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NOISE LEVELS IN U.S. ARMY CORPS OF ENGINEERS POWERHOUSES.(U)
AUG 78 A AVERBUCH, P SCHOMER

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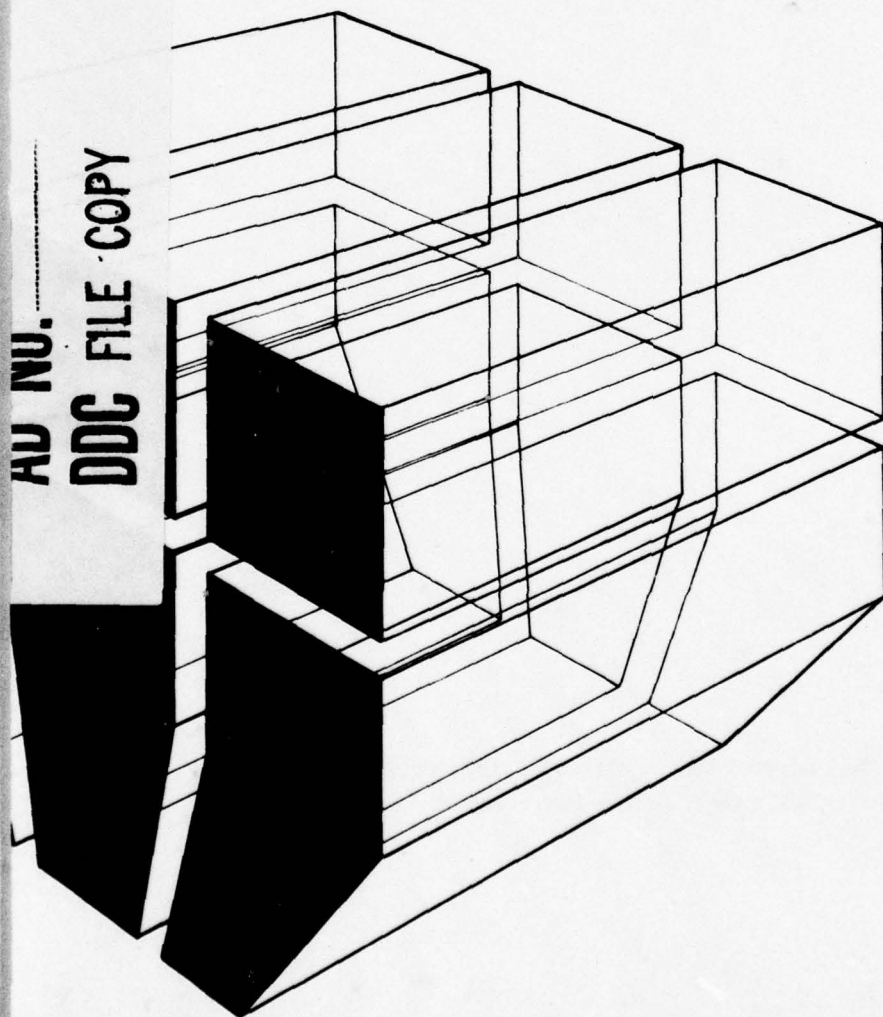
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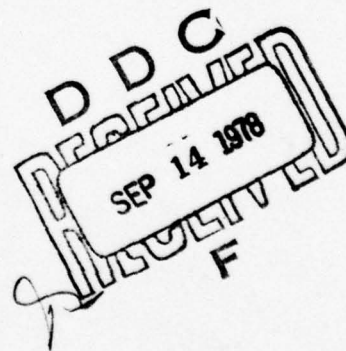
NOISE LEVELS IN U.S. ARMY CORPS
OF ENGINEERS POWERHOUSES

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by
A. Averbuch
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Noise level data were gathered for U.S. Army Corps of Engineers (CE) powerhouses including most of the larger powerhouses, in order to determine (1) the nature and extent of excessive noise levels (in excess of hearing conservation criteria) in CE powerhouses and (2) which noise sources were common to most CE powerhouses. The results indicate numerous areas in CE powerhouses where noise levels are excessive. The general noise sources are the turbines, the generators, and various auxiliary pumps, such as fish pumps or air conditioning chiller pumps. This investigation also determined that the 120 Hz pure tone		

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radiated by the main electrical generators at CE powerhouses may constitute more of a hazard than current hearing conservation standards indicate.

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FOREWORD

This research was conducted for the Directorate of Civil Works, Office of the Chief of Engineers (OCE) under InterArmy Order No. WESRF 77-134. The OCE Technical Monitor was Mr. Jack Robertson, DAEN-CWE-E.

This study was conducted by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. K. Jain is Chief of EN. The CERL Principal Investigator for this study was Mr. A. Averbuch.

The assistance of Mr. Thomas Pfeffer, Mr. Warren Little, and Mr. Robert Pletka of the U.S. Army Corps of Engineers Missouri River Division is greatly appreciated.

COL J. E. Hays is Commander and Director of CERL. Dr. L. R. Shaffer is Technical Director.

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NOISE LEVELS IN U.S. ARMY CORPS OF ENGINEERS POWERHOUSES

1 INTRODUCTION

Background

Recently, the U.S. Army Corps of Engineers (CE) powerhouses at Miller's Ferry, AL, and Dworshak, ID, have received complaints of excessive occupational noise from some of their employees. At Miller's Ferry, one employee complaint resulted in a successful claim against the Government for hearing loss compensation.

These incidents indicate a need to define the character and source of excessive noise in CE powerhouses.

Purpose

This study is part of the first phase of a two-phase effort to determine whether new design criteria are needed and can be developed to reduce noise problems common to most CE powerhouses.

This report's specific purpose was to determine the nature and extent of occupational noise problems in CE powerhouses and to determine which noise sources are common to all CE powerhouses.

Approach

This study had three parts:

1. To gather data on noise levels and sources
2. To review applicable hearing damage criteria
3. To analyze the data, compare it to the hearing damage criteria, and develop a list of sources that may cause hearing damage.

Mode of Technology Transfer

Information from this interim report will be summarized and issued as an Engineer Technical Letter.

2 MEASUREMENT PROCEDURES

Data were collected by the U.S. Army Construction Engineering Research Laboratory (CERL), consultants/contractors, and District safety engineers. The powerhouses surveyed by CERL were chosen after discussions with various CE Districts. These discussions helped identify those powerhouses most likely to have high noise levels and the least existing noise level data. Table 1 lists powerhouses visited by CERL and powerhouses for which CERL received data from others. In some cases, two sources surveyed the same site to allow data comparisons. The powerhouses listed in Table 1 have generation capacities ranging from 30 MW at Jim Woodruff Dam, FL, to 2160 MW at John Day Dam, WA. They also have individual generators ranging in size from 2 MW at Allatoona Dam, GA, to 200 MW at Dworshak Dam, ID. This range of values is representative of sizes found at CE powerhouses.

Powerhouse measurements were made using (1) a type 1 sound-level meter, (2) a two-channel tape recorder, and (3) a geophone for correlating noise measurements with primary vibrating surfaces. These measurements, plus those supplied by contractors and safety personnel, are the data base for the analysis chapter of this report.

Channel 1 of the tape recorder recorded the alternating current (ac) output of the sound-level meter on the flat range; channel 2 was used for the geophone since the geophone output was sufficient to drive the tape recorder directly. At each measurement site within a powerhouse, the tape recorder was turned to its test position and its levels set to prevent overload. Audio channel gain was set by (1) adjusting the sound-level meter on channel 1 to read on scale, and (2) adjusting channel 1's attenuator 5 to 10 units below full scale. The geophone was adjusted by reducing channel 2 attenuation to 5 to 10 dB below full scale; no separate preamp was associated with the geophone.

The geophone was mounted at the site that produced, in the experimenter's judgment, the most vibration (usually a floor)*. The microphone was generally placed within 5 ft of the geophone. No more than two geophone readings were taken at any one site. To collect data over a wide range of frequencies, a 1-minute section of tape was recorded at 7-1/2 in./sec during each measurement session. An additional 1 minute of tape at 1-1/2 in./sec was run at each site in an attempt to record low frequencies, especially from the geophone channel (which had response down to 4 Hz). The readings on the sound-level meter were also manually recorded in a logbook. Measurements of flat, A-weighted, C-weighted, and peak noise levels were taped separately.

