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I. SUMMARY

In June 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at the Nassif Building in Washington, D.C. This facility houses the headquarters of the United States Department of Transportation (DOT). The request was submitted by the Chief of the Safety and Health Branch due to employees' concern for potential exposure to extremely low frequency (ELF) electric and magnetic fields at the facility. An evaluation of the ELF fields at the facility was conducted in October 1993 by NIOSH investigators. Measured levels ranged from 1.6 to 1.9 volts per meter (V/m) for the electric field and 0.2 to 1271 milligauss (mG) for the magnetic field. These levels are below the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV)s for sub-radiofrequency electric and magnetic fields of 25,000 V/m and 10,000 mG, respectively.

NIOSH investigators, based on the measurements performed and comparisons with current occupational criteria, have concluded that no health hazard existed on the days of measurements from exposure to ELF electric and magnetic fields. Information about the nature and magnitude of the magnetic fields measured on the southeast quadrant of the 5th, 6th, and 7th floors at the DOT facility is presented in this evaluation. The slightly higher magnetic fields in the southeast quadrant of the 6th floor may be due to a number of sources, such as transformers, handholes, and laser printers. Recommendations are presented to help in reducing potential occupational exposure to electromagnetic fields.

KEYWORDS: SIC 9621 (Regulation and administration of transportation programs), ELF, EMF, office building

II. INTRODUCTION

In March 1993, a U.S. Department of Transportation (DOT) employee measured extremely low frequency (ELF) magnetic field levels up to 200 milligauss (mG) in room 6221C at the Nassif Building using a personal meter. These levels appeared to originate from electrical lines located under the existing floor. Using DOT-procured ELF magnetic field equipment, electricians confirmed these initial measurements and also found magnetic field levels that were even higher. Based on this information, the DOT staff contacted the Division of Federal Occupational Health (FOH), U.S. Public Health Service and requested an ELF evaluation be conducted at the Nassif Building. Measurements were conducted on July 1, 1993, by FOH and it was concluded that the magnetic field levels on the 6th floor, and in particular, the space around room 6221, the Coast Guard Clinic, and the Research and Development offices, were higher than levels measured on the 5th and 7th floors. FOH recommended the problem be further identified and corrected.[1] DOT personnel then submitted a health hazard evaluation (HHE) to the National Institute for Occupational Safety and Health (NIOSH) requesting further ELF evaluations be performed.

III. BACKGROUND

The Nassif Building, located at 7th and D Streets in Washington, D.C., houses the headquarters of the U.S. DOT. The 22-year old building is eight stories tall, occupies a city block, and is built in the shape of a square with a large courtyard in the middle, as shown in Figure 1. Each floor in the building is divided into sectors, with a transformer room supplying electrical power for each sector.

On October 3-5, 1993, NIOSH investigators conducted a site visit at the Nassif Building to measure ELF electric and magnetic field levels at various locations within the facility.

IV. EVALUATION CRITERIA

At the present time, there are no Occupational Safety and Health Administration (OSHA) or NIOSH exposure criteria for sub-radiofrequency fields. The American Conference of Governmental Industrial Hygienists (ACGIH) has published Threshold Limit Values (TLVs) for sub-radiofrequency electric and magnetic fields.[2] The TLV for magnetic field (B) requires "routine occupational exposure should not exceed:

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

where mT is millitesla and f is the frequency in hertz (Hz)." Conversely, the electric field (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 kilohertz (kHz), the TLV value is given by:

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

where f is the frequency in Hz. A ceiling value of 625 volts per meter (V/m) is the ceiling value for frequencies from 4,000 to 30,000 Hz. The basis of the ELF electric field TLV is to minimize occupational hazards arising from spark sidecharge and contact current situations. The magnetic field TLV addresses induction of magnetophosphenes (a visual sensation of white light) in the visual system 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.

It should be recognized that the ACGIH has recently proposed new TLVs for the sub-radiofrequency region that will alter the above levels. The proposed TLV for magnetic flux

density (B_{TLV}) in the sub-radiofrequency region recommends the use of the same magnetic field equation TLV but has adopted a ceiling value of 1 mT (10,000 mG) from 1 to 300 Hz and a ceiling value of 0.2 mT (2,000 mG) from 300 to 30,000 Hz. The proposed TLV for electric field strength has now become a ceiling value.

