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U.S. ARMY CORPS OF ENGINEERS
OZARK POWER PLANT
OZARK, ARKANSAS

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I. SUMMARY

On August 4-6, 1992, and January 19-22, 1993, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the U.S. Army Corps of Engineers hydroelectric power plant on the Arkansas River at Ozark, Arkansas. The evaluation was initiated by a request received in May 1992, from the International Brotherhood of Electrical Workers (IBEW) Local 2219 about employees' concerns about excessive noise levels in the power plant resulting from the generation of electricity. During the first site visit, it was learned that the U.S. Army Corps of Engineers had let a contract for an acoustical treatment of the ceiling in the power plant that had been recommended in a private consultant's report on the noise levels in the facility. The second site visit was conducted to test the impact of the acoustical treatment to the building and to measure electric and magnetic field (EMF) strengths in the power plant caused by electricity generation, an additional concern of employees at the facility.

Personal noise exposure measurements were made on all of the electricians and mechanics at work on the days of the surveys with noise dosimeters set to measure noise according to Department of the Army noise regulations.[1] Spot measurements of infrasound (sound below the sonic range of human hearing) and simple measurements of structural vibration were also made during the first site visit. During the second visit, a survey of the occupational exposure level of EMF encountered by the electricians and mechanics was conducted.

All of the mechanics and electricians who worked in the power plant had noise exposures that exceeded the U.S. Army Corps of Engineers safety and health requirements. However, worker compliance with the wearing of hearing protective devices while working was observed to be good. Deficiencies were discovered in the audiometric testing program used at the power plant. All other measured occupational exposures were found to be below relevant evaluation criteria.

Personal noise levels exceeding the U.S. Army Corps of Engineers regulations were measured during both site visits. A statistical analysis of the amount of time a worker spent in noise above the regulation during the site visits revealed that there was no difference in noise above 85 dB(A) as a result of the acoustical treatment done to the powerplant. Additional suggestions for noise controls in the facility are given in Section VII of this report. Occupational levels of infrasound, vibration, and EMF were low. However, a potentially higher exposure to magnetic fields was found for workers who worked directly on or near a cable tray located at the back wall behind the electrical generators. Suggestions for changes in work practices are offered in the Recommendation Section to reduce the EMF exposures to employees.

KEYWORDS: SIC 4911 (Electric Services), noise, vibration, infrasound, hearing conservation, electric and magnetic fields (EMF), hydroelectric power plant, U.S. Army Corps of Engineers.

II. INTRODUCTION

On May 4, 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the International Brotherhood of Electrical Workers (IBEW) Local 2219 about employees' concerns about excessive noise levels in the U.S. Army Corps of Engineers hydroelectric power plant at Ozark, Arkansas. The Corps of Engineers had contracted with an outside firm to measure noise levels in the power plant in November 1991, and a recommendation for the treatment of the turbine and generator bay ceilings with sound absorbing materials to reduce reverberant noise levels was made by the consultant.

NIOSH investigators decided to conduct an employee noise exposure survey before the acoustical treatment was started and return to repeat the survey when the noise control had been put into place. Both surveys were done when the Ozark Power Plant was operating with all five of its turbines/generators at maximum output capacity. During the first survey, employees raised concerns about vibration and infrasound that were able to be addressed with the measurement equipment taken to the site. However, in order to address the question of electric and magnetic field (EMF) exposures to the workers, additional NIOSH personnel and equipment was required. Thus, an EMF survey was also completed during the second site visit to the power plant. For this evaluation, EMF refers to the presence of fields that have frequencies below 1000 Hertz (Hz). Sometimes these fields are referred to as extremely low frequency (ELF) radiation.

An opening conference was held on the first day of both site visits with the power plant employees and management representatives to explain the evaluation plans and listen to concerns about the working environment. A closing conference was also held at the end of both site visits to verbally explain preliminary findings from the evaluations. Written results from the first NIOSH noise survey were conveyed to the power plant management and IBEW Union by an interim report dated August 21, 1992. Additionally, the area octave-band noise results collected in the archways of the generator bay during the second site visit were sent by facsimile machine to the U.S. Army Corps of Engineers Little Rock, Arkansas headquarters on February 11, 1993, in order to provide the Corps' engineers data on which to base additional noise controls for the power plant.