* The exceptions were powerhouse control rooms where generators were usually situated immediately adjacent to walls and windows. In these cases, the geophone was mounted on a wall. Some measurements were also made on the top cover plates of the main electrical generators.

Table 1
Sources of Powerhouse Noise Data

Powerhouse	CERL Data	Contractor or Safety Office Data
Allatoona, GA	yes	
Big Bend Power Plant, SD	yes	yes
Bonneville Dam, WA		yes
Carter's Lake, GA	yes	
Clark Hill Dam, GA	yes	
Detroit Dam, OR		yes
Dworshak Dam, ID	yes	yes
Fort Peck Power Plant, MT	yes	yes
Fort Randall Power Plant, SD	yes	yes
Garrison Power Plant, ND		yes
Gavin's Point Power Plant, NB	yes	yes
Hartwell Power Plant, GA	yes	
Jim Woodruff Power Plant, FL	yes	
John Day Dam, WA		yes
Libby Dam, MT		yes
Miller's Ferry Power Plant, AL	yes	yes
Oahe Power Plant, SD	yes	yes
Stockton Power Plant, MO		yes
Walter F. George Power Plant, GA	yes	

Tape-recorded data were gathered primarily to assist with a later phase of this study which will develop specific and mitigated noise abatement measures.

At each measurement site, a photograph was taken to document the placement of the tape recorder, the sound-level meter, and whether the geophone was mounted on a wall or a floor.

Measurement sites were generally selected by asking the powerhouse supervisor to indicate which pieces of equipment operated at significantly high noise levels. Main generators, turbine pits, and draft tube access doors were measured at most of the powerhouses surveyed. Auxiliary equipment rooms were generally visited; these rooms included traditionally noisy equipment such as air conditioners, chillers, auxiliary pumps for the station air pressure, and the back-up generator.

All measurements were in accordance with American National Standards Institute (ANSI) standards and procedures. Calibration was performed using a pistonphone acoustical calibrator.

3 DISCUSSION OF NOISE STANDARDS AND DAMAGE RISK CRITERIA

The maximum 8-hour noise level at Federal facilities is regulated by Department of the Army (DA) Technical Bulletin (TB) MED 251¹ and the Occupational Health and Safety Act (OSHA).² Both TB MED 251 and OSHA require the use of a frequency weighting during noise level measurements. This weighting approximates the hearing of the human ear as a function of frequency at moderate noise levels. It was chosen as a simplified screening measure which would be appropriate to most industrial noise situations. Both methods consider exposure durations of up to an 8-hour work day. OSHA sets a 90-dBA limit for 8 hours of exposure. (Reduction of this level by 5 dBA to 85 dBA is currently under review by OSHA.) TB MED 251 sets the 8-hour hazard level at 85 dBA. Both procedures allow the maximum acceptable noise levels to rise by 5 dBA for each halving of exposure time; i.e., if the maximum acceptable 8-hour exposure level is 85 dBA, 4 hours of exposure is allowed at 90 dBA, 2 hours at 95 dBA, etc. The remaining hours of the day must be spent in a quiet area. The U.S. Environmental Protection Agency (EPA) has also recommended an 8-hour exposure criterion level of 85 dBA. This is only a 3 dBA increase for each halving of exposure.³ Thus, the EPA recommends allowing 4 hours of exposure at 88 dBA and 2 hours of exposure at 91 dBA.

TB MED 251 and OSHA differ on the way in which excessive noise levels are to be handled. OSHA requires a hearing conservation program and engineering controls, if feasible, when noise levels are found to exceed OSHA criteria. On the other hand, TB MED 251 allows for the use of personal hearing protectors in lieu of engineering controls. TB MED 251, however, does require a hearing conservation program; both allow for the use of management controls, i.e., limiting the hours of exposure of an individual employee to high noise levels.

A recent report to the Congress by the Comptroller General of the United States faults the Department of Defense (DOD) on three points: (1) inadequacy of hearing conservation programs, (2) failure to adopt uniform criteria for the implementation of engineering controls, and (3) failure to enforce penalties upon employees who fail to wear the personal protection devices. Specifically, the U.S. Government Accounting

¹ *Noise and Conservation of Hearing*, DA Technical Bulletin TB MED 251 (DA, 7 March 1972).

² Occupational Health and Safety Act, Public Law (PL) 91-596, 91st Congress, 5-2193, 28 April 1971; as amended by PL 93-237, 2 January 1974.

³ U.S. Environmental Protection Agency (EPA), Federal Register P12336, 18 March 1975.

Office (GAO) recommends "...that the Secretary of Defense have the service secretaries and Defense agency directors adapt uniform criteria for determining when engineering controls should be used...the 85 dB, 8-hour exposure limit which DOD says it will adapt could constitute a uniform noise-hazard criterion for determining the need for engineering controls, but DOD's reply did not resolve this issue or clarify whether engineering controls should be mandatory at that exposure limit or at any other exposure limit."

Equipment at CE powerhouses includes large electrical generators. These generators usually radiate a noise composed of a pure tone at 120 Hz (see Chapter 4). The hearing damage risk potential of this pure tone noise is not adequately accounted for in the TB MED 251 and OSHA standards because the broad band A-weighted measure they use was developed for environments such as traditional industrial situations where there are numerous, individual noise sources.

The A-weighted criteria were derived from the octave band criteria developed by the National Academy of Science.⁵ At smaller band widths, such as the one-third octave band width (Figure 1a) or the pure tones (Figure 1b), the National Academy damage risk criteria became more stringent, especially at the lower exposure levels. For example, the 8-hour* damage risk criterion for an octave band centered at 125 Hz is approximately 97 dB. A one-third octave band or pure tone centered at 125 Hz has a damage risk criterion of 92 dB. At 4 hours, this criterion allows a one-third octave band or pure tone noise level of 93 dB; at 2 hours the level allowed is 95 dB. These levels would read at approximately 16 dB lower if measured on an A-weighted sound-level meter. Therefore, the acceptable 8-hour noise level of 120-Hz pure tones at CE powerhouses should not exceed 76 dBA when measured on an A-weighted sound-level meter. TB MED 251 and OSHA, however, do not presently require CE to take into account pure tone noise sources, probably because their original guidelines were designed for equipment which does not issue a pure tone.

⁴ *Hearing Protection -- Problems in the Department of Defense*, Congressional Report, LCD-77308 (U.S. Government Accounting Office, 1977).

⁵ Kryter, K. D., W. D. Ward, T. D. Miller, and D. H. Eldredge, "Hazardous Exposure to Intermittent Steady State Noise," Vol 39, No. 3, *Journal of the Acoustical Society of America* (1966), pp 451-464.

* 480 minutes in Figure 1.

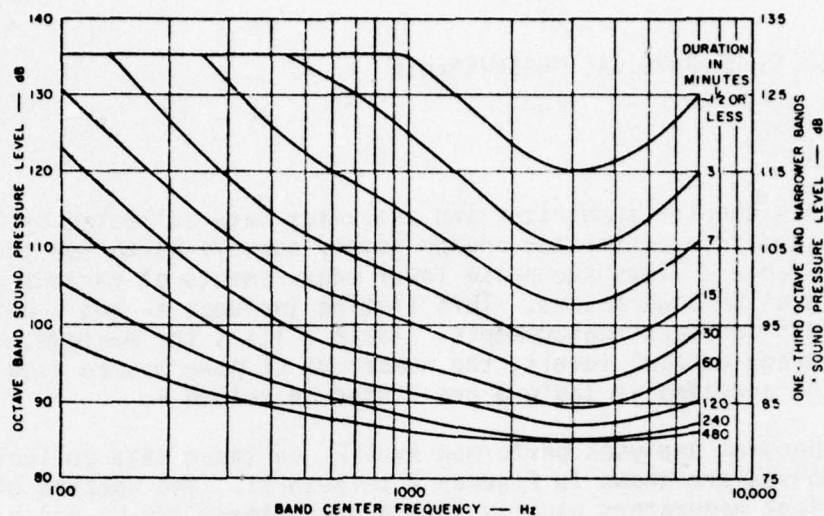


Figure 1a. Damage-risk contours for one exposure per day to full octave (left-hand ordinate) and one-third octave or narrower (right-hand ordinate) bands of noise (from Kryter, K. D., W. D. Ward, T. D. Miller, and D. H. Eldredge, "Hazardous Exposure to Intermittent Steady State Noise," Vol 39 No. 3, *Journal of the Acoustical Society of America* [1966], pp 451-464).

