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ELECTROMAGNETIC EMISSION MEASUREMENT OF THE SHIELDED METAL ARC WELDING (SMAW) PROCESS

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ABSTRACT

Electromagnetic emissions from electrical devices may interfere with electronic safety systems or other devices in the mining environment. This electromagnetic interference (EMI) may cause unwanted changes in the performance of the affected devices and may cause safety issues for miners. To minimize the risk of EMI, the National Institute for Occupational Safety and Health (NIOSH) has conducted research quantifying the electromagnetic emissions of several types of equipment that might be used in the mining environment.

Previous research has shown that welding arcs can give off ultraviolet (UV) emissions, visible light, and infrared (IR) emissions that can cause health problem on skin and eyes. In this study, the electromagnetic emissions of the shielded metal arc welding (SMAW) process were monitored and measured. Several factors including operating mode (AC, DC positive or DC+, DC negative or DC-), current setting (low, medium, high, maximum), and electrode type were investigated to compare their effect on emission level. The test shows that the emission level from the welding process can be affected by those factors. The test data also shows that, among those factors, the operating mode has more influence on emission level than do current setting and electrode type. The information in this paper can be useful for the mining industry to better understand the emission in the 9-kHz to 500-MHz frequency range from a SMAW welder.

INTRODUCTION

Welding processes generate electromagnetic (EM) emissions. Those EM emissions may interfere with electronic devices in the vicinity and cause electromagnetic interference (EMI) and electromagnetic compatibility (EMC) issues [1] [2] [3]. There are several guidelines, standards, and regulations on EMI/EMC related to welding [3] [4] [5] [6]. However, there are no standards or regulations in the mining sector as there are in other industrial sectors related to EMI caused by welding [4]. Prior research has investigated the effect of EM emissions from the welding process on nearby instruments and implanted medical devices [7] [8] [9] [10]. Tests were conducted to characterize the effects of EMI from arc welding on startup instrumentation [10]. In [8], the magnetic fields generated by the arc welding process were calculated theoretically and compared with test data. Zhang developed a mathematical model to simulate the high-frequency electric field of a welding arc [9]. The model predicted that the high-frequency electric field emissions near the arc are stronger and decrease quickly along with the distance. However, more research is needed to further investigate the EMI effect of the welding process. For example, how the welder setting and individual component, such as the welding arc and electrode, will affect the welding process needs further investigation.

There are several types of welders used in industry. The shielded metal arc welding (SMAW) machine is one of the welders widely used in the mining industry. These machines can be found with both AC and DC current capabilities. The welder uses coated electrodes in varying coating, size, and material (tensile strength). Welding can take place outside or indoors. In this study, a Lincoln Idealarc® TIG 300/300 SMAW welder was used (Figure 1). It has three operating modes (AC, DC+, DC-) and five current level selections (minimum, low, medium, high, maximum). The EM emissions from the welding process were recorded to investigate the effects of welder components, operating mode, current setting, and electrode type on emission level.

Figure 1. The shielded metal arc welding (SMAW) machine used for the test. It has three operating modes and five current level selections.

TEST METHODOLOGY AND SETUP

The electromagnetic field from the environment, the welder, and the welding process was monitored and measured using a spectrum analyzer and antennas. An A.H. Systems SAS-521-7 bilogical antenna was used to measure the electric field (E-field) emissions. It has a measurement range of 25–7,000 MHz. For all measurements, the vertical antenna polarization was used, and the antenna was positioned 1m away from the Equipment Under Test (EUT) as specified in MIL-STD-461 RE102 [6]. The frequency range measured during the test was 25–500 MHz.

A Com-Power AL-RE101 passive loop antenna was used to measure the magnetic field (B-field) emissions. The antenna has a measuring range of 30 Hz to 100 kHz and was specifically designed for measuring the magnetic field due to radiated emissions. For all measurements, the loop antenna was positioned 7cm away from the

EUT as specified in MIL-STD-461 RE101 [6]. The frequency range measured during the test was 9–100 kHz.

The arc was considered as a EUT and the same distance between EUT and the antenna was applied.

The Tektronix RSA 5115B and Anritsu MS2722C spectrum analyzer were used for the test. The Tektronix RSA 5115B was used for the E-field measurement and has a frequency range of 1 Hz to 15 GHz. The Anritsu MS2722C was used for the B-field measurement and has a frequency range of 9 kHz to 9 GHz.

Several factors related to electromagnetic emissions during the welding process were investigated. The first is the location of the emission source. Potential sources include the welder itself, the cable coil, and the arc (at the welding table). The second factor is the operating mode of the welder. The machine has three operating modes—AC mode, DC negative mode (DC-), and DC positive mode (DC+). The third factor is the current setting. For each mode, the machine has five current settings—minimum (min), low, medium (med), high, and maximum (max). The last factor is the type of welding electrode (or stick). Welding electrodes vary in size and material. All the factors mentioned above may affect the characteristics of the electromagnetic emissions during the welding process.