III. BACKGROUND

The Ozark Power Plant is part of the Ozark-Jeta Taylor Lock and Dam located on the Arkansas River in Ozark, Arkansas. The facility is operated and maintained by U.S. Army Corps of Engineers civilian personnel. Four mechanics, three electricians, and a student intern operated the power plant along with the administrative personnel. Hydroelectric power generated at the plant is marketed by the Southwestern Power Administration (SPA), Department of the Interior. The electricity is delivered over a network of high voltage transmission lines owned by the SPA and by public and private utility systems. The power is sold to municipalities, rural electric cooperatives, and to public and private utilities in Arkansas, Missouri, Oklahoma, Louisiana, and Eastern Texas.

The power plant contains five inclined axis hydraulic turbine-driven generators. Each turbine consists of a water passage, 60.24 revolution per minute (rpm), 27,900 horsepower inclined axis, movable-blade turbine connected through a 8.533 to 1 speed increaser to a 514 rpm, 20,000 kilowatt (kW) generator. Other features of the facility include a mechanical service area and offices inside the plant, and a transformer and switching yard adjacent to the power plant.

There are five electrical generators at the Ozark facility each rated at 20 megawatt (MW) capacity, with an average annual electrical output of 400 million kilowatt-hours per year. The power plant operates at full capacity only about 25% of the time. The remaining 75% of the time the facility operates at 60 to 80 MW capacity, or about 12 to 15 MW per generator. Each generator has 14 poles and produces electricity at 60 Hz (±0.5 Hz). The generators are three phase, with two cables per phase. This means there are a total of six cables containing electrical energy per generator, or a total of 30 cables for the entire facility. The cables coming from each generator are routed on wall-mounted racks located behind the generators. The electrical energy carried in these cables is ultimately directed to a step-up transformer, located in front of the facility, before it is sent to the switching yard. Once the power is in the switching yard, it is distributed via overhead cables to the power grid network.

The Ozark Power Plant is constructed of concrete and steel with ceramic tile on the floors and lower walls of the turbine and generator bays. The turbines are in open pits on the upriver side of the building and the generators are on the main floor on the downriver side of the facility. The center section of the power plant has several enclosed maintenance shops, pumps, and oiling equipment along a central corridor. An employee lounge and shower area is also located on the main floor of the power plant, between the turbine and generator bays. A turbine shaft runs directly below the lounge and shower area. The turbine bay, generator bay, and central support section are separated from each other by walls that have several doors and archways which allow movement between the three general areas. Additional maintenance shops are located along one perimeter wall (Figure 1). A control room, administrative offices, mechanical ventilation room, and visitor observation galleries are on the upper floors of the power plant.

IV. MATERIALS AND METHODS

Noise

The personal exposure noise survey was conducted with Quest Electronics Model M-27 Noise Logging Dosimeters placed on all mechanics and electricians who reported for work on the days of the two site visits. The employees wore them for their entire work shift. A dosimeter was suspended from the employee's waist, generally through the worker's belt, and a small remote microphone fastened near the top of the worker's shoulder to continuously monitor and record the noise exposure from the employee's daily work activities. The noise dosimeters were set at an 85 decibel on an A-weighted scale [dB(A)] criterion level with a 4 dB exchange rate according to existing noise regulations in effect at the facility. The dosimeters were calibrated according to the manufacturer's instructions both before and after each work shift. Data collected with the dosimeters were downloaded into a laptop computer with supporting Quest M-27 Metrosoft software for later analysis.

Area noise samples were made with a Larson-Davis Laboratories Model 800B Precision Integrating Sound Level Meter. Octave band measurements at consecutive center frequencies of 31.5 Hertz (Hz) to 16 kilohertz (kHz) along with A-weighted and C-weighted scales were made in the various locations of the power plant as it was in full operation. Additional octave band noise measurements were made in the infrasonic sound range (4 - 16 Hz) during the first site visit around the turbines, generators, and turbine-access tunnels. Octave measurements were made with the sound level meter integrating the sound energy over a 1-minute period with a 3 dB exchange rate.

EMF

The radiation evaluation was designed to survey workers' exposures to EMF during a typical workday. Up to ten workers were at the facility on the days the measurements were collected during the second site visit. The limited number of measurements taken in and around the power plant were not intended to represent an in-depth evaluation of the radiation fields at the site; rather, they were intended to approximate occupational exposure levels found on the days of the evaluation.

