Exposures to Electromagnetic Fields While Operating Walk-Through and Hand-Held Metal Detectors

Dawn Tharr, Column Editor

Reported by C. Eugene Moss

Introduction

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation to evaluate occupational exposure to magnetic fields generated by metal detectors located in various U.S. courthouses. Visitors entering federal courthouses today are checked for weapons and explosive devices using metal detectors. All federal courthouses use very similar metal detection equipment. In this evaluation, a total of 52 walk-through style (denoted as arch in this report) and several types of hand-held metal detectors were evaluated in federal courthouses located in 15 states over a 17-day period.

Background

Following a 1968 congressional mandate that called for new and improved techniques, systems, and equipment to strengthen law enforcement and criminal justice, the National Institute of Law Enforcement and Criminal Justice (NILECJ) in 1974 established a Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards. One of the accomplishments of LESL was to develop a law enforcement equipment standard entitled NILECJ-STD-0601.00 Walk-Through Metal Detectors for Use in Weapons Detection. This standard is a technical document that consists of performance requirements and test methods to help manufacturers of law enforcement equipment meet NILECJ requirements. No occupational exposure standards were developed for this document. However, information developed by the Federal Aviation Administration was presented that addressed allowable generated magnetic field levels as a function of frequency for equipment used for security purposes.

Metal detection is based on changes in induced electromagnetic signals caused by the presence of metal within a defined detection area. When a coil is excited with alternating current, a primary magnetic flux (θo) is produced within the coil and a voltage (Vo) is developed across the coil. The insertion of a metal object, such as a gun, into the coil causes eddy currents to be induced in the metal object. These eddy currents will generate a secondary magnetic flux ($\Delta\theta$). These primary and secondary magnetic fluxes combine to form a net flux of $\theta = \theta o + \Delta\theta$. The flow of this net flux produces a voltage change across the coil (ΔV). If one assumes that a constant current (I) flows in the coil, then the ΔV corresponds to a change in coil impedance of $\Delta V/I$. This coil impedance can be electrically amplified and processed, resulting in a detector signal such as an alarm. It is the movement of metal through various coil arrangements (detector system) which creates the impedance change that forms the basis for metal detection.[1]

During this evaluation, both old and new model metal detector units were evaluated; however, few of the units evaluated were older than 10 years, and most were in good operating condition. On older models, magnetic fields are produced on only one side (hot) of the arch. Improved newer models produce magnetic fields on both sides of the arch (typically lower fields on both sides).

Methods

Location of Measurements

Measurements of subradiofrequency magnetic fields were made inside the arch as well as at specific distances outside and away from the surface of the arch. Inside the arch, measurements were made at four vertical sites above the floor, designated as head (180 cm), chest (140 cm), waist (110 cm), and knee (50 cm). At each of these vertical sites measurements were made at five equally spaced positions across the horizontal inside width of the arch (typically 76 cm). Measurements across the horizontal inside width of the arch were made every 19 cm on an imaginary line connecting the middle of the two arch sides.

Outside the arch, measurements were made at a distance of 0 (arch contact), 30, and 61 cm on each of the three outside arch sides 112 cm above the floor to develop magnetic field isocontour lines for estimating occupational exposure. Unfortunately, walls and equipment at some of the sites prevented measurements from being performed at the 30- and 61-cm locations. To determine actual employee exposure, measurements were made at the closest metal detector location where a worker normally stood.

Measuring Equipment

The following equipment was used to assess the magnetic field exposures:

- Selected magnetic field 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 at various time intervals in the instantaneous read or storage mode. The system was designed to measure, record, and analyze power frequency magnetic fields up to about 5.6 gauss (G) (low read) in the frequency region from 30 to 800 Hertz (Hz). In addition, the system has been modified to read up to 140 G (high read) over the frequency range from 40 to 3000 Hz. The high read meter was used exclusively in this evaluation.
- The Multiwave System II waveform capture instrument was used at one location to both confirm EMDEX readings and measure the real-time static magnetic field (0 Hz) and subradiofrequency magnetic fields up to 3000 Hz as an individual walks through a metal detector. This system

TABLE 1. Range of Magnetic Field Strength Levels (in Milligauss) at Different Inside Arch Locations by Manufacturer

