highway 30, about 1 mile southeast of La Grande, Oregon. The substation is in Union County.

The layout of the substation is shown in Fig. A9.1. Details of the single transformer bank are given in Table A9.1.

The noise situation at La Grande is complicated by the presence of a California Pacific Utilities Company (CALPAC) substation immediately to the north of the BPA substation, and an Idaho Power (IPC) Company substation, 400 ft to the south. Subjectively the CALPAC transformer sounds as loud as the BPA transformer. The IPC phase shifting transformer is, subjectively, substantially louder than either the BPA or CALPAC units.

During our visit we were able to gain access to the CALPAC yard. Details of this transformer are included in Table A9.1. We were not able to gain access to the IPC yard.

The terrain around the La Grande substation is flat. BPA owns a 300 ft wide strip of land to the west beyond which are located residential properties on Century Lane. To the north, BPA land ownership extends to Highway 30.

A church and church school are located immediately to the northeast of the CALPAC yard. An open 350 ft wide, uncultivated field lies between the BPA east property line and the nearest residential properties. It is not known who owns this field. We understand however that the pressures for residential development in this area are small.

The land to the south of Gekeler Lane is exclusively farmland with the exception of that land parcel occupied by the IPC substation.

FIELD SURVEY

The field measurements were carried out over the period 16th to 17th March 1976. We were accompanied within the substation by Mr. Owen Anson.

The weather during the measurement period was overcast but dry. The wind was from the southeast with velocities gusting in the range from 8 to 15 mph. However, there were periods of relative calm during which acceptable nighttime ambient levels could be established. On the morning of 17th March the air temperature was 52°F at a relative humidity of 51%.

- Close-In Measurements

The results of 10 ft measurements on the BPA transformer and on the [redacted] are given in Table A9.2.

- Perimeter Measurements

The results of the perimeter measurements are given in Fig. A9.2. The perimeter survey included both the BPA and CALPAC yards.

- Community Measurements

Some limited measurements were taken around the Idaho Power Company substation. These indicated 500 ft distance levels of about 60 dB at 120 Hz and 46 dB at 240 Hz. Measurements were also taken of the major tonal levels at the following positions:

a) At the microsample location.

b) At the southwest corner of the church school.

c) At the house to the southeast of the substation.

The results are summarized in Table A9.3.

• Microsample Data

Microsampling was carried out at the position shown in Fig. A9.1, representative of the closest residential properties to the BPA substation.

The results are shown in Figs. A9.3, 4 and 5. The full computer output sheets are included in Appendix B.

During the period 0200 hours to 0600 hours, the wind velocities increased to the extent that the measured ambient levels were substantially affected. This can be seen in Fig. A9.3. The effect on the ambient spectrum is illustrated in Fig. A9.6.

We have used the earlier nighttime data to reconstruct the form of the ambient during the 0300 to 0400 "quietest" period. These reconstructed data are presented in Figs. A9.4 and 5.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Neither the church nor the church school can be considered as critical from the point of view of noise as can the residential properties to the west and east of the substation. The reason of course is that the nighttime noise requirements must be applied to residential properties, whilst the major use of the church buildings is a daytime one. Nevertheless, in the event that noise control is required, the influence of such control upon the church must be considered; a noise reduction of course would be desirable.

The data of Table A9.3 and of Figures A9.3 to A9.5 indicate that the noise levels at positions (a) and (b) (representing the affected residential properties) satisfy the A-weighted noise level and pure tone noise requirements of the Oregon Noise Regulations. However, they are in violation of the octave band requirements of the Oregon Noise Regulations by about 4 dB at 120 Hz.

A detailed analysis of the problem, using the measurement data acquired close to the [redacted] located in this area, suggests, in fact, that the [redacted] is a major contributor to the environment and that the [redacted], in isolation, would be in complete compliance with the regulations.

The Oregon Noise Regulations apply to the composite of noise sources owned or controlled by any one person (agency, corporation, etc.). On this basis it must be presumed that neither BPA nor CALPAC are in violation of the noise regulations, but that IPC *may* be in violation--especially in the vicinity of Position (c).

RECOMMENDATIONS

No noise control is required for the La Grande Substation. We recommend however that, in the event of noise complaints being received in the area, any action to reduce noise levels be taken jointly with CALPAC and IPC. Unilateral noise control action by BPA would serve no useful purpose since the noise levels would not be significantly reduced.

We recommend also that BPA keep a close watch on residential development plans in the area. The land plot to the east of the substation might usefully be acquired by BPA to ensure a "buffer zone". BPA ownership of that land to the west should certainly be retained.

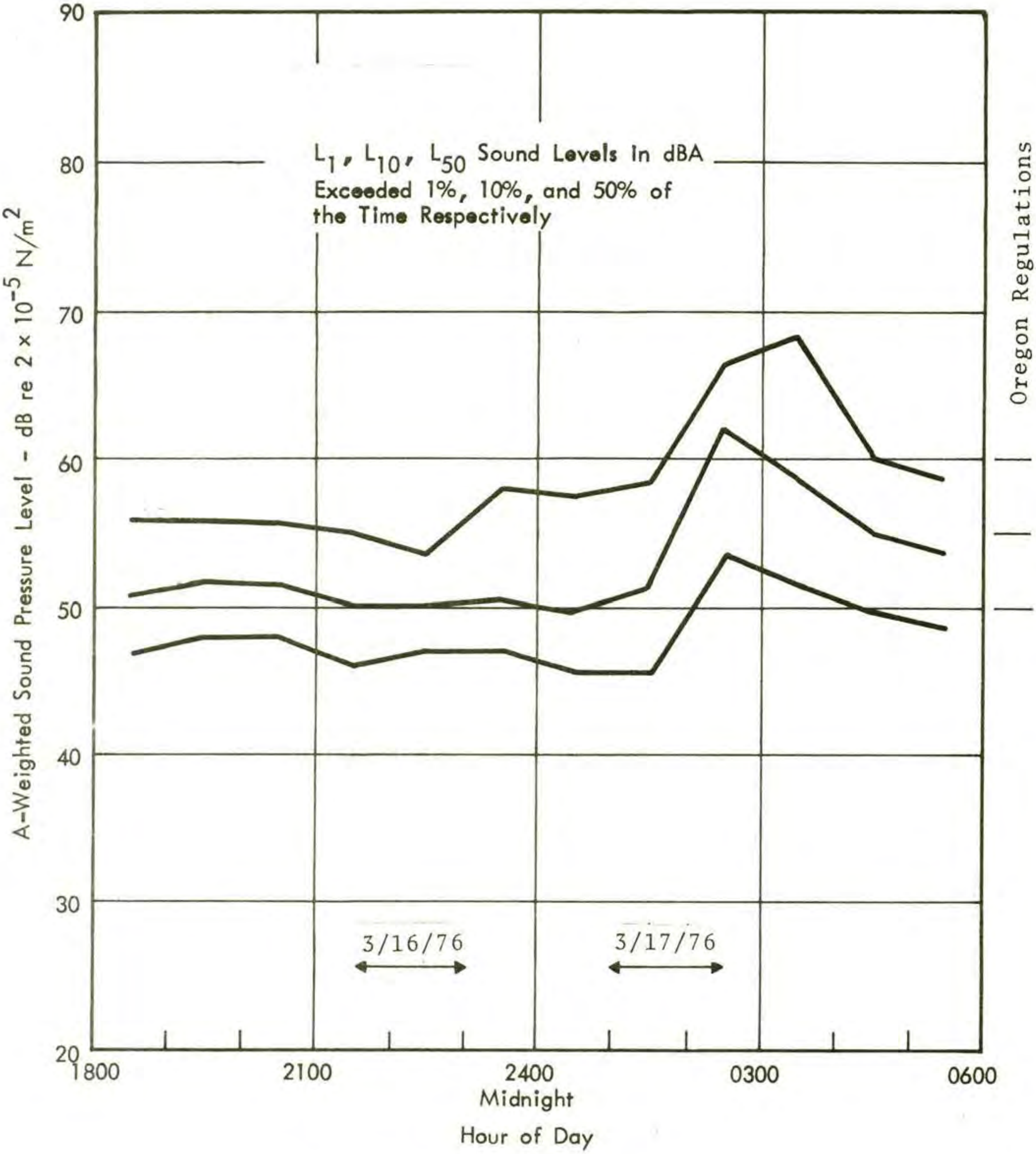


FIGURE A9.3 - LA GRANDE SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

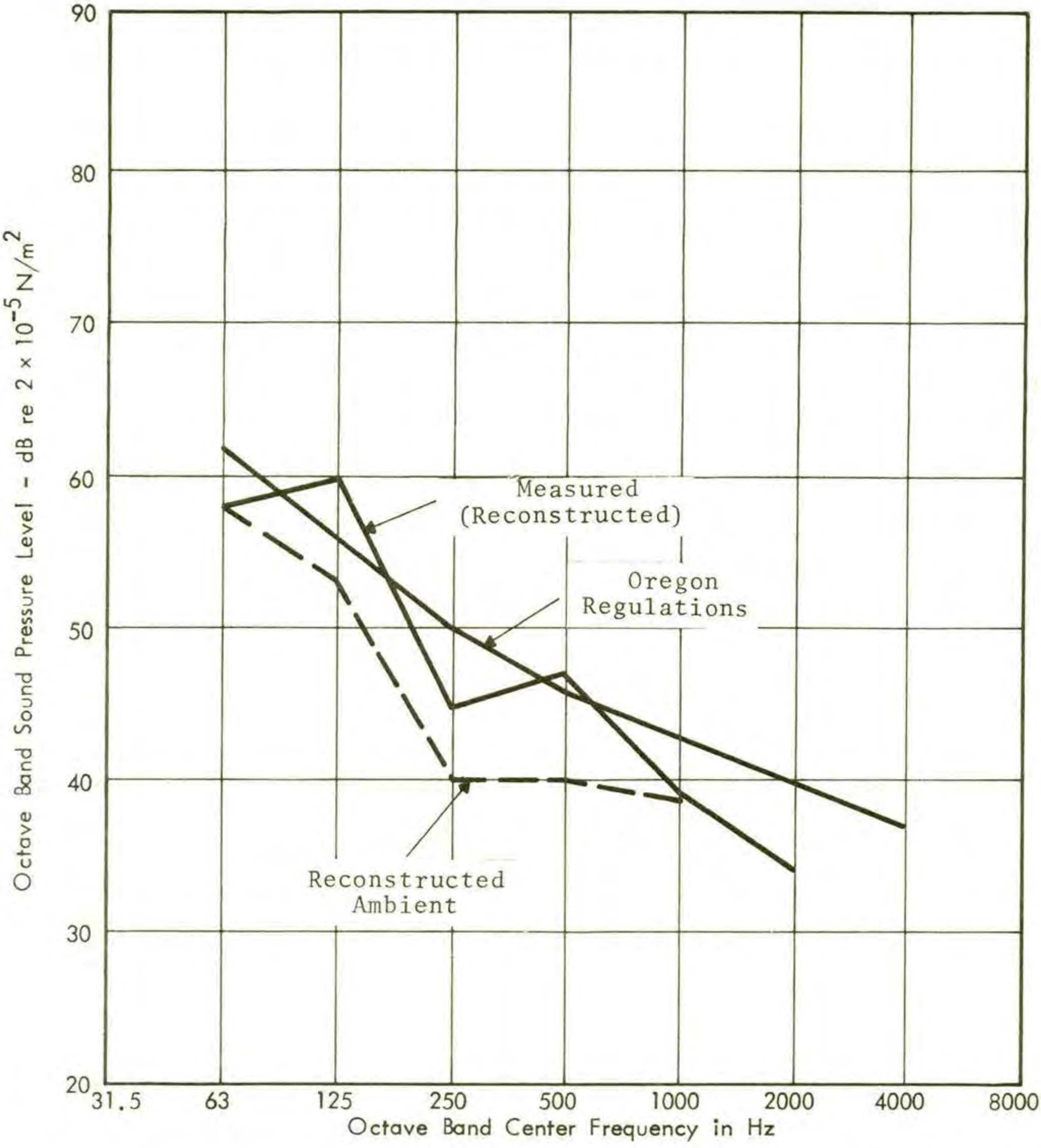


FIGURE A9.4 - LA GRANDE SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS (RECONSTRUCTED TO REMOVE WIND EFFECTS)

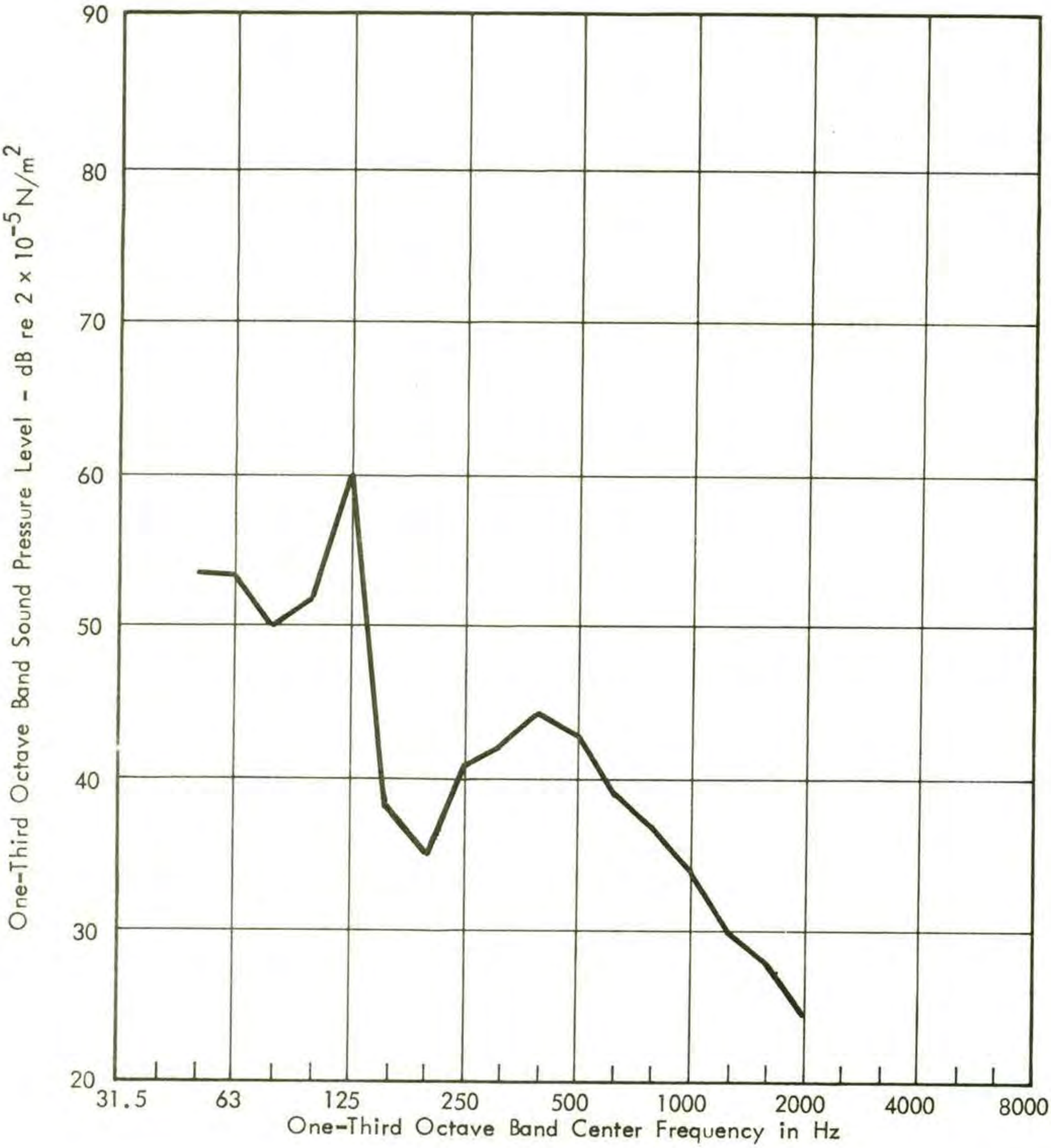


FIGURE A9.5 - LA GRANDE SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS (RECONSTRUCTED TO REMOVE WIND EFFECTS)

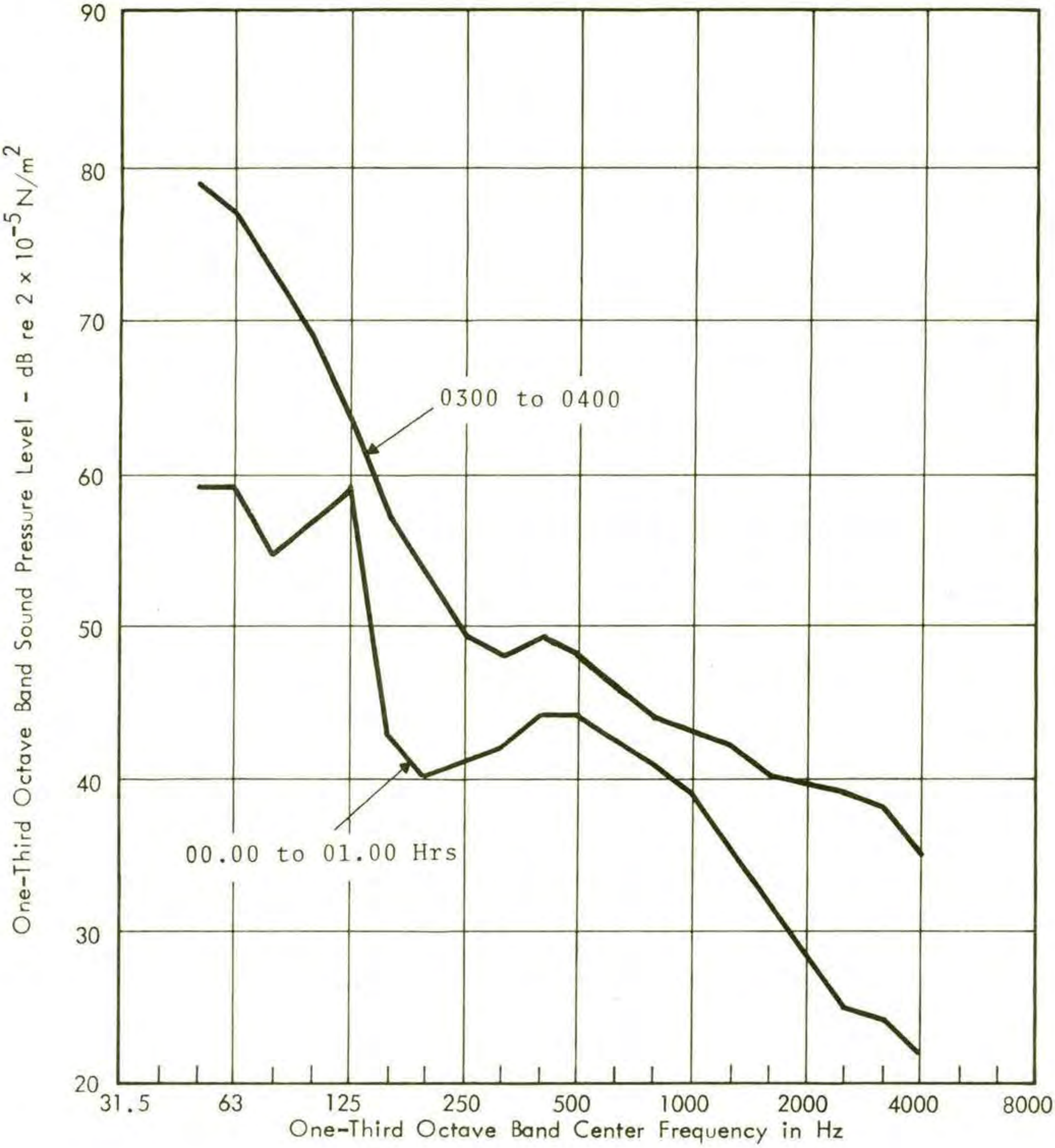


FIGURE A9.6 - LA GRANDE SUBSTATION - EFFECT OF WIND ON MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND DATA

A10. LANE SUBSTATION

Lane substation is located 5 miles west of Eugene on the south side of State Highway 126, in Lane County, Oregon.

The layout of the substation and of some of the surrounding features are shown in Fig. A10.1. Details of the [redacted] are given in Table A10.1.

The predominant land use around the substation at present is farming. There are only two residential properties within 1500 ft of the boundary fence. The indications are, however, that there could be residential development in the near vicinity of the substation in the next 5 to 15 years.

To the south and west of the substation the land is flat. To the south the BPA property holding is substantial. To the west, however, developments (on the south side of the dirt road--Eugene to Elmer) could approach within 400 ft of the substation fence. The presence of power line easements might, however, inhibit developments at such a close distance.

To the north the land is also flat, until it starts to rise on the north side of Highway 126. The strip of land between the dirt access road and the railroad would appear to be suitable for development within the constraints of existing power line easements.

At present the closest property to the substation is a very dilapidated house to the northeast, as shown in Fig. A10.1.

To the east of the substation (to the south of the dirt road) the land rises to form a tree-covered hill. We understand that this land may already be considered as potential development land for residential properties. The microsampling location (shown in Fig. A10.1) is considered to be representative of the closest of such developments. The distance is about the same as that to the northeast house.

FIELD SURVEY

The major field measurements were carried out over the period 10th to 11th March 1976. We were accompanied within the sub-station by Mr. Dale Plunkett and Mr. Courtney (Operator). A later supplementary visit was made on 12th May 1976.

During the March measurements the sky was overcast. Wind was from the west, gusting to 10 mph. However during the evening and night, wind velocities fell to about 3 mph. The temperature was 51°F at a relative humidity of 88% during the afternoon of 10th March.

• Close-In Measurements

The results of measurements at 10 ft from the transformer banks are given in Table A10.2.

• Perimeter Measurements

The results of the perimeter measurements at the first two tonal frequencies are shown in Fig. A10.1. Using [redacted] the major source center, these data normalize to 500 ft levels of 66 dB at 120 Hz and 56 dB at 240 Hz. This is in good agreement with the Table A10.2 predictions.

• Community Measurements

Data were obtained:

a) On the dirt road outside the house to the northeast of the substation,

b) On the dirt road about 200 ft east of the farmhouse the position of which is indicated in Fig. A10.1, and

c) At the microsample location.

The results at the major tonal frequencies are given in Table A10.3. The results normalized to 500 ft distance are in reasonable agreement with each other. However only the data at 120 Hz are in agreement with the close-in and perimeter measurements. Presumably ground effects and scattering provide attenuation at the higher frequencies. The data do show, however, the unusual strength of the 480 Hz component which was observed in the close-in measurements on Bank 2.

• Microsample Data

The microsample location is shown in Fig. A10.1. The results of the analyses are given in Figs. A10.2, 3 and 4. The full computer output sheets are included in Appendix B.

An example of the narrowband (1 Hz) spectrum is given in Fig. A10.5. Note the presence of odd harmonies of the 60 Hz line frequency. Note also a component at 77 Hz; this is likely to be the fundamental blade passage frequency of the cooling fans on one of the transformer banks.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

As measured at the microsample location the substation is in compliance with the Oregon Noise Regulations.

A detailed study of the various data obtained in the survey show that [redacted] is the major source at the 120-240 Hz frequencies, but that [redacted] generates strongly at the 480 Hz frequency. At a distance of 500 ft from the center of the substation, the appropriate average sound pressure levels are about 64 dB at 120 Hz and 50 dB at 240 Hz. At the same distance the noise level is about 50 dBA. The octave band requirement of the State regulations should be complied with, therefore, at distances from the yard center in excess of about 1200 ft, in the absence of shielding.

On this basis, a 3 dB compliance problem could arise in the event of residential developments to the northwest of the substation on the south side of the dirt road. A 6 dB compliance problem could arise for developments to the north of the substation. The substation should remain in compliance for developments to the west so long as these lie no closer to the property line than the microsample location. No future problems are anticipated to the south.

RECOMMENDATIONS

There is no requirement for noise control at the present time. We recommend that BPA remain cognizant of land transactions and planning applications in the area--particularly to the north and northwest of the yard and to the east of the yard.

We advise that if necessary BPA make long range plans for the erection of a two- or three-sided barrier around the [redacted].

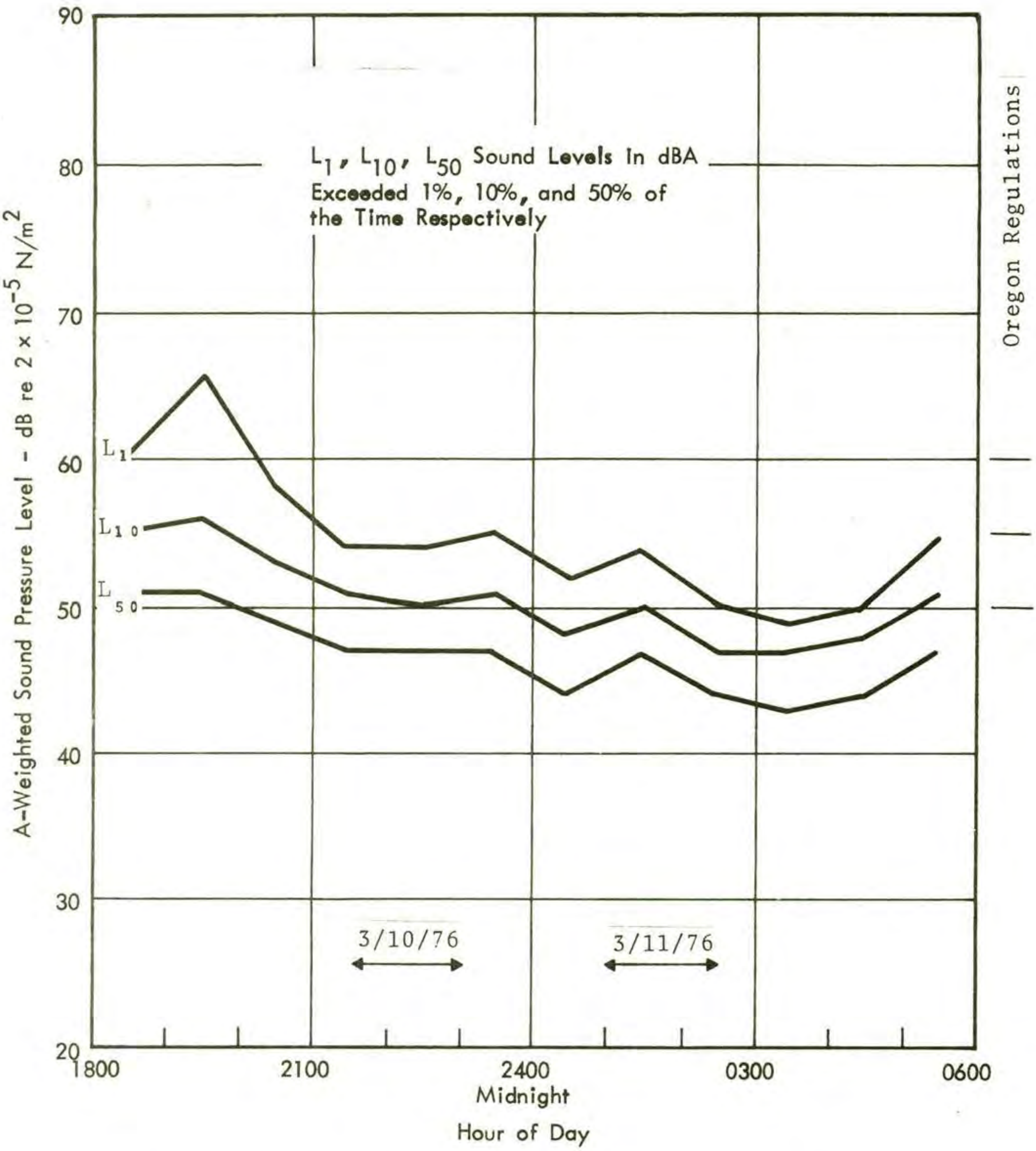


FIGURE A10.2 - LANE SUBSTATION - MICROSAMPLE LEVEL VERSUS TIME OF DAY

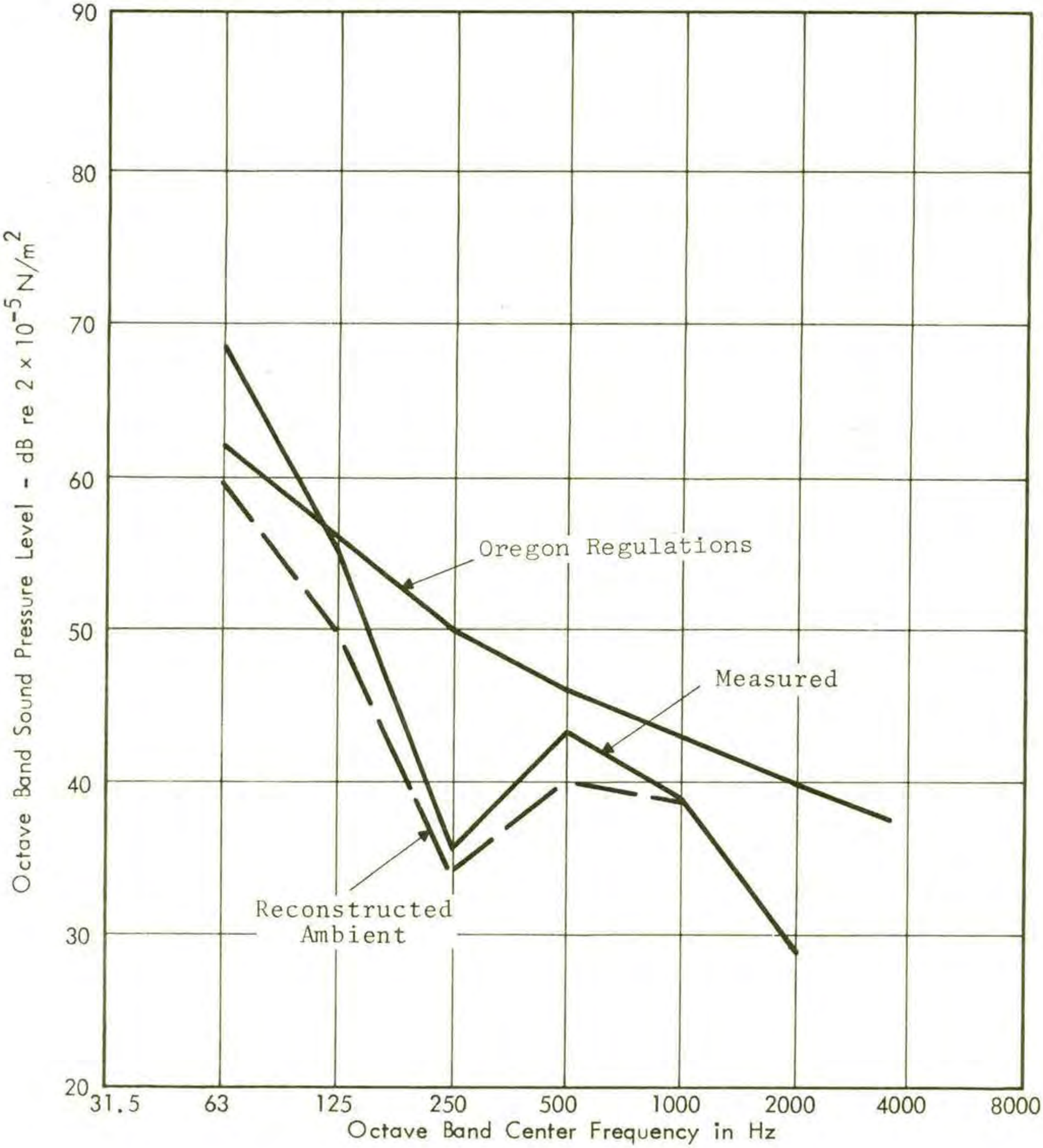


FIGURE A10.3 - LANE SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

FIGURE A10.4 - LANE SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

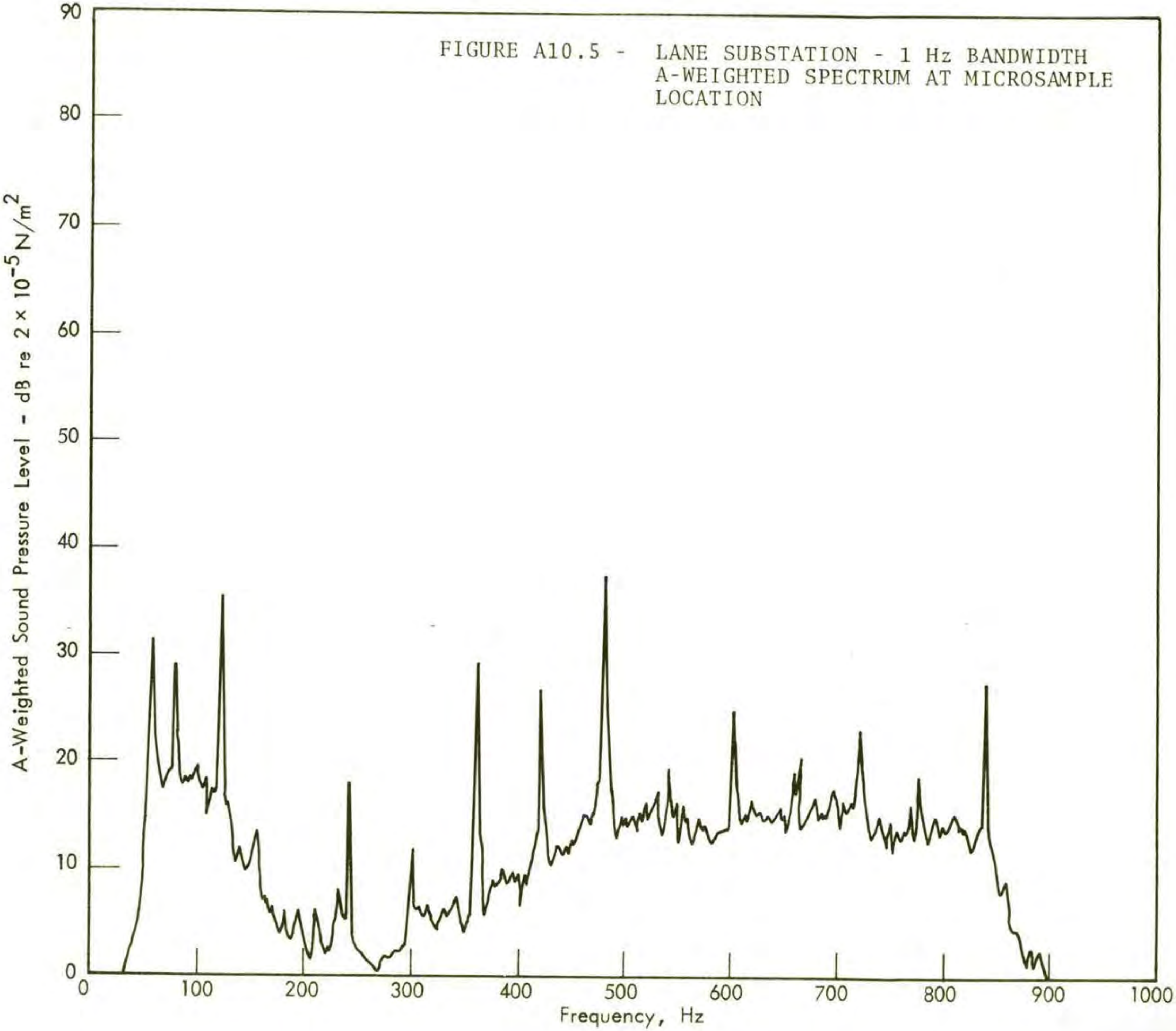


FIGURE A10.5 - LANE SUBSTATION - 1 Hz BANDWIDTH A-WEIGHTED SPECTRUM AT MICROSAMPLE LOCATION

A11. LYONS SUBSTATION

The site for the 1100 kV Lyons Test Substation lies 2 miles west of the village of Lyons, in Linn County, Oregon. The substation lies at the junction of Weasel Flat Road (which is the access road to Santiam Substation) and State Highway 226.

Details of the layout of the substation and of the environs are given in Fig. A11.1. The single phase test transformers are described in Table A11.1.

The terrain around the west, south and east of the substation is fairly flat. To the north the land drops. The major land use would appear to be grazing. The four properties in the vicinity of the substation site are shown in Fig. A11.1. The closest of these will lie at a distance of [redacted]. There is no indication in this area of pressures for further residential developments.

FIELD SURVEY

The field survey was carried out over the period 7th to 8th March 1976. The weather was overcast with occasional rain. The wind was from the northwest with velocities up to 4 mph. On the afternoon of the 7th of March, the air temperature was 44°F and the relative humidity was 92%.

The purpose of the field study was simply to establish the existing ambient levels so that the impact on the environment of the new transformer bank could be determined. A daytime ambient noise spectrum recorded close to the gate of the site is shown in Fig. A11.2. It is interesting to note that the 1200 MVA transformer bank at Santiam Substation has an influence upon the readings at Lyons. The recorded level of 46 dB at 120 Hz would correspond to a 500 ft level of about 70 dB. The low daytime ambient levels reflect the fact that these measureemnts were carried out on a Sunday.

Microsampling was carried out at the location shown in Fig. A11.1. The results are summarized in Figs. A11.3 to A11.5. The full computer output sheets are given in Appendix B. It should be noted that the Santiam transformer bank has no noticeable influence at the microsample location.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The Lyons site may be subject to the nondegradation clause contained within the Oregon Noise Regulations. This limits any increase in the ambient levels caused by the introduction of a new source "... on property previously unoccupied by an industrial or commercial noise source ..." to 10 dBA at both the L_{10} and L_{50} levels.

A substantial problem is encountered in predicting the noise levels of the 1100 kV transformer bank. The high voltage and unusually low capacity of this bank make it unique.

The NEMA rating of each transformer phase would be 82 dBA. Based on a tank size of 13 ft x 10 ft x 23 ft high (Table A10.1) we arrive at a level at 500 ft (for combined phases) of 56 dBA.

Using the methodology derived from our own experience with power transformers in the BPA system--described in Chapter 5--we arrive at the following 500 ft estimates.

Frequency (cps)	120	240	360	480	dBA
Sound Pressure Level dB re $2x10^{-5}N/m^2$	58	51	45	44	47

We shall select these as the basis for design, but bear in mind that levels could be somewhat higher because of the unique nature of the transformer design. It is assumed that these values are representative of both L_{10} and L_{50} levels.

These levels are used to reconstruct the likely future noise characteristics in Figs. A11.3 to A11.5. This is the situation that is likely to occur at the closest residence--assuming little or no terrain shielding, and taking no account of the corona noise that will be generated by the substation buswork and by the 1100 kV test transmission lines.

Based on these predictions the substation is likely to be in default of the Oregon Regulations as follows:

a) By 17 dBA based on the nondegradation clause--corona noise levels will, in all probability, in themselves be in violation on this basis, too.

b) By 2 dB at 120 Hz and at the higher tonal frequencies, on the basis of the octave band specification, and

c) By 3 dB at 120 Hz, and at 240 Hz on the basis of the one-third octave band requirements, neglecting the influence of corona noise.

In this analysis we pay no regard to fan noise on the basis that it rarely plays a significant role in substation noise problems.

The major problem lies in satisfying the State of Oregon non-degradation clause. This poses a severe problem which is likely to be exacerbated by the corona noise which will certainly be associated with the new installation.

RECOMMENDATIONS

The potential substation noise problem is predicted to be 17 dB at 120 Hz for the transformer bank alone, if the nondegradation requirement of the regulations is to be met. This is a most severe requirement, being 15 dB more critical than would otherwise be required by the regulations. Thus we recommend that BPA discuss the Lyons site problem with the Department of Environmental Quality for the State of Oregon to obtain their views on the purpose served by applying the nondegradation requirement in this situation.

Because we expect that corona noise from the substation will also pose a problem, we recommend that some predictions of such noise also be made for consideration in these discussions.

In the meantime it would seem prudent that BPA budget for a full wall noise control enclosure for the Lyons transformer bank.

There seems to be little pressure for residential development in this area in the foreseeable future although we do recommend that BPA keep a close watch on any development plans for the area. Thus, if the nondegradation requirement is waived by the State, satisfaction of the requirements of the Regulations should be achieved with a simple L-shaped barrier of height equal to the height of the transformer lid, placed around each transformer's phase in such a way as to shield the south and west exposures.

FIGURE A11.2 - LYONS SUBSTATION - TYPICAL DAYTIME ENVIRONMENTAL LEVELS

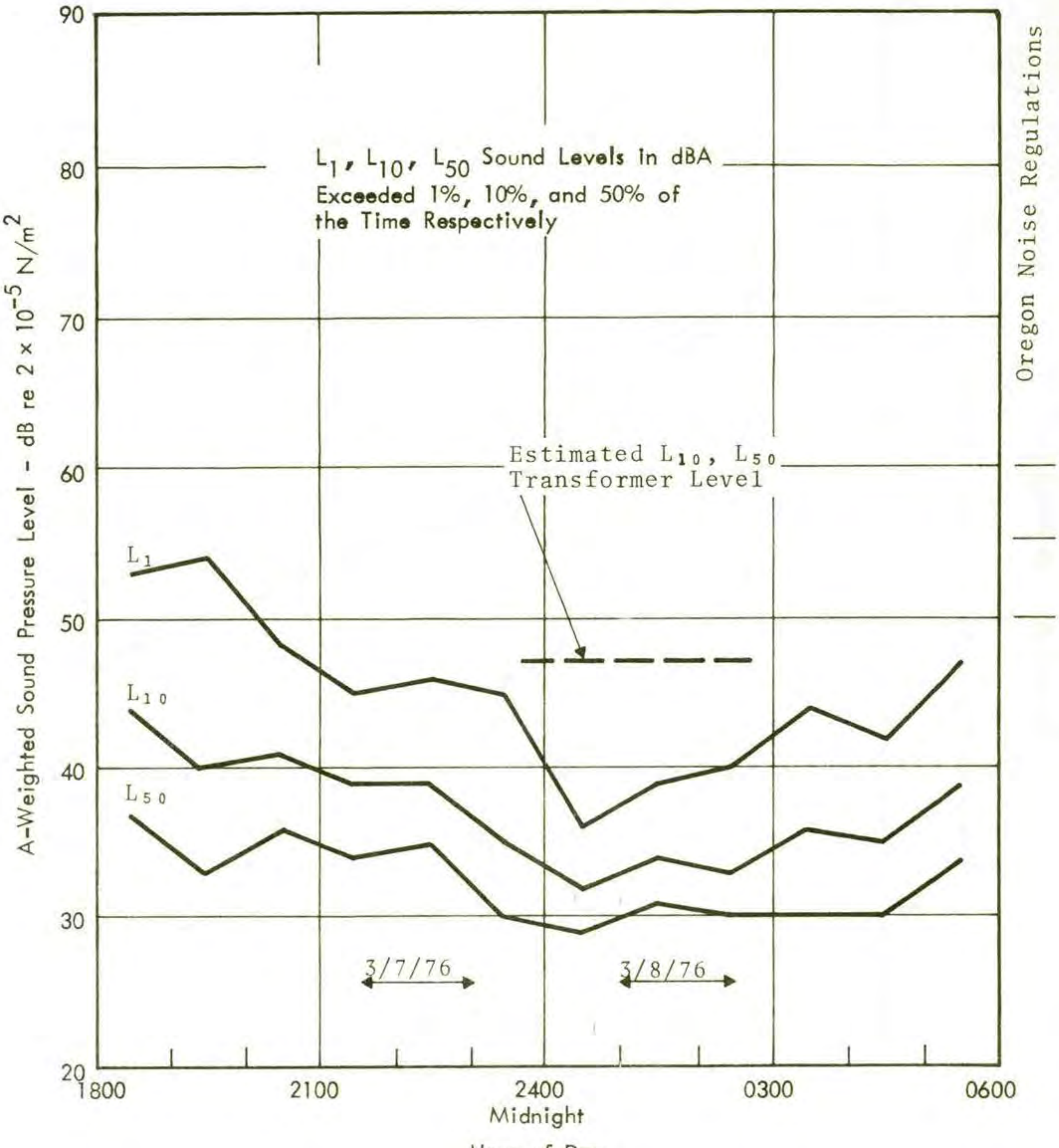


FIGURE A11.3 - LYONS SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

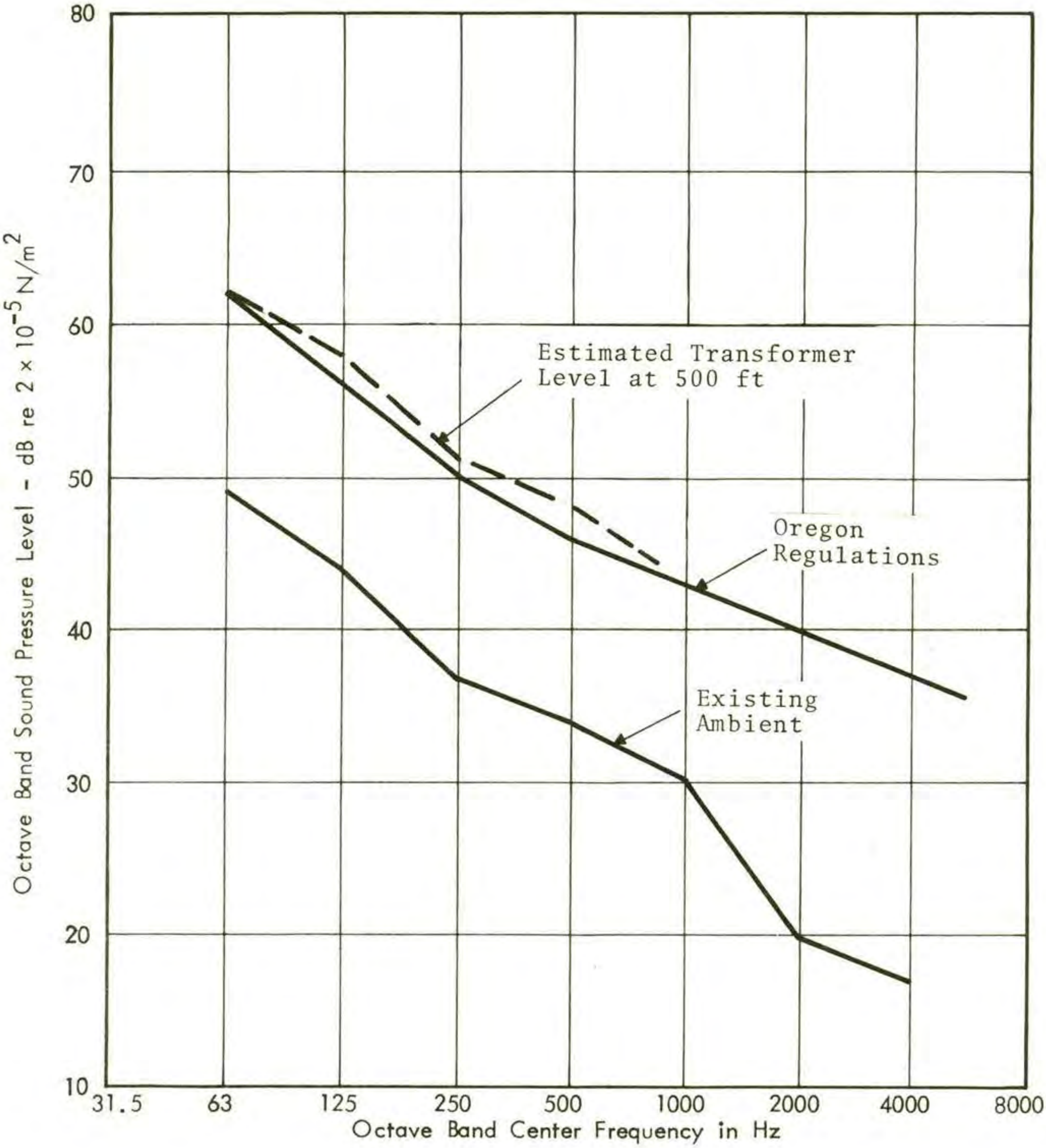


FIGURE A11.4 - LYONS SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS 0300 TO 0400 HRS

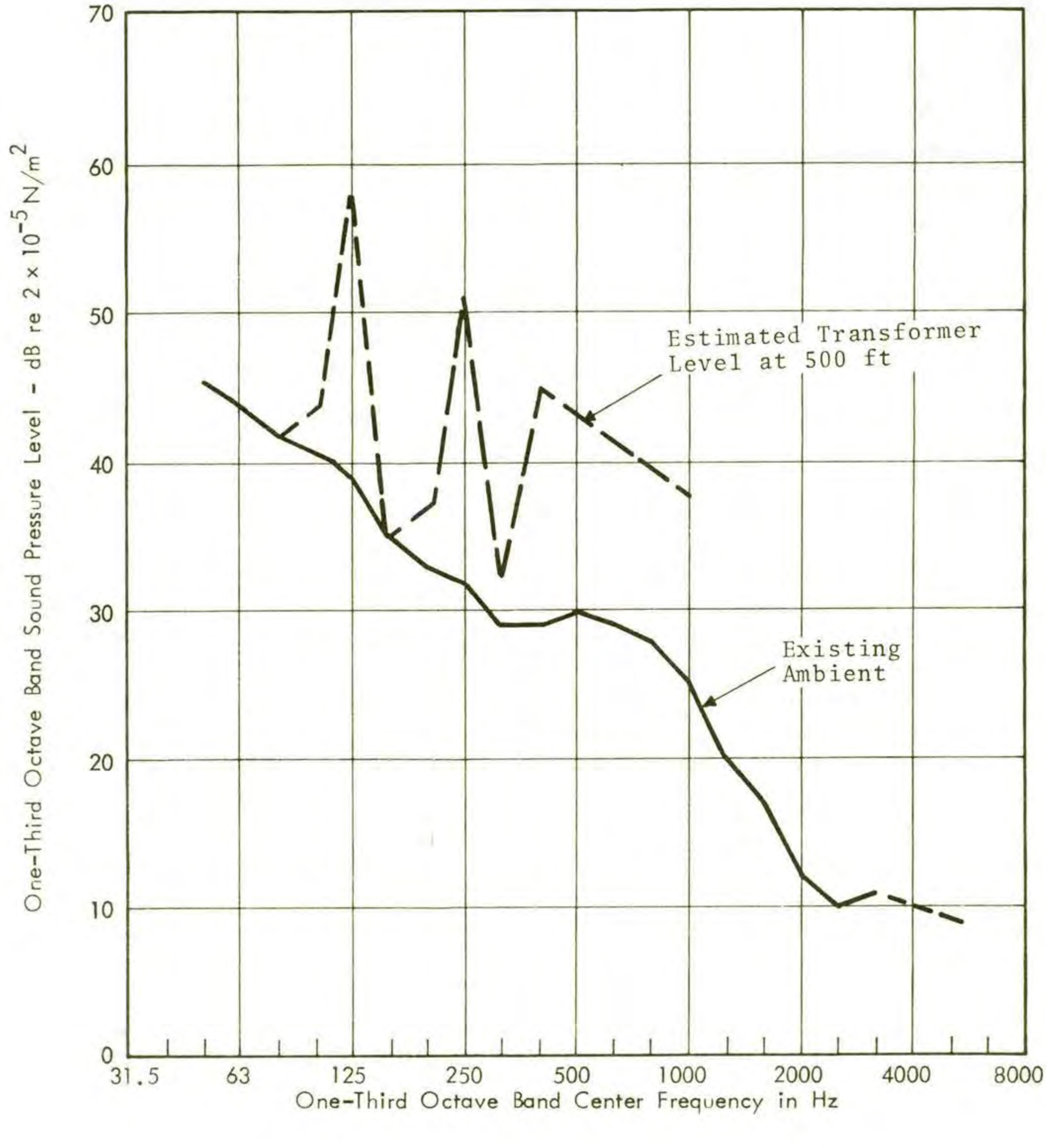


FIGURE A11.5 - LYONS SUBSTATION - MICROSAMPLE (L_{10})
ONE-THIRD OCTAVE BAND LEVELS,
0300 TO 0400 HRS

A12. MARION SUBSTATION

Marion Substation lies in Marion County, Oregon, five miles east of Stayton, on the north side of State Highway 222. The station is a 500 kV switching yard. The layout of the yard is shown in Fig. A12.1. This figure also shows the major features of the substation's environs. At present the substation contains [redacted] Some tentative details of these shunt reactors are given in Table A12.1. We understand that a second bank of reactors may be energized in 1980.

The landscape around the station is fairly flat. Crop farming and grazing are the primary land uses. The closest residential properties lie to the south of the substation on the south side of State Highway 222 at a distance of about 1000 feet from the proposed location of the shunt reactor bank. These properties are not visible from the substation. The only visible residential properties are those associated with the farm buildings to the west of the substation at a distance of about [redacted].

From a discussion with the operator and from a viewing of the general area we anticipate that there will be little further residential development around the substation within the next 10 to 15 years.

FIELD SURVEY

The field measurements were carried out over the period 7th to 8th March 1976. We were accompanied within the substation by Mr. Ziegler (Operator).

During the course of the measurements the weather was overcast with winds from the northwest at 3 to 4 mph. The afternoon temperature on 7th March was 44°F at a relative humidity of 90%.

Spot measurements were made of the daytime environmental levels at two points within the Marion substation. Because of the presence of significant corona noise from the 500 kV busbars and bushings, it was decided to locate the microsampler equipment at the extreme westerly corner of the yard. This location is shown in Fig. A12.1. The results of the microsample analysis are summarized in Figs. A12.2, 3 and 4. The complete computer output sheets are included in Appendix B.

SHUNT REACTOR PREDICTION

In Table A12.2 we summarize the levels that can be expected at a distance of [redacted]. These levels are based on a NEMA-rating level of 82 dBA. In predicting the tonal component levels for the shunt reactor, we have made use of our experience on three other shunt reactors within the BPA system, as described in the main report. It will be assumed that these values may arise at both the L_{50} and L_{10} levels.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

On the basis that some terrain shielding will apply to those properties to the south of the substation, we choose to analyze the compliance situation on a minimum distance between the shunt reactor and the nearest residential property to the west of 2000 ft. We therefore apply a 12 dB reduction to those levels given in Table A12.2.

The resulting levels are incorporated in Figs. A12.2 to 4. Our predictions suggest that the substation will remain in compliance with the State Noise Regulations. This conclusion could be at fault in the event that the reactor is noisier than predicted or in the event that it generates an abnormally strong third harmonic (360 Hz) which does sometimes occur. Residential developments at distances substantially closer seem unlikely in the foreseeable future.

Because of the existing use of the substation, we are of the opinion that it should not be subject to the nondegradation clause of the Regulations with the introduction of the reactor bank.

RECOMMENDATIONS

There is no need for noise control at the present time and since there would seem to be little pressure for future residential developments in the area, it would seem unlikely that the situation should change. We do recommend, however, that BPA remain cognizant of planning applications and land transactions in the area.

We recommend further, that a noise monitoring program be undertaken as soon as the shunt reactor bank is energized. Noise level data should be acquired at the farmhouse 2000 ft to the west of the substation and, also, at the residential properties to the south.

