Electromagnetic Fields in the Steel Industry

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

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Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

Electromagnetic fields, better known as EMFs, are not readily known in the steel industry. Many people in the steel industry ask: What are EMFs and what is their potential effect on health and safety in the steel industry?

EMFs can be viewed as the combination of an electric field and a magnetic field. The electric field is produced by stationary charges, and the magnetic field by moving charges (currents); these two are often described as the sources of the field.

One of the main characteristics that define an EMF is its frequency or its corresponding wavelength. Frequency is the number of oscillations or cycles per second, and wavelength is the distance between one wave to the next. The higher the frequency, the lower the wavelength, and vice versa. There are many formulas related to both frequency and wavelength. In this case, frequency and wavelength are important characteristics of EMFs. How close or far the wavelengths are and how high the frequency is determine whether non-ionizing or ionizing radiation is being produced. Figure 1 is the electromagnetic radiation spectrum, which shows all known possible frequencies of electromagnetic radiation.

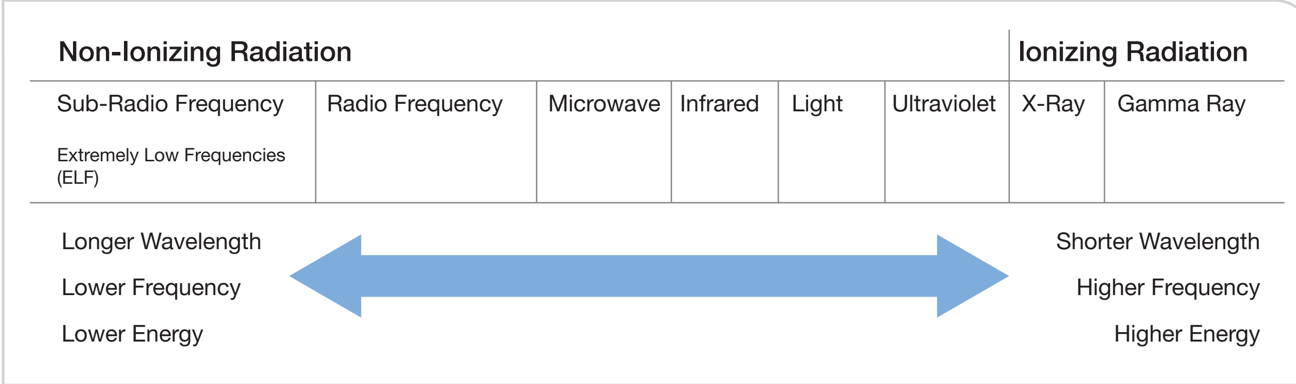
A wealth of information is available about ionizing radiation and most types of non-ionizing radiation, including potential health and safety effects and how to quantify them. However, it is still somewhat unknown where sub-radio frequency or extremely low frequencies (ELF) are found, how to measure them, and the potential health and safety effects that they may cause.

The U.S. Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH) and the American Industrial Hygiene Association (AIHA) have agreed that ELF includes frequencies between 1 and 300 Hz.

ELF includes alternate current (AC) and direct current (DC) fields and other electromagnetic, non-ionizing radiation from 1 to 300 Hz. Many different sources and exposures to ELF can be found in living and working environments, such as, but not limited to: computer screens, cell phones, electrical equipment, induction furnaces, power lines, radio-frequency welding machines, diathermy equipment and radar. These have been evaluated by the World Health Organization (WHO), AIHA, National Institute of Occupational Safety and Health (NIOSH) and other organizations.

Overall, the evidence shows that exposure to ELF at the levels between 50 to 300 Hz does not increase the risk of any adverse outcome like spontaneous abortions, malformations, low birth weight and congenital diseases. There have been occasional reports of associations between health problems and presumed exposure to EMF at higher frequency levels (>450 KHz), such as reports of prematurity and low birth weight in children of workers in the electronics industry, but these have not been regarded by the scientific community as being necessarily caused by ELF exposure. Some epidemiological studies have suggested increased cancer risk associated with magnetic field exposures near electric power lines.

Figure 1



Electromagnetic radiation spectrum.

Occupational Exposure Limits (OELs)

At this time, OSHA has not established permissible exposure limits (PELs) for EMF strength. However, in the 2013 TLV booklet, the ACGIH recommended threshold limit values (TLVs) for sub-radio frequency ELF. These guidelines are applicable for magnetic and electric fields, which are the two components of ELF.

Magnetic fields are created by moving charges, or currents. They are defined by the magnitude and direction of the force exerted by a moving charge or current. The magnetic flux density, B, characterizes the magnetic field strength. The units of B are the tesla (T) that is usually scaled to microtesla (μT) for workplace evaluations. Another unit of B is the gauss (G), which is usually scaled to milligauss (mG). The conversion factor from teslas to Gauss is 1T= 10,000G. The magnetic fields TLV in the ELF range should not exceed the ceiling value given by:

$$B_{TLV} = 60/f \qquad \text{(Eq. 1)}$$

where

f = frequency in Hz and

B_{TLV} = the magnetic flux density in millitesla (mT).

Electric fields are created by electric charges. The electric field, E, is defined by the magnitude and direction of the force it exerts on a static unit charge. The units of electric field strength are volts per meter (V/m or kV/m).

Table 1 presents the ACGIH TLV electric and magnetic field guidelines depending on the frequency in Hz with the respective units.

Other organizations also establish guidelines for EMF strengths. The Institute of Electrical and Electronics Engineers Inc. (IEEE), under "C95.6-2002 IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz," has established MPEs for whole-body exposure to electric fields. Table 2 presents the MPEs that would apply for general public as well as for "controlled environments."