MFGS	No. of Units	Head ELF	Head VLF	Chest ELF	Chest VLF	Waist ELF	Waist VLF	Knee ELF	Knee VLF	Floor ELF	Floor VLF
A	9	7–2736	0–200	12–1776	0–180	12–1850	0–180	12–1850	0–180	1–484	0–70
B	18	41–1550	10–200	30–640	5–80	33–470	10–100	32–544	10–80	36–1310	10–250
C	2	4–950	0–180	4–944	0–140	4–1084	0–190	4–841	0–140	4–588	0–140
D	16	0–1352	0–410	0–1260	0–410	0–1100	0–410	0–784	0–400	0–900	0–600
E	7	8–2100	0–180	10–1800	0–180	9–1780	0–180	10–1420	0–180	9–432	0–120
Total	52	0–2736	0–410	0–1800	0–410	0–1850	0–410	0–1850	0–400	0–1310	0–600

ACGIH exposure guidelines for EMF frequencies 300 to 30,000 Hz = 0.2 mT = 2000 mG; for EMF frequencies <300 Hz (assuming 60 Hz) = 1.0 mT = 10,000 mG. MFGS = metal detector manufacturers (coded).

has a three-axis fluxgate magnetometer probe and is manufactured by Electric Research and Management, Inc. of State College, Pennsylvania. Waveform measurements in three orthogonal directions are digitized and put through a fast Fourier transform to obtain frequency spectra, magnitude of the magnetic fields, polarization components and spatial orientation of the fields, and total harmonic distortion.

- A Holiday Industries, Inc. model HI-3637 three-axis very low frequency (VLF) magnetic field meter was used to make isotropic measurements of the magnetic field produced by the metal detectors. The magnetic field is measured over the frequency region from 2 to 400 kHz, and the dynamic range of the meter is 6 mG to 400 G when using special probe adapters.

Measurements made on several metal detectors by NIOSH, using a Hewlett-Packard model 3561A digital signal analyzer with a special calibrated antenna, documented frequencies up to 50 kHz. The Multiwave system, which has a maximum response of 3 kHz, documented dominant frequencies of 924, 936, and 2783 Hz. Coverage of these frequencies and others up to 3 kHz was accomplished by the use of either the EMDEX or Multiwave system. Coverage of frequencies up to 50 kHz and beyond was accomplished using the Holiday HI-3637 VLF probe.

Evaluation Criteria

At the present time there are no Occupational Safety and Health Administration or NIOSH exposure criteria for subradiofrequency fields. The American Conference of Governmental Industrial Hygienists (ACGIH®) has published threshold limit values (TLVs®) for subradiofrequency electric fields (E-fields) and magnetic fields (B-fields) (30 kHz and below).[(2)] The TLV for subradiofrequency magnetic fields (B_{TLV}) states that occupational exposure from 1 to 300 Hz should not exceed the ceiling value given by the equation

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

where f is the frequency in hertz and mT is the magnetic flux density in millitesla. One millitesla equals 10 G. 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.

Conversely, the subradiofrequency electric field TLV (E_{TLV}) states that 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 ceiling value is given by

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

where f is the frequency in hertz. A value of 625 V/m is the ceiling value for frequencies from 4 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, 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 subradiofrequency E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The B-field TLV addresses induction of magnetophosphenes 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 to subradiofrequency electric and magnetic fields has not been conclusively linked to cancer.

Results

This evaluation estimated occupational electromagnetic field levels to personnel working with metal detector units by recording magnetic fields emitted from different manufacturers' units. Company names appearing on metal detector units at the time of evaluation were Federal Laboratory Inc., Metorex, Sentrie, EG&G Astrophysics Research Corporation, and Outokompo. Data from all the above names have been combined without regard to model differences, and only maximum magnetic field ranges by metal detector manufacturer are presented. None of the 52 units measured, regardless of their manufacturer, exceeded the ACGIH exposure limits. Preliminary measurements made on metal detectors suggested that the electric field levels were considerably below the TLV and therefore were not further evaluated.