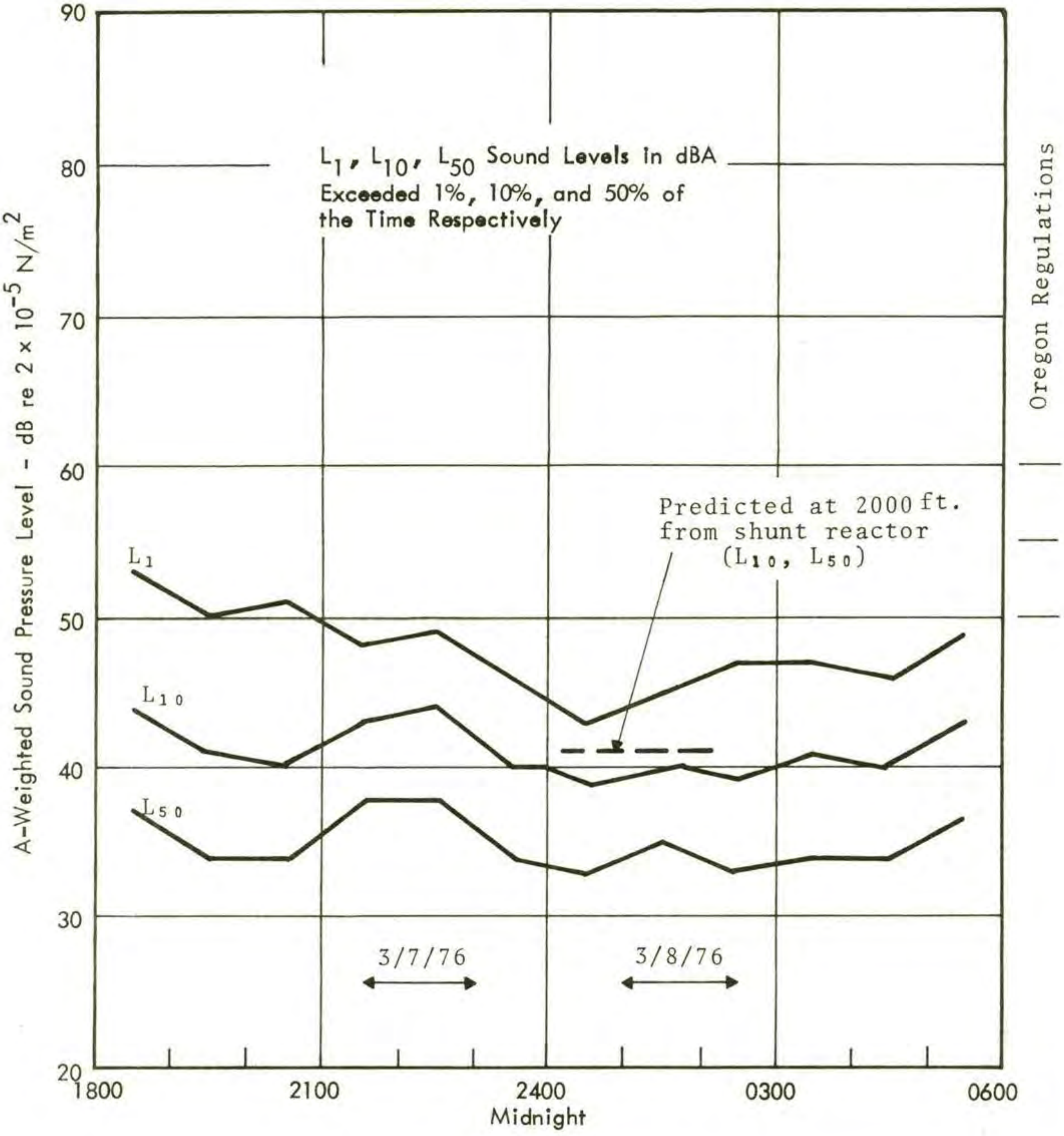


FIGURE A12.2 - MARION SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

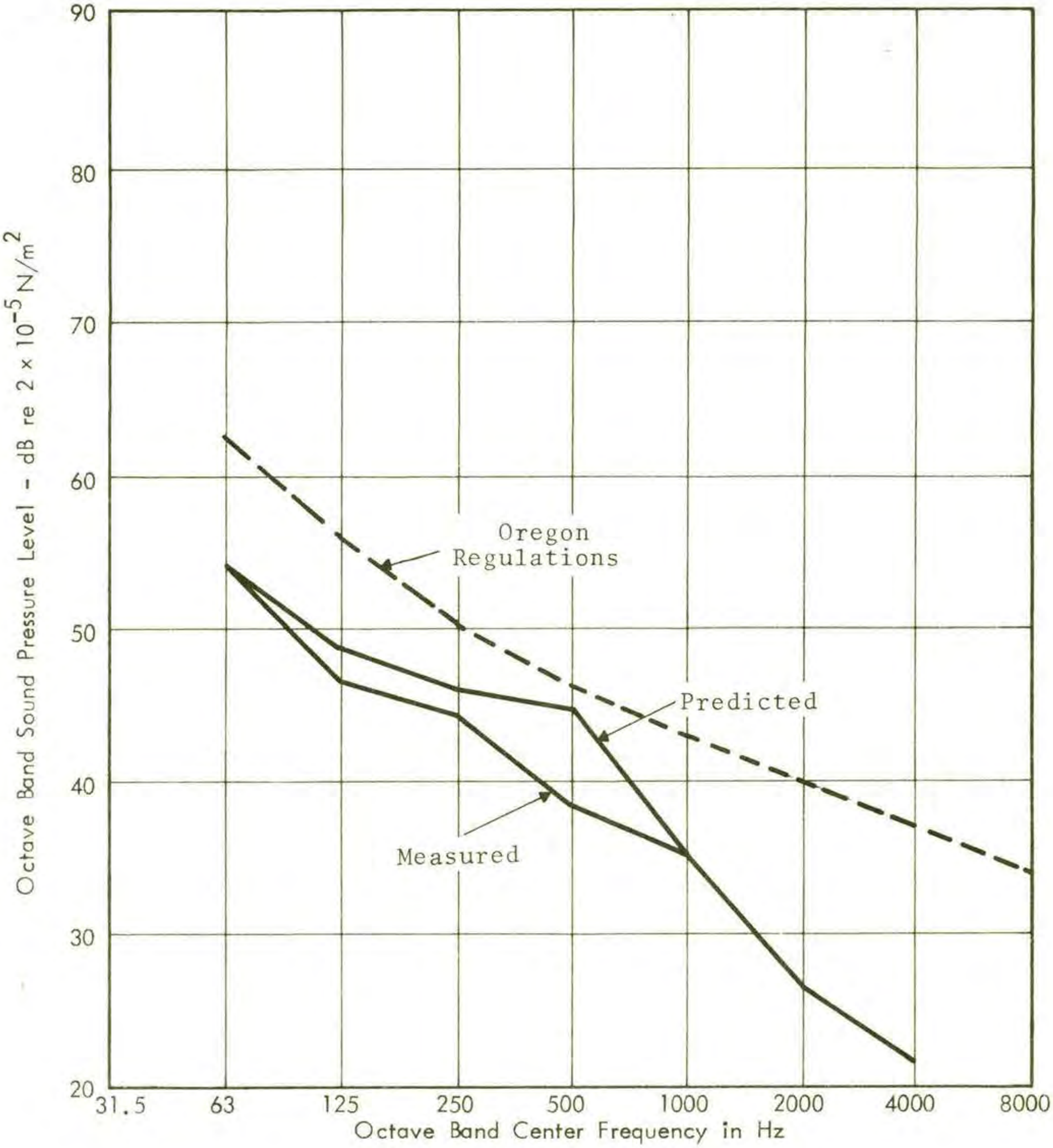


FIGURE A12.3 - MARION SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS, SHOWING 2000 FT. PREDICTIONS FOR SHUNT REACTOR INSTALLATION

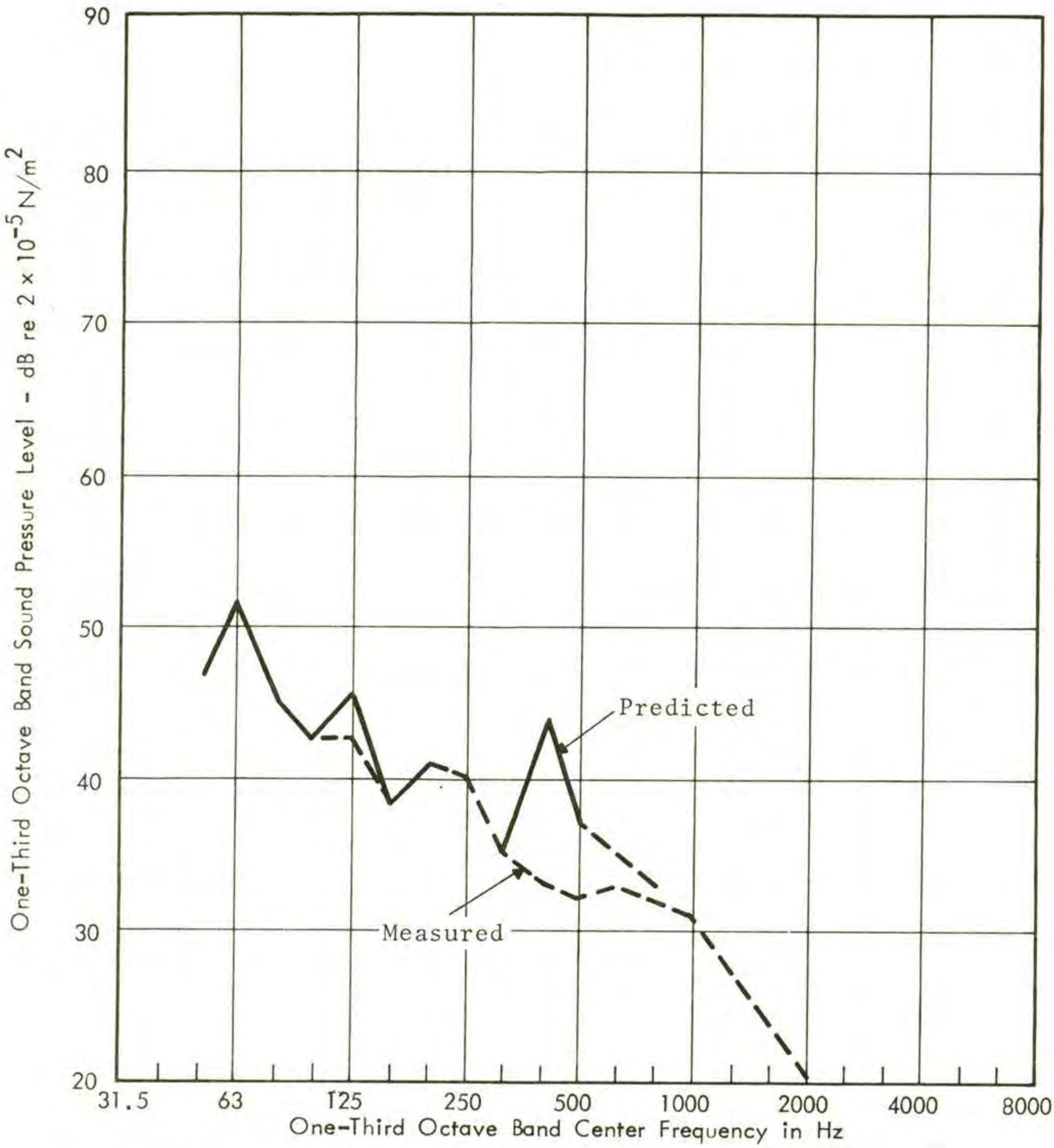


FIGURE A12.4 - MARION SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS, SHOWING 2000 FT. PREDICTIONS FOR SHUNT REACTOR INSTALLATION

A13. McNARY SUBSTATION

McNary Substation is located about one mile east of Umatilla, in Umatilla County, Oregon. The substation lies on the lowlands between U.S. Highway 730 and the Columbia River.

The layout of the substation and of the surrounding features are shown in Fig. A13.4. The nature of the land holding around the substation is very complex. The U.S. Army Corps of Engineers has large holdings associated with the nearby McNary Dam. The only areas of privately owned land would appear to lie (a) to the southeast of the switchyard (Shepler Subdivision) at a distance of about 1000 ft from the perimeter fence and (b) to the west and southwest of the switchyard, in the vicinity of the Sandy Burr Addition, again at distances from the perimeter fence approaching 1000 ft. Currently some new residential properties are under construction on the north side of the U.S. Highway 730, at a distance of 2000 ft or more from the perimeter fence. [redacted].

FIELD SURVEY

The field survey was carried out over the period 16 to 17 March 1976. We were accompanied within the switchyard by Mr. Owen Ansen (System Protection Maintenance) and by Mr. R. Leslie (Chief Operator).

The weather during our visit was sunny with light cloud cover. Winds were from the east at 4 mph. The air temperature was 59°F; the relative humidity was 58%.

• Close-In Measurements

The results of the measurement at 10 ft are summarized in Table A13.2.

• Perimeter Measurements

The results of the perimeter survey are shown in Fig. A14.1 at the first two tonal frequencies. These levels normalize to 500 ft levels of about 69 dB at 120 Hz and 56 dB at 240 Hz. The high second harmonic level measured close to Bank 8 (see Table A14.2) is not found at the more distant positions.

• Community Measurements

Measurements were taken at the following positions external to the substation.

a) At a position on 3rd Avenue close to the BPA property line, i.e., about 900 ft west of the substation perimeter fence,

b) At a position in the yard of the closest house, to the southeast of the substation.

The results of these measurements are summarized in Table A13.3. A typical 1 Hz bandwidth spectrum at Position (a) is shown in Fig. A13.2.

The results of normalization to a distance of 500 ft using [redacted] as the source center, show good agreement at 120 Hz with the perimeter and close-in data. At higher frequencies ground or other effects impose some attenuation.

• Microsample Data

Microsampling was carried out on the site of a new house under construction close to Highway 730. This position is elevated relative to the substation and it was felt that in spite of the larger distance involved, the noise environment here might be more critical.

The results of the microsampling are presented in Figs. A13.3, 4 and 5. The full computer output sheets are included in Appendix B.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The closest residential properties lie at a distance of 2000 ft from the [redacted]. The microsample distance was about 2600 ft. It is clear from the tonal levels established in the close-in, perimeter and community measurements that the octave band and one-third octave band levels given in Figs. A13.4 and A13.5 are not the result of the [redacted]. In fact, the environment at the microsampling location is dominated by traffic noise on U.S. Highway 730 and on the Umatilla Toll Bridge, which passes through the Sandy Burr Addition to the west. Spillage noise from the nearby McNary Dam also contributes to the neighboring environment.

Our analyses show that at present the McNary Substation is in compliance with the State Regulations at the closest residential properties, both to the west and to the southeast of the substation. In the event of future developments at distances closer than 1800 ft from the [redacted], the possibility of a noncompliance situation could arise. Future developments in that area to the east of the Sandy Burr Addition thought to be under private ownership, could lead to a situation of noncompliance. The extent of noncompliance would however probably amount to no more than 5 dB at 120 Hz.

RECOMMENDATIONS

There is no need for noise control at the present time. We recommend however that BPA pay regard to land transactions and planning permits occurring in the area--particularly in those areas designated as the Sandy Burr Addition and the Shepler Subdivision.

In the event of future noise problems, a simple "c" shaped barrier to the south of [redacted] would probably correct the situation.

Position	Distance (ft) (to Bks. 8/9)		Frequency (Hz)				dBA
			120	240	360	480	
a	1450	M	58	35	26	18	51
		N	67	44	35	27	50
b	2000	M	54	30	19	11	37
		N	66	42	31	23	49

M = Measured.

N = Normalized to 500 ft.

TABLE A13.3 McNARY SUBSTATION--COMMUNITY MEASUREMENTS
Tonal Noise Levels (SPL in dB re $2x10^{-5}N/m^2$)

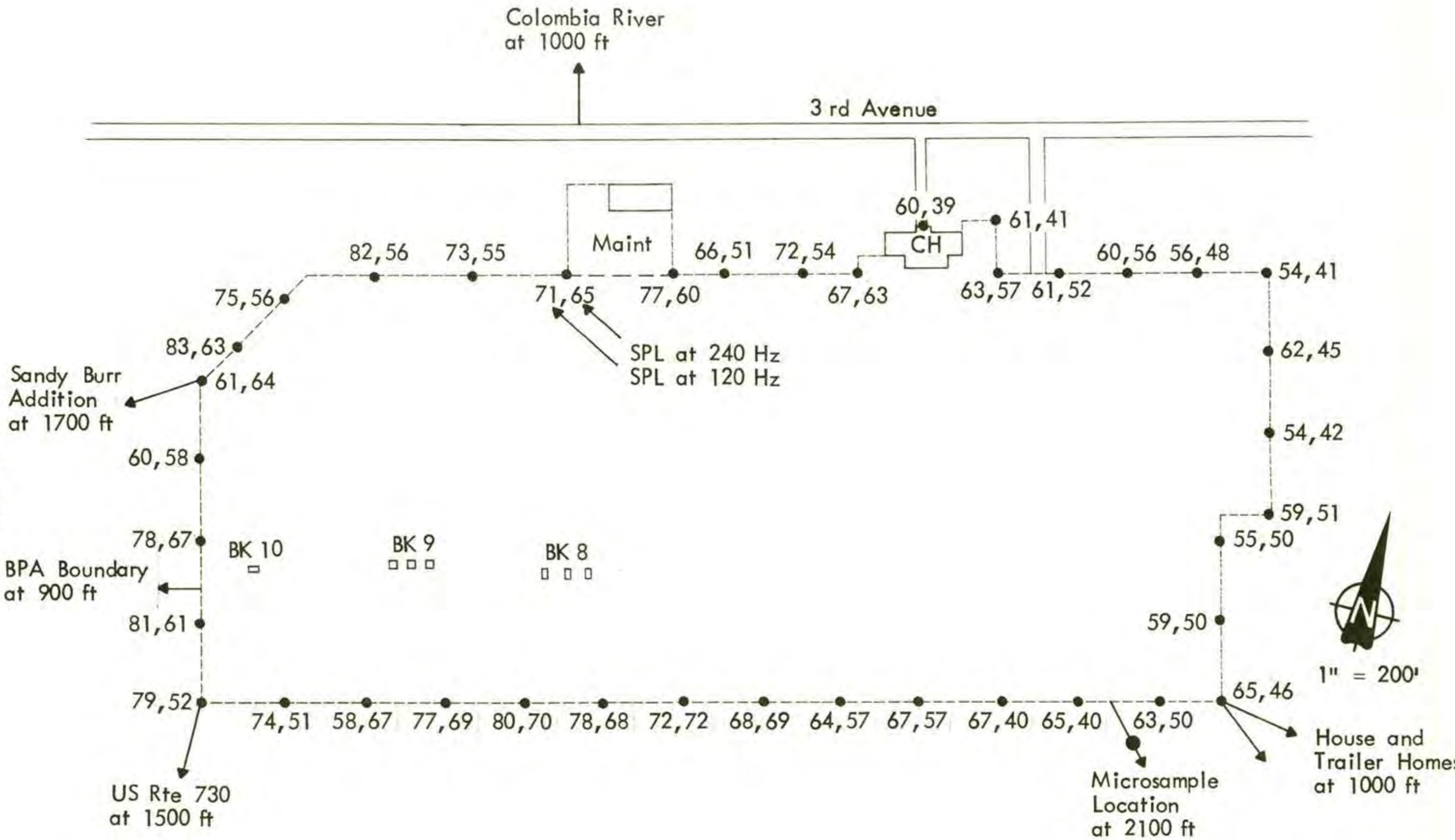


FIGURE A13.1 McNARY SUBSTATION AND ENVIRONS
SHOWING PERIMETER SOUND PRESSURE LEVELS

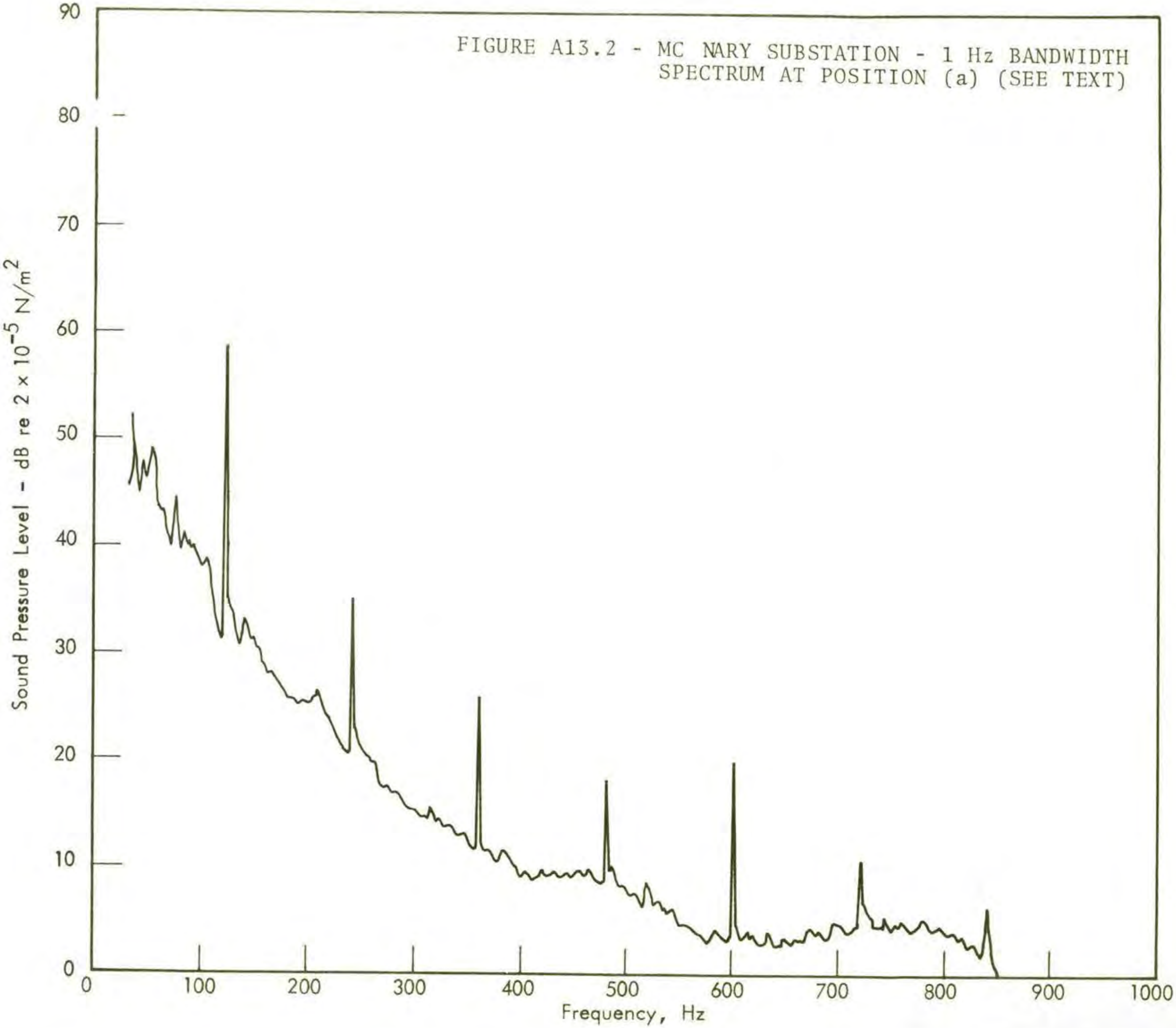


FIGURE A13.2 - MC NARY SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POSITION (a) (SEE TEXT)

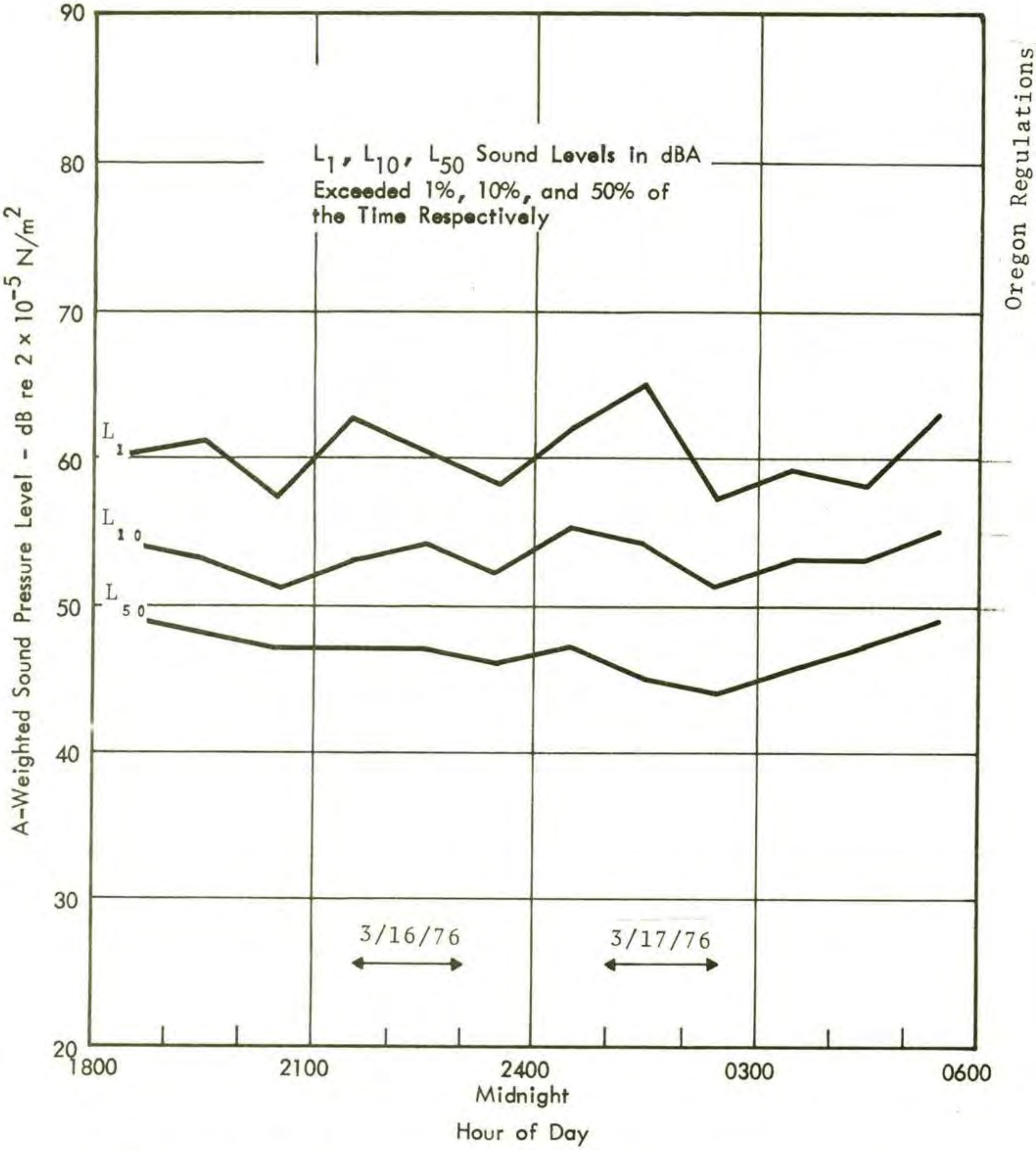


FIGURE A13.3 - MC NARY SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

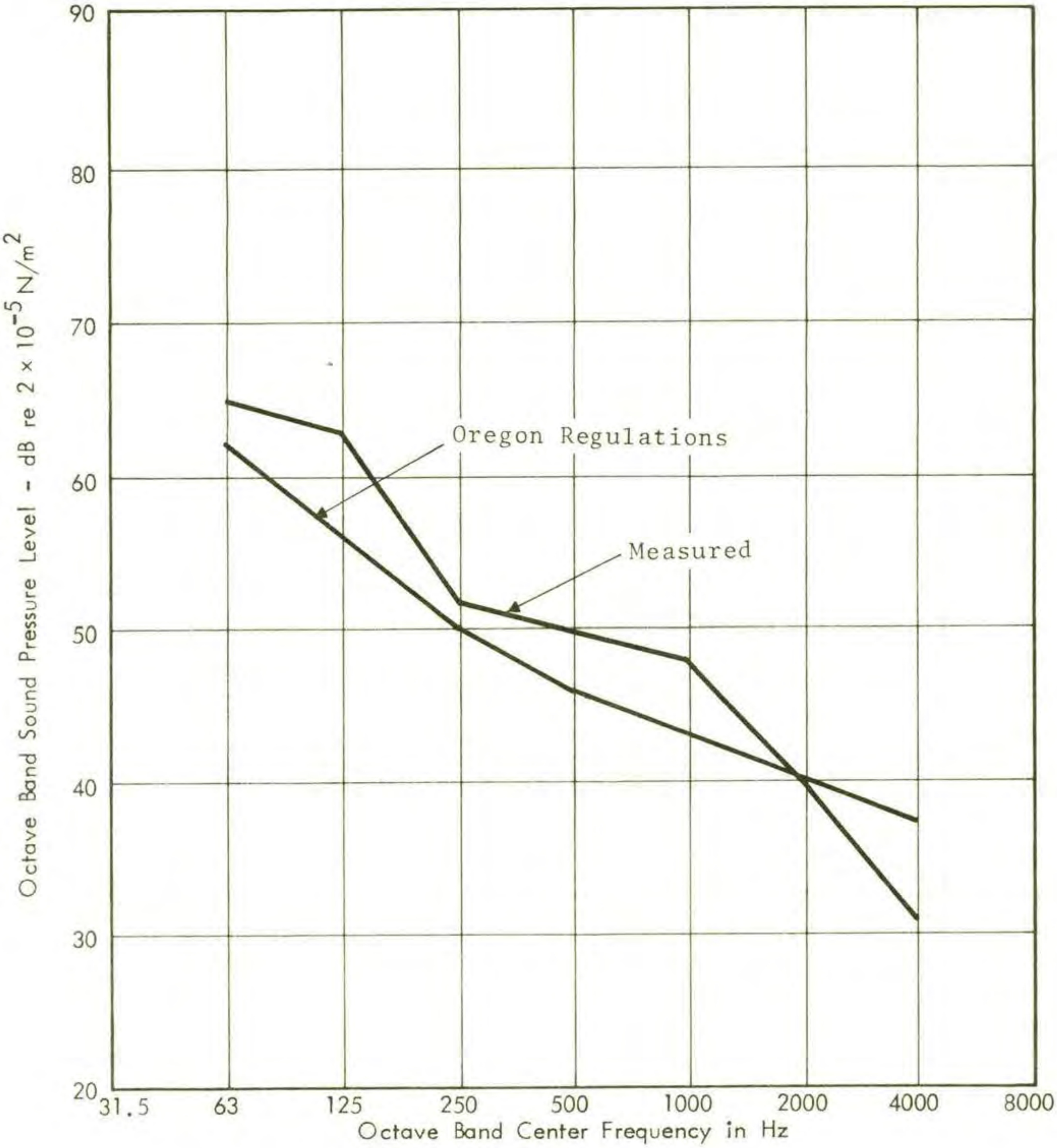


FIGURE A13.4 - MC NARY SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

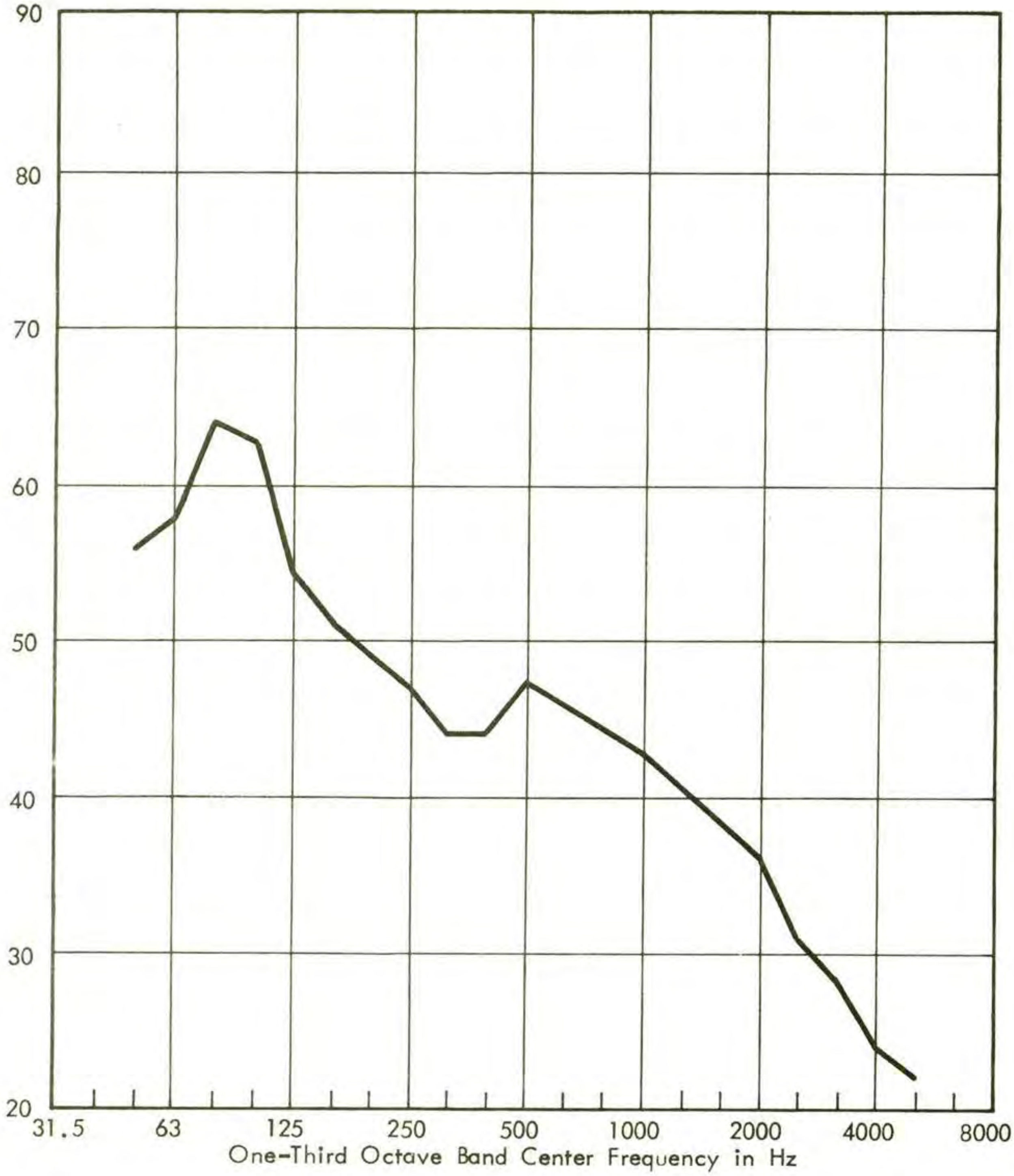


FIGURE A13.5 - MC NARY SUBSTATION - MICROSAMPLE (L_{10})
ONE-THIRD OCTAVE BAND LEVELS,
0300 TO 0400 HOURS

A14. OREGON CITY SUBSTATION

Oregon City Substation lies 15 miles south of Portland, Oregon, on the line separating Washington and Clackamas Counties. The substation lies one-half mile west of U.S. Interstate Highway 5.

The layout of the substation and of its immediate environs is shown in Fig. A14.1. [redacted] Details of this unit (which will be similar, but not necessarily identical, to the new Maple Valley transformer) are given in Table A14.1. [redacted]

The terrain around the substation is effectively flat. The predominant land-use is agricultural. The area is sparsely populated. There is only one property (a farmhouse) within [redacted].

It may be anticipated however that within the next 10 to 15 years there could be substantial residential developments at [redacted]. However, in the future the land to the west of the 230/500 kV yards will be covered by line easements and therefore will be unsuited for residential development. For the same reasons the land directly to the east of the existing 500 kV yard will be restricted in use. Residential development could arise on that land currently used for grazing, directly to the south of the 500 kV yard. However, because of access problems, such development would be less likely than development on or close to Peters Road to the east of the BPA property line. Such development could lie as [redacted]

Thus the existing and future problems at Oregon City Substation can be evaluated on the basis of a minimum distance to residential properties of about 1000 ft, unless it is realistically considered that the southern station boundary is likely to support future developments. In this case properties could lie as close as 600 ft from the transformer bank.

FIELD SURVEY

The field survey was carried out over the period 5th to 6th March 1976. We were accompanied within the substation by Mr. Lyle Howard (BPA Substation Design).

The weather during the survey was fine. There was a light cloud cover and the wind was from the northeast at 3 mph. On the afternoon of the 5th March the air temperature was 52°F and the relative humidity, 58%.

The presence of corona noise influenced the positions at which measurements of the existing ambient conditions were obtained. The measurement program was as follows:

"Daytime" data samples were obtained at two positions within the 500 kV yard. Average readings obtained using the sound level meter with a one-third octave band filter set are shown in Fig. A14.1. The effects of corona noise in the frequency range 315 Hz to 1600 Hz can be seen. Data were also obtained at a position close to the southern fence of the 115/57 kV substation, at a distance of about [redacted] [redacted] [redacted]). The transformer tonal levels recorded were 67 dB at 120 Hz and 65 dB at 240 Hz.

Microsampling was carried out at the position shown in Fig. 14.1. The results are summarized in Figs. A14.3 to A14.5. The computer output sheets are included in Appendix B.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The environmental levels at the microsample position are controlled by corona noise. Figure A14.5 displays the characteristic spectrum shape within the switchyard (Fig. A14.2). The farmhouse to the southeast of the substation lies at a similar distance from the switchyard; it may therefore be expected that the environmental levels here will be similar to those obtained by microsampling. It should be noted also that the measured daytime relative humidity during the survey was only 58%. It is therefore reasonable to suppose that the corona activity during microsampling was less than that which would occur under high humidity or wet weather conditions. We conclude that the microsample data form a reasonable basis on which to judge the compliance of the future transformer installation.

We have based our prediction of the transformer bank noise levels on the assumption that BPA will be able to obtain a guaranteed noise rating for the unit of 84 dBA (this is the guaranteed level given on the Maple Valley bank). Assuming a measurement (NEMA) area of about 1000 sq ft *per phase* and following the methodology outlined in Chapter 4, we predict the following average noise and tonal sound pressure levels at 500 ft.

dBA	120 Hz	240 Hz	360 Hz	480 Hz
57	68	61	55	54

The level of 57 dBA compares with a level of 65 dBA based on the NEMA standard rating of 92 dBA, and with a level of 56 dBA based on the regression analysis discussed in Chapter 4. The tabulated levels will be assumed to apply at both the L_{50} and L_{10} statistical levels.

It has been suggested that the present *and* future problems at Oregon City substation can be evaluated on a minimum distance between transformer and sensitive properties of about 1000 ft. Therefore the levels tabulated above may be reduced by 6 dB. These levels are shown superimposed on Figs. A14.4 and A14.5.

Based on these predictions the substation is likely to be in default of the noise regulations as follows:

a) By 1 dBA on the basis of specified noise levels.

b) By 6 dB at 120 Hz and by 5 dB or less at higher frequencies, based on the octave band specification, and

c) By 0 dB at 120 Hz and by 6 dB at 240 Hz on the basis of the pure tone definition.

In this analysis we pay no regard to fan noise on the basis that this rarely plays a significant role in substation noise problems.

The major problem--not unexpectedly--is compliance with the octave band specification of the Oregon Ordinance. The engineering of noise reduction of about 6 dB at 120 Hz and 240 Hz should remove this problem.

In the event that future developments could arise on the southern property boundary [redacted]

[redacted], the requirement for noise control would be increased by about 4 dB--i.e., to 10 dB at 120 Hz.

RECOMMENDATIONS

We recommend that noise control taking the form of a full height barrier be planned by BPA at Oregon City. These plans however should be open to modification following measurements on the Maple Valley transformer as soon as this is energized.

BPA should remain cognizant of land transactions and planning applications in those areas around the substation.

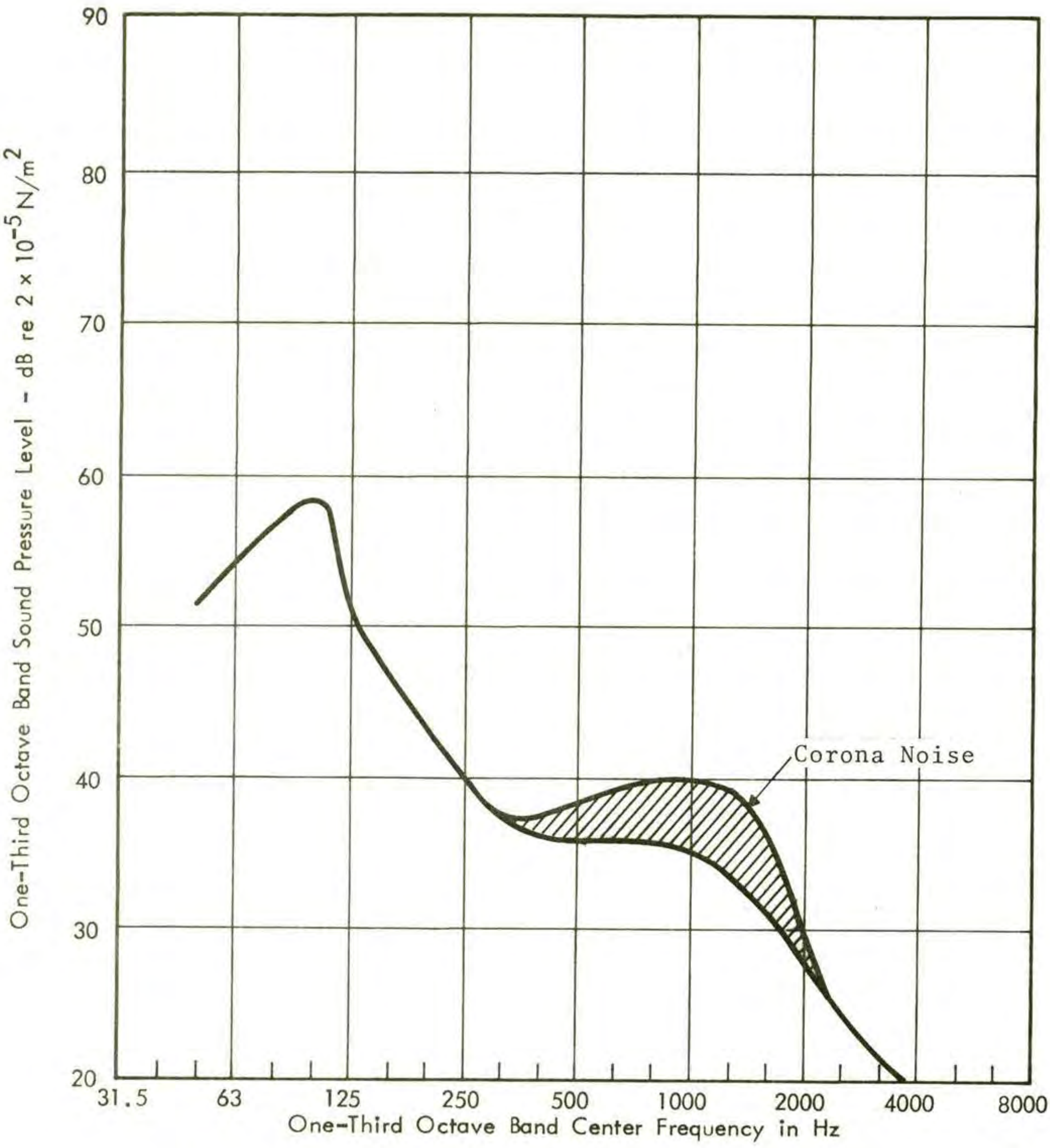


FIGURE A14.2 - OREGON CITY SUBSTATION - RANGE OF SPECTRA MEASURED IN 500kV YARD

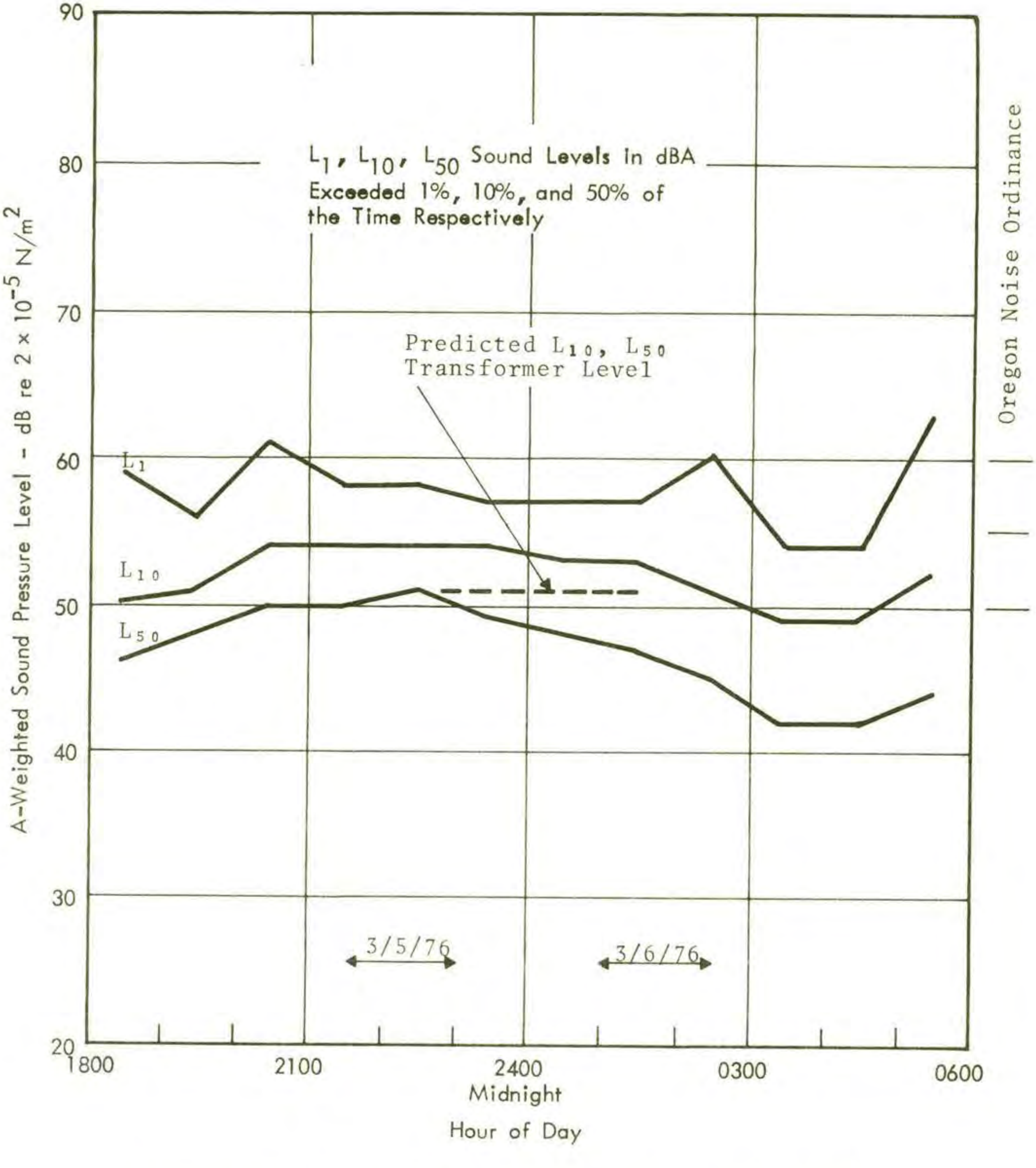


FIGURE A14 .3 - OREGON CITY SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

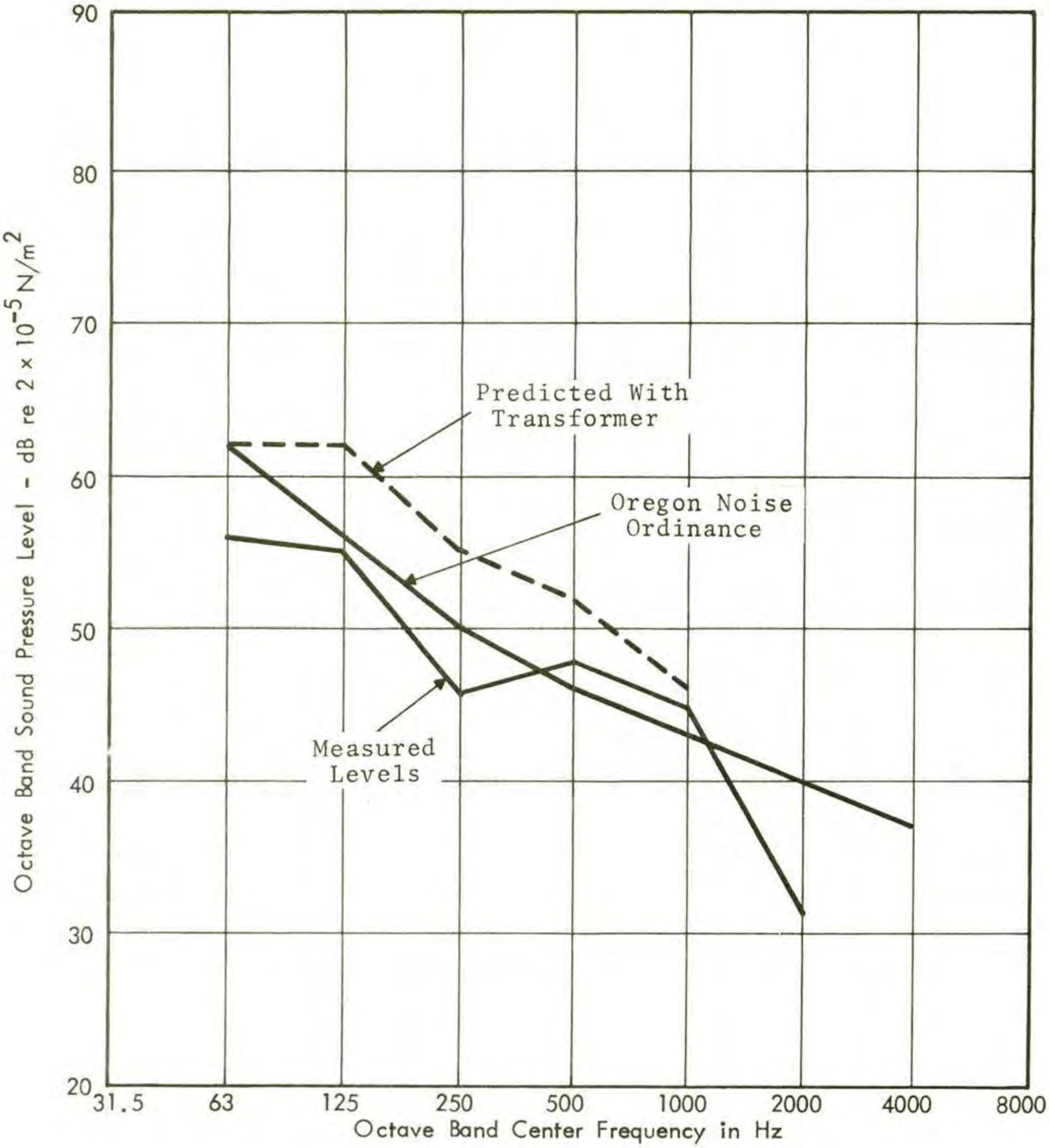


FIGURE A14.4 - OREGON CITY SUBSTATION - MICROSAMPLE (L_{10})
OCTAVE BAND LEVELS, 0300 TO 0400 HRS.

FIGURE A14.5 -OREGON CITY SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS 0300 to 0400 HRS.

A15. SANTIAM SUBSTATION

Santiam Substation lies in Linn County, Oregon, some 1500 ft south of the North Santiam River, and about 3 miles west of the township of Lyons. The station lies some 2500 ft northwest of the junction of State Highway 226 and the road to Kingston. The Lyons 1100 kV test substation is currently under construction at this junction.

Figure A15.1 shows the layout of Santiam Substation and indicates some of the major features pertinent to this study. The substation consists of two yards. These will be designated in this report as the 230 kV yard and the 500 kV yard. Details of the [redacted]. The possible intention of [redacted] is not considered in this report since this intention was not included in the contract instructions.

The main features of the terrain and uses of the surrounding land can be described as follows.

To the south the land rises towards the Kingston road. This land is covered with grass and rough scrub with occasional trees. The land would appear to be used primarily for grazing. The greater part of this land (and also of the land to the southeast of the substation) is subject to easements in connection with BPA transmission lines. Two properties, both located on the Kingston road, are visible from the substation. These lie at a distance of about 2600 ft from the perimeter fence.

To the west of the substation, the land drops towards a creek. No properties are visible from the substation in this direction but aerial photographs show a cottage on the south side of Weasel Flat Road at a distance of about 1600 ft from the perimeter fence.

To the north the land falls towards the North Santiam River. There are no residential properties in this area. The land would appear to be used for grazing and crop farming.

To the east the land rises steeply to a tree covered hill. Hidden within the trees is a residential property occupied by the "Quinter family". This property lies at a distance of about 1000 ft from the 500 kV yard perimeter fence. There is a trailer home, located immediately to the north of Weasel Flat Road, at a distance of 480 ft from the 500 kV yard fence. The home is visible from the substation.

The extent of BPA land ownership around the substation is indicated in Fig. A15.1. The most adverse future residential development from the point of view of noise regulations would be on the north side of Weasel Flat Road, directly opposite the 500 kV yard--at a distance of only 400 ft from the single phase bank. However, in talking with substation personnel and considering local government development plans, we are of the opinion that there is a low probability of further residential development in the Santiam area in the foreseeable future.

FIELD SURVEY

Field measurements were carried out over the period 9th to 10th March 1976. We were accompanied within the substation by Mr. John McGinness (Operator) and Mr. L. Morales (Substation Design).

During the course of the measurements the weather was clear and sunny. The wind was from the northwest at about 6 mph. The temperature was 60°F at a relative humidity of about 59% during the afternoon of 9th March.

• Close-In Measurements

The results of measurements taken at a distance of 10 ft from the [redacted] are given in Table A15.2, together with the measurement (wall) surface area for each of the units. The shunt reactor was not energized at the time of the visit and so this unit is not included in the analysis.

• Perimeter Measurements

The results of the substation perimeter survey at the first two transformer tonal frequencies are presented in Fig. A15.1. The smaller (230 kV yard) transformer formed a significant source only over a limited portion of the 230 kV yard perimeter. Elsewhere the large (500 kV yard) transformer bank was the dominant noise source. For this reason the [redacted].

The measured data around the 500 kV yard are consistent with 500 ft levels of 61 dB at 120 Hz and 50 dB at 240 Hz.

• Community Measurements

Data samples were acquired (a) at the Quinter home, (b) at the trailer home, and (c) at a position 250 ft north of the

Kingston road, 1000 ft west of the Lyons Substation junction, on the hill overlooking the Santiam Substation. This last position was at a distance of about [redacted] These data are summarized in Table A16.3.

• Microsample Data

Microsample data were obtained at the Quinter residence. These data are summarized in Figs. A15.2, 3 and 4. Ambient reconstruction is based on data analysis using the notched rejection filter and on narrow band analyses. The computer output sheets are included in Appendix B.

DATA INTERPRETATION AND COMPLIANCE ANALYSES

Evaluation of the data obtained at the three community measurement locations, shows the substation to be in compliance with the ordinance at those locations.

Evaluation of other areas in which development may occur in the foreseeable future may be made by extrapolation of normalized levels based on the close-in data and the community data from the Quinter home and the site beside the Kingston road. Data from these two sites agree generally with the levels predicted from close-in measurements when normalized to 500 ft, thereby providing confidence in the extrapolation. The trailer home location is shielded by the terrain from the 500 kV yard and thus data from this location were not used.

Overall, the evaluation has shown that the substation is in compliance with the Oregon Noise Ordinance at the present time. It should remain so in the foreseeable future, bearing in mind our earlier assessment of the likelihood of further development around the substation.

NOISE CONTROL RECOMMENDATIONS

No noise control is required for this substation.

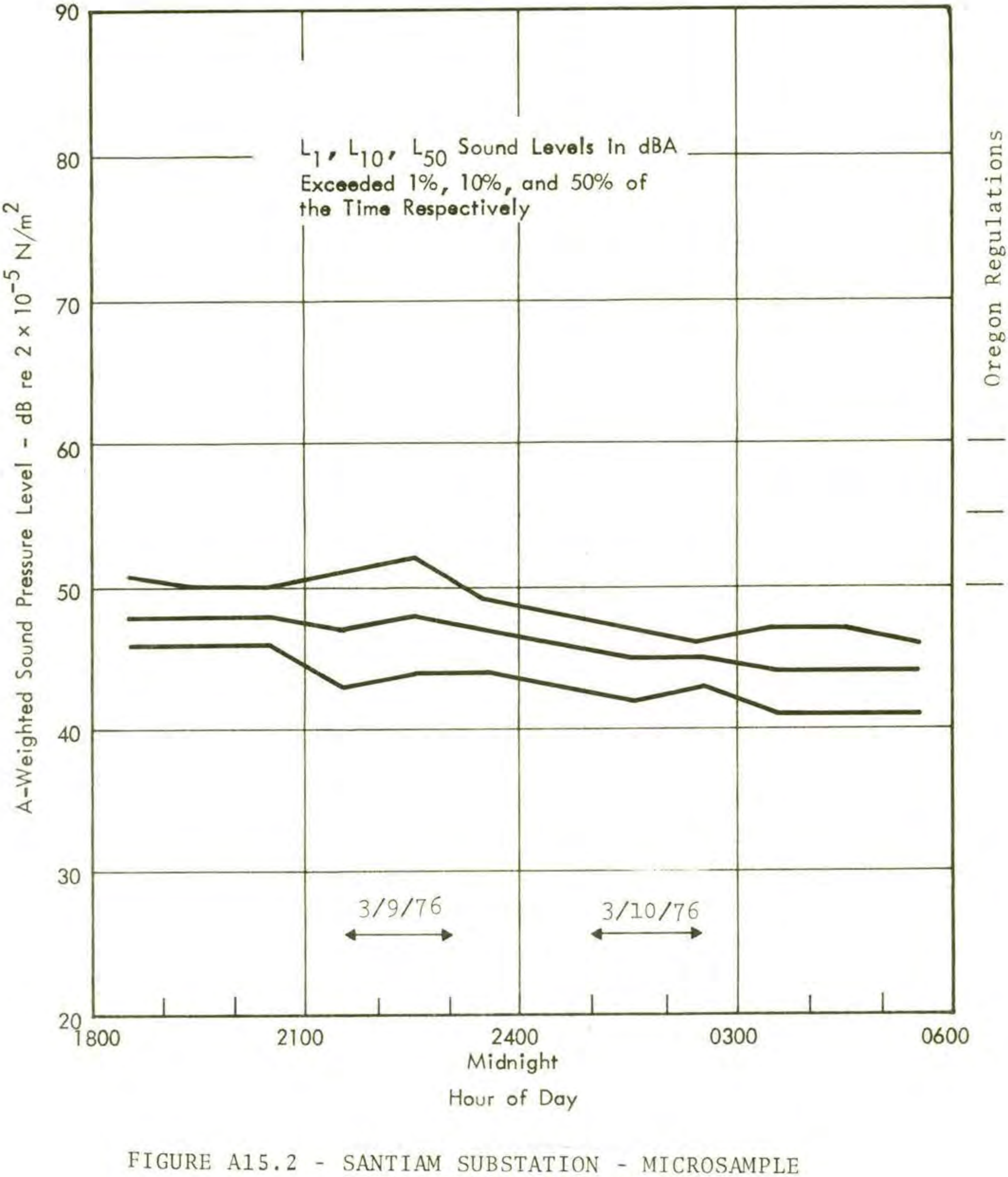


FIGURE A15.2 - SANTIAM SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

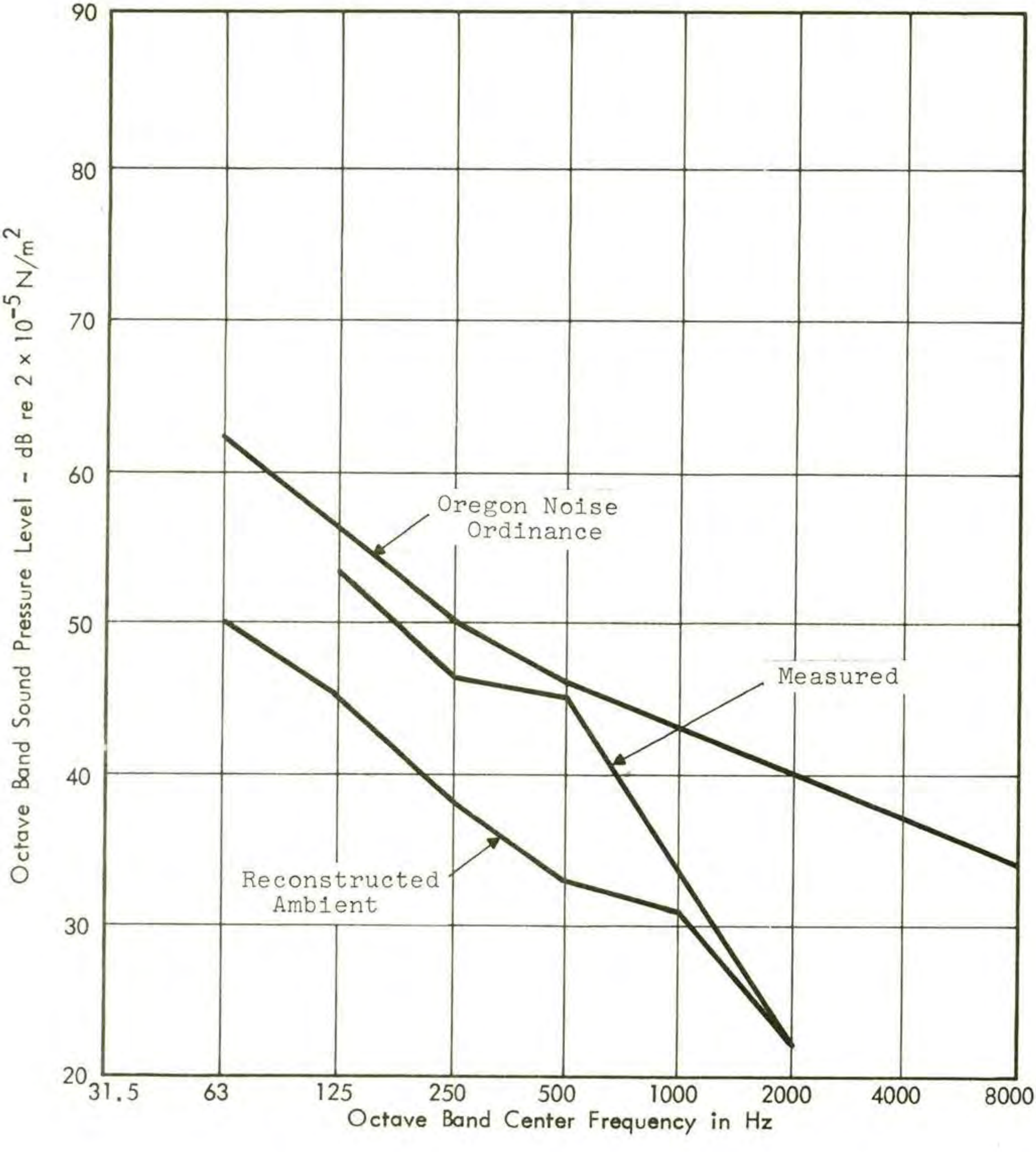


FIGURE A15.3 - SANTIAM SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HOURS.

