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Illinois Power Company
Baldwin, Illinois

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Preface

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Acknowledgments and Availability of Report

This report was prepared by Allison Tepper, Dino Mattorano, and C. Eugene Moss, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Kevin Hanley and Vlasta Deckovic-Vukres. Desktop publishing by Kathy Mitchell.

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Health Hazard Evaluation Report 96-0006-2604
Illinois Power Company
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SUMMARY

In October 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Illinois Power Company's Baldwin station in Baldwin, Illinois. The requestor, the Corporate Medical Director, reported the occurrence of three cases of brain cancer diagnosed among employees between 1990 and 1994. NIOSH investigators conducted a site visit at the facility from May 14 through May 15, 1996. The site visit included a walk-through tour of the facility, interviews with employees, and environmental monitoring for volatile organic compounds, polycyclic aromatic hydrocarbons (PAC), and extremely low frequency (ELF) electromagnetic radiation.

The three cases of cancer were confirmed by medical information provided by the company. This information showed that each of the three affected individuals had a glial cell tumor; two had an astrocytoma; and one had an ependymoma. All three were male employees between the ages of 38 and 57 and had worked at Baldwin from 14 to 19 years at the time of their diagnosis. For nearly all this time, each had worked as a maintenance mechanic. Eight other individuals from several job titles with varied diagnoses also were reported to have cancer.

Six personal breathing zone (PBZ) and six area air samples were collected for PACs. The PBZ sample concentrations were below the minimum detectable concentration (MDC) of 1 microgram per cubic meter of air (ug/m^3) using a sample volume of 1028 liters. Trace concentrations of PACs were detected in the area air samples, but the concentrations were much lower than occupational exposure limits. Surface vacuum samples were collected at four locations throughout the Baldwin station. The sample results identified trace concentrations of PACs in the settled dust.

ELF electric and magnetic field strength levels, both inside and outside the facility, are below the current occupational exposure ceiling limit recommended by ACGIH, and are generally within the range of exposure levels previously measured by NIOSH in similar evaluations.

Although NIOSH investigators did not conduct a comprehensive heat stress evaluation, temperature and relative humidity measurements were made. The results ranged from 78 °F to 104 °F and from 35 % to 60 % for temperature and relative humidity, respectively.

The cause of brain cancer among three employees at the Baldwin station of the Illinois Power Company could not be identified in this investigation. The features of this cluster (such as the variable nature of maintenance mechanics' jobs) and the limitations in the scientific methods available to evaluate such clusters preclude a definitive statement about whether brain cancer among employees is related to occupational exposures. Heat-related disorders such as heat rash, heat cramps, heat exhaustion, and heat stroke are important concerns for workers exposed for extended periods of times to the higher temperatures measured at the Baldwin station.

Keywords: SIC 4911 (power, electric: generation, transmission or distribution), brain cancer, EMF, volatile organic compounds, polycyclic aromatic hydrocarbons

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INTRODUCTION

In October 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Illinois Power Company's Baldwin station in Baldwin, Illinois. The requestor, the Corporate Medical Director, reported the occurrence of three cases of brain cancer diagnosed among employees between 1990 and 1994. All affected individuals had been employed as maintenance mechanics. NIOSH investigators conducted a site visit at the facility from May 14 through May 15, 1996.

BACKGROUND

Baldwin is one of four fossil fuel stations producing electricity for the Illinois Power Company. It consists of three generating units, which became operational between 1970 and 1975. Each unit can produce approximately 600 Megawatts (MW) for a total output of nearly 1800 MW. At the time of the NIOSH HHE, boiler Unit #2 was shut down for maintenance. During this time, a majority of the workers' activities were located around Unit #2 turbines. During the outage, employees worked six 10-hour days per week.

At the time of the NIOSH site visit, approximately 250 Illinois Power employees worked at Baldwin. These individuals were divided into two organizational groups, Baldwin employees, who worked permanently at the Baldwin station, and Power Plant Services employees, who mostly worked at the Baldwin station, but could be assigned to other Illinois Power stations. Fifty-two maintenance mechanics were in the latter group. Some employees who previously were maintenance mechanics had been given a new job title, shift technician (tech), and were now permanent Baldwin employees.

Information received from representatives of Local 51 of the International Brotherhood of Electrical Workers (IBEW) and Illinois Power Company, and observations made by NIOSH investigators revealed that the following job activities could be performed by maintenance mechanics/shift techs at the Baldwin station. This list should not be considered a comprehensive list of duties but a general description of activities performed by maintenance mechanics/shift techs.

1. Disassembly and assembly of turbines.
2. Disassembly, assembly, and re-packing of generator and associated valves.
3. General repair work on pumps, grinders, crushers, water systems (demineralizer), gear boxes, chain drives, rubberized conveyor belts, bunker room conveyor belts, coal mills, coal handling feeders, cyclones, various fans, ventilation duct work, bottom and fly ash piping, steam soot blowers.
4. Lubrication of various moving parts.
5. Changing of oil and filters on various equipment.
6. Welding, torch cutting, grinding, machining, and sandblasting on various materials.
7. A variety of activities on the interior and exterior of boiler.
8. Insulation work (limited).

Chemicals used for the above activities include: non-halogenated hydrocarbon based degreaser, turbine oil (heavy paraffinic petroleum distillate), diesel fuel, transformer oil (light naphthenic petroleum distillate), fire resistant hydraulic fluid (fyrquel EHC - organophosphate), powdered anion hydroxide resin (epicor PD 1 -divinvylbenzene, styrene), and powdered anion hydroxide resin (epicor PD 2 - divinvylbenzene, styrene).