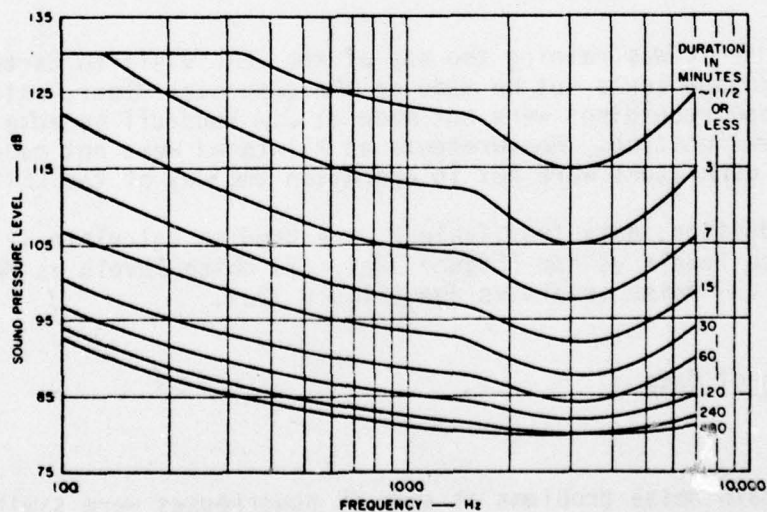


Figure 1b. Damage-risk contours for one exposure per day to pure tones (from Kryter, K. D., W. D. Ward, T. D. Miller, and D. H. Eldredge, "Hazardous Exposure to Intermittent Steady State Noise," Vol 39 No. 3, *Journal of the Acoustical Society of America* [1966], pp 451-464).

4 RESULTS OF PHYSICAL MEASUREMENTS

General

This chapter summarizes and evaluates data collected by CERL or abstracted from contractor and/or safety surveys (also see the Appendix). Table 2 lists the noise level measurements of various noise sources at CE powerhouses. This listing includes A- and C-weighted measurements and peak measurements. Table 3 lists the maximum, minimum, and average decibel levels; the number of CE powerhouses used to calculate the averages in Table 3 are listed in column 4.

Spectral analyses performed by CERL on taped data collected at CE powerhouses are shown in Figures 2 through 11. The spectra of the main electrical generators usually show a predominant 120-Hz noise component -- the familiar "hum" associated with electrical power equipment. Table 4 shows the magnitude of this component and other pure tone noise levels at powerhouses where tape recordings were made. The blank spaces in the table indicate that no pure tone was found at that frequency and place. Six of the 10 powerhouses measured show levels in excess of 92 dB for the 120-Hz component on either the generator floor or in the turbine pit, or both. Miller's Ferry has, in addition, a level of 97 dB at 360 Hz, well above the damage risk criterion of 86 dB for that frequency. Two dams, Gavin's Point and Oahe, exhibited little or no pure tone noise.

Because it was raining the day of the CERL visit to Hartwell Dam, tape recordings could not be made on the generator floor, which was outdoors. Tape recordings were not made at Jim Woodruff because of a recorder malfunction. Measurements at Allatoona were not made because the 36 MW generators were not in operation the day of the CERL visit.

In addition, data from Table 2 were used to calculate (1) CE powerhouse noise levels vs rpm (Figure 12a), (2) noise levels vs MW (Figure 12b), and (3) noise levels vs age (Figure 12c).

Evaluation of Data

General

The main noise problems at some CE powerhouses were similar. In most cases, main steady noise sources are generators and turbines. Although many secondary noise sources were measured at levels above 85 dBA, they were not considered critical in terms of noise exposure since they affected only the areas near them; e.g., air conditioning compressors and back-up generators. Other specialized equipment creating

Table 2

Noise Levels for Power Plants*

	Back-Up Generator			Chiller Pump			Control Room			Draft Tube Access Door			Generator Floor			Inside Generator Housing			Top Generator Housing			Turbine Floor			Turbine Pit		
	A	C	P	A	C	P	A	C	P	A	C	P	A	C	P	A	C	P	A	C	P	A	C	P	A	C	P
Allatoona**	--	--	--	86	88	101	52	--	--	--	--	--	72	89	94	--	--	--	--	--	--	--	--	--	82	87	100
Big Bend	101	104	117	84	94	--	66	73	88	92	97	109	84	93	--	100	110	121	87	101	109	79	91	--	90	99	112
Bonneville	--	--	--	--	--	--	--	--	--	96	--	--	81	--	--	--	--	--	--	--	--	86	--	--	100	--	--
Carter's Lake	79	93	107	82	85	105	66	80	--	98	104	116	84	98	101	--	--	--	--	--	--	--	--	--	88	92	100
Clark Hill Dam	--	--	--	82	84	96	--	--	--	92	102	115	76	89	101	--	--	--	--	--	--	--	--	--	87	93	106
Detroit	--	--	--	--	--	--	70	--	--	89	--	--	83	--	--	--	--	--	--	--	--	86	--	--	94	--	--
Dworshak	--	--	--	--	--	--	60	75	94	102	105	--	84	--	--	--	--	--	88	--	--	83	--	--	101	106	--
Fort Peck	79	85	--	--	--	--	72	85	96	101	110	132	86	91	104	97	106	118	88	106	112	86	95	--	87	92	104
Fort Randall	--	--	--	89	89	102	56	67	85	82	92	--	72	87	98	--	--	--	--	--	--	82	92	103	85	92	--
Garrison	--	--	--	65	80	--	52	73	--	87	97	--	80	94	--	--	--	--	60	77	--	--	--	--	91	103	--
Gavin's Point	102	104	117	83	89	102	64	81	92	90	103	115	76	87	102	96	101	115	--	--	--	80	89	103	89	96	107
Hartwell	98	100	112	--	--	--	60	78	92	95	105	117	78	96	98	--	--	--	--	--	--	83	93	106	92	105	117
Jim Woodruff	--	--	--	86	90	103	--	--	--	93	106	117	91	93	103	--	--	--	--	--	--	--	--	--	88	88	103
John Day	--	--	--	--	--	--	--	--	--	96	--	--	80	--	--	--	--	--	--	--	--	--	--	--	94	--	--
Libby Dam	--	--	--	--	--	--	71	--	--	94	--	--	83	--	--	--	--	--	--	--	--	87	--	--	97	--	--
Miller's Ferry	107	107	117	88	92	104	70	84	95	88	98	110	92	102	104	66	112	121	--	--	--	--	--	--	92	98	109
Oahe	102	103	115	79	82	98	63	72	78	100	112	123	82	97	111	101	109	123	--	--	--	--	--	--	88	95	108
Stockton	--	--	--	--	--	--	77	89	--	89	104	--	76	92	--	--	--	--	--	--	--	--	--	--	97	102	--
Walter F. George	105	107	120	--	--	--	70	84	97	99	110	124	85	100	110	--	--	--	--	--	--	--	--	--	85	97	109

**The figures shown are for the 2MW station generator only.

*A = A-weighted in dB
 C = C-weighted in dB
 P = Peak in dB

Table 3
Maximum, Minimum, and Average Power Plant Sound Levels*

Area		Maximum	Minimum	Average	Number in Average
Back-up generator	A	107	79	97	8
	C	107	85	100	8
	Peak	120	107	115	7
Chiller pump	A	89	65	82	10
	C	94	80	87	10
	Peak	105	96	101	8
Control room	A	77	52	65	15
	C	89	67	78	12
	Peak	97	78	91	9
Draft tube access door	A	102	82	94	18
	C	112	92	103	14
	Peak	132	109	118	10
Generator floor	A	92	72	81	19
	C	102	84	93	14
	Peak	111	94	102	11
Inside generator housing	A	106	96	100	5
	C	112	101	108	5
	Peak	123	115	116	5
Top generator housing	A	88	60	81	4
	C	106	77	95	3
	Peak	112	109	111	2

*A = A-weighted in dB; C = C-weighted in dB; P = peak in dB.