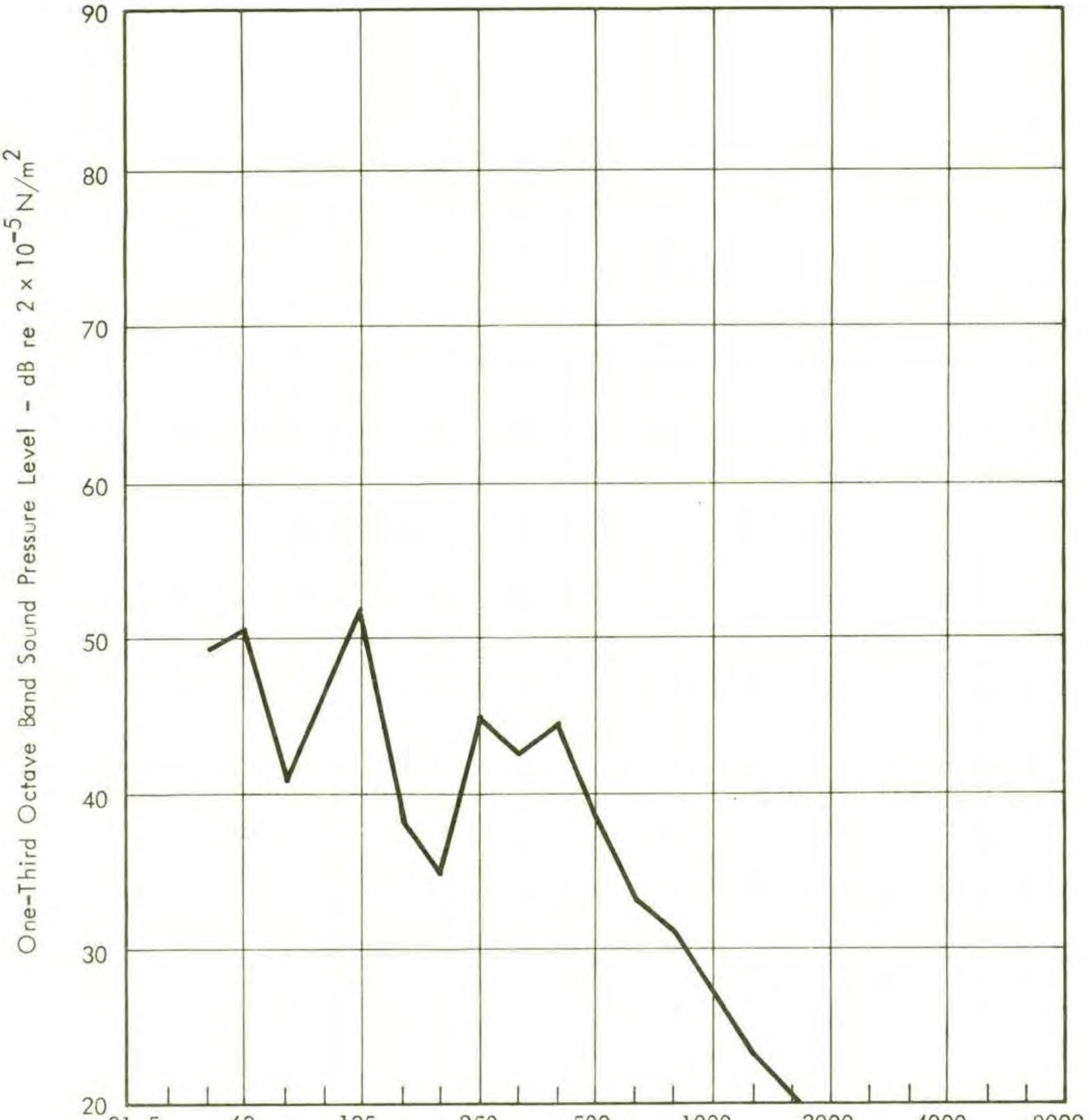


FIGURE A15.4 - SANTIAM SUBSTATION - MICROSAMPLE (L_{10})
ONE-THIRD OCTAVE BAND LEVELS,
0300 TO 0400 HOURS

A16. TOLEDO SUBSTATION

Toledo Substation is located about one-half mile east of Toledo township and on the east side of Ollalla Creek which is a tributary of the Yaguina River. The substation is in Lincoln County, Oregon.

The layout of the substation and of its immediate environs is given in Fig. A16.1. The relevant details of the [redacted].

The substation lies on the side of a hill some 30 ft above Upper Ollalla County Road. There are no residential properties within a distance of 1000 ft on the west side of the road; the land here lies at the level of the Ollalla Creek and would appear to be liable to flooding under high water conditions. The adjoining PUD Substation has no significant noise sources.

There are some well-spaced properties on the east side of the road to the north of the substation. These lie at the level of the road and so are some 30 ft or so below the grade level of the yard. The closest of these properties is shown in Fig. A16.1. This was the location used for microsampling.

There is a single residential property to the south of the substation. This property lies at a height of about 15 ft above the yard grade level. It is shielded from the substation by the terrain and by a stand of trees.

There are several residential properties to the southeast of the substation. These lie further up the hill and have a clear view of the substation hardware--but at a substantial distance from it.

There are no residential properties to the east or northeast of the substation. Part of this land lies under the incoming 230 kV transmission lines. Access and difficult terrain would be likely to hinder future development in this area.

Future residential developments in the area of Toledo Substation are, therefore, not likely to impose noise problems which are significantly different from those existing today.

FIELD SURVEY

The field survey was carried out over the period 8th to 9th March 1976. We were accompanied within the substation by Mr. George Wood (Operator).

The weather during the survey was clear and sunny. There was virtually no wind. The air temperature and relative humidity on the afternoon of 8th March were 52°F and 75%, respectively.

• Close-In Measurements

The results of measurements at a distance of 10 ft from the transformer banks are summarized in Table A16.2.

• Perimeter Measurements

The results of measurements on the substation perimeter are included in Fig. A16.1. These normalize to average levels at 500 ft of 60 dB at 120 Hz and 38 dB at 240 Hz. The agreement with the close-in predictions is reasonably good.

• Community Measurements

Data samples were obtained at the following positions:

a) To the north of the substation close to the microsample location,

b) To the south of the substation midway between the house and the perimeter fence.

The latter position was on top of the embankment above the substation and therefore in full view of the transformers.

The tonal data are given in Table A16.3.

• Microsample Data

Microsampling was carried out at the location shown in Fig. A16.1. The data are summarized in Figs. A16.2, 3 and 4.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The substation is in compliance with the Oregon Regulations at the microsample location. However the results of other measurements in and around the substation show that compliance at the closest properties can only be assured if the terrain imposes at least 5 dB of attenuation at the 120 Hz frequency. This should certainly be achieved under normal circumstances at properties both to the south and to the north of the substation. [redacted] of the combined transformer banks would, in all probability, be exposed to environmental levels above the Oregon Noise Regulations. Such developments would appear to be unlikely in view of transmission line easements and access difficulties.

RECOMMENDATIONS

No noise control is required at Toledo Substation at this time. We recommend that BPA remain cognizant of land transactions and planning applications in the area--especially to the east and northeast of the substation (where the line of sight to the substation is unobstructed). In the event of future developments here, it might prove necessary to erect a two or three sided barrier configuration around both transformer banks. The barrier height should take account of the elevation of the residential development with respect to the transformer.

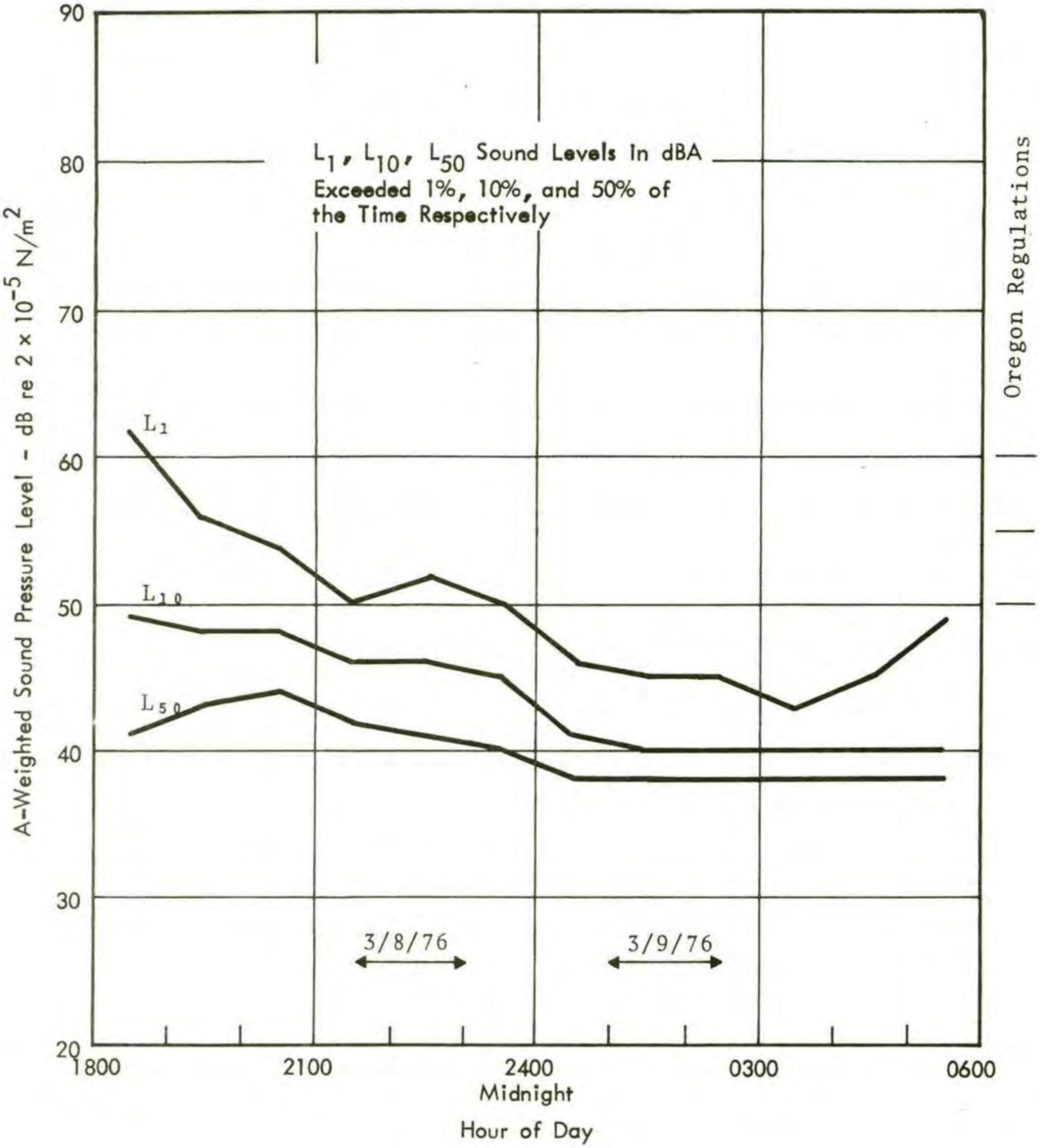


FIGURE A16.2 - TOLEDO SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

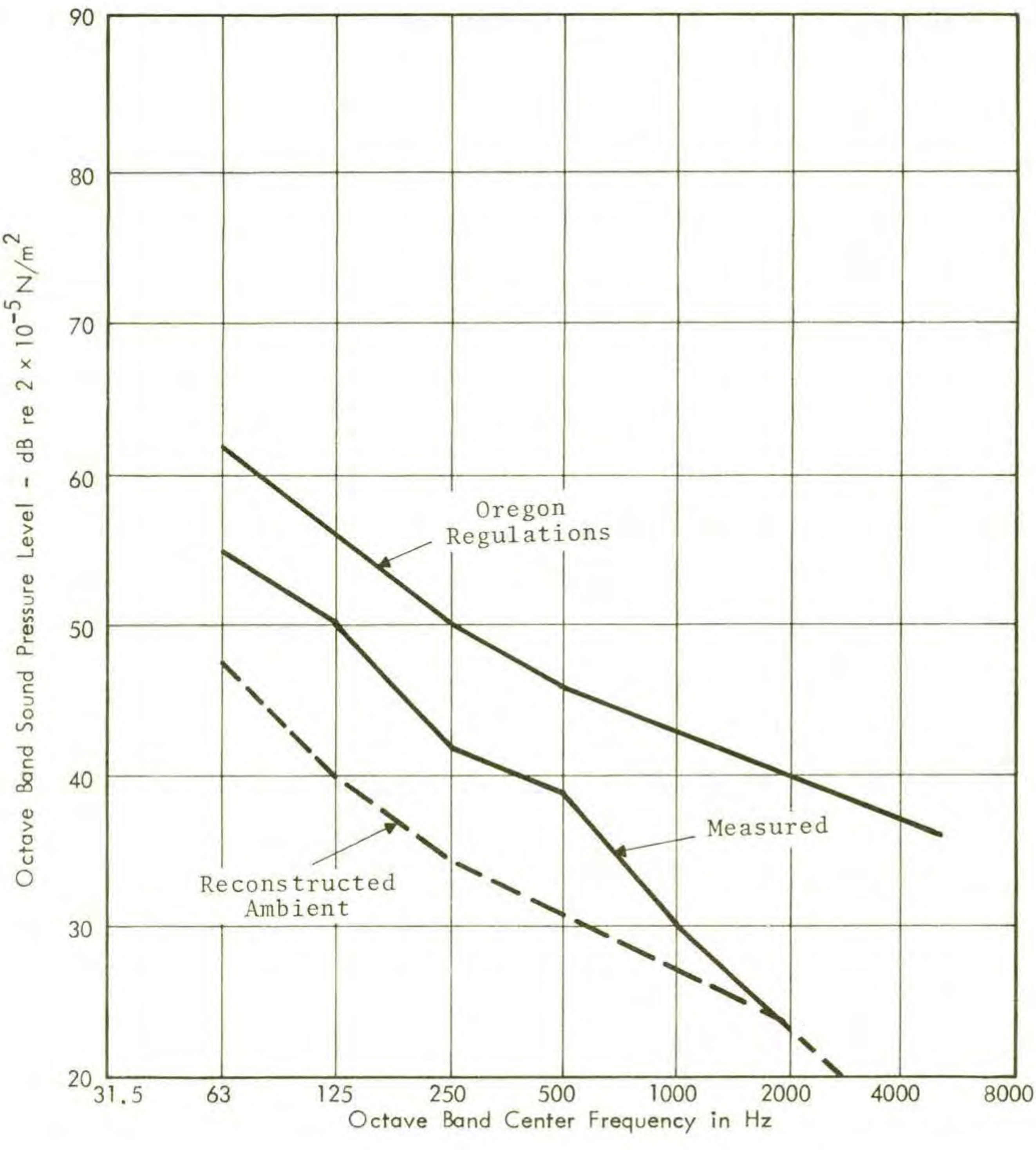


FIGURE A16.3 - TOLEDO SUBSTATION - MICROSAMPLE (L_{10})
OCTAVE BAND LEVELS, 0300 TO 0400 HRS

FIGURE A16.4 - TOLEDO SUBSTATION - MICROSAMPLE (L_{10})
ONE-THIRD OCTAVE BAND LEVELS,
0300 to 0400 HOURS

A17. WALNUT CITY

Walnut City Substation is located on the western outskirts of McMinnville, in Yamhill County, Oregon. The substation lies on the north side of Western Avenue. The layout of the substation and the major features of its environs are shown in Fig. A17.1. [redacted] Further details of the situation around the substation are as follows.

The primary land-use is agricultural. To the northeast of the substation the land rises to about 30 ft above station datum. The terrain elsewhere is essentially level.

There is a number of residential properties, primarily on the northern side of Western Avenue, both to the west and to the east of the substation. The closest of these is shown in Fig. A17.1; [redacted] The properties to the east are at a substantially larger distance from the transformer. There is also a house on top of the rise to the northeast of the substation. [redacted]

The transformer was partially enclosed by BPA some years ago. The enclosure consists of 16 gage sheet steel with a 4 in thick absorbent internal lining covered by a perforated steel sheet facing. The enclosure partially covers the transformer lid but is not sealed to the transformer; the clearance between the tank wall and the enclosure is estimated to be about 2 ft. The coolers are located on the outside wall of the enclosure. The enclosure was constructed because of noise complaints received by BPA from the occupants of the property immediately to the west of the substation fence.

FIELD SURVEY

The field survey was carried out over the period 8th to 9th March 1976. We were accompanied within the substation by Mr. Cox (Operator).

The weather during the measurement program was clear and sunny, with virtually no wind. At midday on the 8th March the air temperature and relative humidity were 51°F and 75%, respectively.

- Close-In Measurements

The results of measurements at 10 ft from the enclosure wall are given in Table A17.2.

- Perimeter Measurements

The results of perimeter measurements are included in Fig. A17.1. These values normalize to 500 ft levels of 31 dB at 120 Hz and 22 dB at 240 Hz. The latter level is substantially lower than the predicted level presented in Table A17.2.

- Community Measurements

Measurements of the major tonal components of the transformer were made at the following positions:

a) At a position midway between the nearest house and the perimeter fence (see Fig. A17.1), and

b) At a position on top of the hill to the northeast, some 50 ft from the house.

The obtained data are presented in Table A17.3.

It is noted that at position (b) the 120 Hz measured level is substantially higher than the 30 dB level predicted from the close-in and perimeter data. It is likely that this is the result of transformer lid radiation which, because of the land elevation, affects levels at position (b).

It was observed that the cooling fans on the Walnut City transformer are noisy in comparison with the transformer itself. A comparison of narrow band (5 Hz bandwidth) data at Position (a) with and without the fans in operation is shown in Fig. A17.2. The blade passage pure tone noise and broad-band noise from the fan is very clearly evident. The overall noise level represented by this spectrum is 60 dBA.

• Microsample Data

For reasons of security, microsampling was carried out at the northwest corner of the yard as shown in Fig. A17.1. The results are summarized in Figs. A17.3, 4 and 5. The full computer output sheets are given in Appendix B. The fan was not operating throughout the microsampling period.

In Fig. A17.4 we include the Position (a) cooling fan octave band spectrum for comparison with the State of Oregon noise ordinance.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The substation is currently in compliance with the Oregon Noise Regulations, but only when the cooling fans are not operating. We understand however that these fans are rarely used. It is probably reasonable to say that they would never operate at night--except in highly unusual circumstances.

In 1978 a second transformer will be installed at Walnut City. This will be located to the east of the existing one and will have identical power and voltage rating. We understand that it will be ordered 7 dB below the specified NEMA level (71 dBA) *at its 12 MVA naturally cooled rating*. The resulting level of 64 dBA normalizes to a 500 ft level of 30 dBA based on a 600 sq ft radiating wall area. This is substantially lower than the normalized mean level of 40 dBA arising out of our own survey of BPA transformers. However it should be noted that in the course of our survey, two transformers in this size range (excluding the present enclosed Walnut City transformer) were found to have normalized levels below the 30 dBA value. It is presumed therefore that this specified level will be met by the new transformer.

Assigning a tonal composition typical of this rating of transformer we arrive at the following 500 ft predictions:

dBA	120 Hz	240 Hz	360 Hz	480 Hz
30	41	33	28	25

The closest residential property lies at a distance of about [redacted]. The predicted levels above should therefore be increased by 11 dB. A comparison of the resulting levels with Figs. A17.3, 4 and 5, and with the Oregon Noise Regulations, shows that the substation should remain in compliance with the regulations after the new transformer is energized.

RECOMMENDATIONS

No noise control is required at the present time, unless it is anticipated that the fans on the transformer are likely to be run during night-time hours. In this event BPA should take steps to refan the transformer to achieve a reduction in fan noise of about 10 dBA. (This would probably involve the use of larger diameter or higher "solidity" fans having a tip speed of about 50% of the present tip speed.)

Provision should be made in the design for the new transformer installation for the erection of a three sided barrier around the new transformer, with a height equal to the lid height. In the event that the new transformer is noisier than predicted or that residential development occurs on the eastern boundary within a distance of 120 ft from the new transformer, a barrier of this form may be required.

BPA should undertake noise monitoring as soon as the new transformer is energized. BPA should remain cognizant of land transactions and planning applications close to the substation fence. BPA should also consider the possibility of purchasing or leasing land to the east and the north to provide a "buffer" zone.

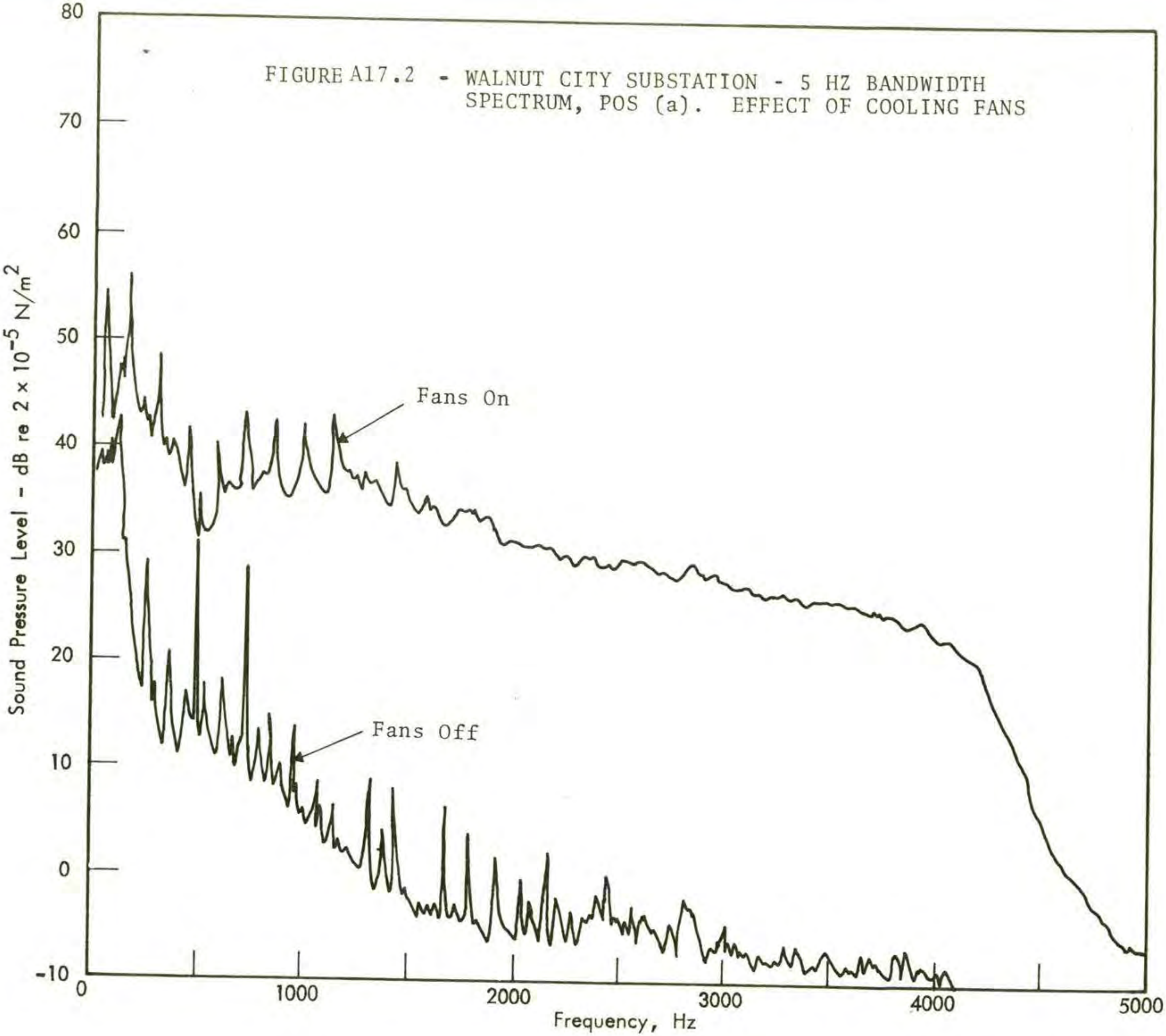


FIGURE A17.2 - WALNUT CITY SUBSTATION - 5 HZ BANDWIDTH SPECTRUM, POS (a). EFFECT OF COOLING FANS

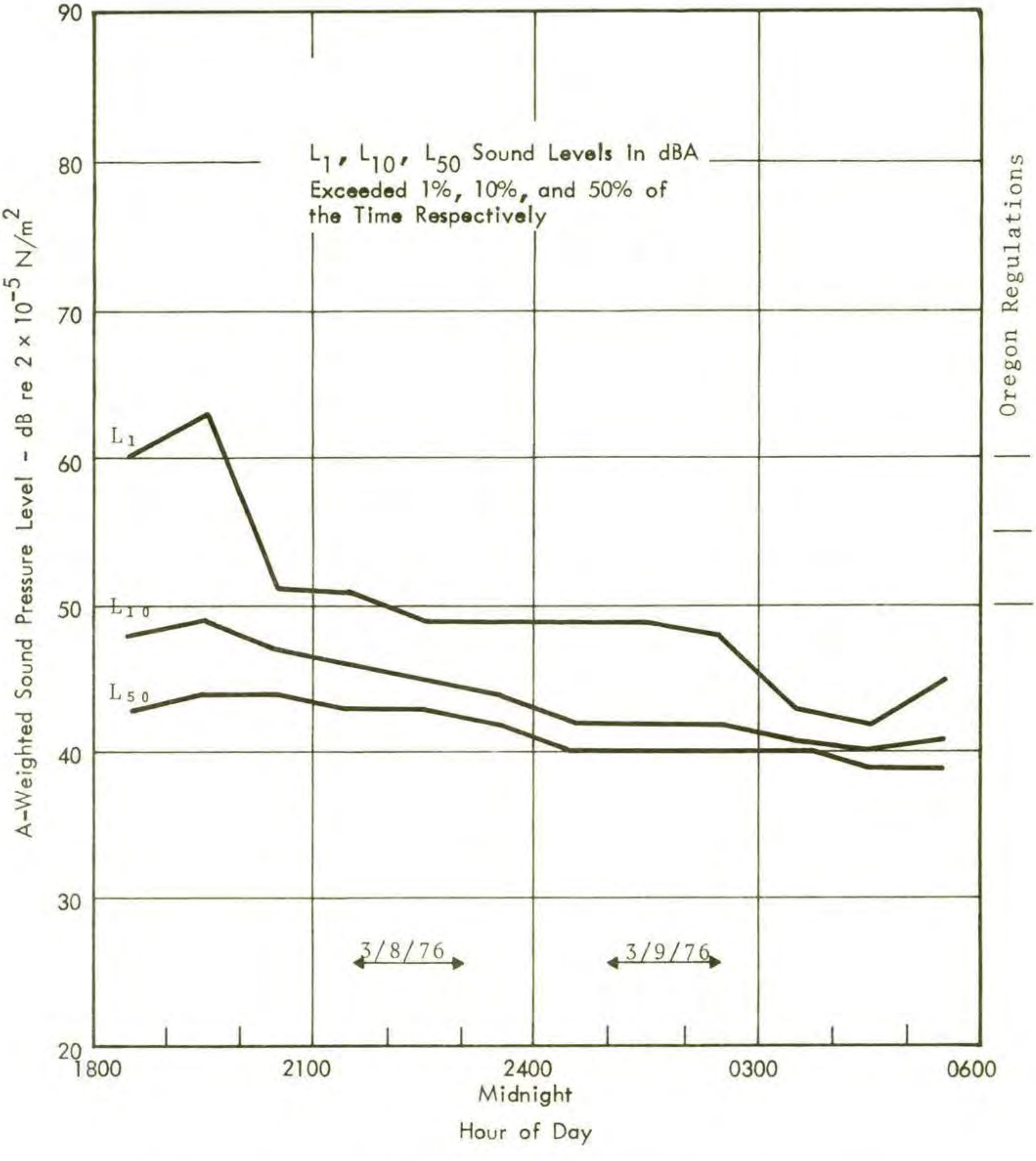


FIGURE A17.3 - WALNUT CITY SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

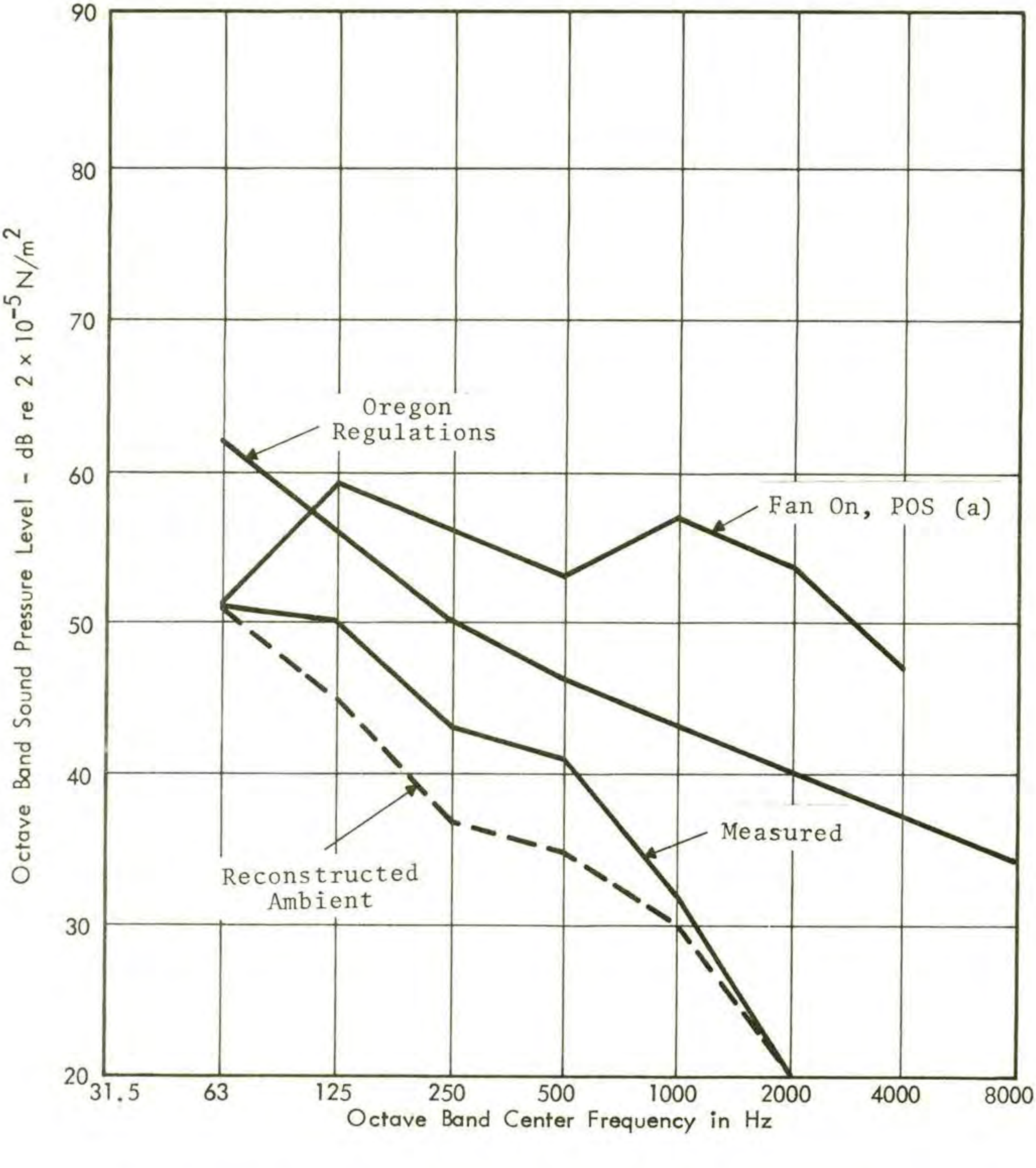


FIGURE A17.4 - WALNUT CITY SUBSTATION - MICROSAMPLE (L_{10}) OCTAVE BAND LEVELS, 0300 TO 0400 HRS

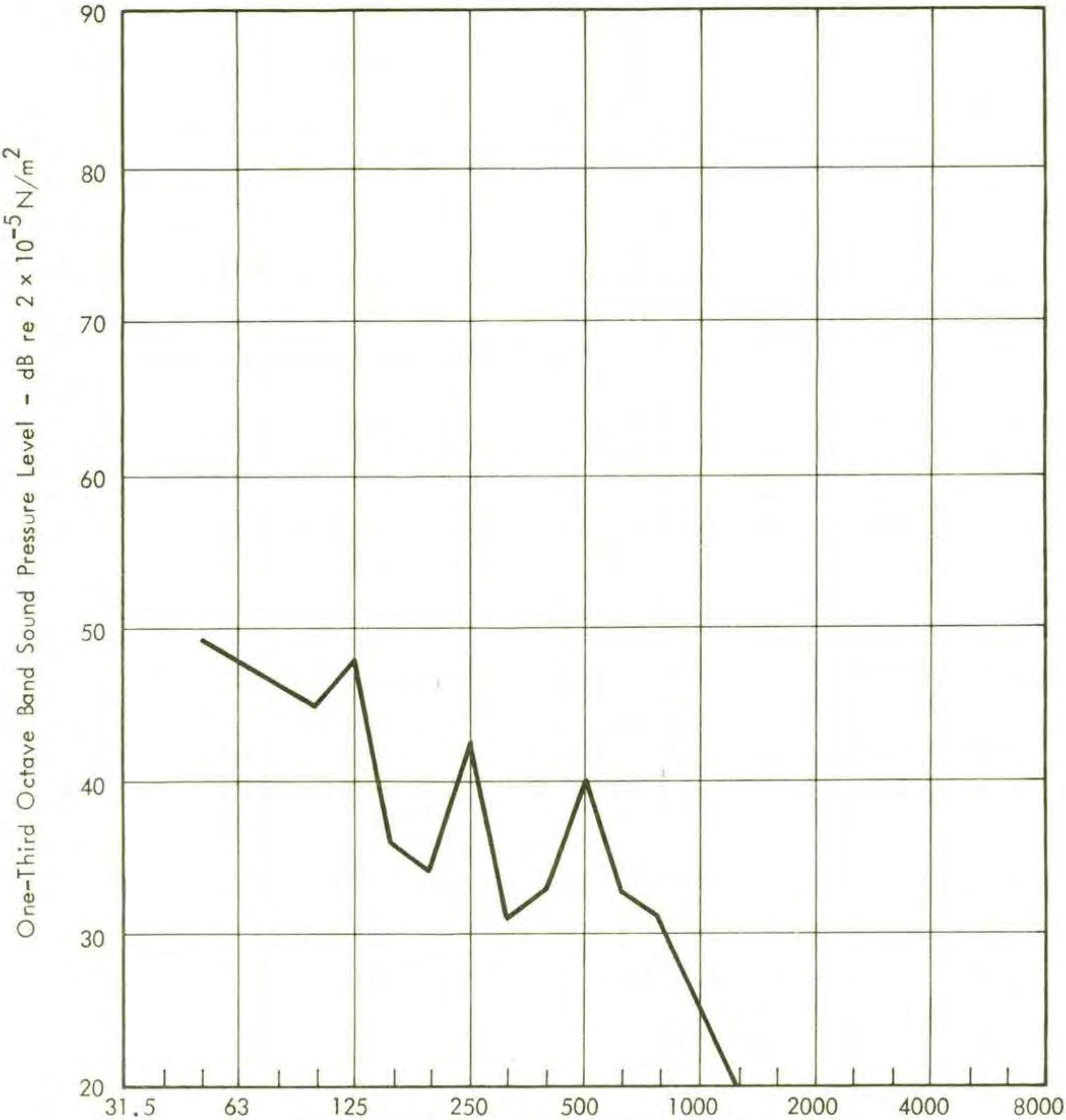


FIGURE A17.5 - WALNUT CITY SUBSTATION - MICROSAMPLE (L_{10}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS

BOLT BERANEK AND NEWMAN INC

CONSULTING · DEVELOPMENT · RESEARCH

Report No. 3172
Job No. 10908

MCLOUGHLIN SUBSTATION NOISE STUDY

BPA Contract No. 14-03-6020N

Roger J. Sawley

Colin G. Gordon

Michael A. Porter

April 1976

Submitted to:

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Submitted by:

Bolt Beranek and Newman Inc.
21120 Vanowen Street
Canoga Park, California 91303

TABLE OF CONTENTS

MCLOUGHLIN SUBSTATION NOISE STUDY

1. INTRODUCTION

There are approximately 300 substations in The Bonneville Power Administration (BPA) System in the states of Oregon and Washington. The BPA is concerned that the sound levels emanating from these substations be in compliance with the noise control regulations and, towards this end, has retained Bolt Beranek and Newman Inc. (BBN) to undertake an acoustical engineering study of 34 of these substations. This report describes the results of the study at the McLoughlin Substation, Oregon City, Oregon.

In this report, a general description is first presented of the substation and the electrical equipment. The field noise survey is then described and the obtained noise level data, presented. These data are interpreted in terms of the Oregon noise ordinance and the extent of noise reduction required for compliance, defined. Noise control treatments sufficient to achieve compliance are then recommended. Finally, the impact on the acoustical environment about the substation of possible future BPA equipment expansion is assessed.

The findings of the study can be summarized as follows:

. The existing BPA transformer noise environment is in violation of the Oregon noise ordinance,

. The noise reduction requirement is controlled by that in the 125 Hz octave band where it is equal to 20 decibels. The source is the fundamental tone of the transformer noise at 120 Hz.

- The recommended noise control treatment entails the construction of a barrier wall system about each transformer with the wall being sealed to the top of the transformer tank in each case.

- The proposed future installation of a second 900 MVA transformer bank should be undertaken with noise control in mind. A number of alternatives are considered in the report which, in combination, could provide the predicted, required noise reduction. They include:

    - Purchase of a "quiet" unit
    - Below grade installation
    - Barriers
    - Enclosures

2. SITE DESCRIPTION

McLoughlin substation is located on property owned by the Portland General Electric Company, and is approximately 1-1/2 miles east of Oregon City, Clackamas County, Oregon. [redacted]

The general layout of the substation and of the equipment is presented in Figure 1. Additional information on the BPA transformers which are of concern in this study, is presented in Table 1.

The land along the south side of Maple Lane Road is presently used primarily for residential purposes, as is the land east of Waldow Road. North of the substation site, along the west side of Waldow Road are several one to two acre plots. Although currently vacant, the potential for residential development on these sites does exist.

The area surrounding the substation site is now zoned R-20 (approximately 2 units per acre). The lack of a public sewage system combined with the fairly poor soil conditions in combination provide the major retarding force for further residential development.

The land surrounding the substation site has been designated Suburban Residential in the Clackamas County General Plan. The land approximately one-half mile west of the substation has been designated Urban Residential by Clackamas County and current plans call for a public sewage system to be installed there in the near future. This Urban Residential region might be extended to the east encompassing or nearly encompassing the substation site at some future date. Such actions would substantially increase the pressure for residential development surrounding the existing site.

3. FIELD MEASUREMENTS

The field measurement program used three basic methods for data acquisition. These methods included direct reading of sound level meters in the field, direct tape recording of short term (10 to 60 seconds) samples at many locations around the substation boundaries and in the surrounding community as well as long term microsampled* data acquisition at three noise sensitive locations in the surrounding community.

The locations for the microsampled data acquisition are labelled A1, A2, and A3 on Figure 1. The time periods during which data were obtained are as follows:

Position	Start	Finish
A1	1530 Hrs, 3/5/76	1130 Hrs, 3/6/76
A2	1800 Hrs, 3/24/76	1000 Hrs, 3/25/76
A3	1830 Hrs, 3/24/76	1030 Hrs, 3/25/76

The 1/3 octave band statistical analyses obtained from the microsampled data for the hours 1800 hours to 0600 hours are included at the end of this report as Appendices A1 through A3.

As a means of assessing the sound radiation characteristics of the transformer bank, tape recorded samples of the sound levels were made at 27 points around the perimeter of the substation. Additionally, tape recorded samples were obtained at a number of locations in the surrounding community. Within the substation yard, direct sound level meter readings were recorded at

---

* Microsample refers to a temporal sampling technique of analogue data acquisition. The method records 1.5 seconds of data every 30 seconds of real time.

the 1/3 octave band center frequencies which most closely correspond to the first four harmonics (120 Hz - 480 Hz) of the transformers' tonal components. These levels were recorded both close in to the transformers (10 ft.) and at several other positions within the yard.

The weather during the measurement period was generally conducive to good acoustic measurements. On March 5, 1976, the temperature was approximately 50° F with a 3 mph wind out of the N.W.. The relative humidity on this date was 50% and the cloud cover was light. On March 24, 1976, the temperature was approximately 44° F with a 5-10 mph wind out of the S.W.. The relative humidity was 90% with overcast skies. Rain fell during the daytime measurements but conditions were dry during the night.

A schematic of the data acquistion system is shown in Figure 2.

4. ANALYSIS AND DISCUSSION OF RESULTS

Two main methods of noise analysis of the tape recorded data have been employed. First, the microsample data have been analyzed statistically in third octave bands of frequency and, additionally, third octave band and/or narrow band analyses have been made of the perimeter and community tape samples to determine the levels of the major transformer tonal noise components. Second, in order to establish the ambient levels which would exist in the vicinity of the substation with the substation entirely de-energized, notch filters have been used to remove the principal tonal components. Furthermore, at low frequencies allowance has been made where necessary for the presence of electromagnetic pick-up due to the proximity of high voltage power lines to the measurement point and also, for the presence of transformer cooling fan noise.

A schematic of the major data reduction equipment is shown in Figure 3.

The major results of the data analysis are presented in Figures 4 to 8 and in Appendices A1, A2, and A3. They are discussed in that which follows. With respect to the three microsample positions, those data obtained at Position A2 (see Figure 1) are used primarily in this analysis since this position appears to be representative of the areas most adversely affected by the substation noise.

4.1 A-Weighted Sound Levels

The Oregon Noise Control Regulations set, as their basic objective, a limit on the statistical A-weighted noise levels that can be generated by noise sources. Figure 4 shows the appropriate measured levels at Position A2, giving the A-weighted noise levels exceeded for 1%, 10%, and 50% of the time during each hour of the period from 1800 hours on one day to 0600 hours on the next. For comparison, the figure also shows the appropriate Regulation Levels (Post 1977 10 p.m. to 7 a.m.).

4.2 Octave Band Levels

When the statistical A-weighted noise level limits are considered inadequate for the protection of the health, safety or welfare of the public, further restrictions are imposed on the noise levels permitted. It seems certain that in the case of the substations, the Oregon Regulations covering octave bands and audible discrete tones will also apply. In this regard, Figure 5 shows the substation octave band levels at the ten percent statistical level measured at Position A2 between the hours of 0300 to 0400. This figure also shows the "reconstructed" ambient levels and the appropriate Oregon Regulation Levels (10 p.m. to 7 a.m.). The very dominant influence of the 120 Hz fundamental transformer tone is clearly seen.

4.3 One-Third Octave Band Levels

In order to set a limit on the extent to which pure tones may intrude into the environment, the Oregon Regulations set limits on the extent to which any third octave band level may "stand" above the immediately adjacent band noise levels -- all at the ten percent statistical level. The measured third octave band levels of substation noise at Position A2 are given in Figure 6, for the period 0300 to 0400 hours.

4.4 Tonal Character and Directivity Characteristics

In interpreting the measured data and in making judgments about the confidence with which we can consider the Position A2 data, it is useful to consider the general characteristics of the noise that was measured at McLoughlin.

Figure 7 shows a typical narrow band spectrum at a position on the substation perimeter close to the [redacted] The analysis shows the strong tonal nature of the transformer noise radiation and the predominance of the 120 Hz fundamental component.

During the various measurement visits it was observed that the tonal levels could vary substantially as one made relatively small changes in spatial position. This effect, which is especially pronounced at positions close to the transformer bank, arises because of the strongly "coherent" character of the individual noise sources comprising the transformer bank. At positions within the surrounding communities, variations in the tonal level of 5 dB could be observed over distances of 50 ft. or so.

In order to examine this effect and at the same time to make judgments as to the directivity characteristics of the transformer a polar diagram was created based on the major, measured data at the 120 Hz and 240 Hz tonal frequencies. The data sources included the substation perimeter samples, the community samples obtained during the survey and some data obtained by the Portland General Electric Company (PGE). All data were normalized to a distance from the center of the [redacted], of 500 ft., using inverse square law.

The results for the 120 Hz analysis are shown in Figure 8. It is seen that the agreement between the various sources of data is good. In general the data scatter is about ±4 dB with respect to the mean noise level over any segment. The data also show that the transformer bank has a distinct directivity pattern which favours radiation to the southeast and to the southwest.

Our best estimates of the directivity "tendency" for both the 120 Hz and 240 Hz components are demonstrated by the plots in Figure 9.

Spot measurements of 81 dB at 120 Hz have been obtained at certain very localized positions to the southwest of the substation. These levels would lie within the ± 4 dB scatter observed in Figure 7. It is our belief, however, that these "hot spots" are probably not spatially stable: that it is unlikely that any one property would consistently be exposed to such levels. On the occasion of one visit to the site the only 80 dB level was measured in the middle of the Maple Lane/Waldow Road junction.

With respect to the plots in Figure 9 the directivity pattern indicated symmetry and has thus been made symmetrical about the north-south axis of the bank. The asymetry about the east-west axis is almost certainly due to the fact that the fan cooled radiators do not extend to the southern end of the side of the tank in each case. These radiators apparently shield or load the tank wall to provide an effective 5 to 7 dB attenuation of the sound radiated to the north from the bank over that radiated to the south.

4.5 Transformer Near Field Measurements

Measurements were taken at a distance of about 10 feet from a line encompassing the tanks of the three single phase units. Seven measurement positions were used. The *maximum* level detected in the general vicinity of the prescribed measurement position was noted. This avoided the possibility of recording phase cancellation nodal points. Similar measurements were taken around the two PGE transformers. The results of these measurements are summarized in Table 2. This table also shows the predicted levels at 500 ft. distance assuming hemispherical radiation. In the case of the BPA transformer the predicted levels (71 dB at 120 Hz and 57 dB at 240 Hz) are in good agreement with the average levels derived from Figure 9 (72 dB at 120 Hz and 54 dB at 240 Hz).

It would appear that this technique could be used to estimate the extent of noise control that might ultimately be required of the PGE transformers -- although at this stage it is clearly the BPA 900 MVA bank which is dominating the far field environment.

The average A-weighted noise level derived from the 10 ft. measurements around the 900 MVA band is about 82 dBA. This is consistent with the 85 dBA MEMA level estimated on-site.

5. COMPLIANCE ANALYSIS

In those community areas of worst exposure to the McLoughlin substation, the problem with regard to the Oregon Noise Regulations can be summarized as follows:

1) The station is not in default on the basis of the nondegradation clause.

2) The station is in default of the dBA requirements to the extent of 2 dB at the 1% level, 6 dB at the 10% level and 10 dB at the 50% level.

3) The station is in default of the octave band requirements to the extent of 20 dB in the 125 Hz band, 7 dB in the 250 Hz band and 7 dB in the 500 Hz band.

4) The station is in default of the one-third octave band requirements (pure tone definition) to the extent of 2 dB at 125 Hz and 2 dB at 250 Hz.

The greatest noise control requirement is therefore set by (3) above and it is in compliance with the octave band regulations which forms the basis of our noise control discussions and recommendations.

6. CONSIDERATIONS OF NOISE CONTROL

There is a substantial need for noise control of the 900 MVA transformer bank at the McLaughlin substation if the Oregon Noise Control Regulations are to be met.

The closest properties, those to the southeast of the station (at the junction of Maple Lane and Waldow Road), lie at a distance of about 500 ft from the bank. Here the requirement is for 20 dB attenuation at 120 Hz. At those properties to the southwest the attenuation requirement lies in the range of 14 to 19 dB. This requirement drops to about 11 dB adjacent to the "roadway reservation" directly to the west of the station. The requirement is only 6 dB to the northwest, north, and northeast where substantial property development may occur in the future. Directly to the east of the station the requirement lies in the range of 10 to 15 dB.

The attenuation requirement of 20 dB (24 dB if the 4 dB "factor of safety" discussed in an earlier chapter is included), will not be met easily. Our thoughts on the potential candidate noise control treatments are as follows:

1) Transformer Panels. Various panel treatments which may be applied to the transformer, to reduce the radiated noise levels, are discussed in the literature. However it is unlikely that such treatments would achieve more than 5 to 10 dB attenuation and the engineering of such treatments would be difficult and expensive.

2) Free Standing Barriers. Free standing barriers sufficient to provide 20 to 25 dB of sound attenuation would have to be extremely long and high. Assuming an effective transformer/barrier separation of 10 ft and a source height in the range of 10 to 15 ft, calculation shows the need for a barrier height in the range of 40 to 45 ft. The engineering problems--both mechanical and electrical--which would result with such a structure would appear to rule out this approach.

3) Partial Enclosure. Partial enclosures would be limited in their performance by the radiation and diffraction of sound from those parts of the transformer which are not enclosed. As in the case of (1) above it would be difficult to engineer sound attenuations in excess of 5 to 10 dB at 120 Hz.

4) Total Enclosure. The most positive engineering solution for the present problem would be a total enclosure enveloping the roof of the transformer as well as the walls. The acoustical performance of such an enclosure would be limited only by the density of the wall (and roof) materials used, the efficiency of acoustically absorbent materials used internally, and the efficiency with which gaps and cracks in the structure are sealed. In engineering such an enclosure it would be necessary to relocate the fan cooled radiators outside the enclosure. It might well be necessary also to fit extension bushings to the lid of the transformer to maintain adequate clearance between the enclosure roof and the high voltage lines. Such a total enclosure could envelope all three transformers.

5) Wall Enclosure. As an alternative to the above approach, we have considered the possibility of a wall enclosure which would leave the transformer tank lid uncovered. Industrial experience with this sort of treatment suggests that attenuations in the range of 15 to 20 dB should be achievable, depending upon the extent to which radiation from the uncovered lid limits the final solution.

Of the above approaches to noise control, it is the last approach--the wall enclosure--which we favor as offering the most practical engineering solution to the McLoughlin noise problem. Design considerations and details are given in Chapter 7.

In addition to the above, other, nonengineering, methods of noise control have been considered and discussed with BPA. These include the following:

6) The possibility of relocating the 900 MVA transformer bank at Ostrander. The cost of relocation would be substantial but we understand that the added line losses would probably be acceptable. For other reasons however, we understand that this solution is unlikely to be acceptable to BPA.

7) The replacement of the present unit with a larger 1600 MVA unit (to take care of future expansion). The unit would be purchased as a unit designed to have a noise level substantially quieter than the standard NEMA rating (92 dBA) for the particular size. In this regard, our measurements indicate that the present unit lies some 5 dBA below its NEMA rating of 90 dB. Some account will also have to be taken of the increased surface area of the larger units--As a rough guess this would imply a debit of some 2 dBA for a 1600 MVA bank. The total solution would require a

NEMA purchase specification in the range from 63 to 68 dBA, i.e. about 27 dBA below standard. The possibility could also be considered of locating the transformer below grade level (as is presently being done for the [redacted]). A below-grade installation is likely to provide about 10 dBA of shielding. The purchase specification could then be relaxed to about 17 dBA below NEMA.

We understand that manufacturers at present are able to engineer up to 15 dBA reduction (below NEMA) by internal modifications to their transformers. Further noise reductions would then generally involve external treatments--most likely some form of partial or full enclosure. Based on an additional cost of about 1-1/2% of the delivery cost per decibel reduction, the additional cost of a [redacted] quieted to 17 dBA below NEMA would be about $0.9 million. The additional cost involved in preparing the below-grade site and the other indirect costs involved in such a change from the present proposed expansion plan, are not known at this time.

8) The acquisition of sufficient land by BPA to provide an additional buffer zone around the substation would appear to be impractical in the present situation--especially to the southeast and east of the station.

9) Other possibilities such as requesting exemption from the noise regulations or requesting a zoning variance for those areas around the substation which are presently undeveloped, would seem to be undesirable or impractical at this time.

7. RECOMMENDATIONS

We recommend that BPA install a full wall enclosure of the type discussed in Chapter 6, Item (5) above. Details of the enclosure concept are shown in Figures 10 through 13. In order to limit the extent of tank lid radiation we recommend that (as shown) the enclosure wall be extended above the lid flange seal to provide some shielding. We are of the opinion that such an enclosure should provide attenuation in the range from 15 to 20 dB at a frequency of 120 Hz.

As a short term partial solution, BPA might consider the possibility of erecting a temporary full-height C-shaped barrier encompassing the east, west and south sides of the bank. Such a barrier should provide on the order of 10 dB reduction.

7.1 Materials

Two possibilities as regard materials for the enclosure are considered in Figure 12. The addresses of the relevant suppliers are given in Appendix B. Many other material possibilities exist and the final selection may well be determined by BPA's own engineering requirements. One such alternative would be "Noise Lock" panels (10 lbs/sq. ft.) by Industrial Acoustics Company. In general the design wall weight will lie in the range of 6 to 10 lbs/sq. ft., in order to achieve the desired transmission loss.

7.2 Lid Radiation

In the event that lid radiation proves a limit to the amount of noise reduction achievable, it may be possible to apply a secondary noise control treatment directly to the roof surface to achieve some further attenuation. Such a treatment could consist of a two inch thick layer of glass fiber covered with a layer of roofing lead weighing about 3 lbs./sq. ft..

7.3 Enclosure Absorption

Details of the sound absorption treatments to limit reverberation within the enclosure are given in Figure 12.

7.4 Access and Clearances

The design is shown with a clearance between the transformer wall and enclosure of about 2.5 ft. (this being equal to about 1/4 wavelength at 120 Hz). Clearance dimensions of 1/2 wavelength should be avoided if possible. In the event that BPA wishes or requires more adequate access and working space within the enclosure, we would recommend that clearances of the order of seven feet be sought (3/4 wavelength). Doors can also be provided in the structure.

7.5 Vibration Isolation

It will be important to ensure that the transformer vibration is not transmitted mechanically to the enclosure structure. For this reason it is recommended that either the transformer or the enclosure be mounted on ribbed or waffled neoprene pads. (It may be that the transformer is already so mounted.) Direct mechanical contact between the transformer and the enclosure should be strictly avoided. Any pipe penetrations should be soft -- i.e., clearance holes stuffed with fiberglass or equivalent and sealed with non-hardening mastic (or equivalent). The seal between the enclosure "roof" and the lid flange should be soft. A suggested arrangement is shown in Figure 12.