METHODS

Medical Evaluation

NIOSH investigators asked Illinois Power to provide information about workers known to have brain cancer, including date of hire, job title, type of cancer, date of cancer diagnosis, and birth date.

Information about the total number of employees who had worked in the same area as the individuals with brain cancer also was requested. NIOSH investigators met with corporate and plant health and safety personnel and interviewed 19 workers during the site visit on May 14 and 15. Seven workers from the second shift were interviewed in a group and 12 workers from the first shift were interviewed individually. NIOSH investigators selected workers for the interviews from a list of Baldwin and Power Plant Services employees provided by Illinois Power. Employees on the list were ranked by seniority and those with the longest seniority were selected for interviews to help investigators understand historical practices and exposures. As time permitted, several of the most recent employees were also selected for interviews. All employees who were selected for the interviews agreed to participate. The interviews involved informal discussion of general health and safety concerns, availability and use of personal protective equipment, health problems believed to be work-related, and workplace exposures and conditions. Among exposures, information on solvents was of particular interest due to information in the scientific literature suggesting a link between solvent exposure and brain cancer.

Environmental Evaluation

Air Monitoring

Personal breathing zone (PBZ) air samples were collected to determine worker exposures to polycyclic aromatic hydrocarbons (PAC), which are by-products of the combustion of coal. Calibrated air sampling pumps were placed on workers and connected via Tygon® tubing to collection media located in the breathing zone. Air samples were collected at a flow rate of 2.0 liters per minute on Zefluor 37-millimeter filters (2 micron pore size) followed by ORBO 32 sorbent tubes. Opaque sorbent tube holders and filter cassettes wrapped with aluminum foil were used to prevent the degradation of PACs by ultraviolet light. Monitoring was conducted for approximately 9 hours. After sample collection, the pumps were post-calibrated and the sorbent tubes were removed from the opaque holders and wrapped with aluminum foil. Sample media were protected from heat and ultraviolet light and submitted to the NIOSH contract laboratory for analysis according to NIOSH method 5515 [1] with modifications. Field and media blanks were submitted with the samples.

Samples were desorbed in 4.0 milliliters (ml) of benzene for 30 minutes. A Hewlett-Packard Model 5890II gas chromatograph equipped with a flame ionization detector was used for all measurements. The oven conditions were 100 degrees Celsius (°C) for 5 minutes, then up to 300 °C for 13 minutes at a rate of 5 °C/ minute. PACs identified using NIOSH analytical method 5515 are naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(e) pyrene, benzo(a)pyrene, indeno (1,2,3-cd) pyrene, dibenz(a,h)anthracene, and benzo (g,h,i) perylene. The analytical limit of detection (LOD) for the above PACs was 1.0 microgram per sample (ug/sample), which equates to a minimum detectable concentration (MDC) of 1.0 microgram per cubic meter (ug/m^3) using a sample volume of 988 liters. The limit of quantitation (LOQ) was 3.3 ug/sample, which equates to a minimum quantifiable concentration (MQC) of 3.3 ug/m^3 using a sample volume of 988 liters.

Area air samples for PACs were collected at six locations throughout the power plant where maintenance mechanics or shift techs usually work. The sample equipment was prepared and calibrated as described above. The area samples were also analyzed according to NIOSH analytical method 5515.

Surface vacuum samples were collected at four locations in the power plant to identify PACs in settled dust. Air sampling pumps were attached to Zefluor 37-millimeter filters (2-micron pore size) via Tygon tubing, and a 7.6- x 12.5-centimeter (95 square centimeters) was vacuumed. The filters were analyzed for PACs according to NIOSH analytical method 5515. The analytical LOD and LOQ for this sample set were 1.0 and 3.3 ug/gram (ug/g) of sample, respectively.

Area air samples were collected on thermal desorption media to qualitatively identify volatile organic compounds (VOCs) at various sites throughout the power plant. The thermal desorption tubes were attached via Tygon tubing to personal sampling pumps, and the sampling trains were calibrated at a flow rate of 50 cubic centimeters per minute (cc/min). Calibrated sampling equipment was placed in areas where maintenance mechanics or shift techs may conduct day-to-day activities. The VOC samples were collected during the afternoon. Thermal desorption media for low-level VOCs were prepared by the NIOSH laboratory using stainless steel tubes configured for thermal desorption in a Perkin-Elmer ATD 400 thermal desorption system. Each thermal desorption tube contained three beds of sorbent material: a front layer of Carbopack Y™, a middle layer of Carbopack B™, and a back section of Carboxen 1003™.

When collecting area and PBZ air samples, NIOSH investigators typically record temperature and relative humidity (RH) measurements. The Vaisala HM 34 humidity and temperature meter was used to collect these data.

Electromagnetic Field Measurements

Due to the potential for exposure to non-ionizing electromagnetic radiation (EMF) at power plants, measurements were made of extremely low frequency (ELF) fields of 60 Hertz (Hz), as that is the frequency of the generated current. Radiation measurements were intended to survey potential worker exposures to these fields during work tasks. The limited number of measurements taken in and around the facility was not intended to represent an in-depth evaluation of all ELF radiation present at the site, but was rather intended to identify areas of high exposure that workers might frequent during the course of their workday.

Selected magnetic field measurements were made with the EMDEX II exposure monitoring system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Incorporated. The EMDEX II is a programmable data-acquisition meter which measures the orthogonal vector components of the magnetic field through its internal sensors. Measurements can be read instantaneously or stored. The system was designed to measure, record, and analyze power frequency magnetic fields in units of milliGauss (mG) in the frequency region of 40 to 800 Hz. Walking through the facility, the NIOSH investigator collected these measurements in the instantaneous read mode (walk-around mode).