Table 3 (cont'd)*

Area		Maximum	Minimum	Average	Number in Average
Turbine floor	A	87	79	84	9
	C	95	89	93	4
	Peak	106	103	104	3
Turbine pit	A	101	75	90	19
	C	106	87	96	15
	Peak	117	100	107	11

*A = A-weighted in dB
 C = C-weighted in dB
 P = Peak in dB

Table 4
Magnitude of Pure Tone Noise
for Power Plants

<u>Power Plant</u>	<u>Main Generator Floor</u>		<u>Turbine Pit</u>	
	120 Hz	Other	120 Hz	Other
Big Bend	89 dB	80 dB at 480 Hz	96 dB	
Carter's Lake	80 dB	80 dB at 460 Hz		
Carter's Lake (pumpback operation)	86 dB	80 dB at 460 Hz		
Clark Hill	85 dB		98 dB	
Dworshak	82 dB	78 dB at 180 Hz		
Fort Peck	107 dB	90 dB at 240 Hz		
Gavin's Point				
Hartwell	*	*	100 dB	
Miller's Ferry	90 dB	97 dB at 360 Hz	93 dB	97 dB at 360 Hz
Oahe				
Walter F. George	100 dB		96 dB	

*Data not recorded due to rain on outdoor generator deck.

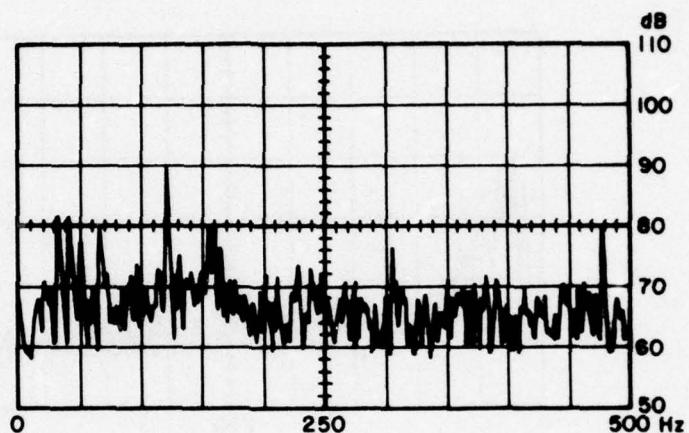


Figure 2a. Spectrum of main electrical generator noise present on generator floor (Big Bend, No. 2 generator, 58.5 MW).

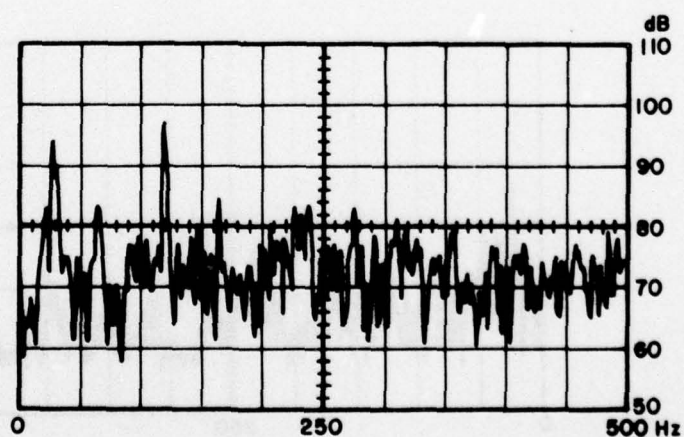


Figure 2b. Spectrum of noise in the turbine pit (Big Bend, No. 2 generator, 58.5 MW).

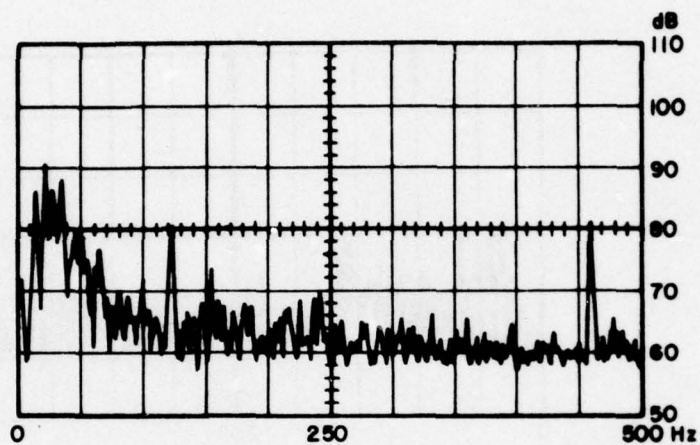


Figure 3a. Spectrum of main electrical generator noise present on generator floor (Carter's Lake, No. 4 generator, 100 MW).

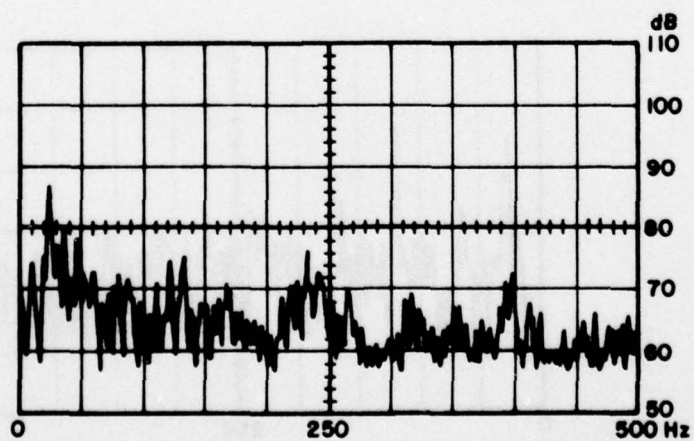


Figure 3b. Spectrum of noise in the turbine pit (Carter's Lake, No. 4 generator, 100 MW).

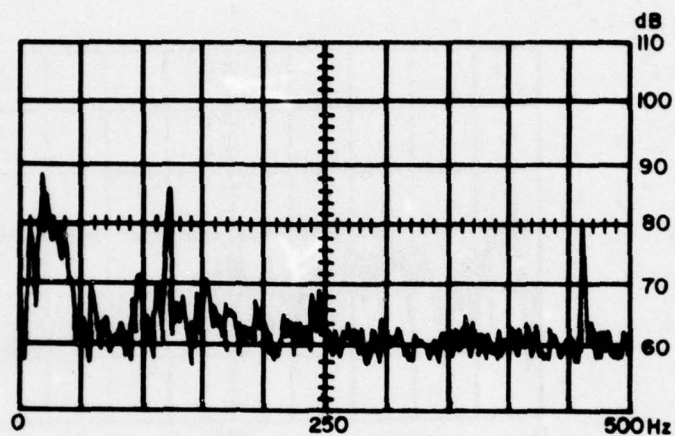


Figure 3c. Spectrum of main electrical generator noise present on generator floor during pumpback operation (Carter's Lake, No. 4 generator, motoring 142 MW).

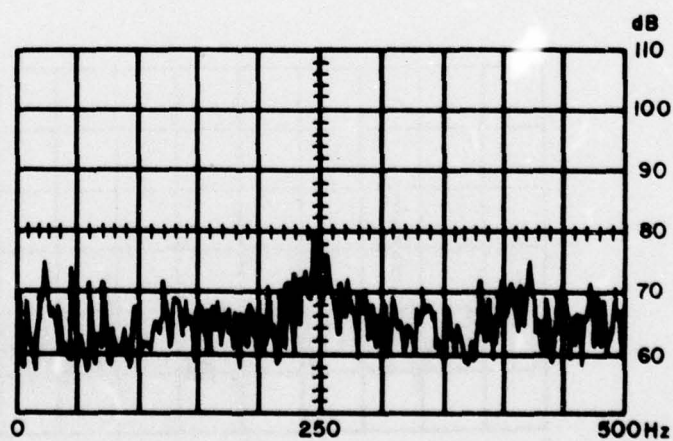


Figure 3d. Spectrum of noise in the turbine pit during pumpback operation (Carter's Lake, No. 4 generator, motoring 142 MW).