Table 1 shows the range of measured magnetic fields at different inside arch locations from all metal detectors by manufacturer code. Figure 1 shows that extremely low frequency (ELF) magnetic field levels (40 to 3000 Hz) are higher inside the arch than are VLF magnetic field levels (2 to 400 kHz). The highest ranges of ELF magnetic field measurements were found at the head location, while the lowest were seen at the floor level. There was not much difference in ELF magnetic field levels at the chest,

TABLE 2. Range of Magnetic Field Strength Levels (in Milligauss) at Various Distances from Unit by Manufacturer

MFGS	No. of Units	Contact		30 cm		61 cm	
		ELF	VLF	ELF	VLF	ELF	VLF
A	9	7–1264	1–1200	4–140	0–107	0–33	0–12
B	18	7–1690	5–70	2–64	2–14	1–25	1–4
C	2	2–1800	0–220	1–58	0–10	1–10	0
D	16	0–2440	0–350	0–115	0–40	0–15	0–10
E	7	0–1100	0–270	4–107	0–20	0–33	0–10
Total	52	0–2440	0–1200	0–140	0–107	0–33	0–12

ACGIH exposure guidelines for EMF frequencies 300 to 30,000 Hz = 0.2 mT = 2000 mG; for EMF frequencies <300 Hz (assuming 60 Hz) = 1.0 mT = 10,000 mG. MFGS = metal detector manufacturers (coded).

waist, or knee locations. While the VLF magnetic field levels are lower, they appear to be fairly uniform at all inside arch locations.

Measurements taken with the Multiwave system while passing through the arch of units which produced magnetic fields on both sides gave maximum field levels of 19.9 and 38.2 mG, respectively. However, these levels were recorded for less than 1 second, since the individual did not stop in the arch. Rapidly passing through the system also affected the frequency distribution and gave smaller dominant values. Results from the Multiwave system at the location of the worker confirmed minimal exposures (i.e., background) to magnetic fields from metal detector units when located at distances greater than 61 cm from the unit.

Table 2 shows the range of measured magnetic fields outside the arch at different distances. Figure 2 shows that the ELF magnetic field levels are higher than the VLF field levels. Moreover, the highest levels for both fields are at contact with the metal detector unit, with field strength quickly dropping at distances farther from the unit. For example, if workers were located beyond 61 cm from the units, the range of both ELF and VLF magnetic field levels would be below 33 and 12 mG, respectively. Almost all personnel seen in the evaluation were located at least 61 cm away from the metal detectors during the course of their workday.

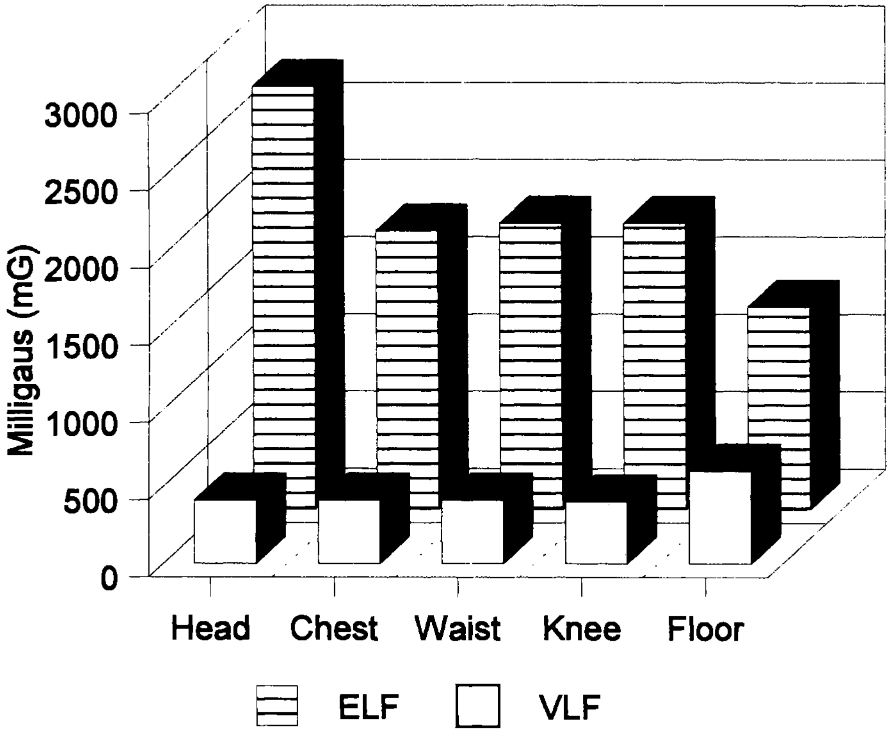

FIGURE 1. Range of magnetic fields from all units at inside arch locations.