EMISSION SOURCE LOCATION

The welding table connects to the welder through a pair of 60-foot-long cables. The welding table is usually located close to the welder and the cable was coiled on the machine (Figure 2). The first E-field measurement was made at Pos #1 which was 1 m away from both the coiled cable/machine and the welding table (Figure 2). The antenna was mounted so that the middle of the antenna had the same elevation as the arc (the table). The coiled cable, the machine, and the welding table were considered as a composite EUT.

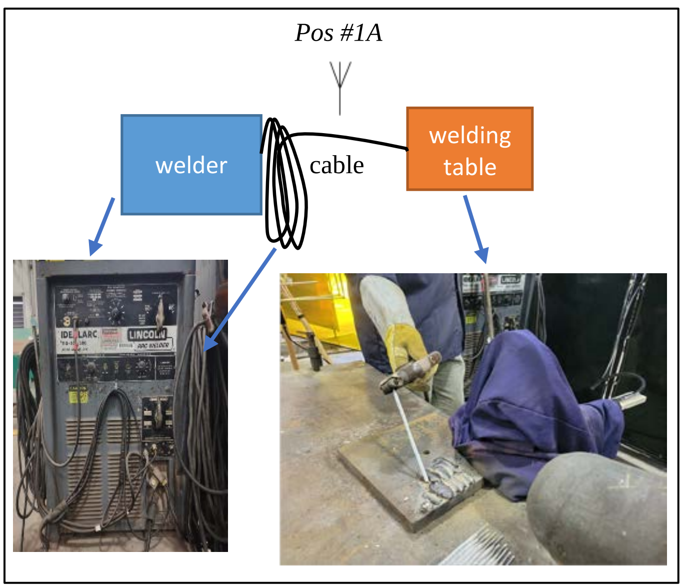


Figure 2. Configuration A—the welder, cable, and welder close by.

To isolate the emission source(s), the welding table and the welder were then separated by ~60 ft (Figure 3). The cables were stretched out from the machine to the table. The E-field emission was measured at three locations—one at the welder (Pos #1B), one at the middle of the cable (Pos #3), and one at the welding table (or the arc, Pos #2). The antenna was mounted so that the middle of the antenna had the same elevation as the arc (the table) at Pos #2. At Pos #3, the cable was elevated so that it was aligned with the middle of the antenna.

OPERATING MODE

The machine has a selection of three operating modes—AC, DC negative, and DC positive (Figure 1). The mode selection will determine the pattern of the current passing through the cable and the welding electrodes—either AC or DC. To investigate the effect of welding mode on the emission characteristics, all the settings, including stick type and current level, were kept the same except the mode selection.

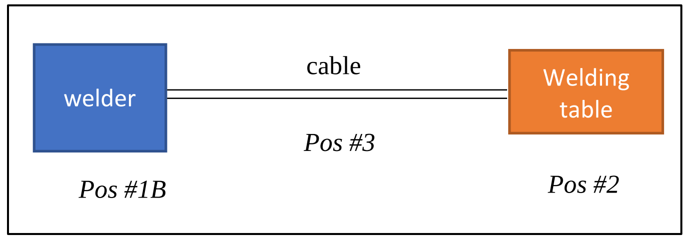


Figure 3. Configuration B—the welder and welding table separated by 60 ft.

CURRENT SETTING

For each operating mode, the machine has a selection of five current levels—minimum, low, medium, high, and maximum (Figure 1). There is also a current control knob to finely adjust the current at each current level (Figure 1), which has a scale of 1 through 10. To investigate the effect of the current level on the emission characteristics, all the settings, including stick type and operating mode, were kept the same except the current range selection. The fine adjustment current control was kept at scale 10 for all the measurements.

TYPE OF ELECTRODES

Three types of electrodes (sticks) were used to compare their effect on emission (Table 1). They are different in diameter and composition materials.

Table 1. Electrodes used in the test.

	Diameter in (mm)	Classification	Brand
Stick #1	1/8 (3.2)	AWS E6010	Fleetweld
Stick #2	1/8 (3.2)	AWS E7018 H4R	Excalibur
Stick #3	5/32 (4.0)	AWS E7018 H4R	Excalibur

TEST RESULTS

E-field Emissions

To measure the E-field emissions, an A.H. Systems SAS-521-7 bilogical wide-band antenna was positioned about 1m away from the EUT and connected to the spectrum analyzer via a radio frequency (RF) coaxial cable. The spectrum analyzer was set to 25–500 MHz sweeping range. The data was recorded using the max hold function to capture the peak values for 800 sweeps.

Emission source location. The radiated E-field was measured for Configuration A and Configuration B (Table 2). For Configuration A, the antenna was positioned at Pos #1A (Figure 2). For Configuration B, the welding table was moved ~60 ft away from the welder. The welder was kept at the same location as in Configuration A. The antenna was also positioned at the same position as in Configuration A (Pos #1B) to measure the radiated E-field from the welder. The antenna was then moved to Pos #2 and Pos #3 to measure the radiated E-field around the targeted EUT sequentially (Figure 3). For both configurations, all the settings (AC welding mode, medium current level) at the welder were kept at the same. The same type of welding electrodes (sticks) was used for both configurations.