7.6 Cooler Relocation

Of necessity, the fan forced cooler banks must be relocated. In the event that a minimum (2.5 ft.) clearance is acceptable between the transformer tank and the enclosure wall, it may be possible simply to extend the cooler pipework and retain them in their present general locations on the east and west side of the transformers. In the event that larger clearances are required, it will probably be necessary to relocate the coolers elsewhere -- probably to the north and/or south sides of the transformer bank. A possible orientation is illustrated in Figure 13. Location to the north would provide some limited shielding of the fans from those communities to the southeast. However, such a location may cause problems with respect to the secondary racks. Location to the south might therefore be more acceptable.

The cooler banks may re-radiate transformer noise because of their direct mechanical coupling to the transformers (via the oil and pipe wall). We recommend that flexible couplings be inserted into the extended pipework connections to the coolers. We understand that the Pennsylvania Transformer Company has used neoprene couplings successfully in some transformer installations. Orientation of the cooling banks so that they are shielded from the sensitive southeast area by the transformer enclosures should further help minimize the re-radiation problem.

7.7 Costs

We have had conversation with Sound Fighter Systems who produce the Schoeller Noise Protection Wall (under license) in the U.S.A.. On the basis of their information for complete installation costs on transformer projects which they have handled recently, we estimate that the wall and footing costs (125 mph wind requirement) for the recommended wall structures would be about $40,000 per transformer.* Including access doors, lid seal, etc., the estimated installed cost approaches $55,000 per unit in the case of the Schoeller construction and $60,000 in the case of proprietary metal panels. To these costs would be added the cost of relocating the cooler banks, modifying the secondary rack, making adjustments to maintain electrical clearances and installing flexible pads and connections.

We understand that BPA has very exacting seismic requirements for substation structures. However the proposed structure should be relatively light-in-weight(6 to 10 lbs./sq. ft.) if the coolers are separately supported. The additional costs that would result from this latter requirement have not been estimated.

---

* The basic cost barrier and installation cost would be somewhat higher, say $45,000 per unit, in the case of proprietary panels (such as IAC Noise Lock).

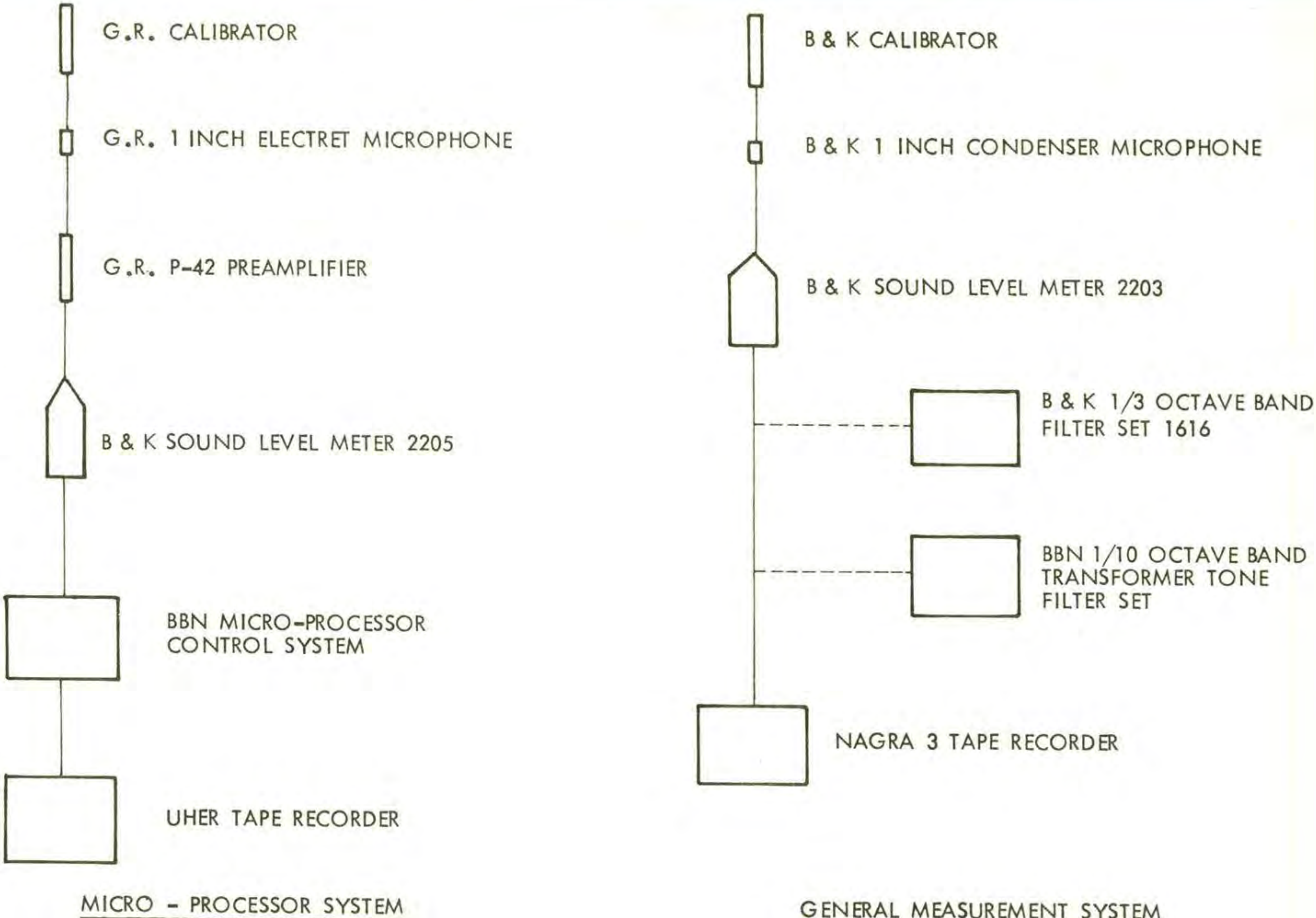


FIGURE 2. NOISE LEVEL DATA ACQUISITION SYSTEMS

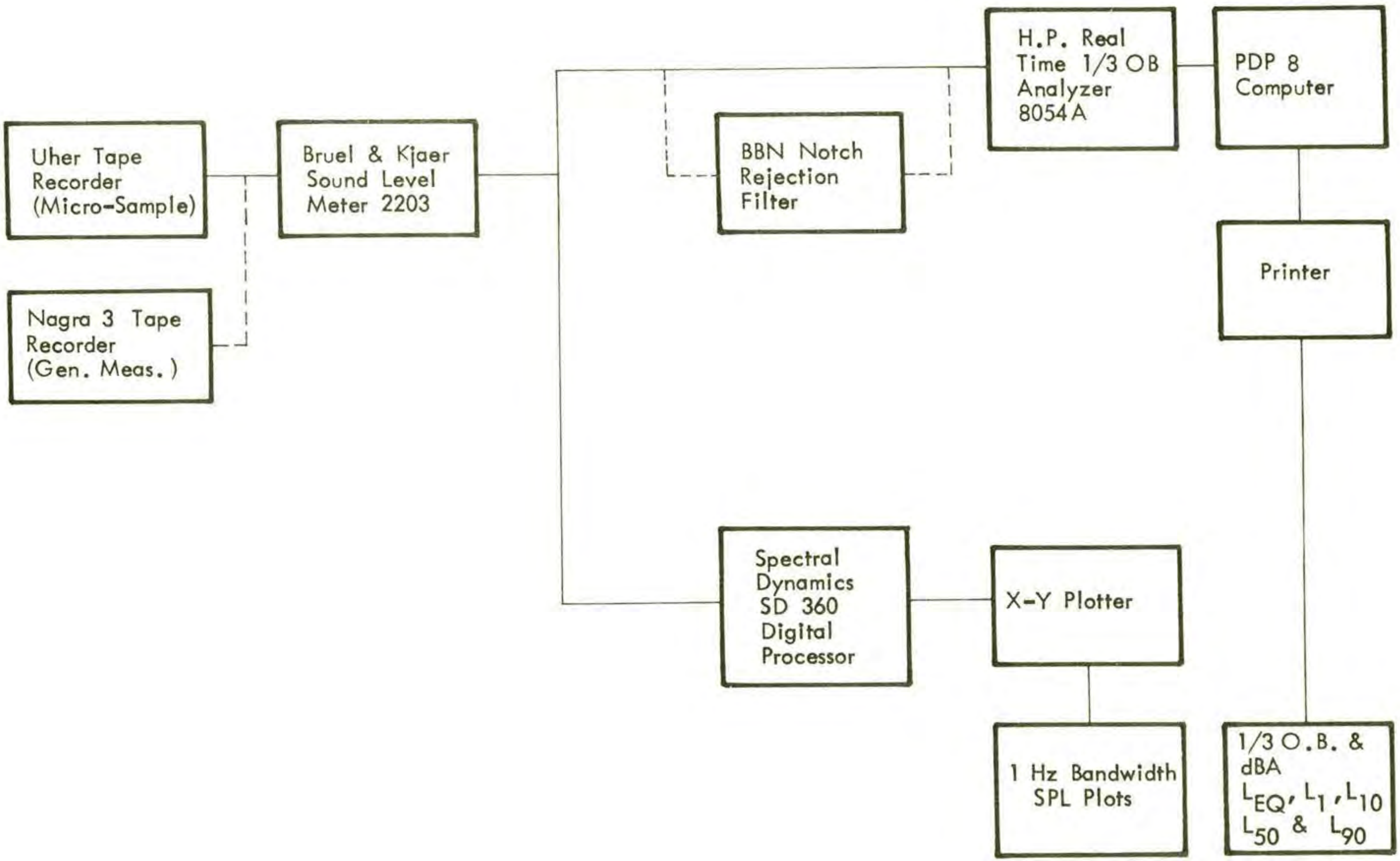


FIGURE 3. DATA REDUCTION SYSTEMS

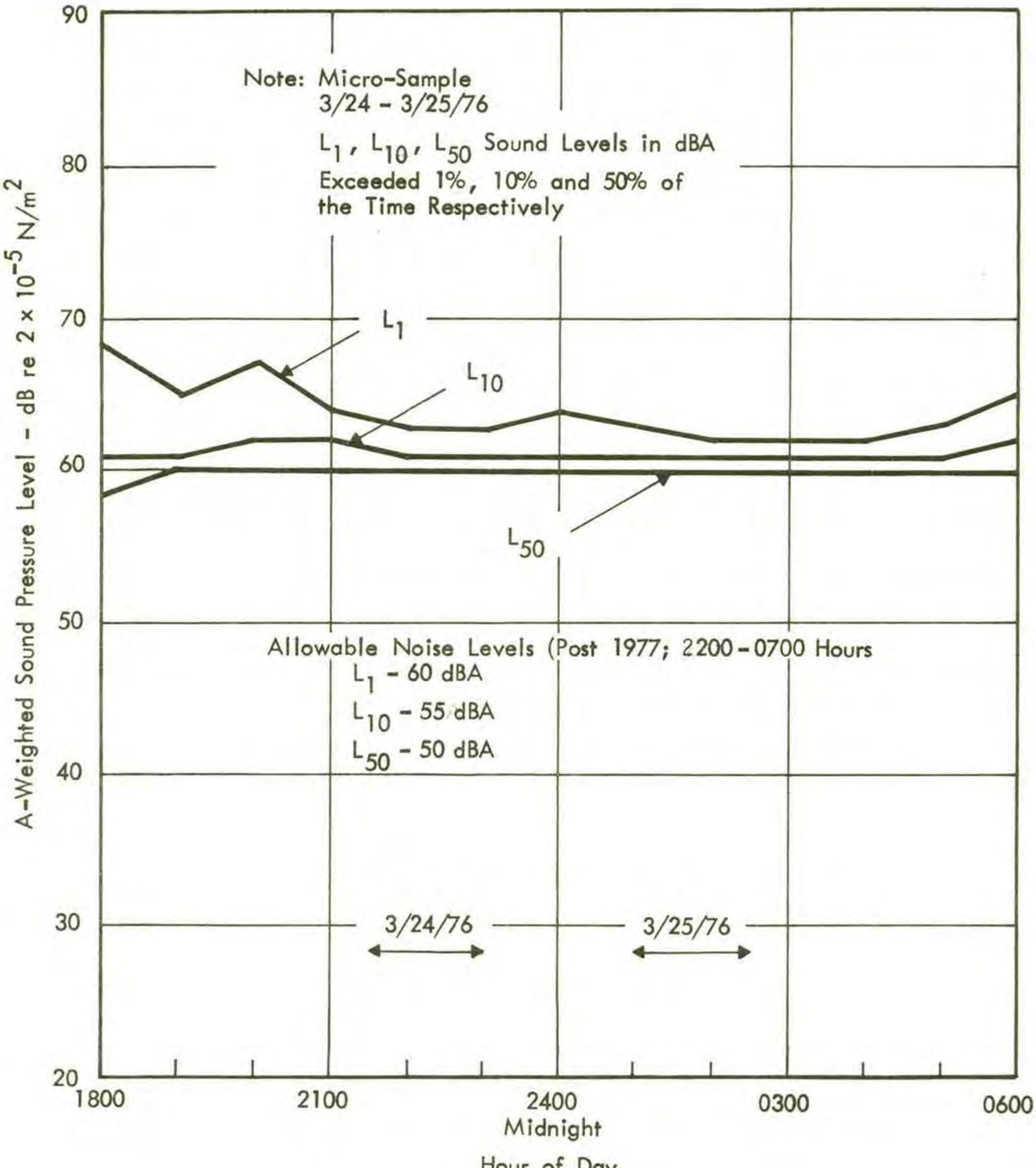


FIGURE 4. STATISTICAL LEVELS AT McLOUGHLIN SUBSTATION AS A FUNCTION OF TIME OF DAY. MEASUREMENT POSITION A-2

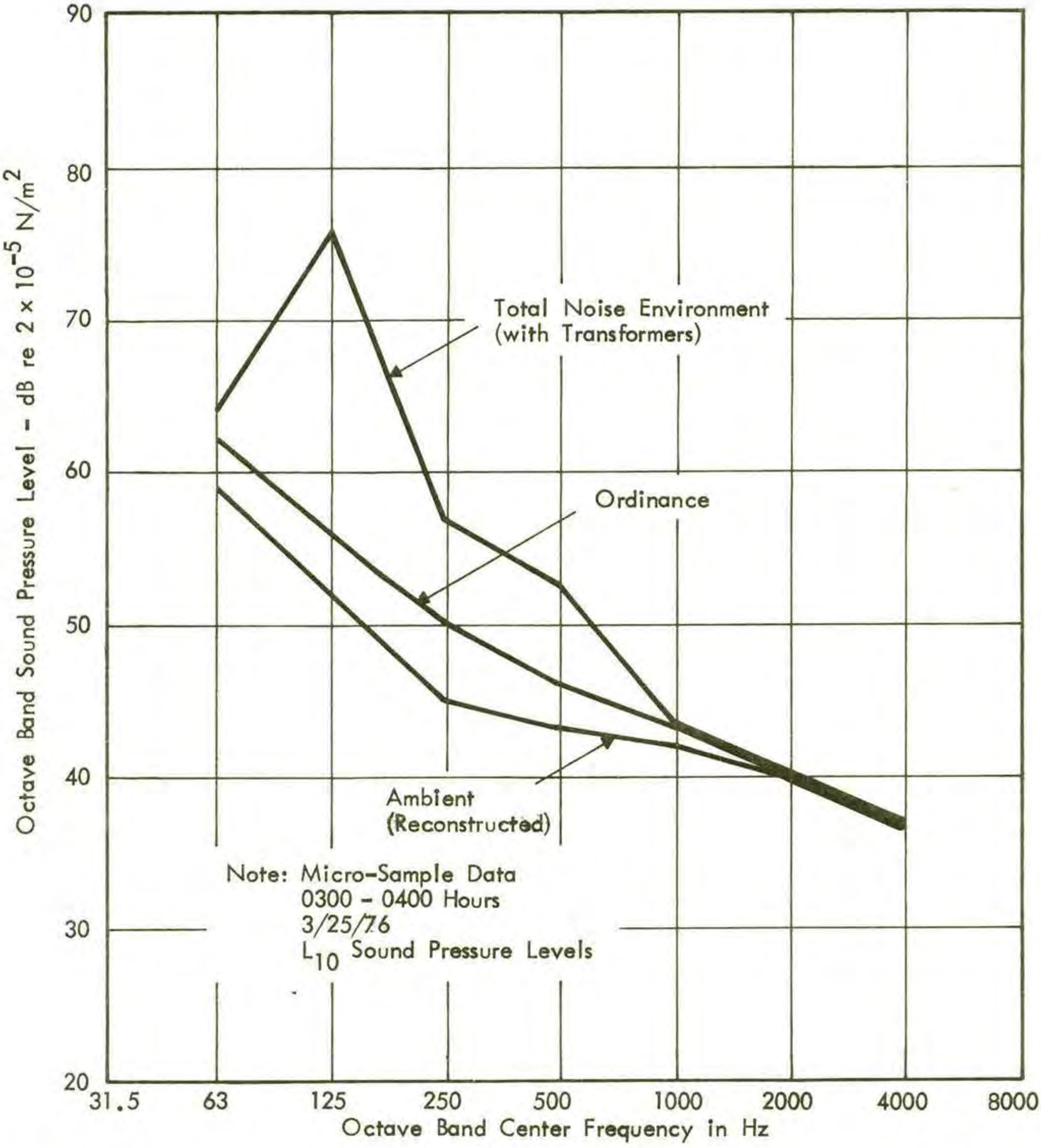


FIGURE 5. COMPARISON OF TRANSFORMER NOISE AT McLOUGHLIN SUBSTATION WITH NOISE ORDINANCE. MEASUREMENT POSITION A-2

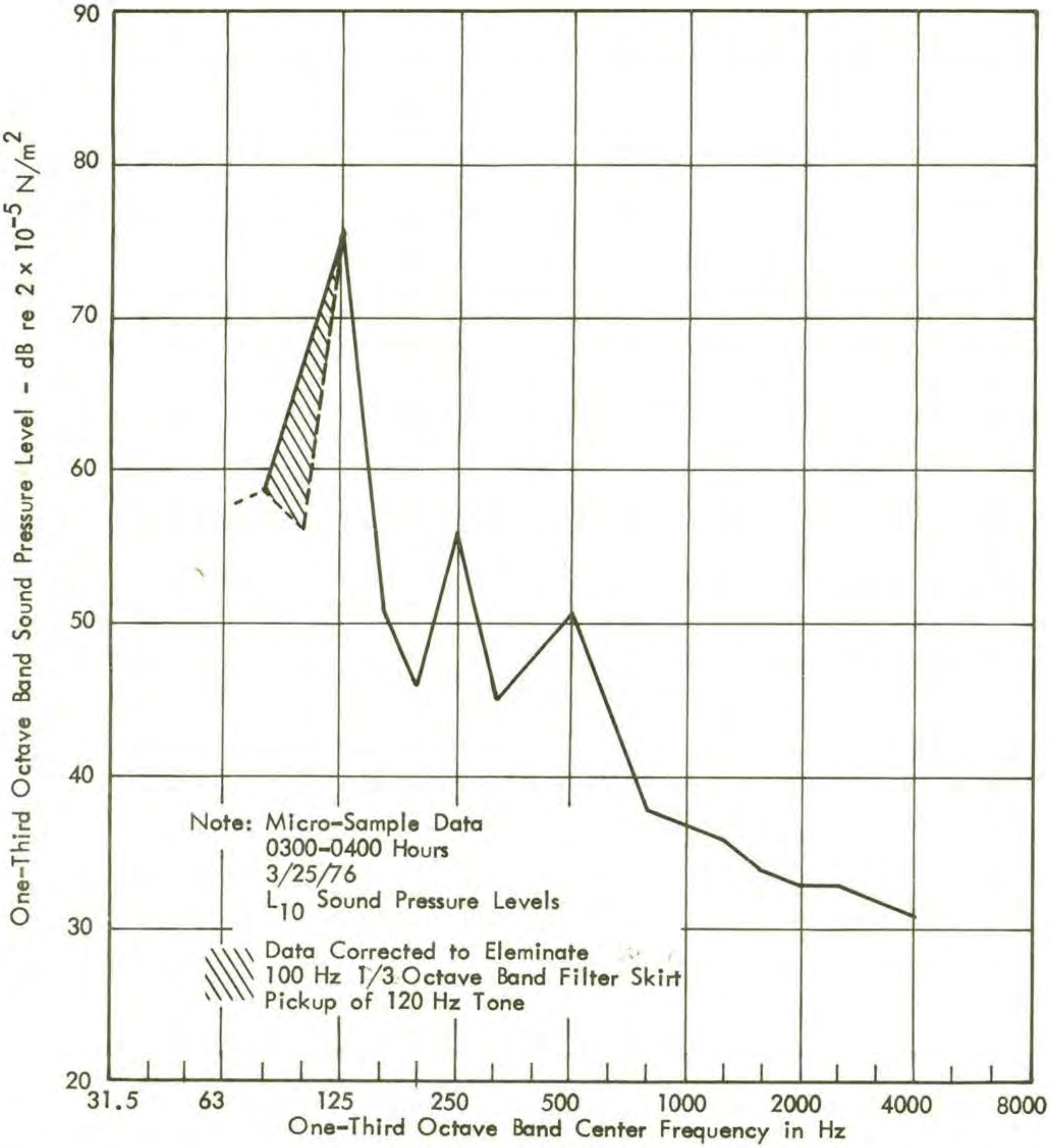


FIGURE 6. TRANSFORMER NOISE AT McLOUGHLIN SUBSTATION. MEASUREMENT POSITION A-2

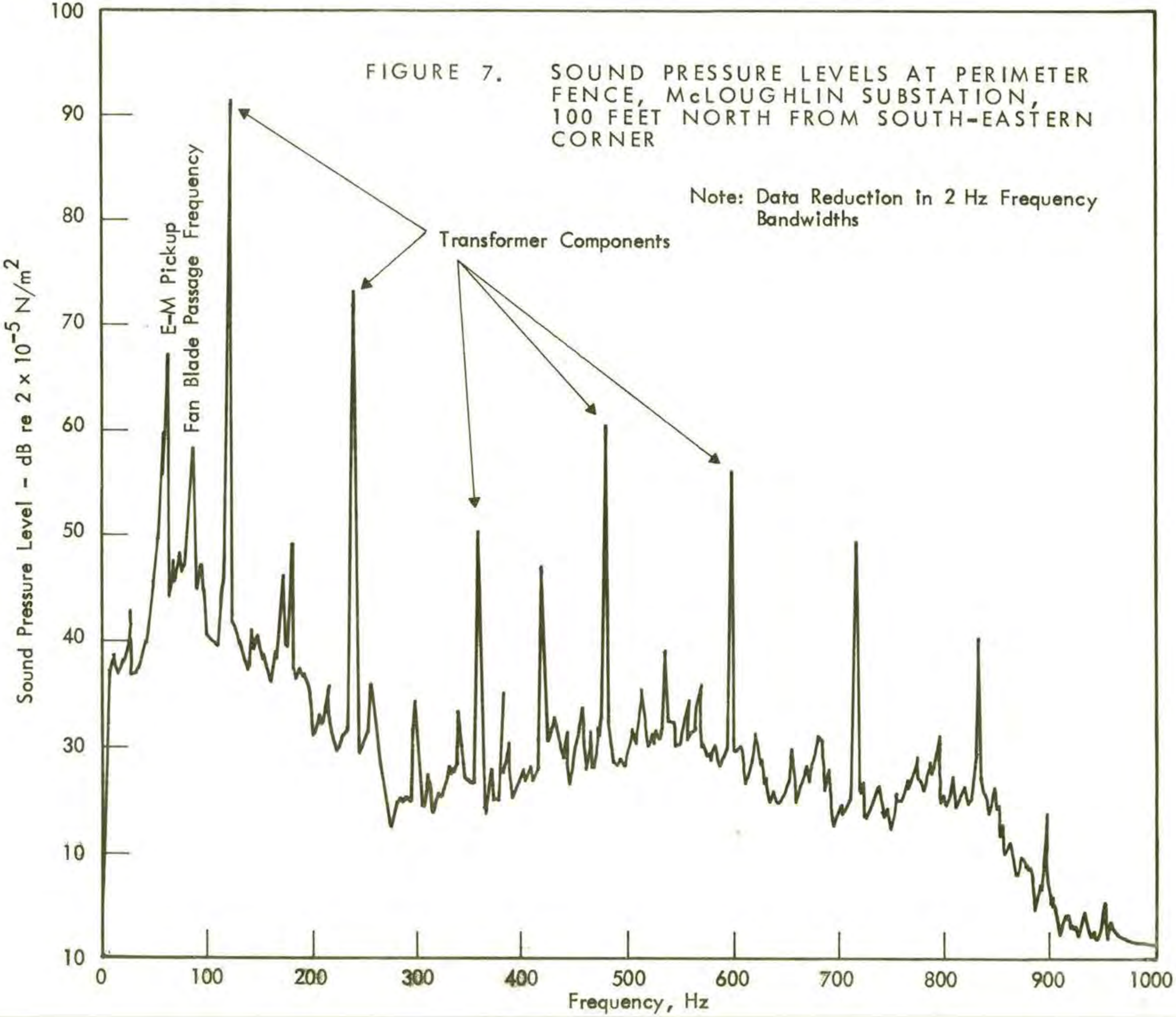
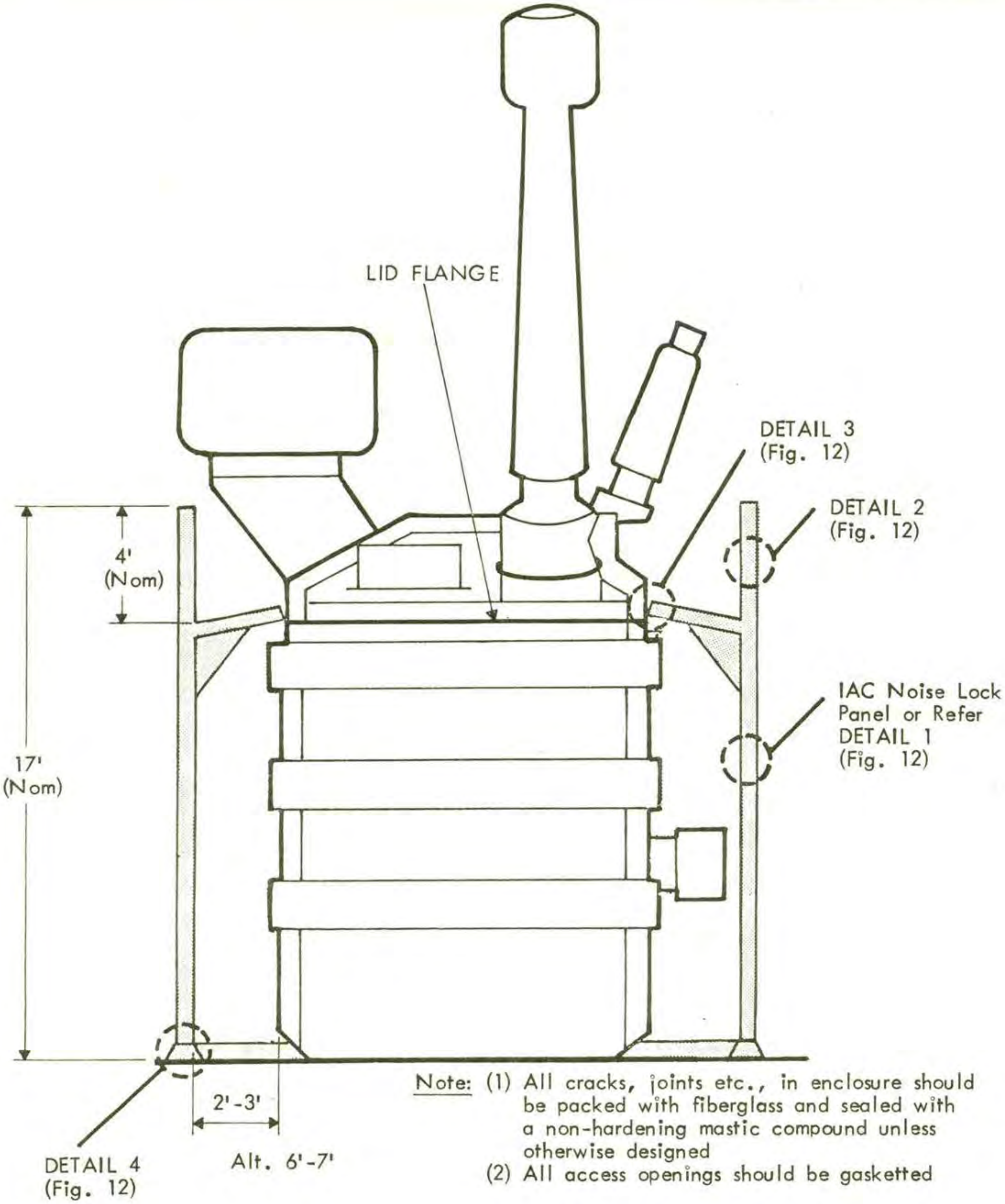


FIGURE 7. SOUND PRESSURE LEVELS AT PERIMETER FENCE, McLOUGHLIN SUBSTATION, 100 FEET NORTH FROM SOUTH-EASTERN CORNER
Note: Data Reduction in 2 Hz Frequency Bandwidths
Transformer Components
E-M Pickup
Fan Blade Passage Frequency
Sound Pressure Level - dB re 2 x 10^-5 N/m^2
Frequency, Hz
0
100
200
300
400
500
600
700
800
900
1000
10
20
30
40
50
60
70
80
90
100



Note: (1) All cracks, joints etc., in enclosure should be packed with fiberglass and sealed with a non-hardening mastic compound unless otherwise designed
(2) All access openings should be gasketted

FIGURE 10. SECTIONAL VIEW OF PROPOSED CONCEPT FOR TRANSFORMER ENCLOSURE

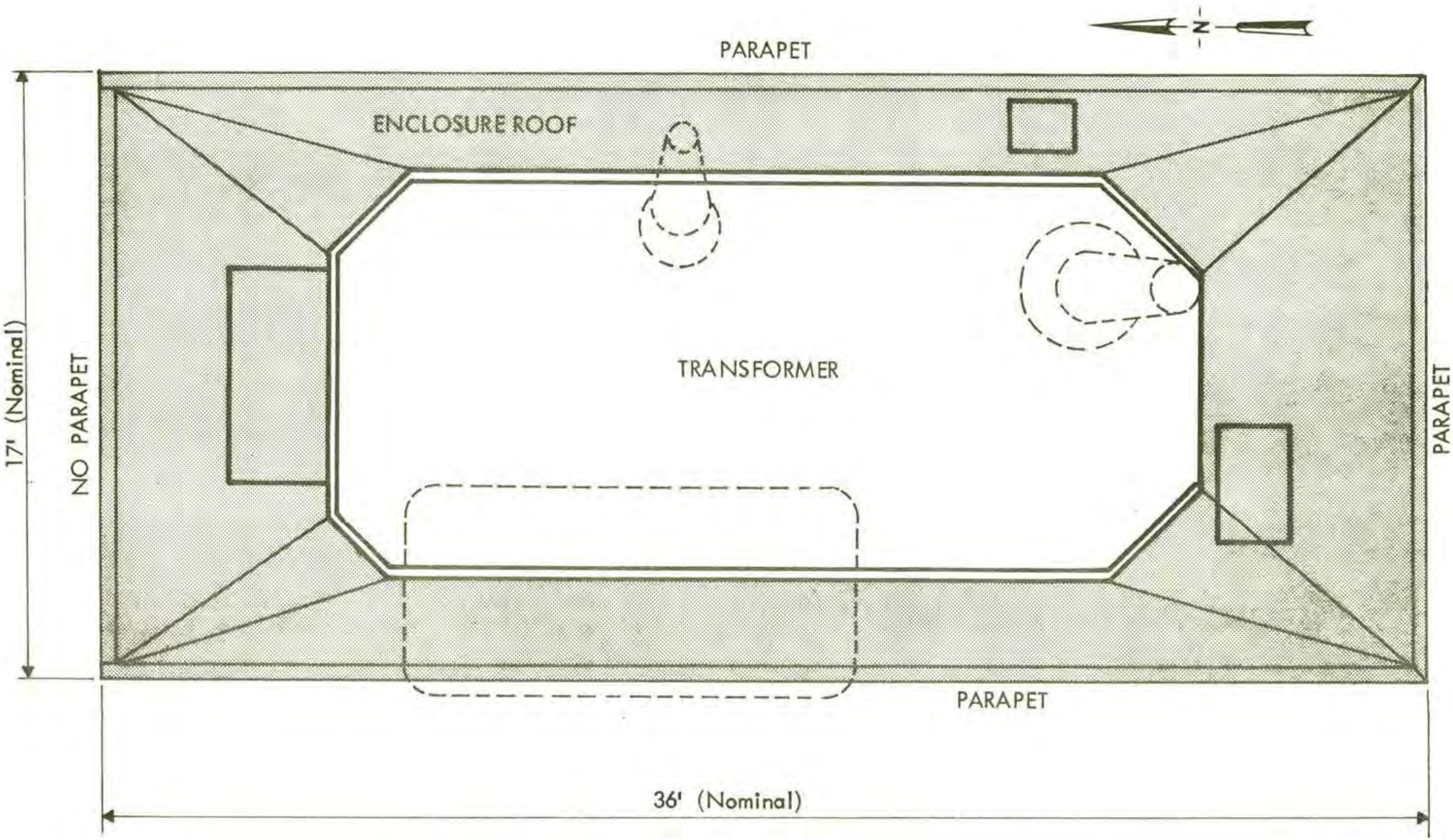


FIGURE 11. TOP VIEW OF PROPOSED CONCEPT FOR TRANSFORMER ENCLOSURE

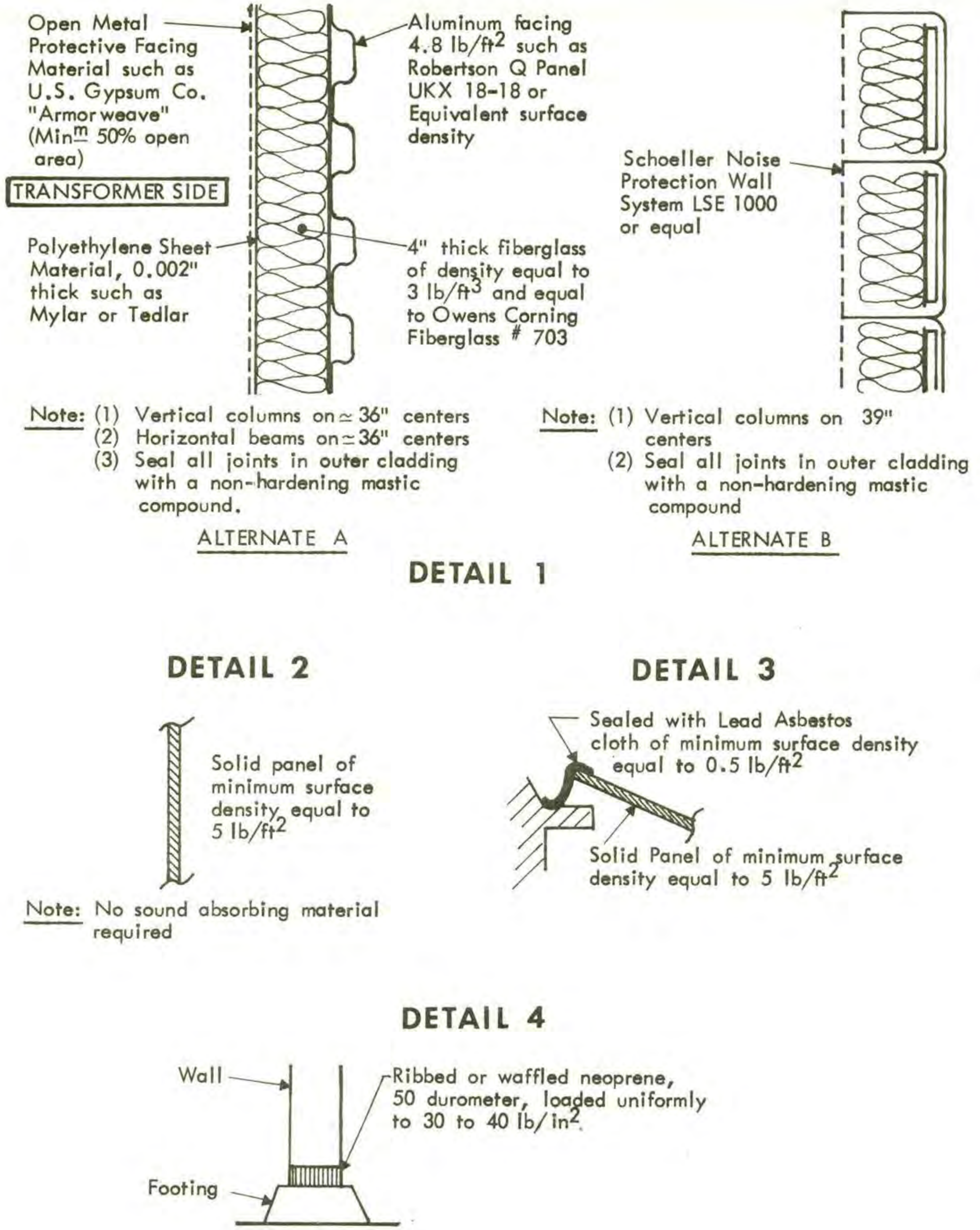


FIGURE 12. TRANSFORMER ENCLOSURE DETAILS

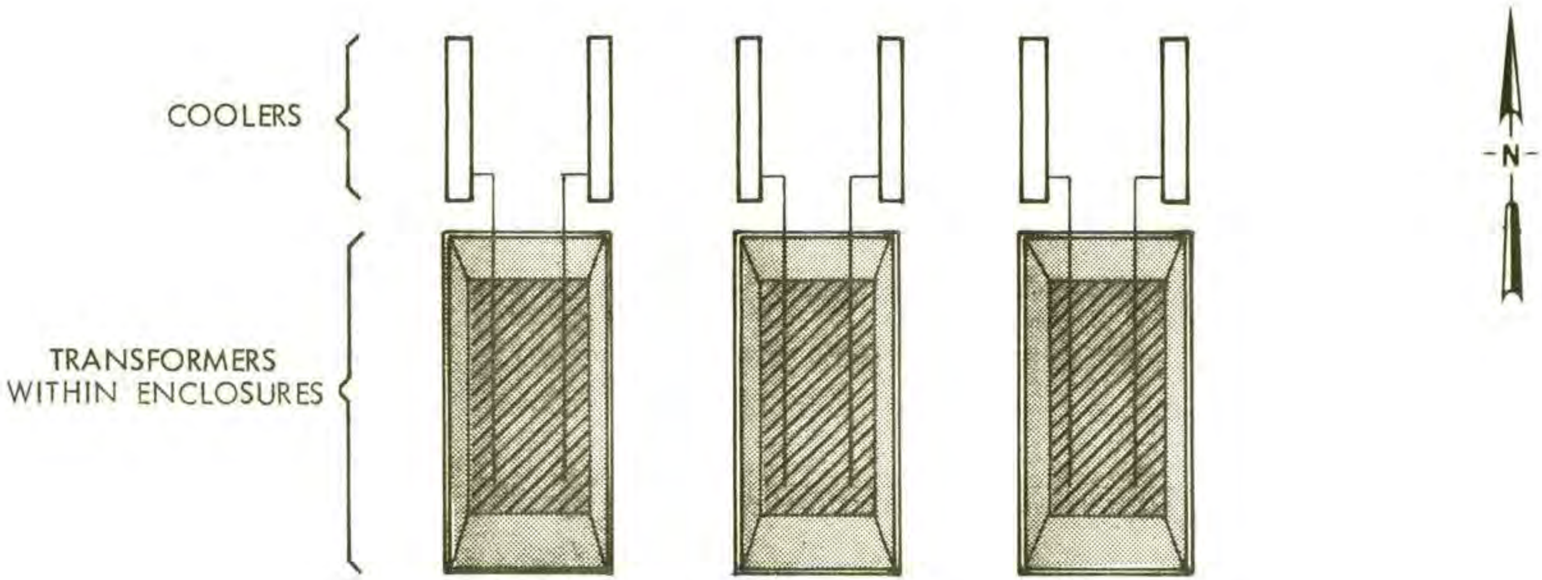


FIGURE 13. PROPOSED LAYOUT OF TRANSFORMER INSTALLATION AFTER INSTALLATION OF NOISE CONTROL TREATMENTS

APPENDIX A-1

MICRO-SAMPLE NOISE DATA

RESIDENCE LOCATED ON THE EAST
SIDE OF WALDOW ROAD, APPROXIMATELY
100 FEET NORTH FROM THE WALDOW
ROAD, MAPLE LANE ROAD JUNCTION

MC LAUGHLIN #2, 3-5-76, 18:00-19:00, 109091+
SAMPLE SIZE = 872

FREQ	LEQ	L1	L10	L50	L90
50	62	68	64	61	57
63	64	74	65	61	58
80	64	76	65	58	54
100	67	74	69	66	65
125	75	76	75	75	73
160	55	66	58	50	47
200	53	65	56	45	42
250	56	67	57	54	52
315	47	62	49	40	35
400	49	56	51	48	44
500	51	56	53	50	46
630	46	50	48	45	44
800	45	52	46	45	43
1000	41	53	42	39	36
1250	40	53	40	36	34
1600	37	49	37	33	31
2000	33	45	34	30	27
2500	32	42	34	30	26
3150	27	36	29	26	19
4000	20	31	22	17	*****
5000	11	23	15	*****	*****
DA	76	82	77	76	74
DBA	60	66	61	60	58

MC LAUGHLIN #2, 3-5-76, 19:00-20:00, 109091+
SAMPLE SIZE = 871

FREQ	LEQ	L1	L10	L50	L90
50	61	68	64	60	56
63	61	68	63	59	55
80	60	70	63	56	52
100	63	69	66	63	60
125	71	74	74	71	68
160	54	65	55	46	43
200	52	63	50	45	42
250	58	64	59	57	54
315	49	62	49	45	41
400	50	58	52	49	46
500	54	58	57	54	48
630	46	51	47	45	43
800	45	48	47	44	41
1000	39	46	41	38	36
1250	38	46	40	36	34
1600	35	42	37	33	31
2000	32	39	34	30	27
2500	32	39	34	31	27
3150	28	33	30	26	21
4000	21	31	22	18	*****
5000	13	27	15	*****	*****
DA	73	78	75	72	70
DBA	59	64	61	58	55

MC LAUGHLIN #2, 3-5-76, 20:00-21:00, 109091+
SAMPLE SIZE = 872

FREQ	LEQ	L1	L10	L50	L90
50	61	67	64	60	56
63	62	67	64	60	55
80	61	75	61	55	51
100	64	76	63	60	58
125	68	72	70	68	66
160	55	66	54	44	42
200	53	65	48	42	38
250	52	59	57	49	40
315	46	51	49	44	41
400	50	54	53	49	46
500	53	58	56	52	48
630	47	52	49	47	45
800	45	49	47	45	42
1000	41	48	43	39	36
1250	39	48	41	36	34
1600	36	45	39	34	31
2000	33	40	35	32	28
2500	32	40	34	31	27
3150	28	35	31	27	21
4000	21	30	24	19	*****
5000	13	24	16	*****	*****
OA	72	80	73	70	67
DBA	57	64	59	56	53

MC LAUGHLIN #2, 3-5-76, 21:00-22:00, 109091+
SAMPLE SIZE = 872

FREQ	LEQ	L1	L10	L50	L90
50	61	66	64	60	55
63	59	64	62	58	54
80	56	65	57	54	51
100	60	67	62	59	57
125	68	72	70	67	65
160	53	65	49	43	41
200	45	55	46	42	39
250	54	58	56	54	49
315	46	52	48	45	43
400	49	53	51	49	47
500	53	57	55	53	49
630	45	50	47	44	41
800	43	49	46	41	37
1000	38	44	40	37	35
1250	37	42	39	36	34
1600	34	40	36	33	31
2000	31	38	33	30	27
2500	32	38	34	31	27
3150	28	34	31	27	21
4000	21	28	24	19	*****
5000	13	20	16	*****	*****
DA	70	76	72	69	67
DBA	56	61	58	55	53

MC LAUGHLIN #2, 3-5-76, 22:00-23:00, 109091+
SAMPLE SIZE = 866

FREQ	LEQ	L1	L10	L50	L90
50	61	69	64	60	55
63	61	68	62	58	54
80	63	71	59	54	50
100	61	74	60	54	50
125	64	72	67	60	56
160	50	62	47	42	39
200	46	58	44	40	*****
250	49	57	53	47	40
315	46	50	47	45	42
400	49	53	50	48	45
500	51	56	54	50	47
630	45	49	47	45	42
800	43	47	45	42	40
1000	39	47	41	38	36
1250	38	48	39	35	33
1600	36	47	36	33	31
2000	34	46	34	31	28
2500	33	41	34	31	27
3150	28	35	31	28	22
4000	22	31	25	21	*****
5000	16	24	17	14	*****
DA	69	79	71	65	61
DBA	54	62	56	52	49

MC LAUGHLIN #2, 3-5-76, 23:00-24:00, 109091+
SAMPLE SIZE = 866

FREQ	LEQ	L1	L10	L50	L90
50	62	69	65	60	55
63	60	68	63	58	54
80	56	66	58	54	51
100	55	64	57	53	49
125	60	69	62	58	51
160	54	66	49	42	39
200	45	59	45	40	*****
250	49	55	53	48	44
315	45	49	46	44	41
400	47	51	49	47	44
500	49	53	51	48	45
630	47	51	49	46	43
800	45	48	47	45	42
1000	40	45	43	39	37
1250	38	43	41	37	34
1600	35	41	37	34	32
2000	32	39	34	31	29
2500	33	39	35	32	28
3150	29	34	31	28	22
4000	22	29	25	21	*****
5000	15	23	17	14	*****
DA	67	75	69	65	60
DBA	53	60	55	52	49

MC LAUGHLIN #2, 3-6-76, 00:00-01:00, 109091+
SAMPLE SIZE = 871

FREQ	LEQ	L1	L10	L50	L90
50	61	67	64	60	55
63	59	65	62	58	54
80	55	63	57	53	50
100	55	60	58	54	51
125	62	67	64	61	57
160	46	58	46	42	40
200	41	51	44	40	*****
250	51	56	55	50	42
315	46	53	51	42	39
400	49	56	53	45	42
500	49	55	53	47	42
630	47	51	49	47	45
800	45	48	47	45	43
1000	40	44	42	39	37
1250	38	45	40	37	35
1600	36	43	38	35	32
2000	33	40	35	31	29
2500	33	39	35	32	28
3150	29	34	31	28	23
4000	22	29	25	22	14
5000	15	22	18	15	*****
OA	67	73	70	66	62
DBA	54	59	57	53	49

MC LAUGHLIN #2, 3-6-76, 01:00-02:00, 109091+
SAMPLE SIZE = 870

FREQ	LEQ	L1	L10	L50	L90
50	61	66	64	60	55
63	60	67	62	58	54
80	55	64	56	53	50
100	55	62	58	53	48
125	61	69	65	59	51
160	42	51	44	40	*****
200	41	49	43	40	37
250	50	55	53	50	45
315	43	46	45	42	39
400	46	49	48	46	43
500	47	51	50	47	43
630	47	51	50	46	43
800	44	48	46	44	42
1000	38	43	41	38	35
1250	36	43	39	35	33
1600	33	37	35	33	31
2000	31	35	33	31	28
2500	31	35	33	31	28
3150	28	32	30	28	22
4000	21	27	24	21	*****
5000	14	20	17	14	*****
DA	66	73	69	65	60
DBA	52	58	55	52	48

MC LAUGHLIN #2, 3-6-76, 02:00-03:00, 109091+
SAMPLE SIZE = 872

FREQ	LEQ	L1	L10	L50	L90
50	61	67	64	60	55
63	59	64	62	58	54
80	57	70	56	52	49
100	57	68	58	55	49
125	63	67	65	62	51
160	48	57	43	40	*****
200	47	52	40	*****	*****
250	48	52	50	45	40
315	41	47	44	39	37
400	44	50	47	42	40
500	45	51	49	44	40
630	46	50	49	45	42
800	43	46	44	43	40
1000	38	42	39	38	36
1250	35	41	37	35	33
1600	33	39	35	33	31
2000	31	36	33	31	28
2500	32	40	33	31	27
3150	28	35	30	27	22
4000	22	28	24	21	*****
5000	14	22	17	14	*****
DA	67	75	70	66	60
DBA	52	58	54	51	47

MC LAUGHLIN #2, 3-6-76, 03:00-04:00, 109091+
SAMPLE SIZE = 872

FREQ	LEQ	L1	L10	L50	L90
50	61	67	64	61	55
63	59	64	62	58	54
80	53	58	55	52	50
100	59	64	61	59	55
125	67	71	69	66	62
160	42	48	44	41	39
200	34	43	39	*****	*****
250	45	50	49	43	36
315	39	43	41	39	37
400	42	46	44	42	39
500	45	51	49	44	41
630	47	50	48	47	44
800	43	46	45	43	41
1000	38	42	39	37	35
1250	35	39	37	35	33
1600	33	37	34	32	31
2000	31	35	32	30	28
2500	31	34	33	31	27
3150	27	31	30	27	22
4000	21	26	24	21	*****
5000	14	19	17	14	*****
DA	69	74	72	68	64
DBA	53	58	56	53	50

MC LAUGHLIN #2, 3-6-76, 04:00-05:00, 109091+
SAMPLE SIZE = 871

FREQ	LEQ	L1	L10	L50	L90
50	61	67	65	60	55
63	59	65	62	58	53
80	55	65	56	53	50
100	61	66	63	61	58
125	69	72	71	69	65
160	51	63	46	43	41
200	46	52	40	37	*****
250	47	51	49	46	38
315	42	48	43	40	37
400	44	49	45	43	40
500	46	50	48	45	42
630	48	52	50	48	44
800	45	51	46	43	41
1000	41	49	41	37	35
1250	39	49	37	35	33
1600	36	46	35	33	31
2000	34	42	33	30	28
2500	33	41	33	31	27
3150	29	34	30	27	22
4000	24	33	25	22	14
5000	17	26	18	15	*****
DA	71	75	73	70	67
DBA	56	61	57	55	52

MC LAUGHLIN #2, 3-6-76, 05:00-06:00, 109091+
SAMPLE SIZE = 869

FREQ	LEQ	L1	L10	L50	L90
50	62	69	65	61	56
63	59	65	62	59	54
80	56	64	59	53	50
100	62	66	64	62	59
125	70	72	71	70	66
160	48	60	51	44	41
200	44	56	47	39	*****
250	49	57	52	47	41
315	43	51	46	41	36
400	44	47	46	44	40
500	44	48	45	43	41
630	45	48	47	45	43
800	43	50	45	42	40
1000	39	46	41	38	35
1250	37	44	38	34	32
1600	34	43	36	32	30
2000	33	41	34	31	28
2500	33	41	34	31	28
3150	28	34	29	27	21
4000	23	32	25	22	14
5000	17	26	19	15	*****
DA	72	76	73	71	68
DBA	56	60	57	55	52

MC LAUGHLIN #2, 3-6-76, 06:00-07:00, 109091+
SAMPLE SIZE = 871

FREQ	LEQ	L1	L10	L50	L90
50	61	67	64	60	55
63	59	64	62	58	53
80	54	59	56	53	50
100	63	66	64	63	60
125	70	73	72	70	67
160	45	52	47	44	42
200	41	52	43	40	37
250	46	53	50	45	38
315	41	47	43	41	38
400	45	48	47	45	43
500	45	50	47	45	42
630	46	48	47	45	44
800	42	45	43	42	40
1000	37	41	39	37	36
1250	34	39	35	34	32
1600	33	40	34	32	30
2000	33	43	33	30	28
2500	31	36	33	31	28
3150	27	32	29	27	22
4000	23	30	25	22	14
5000	15	22	18	14	*****
DA	72	75	74	72	69
DBA	56	59	57	56	53

APPENDIX A-2

MICRO-SAMPLE NOISE DATA

RESIDENCE LOCATED ON THE SOUTH SIDE OF MAPLE LANE ROAD NEAR THE JUNCTION WITH WALDOW ROAD, SOUTH EAST FROM THE SUBSTATION

MC LOUGHLIN #A-2, 3-24-76; 1800-1900; 109091(A)
SAMPLE SIZE = 886

FREQ	LEQ	L1	L10	L50	L90
50	60	69	64	*****	*****
63	66	71	68	65	63
80	60	71	62	58	*****
100	66	69	67	66	65
125	74	75	75	74	73
160	58	72	56	50	48
200	58	70	54	46	44
250	55	60	57	55	52
315	51	60	50	46	43
400	50	57	51	48	45
500	52	59	53	50	47
630	46	58	46	43	40
800	46	58	46	39	37
1000	45	57	46	38	36
1250	44	56	46	37	34
1600	43	56	44	35	33
2000	41	53	43	35	32
2500	39	51	41	35	31
3150	39	51	40	35	29
4000	39	51	40	34	*****
5000	42	54	43	37	*****
DA	76	80	77	75	74
DBA	61	68	61	59	58

MC :LOUGHLIN #A-2; 3-24-76; 19:00-20:00; 109091(A)
SAMPLE SIZE = 883

FREQ	LEQ	L1	L10	L50	L90
50	62	68	65	61	58
63	65	71	67	64	62
80	62	76	62	58	55
100	67	73	67	66	65
125	74	76	75	74	73
160	54	63	54	50	48
200	50	59	52	46	44
250	55	60	57	54	52
315	47	58	48	44	41
400	47	54	49	46	43
500	50	55	53	50	46
630	44	50	45	42	39
800	41	49	42	39	37
1000	40	51	42	38	36
1250	40	51	42	36	34
1600	38	49	40	34	33
2000	37	47	38	35	32
2500	36	46	37	35	31
3150	36	44	38	35	30
4000	36	43	38	35	28
5000	39	47	42	38	33
OA	76	81	77	75	74
DBA	60	65	61	60	58

MC LOUGHLIN #A-2; 3-24-76; 20:00-21:00; 109091(A)
SAMPLE SIZE = 887

FREQ	LEQ	L1	L10	L50	L90
50	60	70	65	*****	*****
63	66	75	67	64	62
80	61	71	63	58	*****
100	67	71	68	67	65
125	75	77	76	75	74
160	53	64	56	51	49
200	55	65	52	46	44
250	56	61	57	55	53
315	47	57	47	44	42
400	48	56	50	47	44
500	51	57	53	50	47
630	47	55	47	44	41
800	45	55	44	40	38
1000	44	54	43	38	36
1250	42	53	43	36	34
1600	41	51	43	34	32
2000	41	52	41	35	32
2500	40	51	39	35	32
3150	39	51	39	36	30
4000	39	51	39	36	28
5000	43	54	43	39	*****
DA	77	81	78	76	75
DBA	61	67	62	60	59

MC LOUGHLIN #A-2; 3-24-76; 21:00-22:00; 109091(A)
SAMPLE SIZE = 886

FREQ	LEQ	L1	L10	L50	L90
50	61	66	63	60	57
63	64	69	66	64	61
80	58	66	60	57	54
100	67	70	68	66	65
125	75	77	76	75	74
160	52	61	54	50	49
200	48	57	51	46	44
250	56	59	57	56	53
315	45	51	47	44	42
400	47	51	49	47	45
500	51	54	53	51	47
630	44	49	46	44	41
800	41	48	42	40	38
1000	40	49	41	38	36
1250	38	49	39	36	34
1600	37	46	37	34	33
2000	37	47	38	35	33
2500	37	46	38	36	32
3150	37	45	39	36	31
4000	37	43	40	36	29
5000	41	48	44	40	34
OA	76	79	78	76	75
DBA	61	64	62	60	59

MC LOUGHLIN #A-2; 3-24-76; 22:00-23:00; 109091(A)
SAMPLE SIZE = 886

FREQ	LEQ	L1	L10	L50	L90
50	62	67	64	61	58
63	64	69	66	64	62
80	59	70	61	57	54
100	66	70	67	66	65
125	75	77	76	75	74
160	51	57	53	50	48
200	47	54	49	45	44
250	56	59	58	56	54
315	44	51	46	44	41
400	47	50	49	47	44
500	51	55	53	51	47
630	43	48	45	43	40
800	39	45	41	38	36
1000	38	47	39	37	35
1250	37	47	38	35	33
1600	36	48	37	34	32
2000	36	47	37	34	32
2500	36	42	38	35	32
3150	36	41	39	36	31
4000	37	42	40	36	29
5000	41	47	45	40	34
DA	76	79	77	76	75
DBA	60	63	61	60	59

MC :LOUGHLIN #A-2; 3-24-76; 23:00-24:00; 109091(A)
SAMPLE SIZE = 881

FREQ	LEQ	L1	L10	L50	L90
50	62	69	64	61	58
63	65	70	67	64	62
80	58	64	61	57	54
100	66	70	67	66	65
125	75	77	76	75	74
160	53	61	53	50	48
200	48	55	49	45	43
250	56	61	58	55	53
315	44	49	46	43	40
400	46	51	48	46	43
500	50	54	53	50	45
630	42	46	44	41	38
800	39	44	40	37	35
1000	38	46	39	36	34
1250	36	46	37	34	33
1600	35	45	36	33	32
2000	36	43	37	34	32
2500	36	42	37	35	32
3150	36	40	38	36	31
4000	37	41	40	36	30
5000	41	46	45	40	34
DA	76	79	77	76	75
DBA	60	63	61	60	59