A Holaday Industries, Inc. model HI-3602 ELF Sensor, connected to a Holaday Industries, Inc. model HI-3600 survey meter, was used to document both the magnitude of 60 hertz EMF as well as the electrical frequency and the waveform produced by these fields. The electric field (E-field) strength can be measured either in volts per meter (V/m) or kilovolts per meter (kV/m). The magnetic field strength (H-field) can be expressed in units of milligauss (mG).

H-field measurements were made with the EMDEX II exposure system, developed by Enertech Consultants. The EMDEX II is a programmable, data-acquisition meter which measures the orthogonal vector components of the H-field through its internal sensors. Measurements can be made in the instantaneous read or storage mode. The system is designed to measure, record, and analyze power frequency magnetic fields in units of mG in the frequency range from 30 Hz to 800 Hz.

Averaged H-fields were collected with an AMEX-3D exposure meter manufactured by Enertech Consultants. This small, lightweight, three-axis magnetic field meter can be worn by a worker to monitor average H-field exposures. The AMEX-3D frequency response is from 35 Hz to 1000 Hz.

Holaday Industries, Inc. models HI-3600-01 and HI-3600-02 survey meters were used to document the electric and magnetic fields in the ELF frequency bands. The instruments also measure the frequencies of the emitted radiation. Measurements with the meters were made at locations where personnel worked during the day.

The EMF results were collected and documented with the EMDEX, AMEX, and Holaday systems both inside and outside the power plant. The EMDEX units were worn in pouches by selected workers at waist height. The AMEX units were positioned at various locations on the second floor of the power plant. In addition, a limited number of area measurements were made with the Holaday monitors at selected work locations inside the facility. Where possible, at least two readings were taken at each measurement site with the Holaday monitors and the average reading recorded. All systems were calibrated either by NIOSH or the manufacturer within six months of the date of this evaluation.

V. EVALUATION CRITERIA

Noise

Occupational deafness was first documented among metalworkers in the sixteenth century.[2] Since then, it has been shown that workers have experienced excessive hearing loss in many occupations associated with noise. Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[3]

While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist", have still higher frequency components.[4]

Employees at the Ozark Power Plant were under U.S. Army Corps of Engineers noise requirements at the time of the evaluation.[5] These noise requirements are identical to the Department of the Army regulations which stipulate that a worker's noise exposure should not exceed steady-state noise of 85 dB(A), regardless of the duration of exposure; or impulse noise of 140 dB peak.[1] If either of these two criteria are exceeded, the personnel will be enrolled in a hearing conservation program consisting of noise hazard identification, engineering controls, hearing protectors, monitoring audiometry, health education, enforcement, and program evaluation. There are, however, certain situations where the program requirements can be waived, such as, visitors in the noise-hazardous areas must wear hearing protectors but do not need to undergo monitoring audiometry; or when noise levels rise infrequently and unpredictably to 85 dB(A) or greater for short durations, then hearing protectors may be impractical and unnecessary. In all waiver situations, the installation medical authority (IMA) must perform a thorough noise-hazard evaluation of the area and consider all factors which may potentially cause hearing impairment before waiving any hearing conservation program requirements.

Contract employees working at the power plant are under the Department of Labor's Occupational Safety and Health Administration (OSHA) noise regulations. The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[6] specifies a maximum permissible exposure limit (PEL) of 90 dB(A)-slow response for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in order to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. Both NIOSH, in its Criteria for a Recommended Standard,[7] and the American Conference of Governmental Industrial Hygienists (ACGIH), in their Threshold Limit Values (TLVs),[8] propose an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average (TWA) noise limits as a function of exposure duration are shown as follows:

Duration of Exposure (hrs/day)	Sound Level (dB(A)) NIOSH/ACGIH	OSHA
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115 *
1/8	115 *	-
		**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).
** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

When comparing the various regulations and standards for noise, the U. S. Army Corps of Engineers' regulation is the most conservative and most protective of employees. Therefore, the noise data obtained at the Ozark Power plant will only be compared to to this latter regulation of 85 dB(A), regardless of the duration of exposure.