Electric field strength measurements were made with the Holaday Industries, Incorporated model HI-3602 ELF sensor, connected to a HI-3600 survey meter, which was used to document both the magnitude of ELF electric field and the frequency. The electric field strength was measured in units of Volts per meter (V/m).

In addition to walk-around measurements, EMDEX II meters were put on eight selected workers for approximately 4 hours to determine their exposure to magnetic fields during their daily work regimen. Unfortunately, data on one of the workers were lost. The meters were worn around the worker's waist in special sashes provided by NIOSH, and each worker was instructed on what the meter records and when to return the meter. All data were collected with the meters set to a 1.5-second data collecting interval. The software program used with the meters is capable of providing minimum, maximum, mean, and median levels, in units of mG, for each worker. On the day of the evaluation, all regularly assigned maintenance workers were performing special duties on Unit #2. Therefore, EMF data were gathered on shift techs assigned to cover those tasks generally performed by
maintenance workers.

EVALUATION CRITERIA

Brain Cancer

The term brain cancer includes a variety of tumors in different parts of the brain. Medical scientists believe that the different types of tumors are separate diseases and that each may have unique causes. Tumors that begin in the brain are known as primary brain tumors. The most common are gliomas, which begin in the glial (supportive) tissue. Gliomas are classified into several types depending on which cell type is affected. The types of gliomas are astrocytomas, brain stem gliomas, ependymomas, and oligodendrogliomas. Tumors that begin elsewhere in the body and spread to the brain are known as metastatic brain tumors. Body cancers that frequently spread to the brain include lung cancer, breast cancer, colon cancer, melanoma, and kidney cancer.[2]

According to data summarized by the National Cancer Institute, brain cancer is a rare disease in the United States.[3] Accounting for age of the United States population, about six new cases of brain cancer occurred among every 100,000 persons each year between 1973 and 1991. Brain cancer occurs more often among men than women and among whites than blacks. For white men, the rate of occurrence of brain cancer increases between the ages of 20 and 64 from about 3 to 19 cases each year among every 100,000 persons. Brain cancer is among the more lethal of adult cancers, with 52 % of affected individuals surviving one year after diagnosis.[3]

The causes of brain cancer are not known, and it is not possible to say why one person gets brain cancer and another doesn't. Researchers have found certain risk factors that increase a person's chance of developing brain cancer. In most cases, however, people who develop brain cancer have no clear risk factors.

Studies show that some types of brain cancer are more frequent among workers in certain industries. These include the rubber industry, oil refineries, and various chemical industries such as polyvinyl chloride production. Workers in these industries have exposures to organic solvents, lubricating oil, acrylonitrile, vinyl chloride, formaldehyde, polycyclic aromatic hydrocarbons, and phenolic compounds. Other industries and occupations found to have elevated risks include agricultural crop production, printing and publishing, and many professional occupations such as engineers, lawyers and judges, and banking/finance managers.[4]

Attention also has been focused on reports of elevated brain cancer risk among workers in various electrical occupations. These reports have suggested a link between brain cancer and exposure to ELF electromagnetic fields. In a January 1991 workshop sponsored by NIOSH, the research studies were reviewed.[5] Many of the studies providing important information about brain cancer were found to contain flaws, such as the lack of direct measurement of exposure and the failure to account for other exposures present in the industries and occupations studied. Although some studies show a possible link with brain cancer in adults, the general consensus is that currently available data are insufficient to conclude that electromagnetic field exposure at power line frequency causes cancer.[5,6]

In addition to occupational factors, researchers continue to investigate other possible causes or risk factors for brain cancer. These include dietary factors, certain medical conditions such as epilepsy or seizure disorders, hormones, viruses, and genetic conditions.[6]

Screening, or looking for disease in groups of people, can sometimes be useful for detecting a disease early in its progression. Screening is only useful if the cancer can be found at a time when it will respond to treatment. Presently, cancers of the breast and cervix are the only cancers for which screening clearly has been shown to be useful.[7] For brain cancer, tests that are used to diagnose the disease in a person who has symptoms consistent with brain cancer, such as a CT (or CAT) scan, are not of demonstrated value in screening people without such symptoms.

Exposure to Chemical and

Physical Agents

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)[8], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®)[9] Threshold Limit Values (TLVs®), and (3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs)[10]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever is the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard, and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Electric and Magnetic Field Exposure

The basis of the ELF electric field TLV is to minimize occupational hazards arising from spark discharges and contact currents. The magnetic field TLV is intended to prevent the induction of magnetophosphenes (a visual sensation of white light) and production of induced currents in the body. Prevention of cancer is not a basis for either of these TLVs because exposure has not been conclusively linked to cancer.

Sub-radiofrequency Electric and Magnetic Fields

At the present time, there are no OSHA or NIOSH exposure criteria for sub-radiofrequency (RF) fields. ACGIH has published TLVs for sub-radio frequency electric and magnetic fields (30 kiloHertz [kHz] and below).[9]

The TLV for sub-radiofrequency magnetic fields (B_{TLV}) states occupational exposure from 1 to 300 Hz should not exceed the ceiling value given by the equation:

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

where f is the frequency in Hertz. One mT equals 10 Gauss. For frequencies in the range of 300 to 30,000 Hz, occupational exposures should not exceed the ceiling value of 0.2 mT (2 G). These ceiling values for frequencies of 300 to 30,000 Hz are intended for both partial– and whole–body exposures. For frequencies below 300 Hz, the TLV for exposure of the extremities can be increased by a factor of 5. This extremity factor means that workers can receive exposure of 50 G to the arms and legs for the 60 Hz power line frequency.