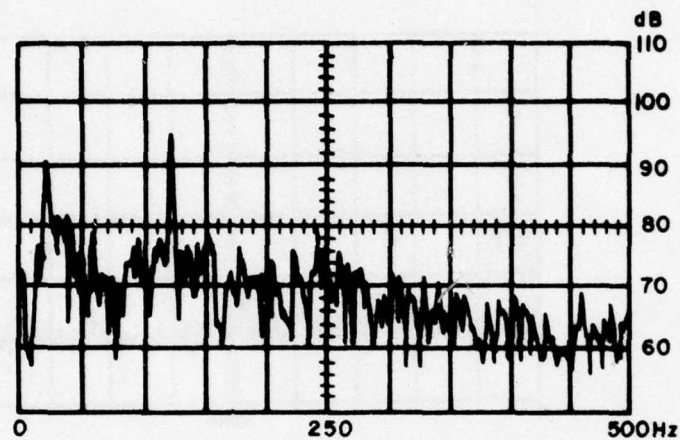


Figure 4a. Spectrum of main electrical generator noise present on generator floor (Clark Hill Dam, No. 4 generator, 40 MW).

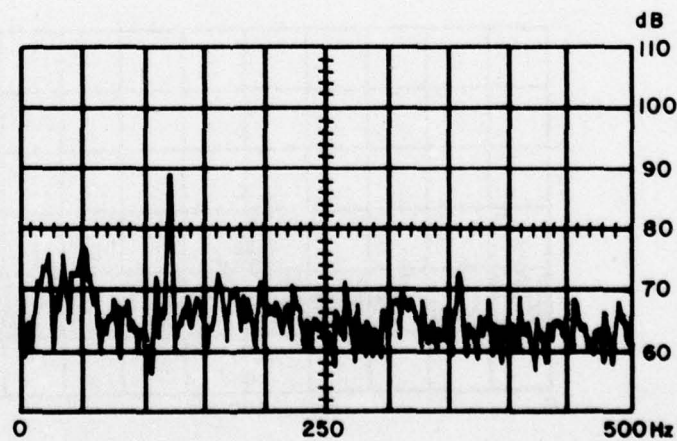


Figure 4b. Spectrum of main electrical generator noise present inside air housing (Clark Hill Dam, No. 4 generator, 40 MW).

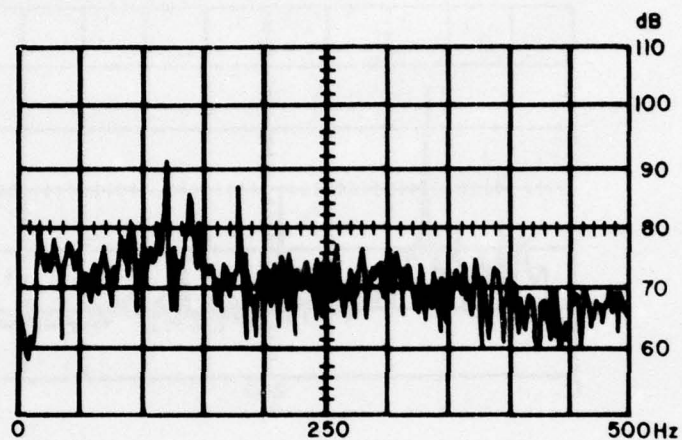


Figure 5a. Spectrum of main electrical generator noise present on generator floor (Dworshak Dam, No. 3 generator, 220 MW).

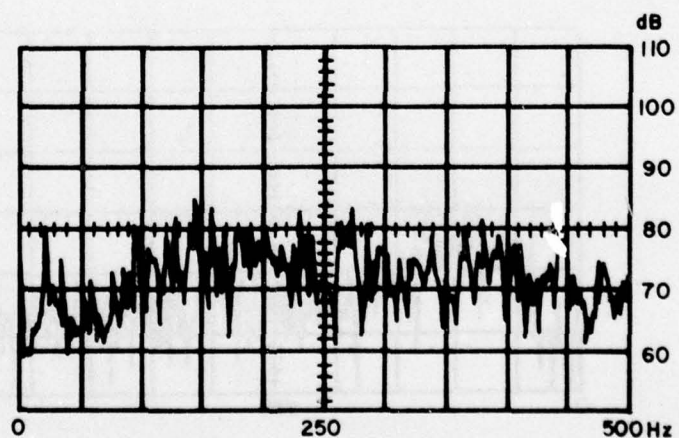


Figure 5b. Spectrum of noise in the turbine pit (Dworshak Dam, No. 3 generator, 220 MW).

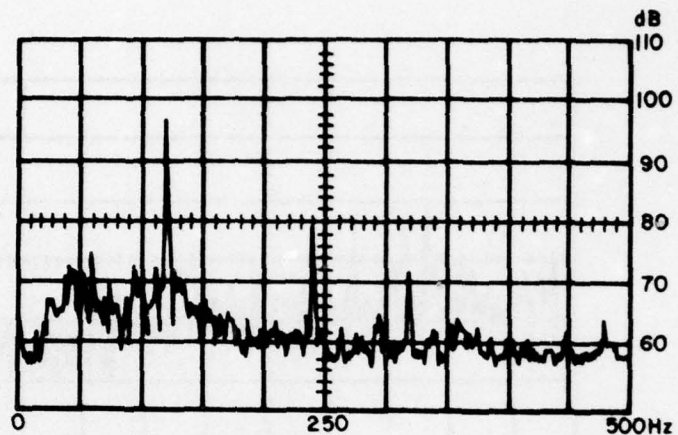


Figure 6a. Spectrum of noise present on generator floor (Fort Peck Dam, No. 3 generator 40 MW).

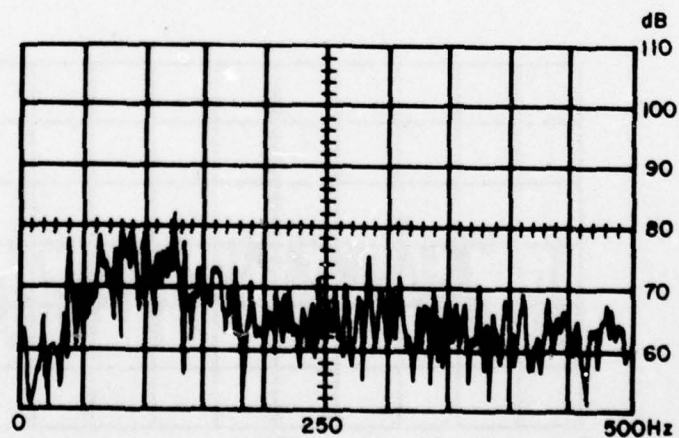


Figure 6b. Spectrum of noise in the turbine pit (Fort Peck Dam, No. 3 generator, 40 MW).

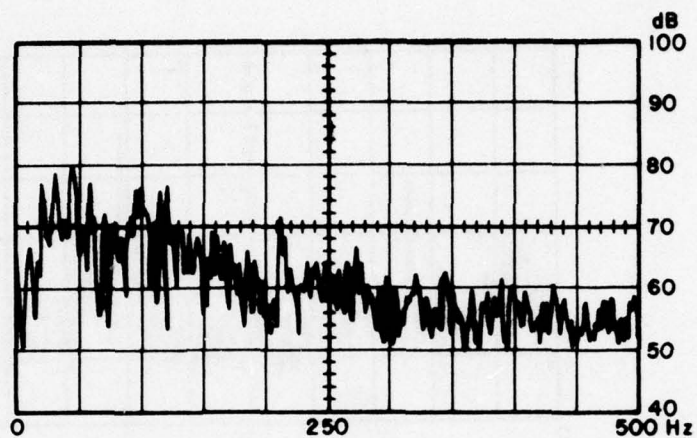


Figure 7. Spectrum of main electrical generator noise present on generator floor (Gavin's Point, No. 2 generator, 33.3 MW).