EMF

At the present time there are no Occupational Safety and Health Administration (OSHA) or NIOSH exposure criteria for sub-radiofrequency (RF) fields. The American Conference of Governmental Industrial Hygienists (ACGIH) has published Threshold Limit Values (TLVs) for sub-radiofrequency electric and magnetic fields.[8] The TLV for magnetic flux density (B_{TLV}) states "routine occupational exposure should not exceed:

$$B_{TLV} \text{ (in mT)} = 60/f$$

where mT is millitesla and f is the frequency in hertz." Conversely, the electric field TLV states "occupational exposures should not exceed a field strength of 25 kV/m from 0 to 100 Hz. For frequencies in the range of 100 Hz to 4 kHz, the TLV is given by:

$$E_{TLV} \text{ (in V/m)} = 2.5 \times 10^6/f$$

where f is the frequency in Hz. A value of 625 V/m is the exposure limit for frequencies from 4 kHz to 30 kHz."

This means, for example, at 60 Hz, which is classified as ELF, the electric field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 1 mT or 10 G. At 1.6 Hz, the electric field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 37.5 mT or 375 G. At 9.9 kHz, which is classified as very low frequency (VLF), the electric field intensity TLV is 625 V/m and the magnetic flux density TLV is 0.006 mT or 4800 milliamp per meter (mA/m) [1 mT = 800 amp per meter (A/m)].

The basis of the ELF E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The magnetic flux density TLV addresses induction of magnetophosphenes in the visual system and production of induced currents in the body.

VI. RESULTS

Noise

A total of 22 full shift noise samples were collected from employees during the first survey period and 15 full shift noise samples were obtained during the return visit. The employees were comprised of mechanics and electricians who worked in the power plant. In both surveys, the time-weighted average (TWA) noise exposures exceeded 85 dB(A) when the dosimeters were set to a 4 dB exchange rate. Specifically, the first survey period results were found to have a median 8-hour TWA of 89 dB(A) [range: 78 to 97 dB(A)], and the second survey found median TWA noise exposures of 88 dB(A) [range: 76 to 93 dB(A)].

When the noise exposures for the mechanics and electricians were viewed separately, it was found that the mechanics had median noise exposures of 92 dB(A) in August 1992 and 85 dB(A) in January 1993. The electricians had median noise exposures of 86 dB(A) during the first site visit and 89 dB(A) on the second survey dates. The decrease in noise exposure in one group with a simultaneous increase in exposure for the other group is likely the result of changes in work tasks during the survey dates rather than a change in the acoustic characteristics of the building. It was observed that the electricians spent more time on the power plant floor during the second survey. A great deal of their day was spent working in the control room during the first survey.

Examples of daily noise exposures for a mechanic and electrician are shown in Figures 2 and 3. The figures show the general decrease in the noise patterns for the mechanic and the general noise increase for the electrician for the two survey dates. The figures also show the effect of changing the workers' break room location from the area between the turbine and generator bays to a room upstairs near the administrative offices. The August 4, 1992, figures show break periods at 2.5 hours, 4.5 hours, and 6.5 hours from the start of the work shift that are greater than 80 dB(A). However, the break periods at 2, 4, and 6 hours from the beginning of the shift seen on the January 21, 1993, figures are less than 80 dB(A).

An alternative way to view the employees' noise dosimeter results is to calculate the percentage of time an employee spends at or above 85 dB(A) since the Corps' noise regulations are written in terms of a noise level [85 dB(A)] that is not to be exceeded for any duration. The employees spent a mean time of 40% of the day at or above 85 dB(A) during the August 1992 survey and a mean time of 42% of the day at the same level during the January 1993, survey period. The differences in the percentage values were analyzed with a *t*-test for two related samples to see if the changes in the power plant affected the employees' noise exposures.[9] The analysis yielded a *t*-value of 0.26 which has an associated probability level greater than 0.20 for a two-tailed test of significance. Thus, the percentage of time employees spent at or above 85 dB(A) was not significantly different between the two survey periods.

The break room located in the power plant was an area included in the acoustical contractor's remediation plan. The break room was to be isolated from the rest of the power plant with an additional door and anteroom, and with the blocking of the attic ventilation ductwork above the break room. The results of the changes are reflected in Figure 4 which show the octave-band sound levels along with A- and C-weighted levels measured during the two survey periods. The figure shows very little change in the overall sound levels or in the individual octave-bands between the two periods as a result of the changes made to the break room.