The sub-radiofrequency electric field TLV (E_{TLV}) states occupational exposures should not exceed a field strength of 25 kiloVolts per meter (kV/m) from 0 to 100 Hz. For frequencies in the range of 100 Hz to 4 kHz, the ceiling value 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. These ceiling values for frequencies of 0 to 30 kHz are intended for both partial- and whole-body exposures. This means, for example, at the power line frequency of 60 Hz, which is classified as extremely low frequency, the E–field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 1 mT or 10,000 mG.

The basis of the ELF E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. Electric field strengths greater than 7 kV/m can produce a wide range of safety hazards, such as startle reactions associated with spark discharges. In addition, for workers with cardiac pacemakers, the electric field TLV may not protect against electromagnetic interference (EMI) to some pacemakers. For example, at the power line frequency of 60 Hz, some older models of cardiac pacemakers may be susceptible to electromagnetic interferences at electric field intensities as low as 2 kV/m.

RESULTS

Medical Evaluation

Illinois Power gave NIOSH investigators background information about the persons known to have brain cancer and about the work force. The medical information was obtained from medical records and death certificates available to the company. This information confirmed a diagnoses of brain cancer in three male employees between the ages of 35 and 60. All three had a glial cell tumor; two had an astrocytoma and one had an ependymoma. All three had worked at Baldwin from 14 to 19 years at the time of their diagnosis and, for nearly all this time, had been maintenance mechanics. Since the opening of the plant, 425 employees have worked in the "production" areas; 168 are no longer working and 257 are current employees. Eighty percent of the current employees are male.

Safety and health personnel described a committed and organized approach to health and safety in the plant, with the presence of a full-time, on-site health and safety coordinator. Union-management safety groups at the corporate and plant level meet regularly. Two-way communication between the plant safety group and employees occurs through distribution of meeting minutes, informal discussions with union safety representatives, and formal complaints. Although one-time surveys of specific hazards (e.g., arsenic) have been conducted, routine environmental monitoring for potential chemical hazards, other than asbestos, is not done. Several EMF surveys, however, have been conducted and the information disseminated to workers. Training materials regarding EMF issues have also been developed and shared with employees. Employees have annual physical examinations that currently include biological monitoring for lead and arsenic.

Workers consistently reported the perception that in the earlier years of the plant's operation, the company had a casual, careless attitude about health and safety. For example, workers were told incorrectly that certain hazards such as asbestos were not present, hazardous substances such as hydrazine were unlabelled, and well-recognized hazards in the industry, such as arsenic exposure, were not acknowledged. Workers generally felt that the current structure for discussing and responding to health and safety issues was effective when issues were raised by workers. Other than general concerns about the potential for cancer, workers did not report current work-related health problems. Workers reported that solvents used widely in the past included Stoddard solvent, carbon tetrachloride, and trichloroethylene. These were replaced about five years ago with PF55, a citrus-based solvent. Gloves were not always available and, when they were, were not always worn when working with solvents. Other issues concerning workers were: using epoxy paints and glues in enclosed areas, cutting/grinding/welding on surfaces coated with lead-based paint, and the effects of downsizing on job duties and expectations. Workers described receiving hazard communication training and were aware of the use and availability of material safety data sheets, reported having confined space training, and noted an informal policy to prevent heat stress.

Several workers noted diagnoses of cancer in other employees, in addition to the three brain cancer cases that were the focus of the NIOSH investigation. A union representative identified eight other employees known to have been diagnosed with cancer since 1990. The types of cancer were varied, including prostate, lung, and breast; several were unknown. The affected individuals worked in a number of different jobs in the plant.

Environmental Evaluation

Air Monitoring

Polycyclic aromatic hydrocarbons

PBZ air samples were collected for PACs from four shift techs and two maintenance mechanics. On the day they were monitored, the shift techs' job tasks included caustic pump work on the ground floor, welding in the morning and monitor work in the afternoon on various floors, main and auxiliary transformer work on various floors, and fire alarm system work on various floors. Maintenance mechanic job tasks included various activities performed on the turbines on the third floor over the entire day. All PBZ sample concentrations for PACs were below the minimum detectable concentration (MDC) of 1 ug/m^3 using a sample volume of 988 liters.

Area air samples for PACs were collected at six locations near units #1 and #3. Unit #1 air sample locations included the turbine floor, east side of boiler (between boiler and turbines) near burners; bottom ash pit, south side of boiler; sixth floor, west side of boiler near coal feeders; and 13th floor, south side of boiler. Unit #3 air sample collection locations included the 1½-floor mill deck, near coal mills; and the 12th floor, north side of boiler near soot blower. Phenanthrene was the only PAC detected, at trace concentrations, at both area air sample locations near Unit #3 (described above) and on the 6th and 13th floor near Unit #1. Trace is defined as a concentration between the MDC and the MQC.

Surface vacuum samples were collected at four locations in the power plant near Units #1 and #3 to identify PACs in settled dust. Unit #1 surface vacuum sample locations included the 3½-floor, on the electrostatic precipitator transport line; 13th floor, south side of boiler on soot blower; and 16th floor, south side of boiler near the main steam relief valve. The Unit #3 surface vacuum sample was collected on the electrostatic precipitator ash hopper. Only trace concentrations (values between the LOD and LOQ for analysis) of the PACs were detected in the surface vacuum samples. On floor 3½ near Unit #1, trace concentrations of phenanthrene, fluoranthene, pyrene, chrysene, and benzo(e)pyrene were detected. On the 13th floor near Unit #1, trace concentrations of benzo(b)fluoranthene, and benzo(e)pyrene were detected. On the electrostatic precepitator ash hopper of Unit #3, trace concentrations of benzo(e)pyrene were detected.