MC LOUGHLIN #A-2; 3-25-76; 00:00-01:00; 109091(A)

SAMPLE SIZE = 881

FREQ	LEQ	L1	L10	L50	L90
50	62	67	64	61	57
63	64	69	66	64	62
80	58	66	60	56	53
100	66	70	67	66	65
125	75	77	76	75	74
160	54	68	53	49	48
200	48	60	48	45	43
250	55	59	57	55	53
315	43	49	46	43	40
400	46	51	48	46	43
500	50	55	52	50	47
630	43	48	45	42	39
800	40	47	40	38	36
1000	39	49	39	37	35
1250	37	48	37	35	33
1600	37	48	36	34	32
2000	36	46	37	35	32
2500	36	43	38	35	32
3150	36	41	39	36	31
4000	37	41	40	36	29
5000	41	46	45	40	34
DA	76	79	77	76	75
DBA	60	64	61	60	59

MC LOUGHLIN #A-2; 3-25-76; 01:00-02:00; 109091(A)
SAMPLE SIZE = 888

FREQ	LEQ	L1	L10	L50	L90
50	61	66	63	60	57
63	64	67	66	64	62
80	56	61	59	55	53
100	66	70	67	66	65
125	75	77	76	75	74
160	50	56	52	49	48
200	45	51	47	44	42
250	55	58	57	55	53
315	43	48	45	42	39
400	45	50	48	45	42
500	50	55	52	50	47
630	43	48	45	43	40
800	37	41	39	37	35
1000	37	42	38	36	34
1250	35	42	36	35	33
1600	34	39	35	33	32
2000	35	39	37	35	32
2500	36	40	38	36	32
3150	36	40	39	36	31
4000	37	42	40	36	29
5000	42	47	45	40	34
OA	76	78	77	76	75
DBA	60	63	61	60	59

MC LOUGHLIN #A-2; 3-25-76; 02:00-03:00; 109091(A)
SAMPLE SIZE = 887

FREQ	LEQ	L1	L10	L50	L90
50	62	68	64	61	57
63	64	68	66	64	62
80	57	63	59	56	53
100	66	69	67	66	65
125	75	77	76	75	74
160	50	55	52	49	48
200	45	50	47	44	42
250	55	58	57	55	53
315	43	47	45	42	40
400	46	50	48	45	43
500	49	53	52	49	46
630	42	46	44	42	39
800	37	40	39	36	35
1000	36	39	37	35	34
1250	34	37	36	34	33
1600	33	36	35	33	31
2000	34	38	36	34	32
2500	35	39	38	35	32
3150	36	40	39	36	31
4000	37	42	40	36	29
5000	42	47	45	40	34
OA	76	78	77	76	75
DBA	60	62	61	60	59

MC LOUGHLIN #A-2; 3-25-76; 03:00-04:00; 109091(A)
SAMPLE SIZE = 888

FREQ	LEQ	L1	L10	L50	L90
50	61	66	64	60	57
63	64	68	66	64	62
80	56	62	59	55	52
100	66	69	67	66	65
125	75	77	76	75	74
160	50	55	52	49	48
200	44	50	46	44	42
250	55	58	57	55	52
315	43	48	45	43	40
400	46	50	48	46	43
500	49	53	51	49	45
630	42	46	45	42	39
800	37	41	39	37	35
1000	36	40	38	36	34
1250	35	38	36	35	33
1600	34	37	35	33	32
2000	35	38	37	35	32
2500	36	39	38	35	32
3150	36	40	39	36	31
4000	37	41	40	36	30
5000	42	47	45	40	34
DA	76	78	77	76	75
DBA	60	62	61	60	59

MC LOUGHLIN #A-2; 3-25-76; 04:00-05:00; 107091(A)
SAMPLE SIZE = 888

FREQ	LEQ	L1	L10	L50	L90
50	62	69	65	61	57
63	63	68	66	63	60
80	57	63	60	56	53
100	66	69	67	66	65
125	75	77	76	75	74
160	50	55	52	49	48
200	45	50	47	44	42
250	55	59	57	55	52
315	43	47	45	43	40
400	46	49	48	46	42
500	48	53	51	47	42
630	42	46	44	41	38
800	37	40	38	36	34
1000	36	39	37	35	34
1250	35	38	36	34	33
1600	34	37	36	34	32
2000	35	38	37	35	33
2500	36	39	38	36	32
3150	37	40	39	36	31
4000	38	42	41	37	30
5000	43	48	46	41	35
OA	76	79	77	76	75
DBA	60	62	61	60	59

MC LOUGHLIN #A-2; 3-25-76; 05:00-06:00; 109091(A)
SAMPLE SIZE = 885

FREQ	LEQ	L1	L10	L50	L90
50	61	67	64	60	56
63	62	67	64	61	58
80	59	66	60	57	54
100	67	70	67	66	65
125	75	77	76	75	74
160	53	58	52	50	48
200	51	53	48	45	43
250	54	57	56	54	52
315	44	53	45	43	41
400	46	50	47	45	43
500	48	53	51	47	44
630	43	49	45	42	40
800	39	49	40	38	36
1000	39	48	39	36	35
1250	38	47	38	35	34
1600	36	46	37	34	33
2000	36	45	38	35	33
2500	37	43	39	36	33
3150	37	43	40	37	32
4000	38	43	41	38	31
5000	43	48	46	42	35
DA	76	79	77	76	75
DBA	60	63	61	60	59

APPENDIX A-3

MICRO-SAMPLE NOISE DATA

FARM HOUSE LOCATED ON THE SOUTH
SIDE OF MAPLE LANE ROAD, DUE SOUTH OF THE
SOUTHWESTERN CORNER OF THE SUBSTATION

MC LOUGHLIN #A3; 3-24-76; 18:30-19:00; 109091(B)
SAMPLE SIZE = 458

FREQ	LEQ	L1	L10	L50	L90
50	55	64	58	54	*****
63	56	63	59	55	51
80	56	66	58	52	49
100	61	71	62	59	58
125	69	72	71	69	67
160	54	67	54	46	44
200	52	67	52	41	37
250	50	60	51	48	43
315	43	54	46	37	33
400	42	53	45	37	34
500	42	53	44	37	34
630	43	53	46	38	35
800	44	55	49	37	34
1000	44	54	49	36	33
1250	43	52	49	34	31
1600	42	52	47	33	29
2000	41	50	46	34	28
2500	39	49	43	32	28
3150	40	50	44	33	28
4000	40	51	44	31	27
5000	42	54	46	33	28
DA	71	77	72	70	68
DBA	57	65	60	54	52

MC LOUGHLIN #A3; 3-24-76; 19:00-20:00 109091(B)
SAMPLE SIZE = 928

FREQ	LEQ	L1	L10	L50	L90
50	55	62	58	54	*****
63	57	63	60	56	52
80	53	62	56	51	48
100	60	65	61	59	58
125	69	71	70	69	67
160	51	62	50	47	45
200	45	56	46	40	38
250	48	54	51	47	43
315	43	58	42	37	34
400	41	53	42	37	34
500	40	50	42	37	34
630	41	51	43	37	35
800	41	52	45	36	33
1000	41	53	45	34	32
1250	40	51	44	32	30
1600	39	52	43	31	28
2000	38	50	41	31	27
2500	36	48	39	29	25
3150	35	47	37	28	24
4000	33	45	34	25	21
5000	35	46	36	27	24
DA	70	74	72	70	68
DBA	55	63	57	54	52

MC LOUGHLIN #A3; 3-24,76; 20:00-21:00; 109091(B)
SAMPLE SIZE = 922

FREQ	LEQ	L1	L10	L50	L90
50	55	61	58	55	*****
63	58	69	60	56	52
80	58	72	58	52	48
100	61	70	62	59	58
125	69	73	70	69	67
160	55	69	52	46	44
200	49	64	48	40	37
250	50	59	52	48	43
315	43	55	44	37	34
400	42	52	44	38	34
500	40	50	43	38	35
630	41	52	43	38	35
800	42	54	44	36	33
1000	42	53	45	34	31
1250	40	52	44	32	29
1600	39	50	43	30	27
2000	37	48	41	30	26
2500	35	46	39	28	25
3150	34	45	38	27	24
4000	32	43	35	24	20
5000	35	48	35	26	23
DA	71	78	72	70	68
DBA	55	64	57	54	52

MC LOUGHLIN #A3; 3-24-76; 21:00-22:00; 109091(B)
SAMPLE SIZE = 930

FREQ	LEQ	L1	L10	L50	L90
50	55	60	58	55	*****
63	57	64	59	56	52
80	54	68	55	51	48
100	60	65	61	59	58
125	69	71	70	69	67
160	49	56	50	46	44
200	46	55	44	39	37
250	49	56	50	47	43
315	39	50	40	36	33
400	39	50	40	37	34
500	38	46	41	37	34
630	39	50	40	37	35
800	39	51	39	36	33
1000	38	51	37	34	32
1250	37	50	36	32	29
1600	36	49	34	30	27
2000	35	46	38	29	26
2500	32	44	34	28	25
3150	31	44	31	27	24
4000	29	40	27	23	20
5000	30	43	30	25	23
DA	70	74	71	70	68
DBA	54	61	55	54	52

MC LOUGHLIN #A3; 3-24-76; 22:00-23:00; 109091(B)
SAMPLE SIZE = 930

FREQ	LEQ	L1	L10	L50	L90
50	55	62	59	54	*****
63	56	63	59	55	51
80	51	58	54	50	47
100	60	64	61	59	58
125	69	71	70	69	68
160	47	55	48	45	44
200	41	50	43	38	36
250	48	52	50	47	44
315	37	47	39	34	31
400	37	44	39	35	32
500	38	45	41	38	34
630	38	47	40	36	33
800	37	48	37	34	32
1000	36	48	37	32	30
1250	35	48	35	30	28
1600	34	47	34	28	26
2000	33	44	37	28	25
2500	31	41	33	27	24
3150	29	40	30	26	23
4000	26	37	27	22	19
5000	29	41	29	25	23
DA	70	73	71	70	68
DBA	54	59	55	54	52

MC LOUGHLIN #A3; 3-24-76; 23:00-24:00; 109091(B)
SAMPLE SIZE = 930

FREQ	LEQ	L1	L10	L50	L90
50	55	62	59	54	*****
63	56	62	59	55	51
80	60	68	54	50	47
100	60	64	61	59	58
125	69	71	70	69	67
160	51	64	49	45	44
200	45	56	43	39	36
250	49	57	51	48	44
315	40	54	38	34	31
400	39	52	39	35	32
500	39	50	41	37	33
630	39	51	39	36	33
800	38	51	37	34	32
1000	37	51	36	32	30
1250	36	51	34	30	28
1600	35	49	33	28	26
2000	34	46	34	27	24
2500	31	43	31	26	23
3150	32	46	29	25	22
4000	28	42	25	22	19
5000	31	46	29	25	23
DA	70	75	71	70	68
DBA	54	62	55	54	52

MC LOUGHLIN #A3; 3:25-76; 00:00-01:00; 109091(B)
SAMPLE SIZE = 928

FREQ	LEQ	L1	L10	L50	L90
50	55	61	58	54	*****
63	55	61	58	54	50
80	50	61	52	49	46
100	59	64	61	59	58
125	69	71	70	69	67
160	47	57	48	45	43
200	42	54	42	37	35
250	47	53	50	47	42
315	35	44	37	33	31
400	36	43	38	34	31
500	37	46	39	35	32
630	37	48	38	35	32
800	37	49	36	33	31
1000	36	49	35	32	29
1250	34	47	34	30	27
1600	33	47	32	28	25
2000	32	44	34	28	25
2500	30	41	32	27	24
3150	28	39	29	25	22
4000	25	37	25	21	19
5000	28	39	28	25	23
DA	70	73	71	69	68
DBA	54	59	55	53	52

MC LOUGHLIN #A3; 3-25-76; 01:00-02:00; 109091(B)
SAMPLE SIZE = 928

FREQ	LEQ	L1	L10	L50	L90
50	55	62	59	54	*****
63	55	61	59	54	50
80	49	56	51	48	*****
100	59	63	60	59	58
125	68	70	69	68	67
160	45	50	46	44	42
200	37	44	40	37	*****
250	47	51	50	46	42
315	33	38	36	32	*****
400	34	39	37	34	31
500	35	40	38	34	31
630	34	39	36	34	31
800	33	38	35	33	31
1000	32	36	34	32	29
1250	30	35	32	30	28
1600	29	34	31	29	26
2000	30	37	32	29	25
2500	30	36	33	29	25
3150	26	31	29	26	22
4000	22	26	24	21	19
5000	25	31	27	25	23
DA	69	72	71	69	68
DBA	53	56	54	53	52

MC LOUGHLIN #A3; 3-25-76; 02:00-03:00; 109091(B)
SAMPLE SIZE = 928

FREQ	LEQ	L1	L10	L50	L90
50	55	61	58	54	*****
63	55	60	58	54	*****
80	48	53	50	48	*****
100	59	62	60	59	57
125	68	70	69	68	66
160	44	49	46	43	42
200	37	43	39	36	*****
250	47	51	49	46	42
315	33	38	35	32	*****
400	34	40	37	33	30
500	36	41	38	35	32
630	34	38	36	34	31
800	33	37	35	33	30
1000	32	36	34	32	29
1250	30	34	32	30	27
1600	29	32	31	28	26
2000	28	37	30	27	24
2500	27	32	29	26	23
3150	26	30	28	25	22
4000	21	26	23	21	18
5000	25	30	27	25	23
OA	69	72	70	69	67
DBA	53	55	54	53	51

MC LOUGHLIN #A3; 3-25-76; 03:00-04:00; 109091(B)
SAMPLE SIZE = 927

FREQ	LEQ	L1	L10	L50	L90
50	55	61	59	54	*****
63	55	60	58	54	50
80	48	53	50	48	*****
100	59	62	60	59	57
125	68	70	69	68	66
160	44	50	46	43	42
200	37	43	39	36	*****
250	46	51	49	45	41
315	33	38	36	33	30
400	35	40	37	34	31
500	36	40	38	35	32
630	35	38	36	34	32
800	33	37	35	32	30
1000	31	35	33	31	29
1250	29	34	31	29	27
1600	28	33	30	27	25
2000	27	35	29	26	24
2500	26	31	29	26	23
3150	25	30	28	24	21
4000	21	25	23	20	18
5000	25	30	27	24	22
DA	69	72	70	69	67
DBA	53	55	54	53	51

MC LOUGHLIN #A3; 3-25-76; 04:00-05:00; 109091(B)
SAMPLE SIZE = 930

FREQ	LEQ	L1	L10	L50	L90
50	56	61	59	55	*****
63	55	60	58	54	50
80	47	53	50	47	*****
100	59	61	60	59	57
125	68	69	69	68	66
160	44	49	45	43	42
200	37	43	40	37	*****
250	46	51	49	46	41
315	33	37	35	33	*****
400	34	38	36	33	30
500	35	39	37	34	31
630	34	38	36	34	32
800	33	36	34	32	30
1000	31	35	33	31	29
1250	30	33	31	29	27
1600	28	32	30	28	26
2000	28	37	30	27	25
2500	27	33	30	26	23
3150	25	29	27	24	22
4000	22	26	24	21	19
5000	26	31	28	26	24
DA	69	71	70	69	66
DBA	52	55	54	52	50

MC LOUGHLIN #A3; 3-25-76; 05:00-06:00; 109091(B)
SAMPLE SIZE = 931

FREQ	LEQ	L1	L10	L50	L90
50	55	61	59	55	*****
63	55	62	58	54	50
80	51	61	54	50	47
100	59	62	60	59	57
125	68	70	69	68	66
160	48	59	47	44	42
200	41	51	42	38	35
250	47	51	49	46	41
315	38	46	38	35	32
400	36	43	38	35	32
500	37	44	40	36	33
630	37	46	38	35	33
800	37	48	37	34	31
1000	36	48	36	32	30
1250	35	48	34	30	28
1600	34	48	33	28	26
2000	32	44	33	27	25
2500	31	42	32	27	24
3150	29	39	30	25	23
4000	26	36	27	23	20
5000	29	38	30	27	24
DA	69	72	70	69	67
DBA	53	59	54	53	51

APPENDIX B.

MATERIALS

MATERIALS

1. Enclosure Cladding.

(a) Composite Wall, Alternate A.

- Outer Surface.

  Impervious material with a minimum sound transmission loss in the 125 Hz, one-third octave band equal to 25 decibels.

  Material equal to panel type UKX18-18 obtainable from:

  H. H. Robertson Company

  Pittsburgh, Pennsylvania

- Sound Absorbing Material

  Sound absorbing material with a minimum sound absorption coefficient in the 125 Hz octave band equal to 0.85 as measured with the material placed against a solid backing.

  Material equal to 4 inch thick, Type 403, 3 lb /ft.^{3} fiber glass obtainable from:

  Owens-Corning Fiberglas Corporation,

  Toledo, Ohio

- Polyethylene Sheet Material

  Material, 0.002 inch thick equal to Mylar film obtainable from:

  Dupont Film Department

  Los Angeles, California.

- Open Metal Protective Facing Material.

  Minimum 50% open area equal to "Armorweave" obtainable from:

  U. S. Gypsum Co.,

  Los Angeles, California.

(b) Composite Wall, Alternate B

Wall system equal to Schoeller Noise Protection Wall System LSE 1000 obtainable from:

Sound Fighter Systems,

Shreveport,Louisiana

(c) Commercially Available Standard Wall Panels

Wall system equal to 1AC Noise Lock Wall system obtainable from:

Industrial Acoustics Company

Santa Monica, California.

2. Lead Vinyl Cloth

Minimum surface density of 0.5 $lb/ft.^2$ and equal to cloth obtainable from:

Soundcoat

Brooklyn, New York

3. Neoprene Pad

Ribbed or waffled neoprene pad equal to that obtainable from:

Mason Industries Inc.

Hollis, New York.

BOLT BERANEK AND NEWMAN INC

CONSULTING · DEVELOPMENT · RESEARCH

Report No. 3296
Job No. 10908

BONNEVILLE POWER ADMINISTRATION
SUBSTATION NOISE STUDY

APPENDIX C
WASHINGTON SUBSTATIONS – ANALYSIS AND RECOMMENDATIONS

BPA Contract No. 14-03-6020N

Roger J. Sawley

Colin G. Gordon

Michael A. Porter

30 September 1976

Submitted to:

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97108

Submitted by:

Bolt Beranek and Newman Inc.
21120 Vanowen Street
Canoga Park, California 91303

APPENDIX C – WASHINGTON SUBSTATIONS

FOREWORD

This appendix contains detailed information on the results of our evaluation of the sixteen (16) substations of concern in the State of Washington. The substations are listed alphabetically in accordance with the table of contents presented over.

In each case, a description is first presented of the substation and its environs. Next information is presented on the results of the field noise survey. The obtained noise level data are then analyzed and assessed for compliance with the State Code and with those stricter standards which we feel might be introduced in the foreseeable future. Finally, recommendations are provided, where necessary, to bring the substation into compliance.

TABLE OF CONTENTS

C1. ABERDEEN SUBSTATION

Aberdeen Substation lies on the north side of Aberdeen City in Grays Harbor County, Washington. It is located immediately to the west of Fry Creek, three blocks north of U.S. 101 (Simpson Avenue). The Grays Harbor Public Utilities Department (PUD) occupies a substantial parcel of land to the south and southwest of the substation. This land is occupied by maintenance and service buildings and by a small 69 kV switching station, containing two small transformers. The layout of the BPA substation and its environs is shown in Fig. C1.1.

Aberdeen Substation currently has [redacted]. [redacted] At the present time, [redacted]

The substation lies at the south end of a small gully, formed around Fry Creek. To the west the land rises abruptly to reach a height some 100 ft above the substation level. This land lies under the ownership of BPA and has been used by them in the past as a sand quarry.

The gully continues to the north and northwest of the substation, served by the access road as shown in Fig. C1.1. There are no residential properties in this area. The use of the land directly to the north of the substation is limited by easements associated with the 230 kV transmission lines.

A number of residential properties are located on Ash Street and on Hemlock Street, to the east of Fry Creek. The land here lies at substation datum level. Further to the east the land rises to form the eastern side of the gully. A hospital is located on top of the rise, overlooking the substation at a distance of about 1000 ft from it.

To the south the land is occupied by the PUD facilities mentioned earlier.

The extent of BPA land ownership around the substation is shown in Fig. C1.1.

We understand from our conversations with the substation staff that plans have already been made known to BPA concerning residential developments in the gully to the northwest of the substation. The exact location of such development is not known and we were unable to gain access into the area. However, it seems unlikely that this development would lie closer than 750 ft from the northwest corner of the substation fence. The future could also bring further residential developments at the north end of Ash Street; these would be at distances that are further from the substation than present residential property.

FIELD SURVEY

The field survey was carried out over the period 31st of March to the 1st of April 1976. We were accompanied within the substation by Mr. Les Williams (Operator).

During the course of the measurements the weather was sunny with scattered clouds. On the morning of the 1st of April the wind was from the east at 6 mph. The temperature was 51°F and the relative humidity was 68%.

• Close-In Measurements

The results of the measurements at 10 ft from each of the transformers are given in Table C1.2.

• Perimeter Measurements

The measured tonal levels on the substation perimeter at 120 Hz and 240 Hz are shown in Fig. C1.2. The data on the northern perimeter, normalized on the basis of the Bank 4/5 cluster as the source center, give 500 ft levels of 60 dB at 120 Hz and 59 dB at 240 Hz. Similarly, data on the southern perimeter normalize to 500 ft levels of 61 dB at 120 Hz and 52 dB at 240 Hz, using the Bank 2/3 cluster as the source center.

These levels agree well with the normalizations given in Table C1.2.

• Community Measurements

Data samples were obtained at the following positions:

a) At the junction of Hemlock Street and Ash Street,

b) At the north end of Ash Street,

c) At the access gate to the north gully, and

d) In the sand quarry to the west of the substation.

The results of data analyses are summarized in Table C1.3. The 500 ft normalizations are based on the distance to the center of the substation.

A typical narrow band spectrum at Position (a) is shown in Fig. C1.3

• Microsample Data

Microsample data were obtained in the backyard of the property shown as No. 2616 Hemlock Street in Fig. C1.1. The measurement point was in full view of the substation. The results of data analyses are given in Figs. C1.4 and C1.5. Ambient reconstruction is based on data analyses using the notch rejection filters. The complete computer output sheets are included in Appendix D.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The substation is in compliance with the existing Washington noise regulations. No future residential developments can be foreseen which would change this situation.

In the event that more stringent noise regulations are introduced in the future, a problem of compliance will certainly arise.

The nighttime environment--in the absence of the substation--is such that the 42 dBA level would apply.

Our analysis of the data obtained in the study shows the following:

1) [redacted] The 240 Hz component is dominant on a loudness basis.

2) [redacted]. The 120 Hz component is dominant on the basis of loudness.

3) The terrain provides some shielding of those areas to the northwest which may be developed in the future.

Some lesser natural shielding may also arise at the north end of Ash Street.

4) In order to meet the 42 dBA standard at the junction of Ash and Hemlock Streets a 10 dBA reduction of the Bank 4/5 cluster will be required, together with a 6 dBA reduction [redacted] A lesser, but still significant noise reduction would be required to meet 42 dBA at properties towards the north end of Ash Street.

5) The hospital should be currently in compliance with the 42 dBA standard.

6) That area to the northwest which has been considered for residential development should be in compliance already with the 42 dBA standard--assuming no sound amplification effects due to the gully configuration.

RECOMMENDATIONS

There is no need for noise control at the Aberdeen Substation based on the current Washington noise regulations.

In the event that stricter standards are introduced in the future, a compliance problem will arise. Irrespective of future residential developments in the area, this problem should be restricted to existing and future properties lying to the east of the substation; primarily those on Ash Street and Hemlock Street.

We recommend that BPA consider making long-range planning provisions for barriers to shield [redacted] The possibility of using an attached skin treatment for [redacted] should be considered. Otherwise some form of partial barrier would be required.

We recommend that BPA retain its land ownership around the substation. We recommend also that BPA remain cognizant of land development plans in the area--especially in the gully area to the northwest of the substation.

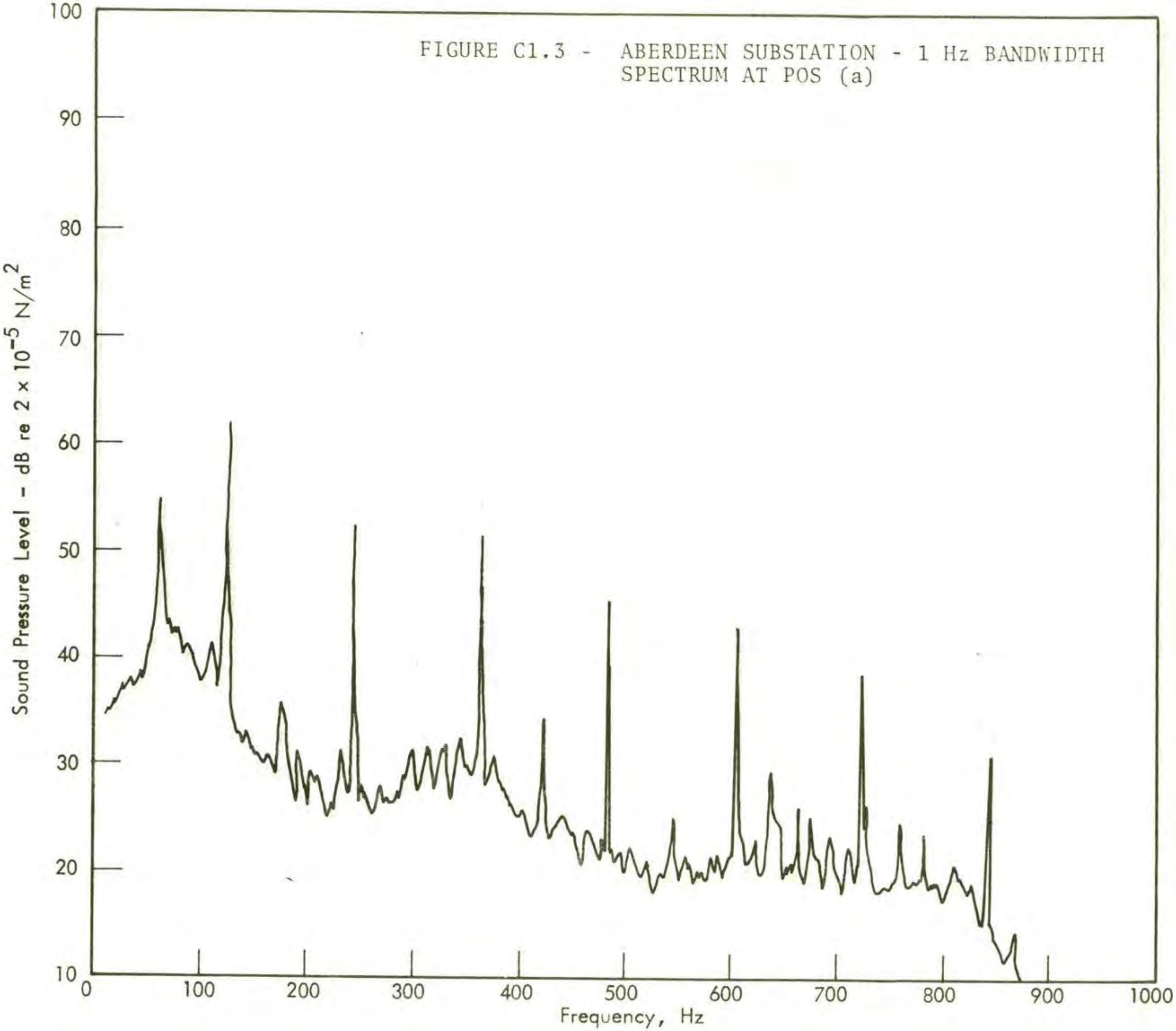


FIGURE C1.3 - ABERDEEN SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POS (a)

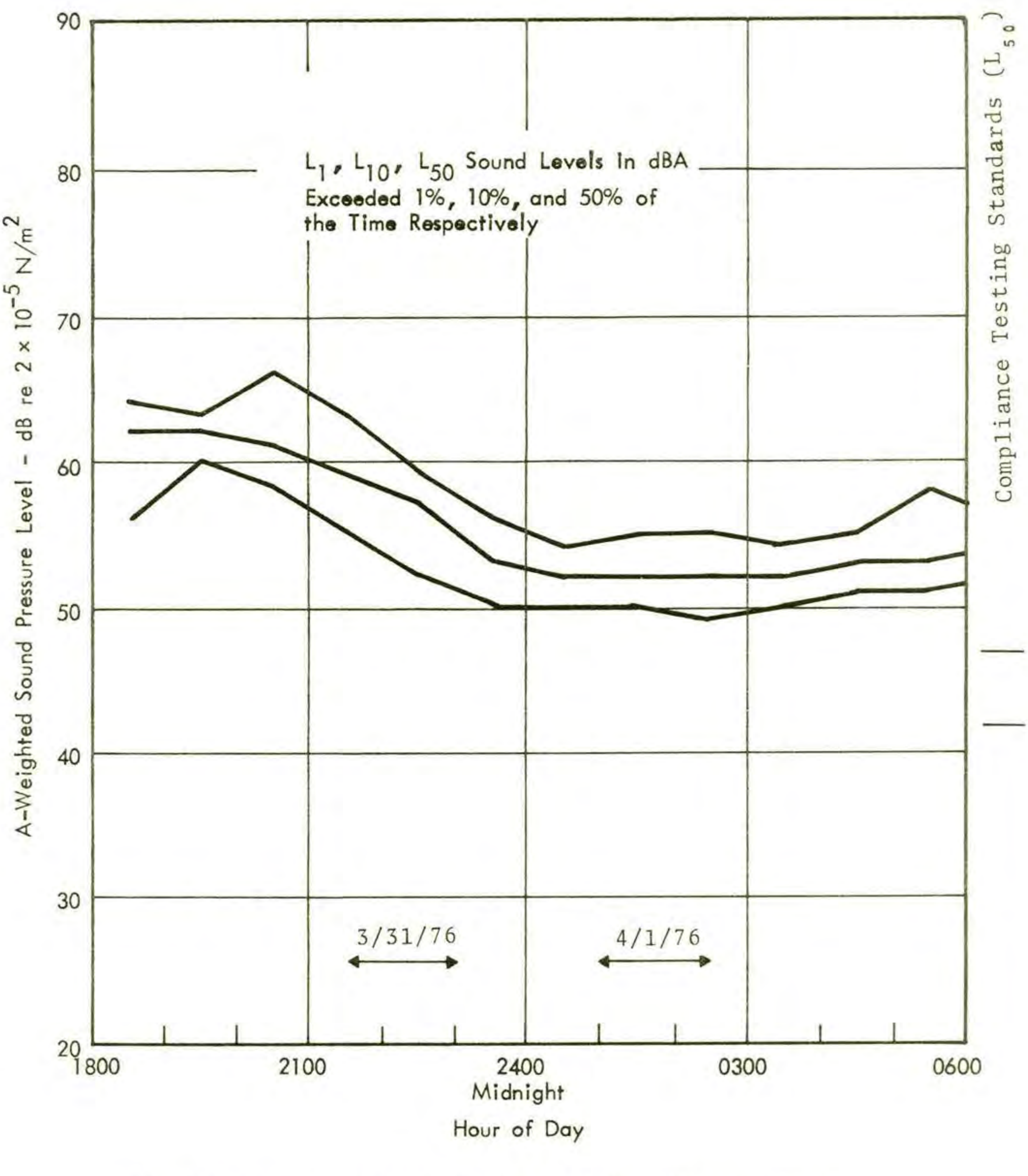


FIGURE C1.4 - ABERDEEN SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

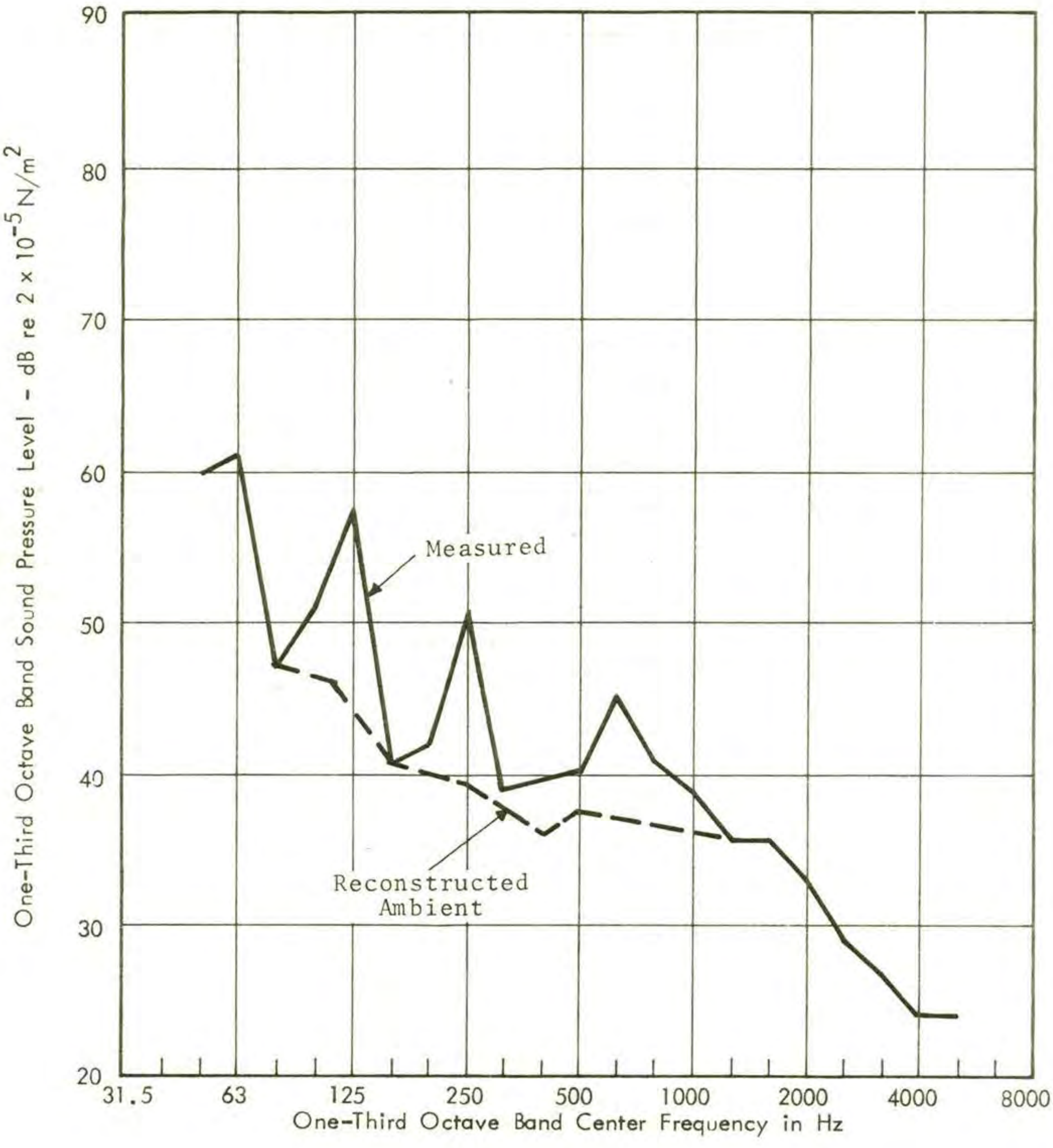


FIGURE C1.5 - ABERDEEN SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

C2. COVINGTON SUBSTATION

Covington Substation is located in King County, Washington, seven miles east of Kent. The layout of the substation and the major features of its environs are shown in Fig. C2.1. Details of the substation transformers and of the shunt reactor are given in Table C2.1.

To the southwest, northwest, and northeast of the station the land is essentially flat and undeveloped. Over this region the BPA land holding is extensive.

The residential properties on Graves Road, the closest of which is shown in Fig. C3.1, are quite distant from the substation transformers. Furthermore, they are partially shielded from the switchyard by the maintenance buildings.

The land to the southeast, on the far side of 164th Place, rises to form a hill. There are some existing properties abutting 164th Place. Further residential development here will be limited by easements associated with the 230 kV transmission lines.

A trailer park lies some 1000 ft southeast of 164th Place. The park lies in a gully within the hills and is not visible from the substation. A derelict house sits at the junction of 169th Avenue and the road to the trailer park. This property lies on top of a hill and is in full view of the substation.

Two houses lic to the south of the substation on the east side of 164th Place. One of these properties was selected as the microsampling location.

Future residential developments around the substation will be severely restricted by the extensive network of transmission lines running to the northwest and to the southeast. It is unlikely that future residential developments would create a situation significantly different from the present situation, either as regards the distances or the directions involved.

FIELD SURVEY

The major field survey was carried out on 25th March 1976. The microsampling was carried out on the following night (26th March). We were accompanied within the substation by Mr. Sterr (Chief Operator), Mr. Potts (Operator in Charge), and Mr. Mick Johnson (Mechanical Laboratory). The weather was unsettled with occasional periods of rain. The wind was from the south, gusting to 8 mph. On the morning of 26th March the temperature was about 48°F. The relative humidity was about 80%.

A second visit to the substation was made on 26th May 1976. The purpose of this visit was to assess the effectiveness of the wall enclosures which had been applied a few weeks earlier to the ASEA shunt reactor.

Under normal daytime load conditions the shunt reactor is not required and therefore is not energized. During both visits therefore special arrangements were made by BPA to energize the reactor for a brief period so that data could be obtained. During the microsampling survey load conditions were such that the shunt reactor was energized between 0200 and 0900 hours (27th March 1976).

During the main field visit the [redacted] was not energized. Our estimates for this bank are based in part on measurements obtained close to the [redacted]

· Close-In Measurements

The results of measurements at 10 ft from the energized units are given in Table C2.2. The appropriate NEMA rating for the shunt reactor is about 84 dBA. Allowing a 3 dBA increase in moving from the 10 ft position to the NEMA position, it would appear that, as supplied by ASEA, the shunt reactor was about 9 dBA in excess of the NEMA rating. The very strong third harmonic was the "culprit". The wall enclosure subsequently provided by ASEA has reduced the close-in levels by about 16 dBA. The unit now certainly complies with the NEMA recommended standard *insofar as measurement positions close to the major surfaces are concerned.* [These levels agree substantially with data subsequently taken by BPA personnel.]

During the course of both visits to the substation measurements were made at a number of other positions in the yard to try to obtain a fairer asscssemnt of the performance of the wall enclosure. Clearly the fact that the radiators lie outside the enclosure has a significant effect on the enclosure performance--an effect which is not truly taken account of by the NEMA measurement procedure. Also the reactor lid radiates significantly.

Subsequent to our latter visit to Covington, BPA made some measurements around the reactor and at distances from the reactor up to 3200 ft. Taking these data in combination with our own, we conclude that the effective attenuation provided by the wall enclosure is approximately 8 dB at 120 Hz, and 10 dB at 240, 360, and 480 Hz.

· Perimeter Measurements

The perimeter data at 120 Hz and 240 Hz are given in Fig. C2.2. The shunt reactor was not energized at the time of these measurements. These data normalize to levels at 500 ft from [redacted] (the only operating unit) of 60 dB at 120 Hz and 52 dB at 240 Hz. This is in fair agreement with the normalizations of Table C2.2.

• Community Measurements

Measurements were taken at the following positions:

a) In front of No. 28624, 164th Place, close to the micro-sample location, and

b) At the derelict house lying at the junction of 169th Avenue and to access road to the trailer park.

Measurements were obtained with and without the shunt reactor operating. The effect of switching in the reactor was measureable only at the 360 Hz frequency. The wall enclosure had not been fitted to the shunt reactor at the time of these measurements. The results are shown in Table C2.2. The quoted normalized levels with the shunt reactor on may be assumed to be due solely to the shunt reactor.

• Microsample Measurements

Microsampling was carried out at the location shown in Fig. C2.1. The results of data analyses are shown in Figs. C2.2 and C2.4. The full computer printout sheets are included in Appendix D. The shunt reactor was energized between 0200 and 0900 hours.

The drop in level after 0400 hours is thought to be the result of a temporary loading of the windscreen by rain. The levels recovered shortly after 0600 hours. The differences between the percentile levels plotted, is a clear indication that the noise environment at the microsample location was not dominated by the substation sources.

There is no clear change in the situation when the shunt reactor is switched on, at 0200 hours. At the microsample location the tonal level at 480 Hz is less than the level measured earlier at the nearby Position (a).

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Analysis of the situation at Covington is complicated by the fact that the Bank 4 transformer was not energized at the time of the measurements and that, since the main field survey, the shunt reactor has been fitted with a wall enclosure.

Based on the level of the reconstructed ambient at Covington, and on the fact that this substation is located in King County and will thereby be subject to the more stringent noise regulation, we have carried out our compliance analysis based on the 42 dBA compliance standard.

A detailed analysis of all the data gathered during the survey shows the following:

1) Under the conditions existing at the time of the survey the substation was in compliance with the Washington State regulations. Judged on the basis of the 42 dBA standard the substation was in default at Position (b) by about 7 dBA. It was in compliance at Position (a) because (apparently) of the shielding provided at this position by the terrain. The shunt reactor was the sole reason for default.

2) Based on our *best estimates* of the sound output from Bank 4 and of the attenuation provided by the shunt reactor enclosure, we estimate the following tonal

RECOMMENDATIONS

We recommend that the Bank 4 transformer be monitored at such time as it has been re-energized. We recommend also that some further far-field monitoring be carried out to establish the noise situation.

Depending upon the final form of the King County/Seattle City noise regulations a condition of noncompliance may exist at existing residential properties. We recommend therefore that BPA make long-range plans for the erection of a two- or three-sided barrier around [redacted] to provide an attenuation in the range 6 to 10 dB at 120 Hz.

We recommend also that BPA remain cognizant of land transactions and building applications in the area.

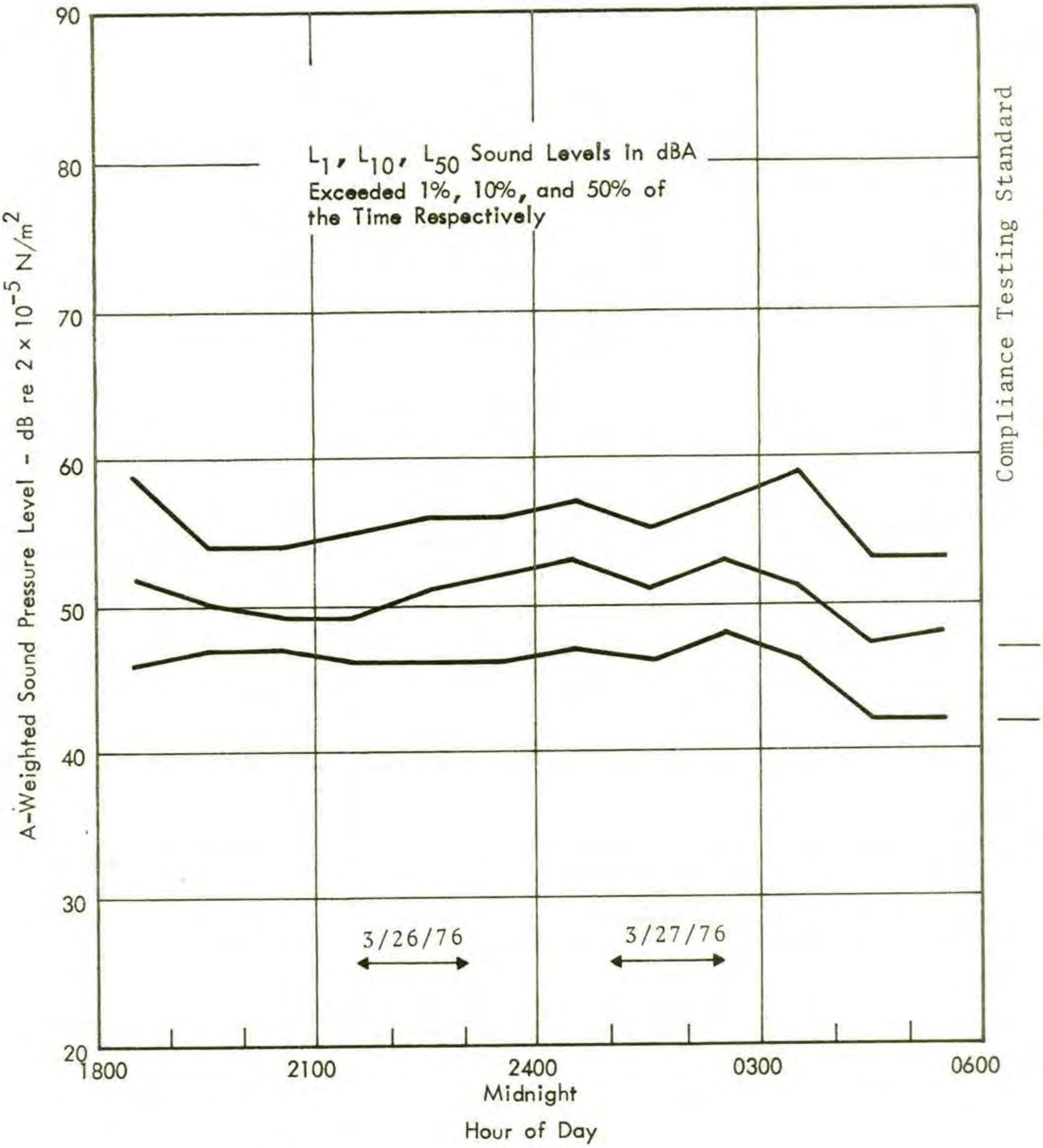


FIGURE C2.3 - COVINGTON SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

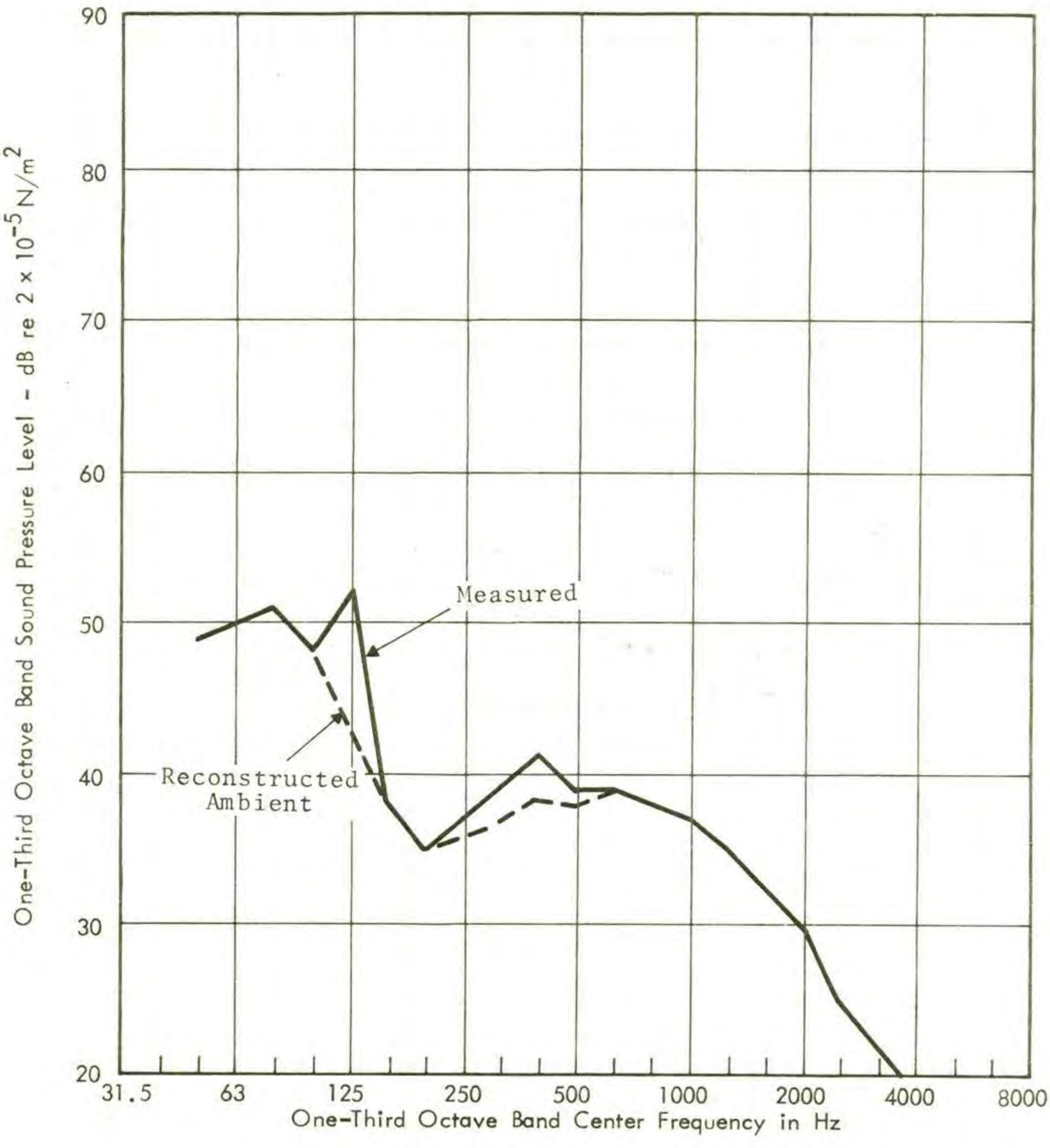


FIGURE C2.4 - COVINGTON SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HOURS.

C3. CUSTER SUBSTATION

Custer Substation is located 8 miles southeast of Blaine in Watcom County, Washington. The station lies 800 ft southwest of Interstate Highway 5.

The layout of the substation and of its immediate environs is shown in Fig. C3.1. Details of the [redacted] located within the substation are given in Table C3.1.

The land around the substation is flat. Currently the main land-use is agricultural. The closest residential property lies to the southeast of the substation at a distance of about [redacted].

Use of the land to the southwest and northeast of the substation is largely controlled by easements associated with the 230 kV and 500 kV power transmission lines.

Directly to the north BPA owns a substantial parcel of land encompassing the substation access road.

Our inquiries have shown that there are no residential developments prescribed for this area within the foreseeable future. We may assume therefore that residential properties will not encroach upon the substation more than at present.

FIELD MEASUREMENTS

Field measurements were carried out over the period 29th to 30th March 1976. We were accompanied within the substation by Lloyd Burgess (Operator) and Jack Maclean (Operator).

During the preliminary measurements the weather was overcast with drizzle. There was some clearing later on but nevertheless the relative humidity remained close to 100%. The air temperature on the afternoon of the 29th of March was 40°F. The wind was from the southwest at 5 mph.

• Close-In Measurements

The results of measurements at 10 ft from the transformer banks are given in Table C3.2.

• Perimeter Measurements

The results of the perimeter measurements are given in Fig. 2 for the first two tonal frequencies. *It should be noted that at the time of these measurements* [redacted] *was not energized.*

These data, normalized to 500 ft from [redacted] give average levels of 66 dB at 120 Hz and 47 dB at 240 Hz. The latter level is substantially lower than the level quoted in Table C3.2.

• Community Measurements

With [redacted] banks operating data were acquired at Positions (a) and (b) shown in Fig. C3.1. The levels are summarized in Table C3.3. A 1 Hz bandwidth spectrum at Position (a) is shown in Fig. C3.3. At the 120 Hz tonal frequency the 500 ft predicted levels are consistent with those given in Table C3.2. Agreement is less good at the higher frequencies.

• Microsample Data

The microsample data were acquired at a position in the extreme south corner of the switchyard as shown in Fig. 1. The analyzed results are summarized in Figs. C3.2 and C3.5. The complete computer output sheets are included in Appendix D. [redacted] were operating throughout the microsampling period.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

On the basis of the data gathered during the survey we estimate the following noise level and tonal sound pressure levels at 500 ft from the Bank 1/2 cluster, on average in the absence of shielding.

dBA	120 Hz	240 Hz	360 Hz	480 Hz
55	71	60	44	42

The closest property, that to the southeast, lies at a distance of 900 ft from the [redacted]. The predicted level at this point is therefore 50 dBA. Clearly the substation is in compliance with the present Washington regulations. Given the possibility of future stricter standards, however, a compliance problem would exist. A problem of about 8 dBA would arise on thc basis of the 42 dBA standard. This standard is warranted on the basis of the combined tonal levels and the reconstructed ambient for the area. A 3 dBA attenuation would be required for those properties to the south and east of the substation.

RECOMMENDATIONS

There is no requirement for noise reduction at the present time. However, in the event that stricter environmental standards are introduced the need will probably arise for a full height barrier to shield the property to the southeast of the substation and to provide lesser shielding for those properties to the south and east. Our calculations suggest that this can be achieved using a single 12 to 14 ft high barrier--of shallow "C" configuration--[redacted], as indicated in Fig. C3.1.

We recommend that BPA take account of the possible future need for a barrier. We recommend also that BPA remain cognizant of land transactions and planning applications in the area.