Octave-band measurements were made at the center of the archways located up river from each of the five generators and speed increasers during the second survey period (Figure 5). The octave-band analysis shows that the median noise levels in the archways are maximum at 500 Hz. There are nearly equal sound energies in the octave-bands of 63 Hz, 125 Hz, and 250 Hz. The noise signature in the archways is also characterized as having decreasing sound levels in the higher octave bands, falling from 90 dB at 500 Hz to 37 dB at 16 kHz. The high frequency reduction is most likely the result of the acoustical treatment that was applied to the ceiling above the generators. However, the noise survey done by NIOSH investigators reveals that there is still a median sound level of 89 dB(A) directed through the archways to the rest of the power plant, a sound level that exceeds the U.S. Army Corps of Engineers noise regulation for their employees.

There was not sufficient evidence obtained during the evaluation about the workers' exposures to whole-body vibration or infrasound (sound energy that has frequencies below the human range of hearing) to warrant concern about possible health effects from these exposures. Neither of these two physical agents approached intense enough levels to cause health effects according to recent research findings and evaluation criteria.[10-12]

Corps employees at the power plant have received audiometric tests in the past. However, the hearing test program has been sporadic with large time gaps between the tests. The hearing tests, conducted by an outside contractor, were supplied to the NIOSH investigators for review. Tests from 1980, 1982, 1990, and 1992, for the four mechanics, three electrician, and plant superintendent were included. The mean hearing levels for the eight employees are presented in Figure 6. The general decline in hearing acuity for the higher frequency test sounds seen in the figure is consistent with a noise-induced hearing loss pattern.

Not all employees were tested on the four test dates. Because of the small number of employees in the test group, any comprehensive analysis of the data would be difficult to interpret. The three workers who were tested in 1980 and 1982 and the eight workers who were tested in 1990 and 1992 were subjected to the type of database analysis proposed by the American National Standards Institute that uses a change of 15 dB Hearing Level (HL) in either the positive or negative direction at any frequency from one year to the next as a metric of unacceptable variance for hearing tests.[13] This simplistic analysis revealed that one of three employees exhibited this amount of variance in the first set of hearing tests and that all eight employees had changes of this magnitude on the second set of hearing tests. Variance of this magnitude on year to year tests is indicative of an audiometric testing program that is experiencing some problems.

EMF

A total of 12 AMEX dosimeters were mounted in pouches and taped to the walls at selected locations on the 2nd floor walkway and around turbine locations in the power house, at a height of 4.5 feet above the floor. The AMEX dosimeters were left at their locations for about six hours. The magnetic fields documented for this portion of the evaluation ranged from a low of 0.14 milligauss (mG) to a high of 0.96 mG. The average for all 12 dosimeters was 0.46 mG.

Ten EMDEX dosimeters were worn for six hours by different plant personnel on two days. The results from the EMDEX dosimeters by employee job titles are shown in Table I. Unlike the AMEX dosimeters which measured the magnetic field strengths at certain locations, the EMDEX dosimeters measured magnetic field strengths recorded by workers as they performed their various work tasks. The 6-hour average magnetic field results for workers, who wore the EMDEX units over the two days, ranged from 0.63 to 27.53 mG.

Using a EMDEX dosimeter as a survey meter measurements at chest height were made around all sides of two different generators operating at 5 megawatts (MW). These measurements demonstrated that the magnetic fields varied from 1.5 mG to 208 mG and that the highest levels were produced at the back side of the generators where the generator cables were located (Figure 7). Additional measurements were then made at the rear of the generator using the EMDEX dosimeter as a survey meter. These additional measurements, shown in Table II, were made at the entrance side of generator #5 and at the exit side of all other generators with the same floor to cable height distance. Table II also shows the results of measurements made at different horizontal distances from the top rack to estimate the falloff effect of the magnetic fields from the cable. It should be noted that cables from the other generators would present contributions to a given measured location. Notice that the maximum magnetic fields recorded were 4.6 G for this measurement at an electrical power generation level of 55 MW.

In order to determine the range of magnetic fields that could be expected to occur at Ozark during a typical day measurements were made near the wall-mounted cable racks at power levels of 22 and 55 MW. Using a EMDEX dosimeter, at chest height, magnetic fields at close cable distances indicated levels of 3.8 and 4.6 G, respectively. Extrapolating this to the maximum plant output of 100 MW, yields magnetic field levels as high as 5.8 G at locations near the cable racks.