Furthermore, the C95.6-2002 IEEE standard lists the maximum permissible exposure (MPE) levels for both

Table 1

ACGIH TLV Electric and Magnetic Field Guidelines

	ACGIH guidelines			
	Magnetic fields (H)			Electric fields (E)
Frequency	Gauss	A/m	mW/cm²	V/m
50/60 Hz DC				
Medical devices	5	17.8	–	1,000
Average worker	20,000	1,126	–	125,000
50/60 Hz AC				
Medical devices	1	0.79	–	1,000
Average worker	10	25.1	–	25,000

electric and magnetic fields as a function of frequency (see Table 3).

The ACGIH TLVs and the IEEE criteria are recommended guidelines designed for use by individuals trained in the discipline of industrial hygiene, and they are not regulatory or compliance standards.

How Can EMF Be Measured?

Usually, EMF surveys are performed to obtain measurements within areas that an employee who has an implanted electronic medical device may be required to enter or traverse as part of his/her routine work. Individuals with implanted pacemakers or similar electronic medical devices must have the results of the EMF survey measurements reviewed by the employee's physician and referenced to the manufacturer's information relative to the device.

There is direct reading equipment available to quantify EMFs. However, it is important to investigate if the machinery located in the work area is either AC or DC, and at what frequency it is operating. This will determine which guidelines to use to compare the EMF readings.

AC equipment has been more readily available than DC equipment. Usually, DC is found on crane magnets and sometimes on motors or pumps. As for the frequency, 50–60 Hz is considered the "standard" frequency used for operating equipment in the steel mill. This type of information may be provided by the electrician or the maintenance department.

When evaluating EMFs, use caution when the machinery is operated by a multi-phase current. For example, a power supply input power may be a 3-phase, 480-volt alternate current (VAC), 50–60 Hz. The input power is converted to approximately 680 volts direct current (VDC) by the power supply front end. The direct current (DC) is then converted back to alternating current (AC) at the desired frequency. The nominal output frequency is 450 kHz. In this case, the AC, DC and the nominal output frequency should be evaluated. As noted in this example, the output frequency is considerably higher than the standard 50–60 Hz. The 450 kHz frequency is considered radio frequency, and the respective occupational exposure guidelines are different than the ones mentioned previously.

There are multiple manufacturers that provide a wide range of instruments to measure EMF. When selecting the appropriate measuring equipment, the following characteristics should be considered in order to obtain accurate readings:

- Frequency range.
- Capability of measuring AC and/or DC current.
- Intrinsic safety.

Table 2

MPE Levels That Apply for the General Public and Controlled Environments

General public		Controlled environment	
Frequency range (Hz)	E (V/M)	Frequency range (Hz)	E (V/M)
1–368	5,000	1–272	20,000
368–3,000	$1.84 \times 10^6/f$	272–3,000	$5.44 \times 10^6/f$
3,000	614	3,000	1,813

Note: A "controlled environment" is an area that is accessible to those who are aware of the potential for exposure as a concomitant of employment, to individuals cognizant of exposure and potential adverse effects, or where exposure is the incidental result of passage through areas posted with warnings, or where the environment is not accessible to general public and those individuals having access are aware of the potential for adverse effects.

Table 3

MPE Levels: Exposure of Head and Torso

	General public		Controlled environment	
Frequency range (Hz)	mT	A/m	mT	A/m
<0.153	118	9.39×10^4	353	2.81×10^5
0.153–20	18.1/f	$1.44 \times 10^4/f$	54.3/f	$4.32 \times 10^4/f$
20–759	0.904	719	2.71	2.16×10^3
759–3,000	687/f	$5.47 \times 10^5/f$	2060/f	$1.64 \times 10^6/f$

Figure 2

(a) (b)

ETS·Lindgren factory-calibrated Holaday Industries Inc. Model HI-3604 EMF meter (a) and an Integrity Design & Research Corp. gauss meter (b).

An ETS·Lindgren factory-calibrated Holaday Industries Inc. Model HI-3604 EMF meter (Figure 2a) and an Integrity Design & Research Corp. gauss meter (Figure 2b) are some examples of equipment utilized to obtain the electric and magnetic fields for the AC and DC current.

Implementation of Controls

After performing an EMF survey, the data should be compared with the applicable ACGIH or IEEE guidelines. In cases where readings exceed the applicable guidelines, they usually exceed the guidelines for people with medical devices. The following are some controls that may be considered:

- Employees or any individual having an implanted electronic medical device must be restricted from the areas with EMF levels above the applicable guidelines.
- Warning signage should be posted at the identified areas.
- Safety barrier rope line may be placed to demarcate areas.
- In cases where the readings are considerably elevated, the feasibility of installing additional shielding mechanisms, such as, but not limited to: reflection, absorption or attenuation, and internal reflection should be investigated by engineering with the manufacturer.

These are some recommendations to reduce the potential exposure to EMF. Every steel company should evaluate EMF in its work areas and establish the necessary controls as applicable.

EMF is not an easy occupational health and safety topic to understand. It takes time and effort to comprehend the technical aspects and be able to perform evaluations and analyze the data obtained from EMF surveys. These are just the basics on how to identify, measure and control EMF in the steel industry. Further information on the subject of EMF can be obtained from:

- OSHA's website: www.osha.gov.
- 2013 ACGIH TLVs and BEIs booklet.
- C95.6-2002 IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz. ✦