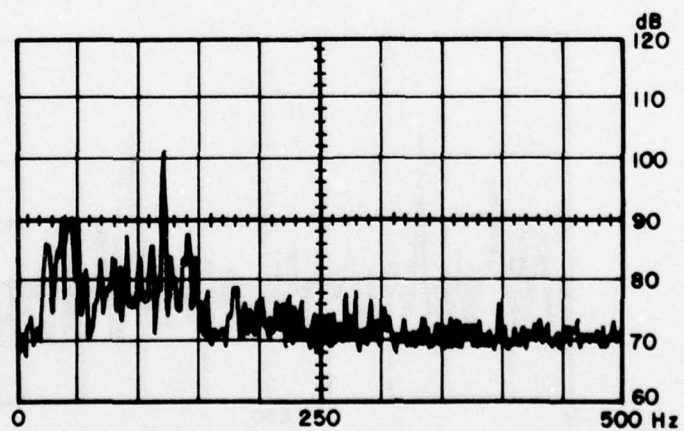


Figure 8. Spectrum of noise in the turbine pit (Hartwell Dam, No. 2 generator, 66 MW).

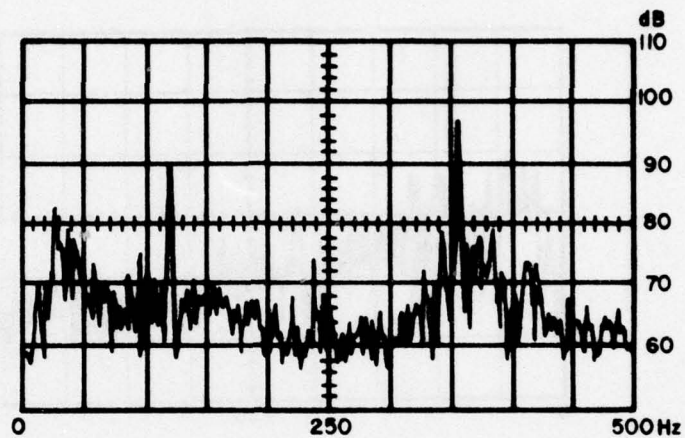


Figure 9a. Spectrum of main electrical generator noise present on generator floor. Note very strong 3rd harmonic at 360 Hz (Miller's Ferry Dam, No. 2 generator, 25 MW).

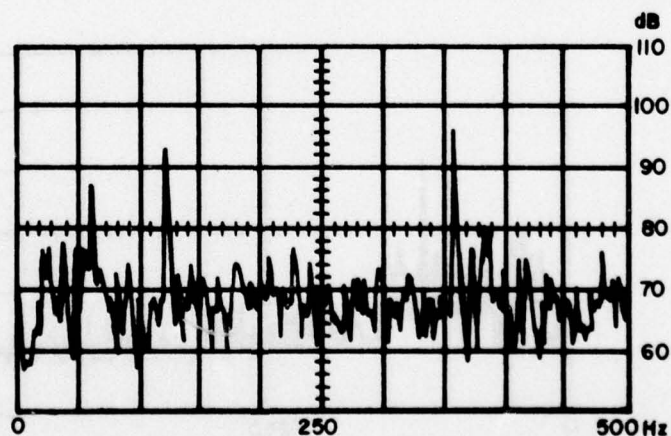


Figure 9b. Spectrum of noise in the turbine pit. Note very strong 3rd harmonic at 360 Hz (Miller's Ferry Dam, No. 2 generator, 25 MW).

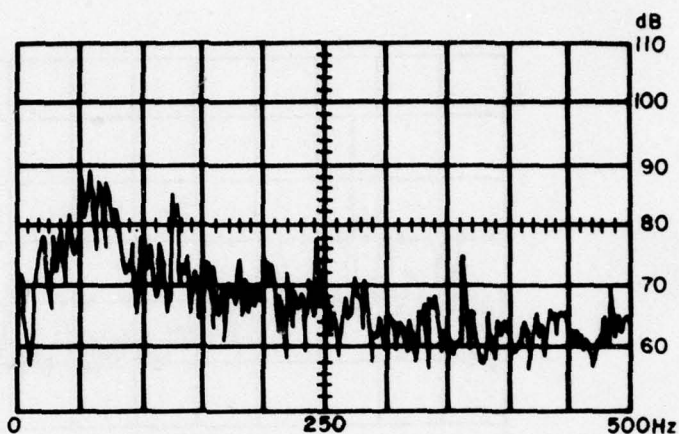


Figure 10a. Spectrum of main electrical generator noise present on generator floor. Note the small value at 120 Hz for this generator (Oahe Dam, No. 4 generator, 85 MW).

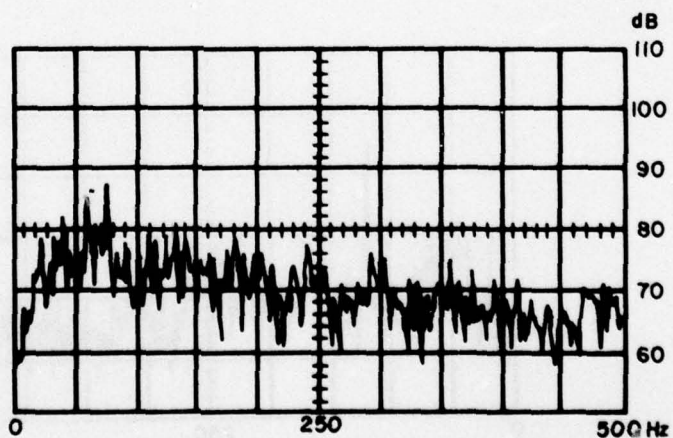


Figure 10b. Spectrum of noise in the turbine pit. Note the absence of a 120 Hz noise peak (Oahe Dam, No. 4 generator, 85 MW).

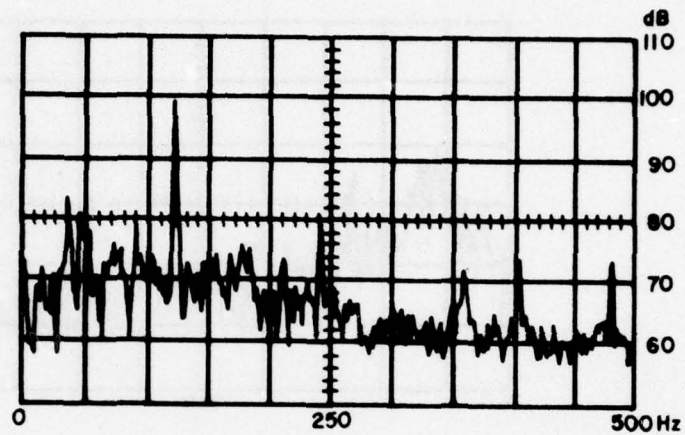


Figure 11a. Spectrum of main electrical generator noise (W. F. George Dam, No. 1 generator, 38.5 MW).

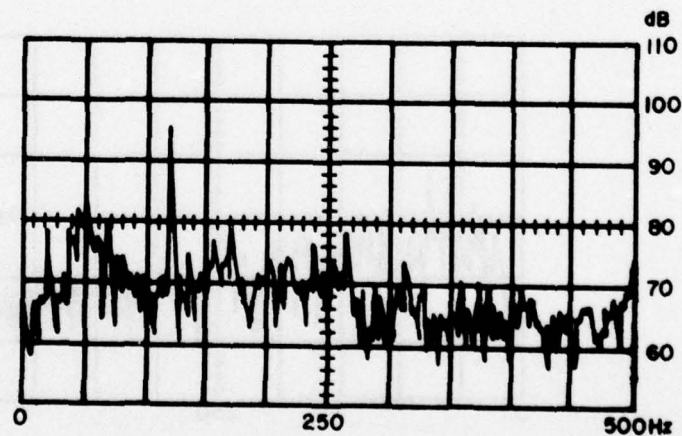


Figure 11b. Spectrum of noise in the turbine pit (W. F. George Dam, No. 1 generator, 30.5 MW).