V. METHODS

This evaluation was designed to assess occupational exposure to sub-radiofrequency electric and magnetic fields on the 5th, 6th, and 7th floors during a typical workday. The number and types of measurements performed in this evaluation were not intended to represent an in-depth investigation of exposure to all electric and magnetic fields present in the building, but are intended to estimate occupational exposure levels found on the days of measurements.

A. Instrumentation

The measurement of electric and magnetic fields in the ELF region (30 to 2,000 Hz) present at the DOT facility was performed using the following equipment:

* A Holaday Industries, Inc. model HI-3602 ELF sensor, connected to a HI-3600 survey meter, was used to document both the magnitude of ELF electric and magnetic fields and the electrical frequency (as well as the waveforms) produced by such fields. The electric field strength was measured in units of V/m and the magnetic field strength was measured in units of mG.

* A Holaday Industries, Inc. model HI-3627 3-axis ELF magnetic field meter was used to make isotropic measurements of the magnetic field in and around different workstations. The dynamic range of the instrument is from 0.2 mG to 20 G.

* Selected measurements were made with the EMDEX II exposure system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Inc. 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 made in the instantaneous read or storage mode. The system was designed to measure, record, and analyze broadband magnetic fields in units of mG in the frequency region from 40 to 800 Hz. The meter has the capability of displaying magnetic field values in three different frequency bandwidths; broadband bandwidth measures fields from 40 to 800 Hz, harmonic bandwidth measures fields from 100 to 800 Hz, and fundamental bandwidth measures fields at 60 Hz.

B. Measurement Approach

The initial walk-through of the DOT facility by NIOSH investigators revealed the presence of electrical raceways on the various floors. Electrical raceways distribute electrical energy by wires leading from the sector transformers to various floor locations within a sector. The design of the electrical raceways is similar from floor to floor and access to wires in the raceways is permitted by removing circular covers fastened to handholes located along the raceways.

The number of wires in each handhole can range from 1 to 35. It was clearly demonstrated to NIOSH investigators that the electrical current in the raceways could produce localized elevated magnetic fields. Hence, the location of workers relative to the handholes might become an occupational issue.

In performing this evaluation, NIOSH investigators obtained data from: (1) locations in room 6221, (2) various locations on the 5th, 6th, and 7th floors, (3) near electrical handholes on the 6th floor, (4) other pertinent building locations such as bathrooms, transformer rooms, and cafeteria, (5) at locations outside the Nassif Building, and (6) on selected personnel working on the 6th floor.

VI. RESULTS

A. Measurements Made in Room 6221

When measurements were made in room 6221 at distances greater than 24" (inches) from any handhole, ELF magnetic field levels typically were in the range of 3 to 6 mG except for those situations where unique electrical sources were present (see *D* below). However, ELF magnetic field measurements made within a distance of 24" in all directions of floor handholes in room 6221 were at least 5 to 10 times higher. Magnetic field levels measured near the desk in room 6221C were quite similar to that reported by the FOH study, ranging from 40 to 50 mG at the desk surface (on which rested several electrical sources). The electric field levels did not vary radically in any direction at different distances from the handholes.

EMDEX meters were used to record simultaneous differences in two handholes in room 6221. The handholes were located about 72" apart and the meters were placed on the floor next to the handholes. The first meter recorded magnetic field levels for 35 minutes at a handhole that was covered. The time-intensity plot for this handhole is shown in Figure 2(a). Magnetic field levels from this handhole ranged from 2.7 to 105 mG with the average being 30.5 mG. At the other handhole in room 6221 that had its cover removed, magnetic field levels ranged from 2.5 to 132 mG with the average of 43.3 mG [shown in Figure 2(b)]. There were more wires in the open handhole than the closed handhole which could explain why the magnetic field levels were slightly higher for the open handhole. The nature of the time-intensity curves clearly indicates that while the exposure intensity is similar for the two handholes at the time of measurements, they present different field intensity patterns. While the time-intensity plots for both handholes show a varying transient magnetic field superimposed over a generally steady baseline magnetic field pattern, the plot for the open handhole shows more structure than the closed handhole. The NIOSH investigators did not believe that the difference in magnetic field levels for these two handholes could be attributed to the attenuation afforded by the handhole cover.