Volatile organic compounds

Area air samples were collected on thermal desorption media to qualitatively identify VOCs at five locations thoughout the power plant, including the ground floor maintenance shop; turbine floor between intermediate and low pressure turbines of Unit #2; 4th floor, east side of boiler near burner of Unit #1; 4th floor, east side of boiler near hot water circulation pumps of Unit #3; and 13th floor, south side of boiler near soot blower. Four of the five area air samples collected for VOCs contained very low concentrations of decane, undecane, and dodecane. These concentrations were generally in the low parts per billion range. The fifth area air sample, collected on the 4th floor near the hot water circulation pumps of Unit #3, did not contain detectable concentrations of VOCs.

EMF Measurements

Walk-around measurements inside facility

The intensity of ELF electromagnetic fields (predominantly power line frequencies) was surveyed mainly on the first through the fifth floors of Unit #1 using an EMDEX II meter in the walk-around mode. Measurements were not performed on Unit #3 since the company has extensive data that document ELF radiation levels in that unit. The NIOSH investigators reviewed the company's data for Unit #3 and concluded that it appeared to be properly taken and was accurate.

Magnetic field intensity levels on the 5th floor of Unit #1 did not exceed 1 mG. Levels on the 4th floor generally were between 2 and 5 mG, except near the gas recirculation fans, where levels near 22 mG were recorded. The 3rd floor levels were low (3 to 5 mG), except in the vicinity of the turbines. Levels 10 feet away from the turbine at a height of 3 feet above the floor could be as high as 100 to 200 mG. Underneath the turbine area on the 2nd floor, a level of 800 mG was measured. On the first floor at the turbine end, levels as high as 500 to 1200 mG were recorded.

Walk-around measurements outside facility

The output cables from the three units in the plant go to a switching yard about 300 feet from the power station. Several cables cross a parking lot about 100 feet above the ground. These cables produce magnetic fields in the 50 to 120 mG range; these results are similar to those documented in the company's 1992 EMF survey. Electric field strengths between 6 and 20 kV/m were found underneath the cables that carry the plant output (345 kV) to the switching yard. The variation in the electric field strengths depended on the vertical distance between cables and automobiles. The parking lot was filled with automobiles, and the NIOSH investigators noted the potential for shock hazards to workers getting in and out of their cars. Workers reported being shocked on occasion. The issue of electrostatic shocks was cited in the company's 1992 EMF survey report, where it was noted that the phenomenon was well understood, and posed no health or safety risk, although nuisance shocks were possible. NIOSH investigators disagree with the contention that nuisance shocks pose little safety risk (as described earlier).

Since the switching yard was located close to the store room building, measurements were taken in the room at various locations. The highest magnetic field strength measured was 25 mG, at a back wall closest to the yard. No workers were seen in that area at the time of the investigation.

Selected personal field measurements

The results of the personal measurements made with the EMDEX II meters are shown in Table 1. The mean magnetic field levels measured on seven workers ranged from 1.7 to 13.6 mG. The highest mean magnetic field levels were obtained on workers who performed welding procedures. The large standard deviation (which is a measure of variation) for the two welders suggests movement throughout the area by the workers as they performed their tasks. The next highest mean magnetic field level was on a worker handling cables operating at a high current.

Temperature and Relative Humidity

Temperature and relative humidity measurements were collected at various locations throughout the power plant. Table 2 includes location of measurement, temperature (°F), and relative humidity (%). Temperature and relative humidity measurements ranged from 78 °F to 104 °F and from 35 % to 60 %, respectively. The lowest temperature was recorded at the bottom ash pit, and the highest temperature was recorded on the 13th floor. The temperature and relative humidity measurements recorded between the 6th and 13th floors were 101°F to 104 °F and 35% to 47%, respectively.

DISCUSSION

Cancer is a group of diseases that have the same feature, the uncontrolled growth and spread of abnormal cells. Cancer is common in the United States. About one in three people will eventually develop cancer. One of every five deaths is from cancer. Among adults, cancer occurs more frequently among men than among women, and the rate of occurrence increases with increasing age. The American Cancer Society estimates that brain cancer will account for 1.4% of all cancers diagnosed and 2.5% of all cancer deaths among men in 1996.[11]

Cancers often seem to occur in "clusters." This happens even when cancers are distributed randomly in time and space. If the mathematics of the random distribution of cancer could be seen, it would show mostly "holes" and "clusters" of cancer. Thus, while cases within a cluster may have a shared cause, such as an occupational exposure, they also may be a coincidental occurrence of unrelated causes. When the number of cases is small, as at the Baldwin station, it is usually difficult to determine whether they have a common cause. In this investigation, further assessment is also precluded by the nature of the job, which requires maintenance mechanics to work everywhere in the plant, and thus potentially involves a wide variety of exposures that are shared by other workers. Moreover, because maintenance mechanics perform different duties in different areas of the plant from one day to the next, their exposures, particularly in the past, are difficult to characterize adequately for epidemiologic investigation.