Other ELF sources found at the facility that presented occupational exposure are listed in Table III. Some of these sources can give quite elevated magnetic field exposures for several minutes. While it may be difficult to entirely eliminate all of this exposure to workers, awareness of these possible exposure levels may motivate employees and management to develop alternative approaches of controlling exposure, such as reducing time of exposure, shielding sources, and/or increasing distance from sources.[14]

Electric field measurements were taken at many places inside the power house. The results of these measurements ranged from 1.7 to 6.8 V/m. However, the levels of electric field under the power cables beyond the switching yard ranged from 1000 to 4600 volts/meter. It should be noted that these higher levels of electric field were not necessarily occupational exposure, since workers were not observed on the days of evaluation under the power lines outside. However, many fisherman use the river for recreational purposes and can be exposed to EMF produced at the power plant.

Waveforms were analyzed at several sites in the power house. Several different waveforms were captured by the Holaday meter and displayed on a digital oscilloscope and found to be of the normal sinusoidal varying 60 hertz types.

VII. DISCUSSION AND CONCLUSIONS

Noise

All of the workers' noise exposures in the power plant exceeded the U.S. Army Corps of Engineers safety and health requirements. Both the electricians and mechanics who worked in the facility were exposed to noise above the regulated noise level of 85 dB(A). Some of the employees spent over 70% of the work shift in noise that equaled or exceeded 85 dB(A). The acoustical treatment on the ceiling of the facility appeared to have its greatest impact on high frequency sounds (≥2000 Hz) made by the electrical generation equipment, but had little effect on the employees' daily noise exposures. This is evidenced by the finding that the median 8-hour noise TWA values only dropped 1 dB(A) from the first to second survey period.

Nearly all of the employees were observed to be wearing hearing protection devices (HPDs) whenever they were on the main floor of the power plant near the turbines or generators. The mechanics were also seen wearing HPDs while they worked on powered equipment (e.g., metal lathe, power press) in the shop area. The HPDs furnished to the employees should adequately protect the workers from the noise levels which they experience in the power plant on a normal basis as long as the integrity of the HPD is maintained and as long as the employees wear them correctly. The Corps should continue to offer workers a selection of HPDs to use in the power plant as well as update their inventory of protectors when new kinds of HPDs become available. Linear attenuation ear plugs and sound amplified ear muffs are two examples of newer technology that might be adaptable to the power plant noise environment.

The acoustical treatment of the employees' break room did not reduce noise levels to a point where the room would be appropriate to be an area where workers would be able to get a period of relief from the power plant noise. The octave band sound levels measured before and after the acoustical alterations were only minimally different from one another (Figure 4). In fact, because workers would routinely remove their HPDs whenever they entered the break room, their ears may actually receive more noise during breaks because of their ears being open to the noise environment with no protection. The dosimeter readouts from the first survey period showed break periods with noise in excess of 80 dB(A) for the three break times, which could equal up to one hour per day. The use of the room located near to the control room on the upper floors of the power plant is a viable alternative to the original break room. In order for the original break room to be used in the future, additional work will be needed that will decouple the room acoustically and vibrationally from the rest of the power plant. An acoustical chamber inside of the existing room which is placed on vibration isolators (dampers) is one approach to reusing the room as it was previously used.

The audiometric testing program for the employees was found to be lacking. Audiometric tests have been administered sporadically in the past. There was no record of employee training in the areas of hearing loss, HPD usage, or the need for audiometric testing. The requirements of the program need to be thoroughly reviewed and bolstered where needed. Some of the newer techniques that have been developed to evaluate hearing conservation programs and audiometric testing could be incorporated into the program to give the Corps feedback about the effectiveness of their hearing conservation efforts.[13,15-18]

EMF

Occupational levels of ELF fields measured at Ozark Power and Dam facility ranged from 1.7 to 4600 V/m and 0.1 to 5800 mG. This evaluation, as with all previous ELF evaluations performed by NIOSH, has demonstrated that magnetic field exposure levels were significantly higher near the ELF sources (i.e.generator cables) than they are at distances away. While this drop-off pattern of magnetic field as a function of distance does exist, the rate does not obey an inverse square law relationship. It has been previously shown that magnetic field near large devices (TV sets, transformers, etc.) will drop-off more slowly than fields produced by smaller devices (switches, bulbs, etc). This observation is based on the fact that large devices have more extended space (volume) for the electric current to move in than does smaller devices-and hence a slower drop-off rate. Since magnetic fields can drop off quickly, it becomes important to determine distances workers are located to ELF sources in order to suggest practical occupational exposure measures. Electric field levels in the ELF frequency region apparently do not have the same drop-off characteristics.