Based on Multiwave analysis on several different metal detectors, there are no magnetic field levels exceeding the TLV of 2000 mG for frequencies greater than 300 Hz.

Discussion/Conclusions

Based on the data collected in this evaluation, security personnel who work with metal detectors are not exposed to magnetic fields in excess of applicable occupational guidelines.

The NIOSH investigator found no publications or reports documenting occupational EMF levels associated with metal detector units. However, a few reports did exist that addressed potential biological effects associated with individuals having pacemakers who use walk-through metal detectors. The general conclusion from these limited reports is that since a person with a pacemaker passes through the metal detector for only a fraction of a cycle, only one heartbeat would be affected. Such a limited exposure time would not be a major concern. In 1972 a medical evaluation was performed on 53 patients with permanently implanted pacemakers.[3–5] The results of that testing found no inhibition of pacemaker response.

There were several situations where workers were in close proximity to metal detectors (i.e., at distances less than 30 cm). When that situation occurred, exposure levels could increase to 70 to 80 mG. This situation is easily remedied by moving the worker farther from the side of the unit.

At several locations metal detectors were close to elevators. These elevators

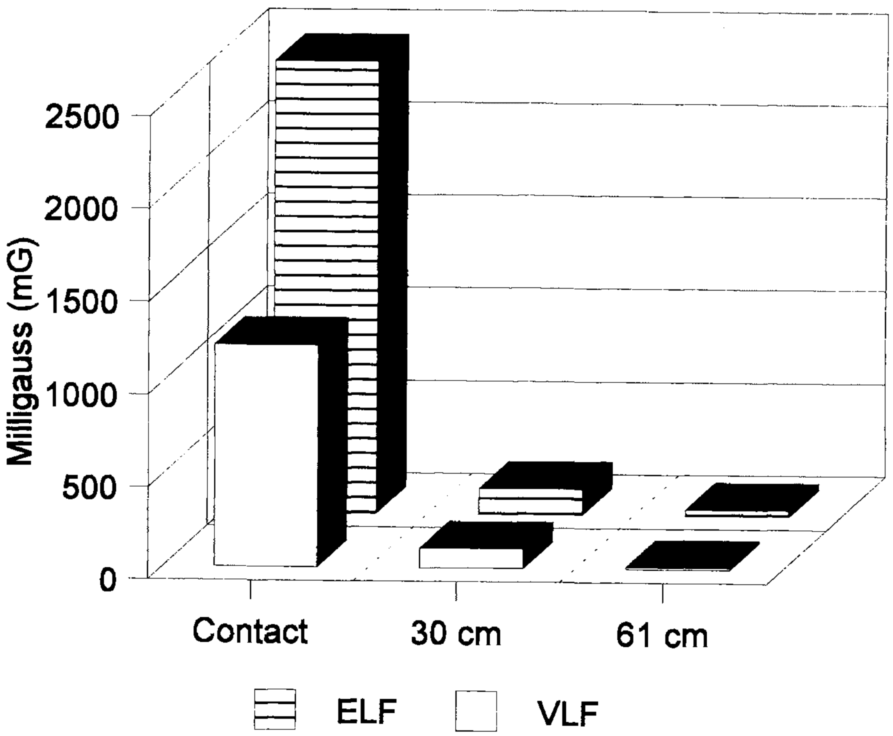

FIGURE 2. Range of magnetic fields from all units at various distances.

can, under some conditions, create impedance changes, resulting in an audible sound indicating metal detection. This false positive response could impact security, especially in crowded areas.

References

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Editorial Note: C. Eugene Moss is with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this evaluation is contained in Health Hazard Evaluation Report No. 96-0113-2644, available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800)35-NIOSH.