Although a specific link between occupational exposures at the Baldwin station and brain cancer was not identified by NIOSH investigators, several features of this investigation are consistent with occupational factors playing a role in the development of brain cancer among employees. These include the diagnosis of the disease in three individuals within a relatively small work force in a five-year period, the similarity in the type of tumor, and the fact that all three worked in the same job and had done so for at least ten years before diagnosis of the disease. The past use of organic solvents and petroleum-based products, which have been identified previously as suspect causal agents, also is consistent with involvement of a workplace exposure. Although workers likely have been exposed to other hazardous agents, such as asbestos and arsenic, these are not known to be related to the development of brain cancer. The fact that brain cancer has not occurred among workers in other job titles, such as electricians, whose jobs involve similar exposures to the maintenance mechanics, is curious. The reported occurrence of other cases of cancer among workers in a variety of jobs is not unusual. Given the frequency of cancer in the general population, some cases of cancer would be expected in the Baldwin work force. NIOSH investigators do not believe that this issue warrants further evaluation.

The levels of electric and magnetic fields found at the facility were below the current occupational exposure ceiling limit of 25,000 V/m and 10,000 mG, respectively, as recommended by ACGIH. The issue of nuisance shock potential, however, is of concern.

PACs were not detected in the PBZ air samples collected for maintenance mechanics and shift techs. Trace concentrations of phenanthrene (the only PAC detected in area samples) were detected in four of six area air samples. These concentrations are very low compared to the OSHA PEL for phenanthrene (coal tar pitch volatiles) of 200 ug/m.[10]

Trace concentrations of PACs were detected in three of four surface vacuum samples of settled dust. If the settled dust becomes airborne, workers may be exposed to PACs via inhalation. In addition, if good hygiene is not practiced (i.e., washing hands before eating or smoking), workers may be exposed to PACs via ingestion. Of the PACs identified in the vacuum samples, NIOSH considers chrysene to be a potential occupational carcinogen of the liver and skin; and ACGIH considers benzo(b)fluoranthene to be a suspected human carcinogen of the liver, skin, and lungs. Exposures to carcinogens should be limited to the lowest feasible concentration. Good housekeeping practices and personal hygiene should be emphasized when trace contaminants are found in settled dust.

VOCs detected in the power plant were found in very low concentrations, generally in the parts per billion range. It is not unusual to detect VOCs such as decane, undecane, and dodecane in industrial environments where organic solvents, degreasers, gasoline, diesel fuel, and various petroleum oils are used.

At the temperatures measured during the NIOSH site visit, heat-related disorders such as heat rash, heat cramps, heat exhaustion, and heat stroke are important concerns when workers are exposed for extended periods of time. Furthermore, the temperatures would likely be even higher during the summer. It is important to note, however, that a comprehensive heat stress evaluation was not conducted by NIOSH investigators.

CONCLUSIONS

The cause of brain cancer among three employees at the Baldwin station of the Illinois Power Company could not be identified in this investigation. The features of this cluster (such as the variable nature of maintenance mechanics' jobs), and the limitations in the scientific methods available to evaluate such clusters preclude a definitive statement about whether brain cancer among employees is related to occupational exposures.

ELF electric and magnetic field strength levels, both inside and outside the facility, are below the current occupational exposure ceiling limit recommended by ACGIH and are generally within the range of exposure levels previously measured by NIOSH in similar evaluations. The NIOSH measurements were of approximately the same magnitude as similar measurements made previously by the Illinois Power safety office.

RECOMMENDATIONS

Based on the temperature and relative humidity measurements and the results of PAC analysis of the surface vacuum samples, the following recommendations are offered to improve the work environment at the Baldwin Power Plant.

1. Based on the temperature and relative humidity measurements collected at the Baldwin station, heat-related disorders such as heat rash, heat cramps, heat exhaustion, and heat stroke are important concerns. Environmental conditions and work loads indicate the need for an occupational heat stress program at the Baldwin station. Appendix A contains details of a heat stress program and evaluation criteria for heat stress.

2. Good housekeeping procedures should be implemented. The surface vacuum sample results show trace concentrations of PACs in the settled dust. By removing settled dust from working surfaces before work begins, the potential for airborne PAC exposures can be reduced. When removing settled dust, dry methods (shoveling and sweeping) should be replaced with wet methods, and/or high efficiency particulate air (HEPA)

vacuum-cleaning methods to minimize aerosolization of settled dust.

3. Further investigation of the problem of electrical shocks in the parking lots is needed. The possibility of moving automobiles to another parking location should be considered.

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Table 1
Baldwin Power Station
Personal Field Measurements
Magnetic Field Levels
May 15, 1996

Worker	(milliGauss)					n*	Distribution (%)**		
	Min	Max	Median	Mean	Std Dev		< 2 mG	< 4 mG	< 10 mG
1	0.2	41.5	2.5	3.68	3.84	9274	45.2	74.7	83.0
2	0.2	246.3	4.0	7.95	11.26	9191	30.3	50.4	73.0
3	0.2	48.9	2.8	3.44	4.19	8069	46.4	55.2	93.6
4	0.2	56.1	1.1	2.60	3.60	9188	62.2	79.8	93.6
5	0.2	163.7	0.9	1.71	3.48	8180	75.9	93.6	98.6
6	0.1	650.0	3.8	13.59	32.79	9501	21.1	51.7	70.4

7	0.2	462.0	2.8	12.69	27.01	9775	24.6	61.6	72.1

* n = number of data readings
** percent of all readings with levels in this range

Table 2
Baldwin Power Station
Temperature and Relative Humidity Measurements
May 15, 1996

Location	Temperature (° F)	Relative Humidity (%)
bottom ash pit	78	53
turbine floor	86	60
mill deck, unit #3	94	58
6th floor, unit #1	101	38
12th floor, unit #3	100	47
13th floor, unit #1	104	35

APPENDIX A

Elements of a Comprehensive Heat Stress Management Program*

1. **Written program** - A detailed written document is necessary to specifically describe the company procedures and policies in regards to heat management. The input from management, technical experts, physician(s), labor union, and the affected employees should be considered when developing the heat management program. This program can only be effective with the full support of plant management.