B. Measurements on the 5th, 6th, and 7th Floors

Figure 3 shows the electric and magnetic field levels measured in the center of the 6th floor corridor. In general, the levels were relatively low, except for a slight elevation in magnetic field values (shown by the shaded area) for that portion of the corridor located next to the computer room (room 6234).

Magnetic field measurements, made at a distance of 6" off the floor, were made on consecutive handholes located along the main electrical raceway leading from the southeast quadrant (SEQ) transformer rooms on the 5th, 6th, and 7th floors. These levels, shown in Figure 4, clearly show that magnetic fields produced by the 6th floor handholes are higher than those on the 5th and 7th floors.

Small quadrant transformers existed on every floor in the same relative location. Measurements were made in the transformer room on the 5th, 6th, and 7th floors. The 5th floor room had two transformers and the maximum magnetic field in the vicinity of the transformers was about 500 mG. The 6th floor had two large transformers and the

magnetic field was over 1800 mG, while the 7th floor had one transformer and produced about 600 mG.

There were no unique ELF sources on the 5th and 7th floors, and the computer room on the 6th floor (across the hall from room 6221) did not produce unusual ELF levels except for some video display terminals.

C. Measurements Made at 6th Floor Electrical Handholes

Figure 5 shows the relationship of magnetic field levels as a function of height above consecutive handholes located on the 6th floor. Notice that the magnetic field levels are very suppressed at 20 and 34" above the floor at handhole locations far removed from the SEQ transformer area. Figure 5 also demonstrates that the DOT meter used to document the earlier results was recording different magnetic field levels than recorded by NIOSH meters.

At selected locations on the 6th floor, the handhole covers were removed and the number of wires in the handhole were counted. The relationship between wires in the handholes and the magnetic field at different distances from the handhole cover is shown in Figure 6. It is obvious, from both physical theory and actual measurements that as the number of wires in handholes increases, the magnetic field produced in handholes will also increase proportionally.

D. Measurements Made at Various Locations in Building

The initial walk-through on the 5th, 6th, and 7th floors of the DOT facility by NIOSH investigators revealed the presence of similar ELF sources found in other NIOSH surveys and included such items as:

laser printers	computer printers
coffee pots	fluorescent lamps
AM/FM radios	FAX machines
electric typewriters	power strips
photocopy machines	video display terminals
electric pencil sharpeners	desk fans
small refrigerator	view boxes
movie projectors	water machines
electric clocks	electric stapler
slide projectors	microwave ovens
small heating ovens	coffee machines
auxiliary lamps	aquariums
air conditioning units	video cassette recorders
terrarium	dictaphones

Electric and magnetic field measurements made in the cafeteria, sitting areas, and bathrooms were on the order of 2 to 6 V/m and 3 to 7 mG, respectively.

E. Measurements Made Outside the Facility

Electric and magnetic field measurements were made in the center courtyard of the Nassif Building and at several entryway locations. Measurements were also made at the four main corners of the building. The range of electric and magnetic field measurements in the center courtyard and at three entryway locations of the Nassif Building ranged from 1.6 to 1.8 V/m and 0.3 to 0.8 mG, respectively. Similar

measurements made at four main corners of the building ranged from 1.6 to 1.9 V/m and 0.2 to 0.9 mG.

F. Personnel Measurements

Only a limited number of personnel measurements were obtained in this evaluation. The range of magnetic field levels obtained from personnel measurements made on DOT workers and NIOSH investigators varied from 0.4 to 1271 mG. The exposure to the 1271 mG level occurred on a NIOSH investigator's meter and was caused from being in close proximity to a step-down transformer in the quadrant sector transformer room. This exposure is one that a DOT employee, other than a electrical or maintenance worker, would not normally encounter during a typical work day. Average magnetic fields levels ranged from 5.4 to 24.2 mG for a one to two hour exposure period. Data was collected on one of the EMDEX meters in such a way as to indicate differences in broadband, fundamental, and harmonic bandwidths. The level of magnetic field measured was higher in the fundamental mode, which suggests exposure to dominant 60 Hz fields.

VII. CONCLUSIONS AND RECOMMENDATIONS

Based on the measurement results obtained in this evaluation, the following observations are noted about occupational ELF electric and magnetic field levels at the Nassif Building.