Another important concern noticed at Ozark was that other plant functions have to be carried out near the wall mounted cable racks, such as cleaning ventilation screens. Since the openings to these ventilation devices are mounted above the racks then workers will stand on the racks to perform their other work tasks. In fact, it was noticed by the NIOSH investigators during the evaluation dates that at times workers will have to stand or lie down on the cable racks to complete portions of their tasks. When this is done, the workers are exposed to elevated levels of ELF magnetic fields (i.e., approximately 5 G). In keeping with a philosophy of "prudent avoidance," it is suggested that a review of work practices be performed for plant workers to eliminate or modify those procedures which can result in short-term elevated magnetic field levels.

VIII. RECOMMENDATIONS

The health hazard evaluation at the Ozark Power Plant found noise levels that are potentially hazardous to the employees working at the facility. Worker exposures to infrasound, vibration, and EMF were below occupational exposure criteria. However, higher exposures to magnetic fields were documented for workers who work directly on or near cable trays located near the electrical generators. The following recommendations are offered to reduce potentially hazardous occupational exposures for employees at the Ozark Power Plant.

1. A comprehensive hearing conservation program needs to be implemented for employees who work in the turbine or generator bays of the power plant. The

measured noise exposures on the two surveys dictate that employees are protected from excessive occupational noise. The program components for a hearing conservation program are given in the Army pamphlet 40-501.[1] Technical assistance on the program may be requested from the Commander, USAEHA, ATTN: HSHB-MO-B, Aberdeen Proving Ground, MD 21010-5422. The Army's regulation for noise is undergoing change so that the technical assistance should be sought prior to implementing the hearing conservation program.

2. Hearing protection devices should continue to be worn by Corps employees and contract employees who are required to work in the turbine and/or generator areas of the power plant. Good compliance with the required wearing of the HPDs was observed during both survey periods. This practice should be continued until noise levels are decreased to a level below Army noise regulations.

3. The acoustical treatment to the ceiling of the power plant seemed to reduce high frequency sounds on the floor of the facility. However, it failed to reduce employee exposures to a level below the Corps' noise regulation. Should the U.S. Army Corps of Engineers consider further acoustical treatments in the power plant, it may want to begin to separate the bays on the main floor from one another. It makes sense to begin this process by separating the generator bay from the rest of the area. The dam and power plant's design with open archways that are approximately 40 feet wide by 15 feet high at each of the generators will lend itself to engineering controls that incorporates acoustic walls and doors that will block the noise from entering the rest of the building. The walls and doors can be manufactured from materials that have been tested for their sound transmission loss characteristics according to methods adopted by the American Society of Testing and Materials (ASTM).[19] Lists of transmission losses for various materials have been published in the scientific literature[20-22] and are also available from the manufacturers of the materials if they have been tested by the ASTM procedure. Transmission loss data for some building materials have already been sent to the U.S. Army Corps of Engineers' regional office in Little Rock, Arkansas.

4. The employees' break room between the turbine and generator bays should not be used as an area to take breaks or to eat lunch. The noise levels are too high to give the workers any relief from the noise during the work shift. The room adjacent to the control room on the upper levels of the power plant is more suitable. If this former conference room cannot continue to serve as a break room, then a trailer or separate building located outside of the power plant may be necessary to serve as the employees' break room.

5. The power plant uses a telephone paging system that has been tied into the fire/security system and uses the warning bells to signal employees that they have a

telephone call. The bells in the visitor's hallway next to the control room were measured and had peak noise levels of 110 dB(A). The ambient noise in the hall was 74 dB(A). This use of the fire/security bells results in unnecessary exposures to high peak noise levels. A paging system that uses its own signaling devices that can be adjusted to levels that are appropriate for the area where they are being used would reduced this unneeded noise exposure without compromising the warning levels needed in an emergency situation.