2. **Environmental monitoring** - In order to determine which employees should be included in the heat management program, monitoring the environmental conditions is essential. Environmental monitoring also allows one to determine the severity of the heat stress potential during normal operations and during heat alert periods.

3. **Medical examinations and policies** - Preplacement and periodic medical examinations should be provided to all employees included in the heat management program where the work load is heavy or the environmental exposures are extreme. Periodic exams should be conducted at least annually, ideally immediately prior to the hot season (if applicable). The examination should include a comprehensive work and medical history with special emphasis on any suspected previous heat illness or intolerance. Organ systems of particular concern include the skin, liver, kidney, nervous, respiratory, and circulatory systems. Written medical policies should be established which clearly describe specific predisposing conditions that cause the employee to be at higher risk of a heat stress disorder, and the limitations and/or protective measures implemented in such cases.

4. **Work schedule modifications** - The work-rest regime can be altered to reduce the heat stress potential. Shortening the duration of work in the heat exposure area and utilizing more frequent rest periods reduces heat stress by decreasing the metabolic heat production and by providing additional recovery time for excessive body heat to dissipate. Naturally, rest periods should be spent in cool locations (preferably air conditioned spaces) with sufficient air movement for the most effective cooling. Allowing the worker to self-limit their exposure on the basis of signs and symptoms of heat strain is especially protective since the worker is usually capable of determining their individual tolerance to heat. However, there is a danger that under certain conditions, a worker may not exercise proper judgement and experience a heat-induced illness or accident.

5. **Acclimatization** - Acclimatization refers to a series of physiological and psychological adjustments that occur which allow one to have increased heat tolerance after continued and prolonged exposure to hot environmental conditions. Special attention must be given when administering work schedules during the beginning of the heat season, after long weekends or vacations, for new or temporary employees, or for those workers who may otherwise be unacclimatized because of their increased risk of a heat-induced accident or illness. These employees should have reduced work loads (and heat exposure durations) which are gradually increased until acclimatization has been achieved (usually within 4 or 5 days).

6. **Clothing** - Clothing can be used to control heat stress. Workers should wear clothing which permits maximum evaporation of perspiration, and a minimum of perspiration run-off which does not provide heat loss (although it still depletes the body of salt and water). For extreme conditions, the use of personal protective clothing such as a radiant reflective clothing, and torso cooling vests should be considered.

7. **Buddy system** - No worker should be allowed to work in designated hot areas without another person present. A buddy system allows workers to

observe fellow workers during their normal job duties for early signs and symptoms of heat intolerance such as weakness, unsteady gait, irritability, disorientation, skin color changes, or general malaise, and would provide a quicker response to a heat-induced incident.

8. **Drinking water** - An adequate amount of cool (50-60 ºF) potable water should be supplied within the immediate vicinity of the heat exposure area as well as the resting location(s). Workers who are exposed to hot environments are encouraged to drink a cup (approximately 5-7 ounces) every 15-20 minutes even in the absence of thirst.

9. **Posting** - Dangerous heat stress areas (especially those requiring the use of personal protective clothing or equipment) should be posted in readily visible locations along the perimeter entrances. The information on the warning sign should include the hazardous effects of heat stress, the required protective gear for entry, and the emergency measures for addressing a heat disorder.

10. **Heat alert policies** - A heat alert policy should be implemented which may impose restrictions on exposure durations (or otherwise control heat exposure) when the National Weather Service forecasts that a heat wave is likely to occur. A heat wave is indicated when daily maximum temperature exceeds 95 ºF or when the daily maximum temperature exceeds 90 ºF and is at least 9 ºF more than the maximum reached on the preceding days.

11. **Emergency contingency procedures** - Well planned contingency procedures should be established in writing and followed during times of a heat stress emergency. These procedures should address initial rescue efforts, first aid procedures, victim transport, medical facility/service arrangements, and emergency contacts. Specific individuals (and alternatives) should be assigned a function within the scope of the contingency plan. Everyone involved must memorize their role and responsibilities since response time is critical during a heat stress emergency.

12. **Employee education and training** - All employees included in the heat management program or emergency contingency procedures should receive periodic training regarding the hazards of heat stress, signs and symptoms of heat-induced illnesses, first aid procedures, precautionary measures, and other details of the heat management program.

13. **Assessment of program performance and surveillance of heat-induced incidents** - In order to identify deficiencies with the heat management program a periodic review is warranted. Input from the workers affected by the program is necessary for the evaluation of the program to be effective. Identification and analysis of the circumstances pertinent to any heat-induced accident or illness is also crucial for correcting program deficiencies.

Heat Stress Evaluation Criteria*

There are a number of heat stress guidelines that are available to protect against heat-related illnesses such as heat stroke, heat exhaustion, heat syncope, and heat cramps. These include, but are not limited to, wet bulb globe temperature (WBGT), Belding-Hatch heat stress index (HSI), and effective temperature (ET).[1,2,3] The underlying objective of these guidelines is to prevent a worker's core body temperature from rising excessively. The World Health Organization has concluded that "it is inadvisable for deep body temperature to exceed 38 ºC (100.4 ºF) in prolonged daily exposure to heavy work."[4] Many of the available heat stress guidelines, including those proposed by NIOSH and the ACGIH, also use a maximum core body temperature of 38 ºC as the basis for occupational exposure limits.[5]

Both NIOSH and ACGIH recommend the use of the WBGT index to measure environmental factors because of its simplicity and suitability in regards to heat stress. The International Organization for Standardization (ISO), the American Industrial Hygiene Association (AIHA), and the U.S. Armed Services have published heat stress guidelines which also utilize the WBGT index.[6,7,8] Overall, there is general similarity of the various guidelines; hence, the WBGT index has become the standard technique for assessment of environmental conditions in regards to occupational heat stress.