A. All levels of ELF measured inside and outside the building, on the days of measurements, are within the range of exposure levels in office settings previously reported by NIOSH, and are below current occupational exposure criteria. While employees may still be concerned about levels of exposure below the established, there is no evidence that lower exposures are related to health effects.

B. The portable ELF meter used by DOT personnel to document magnetic fields covers only the frequency region from 30 to 300 Hz and is a single axis measurement device. NIOSH uses a 3-axis meter that covers a broader frequency region for 40 to 800 Hz. The results obtained in this evaluation will yield much higher and different results. This effect is clearly shown in Figure 5.

C. There are a number of non-essential electrical sources in use at the DOT facility which can produce elevated localized fields to employees during their workday. A list of these sources is shown earlier in this evaluation. Many of these sources, such as video display terminals and photocopy machines, are essential to the modern office environment. Others, however, could be considered "non-essential" and their presence should be re-evaluated by employees and management concerned about their overall exposure to ELF electric and magnetic fields in the office. Electromagnetic field strength decreases in proportion to at least the square of the distance from the source. Thus, while "non-essential" sources in an employee's own work space may be relevant to his or her total exposure, such sources in a neighbor's work space should be of much less concern.

D. In addition to exposures received from other sources in the facility, this evaluation found that those workers who are located or positioned near or directly over handholes have the potential to receive additional exposures. In particular, those workers who are positioned: (1) closer to the sector transformers, and (2) next to handholes that are parallel to the electrical raceways, will receive slightly higher ELF magnetic field exposure than those workers who are located further away from the transformer and raceways. These areas of slightly higher exposure, as measured on the days of this evaluation, were below the exposure criteria cited earlier.

E. It was discovered that a relationship exists between the number of electrical wires found in a handhole and the magnetic field levels (see Figure 6). This finding suggests that workers located near handholes having a higher number of wires/cables may be more exposed to ELF than those workers located near handholes that have fewer wires/cables in them.

F. Laser printers, due to their requirement to maintain a certain temperature, require high current loads. This suggests that for the short time the printers draw higher current loads (increase of 6 to 7 amperes) localized elevated magnetic fields are produced. With the use of so many laser printers, which can operate at various times, the magnetic fields throughout a given area can be very elevated for short periods of times. This erratic (or spiking) characteristic is documented in Figures 2a and 2b and is believed, by NIOSH investigators, to occur due to laser printers. This finding suggests that adding more laser printers may increase ELF magnetic fields, as well as increase the current load on present electrical circuits.

G. The higher magnetic field levels measured on the 6th floor may be due to larger quadrant transformers, proximity of the computer room, the possibility of grounding problems in the handholes, the number of laser printers, and the number of wires in selected handholes near room 6221. There may well be other factors which are important but were not apparent on the days of measurement.

H. It is apparent to NIOSH investigators that the existing wiring circuits within the Nassif Building are not well known and may be almost impossible to trace. While it would be helpful to identify where each wire in the handhole goes and what it controls, it is obvious that such an identification process would take a long time to perform and verify. Rather than embarking on an expensive and time consuming identification process, if the intent is to control ELF exposure, it may be more useful to prohibit any additional wires in existing electrical ducts. All additional wiring required on the floors may have to be addressed in a new system which utilizes ceiling pipes. Unfortunately, such action may impact future expansion requiring electrical energy. Another approach may involve eliminating or controlling the number of laser printers used per floor or work area. However, before any such administrative action is undertaken, it should be realized that there is currently no conclusive evidence to show that chronic exposure to ELF fields causes adverse human effects. It should also be noted, however, that the health effects allegedly related to ELF fields may be linked to many variables, of which field strength is only one. Therefore, depending on these variables, weaker electric or magnetic fields are not necessarily safer than stronger fields. It is noted that while biological concern was expressed as one of the reasons for this evaluation, discussion with workers conducted during the evaluation did not reveal any employee reports of actual biological effects or damage.

I. It is suggested that training courses be offered to affected employees which focus on techniques useful in reducing exposure to ELF electric and magnetic fields.

VIII. REFERENCES

1. USPHS [1993]. Electromagnetic fields survey at Department of Transportation: Nassif Building. Performed by Division of Federal Occupational Health, Region III, Philadelphia, PA.

2. ACGIH [1993]. 1992-1993 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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