6. Warning signs for the presence of high electric and magnetic fields should be placed near the cables in the area beyond the switching yards and close to the rack-mounted cables in the facility, respectively. The signs should state that these fields are present in the posted area and that entry should be limited to authorized personnel.

7. Workers need to be reminded that magnetic field exposure is higher the closer one gets to a source. Not all workers need to go near the rack-mounted cables and those that do need to have their work tasks examined to reduce time of potential exposure.

8. Management needs to re-evaluate work tasks that required Ozark workers to stand or lay on the rack mounted cables for any reason. This action appears to have a high degree of safety risk associated with it due to electrical shock potential, falls, and inducement of body currents.

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1. Union Representative, IBEW Local 2219; Ozark, Arkansas
2. Superintendent, Ozark Power Plant; Ozark, Arkansas
3. Resident Engineer at the Dardanelle Resident Office; Russelville, Arkansas
4. District Engineer; Little Rock, Arkansas, Michigan

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table I

ELF Magnetic Field Exposure Results in the Ozark Powerhouse
Using Emdex® Dosimeter Collecting at 1.5s

Ozark Power Plant
HETA 92-0243

Date	Job Title	Time Worn	Mean (mG)	St. Dev. (mG)	Geo Mean (mG)	Median (mG)	Max. (mG)	Min. (mG)	95% Tile (mG)	mG-HR	Fraction		
											2 mG	4 mG	10 mG
1/20/93	Shop Worker	6.1	1.54	18.88	0.73	0.9	1278	0.2	2.3	9.47	6.1	0.9	0.5
	Mechanic	6.2	23.94	245.03	0.82	0.6	4145	0.2	7.3	149.54	23.9	11.3	3.6
	Electrician	5.9	27.53	96.16	1.43	0.6	3098	0.2	124.9	161.47	28.4	25.8	23.3
	Custodian	6.0	12.46	165.52	0.68	0.6	3806	0.2	5.4	74.39	14.8	6.7	2.9
	Custodian	5.9	0.93	1.47	0.53	0.4	64.1	0.2	3.2	5.51	11.4	2.9	0.3
1/21/93	Mechanic	6.1	0.63	1.17	0.42	0.3	19.6	0.2	2.0	3.84	5.1	2.3	0.4
	Sr. Mechanic	6.1	9.26	82.5	0.42	0.3	1262	0.2	2.5	56.18	5.3	4.1	3.2
	Sr. Mechanic	6.1	8.65	38.8	1.66	0.8	1862	0.1	27.9	52.99	41.5	37.3	28.8
	Engineer	5.9	1.44	1.25	1.00	0.9	15.9	0.2	3.8	8.43	27.7	1.2	0.2
	Electrician	6.3	14.74	37.04	1.92	1.1	1191	0.2	68.9	92.47	41.8	37.8	30.8

Table II

ELF Magnetic Field Levels in mG at Different Distances from Electrical Generator Cables as Function of Location from Various Generators

Ozark Power Plant
HETA 92-0243

	Left Side of Generator 5	Between Generators 4 and 5	Between Generators 3 and 4	Between Generators 2 and 3	Between Generators 1 and 2	Right Side of Generator 1
At Cable Contact	22	4579	4595	4580	4582	4580
6" from Cable	23.8	537	550	556	412	316
12" from Cable	19	284	320	220	200	35
18" from Cable	23.4	192	163	102	100	25
24" from Cable	25.4	145	98	47	60	18

Table III

Maximum Levels of ELF Magnetic Fields (mG) Measured from Various Sources or Locations at Ozark Power Plant

Ozark Power Plant
HETA 92-243

Sources/Locations	Measurements (mG) Made at		
	Source	Arm	Chest
Grinder-Machine	2500	70	110
Horizontal Band Saw	60	1	1
Sander	5	4	2
Small Drill Press	6	2	4
Large Drill Press	1	1	1
Lathe	12	1	2
Vacuum Cleaner	1300	100	2
Hand-Held Disc Grinder	3300	2000	3000
Floor Waxer	138	---	1.2
Can Opener	5700	---	3010
Teletype	650	---	---
Top of Generator	200	---	---
Visitor Area - 1st Floor	14		4
Control Room - 3rd Floor			6