The WBGT index takes into account environmental conditions such as air velocity, vapor pressure due to atmospheric water vapor (humidity), radiant heat, and air temperature, and is expressed in terms of degrees Fahrenheit (or degrees Celsius). Measurement of WBGT is accomplished using an ordinary dry bulb temperature (DB), a natural (unaspirated) wet bulb temperature (WB), and a black globe temperature (GT) as follows:

> $WBGT_{in}$ = 0.7 (WB) + 0.3 (GT) for inside or outside without solar load,
>
> Or
>
> $WBGT_{out}$ = 0.7 (WB) + 0.2 (GT) + 0.1 (DB) for outside with solar load.

Originally, NIOSH defined excessively hot environmental conditions as any combination of air temperature, humidity, radiation, and air velocity that produced an average WBGT of 79 ºF (26 ºC) for unprotected workers.[9] However, in the revised criteria for occupational exposure to hot environments, NIOSH provides diagrams showing work-rest cycles and metabolic heat versus WBGT exposures which should not be exceeded.[5] NIOSH has developed two sets of recommended limits: one for acclimatized workers (recommended exposure limit [REL]), and one for unacclimatized workers (recommended alert limit [RAL]).

Similarly, ACGIH recommends a TLV for environmental heat exposure for different work-rest regimens and work loads.[10] The NIOSH REL and ACGIH TLV criteria assume that the workers are heat acclimatized, are fully clothed in summer-weight clothing, are physically fit, have good nutrition, and have adequate salt and water intake. Additionally, they should not have a pre-existing medical condition that may impair the body's thermoregulatory mechanisms. For example, alcohol use and certain therapeutic and social drugs may interfere with the body's ability to tolerate heat.

Modifications of the NIOSH and ACGIH evaluation criteria should be made if the worker or conditions do not meet the previously defined assumptions. The following modifications have been suggested:[11]

1. Unacclimatized or physically unconditioned - subtract 4 °F (2 °C) from the permissible WBGT value for acclimatized workers.

2. Increased air velocity (above 1.5 meters per second or 300 feet per minute) - add 4 °F (2 °C). This adjustment can not be used for air temperatures in excess of 90-95 °F (32-35 °C). This correction does not apply if impervious clothing is worn.

3. Impervious clothing which interferes with evaporation:

    a. Body armor, impermeable jackets - subtract 4 °F (2 °C).
    b. Raincoats, turnout coats, full-length coats - subtract 7 °F (4 °C).
    c. Fully encapsulated suits - subtract 9 °F (5 °C).

4. Obese or elderly - subtract 2-4 °F (1-2 °C).

Selection of a protective NIOSH WBGT exposure limit is contingent upon identifying the appropriate work-rest schedule and the metabolic heat produced by the work. The work-rest schedule is characterized by estimating the amount of time the employees work to the nearest 25%. The most accurate assessment of metabolic heat production is to actually measure it via calorimetry. However, this is impractical in industrial work settings. An estimate of the metabolic heat load can be accomplished by dividing the work activity into component tasks and adding the time-weighted energy rates for each component. Because of the error associated with estimating metabolic heat, NIOSH recommends using the upper value of the energy expenditure range to allow a margin of safety.[5]

The ACGIH heat exposure TLVs are published for light, moderate and heavy work load categories. The work load categories are described by the following energy expenditure rates:[10] light work (up to 200 kcal/hr), moderate work (200 to 350 kcal/hr), and heavy work (350 to 500 kcal/hr).

The physiological response to an increasing heat load can include an increase in heart rate, an increase in body temperature, an increase in skin temperature, and an increase in sweat production.[5] The physiological response could vary dramatically between individuals and may be related to physical conditioning, level of acclimatization, weight, age, and gender. Measuring the physiological responses and comparing the response to acceptable increases have been proposed. [4, 12, 13, 14]

There are a few general guidelines for recommended maximum heart rate under physical exertion. If the heart rate (pulse) exceeds 110 beats per minute at the onset of the rest period, then the next work cycle should be reduced by one-third and the rest duration should be maintained.[14]

For body core temperature, heat stress guidelines typically list 38ºC (100.4ºF) as the upper limit of body core temperature.[4, 5, 10] This is measured rectally in standard laboratory studies of work physiology. Because this is impractical in an industrial setting, however, oral temperature has been used in lieu of rectal temperature. In general, oral temperature is lower than core temperature, although the amount varies since oral temperature is influenced by various factors. It is generally accepted that oral temperature is lower than core temperature by 0.5ºC (0.9ºF).[12] Thus 37.5ºF (99.5ºF) provides an adequate margin of safety as the upper limit of an acceptable body temperature as measured by an oral thermometer. If oral temperature exceeds 99.6ºF at the beginning of a rest cycle, the next work cycle should be reduced by one-third and the rest duration maintained.[14]

Body water loss from sweat production and inadequate fluid replacement can be measured using a scale accurate to ± 0.25 pounds. Body water loss should not exceed 1.5 percent of the total body weight in a workday.[14]

**Source:* Hanley K [1995]. Hazard evaluation and technical assistance report: Consolidated Aluminum Company, Hannibal, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 93-0871-2507.

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