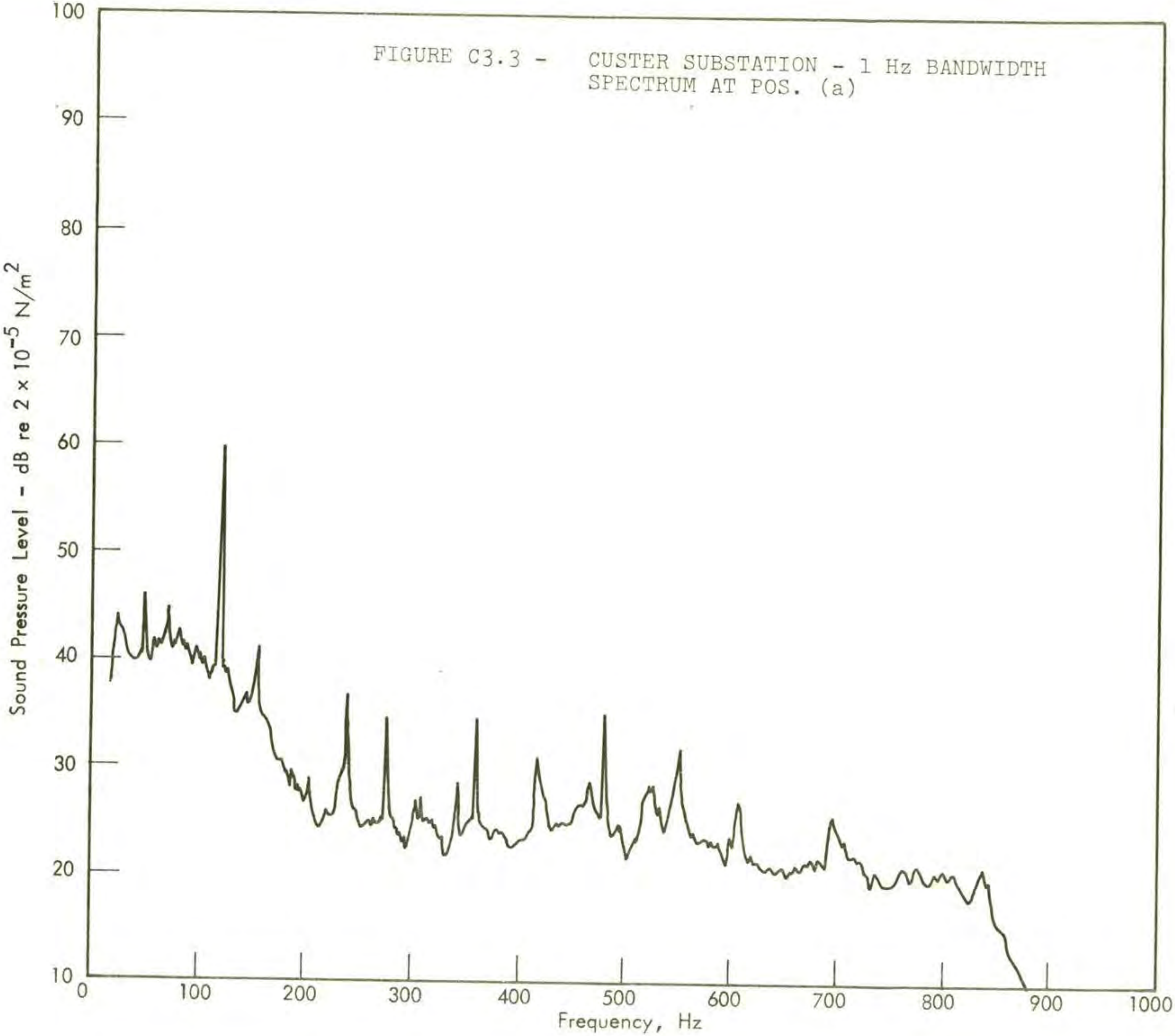


FIGURE C3.3 - CUSTER SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POS. (a)

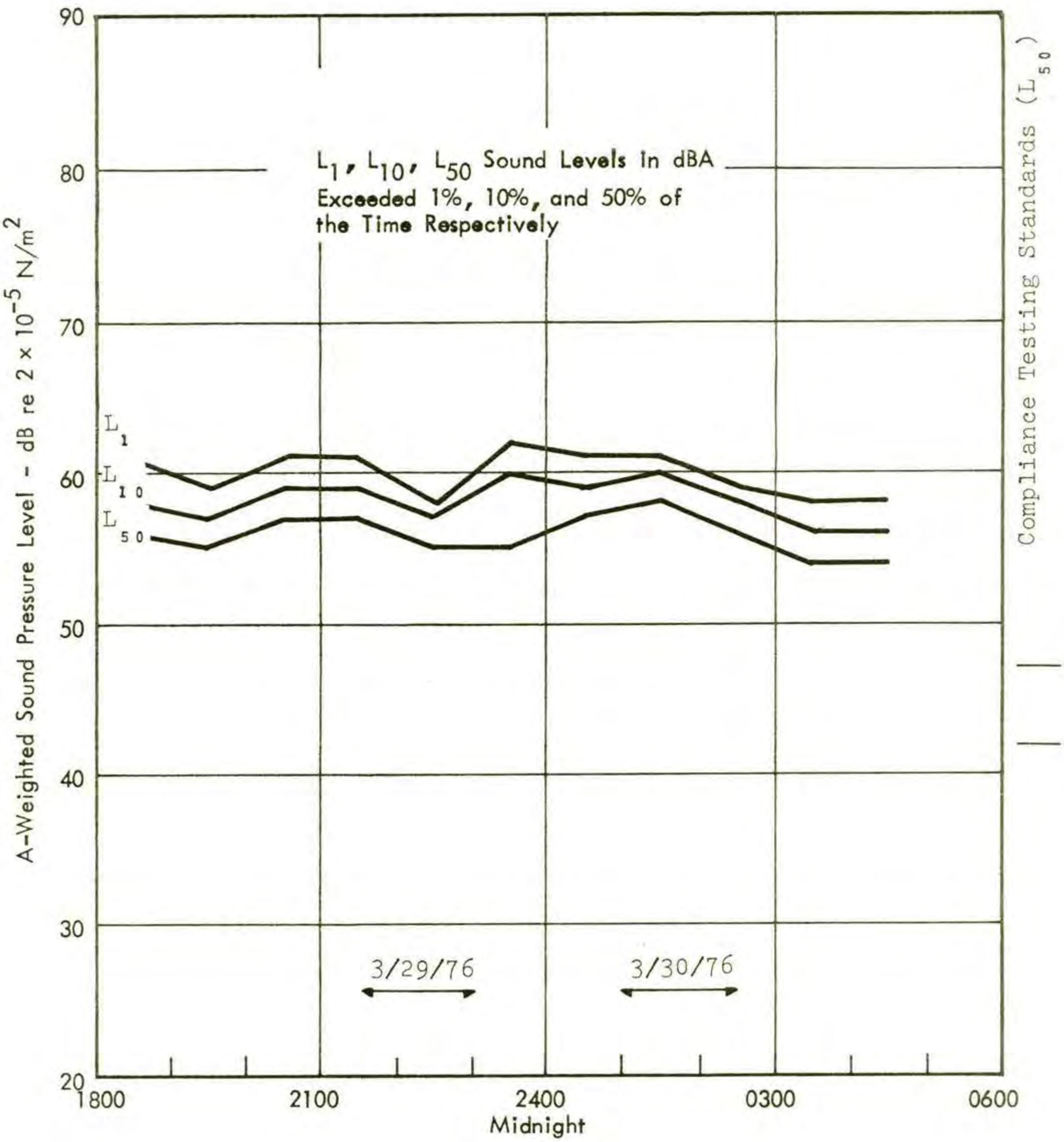


FIGURE C3.4 - CUSTER SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

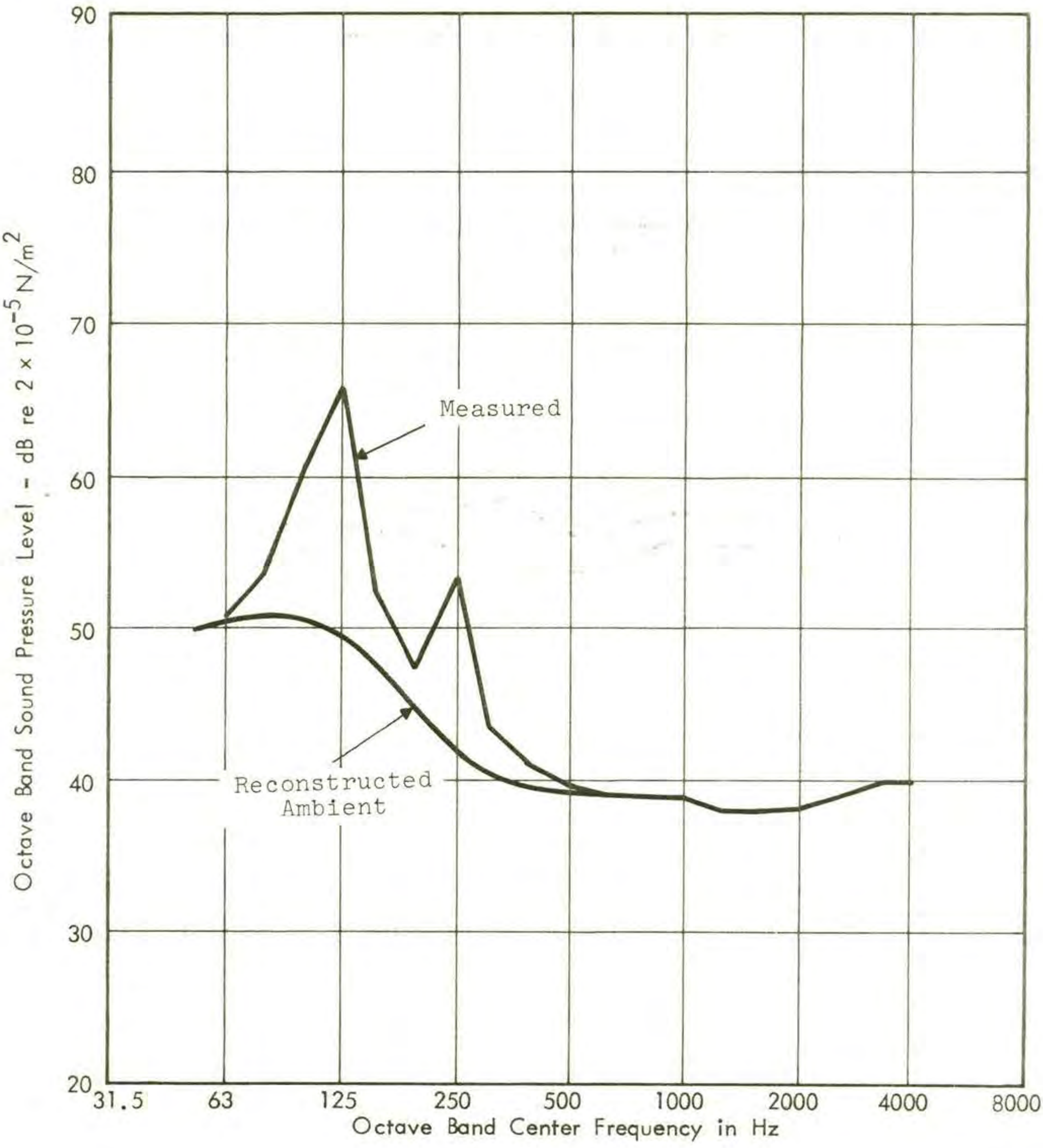


FIGURE C3.5 - CUSTER SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HRS.

C4. FIDALGO SUBSTATION

Fidalgo Substation is located four miles west of Anacortes in Skagit County, Washington. The layout of the substation and of its immediate environs is shown in Fig. C4.1. Details of the [redacted].

Details of the situation at Fidalgo are as follows:

Sunset Beach lies to the west of the substation at a distance of 300 ft from it. The land between Puget Way and the beach is used as a picnic park. Overnight camping facilities are provided at the southern end of the same park. These latter facilities lie no closer than 500 ft from the substation.

Over the northern and eastern quadrants the land is heavily wooded, and gently rising. A parcel of land encompassing the north, east and south boundaries of the substation has been designated for residential development. This is known as the Wood's Addition, City of Anacortes. It must be anticipated that in the next few years residential properties will abut the BPA property line.

At the present time there are only four residential properties within the Wood's Addition land parcel. The closest of these lies to the north at a distance of 200 ft from the substation fence. A second property to the north at a distance of 320 ft was used for microsampling. The third property lies at 350 ft to the southeast.

FIELD SURVEY

The field measurements were carried out over the period 29th to 30th March 1976. We were accompanied within the substation by Mr. Lloyd Burgess.

The weather during the measurement period was overcast but dry. The wind was from the southwest. Wind speeds ranged from 0 to 8 mph. On the afternoon of 29th March the air temperature and relative humidity were 53°F and 79%, respectively.

• Close-In Measurements

The results of measurement *at 3 ft* from the [redacted] are shown in Table C4.2. This table also shows our conservative predictions of the 500 ft noise levels for the two replacement transformers based on an ordering specification 7 dBA below NEMA TR 1 levels.

• Perimeter Levels

The measured perimeter levels are shown in Fig. C4.2. Normalizing to a distance of 500 ft these give levels of 48 dB at 120 Hz and 40 dB at 240 Hz. The latter value is substantially lower than the level predicted from the close-in measurements.

• Community Measurements

Measurements at the principle tonal frequencies were taken at the following positions:

a) At the house 200 ft to the north of the substation,

b) At the microsample location,

c) At the entrance to the picnic grounds 100 ft to the southwest of the substation.

d) Close to the house to the southeast of the substation, at a distance of 300 ft from the perimeter fence.

The results are given in Table C4.3. These indicate some shielding of the levels predicted from the close-in and perimeter surveys.

• Microsample Data

The microsampling was carried out at the property to the northeast as indicated in Fig. C4.1. The closer property was unoccupied and we did not feel that the sampling equipment could be secured at this position.

The results are given in Figs. C4.3 and C4.4.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Figure C4.3 shows, during the evening hours, the effect of the rather gusty wind at the microsample location. Some local traffic noise is also contributing. Between the hours of 1 a.m. and 5 a.m., however, the wind has lulled. Even at the quietest period of the night however the substation is not the dominant noise source. At the present time the substation is in clear compliance with the Washington noise regulations and with the more stringent compliance testing standards which we have used in this study.

We include in Table C4.2 our predictions (using a specification level of NEMA-7 dBA) of the 500 ft levels that will be generated [redacted] These suggest that, in the absence of ground shielding or scattering attenuation, the maximum level at 500 ft from [redacted] together would be 37 dBA. The compliance testing levels of 42 dBA and 47 dBA would therefore be generated at distances from the [redacted], respectively. These figures assume no shielding. Our measurements suggest in fact that some shielding occurs at those community positions measured during the survey.

[redacted] In the worst case therefore these could be exposed to levels in default of the compliance testing standard. They would clearly be in compliance with the present Washington noise regulations.

RECOMMENDATIONS

There is no present need for noise control at Fidalgo Substation. The compliance situation should not change [redacted] Future residential developments up to the eastern BPA property line could pose a compliance problem on the basis of the selected compliance testing standards--although no problem would arise on the basis of the present Washington noise regulations.

We recommend no noise control action at Fidalgo Substation. The probability of encountering a future need for noise control is considered to be quite small. We recommend that BPA monitor the noise situation when the new transformers are energized. We recommend further that BPA remain cognizant of development plans within the subdivision.

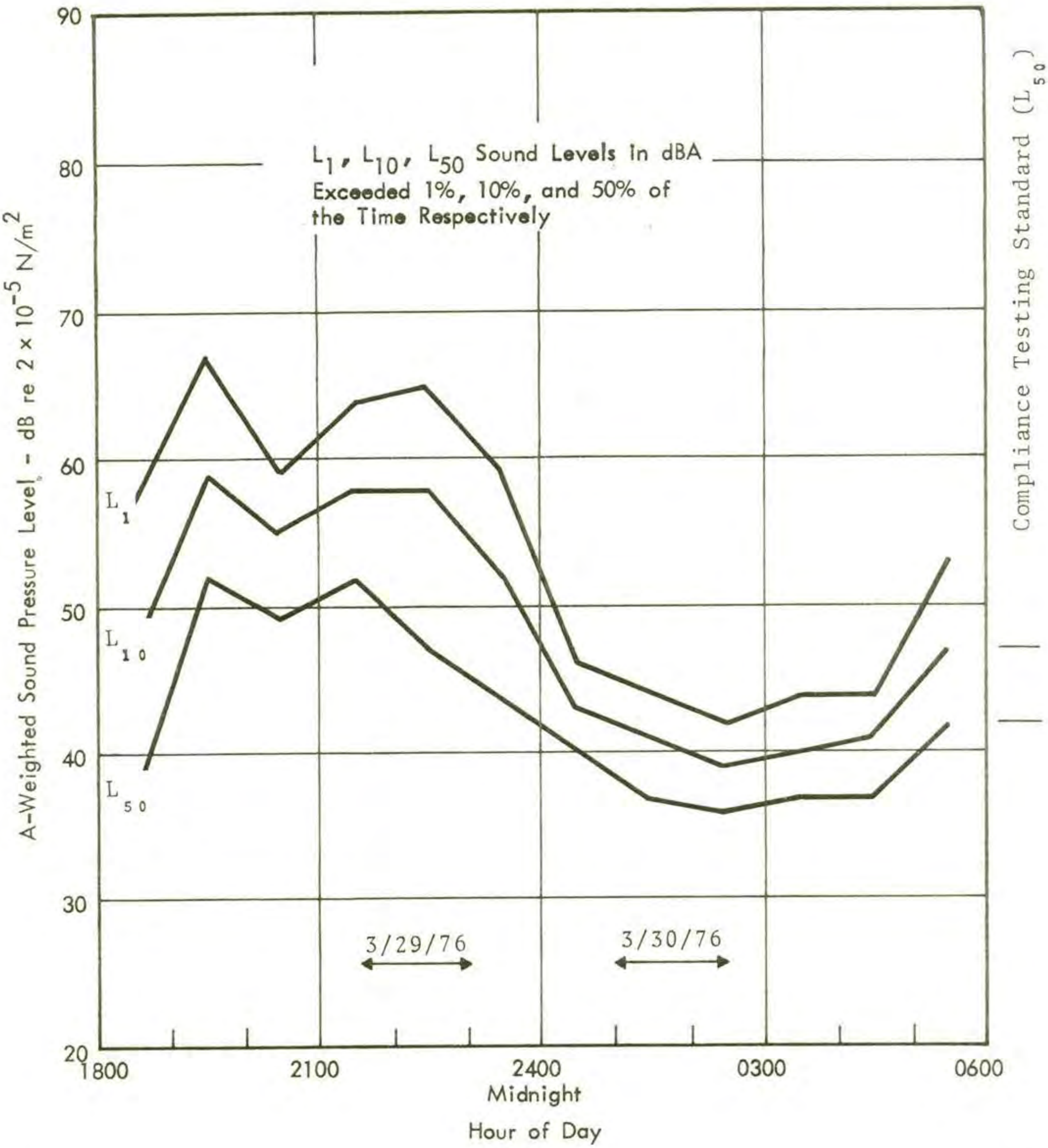


FIGURE C4.3 - FIDALGO SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

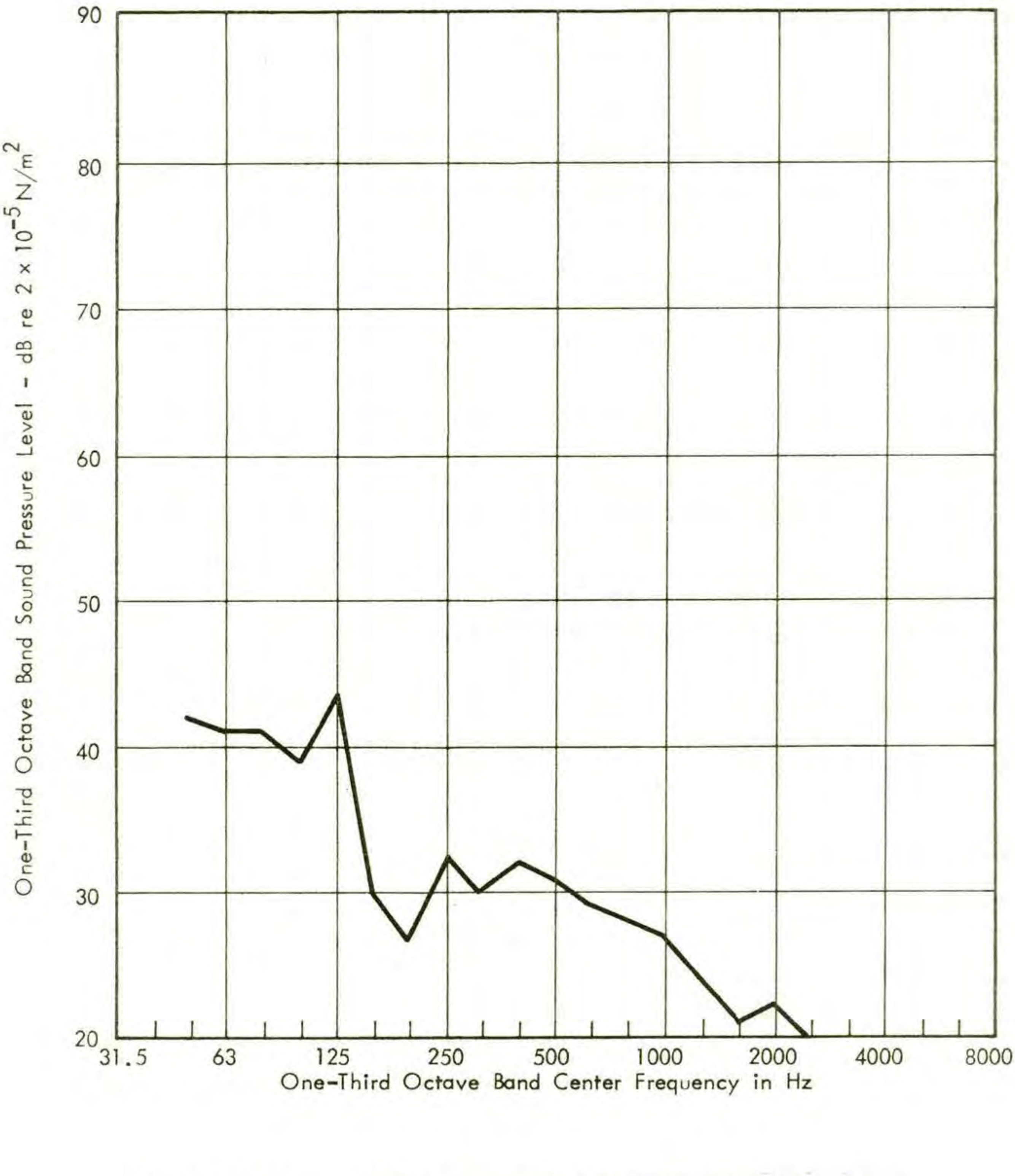


FIGURE C4.4 - FIDALGO SUBSTATION - MICROSAMPLE (L_{50})
ONE THIRD OCTAVE BAND LEVELS,
0300 TO 0400 HOURS

C5. FISHERS ROAD SUBSTATION

Fishers Road Substation is located five miles east of Vancouver, in Clark County, Washington. It lies on the north side of SE 1st Street.

The layout of the yard and of its immediate environs is given in Fig. C5.1. [redacted]

The terrain around the substation is flat and the predominant land use is agriculture. The yard lies next to a property occupied by Ms. M. Williams. [redacted] No other residential properties lie closer than 600 ft from the substation.

We understand from Ms. Williams that the owner of the land to the north and west of the substation is planning to build a trailer park close to the BPA property line. This would probably encompass the "Dutch" barn to the northeast of the substation. Easements associated with the 115 kV transmission lines would restrict development directly to the north of the yard but no such restriction would apply to the northwest and west land sectors.

FIELD SURVEY

The field survey was carried out over the period 4th to 5th March 1976. We were accompanied within the substation by Mr. Lyle Howard (BPA Substation Design).

The weather during the measurement period was clear and dry. The wind was from the southwest at 2-3 mph. On the afternoon of 4th March the air temperature and relative humidity were 47°F and 60%, respectively.

• Close-In Measurements

The results of measurements at 10 ft from the [redacted] are given in Table C5.2. [redacted] ([redacted] [redacted] [redacted] Allowing a 2 dBA increase in moving from the 10 ft measurement distance to the NEMA distance, the transformers would have approximate NEMA ratings of 74 dBA and 72 dBA, respectively. [redacted] would thus seem to be substantially in excess of the NEMA-10 dBA level used in the ordering specification.

• Perimeter Measurements

The results of the perimeter survey are shown in Fig. C5.1. These normalize to an average level at 500 ft of 58 dB at 120 Hz and 43 dB at 240 Hz.

• Community Measurements

A data sample was recorded in the backyard of the house to the east of the substation fence, close to the microsampling location. The results are given in Table C5.3. Further data were taken at a number of positions just outside the perimeter fence. These gave normalized levels at 500 ft of 53 dB at 120 Hz and 44 dB at 240 Hz.

• Microsample Data

Microsampling was carried out at the location shown in Fig. C5.1 The results are summarized in Figs. C5.2 and C5.3. The full computer output sheets are included in Appendix D.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Figures C5.2 and C5.3 clearly show the extent to which the substation transformers dominate the noise environment at the microsample location. At this location the substation lies 3 dBA above the present Washington noise standard. It lies 13 dBA above the 47 dBA compliance testing standard; it is this standard, rather than the 42 dBA standard, which we feel may be appropriately invoked in future years taking into consideration the normal ambient levels.

Future residential (trailer home) developments could lie to the west and to the northeast. [redacted] i.e., about twice the microsample distance. At this distance the substation should be in compliance with the present Washington noise regulations, but lie about 7 dBA above the 47 dBA compliance standard.

[redacted]

RECOMMENDATIONS

The substation is presently in default of the Washington noise regulations to an extent that could probably be resolved by the use of attached skin treatments as described in the main report. An adequate treatment however would require temporary removal of the radiator banks. This may be unacceptable in terms of cost and transformer outage time.

If it is to be anticipated that the more stringent noise standard of 47 dBA may have to be met in the future, then a more effective means of noise control must be used. If, furthermore, the land to the northeast and/or to the west is to be developed for residential purposes, significant attenuation will be required in these directions also.

We recommend that BPA take steps to construct an "L" shaped barrier [redacted] to provide shielding to the east and to the south. The design height of each barrier should be the lid height--to achieve an attenuation of about 10 dBA. We recommend that the treatment initially be applied to [redacted] and that the effectiveness of the treatment at Ms. Williams' property be monitored before an immediate commitment to the [redacted] is made. It is likely that compliance with the 57 dBA standard will be achieved without the [redacted] treatment.

We recommend that the design of these barriers be such that they may be later modified to a complete four-sided configuration and that the footings be sufficient to carry some height increase on the east side should this be necessary. Depending upon the nature of future residential developments, it should prove possible to leave some gaps in the wrap-around structure for ventilation purposes.

We recommend that BPA immediately take steps to find out details of development plans in the area and, if possible, try to obtain agreement to maintaining a minimum distance of 350 ft between the transformers and the closest new residential properties.

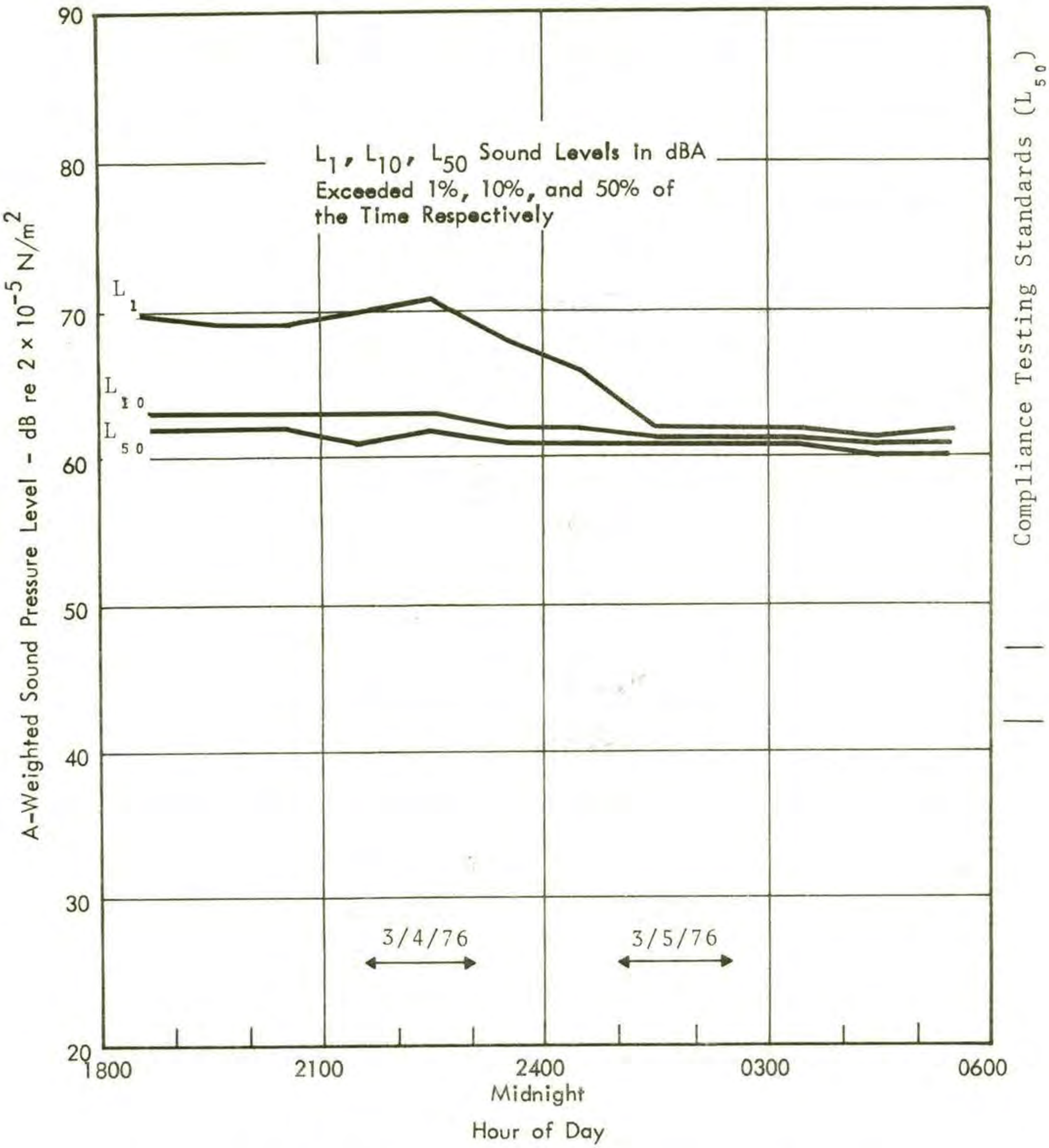


FIGURE C5.2 - FISHERS ROAD SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

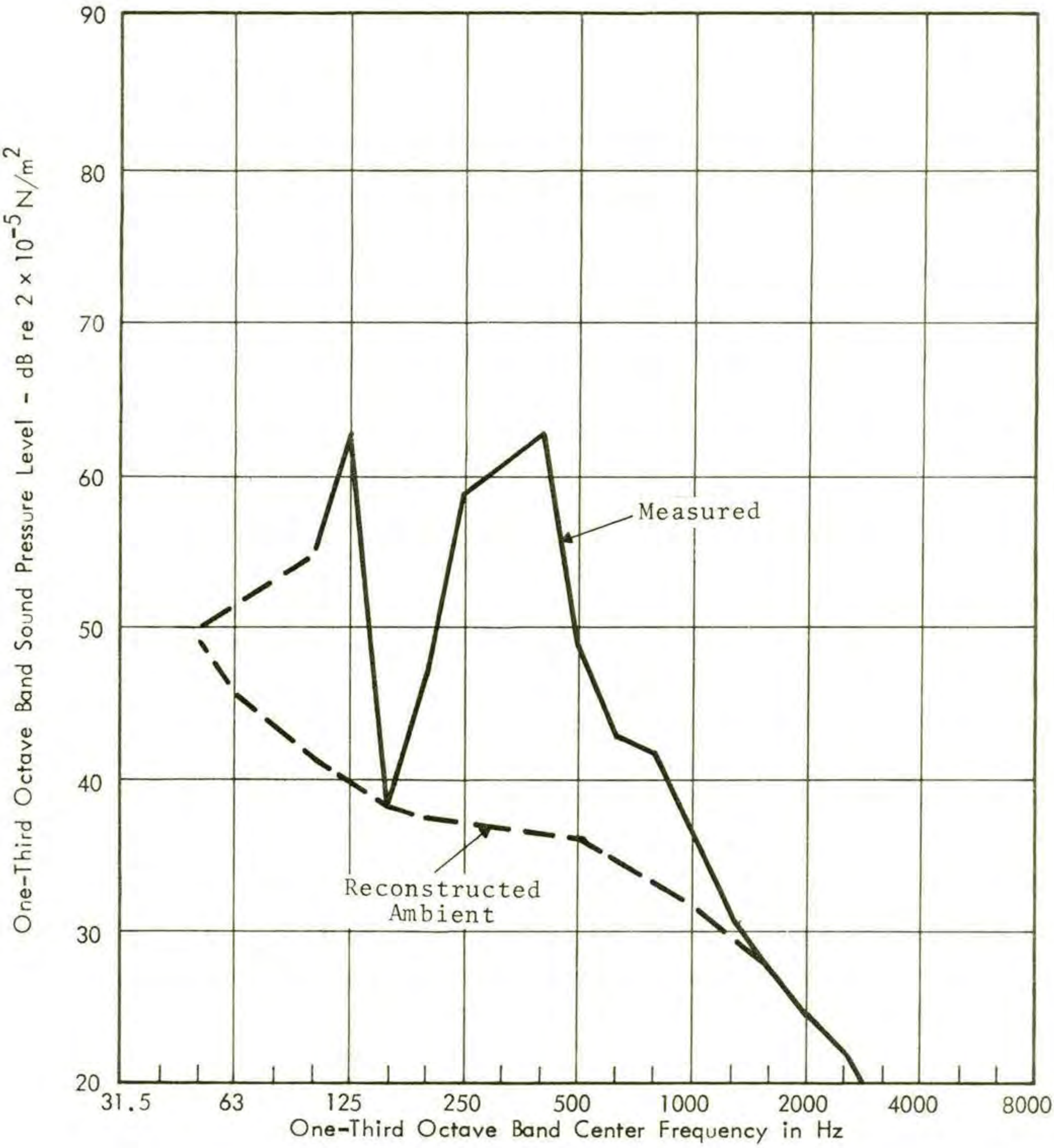


FIGURE C5.3 - FISHERS ROAD SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

C6. FOUR LAKES SUBSTATION

Four Lakes Substation is located three miles north of Cheyney in Spokane County, Washington. It lies on the south side of Jensen Road, about 900 ft east of its junction with State Highway 904.

The main features of the station and of the surrounding terrain are indicated in Fig. C6.1. Details of the [redacted]. There are no significant noise sources in the City of Cheyney substation which adjoins the BPA property line.

The substation is quite remote from residential developments. The primary land use is farming.

To the north the land rises gently. It is cultivated. There are farm buildings to the northwest at a distance of about 700 ft.

To the east the land falls gradually towards Merriney Street, which forms part of a recent (post 1971) development. There are a number of expensive residential properties located on Merriney Street. The most northerly of these properties was used for microsampling.

The land to the south is grazing land; this is associated with the farm buildings which lie at a distance of about 800 ft from the substation.

To the west the land drops abruptly towards Highway 904. This land would seem unsuitable for housing development.

In the next 5 to 15 years there is likely to be further residential development in this area. Developments to the east and to the southeast would be circled by transmission line easements.

FIELD SURVEY

The field survey was carried out over the period 18th to 19th March 1976. We were accompanied within the substation by Ben Carney and Willis Pratt (BPA, Spokane Area). During most of the field study, the weather was overcast but dry. Wind was from the southeast at about 6 mph. Air temperature on the afternoon of 18th March was 48°F. The relative humidity was 66%.

• Close-In Measurements

The results of the measurements at 10 ft from the [redacted] are given in Table C6.2. [redacted]

• Perimeter Measurements

The results of the perimeter measurements are included in Fig. C6.1. These data normalized to 500 ft levels of about 54 dB at 120 Hz and 37 dB at 240 Hz. The agreement with Table C6.2 is reasonable.

• Community Measurements

Information on the tonal noise levels of the transformers was obtained at the following positions:

a) At a position on the north side of Jensen Road about 30 ft from the roadside fence (see Fig. C6.1).

b) At a position close to the farm buildings to the northwest of the substation.

c) At the microsample location to the southeast of the substation.

These data are summarized in Table C6.3. At Positions (b) and (c) the tonal frequencies of 240, 360 and 480 Hz could not be detected. The levels at 120 Hz are fairly consistent with the results of the close-in and perimeter measurements. A typical 1 Hz bandwidth spectrum at Position (a) is given in Fig. C6.7.

• Microsample Data

The results of the microsample measurements are given in Figs. C6.3 and C6.4. The full computer printout sheets are included in Appendix D. During the early evening hours the weather deteriorated; the wind velocity increased and there were periods of rain and of hail. The wind abated at about 4 a.m. The one-third octave band spectrum shown is that for 0400 to 0500 hours. In reconstructing the ambient we have made allowance for wind noise in the trees which surrounded the microsampling position.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The data show that the noise emanating from this substation is predominantly at the 120 Hz tonal frequency. It is this component only which is measurable at distances from the substation representative of current residential developments.

The dominance of the 120 Hz component has the effect that dBA levels can be reasonably predicted on the basis of the close-in data. Allowing a 3 dBA standard deviation for spatial position at fixed radius (see Chapter 4), we find that residential developments are unlikely to be exposed to levels in excess of the specified compliance limits unless they lie closer to the combined transformers than

Compliance Limit	Distance (ft)
57 dBA	100
47 dBA	350
42 dBA	650

We are of the opinion that the normal ambient levels in this area are such that the 42 dBA compliance standard is unlikely ever to be invoked.

The substation is in clear compliance with the existing and projected Washington standards at the present time.

Future residential developments would have to lie close to the southern BPA property line to cause a compliance problem in terms of the current Washington noise regulations.

Future developments within a distance of 350 ft of the combined transformers could pose a problem at the projected 47 dBA standard level. Developments on the north side of Jensen Road or to the south of the substation could lie within this category.

RECOMMENDATIONS

No noise control is required at the present time. We consider it unlikely that compliance problems will arise in the future either. However we do recommend that BPA remain cognizant of land transactions and planning applications in the immediate vicinity of the substation--especially on the land to the north of Jensen Road and on the grazing land immediately to the south of the substation.

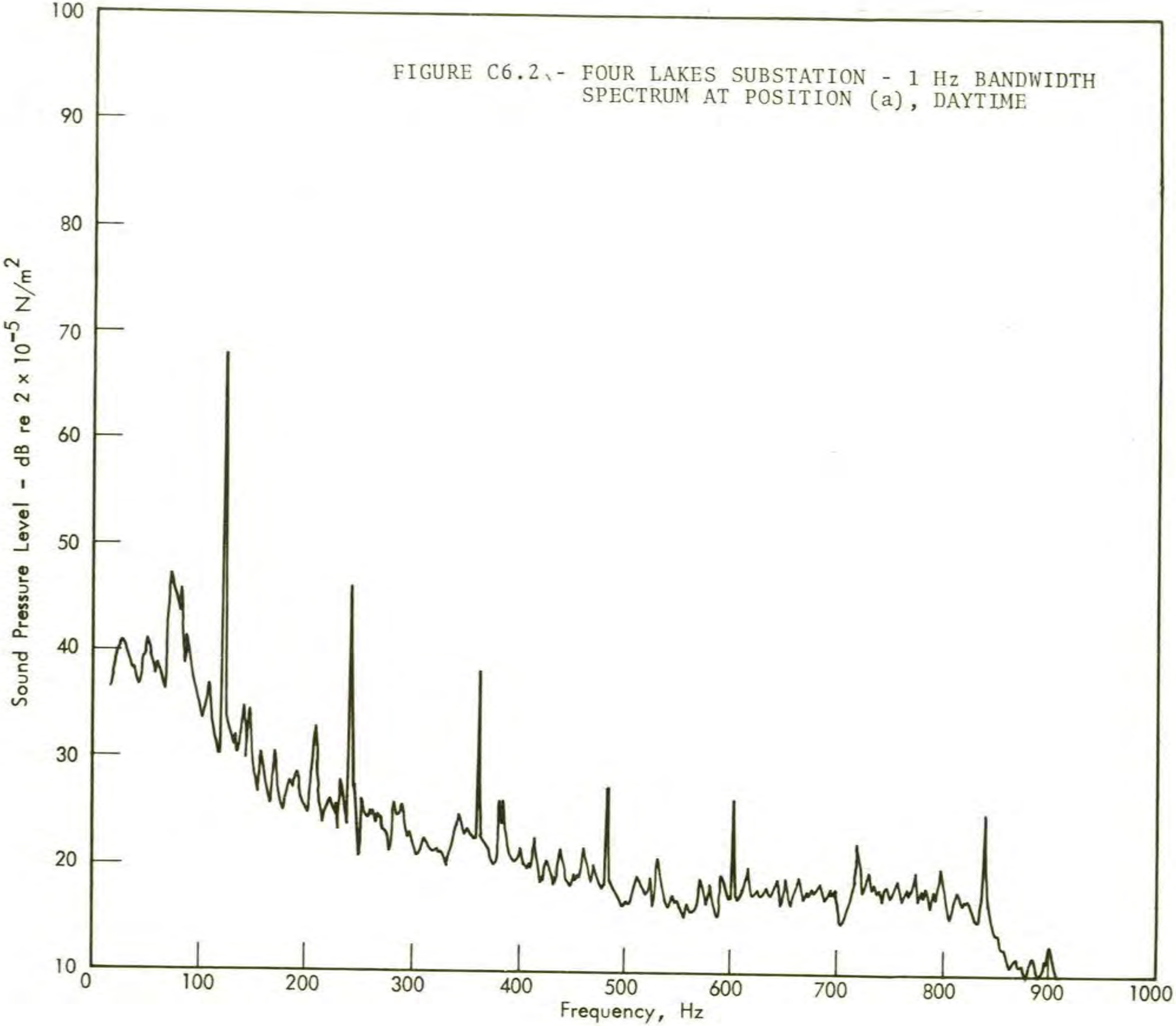


FIGURE C6.2.- FOUR LAKES SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POSITION (a), DAYTIME

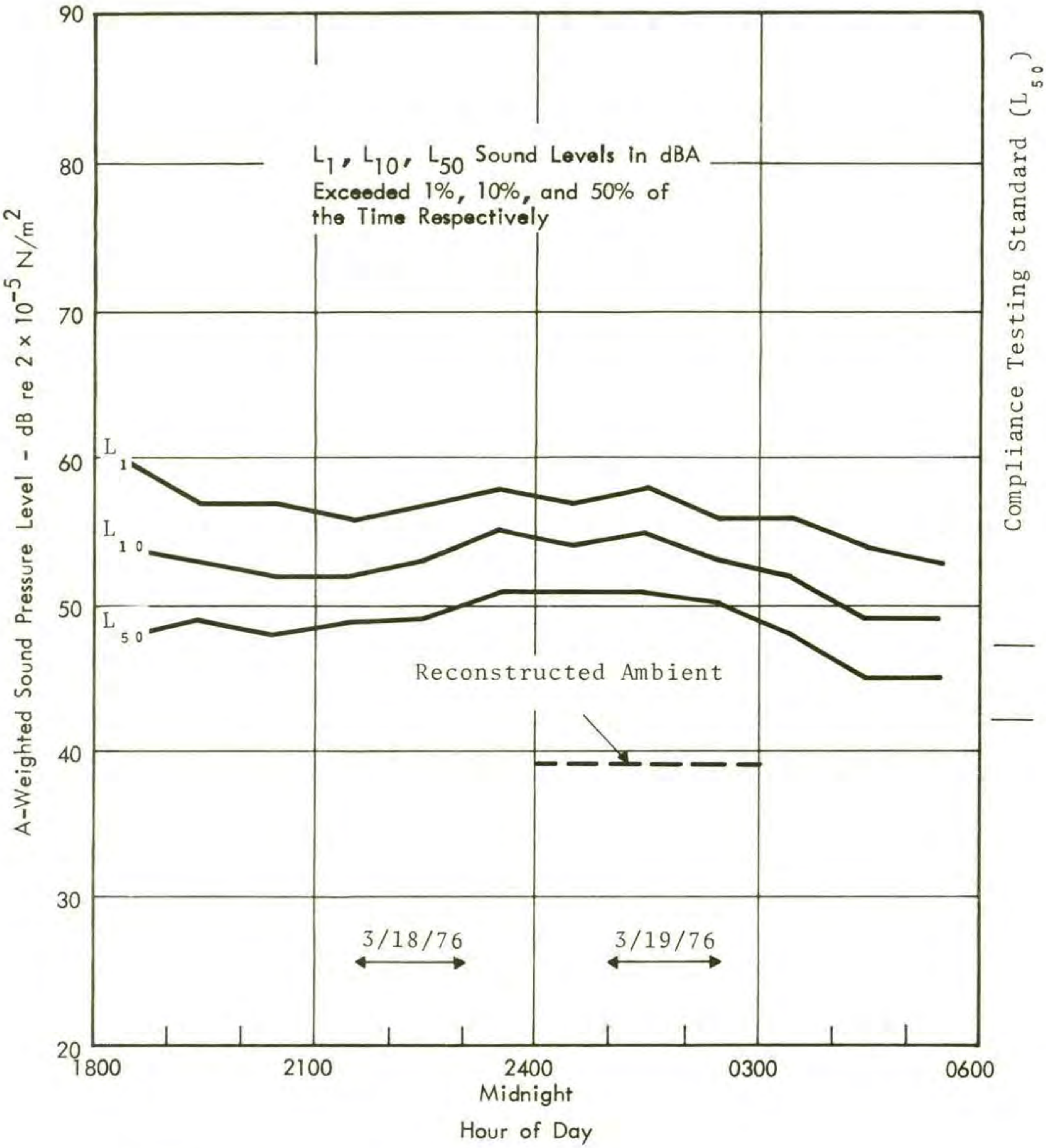


FIGURE C6.3 - FOUR LAKES SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

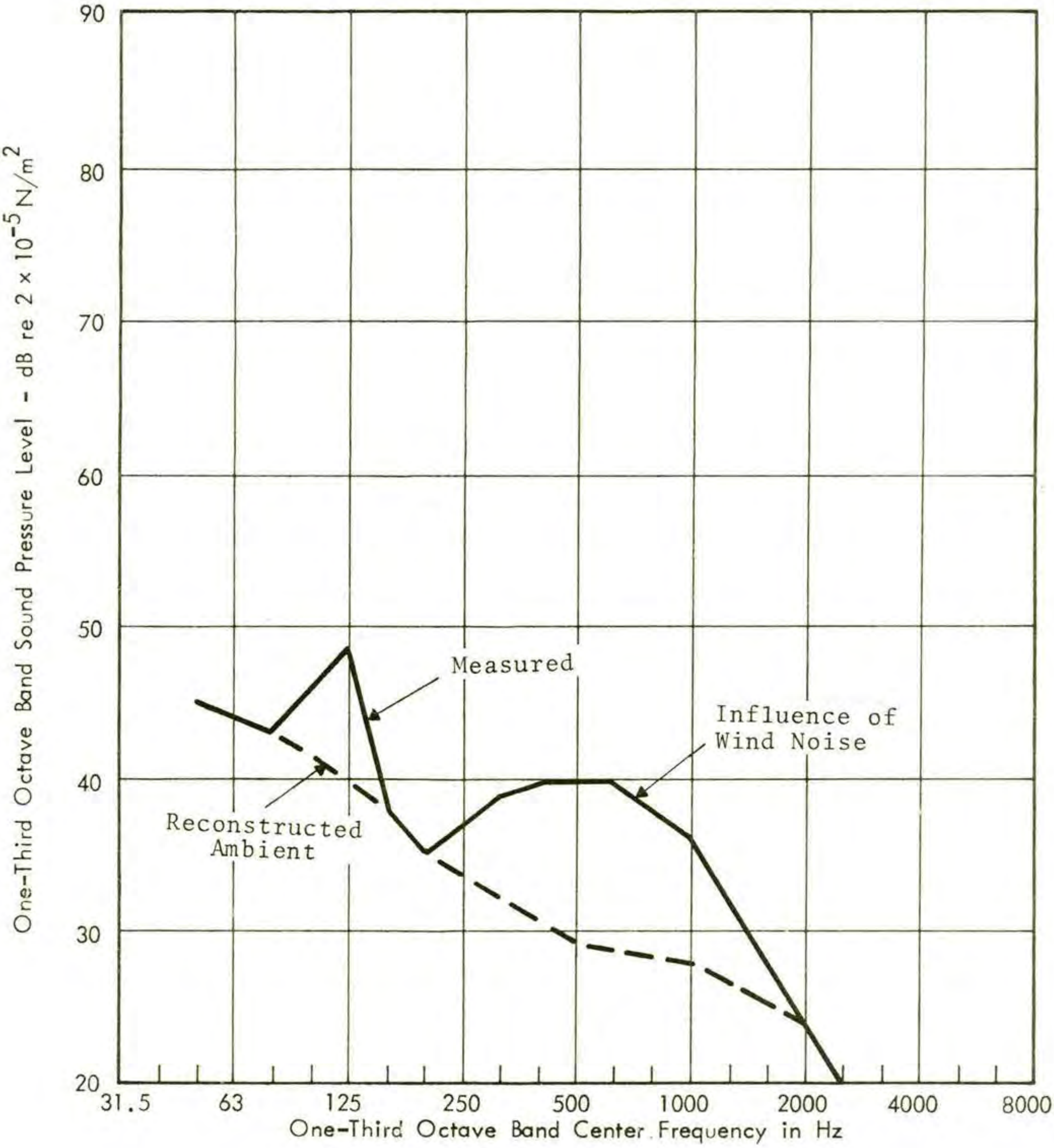


FIGURE C6.4 - FOUR LAKES SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS
0400 TO 0500 HOURS

C7. MAPLE VALLEY SUBSTATION

Maple Valley Substation lies 3 miles southeast of Renton in King County, Washington. It lies at the junction of 116th Avenue, S.E., and Royal Oaks Drive, S.E.

The layout of the substation and its environs is shown in Fig. C7.1. [redacted]

The major land uses and features of the surrounding terrain are as follows.

To the north and east the land drops in level from the substation site. Much of this land is heavily wooded. The presence of transmission line easements would prevent residential developments entirely to the east (on the north side of Royal Oaks Drive) and would preclude development to the north at distances closer [redacted] The configuration of the "hole" that will [redacted] such that only limited attenuation will be provided in this direction.

The land also drops to the south and it is in the area to the south of Royal Oaks Road that we have the primary present and future residential areas. The form taken by these developments is shown in Fig. C7.1. In the area to the west of Lake Youngs Way residential development is currently complete. New residential properties are in process of building in the area to the east of Lake Youngs Way. It is only these properties close to the most southern corner of the substation that have effective view of the substation. Elsewhere the terrain provides shielding.

To the southwest and to the west the land rises gradually. A Puget Sound Power and Light Company substation occupies part of this land. The additional presence of line easements would seem to preclude residential development in this area.

Most of the potential for residential development around Maple Valley Substation has already taken place or is in the course of development. The major problematic area for future development would seem to lie in that area to the north of the dirt road, as already mentioned.

FIELD SURVEY

The field measurements were carried out over the period 25th and 26th March 1976. We were accompanied within the substation by Gerald Armstrong (Operator) and by M. D. Johnson (Mechanical Laboratory).

During the course of the measurements the weather was varied, generally overcast with some rain. The weather cleared substantially overnight. On the morning of 26th March the wind was from the south gusting to 8 mph. The temperature was 48°F; the relative humidity was 80%.

• Close-In Measurements

The results of the measurements at 10 ft from [redacted] are given in Table C7.2. In this table we also show our predictions for the "equivalent" 500 ft levels (based on close-in tonal analyses) [redacted]. This unit has been measured by the manufacturer in his factory at NEMA 80.3 dBA. Our extrapolation is based on a measurement area per bank of 1000 sq ft. The prediction technique is discussed in the main report.

• Perimeter Measurements

The results of the perimeter measurements, at the first two tonal frequencies are included in Fig. C7.1. These values normalize to 500 ft levels (from Bank 1) of 66 dB at 120 Hz and 52 dB at 240 Hz. The agreement with the Bank 1 close-in measurements is good.

• Community Measurements

Measurements were taken in the community at the following positions:

a) At the road junction to the south of the substation in full view of the substation,

b) At the junction of Royal Oaks Drive and Lake Youngs Way, and

c) At the most southerly cul-de-sac, shown in Fig. C7.1.

Both Positions (b) and (c) are shielded from the substation by the terrain.

The results are shown in Table C7.3.

• Microsample Data

Microsampling was carried out at the position shown in Fig. C7.1. The results of analysis are summarized in Figs. C7.2 and C7.3.

Ambient reconstruction is based on the use of rejection filters. The microsample location may be somewhat shielded from Bank 1 by the control house.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Based on the survey data--relating only to the operation of [redacted] we predict that at a distance of 500 ft from [redacted] in the absence of shielding, noise levels and tonal sound pressure levels are:

dBA	120 Hz	240 Hz	360 Hz	480 Hz
48	64	51	42	36

The closest existing residential developments lie at a distance in excess of 600 ft for [redacted] and then properties are shielded by the terrain. The closest unshielded properties lie at a distance (to the south) of 850 Ft. Clearly, therefore, the substation is in compliance with the current Washington regulations. It is most probably just in compliance with the 42 dBA standard (for strongly tonal sources) proposed by the King County authorities.

We have undertaken estimates of the likely influence of [redacted] upon these findings. Based on the predicted "equivalent" 500 ft levels for the new bank given in Table C7.2, we estimate that in a totally unshielded configuration [redacted] will increase the present exposure levels by about 4 dBA. We estimate also, however, that the "below grade" installation should provide an attenuation to [redacted] of about 6 to 8 dBA, at the four principal tonal frequencies. This estimate is based on an equivalent source height of 10 ft, a barrier height (above grade) of 17 ft, a source to barrier distance in the range 75 to 170 ft (depending upon the direction) and an observer distance of about 1000 ft. Given this degree of attenuation the [redacted] installation should add only 1 dBA to the present community levels. Thus the compliance situation should not be significantly affected.

The possibility of residential developments to the north of the dirt road may however pose a problem--since [redacted]

dBA	120 Hz	240 Hz	360 Hz	480 Hz
46	61	49	41	36

Whilst the situation would be one of compliance with the present Washington regulations, a potential 4 dBA problem could occur with respect to the 42 dBA compliance standard. No problem would be anticipated with Bank 1 alone. It may be, of course, that the below-grade configuration would provide some attenuation.

RECOMMENDATIONS

We anticipate no need for noise control at Maple Valley even given the stricter noise regulations proposed by the King County authorities. This presupposes the accuracy of our estimates both as regards the noise output of the [redacted] and as regards the performance of the below-grade installation. The potential for a noncompliance problem is anticipated, however, if residential developments take place to the north of the dirt road just beyond the present transmission line easements.

We recommend that BPA undertake close-in and more distant measurements on [redacted] [redacted] [redacted] We recommend also that BPA remain cognizant of land transactions and planning applications in the area.

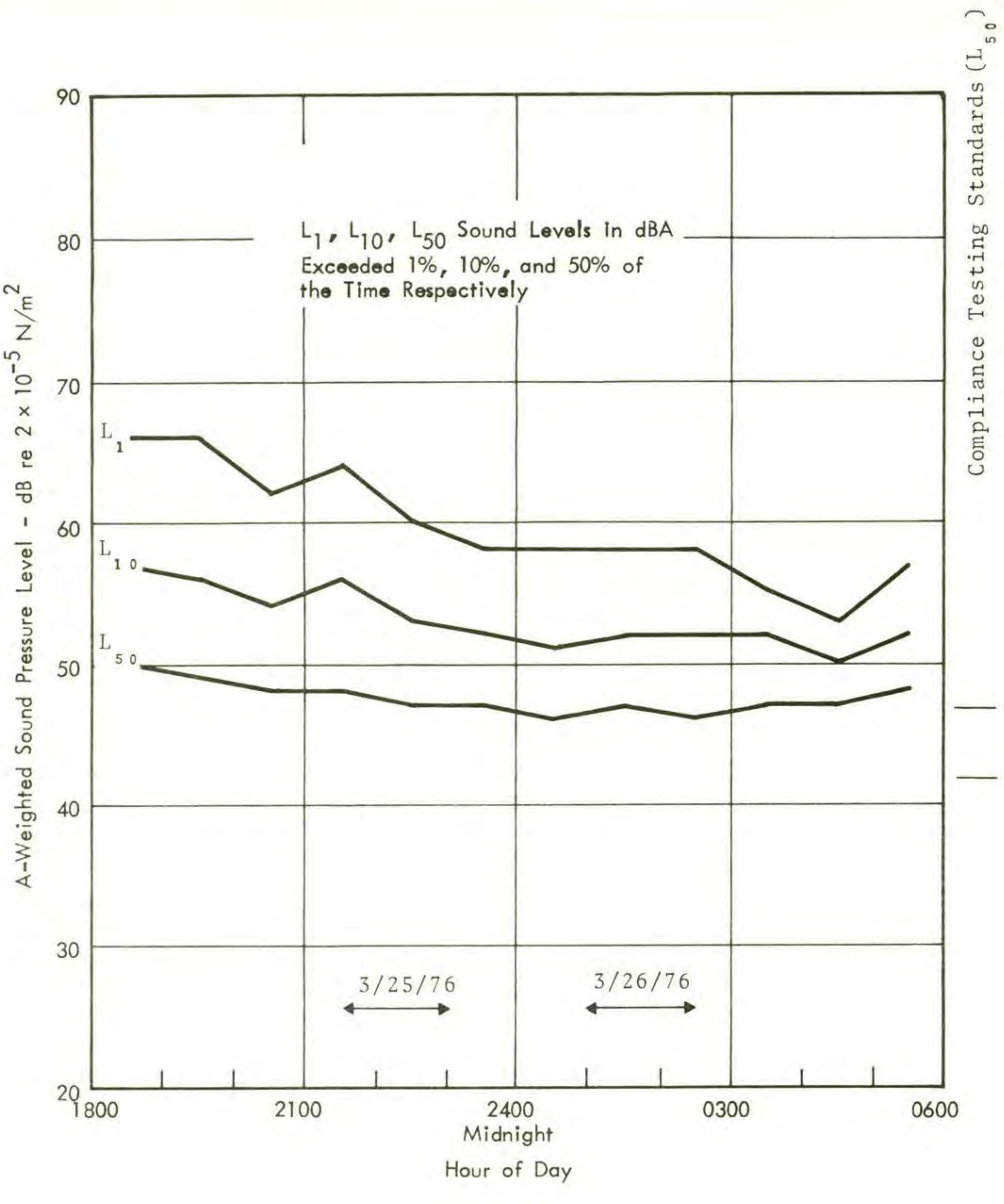


FIGURE C7.2 - MAPLE VALLEY SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

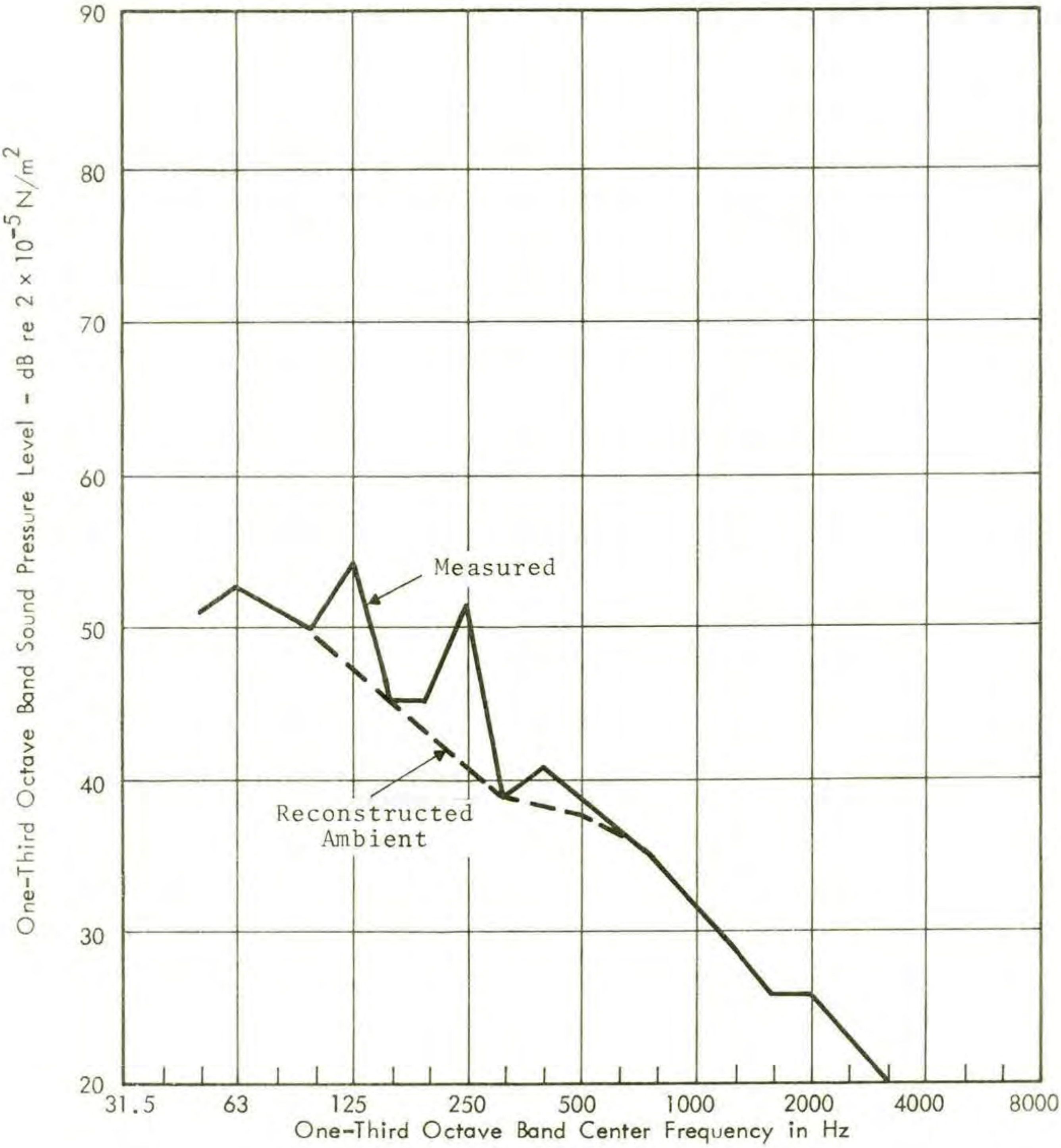


FIGURE C7.3 - MAPLE VALLEY SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS, 03-0 TO 0400 HOURS.