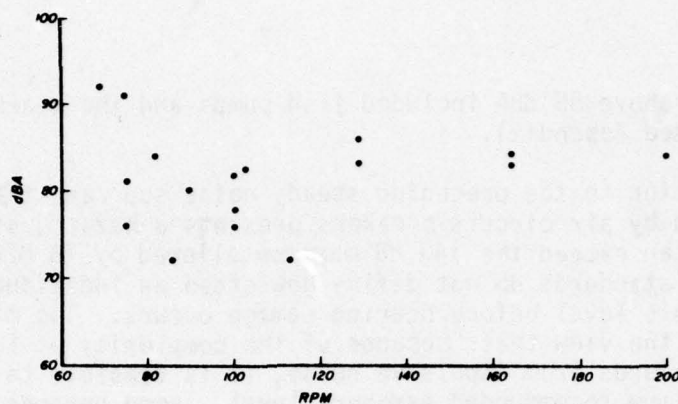


Figure 12a. Noise levels vs rotational speed.

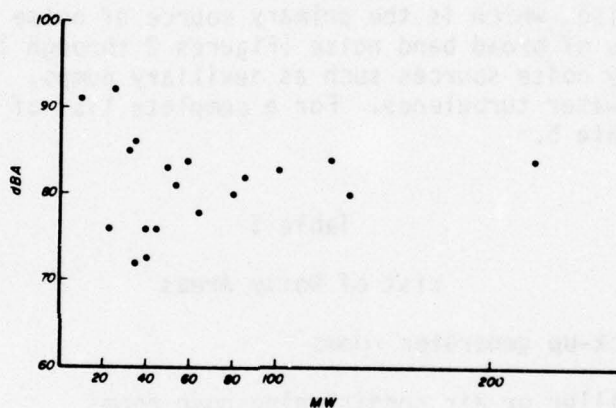


Figure 12b. Noise levels vs generator size.

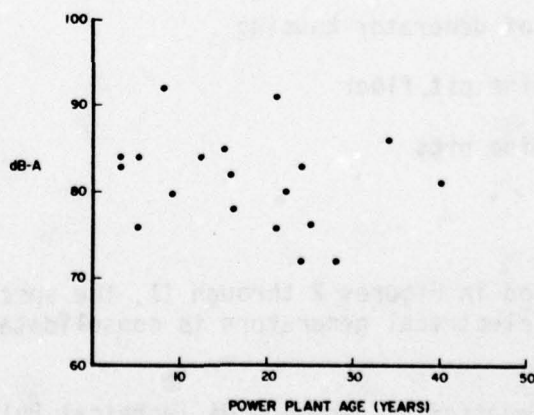


Figure 12c. Noise levels vs age.

noise levels above 85 dBA included fish pumps and the gearbox on slant shaft dams (see Appendix).

In addition to the preceding steady noise sources, the impulse noise created by air circuit breakers presents a hazard, since their peak levels can exceed the 140 dB maximum allowed by TB MED 251 and OSHA. These standards do not define how often an individual can be exposed to this level before hearing damage occurs. The maximum level was set with the view that "because of the complexity of factors influencing the hazards from impulsive noise, it is feasible to establish only one maximum recommended exposure level...some persons may be susceptible to damage from lower levels."⁶

Turbine noise, which is the primary source of noise at CE powerhouses, consists of broad band noise (Figures 2 through 11) as do many of the secondary noise sources such as auxiliary pumps. Turbine noise is produced by water turbulence. For a complete list of common noise sources, see Table 5.

Table 5

List of Noisy Areas

Back-up generator rooms
Chiller or air conditioning pump rooms
Draft tube access corridors
Generator floor
Inside generator housing
Top of generator housing
Turbine pit floor
Turbine pits

Pure Tone Noise

As illustrated in Figures 2 through 11, the spectrum of noise emanating from main electrical generators is consolidated at 120 Hz. This

⁶ *Noise and Conservation of Hearing*, DA Technical Bulletin TB MED 251 (DA, 7 March 1972).

is caused by the expansion and contraction of magnetic materials as the generator's field builds and falls twice each cycle. The resulting 120 Hz noise is heard as a pure tone. This pure tone, as discussed in Chapter 3, registers deceptively low on the A-weighted scale required by TB MED 251 and OSHA. There is, therefore, a potential damage risk from this pure tone, despite the fact its A-weighted measure conforms to TB MED 251 and OSHA standards. At the CE powerhouses at Miller's Ferry (Figure 9) and Jim Woodruff, the generator noise had a strong third harmonic (360 Hz) component.

Six of the 10 generators whose spectra are shown in Figures 2 through 11 have a strong 120-Hz component which exceeds the damage risk criterion of 92 dB. Miller's Ferry (Figure 9) has a strong 98 dB peak at 360 Hz. This is well above the 86 dB recommended by the damage risk criterion for this frequency. Although tape recordings were not made at Jim Woodruff Dam, the noise has a similar 360-Hz component. The maximum C-weighted level was 93 dB on the generator floor; this would probably yield about 91 dB for the 360-Hz component.

5 CONCLUSIONS

CE powerhouse noise is generally broad band in nature. The exceptions are the main electrical generators, which produce a pure tone at 120 Hz. Eight out of 10 generators have a clear 120-Hz peak; in six of these, the amplitude is greater than the 92-dB limit allowed by the damage risk criteria. Miller's Ferry has a 360-Hz peak of 98 dB, which exceeds the 86-dB limit allowed by the damage risk criterion.

The primary broad band noise source is generated by water turbulence. Secondary noise sources include back-up diesel generators, air conditioning compressors, and auxiliary pumps.

The broad band noise levels common to most CE powerhouses measured by this investigation often exceeded the maximum acceptable 85-dBA level required by TB MED 251 and OSHA. In addition to these common sources, there are many secondary noise sources with noise levels that were often measured in excess of 85 dBA, but were not considered as significant because (1) the noise levels did not extend far beyond the immediate source area, and/or (2) the sources were unique to one or a small group of CE powerhouses.

Chapter 3 presented limits allowed by the damage risk criteria, TB MED 251, and OSHA. These limits allow personnel to be exposed to high noise levels greater than the 8-hour level if the time exposure is reduced. However, personnel may move from one high noise area to another throughout the day, resulting in an 8-hour noise exposure level greater than the standards permit. When the noise sources emit pure tones, the A-weighted measurement required by TB MED 251 and OSHA does not correctly state the damage risk. Therefore, a second-phase effort is recommended to develop design criteria for new powerhouses and remedial measures for existing ones so that safe noise levels can be maintained at these CE facilities.

APPENDIX:

DATA SHEETS

Power Plant: Allatoona, GA

Information Source: CERL

Sound Pressure Levels:

Source	dBA	dB C	Peak
Back-up generator	--	--	--
Chiller pump	86	88	101
Control room	52	--	--
Draft tube access door	--	--	--
Generator floor	72	84	94
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	82	87	100
Sewage disposal pump room	82	96	103
Leakage noise	75	76	89
Strainer and motor	82	84	95

Other:

Generator size (MW): 36, 2

Generator speed (rpm): 112.5, 450

Age: 28 years

Power Plant: Big Bend Powerhouse, SD

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	101	104	117
Chiller pump	84	94	--
Control room	66	73	88
Draft tube access door	92	97	109
Generator floor	84	93	--
Inside generator housing	100	110	121
Top generator housing	87	101	109
Turbine floor	79	91	--
Turbine pit	90	99	112
Machine shop	70	74.5	--
DTDA make up air valve area (valve open)	95	97	--
Governor air compressor	86	--	--
Front of governor cabinet	83	93	--
Thrust bearing access passage	95	102	--
Mag-a-stat regulator	82	88	--

Other:

Generator size (MW): 58.5

Generator speed (rpm): 81.8

Age: 13 years

Power Plant: Bonneville, WA

Information Source: Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	--	--	--
Chiller pump	--	--	--
Control room	--	--	--
Draft tube access door	96	--	--
Generator floor	81	--	--
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	86	--	--
Turbine pit	100	--	--
Turbine floor oil pumps	86	--	--
Lower pipe tunnel	92	--	--
Compressor room floor	82	--	--

Other:

Generator size (MW): 43.2, 54

Generator speed (rpm): 75, 75

Age: 40 years

Power Plant: Carter's Lake, GA

Information Source: CERL

Sound Pressure Levels:

Source	dBA	dB	Peak
Back-up generator	79	93	107
Chiller pump	85	85	105
Control room	66	80	--
Draft tube access door	98	104	116
Generator floor	84	98	101
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	88	92	100
Leakage	96	96	108
Fan in diesel generator room	98	102	115
Turbine pit with unit motoring	83	94	108

Other:

Generator size (MW):125.0

Generator speed (rpm): 163.6

Age: 3 years

Power Plant: Clark Hill Dam, GA

Information Source: CERL

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	82	84	96
Chiller pump	--	--	--
Control room	--	--	--
Draft tube access door	92	102	115
Generator floor	75.5	88.5	101
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	87	93	106
Machine shop	68	82	94
Doorway of generator housing	95	103	115

Other:

Generator size (MW): 40

Generator speed (rpm): 100

Age: 25 Years

Power Plant: Detroit Dam, OR

Information Source: Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	--	--	--
Chiller pump	--	--	--
Control room	70	--	--
Draft tube access door	89	--	--
Generator floor	83	--	--
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	86	--	--
Turbine pit	94	--	--
Air compressor room	88	--	--
Motor pump room	84	--	--
Centrifuge room	90	--	--

Other:

Generator size (MW): 50

Generator speed (rpm): 163.6

Age: 24 years

Power Plant: Dworshak Dam, ID

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	--	--	--
Chiller pump	--	--	--
Control room	60	75	94
Draft tube access door	102	105	--
Generator floor	84	--	--
Inside generator housing	--	--	--
Top generator housing	88	--	--
Turbine floor	83	--	--
Turbine pit	101	106	--
Circuit breaker	--	--	140
Machine shop	75	--	--
Air housing (on)	113	118	--
Fish pump	93	--	--
Turbine pit oil pump	93	--	--
Air compressor	93	--	--

Other:

Generator size (MW):90, 220

Generator speed (rpm):200, 128.6

Age: 5 years

Power Plant: Fort Peck Powerhouse, MT

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	79	85	--
Chiller pump	--	--	--
Control room	72	85	96
Draft tube access door	101	110	132
Generator floor	86	91	104
Inside generator housing	97	106	118
Top generator housing	88	106	112
Turbine floor	86	95	--
Turbine pit	87	92	104
Machine shop	78	88	--
Station air compressor (running)	100	104	--
Butterfly valve corridor (north end)	92	101	--
Exciter unit	93	103	--
Penstock area (spiral core door)	92	103	--
Station service transformer room	71	85	--

Other:

Generator size (MW): 35, 15, 40

Generator speed (rpm) 128.6, 164, 128.6

Age: 34 years

Power Plant: Fort Randall, SD

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dB	Peak
Back-up generator	--	--	--
Chiller pump	89	89	102
Control room	56	67	85
Draft tube access door	82	92	--
Generator floor	72	87	98
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	82	92	103
Turbine pit	85	92	--
Main exciter	73	86	--
De-icing air compressor (both operating)	99	102	--
Machine shop	59	71	--
ACB-124 air receiver with silencer	103	--	--

Other:

Generator size (MW): 40

Generator speed (rpm): 85.7

Age: 24 years

Power Plant: Garrison, ND

Information Source: Safety Office

Sound Pressure Levels:

Source	dBA	dB(C)	Peak
Back-up generator	--	--	--
Chiller pump	65	80	--
Control room	52	73	--
Draft tube access door	87	97	--
Generator floor	80	94	--
Inside generator housing	--	--	--
Top generator housing	60	77	--
Turbine floor	--	--	--
Turbine pit	91	103	--
Compressor room	98	89	--
Machine shop	73	86	--
Spreader room	63	79	--
Station service switchgear room	83	93	--
Water pump treatment room	80	89	--
Fan room No. 2	70	86	--

Other:

Generator size (MW): 80

Generator speed (rpm): 90

Age: 22 years

Power Plant: Gavin's Point, NE

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	102	104	117
Chiller pump	83	39	102
Control room	64	31	92
Draft tube access door	90	103	115
Generator floor	76	87	102
Inside generator housing	96	101	115
Top generator housing	--	--	--
Turbine floor	80	89	103
Turbine pit	89	96	107
Machine shop	67	82	95
Cable spreading room	79	86	99
Governor cabinet	79	90	--
Air compressor room	82	91	--

Other:

Generator size (MW): 33.3

Generator speed (rpm): 75

Age: 21 years

Power Plant: Hartwell Dam , GA

Information Source: CERL

Sound Pressure Levels:

Source	dBA	dB	Peak
Back-up generator	98	100	112
Chiller pump	--	--	--
Control room	60	78	92
Draft tube access door	95	105	117
Generator floor	78	96	98
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	83	93	106
Turbine pit	92	105	117

Other:

Generator size (MW):66

Generator speed (rpm): 100

Age: 16 years

Power Plant: Jim Woodruff Power Plant, FL

Information Source: CERL

Sound Pressure Levels:

Source	dBA	dB(C)	Peak
Back-up generator	--	--	--
Chiller pump	86	90	103
Control room	--	--	--
Draft tube access door	93	106	117
Generator floor	91	93	103
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	88	88	103
Fan room	76	81	93
Machine shop	78	83	94

Other:

Generator size (MW): 10

Generator speed (rpm): 75

Age: 21 years

Power Plant: John Day Dam, WA

Information Source: Safety Office

Sound Pressure Levels:

Source	dBA	dB(C)	Peak
Back-up generator	--	--	--
Chiller pump	--	--	--
Control room	--	--	--
Draft tube access door	96	--	--
Generator floor	80	--	--
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	94	--	--
Compressor room	85	--	--
Fish pump room	98	--	--

Other:

Generator size (MW): 135

Generator speed (rpm): 90

Age: 9 years

Power Plant: Libby Dam, MT

Information Source: Safety Office

Sound Pressure Levels:

Source	dBA	dB C	Peak
Back-up generator	--	--	--
Chiller pump	--	--	--
Control room	71	--	--
Draft tube access door	94	--	--
Generator floor	83	--	--
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	87	--	--
Turbine pit	97	--	--
Circuit breaker alcove	85	--	--

Other:

Generator size (MW): 105

Generator speed (rpm): 128.6

Age: 3 years

Power Plant: Miller's Ferry , AL

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dB C	Peak
Back-up generator	107	107	117
Chiller pump	88	92	104
Control room	70	84	95
Draft tube access door	88	98	110
Generator floor	92	102	104
Inside generator housing	106	112	121
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	92	98	109

Other:

Generator size (MW): 25

Generator speed (rpm): 69.3

Age: 8 years

Power Plant: Oahe Power Plant, SD

Information Source: CERL/Safety Office

Sound Pressure Levels:

Source	dBA	dB(C)	Peak
Back-up generator	102	103	115
Chiller pump	79	82	98
Control room	63	72	78
Draft tube access door	100	112	123
Generator floor	82	97	111
Inside generator housing	101	109	123
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	88	95	108
Machine shop	71	81	--
Spreading room	67	79	--
De-icing air compressor	86	100	--
Draft tube depressing air compressors	94	108	--
Sewage treatment room	73	86	--

Other:

Generator size (MW): 85

Generator speed (rpm): 100

Age: 16 years

Power Plant: Stockton, MO

Information Source: Safety Office

Sound Pressure Levels:

Source	dBA	dBC	Peak
Back-up generator	--	--	--
Chiller pump	--	--	--
Control room	77	89	--
Draft tube access door	89	104	--
Generator floor	76	92	--
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	97	102	--
Air handling unit	77	--	--

Other:

Generator size (MW): 45.2

Generator speed (rpm): 75

Age: 5 years

Power Plant: Walter F. George, GA

Information Source: CERL

Sound Pressure Levels:

Source	dBA	dB C	Peak
Back-up generator	105	107	120
Chiller pump	--	--	--
Control room	70	84	97
Draft tube access door	99	110	124
Generator floor	85	100	110
Inside generator housing	--	--	--
Top generator housing	--	--	--
Turbine floor	--	--	--
Turbine pit	85	97	109
Water depressing air compressors	72	80	93

Other:

Generator size (MW): 32.5

Generator speed (rpm): 112.5

Age: 15 years

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