C8. MILL PLAIN SUBSTATION

Mill Plain Substation lies on the north side of Mill Plain Boulevard, about two miles east of Vancouver City center, in Clark County, Washington. The substation adjoins a yard (without transformers) operated by the Public Utilities Department.

The layout of the substation and some details of the surrounding environs are given in Fig. C8.1. [redacted]

The land around the substation is already fully developed with houses; on the south side of Mill Plain Boulevard as well as on the north.

For aesthetic reasons part of the substation perimeter is enclosed using a 9 ft high masonry wall. The remainder of the perimeter is formed of the conventional chain-link fencing. The masonry wall is not solid; there are vertical gaps of some 4 inches between each 10 ft long wall segment. This should have little influence on thc performance of the wall as a barrier.

The small strip of land between the north chain link fence and the BPA property line is planted with shrubs and small spruce trees. These do much to shield those houses to the north from direct view of the substation hardware.

FIELD SURVEY

The main field survey was carried out over the period 23rd to 24th March 1976. We were accompanied within the substation by Mr. Ken Jacks (Substation Design). A supplementary visit was made on the 11th May 1976.

During the first visit the weather was generally cloudy with periods of rain. The wind was from the south gusting to 10 mph. The air temperature was 46°F; the relative humidity was close to 100%.

• Close-In Measurements

The results of measurements at 10 ft from the transformer are given in Table C8.2.

• Perimeter Measurements

The results of measurements around the perimeter fence are included in Fig. C8.1. Neglecting those positions which lie outside the masonry wall (and are therefore shielded), these data normalize to average levels at 500 ft of 54 dB at 120 Hz and 44 dB at 240 Hz. These levels are in reasonable agreement with the close-in measurements.

• Community Measurements

Transformer tonal data were acquired at two positions external to the substation (see Fig. C8.1).

a) At the microsample positions.

b) At a position on East 13th Street in view of the yard.

These data are presented in Table C8.3.

• Microsample Data

The microsample survey was carried out at the position shown in Fig. C8.1, at a distance of 140 ft from the transformer. The data obtained are summarized in Figs. C8.2 and C8.3. The reconstructed ambient spectrum in Fig. C8.3 represents the quietest condition likely to arise in this area during calm weather conditions. At all times the ambient is influenced by traffic flow on Mill Plain Boulevard and general traffic and other activity within the Vancouver urban area.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The substation is in compliance with the present State regulations.

As measured at the microsample location the substation does not have a pure tone component in accordance with the definition used in our secondary compliance testing standard. However, the levels of the reconstructed quiet ambient are such that we are of the opinion that a pure tone component condition must be assumed, and that the appropriate design goal for the substation should be 42 dBA.

By examining the various data obtained in the survey we conclude that the tonal levels at the closest property could be higher than measured at the microsample position. Our predictions are included in Fig. C8.3. This reinforces our opinion that 42 dBA is the proper design goal to use.

The predicted maximum tonal levels, confirmed by the data in Fig. C8.2, show that an attenuation of 10 dB at 120 Hz, and slightly more attenuation at the higher frequencies, should ensure the substation's compliance with the 42 dBA goal.

It is predicted that the masonry walls to the east and to the west of the substation provide no more than 5 dB of attenuation for those properties shielded by them. These properties are at present, therefore, in excess of the 42 dBA goal also.

It is important to realize that in the event that a barrier is erected around the transformer, the small attenuation achieved at present by the masonry perimeter wall will *in all probability* be lost. Therefore the required barrier performance to the east and to the west of the substation must not be significantly less than that attenuation required to the north (i.e., about 10 dB at 120 Hz).

RECOMMENDATIONS

There is no present requirement for noise control at Mill Plain. However, given more stringent noise standards in the future a need for noise control could arise. We recommend that BPA make long-range plans for the construction of a three-sided barrier of height equal to the lid height of the transformer (i.e., about 13 ft). The fourth (open) side should face towards the south. The east and west sides of the barrier should extend sufficiently beyond the transformer to shield those properties closest to Mill Plain Road from line-of-sight of the transformer bank.

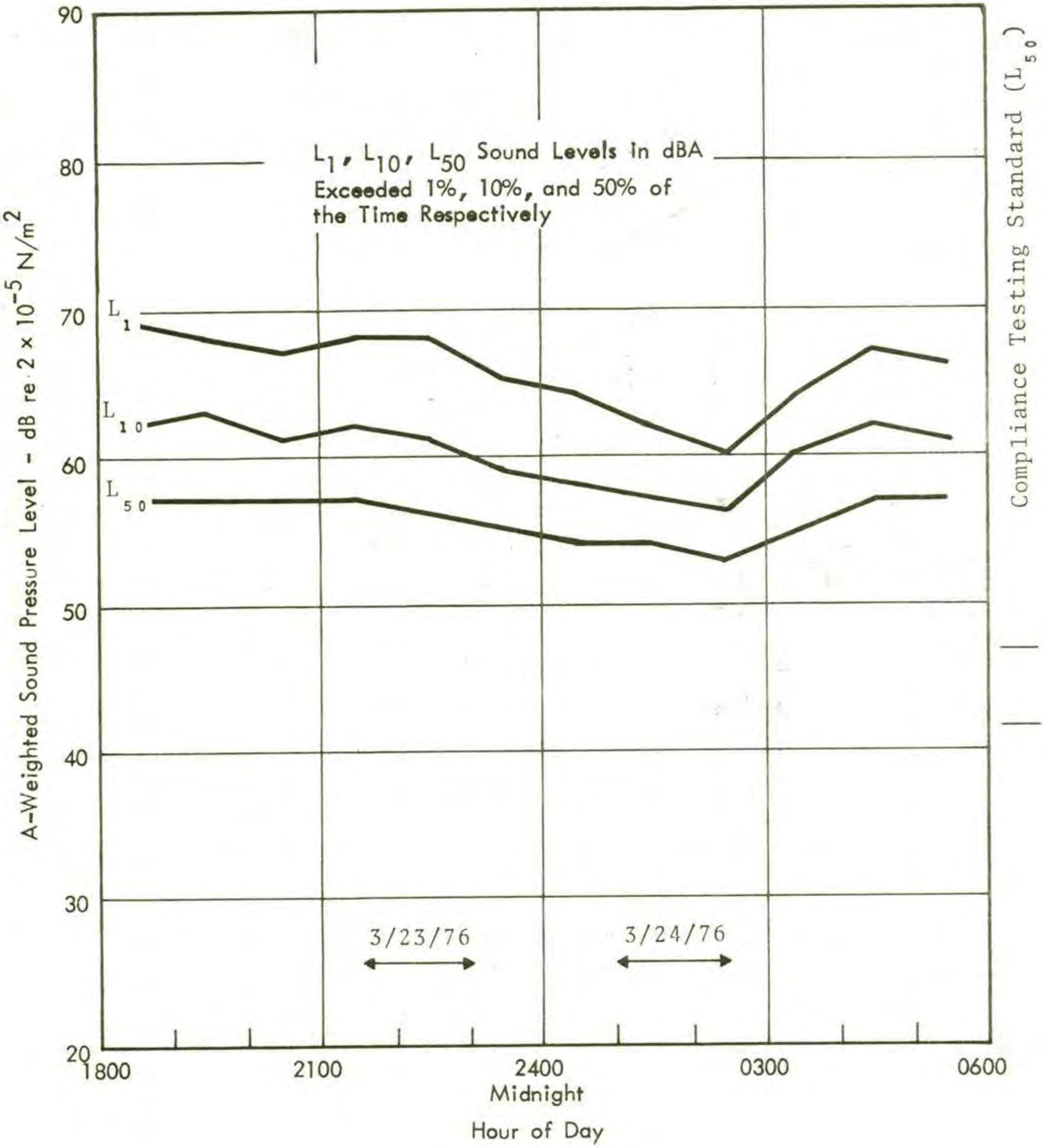


FIGURE C8.2 - MILL PLAIN SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

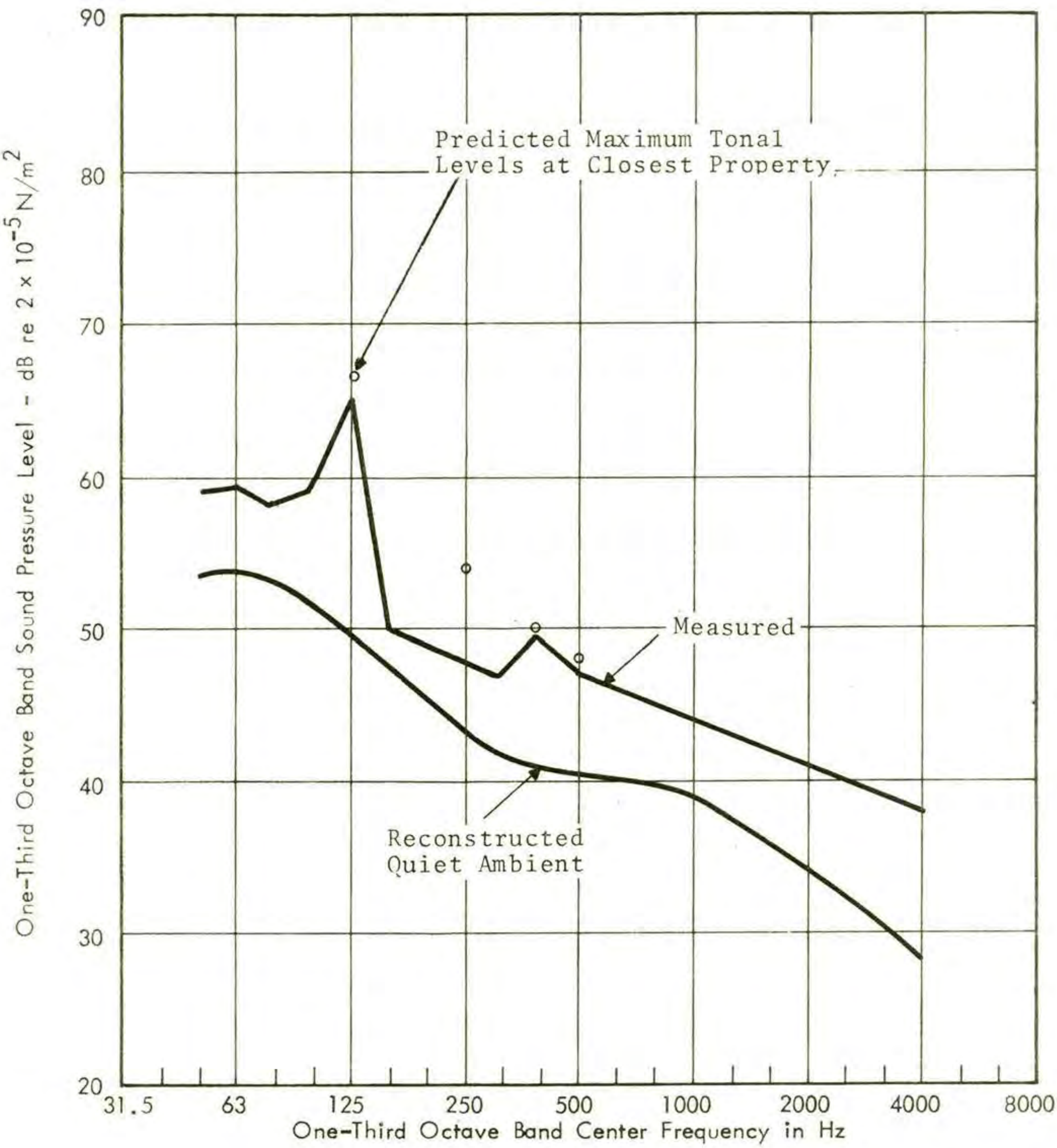


FIGURE C8.3 - MILL PLAIN SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS,
0300 TO 0400 HOURS

C9. OLYMPIA SUBSTATION

Olympia Substation is located 2 miles west of Tumwater in Thurston County, Washington. The substation is split into two parts: the 230 kV yard lies to the north of Trosper Road, while the 500 kV yard lies to the south.

The layout of the substation and some of the features of its environs are shown in Fig. C9.1. [redacted].

The situation of the substation is quite remote. There are a few residential properties on Trosper Road both to the east and west of the substation. The terrain is fairly flat and in most areas is heavily wooded. Future development to the north will be limited by transmission line easements. Further development to the east is likely in the future, but at distances no closer than at present. To the south and southeast of the 500 kV yard the land drops gradually. This area is heavily wooded and development in the foreseeable future would seem unlikely. Some of this land is or will be influenced by transmission line easements.

The land to the southwest and west of the 500 kV yard is again heavily wooded. This land apparently lies under the ownership of Burlington Northern Railroad Company. Future development is thought to be unlikely here also.

The major area for future development lies on or close to Trosper Road to the west and northwest of the 230 kV yard. Development however should not occur at distances which are significantly closer than at present.

FIELD SURVEY

The field survey was carried out over the period 31st March to 1st April. We were accompanied within the substation by Mr. Rowland (Chief Operator) and Mr. K. Watkins (Substation Design).

The weather during the survey period was generally dry with scattered showers. On the afternoon of 31st March the wind was at 6 mph from the northeast. Air temperature was 46°F and relative humidity, 80%.

[redacted]

• Close-In Measurements

The results of the 10 ft measurements on each of the [redacted] and the results of normalizing these to 500 ft are summarized in Table C9.2. [redacted].

• Perimeter Measurements

The results of the perimeter survey at the first two tonal frequencies are included in Fig. C9.1. These levels are in reasonable agreement with the close-in transformer data shown in Table C9.2.

• Community Measurements

Measurements were taken close to the two nearest residences, at Positions (a) and (b) as shown in Fig. C9.1. The results are summarized in Table C9.3.

• Microsample Data

Microsampling was carried out at the southeast corner of the 500 kV yard as shown in Fig. C9.1. The results are summarized in Figs. C9.2 and C9.3. The full computer output sheets are included in Appendix D.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

At the microsample location (within the 500 kV yard) and at Positions (a) and (b), representative of the closest residences, the substation is currently in compliance with the Washington noise regulations. This situation will not change with the energizing of Bank 3.

The compliance situation is less clear if we assume the possibility of more stringent future noise regulations. Based on our analysis of the various results of the field survey including those results obtained at Positions (a) and (b), we find the following.

1) For existing or future properties in the vicinity of Position (a), the appropriate standard (in the event of a pure tone clause) would be 42 dBA. A noise reduction of about 6 dBA below the present level would be required therefore. A satisfactory solution could probably be achieved by reducing the radiated level from the [redacted] *alone* by 10 dB at 120 Hz. Treatment of the [redacted] should be unnecessary.

2) For existing or future properties in the vicinity of Position (b) the appropriate standard would also be 42 dBA. This standard may currently be exceeded but only marginally. The BPA maintenance facilities appear to provide some shielding of both the 230 kV and the 500 kV yards.

Insofar as development elsewhere may be concerned, our analysis shows that *on average* the [redacted] generates a level of 51 dBA at a distance of 500 ft whilst the combined [redacted] generate a level of 52 dBA at the same distance. This latter level may be increased by 2 to 3 dBA when the [redacted].

The only area where problems of compliance with the existing Washington noise regulations (57 dBA) could arise would be on that land (owned by Burlington Northern Railroad Company) to the west of the [redacted] The more stringent compliance standards of 42 dBA and 47 dBA would of course cause problems over a much wider area of potential residential development.

RECOMMENDATIONS

The substation is currently in compliance with the noise regulations. Therefore no immediate noise control action is required.

We recommend that BPA keep a close watch on land transactions and planning applications around the substation. Those land parcels immediately to the east and to the west of the 500 kV yard would seem to be the most critical. BPA should consider the possibility of acquiring additional land as a "buffer" against future compliance problems.

It may be necessary in the future to provide some shielding around the [redacted]. In making forward plans for this BPA should plan on a full height barrier (lid height) shielding the area to the east. In the event that future residential developments appear likely in other areas, it may be advisable to extend this barrier to provide the necessary shielding.

[redacted] NR [redacted].
Noise should certainly be considered in finalizing the location, layout, and purchase specification for this unit.

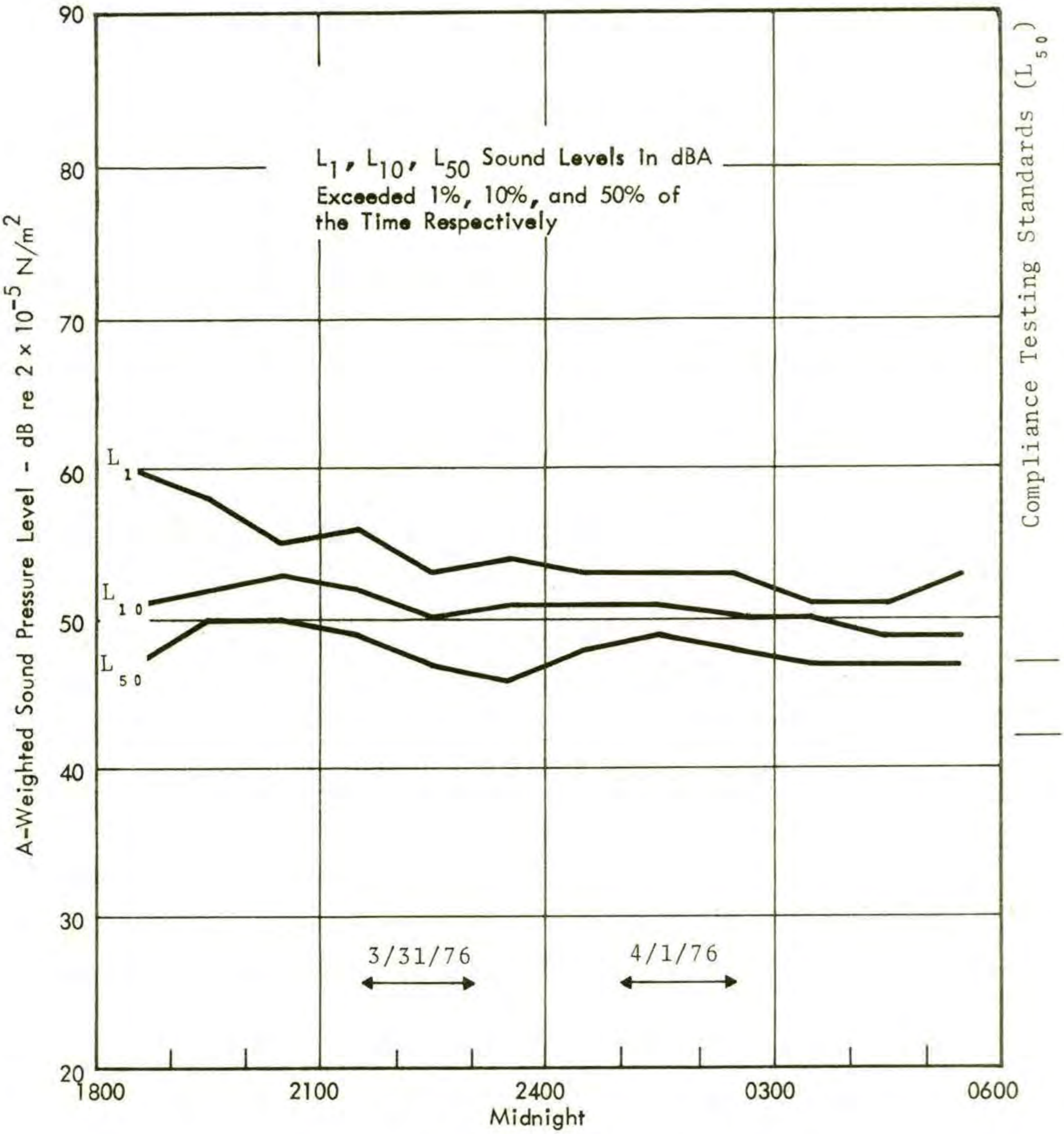


FIGURE C9.2 - OLYMPIA SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

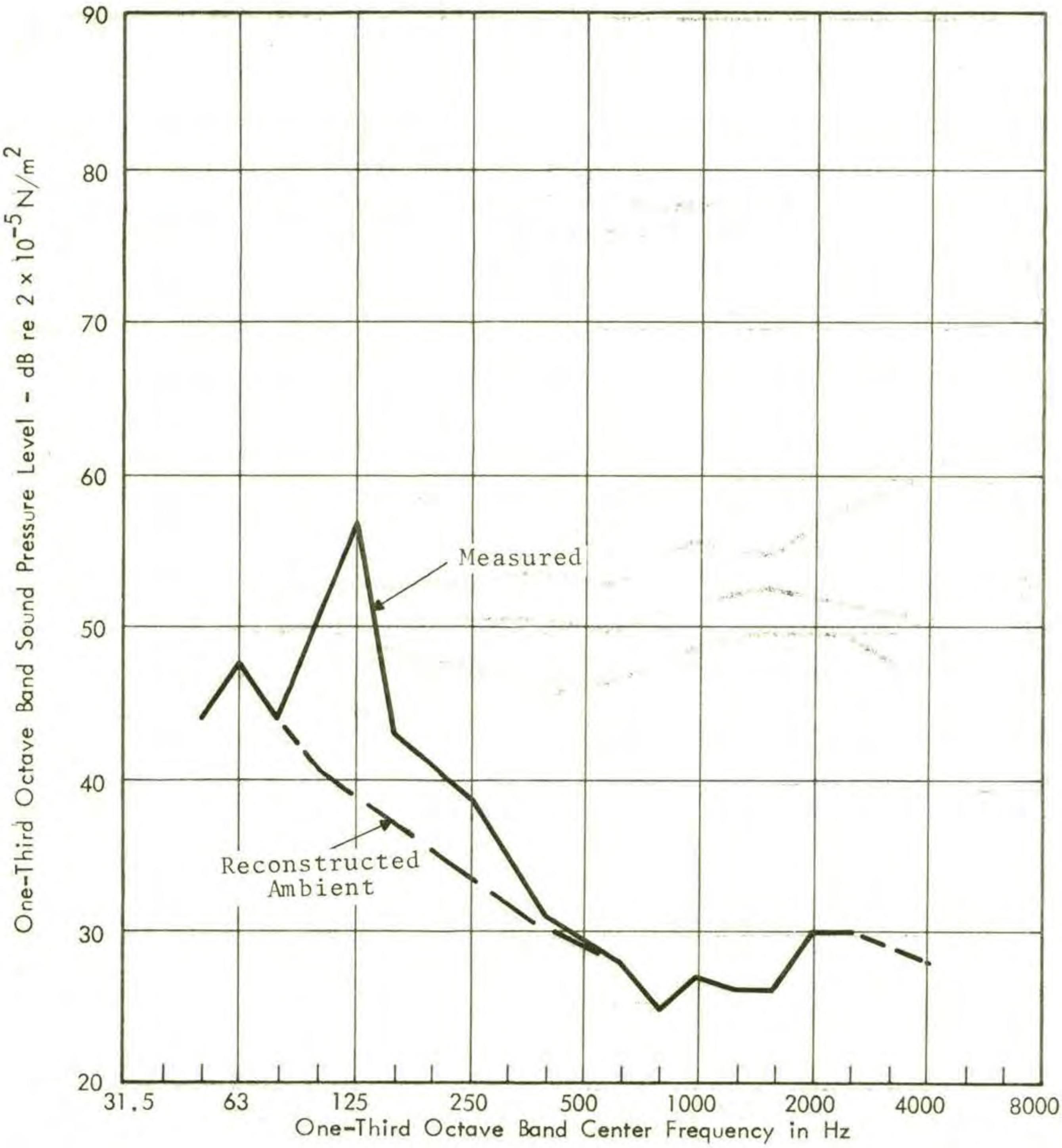


FIGURE C9.3 - OLYMPIA SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS
0300 TO 0400 HOURS

C10. PORT ANGELES SUBSTATION

Port Angeles Substation lies in Clallum County, Washington, southeast of the city of Port Angeles, and one mile south of U.S. Highway 101.

Figure C10.1 shows the layout of the Port Angeles Substation and indicates some of the major features pertinent to this study. [redacted]

The main features and uses of the surrounding land can be described as follows:

The terrain around the substation is effectively flat over a wide area.

Directly to the north of the substation on the far side of Park Road, the land use is limited by easements in connection with the outgoing 69 kV lines. To the northwest and west there are residential properties as indicated in Fig. C10.1.

To the northeast and east there is a college. The closest college buildings lie at a distance of about 300 ft from the perimeter fence. The southern part of the college property is at present planted heavily with trees. There is a small Pacific Power and Light (PPL) substation between the college and the BPA yard.

The BPA property line to the south lies at a distance of 400 ft from the substation fence. The use of land further to the south and also to the southeast is limited by easements in connection with the 230 kV incoming transmission lines. There is a substantial number of residential properties to the southwest.

Some future residential developments, of a fill-in nature, may be expected to the southwest, west, and northwest of the substation. In particular, the plot of land lying to the west of Porter Street between Highland Avenue and Park Road would appear suitable for development. None of these developments would be closer to the substation than existing properties. A more critical future situation would arise if the tree covered property (thought to be owned by the college) to the east and southeast of the substation were to be developed. The consequences of this will be discussed in this report.

FIELD SURVEY

The field survey was carried out over the period 30th to 31st March 1976. We were accompanied within the station by Mr. Elliot (Chief Operator) and Mr. Munro (Operator in Charge).

During the afternoon of 30 March the weather was wet and squally. In the evening and during the night the conditions improved and by morning the weather was sunny with scattered clouds. The wind had abated to 6 mph from the northeast. The air temperature was 44°F; the relative humidity was 64%. The weather conditions were acceptable during microsampling.

• Close-In Measurements

The results of the 10 ft measurements on the transformers are summarized in Table C10.2. This table shows the results of

These data are summarized in Table C10.3. A typical narrow band spectrum at Position (a) is given in Fig. C10.2.

• Microsample Data

Microsample data were obtained at the southwest corner of the yard. The results are summarized in Figs. C10.3 and C10.4. Ambient reconstruction is based on the analysis with the notch rejection filters.

The full computer output sheets are included in Appendix D.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The substation is in compliance with the Washington noise regulations. Based on our estimated values for [redacted] the substation will remain in compliance when this new transformer is energized.

In order to analyze the situation, given the more stringent compliance standards developed and discussed in the main study report, we have attempted to separate the environmental noise contributions from the individual transformer banks.

We find that at the reference distance of 500 ft, the [redacted] generates a level of about 41 dBA. The 120 Hz and 240 Hz components are both significant contributors to the loudness level. [redacted]s the noisier of the two units.

We find that at the 500 ft distance [redacted] generates a level of 45 dBA. This may increase to 49 dBA when [redacted] is energized. Again both the 120 Hz and 240 Hz components may be important contributors to the loudness of the [redacted].

Based on the reconstructed ambient levels given in Fig. C10.4 we are of the opinion that a target level of 47 dBA would probably satisfy future legislation trends. Taking this as a design standard, together with the 500 ft *estimated* levels given above, we foresee the following needs for noise control.

1) For those closest properties on Porter Street a compliance problem of about 4 dBA would arise. Attenuation of the Bank 4 transformer by 10 dBA would produce a situation close to acceptance.

2) For existing properties further to the south on Porter Street or for future developments close to the BPA southern property line no compliance problem is anticipated.

3) In the event of residential developments close to the BPA eastern boundary (in the wooded area to the south of the college) a 6 dBA compliance problem may be expected. This would be resolved by a 10 dBA attenuation of the Bank 4 transformer.

4) The 47 dBA standard would not apply to the college buildings since these are intended for daytime occupation only.

5) A 5 dBA compliance problem is estimated in the event of developments on the north side of Park Road, directly to the north of the substation. This would be almost resolved by attenuation of the [redacted] by 10 dBA. This estimate does not take account of shielding that may arise because of substation hardware. Further, it would seem that residential developments would be unlikely in this area.

6) No compliance problem is anticipated at that property to the northwest of the yard.

It should be noted that these analyses suggest that the extent of future noncompliance will depend entirely upon the noise output from the [redacted]. The attenuation requirements quoted are based on what we consider to be the average noise characteristics of this size and type of unit.

RECOMMENDATIONS

There is no present need for noise control at the Port Angeles Substation. [redacted].

Even given stricter environmental noise standards we anticipate no need for future control to the existing [redacted]

[redacted].

In the event that its noise characteristics lie close to the characteristics quoted in Table C10.2, then design (layout) and planning steps should be taken for noise control. The eventual treatment would probably involve barrier walls to the west and also to the east--the latter depending upon development plans in the wooded area. The need for treatment is unlikely to the south, but some treatment (i.e., barriers) may be required to the north.

We recommend that BPA remain cognizant of land transactions and planning applications in areas surrounding the substation.

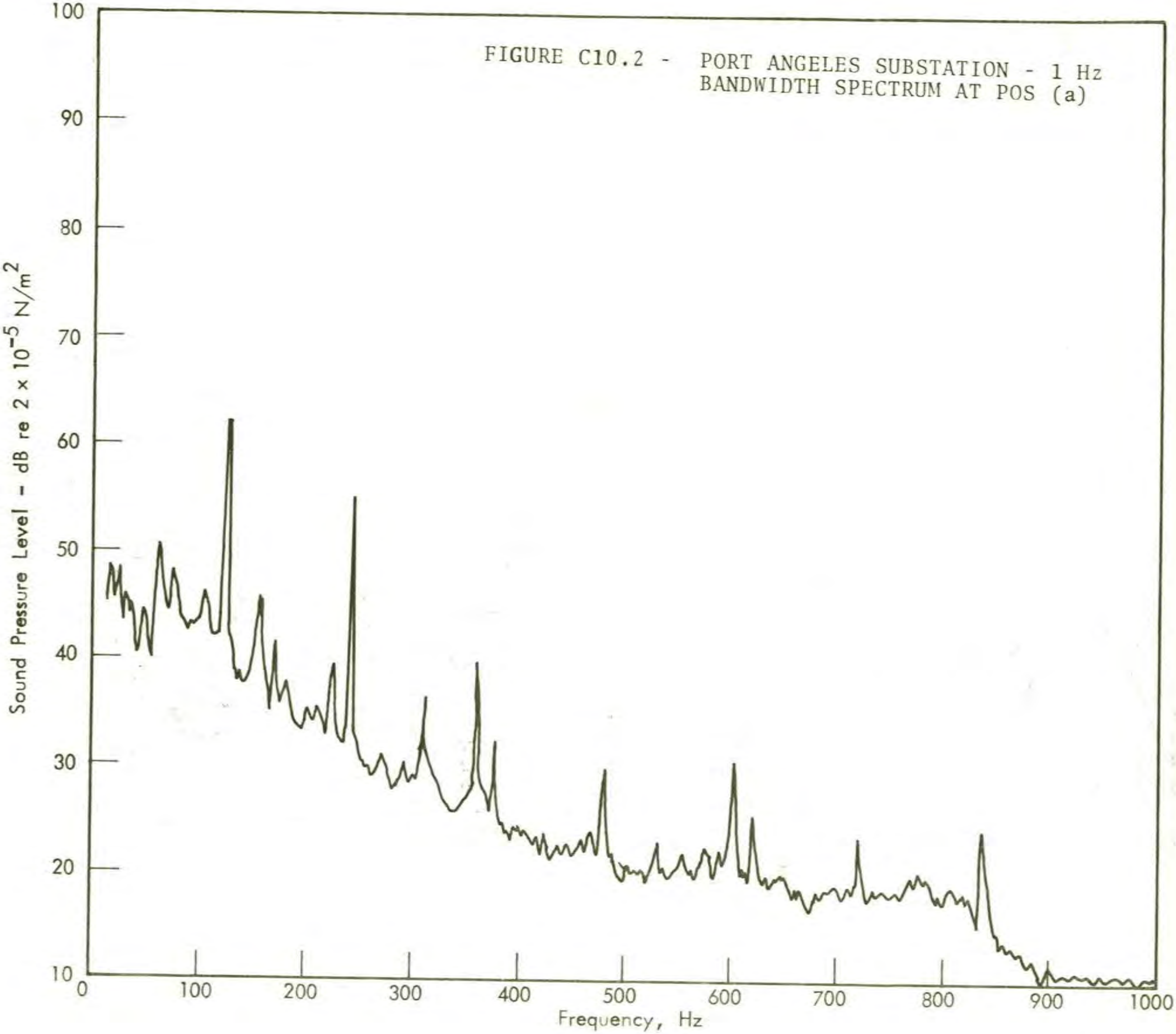


FIGURE C10.2 - PORT ANGELES SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POS (a)

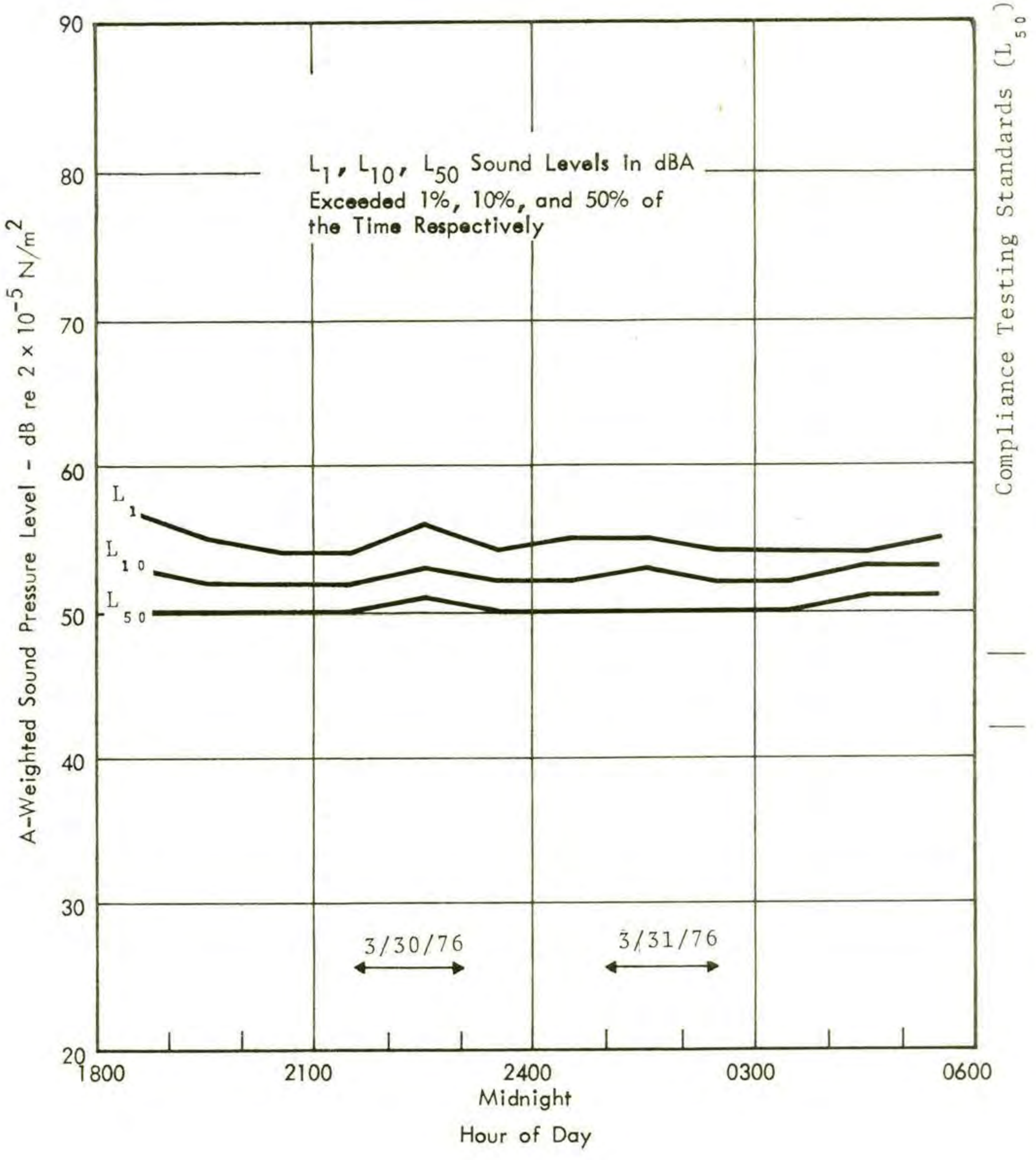


FIGURE C10.3 - PORT ANGELES SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

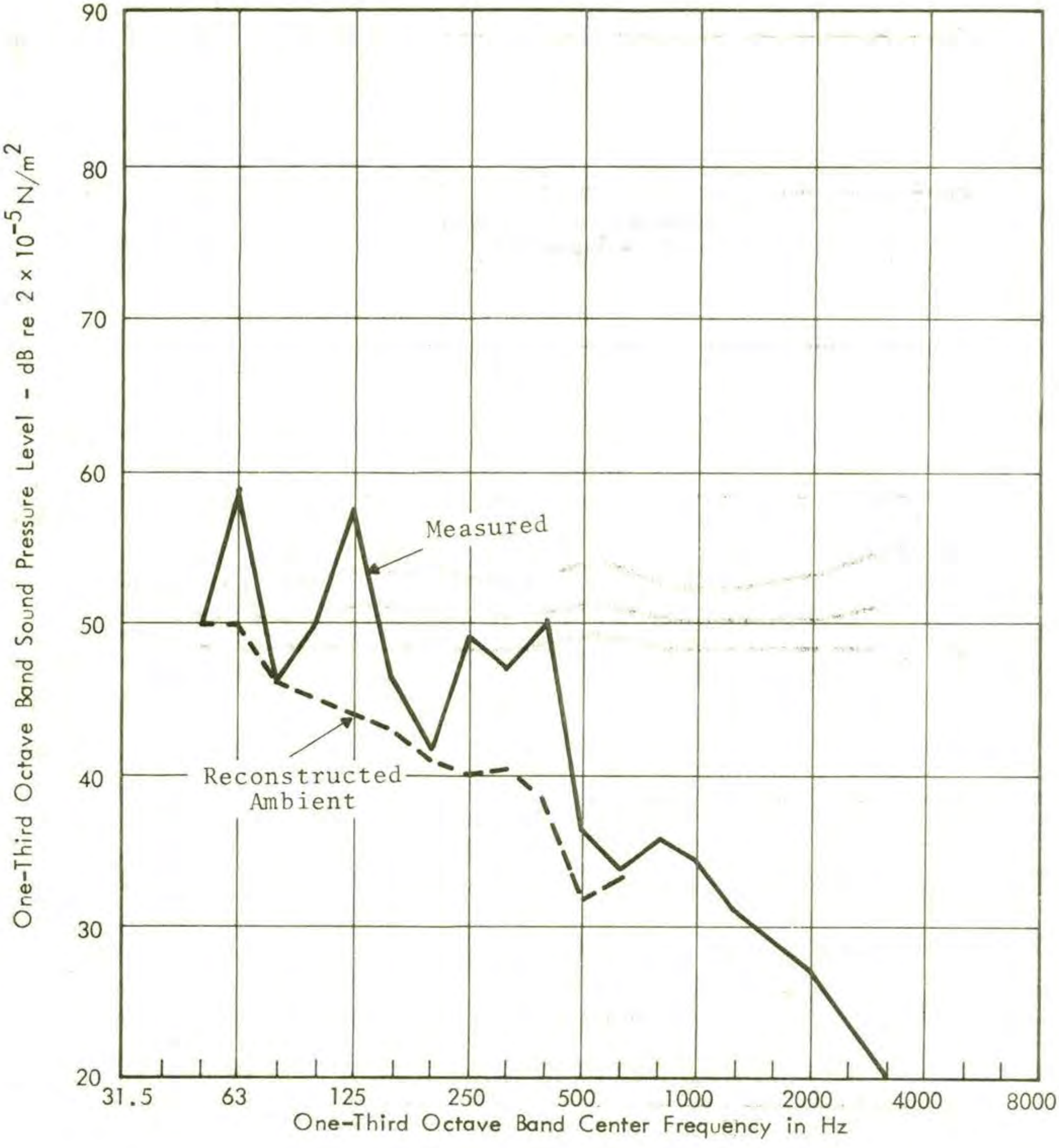


FIGURE C10.4 - PORT ANGELES SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS
0300 TO 0400 HRS.

C11. RITZVILLE SUBSTATION

Ritzville Substation lies to the northwest of the center of Ritzville, close to the junction of Marcellus Road and Rosenhoff Road in Adams County, Washington. The layout within and around the substation is shown in Fig. C11.1. [redacted] Some details are also given of the [redacted] operated by Washington Water and Power Company in the small yard to the south of the BPA facility. [redacted]. These however are not sufficiently noisy to be a problem at this time.

The terrain on which the substation sits slopes gently towards the south.

The closest property to the substation is a house immediately to the east at a distance of about 100 ft from the substation fence. This house is at present being remodeled. There are several other properties further to the east on Olive Street. There are a few properties also on the south side of Fir Avenue, and in the vicinity of the junction of Marcellus Road and Rosenhoff Road to the southwest of the substation. [redacted].

A farmhouse is located on the cultivated land to the west of Marcellus Road. A shallow gully between the farm buildings and the road would appear to make this land unsuitable for residential development.

The land to the north and to the northeast of the substation is at present farmed. It would appear to be suited for future development.

The triangle of land between Marcellus Road, Olive Avenue, and Fir Avenue contains no development at the present time. However the BPA Drawing E4843 suggests that future development is planned here and also further to the east--as part of "Jensen's Addition". These plans are not confirmed by our local enquiries. At any rate, such developments would not bring properties any closer to the BPA transformer than at present. Future developments in this triangular area would pose problems for the Washington Water and Power Company.

Our enquiries have shown that there are currently no specific projections for residential development in the vicinity of the Ritzville Substation.

FIELD SURVEY

The field survey was carried out over the period 18th to 19th March, 1976. We were accompanied within the substation by Mr. B. Carney and Mr. W. Pratt (BPA Operators).

The weather during most of the survey was fine. The sky was overcast on the afternoon and during the night of 18th March there was virtually no wind. By midmorning on the 19th the wind has risen from the southwest and was gusting up to 15 mph. On the morning of the 19th the air temperature was 48°F and the relative humidity was 72%.

• Close-In Measurements

The results of the measurements at 10 ft from the transformer bank are given in Table C11.2.

. Perimeter Measurements

The results of the perimeter survey are included in Fig. C11.1. These values give normalized levels at 500 ft of 56 dB at 120 Hz and 21 dB at 240 Hz. These levels are in good agreement with the predicted levels in Table C11.2.

. Microsample Data

The microsample survey was carried out at the position shown in Fig. C11.1. The results are presented in Figs. C11.2 and C11.3. The full computer output sheets are given in Appendix D. The tonal level of 63 dB at 120 Hz normalizes to a 500 ft level of 54 dB. This is in good agreement with the findings of the close-in and perimeter studies.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Ritzville Substation is in compliance with the present State noise regulations. However, it is in default of the standards which may arise in the future. Because of the strong tonal component at 120 Hz and the very quiet ambient typical of this area, the appropriate secondary (future) compliance standard is 42 dBA.

The small differences between the percentile levels shown in Fig. C11.2 are a clear indication that the environment at the microsampling location is entirely dominated by the substation transformer. The dominance of the tonal components is further confirmed by the computer output data using the notch rejection filter (see Appendix D).

A minimum attenuation at the closest property of 6 dB at 120 Hz is required. Our data indicate that properties to the southeast, to the southwest, and to the west of the substation are currently in accord with the 42 dBA standard.

[redacted] is not currently a significant source of noise at the eastern residential property. It is, however, a significant contributor at those properties to the southeast. In the event (considered unlikely) of future development on the northwest side of Fir Avenue an acceptable noise control program would involve action by WWP.

RECOMMENDATIONS

The substation is currently in compliance with the law insofar as the State of Washington noise regulations are concerned. Tested against the stricter standards which we feel could be applied in the future, the substation is not in compliance.

We recommend therefore that action be taken, at least of a long-range planning nature, to design and erect an L shaped barrier of height equal to the lid height (about 12 ft) to provide shielding to the east [redacted]

In addition, BPA should become cognizant of development plans in the area--especially in that part indicated on the site plan as "Jensen's Addition."

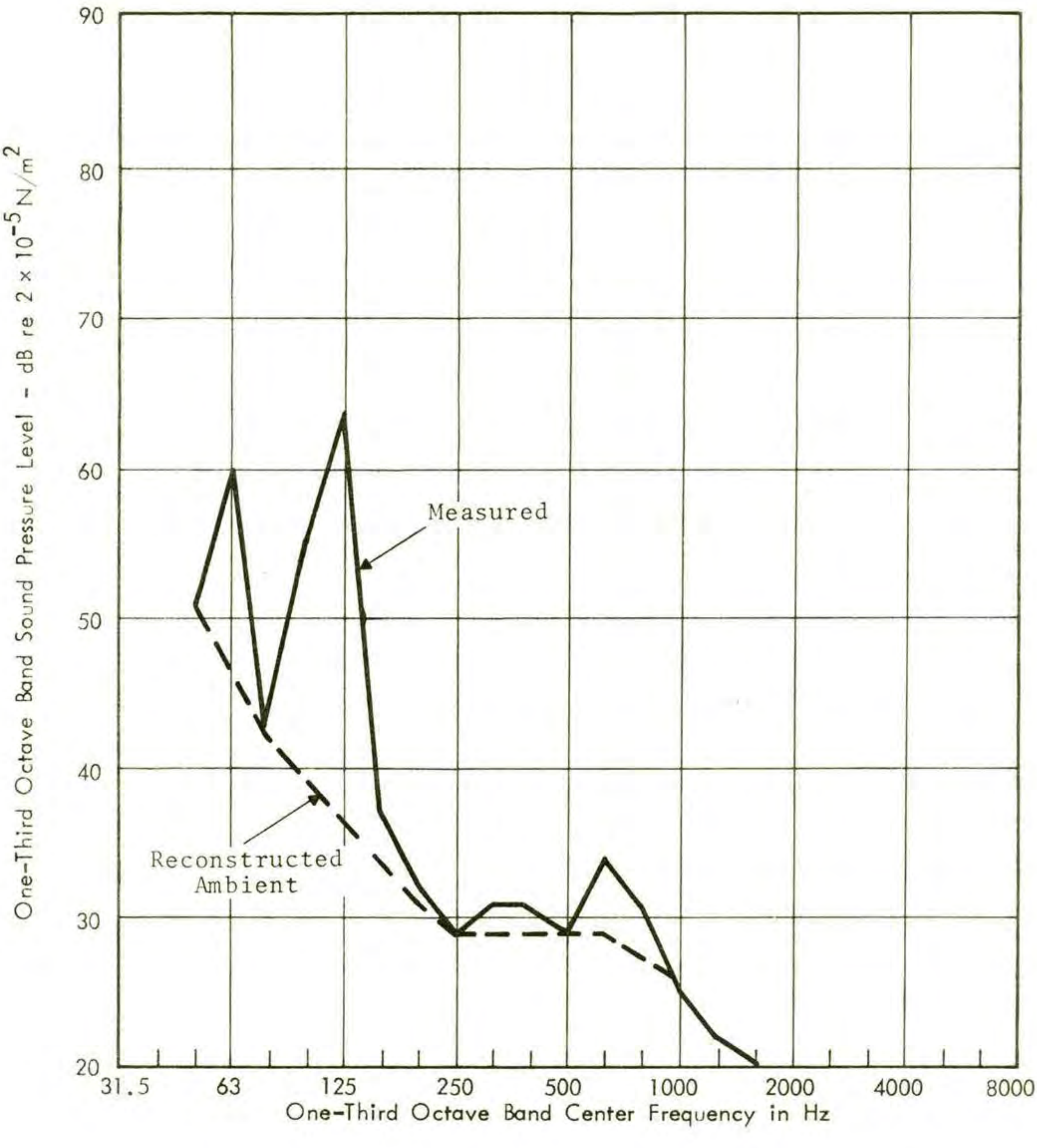


FIGURE C11.3 - RITZVILLE SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS
0300 to 0400 HOURS

C12. J. D. ROSS SUBSTATION

J. D. Ross Substation is located about 2 miles north of Vancouver in Clark County, Washington. There are many BPA facilities located on the site and the land holding by BPA around the 345 kV yard, which formed the subject of this study, is very substantial. The layout of the substation and some of the features around the substation are shown in Fig. C12.1. [redacted]

The terrain around the substation is gently rolling in character. The only area of likely concern lies to the east and southeast of the 345 kV yard. Here the land rises fairly abruptly to an elevation of about 40 ft above the yard grade level; several properties on the west side of N.E. 18th Avenue overlook the transformer bank (see Fig. C12.1). No future residential developments are possible which would affect the current noise situation.

FIELD SURVEY

The field measurements were carried out over the period 4th to 5th March 1976. We were accompanied within the substation by Mr. Lyle Howard (Substation Design).

The weather during the survey was sunny with scattered clouds. On the afternoon of 4th March the air temperature was 49°F and the relative humidity was 60%. The wind was from the west at 5 to 7 mph.

- Close-In Measurements

The results of the measurements at 10 ft are shown in Table C12.2.

• Perimeter Measurements

The results of the perimeter measurements are shown in Fig. C12.1. Over the southern section of the perimeter the results are affected by acoustic shielding provided by the cable drums in the storage area. The northern section data normalize to average levels at 500 ft of 64 dB at 120 Hz and 61 dB at 240 Hz. These levels are in reasonable agreement with the results in Table C12.2.

• Community Measurements

Data were acquired at the three positions shown in Fig. C12.1, as follows:

a) Close to the 345 kV Tower to the east of the yard, 40 ft above yard datum,

b) On the BPA property line to the southeast, 20 ft above datum,

c) East of the yard access road, 20 ft above datum.

These data are summarized in Table C12.3. The 120 Hz sound pressure level at Position (b) is indicative of destructive interference reflections from the cable drums in the storage yard. Otherwise the data are fairly consistent with the 120 Hz, 240 Hz, and A-weighted levels measured at 10 ft from the transformer bank and on the yard perimeter. A typical 1 Hz bandwidth spectrum at Position (c) is given in Fig. C12.2.

• Microsample Data

The microsample was obtained in the backyard of the closest residential property, as shown in Fig. C12.1. The data are summarized in Figs. C12.3 and C12.4.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The microsample data are consistent in level with those data gathered elsewhere. On the basis of these measurements we conclude that *on average* in the general southeasterly direction the 500 ft tonal level is about 52 dBA; this level is contributed to equally by the 120 Hz and the 240 Hz components. The higher harmonics are of secondary importance.

The present Washington noise regulations are clearly satisfied. In the event that more stringent regulations, of the form discussed in the main report, are introduced, a compliance problem will arise.

The ambient levels in this area are such that the 42 dBA compliance standard would probably apply. Potentially, therefore, a 10 dBA noise reduction would be required. The design of noise control must take account of the height of the noise sensitive properties above the 345 kV yard datum.

RECOMMENDATIONS

No noise control is required at the present time.

A need for noise control, amounting to 10 dBA at those properties to the southeast of the yard, may arise in the future. We recommend that BPA take account of this potential requirement. A single "L" shaped barrier screening the bank would probably be sufficient. The barrier would extend about 2 ft above the transformer lid height.

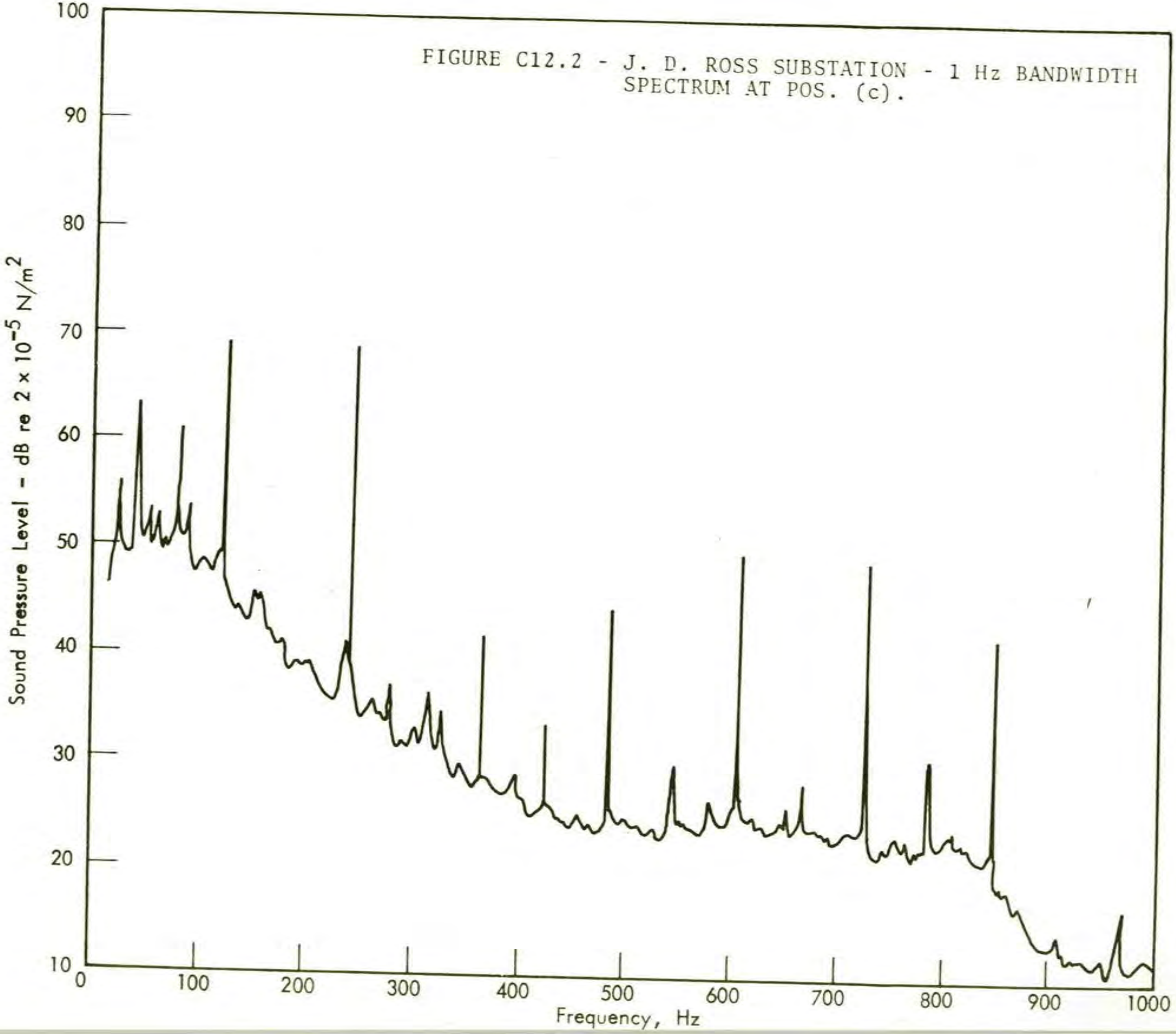


FIGURE C12.2 - J. D. ROSS SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POS. (c).

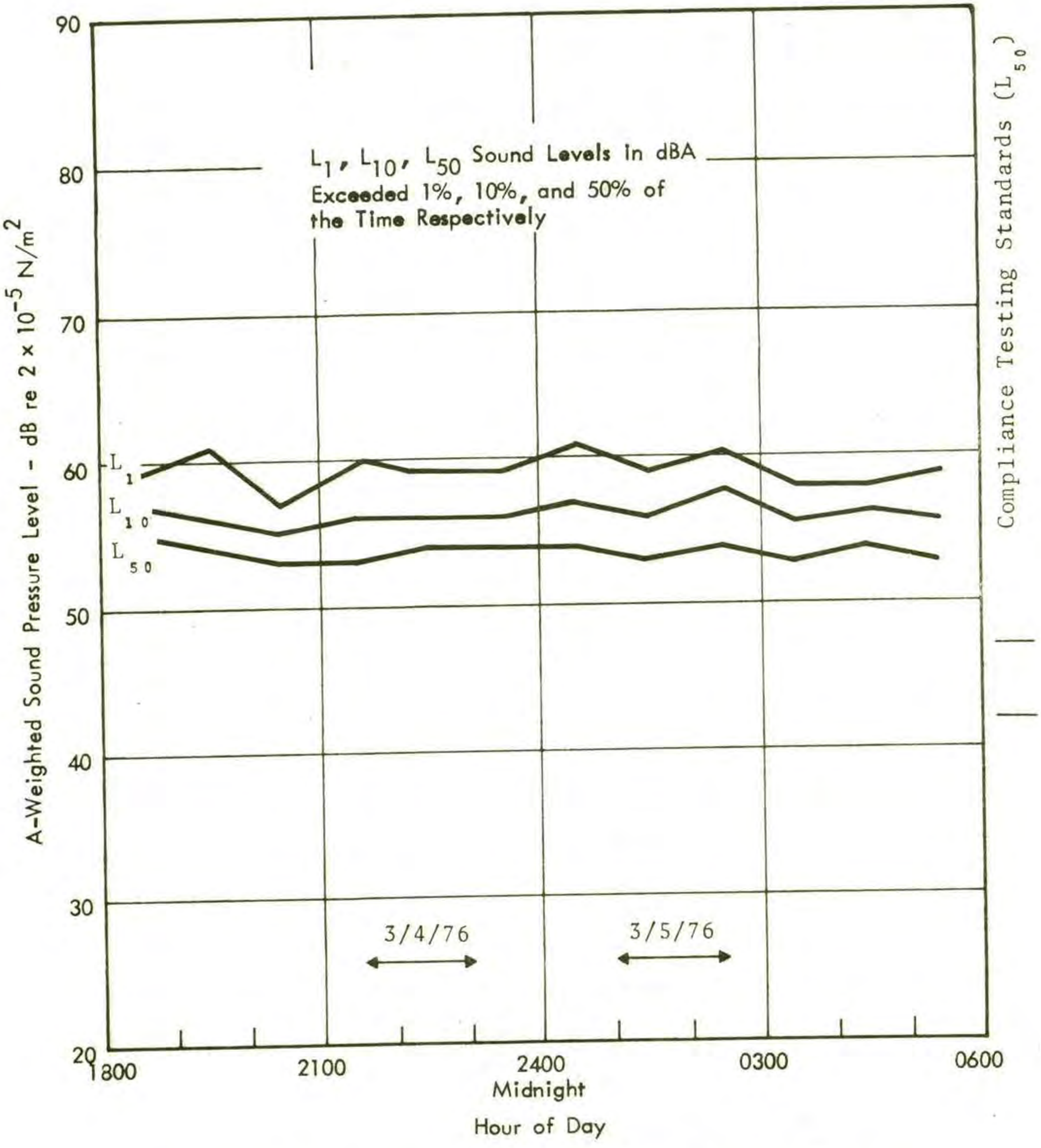


FIGURE C12.3 - J. D. ROSS SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

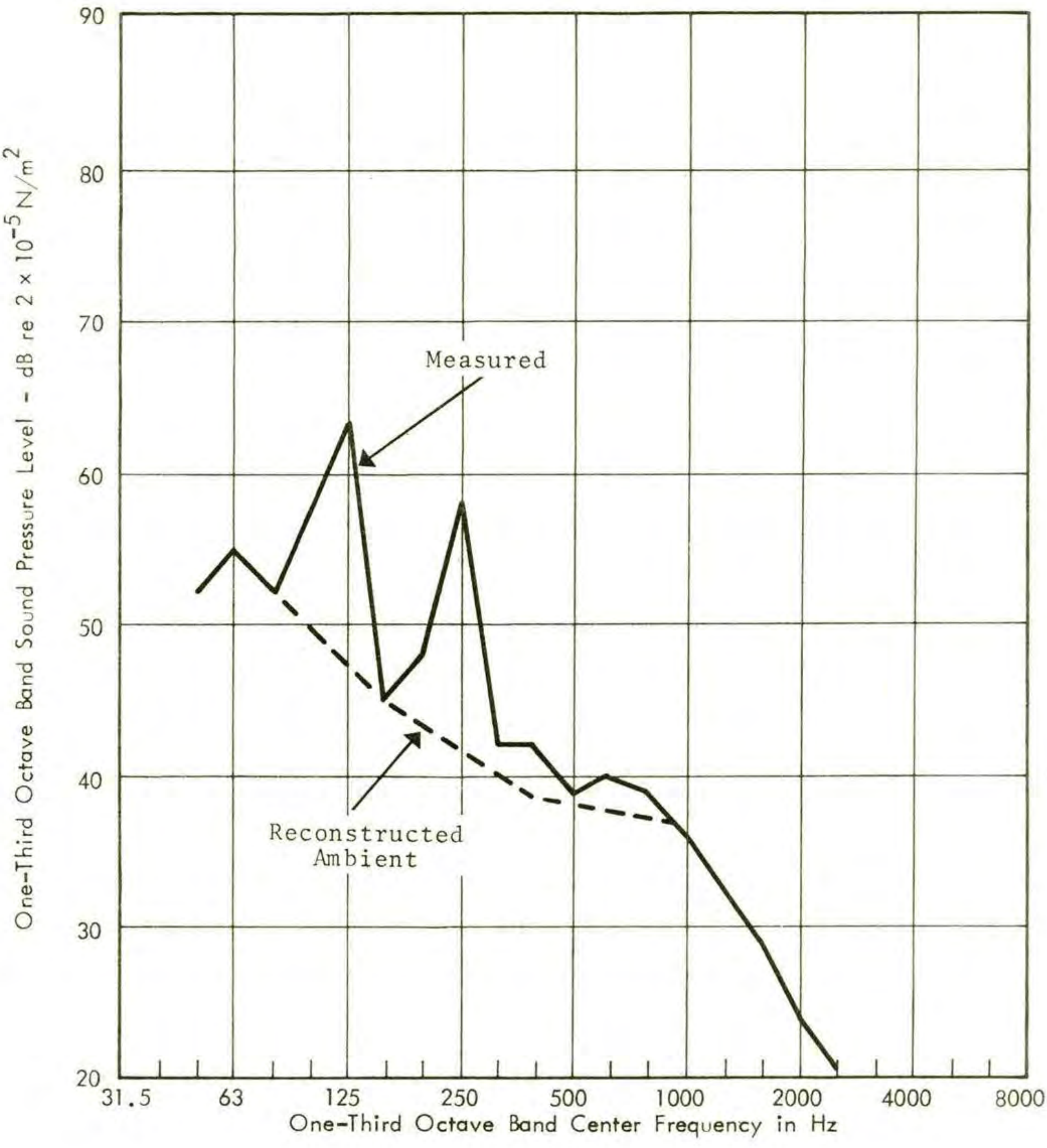


FIGURE C12.4 - J. D. ROSS SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS
0300 to 0400 HOURS

C13. SIFTON SUBSTATION

Sifton Substation is located nine miles northeast of Vancouver, in Clark County, Washington. It lies about 2 milcs south of State Highway 500.

The layout of the substation and its relationship to the surrounding environs are given in Fig. C13.1. [redacted].

The primary land use around the substation is agriculture. There are few residential properties; the closest lie on the east side of 162nd Avenue at a distance of about 1400 ft from the transformer. At the present time there is no sign of planned residential development in this area, although it is likely that some will occur in the next ten to fifteen years.

The BPA property ownership around the yard is very restricted. Future developments to the south and north of the yard will be restricted by transmission line easements. In the most adverse case development could arise on the east and west property lines at a distance from the transformer of only 400 ft.

The terrain slopes gently downwards from the south to the north.

FIELD SURVEY

The field survey was carried out over the period 22nd to 23rd March 1976. Further observations at the site were made on 11th May 1976. The weather during the March survey was cloudy with periods of rain. The wind was from the southwest at 4 mph. Air temperature on the afternoon of 22nd March was 44°F; the relative humidity was 98%.

At the time of both visits to the site the transformer was in process of installation and had not yet been energized. The purpose of the survey, therefore, was simply to establish the character of the noise ambient in the vicinity of the substaion.

• Microsample Data

The microsample measurements were carried out at the position shown in Fig. C13.1. The results are summarized in Figs. C13.2 and C13.3. It should be noted that electromagnetic pick-up at 60 Hz from the substation bus-bars and lines (see Fig. C13.3) influences the recorded dBA levels in Fig. C13.2. The appropriate corrected L_{50} level at the quietest nighttime condition is indicated in Fig. C13.2.

TRANSFORMER PREDICTIONS

[redacted] Based on our analyses of the close-in data on these units we predict the following levels at a distance of 500 at in the absence of shielding or ground attenuation effects.

dBA	SPL (dB re $2x10^{-5}N/m^2$)			
	120 Hz	240 Hz	360 Hz	480 Hz
50	57	54	51	48

The A-weighted noise level applies to the first four tonal components only. The possibility of significant higher frequency tonal components or of significant fan noise is neglected, on the basis that these rarely have been encountered at significant levels in our field experience. The NEMA specification level for this size of transformer is 86 dBA. At a 500 ft distance this would correspond to a level of about 55 dBA. The agreement is considered reasonable. We shall use the levels tabulated above as the basis for our compliance analysis, remembering of course that the transformer could be noisier than the average transformer assumed.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The natural environment around the substation is such that, in the event that stricter noise regulations having the form discussed in the report are introduced, it is the 42 dBA standard which would apply. We shall therefore base our analysis upon the existing 57 dBA Washington regulation and upon the 42 dBA compliance standard.

[redacted] At this distance we predict that the tonal level *on average* will be 41 dBA in the absence of ground attenuation effects. Thus the situation will clearly be in compliance with the existing regulations; it should remain in compliance for those properties even given the much stricter noise regulation standard.

[redacted]. Given this situation a potential for noncompliance amounting to 10 dBA (on average) could arise in the future with respect to the 42 dBA compliance standard. No problem should arise however with respect to the present State regulation.

RECOMMENDATIONS

We recommend that BPA undertake noise measurements [redacted]- [redacted] (which is now in service) to determine its noise characteristics. These measurements should be carried out at the close-in positions used in our survey (on other transformers) and at greater distances also.

We recommend also that BPA make themselves cognizant of trends in residential developments in this area so that the potential for developments arising close to the substation can be better assessed. Depending upon the outcome of these recommendations, and depending upon the views of the State as regards the future revisions to their standards, it may be necessary to make long-range plans to erect a full height barrier on one or more sides of the transformer.

No requirement for noise control is indicated at the present time, however.

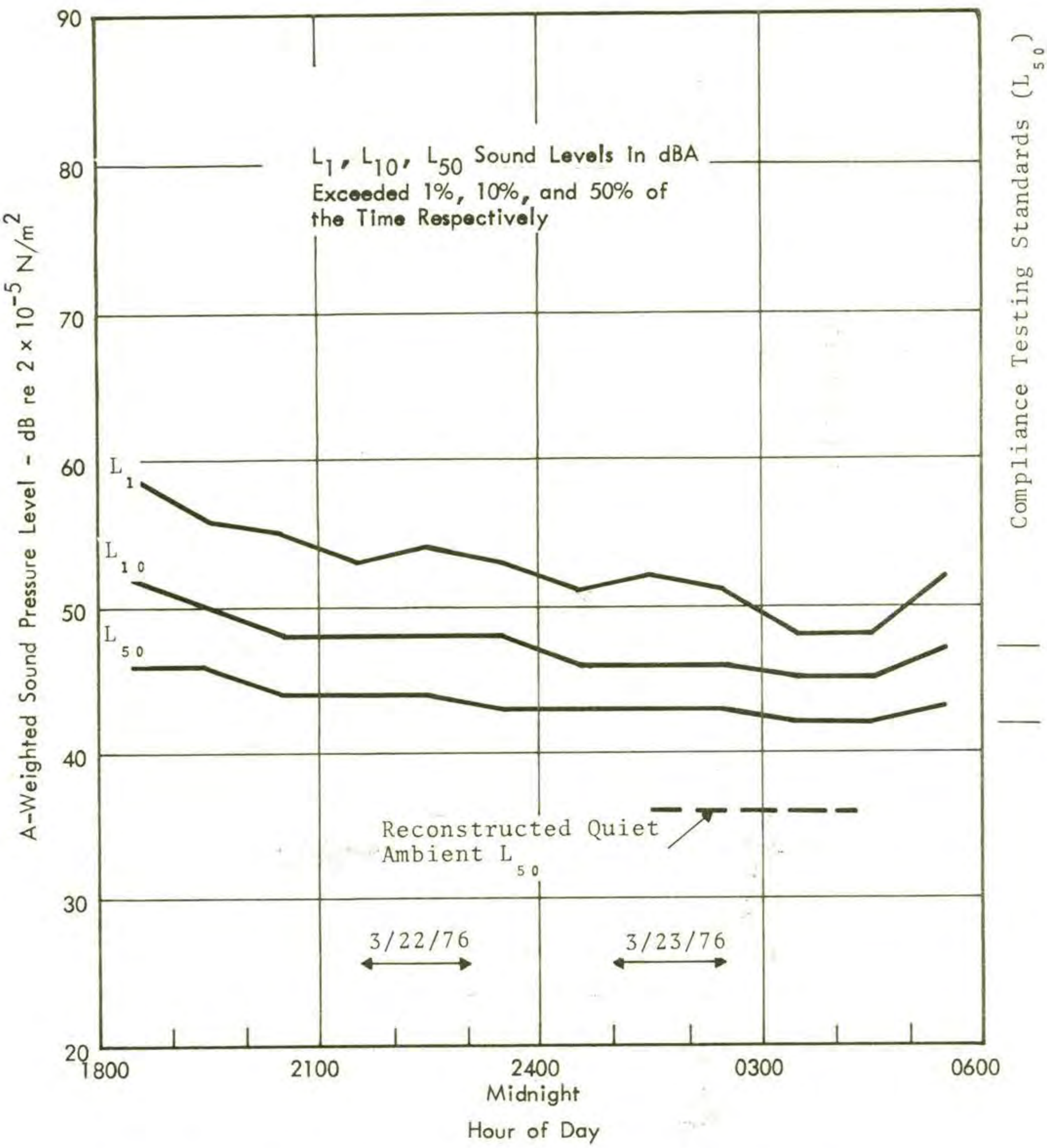


FIGURE C13.2 - SIFTON SUBSTATION - MICROSAMPLE LEVEL VERSUS TIME OF DAY

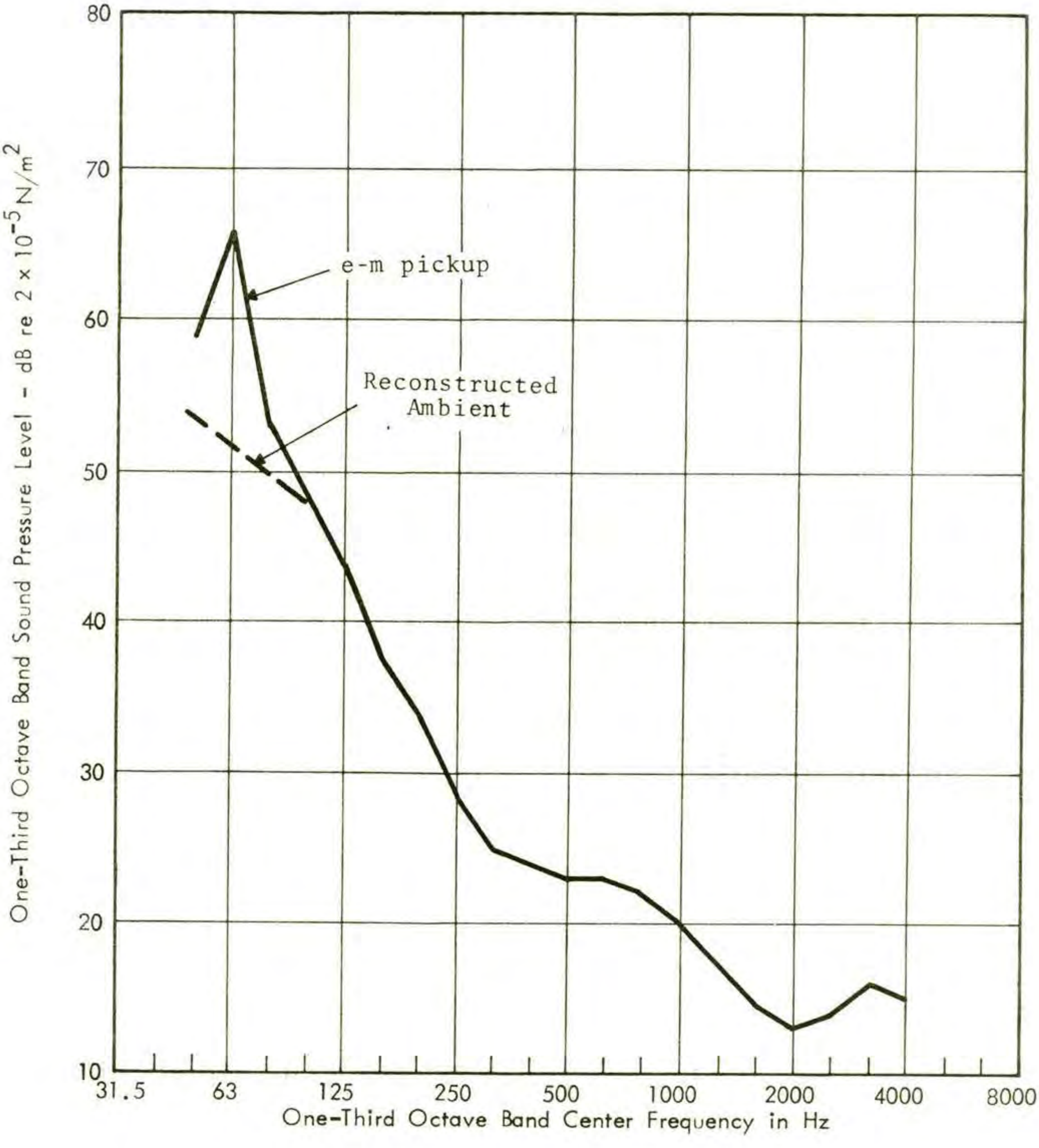


FIGURE C13.3 - SIFTON SUBSTATION - MICROSAMPLE (L_{50})
ONE THIRD OCTAVE BAND LEVELS
0300 TO 0400 HOURS

C14. SNOHOMISH SUBSTATION

Snohomish Substation lies in Snohomish, Snohomish County, Washington. The BPA property is bounded on the west by State Highway 9 and on the east by Federal Highway 2.

The layout of the substation and its location with respect to surrounding properties are shown in Fig. C14.1.

[redacted]

The land to the west, north, and east of the yard is fairly flat. BPA land ownership to the west extends to Highway 9. To the north the land use is restricted by easements associated with the substation transmission lines. The closest existing residential properties lie to the northeast as shown in Fig. C14.1. BPA land ownership on the east extends to Highway 2.

The land rises to the south of the substation; those properties to the north of 7th Street are hidden from view of the substation by the brow of the hill. The BPA land holding to the south extends to the top of the hill.

There would appear to be little likelihood of future residential developments at positions closer than existing properties.

FIELD SURVEY

The field survey was carried out over the period 27th to 29th March 1976. We were accompanied within the substation by Mr. John Lynam (Operator).

The weather during the measurements on the afternoon of 27th March was overcast but dry. Wind was from the southeast gusting to 10 mph. The air temperature was 45°F and the relative humidity was 79%.

• Close-In Measurements

The results of the 10 ft measurements on each of the transformer banks are shown in Table C14.2.

• Perimeter Measurements

The results of the perimeter measurements at the first two tonal frequencies are shown in Fig. C14.2

Based on the distance from the [redacted], the data on the southern boundary normalize to 500 ft levels of 67 dB at 120 Hz and 57 dB at 240 Hz. These levels are in good agreement with the normalizations of Table C14.2. Data on the northern perimeter, normalized according to the distance from the [redacted], give average levels of 65 dB at 120 Hz and 59 dB at 240 Hz. Again these are in reasonable agreement with Table C14.2.

• Community Measurements

Measurements were taken at the following positions.

a) On 97th Street at a position 1500 ft from its junction with Highway 2,

b) On the brow of the hill, due south of the station, and

c) 200 ft south from the brow, in line with the properties to the north of 7th Street.

These data are summarized in Table C14.3.

• Microsample Data

The position selected for microsampling was the most northerly corner of the shunt capacitor yard as shown in Fig. C14.1. Because of suspected instrumentation problems the microsampling carried out on the night of the 27th March was repeated on the night of the 28th March. It is the latter data which are used in this study.

The data are summarized in Figs. C14.3 and C14.4. The full computer output sheets are included in Appendix D.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The dip in the L_{50} level shown in Fig. C14.3 in the 2300 to 2400 hour period may be associated with a loading condition on one or more of the transformer banks. It is certainly not representative of a normal operating condition and so is not considered in this analysis.

An analysis of our data indicates that on average the noise level generated at 500 ft from the [redacted] is 50 dBA and that this is dominated by the strong 240 Hz component radiated from these banks. The level at 500 ft from the Bank 1/2/3 cluster is 52 dBA, this being dominated by radiation at 120 Hz.

All existing residential areas around the substation are in clear compliance with the 57 dBA Washington noise regulation. The only possible area of future development where this compliance situation could be at risk would be on or close to the northern boundary line directly north of the [redacted] Development here would seem to be unlikely because of transmission line easements.

Of the two stricter compliance testing standards proposed in the main text, it is the 42 dBA standard which would most probably apply.

Our analysis shows that, in order to satisfy this standard at the closest property to the northeast of the yard, the [redacted] would require an attenuation of about 8 dBA. It is unlikely that the [redacted] would require treatment.

The hill to the south of the substation provides some shielding for those properties on the north side of 7th Street. The 42 dBA standard is satisfied here at present.

A compliance problem is unlikely to arise at those properties, shown in Fig. C14.2, on Route 2 just south of the substation access road. The maintenance facilities provide some shielding at this position.

Problems at the 42 dBA compliance level would arise if future residential developments were to take place on that land to the north of the BPA property line between the north running transmission lines and Route 9. This problem would be similar in order to that estimated at the house to the northeast.

RECOMMENDATIONS

No noise control is required at this time at the Snohomish Substation. We recommend however that BPA consider planning provisions for noise control to be applied to the [redacted] transformers. This should be designed to achieve 8 to 10 dB at the dominant 240 Hz frequency. At present the need for control applies only to those properties to the east and to the northeast of the [redacted]. Design provisions might have to extend to the north and to the northwest in the event that future residential developments could arise in these areas.

We recommend that BPA remain cognizant of land transactions and planning applications in these areas.

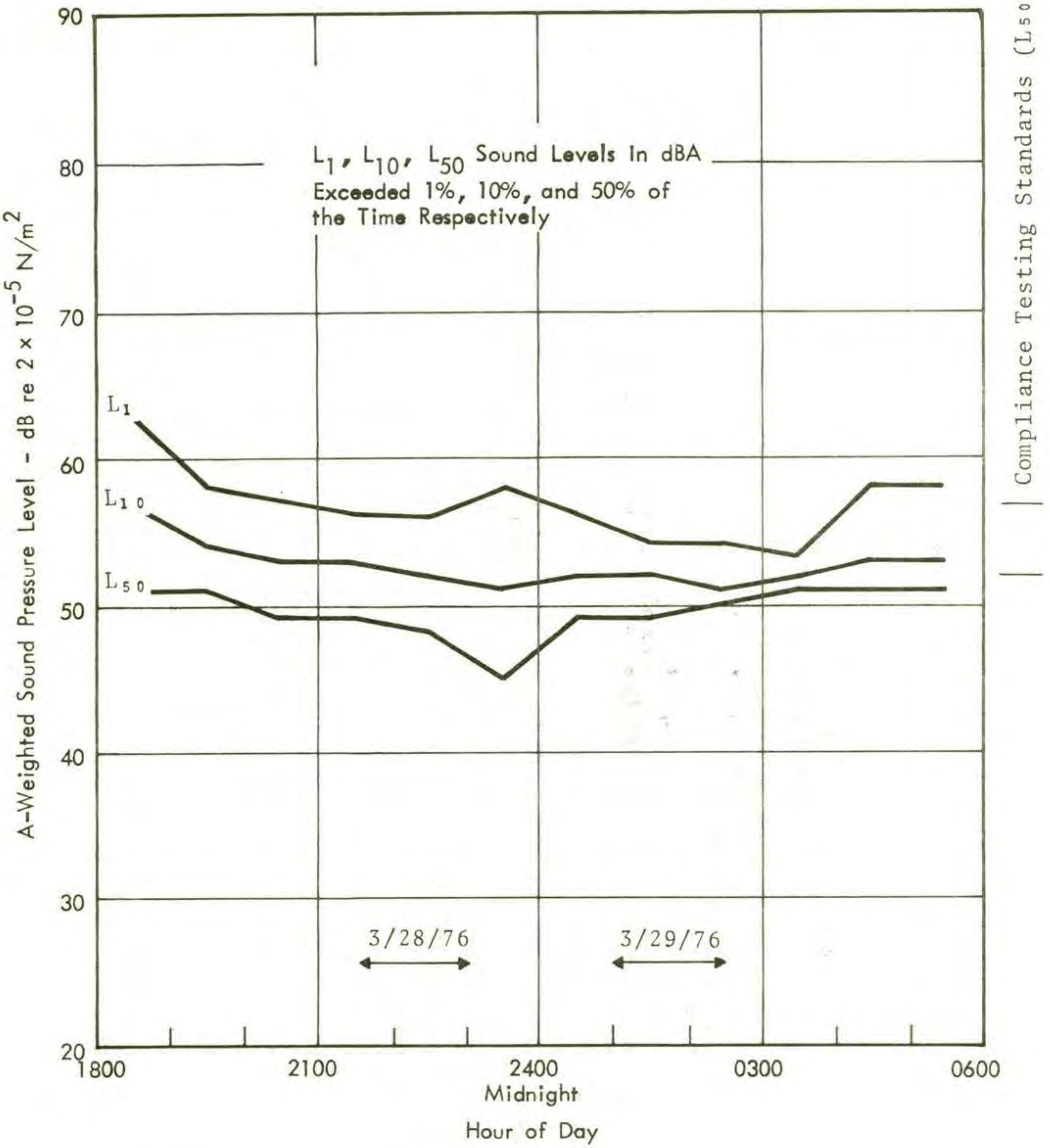


FIGURE C14.3 - SNOHOMISH SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

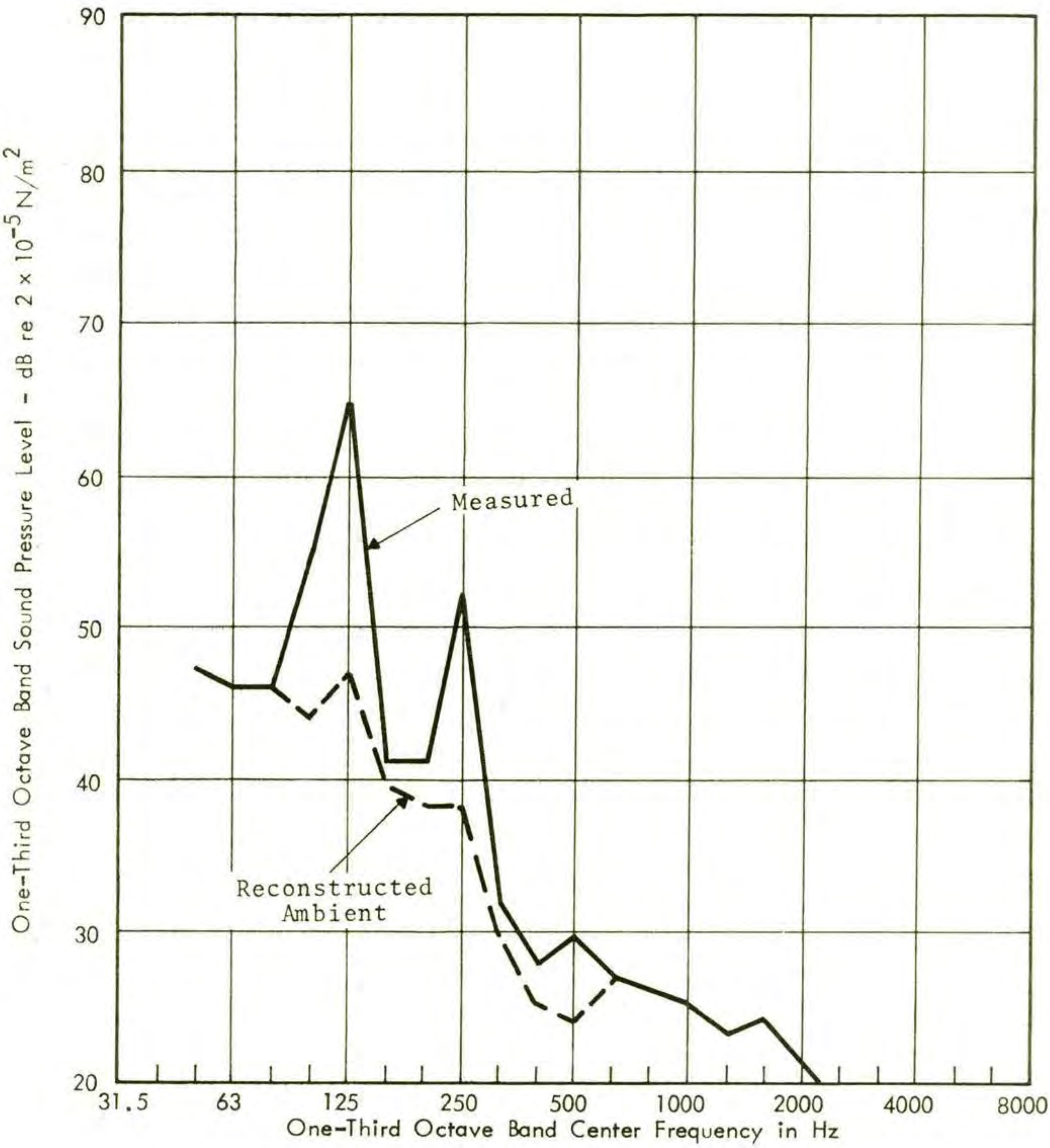


FIGURE C14.4 - SNOHOMISH SUBSTATION - MICROSAMPLE (L_{50})
ONE-THIRD OCTAVE BAND LEVELS
0300 TO 0400 HOURS

C15. SNO-KING SUBSTATION

Sno-King Substation is located 5 miles north of Bothell, in Snohomish County, Washington. It lies on Maltby Road which runs between State Highways 527 and 9. The layout of the yard and some details of its immediate environs are given in Fig. C15.1. [redacted]

The land to the south, west, and north of the substation is heavily forrested. We found it difficult therefore to determine accurately the relationship between the substation and surrounding properties. As far as we could determine the situation is as follows.

To the west and south the land drops gently. The only residential properties lie in a trailer park, close to the southwest corner of the BPA property. It is estimated that the closest trailers probably lie some 400 ft from the perimeter fence.

To the north, on the north side of Maltby Road, the land rises to form a small hill. On and around the west side of this hill there is an extensive housing development known as the Park Ridge Development. This lies to the south of York Road. We estimate that the closest property lies some 500 ft from Maltby Road. This area is still under development.

York Road runs west from Jewell Road (38th Avenue, S.E.) which itself runs north from Maltby Road. Midway between the substation and the Jewell Road junction there is a house. This was the position eventually selected for microsampling. It would appear that the terrain immediately on the north side of Maltby Road, opposite and to the west of the substation, is not suitable for development.

To the east the land is fairly flat. BPA land ownership extends to 39th Avenue.

Whilst it is likely that there will be further residential developments around the Sno-King site, it is unlikely that they will lie any closer to the substation than existing properties.

FIELD SURVEY

The major field survey was carried out on the 26th of March 1976. The microsampling was done on the night of 27 March 1976. We were accompanied within the substation by Mr. Calvert (Operator in Charge).

The weather conditions during the survey were very unsettled. The sky was overcast and winds were from the south gusting to 6 mph. During the microsampling wind velocities were lower. There was no rain of any significance.

. Close-In Measurements

The results of the 10 ft measurements are given in Table C15.2. [redacted] was subjectively very noisy. This was due in part to a strong "beating" at 120 Hz generated by interference between the transformer 120 Hz tone and the fundamental blade passage frequency of the fans (128 Hz).

. Perimeter Measurements

The results of the perimeter measurements are shown in Fig. C15.1. Using [redacted] the dominant source these data normalize to average levels at 500 ft of 65 dB at 120 Hz and 53 dB at 240 Hz. This is in reasonable agreement with the normalizations of Table C15.2.

• Community Measurements

Data samples were obtained at the following positions:

a) At the microsampling position,

b) At a point on York Road northeast of the substation at a distance of about 1000 ft from it,

c) At a point in the Park Ridge Development (on 31st Drive, S.E.) thought to represent the closest property,

d) At a point in the trailer park representative of the closest property.

The results at the major tonal frequencies, are given in Table C15.3. A distinct tone was detected at 128 Hz; this corresponds to the blade passage frequency of the Bank 1 cooling fans.

The results at 120 Hz indicate that Positions (b) and (c) are substantially shielded from the substation by the terrain. Because of the land fall there is some shielding at Position (d) also. A typical 1 Hz bandwidth spectrum at Position (d) is given in Fig. C15.2.

• Microsample Data

Microsampling was carried out at the position indicated in Fig. C15.1--at a distance of some 900 ft from the [redacted] NR [redacted]. The results are summarized in Figs. C15.3 and C15.4.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

Analysis of all the data obtained in the study shows that the Bank 1 transformer is the dominant source and that the average level at an *unobstructed* distance of 500 ft from this transformer is about 50 dBA. The dominant tonal frequencies are 120 Hz and 128 Hz, the latter corresponding to the blade passage frequency of the cooling fans. The two tones generate a "beat" frequency which is unpleasantly audible within the yard.

The terrain provides a small amount of shielding at the trailer park to the southwest of the yard. [redacted] levels are unlikely to exceed 45 dBA. Those properties to the north of the yard in the area called the Park Ridge Development are well shielded by the terrain. Here, at a distance of [redacted] the tonal levels are unlikely to exceed 35 dBA. The microsample location represents the closest existing directly-exposed property. Here the recorded level was about 45 dBA.

The substation is in clear compliance with the existing Washington noise regulations. The BPA property holding is such that no future residential developments can occur which would change this finding.

Of the more stringent compliance testing standards discussed in the main text, the 42 dBA standard would be applicable; the tonal definition clause is clearly exceeded at the microsample location as shown in Fig. C15.4. On the basis of this standard the substation is in default by about 3 dBA at the trailer park and at the microsample location.

In the unlikely event of residential developments on Maltby Road, directly to the north of the substation, the compliance problem could amount to 8 dBA.

RECOMMENDATIONS

No noise-control action is required at Sno-King substation at the present time. Even in the event of more stringent noise regulations being introduced in the future, it is unlikely that significant noise compliance problems will arise. We see no need therefore to make planning provisions for future noise control.

We recommend, however, that BPA remain cognizant of land transactions and planning applications in the area--especially on that land lying directly to the north of the substation on the north side of Maltby Road. Any further building plans of the developers of the Park Ridge Development should be examined.

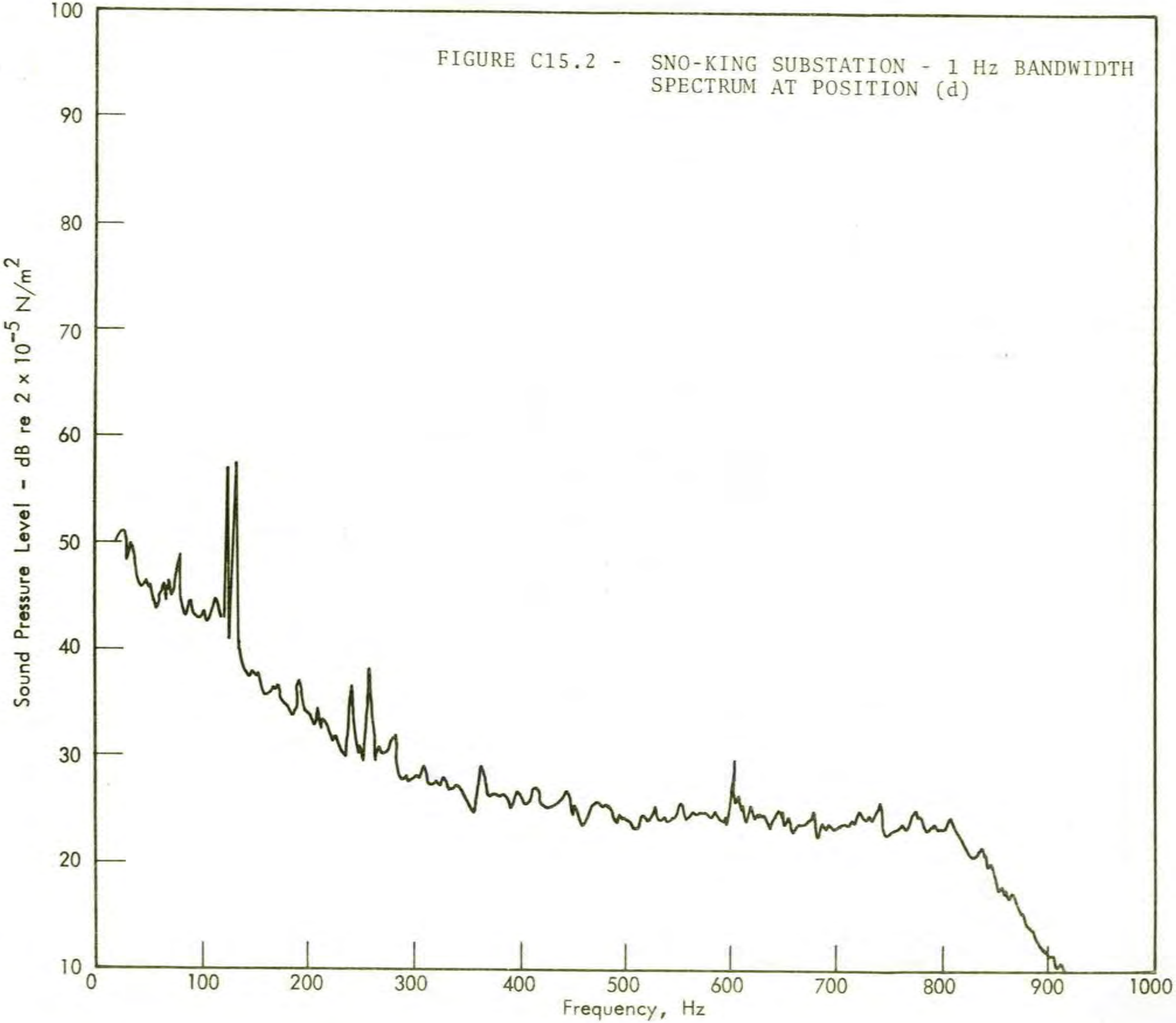


FIGURE C15.2 - SNO-KING SUBSTATION - 1 Hz BANDWIDTH SPECTRUM AT POSITION (d)
Sound Pressure Level - dB re 2 x 10^-5 N/m^2
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
Frequency, Hz

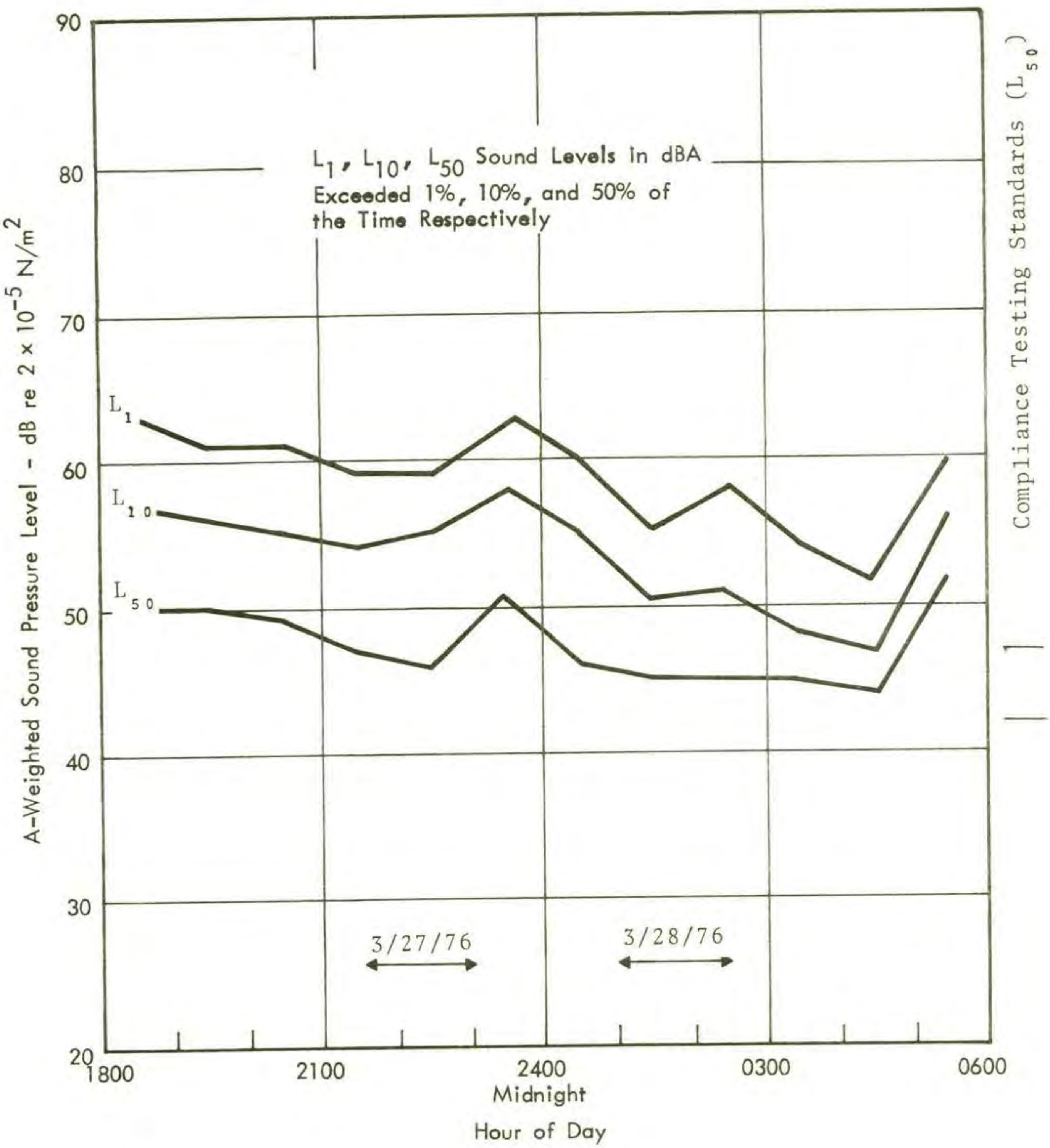


FIGURE C15.3 - SNO-KING SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

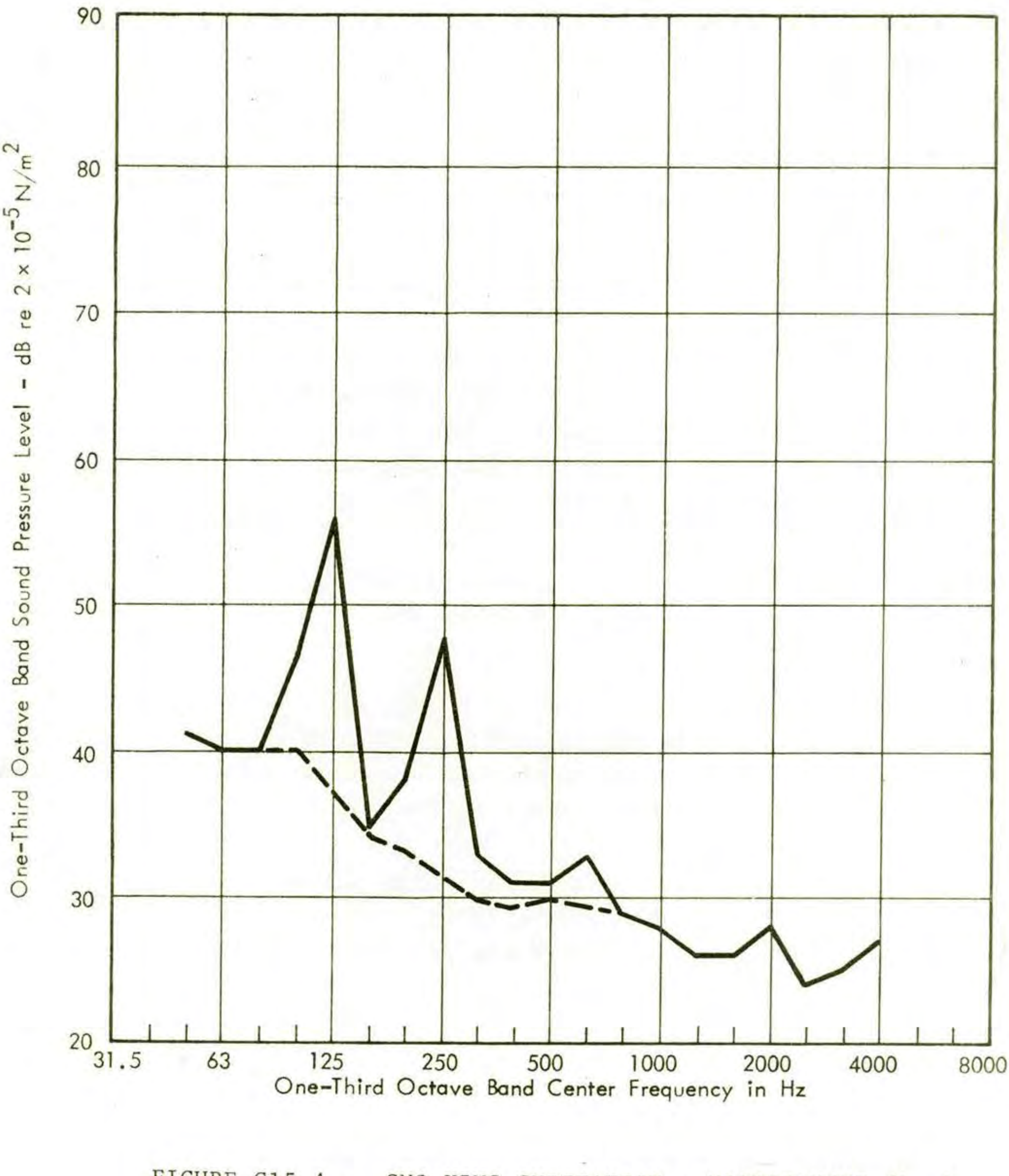


FIGURE C15.4 - SNO-KING SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS

C16. THAYER DRIVE SUBSTATION

Thayer Drive Substation is located on the west side of Richland in Benton County, Washington. It lies on the east side of Thayer Drive and southwest of the Columbia High School buildings and facilities.

The layout of the substation and of the immediate environs is shown in Fig. C16.1. [redacted]

The land to the north and west is owned by the high school. A city maintenance depot lies to the south. To the west, on the west side of Thayer Drive, the land is fully developed with residential properties.

There would appear to be little likelihood of any future changes in the land uses and development around the substation.

FIELD SURVEY

The field survey was carried out over the period 17th to 18th March 1976. We were accompanied within the substation by Mr. John Daume and Mr. Jerry Kyle (BPA Area Staff).

During the survey the weather was clear and dry. The wind was from the southwest gusting up to 10 mph. On the afternoon of 17th March the air temperature and relative humidity were 70°F and 40%, respectively.

• Close-In Measurements

The results of measurements at 10 ft from each of the transformers are given in Table C16.2.

• Perimeter Measurements

The results of the perimeter survey are included in Fig. C16.1 These levels normalize to average levels at a distance of 500 ft [redacted] of 58 dB at 120 Hz and 48 dB at 240 Hz and [redacted] of 55 dB at 120 Hz and 42 dB at 240 Hz. These are in good agreement with the normalized levels in Table C16.2.

• Community Measurements

Data were obtained at a number of positions external to the substation representative of the residential properties on the west side of Thayer Drive and of the school buildings to the east of the substation. These measurements gave average normalized 500 ft levels, of 58 dB at 120 Hz and 47 dB at 240 Hz. These levels are consistent with the close-in and perimeter data.

The highest levels recorded at positions representative of the closest properties on Thayer Drive (distance ~350 ft) were 62 dB at 120 Hz and 56 dB at 240 Hz.

• Microsample Data

Microsampling was carried out at the position shown in Fig. C16.1. The results of data analyses are shown in Figs. C16.2 and C16.3. The full computer printout sheets are included in Appendix D. It should be noted that the microsample spectrum (Fig. C16.3) is influenced in the 63 Hz band by electromagnetic pickup. These levels were not observed at the external measurement positions using the field measurement (Nagra) equipment, however.

DATA INTERPRETATION AND COMPLIANCE ANALYSIS

The substation is in compliance with the present State regulations. A non-compliance situation exists, however, when the more stringent secondary environmental standard is used.

The microsample data in Fig. C16.3 are consistent, when normalized to 500 ft, with the data obtained at other positions within and around the substation at the 120 Hz tonal frequency. The spectrum is such that the substation has a pure tone component in accordance with the definition used in our compliance analysis. Thus the appropriate secondary standard is 42 dBA.

Figures C16.2 and C16.3 indicate that at the quietest period of the night the substation is the dominant source of environmental noise. A minimum noise reduction of about 6 dB at 120 Hz is therefore required at the microsample location. It is interesting to note that on the basis of the Fig. C16.3 spectrum this reduction would just allow the substation to escape the pure tone component penalty--thus apparently allowing us to relax somewhat the regulation level. This is an interesting but not very relevant paradox when we consider the uncertainties involved in measurement. We are of the opinion that 42 dBA is a realistic regulation level for the Thayer Drive Substation. The community noise measurements indicate that the noise reduction goals should be not less than 8 dB at 120 Hz and at 240 Hz. Some noise reduction is required at the higher frequencies also.

At the high school the substation is in clear compliance with the daytime noise regulation levels, and of course at all positions the substation is in compliance with the present Washington regulations.

Table C16.2 indicates that the identical [redacted] are the primary sources at the 120 Hz frequency. [redacted] have the potential to contribute equally at the 240 Hz frequency. The data show that the positioning of the switchgear and of the control house have little directional influence on the noise radiation from Banks 1 and 2.

RECOMMENDATIONS

There is no present requirement for noise control at the Thayer Drive Substation. With the advent of more stringent noise regulations in the future (42 dBA) a need for noise control will arise, amounting to about 8 dB at both 120 and 240 Hz. Treatment of [redacted] will be required.

We recommend that BPA make long-range planning provision for the erection of barriers to the [redacted].

The presence of the switching cubicles to the west of [redacted] pose a problem for the installation of barriers for these units. We suggest that a single barrier could be "tailored," as indicated in Fig. C16.1, to provide close-in shielding. A barrier configuration for [redacted] is also shown in this figure.

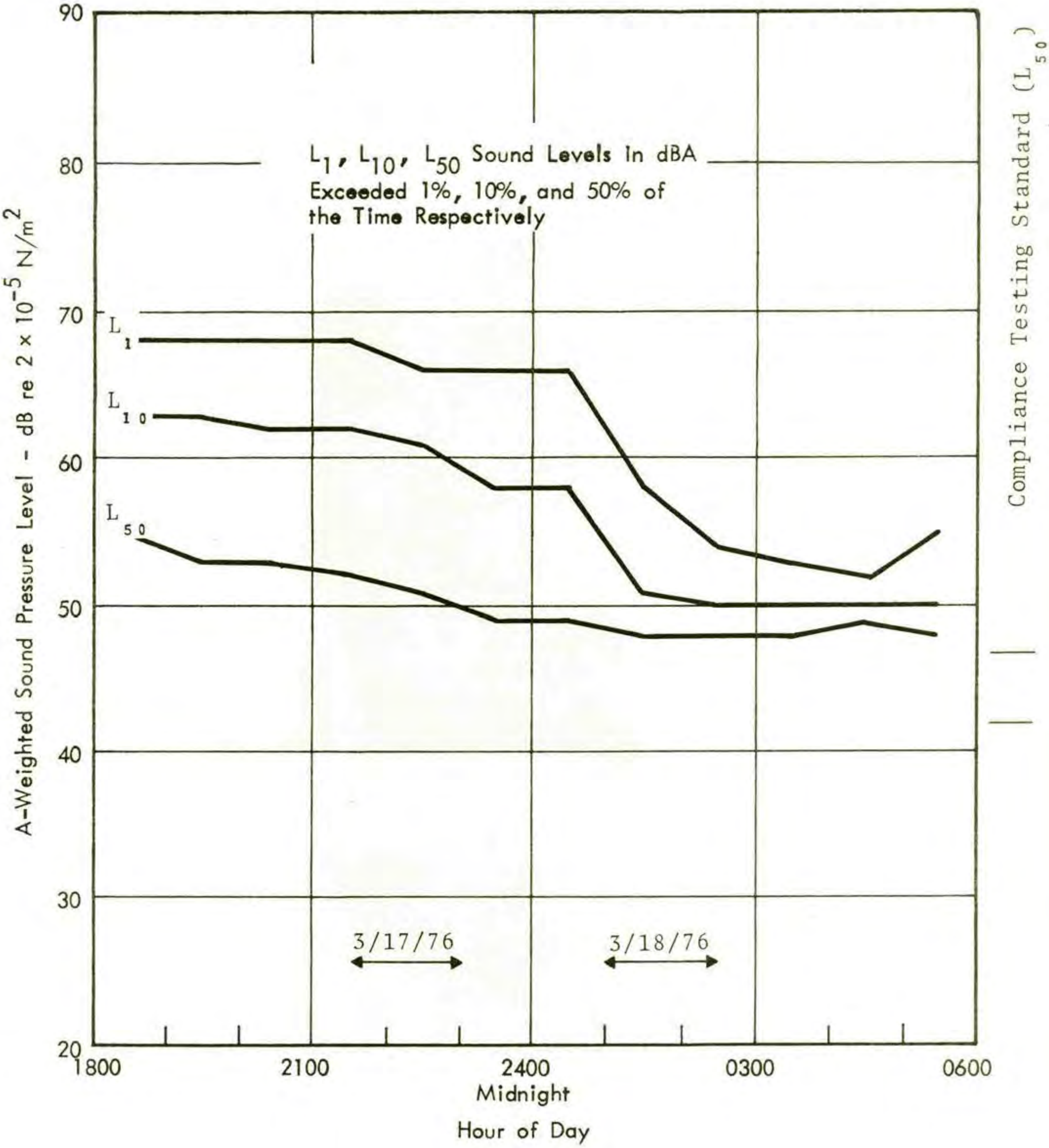


FIGURE C16.2 - THAYER DRIVE SUBSTATION - MICROSAMPLE LEVELS VERSUS TIME OF DAY

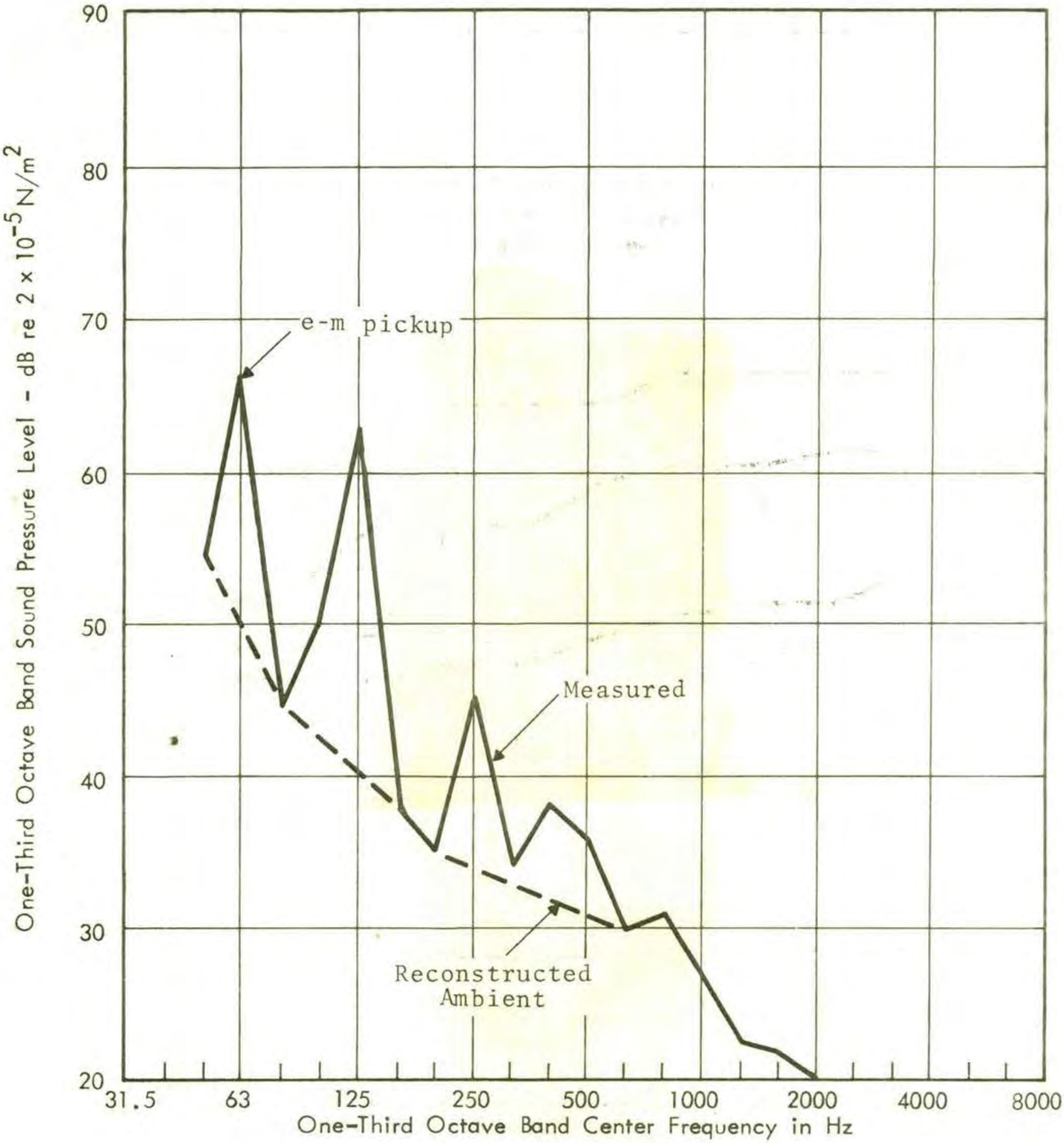


FIGURE C16.3 - THAYER DRIVE SUBSTATION - MICROSAMPLE (L_{50}) ONE-THIRD OCTAVE BAND LEVELS, 0300 TO 0400 HOURS

DATE DUE