Table 2. EUT for each configuration.

	Measuring point	EUT
Configuration A	Pos #1A	Cable (coiled), machine, and arc as a composite EUT
Configuration B	Pos #1B	Welder only
	Pos #2	Arc
	Pos #3	Cable (stretched)
Ambient noise	Pos #1A	N/A

The ambient noise and the radiated E-field for Configuration A and Configuration B were recorded and plotted in Figure 4. Based on the plot, Pos #1A and Pos #2 had the strongest emissions among all the measurements. This suggests that the E-field emissions in the welding process are mainly from the welding table (or the arc), even after separating the welding table from the welder. For the measured frequency range (25–500 MHz), the cable and the welder had less emissions than the welding arc. While the welder was isolated from the arc, there was almost no emissions in this frequency range, except the ambient noise.

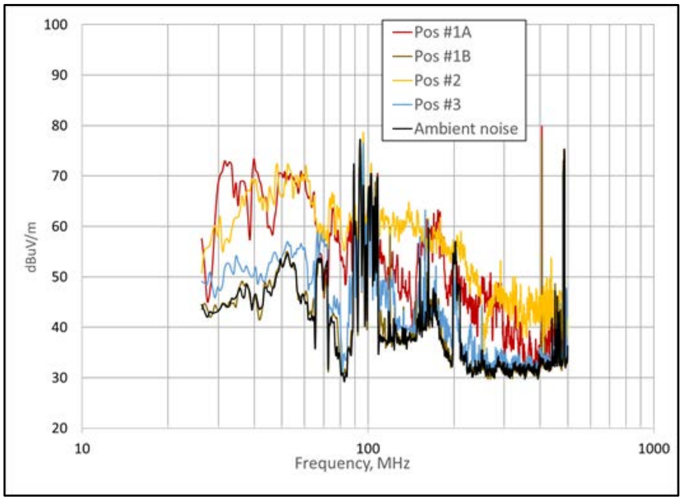


Figure 4. The E-field emissions at various locations—Stick #2, AC mode, medium current level.

The E-field emissions and the ambient noise are compared with the RE102 limit level [6] for ground application as in Figure 5. The black curves are the limit level for Navy fixed objects and Air Force objects, and Navy mobile objects and Army objects, respectively. As reflected in the plot, the emissions from welding are above both limits in the 25–110 MHz range, and above the Navy mobile and Army limit in the 25–300 MHz range.

Operating mode. As shown in Figure 6, the E-field emissions was compared for different operating modes for medium (Figure 6, top), high (Figure 6, middle), and maximum (Figure 6, bottom) current level. The testing was conducted based on Configuration A as in Figure 2. The same type of stick (Stick #1) was used. For the high and maximum current levels, the AC mode has stronger E-field emissions (up 20 dBuV/m) than DC mode does, given all other parameters (current level, type of stick) are the same.

Current setting. Figure 7 shows the comparison between different current levels for Stick #1 (top), Stick #2 (middle), and Stick #3 (bottom). The testing was conducted based on Configuration A in Figure 4 and using AC mode. While there is no obvious difference in the E-field emission measurements among all the current levels using Stick #1 (top plot, Figure 7), the medium current level has slightly higher emissions (up to 10 dBuV/m) than other current levels when using Stick #2 and Stick #3 (middle and bottom plots) in the 30-MHz region. This may be caused by the difference in the property of the materials of which the sticks were made.

Type of electrodes (sticks). Figure 8 shows the comparison between different stick types for medium (top), high (middle), and maximum (bottom) current levels. The testing was conducted based on Configuration A in Figure 4 and using AC mode. While there is no obvious difference in the E-field emission measurements among all the stick types using high (middle plot) and maximum (bottom plot) current setting, Stick #1 has slightly lower emissions (up to 15 dBuV/m) than other stick types do in the low frequency range for medium current level (top plot). Again, that might be caused by the difference in the property of the materials of which the sticks were made.

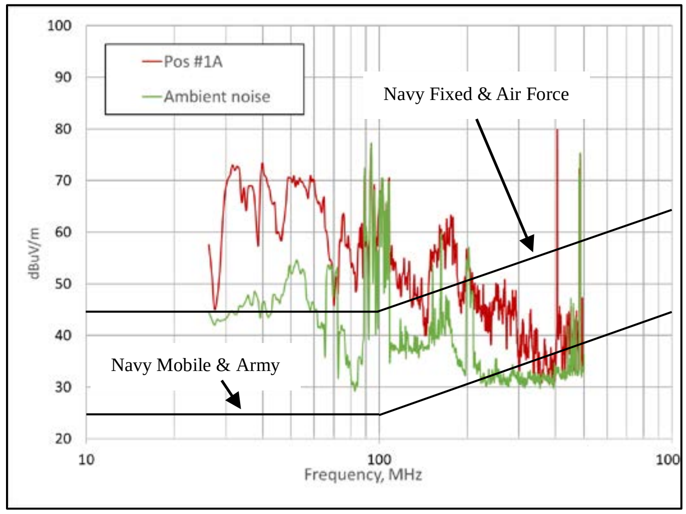
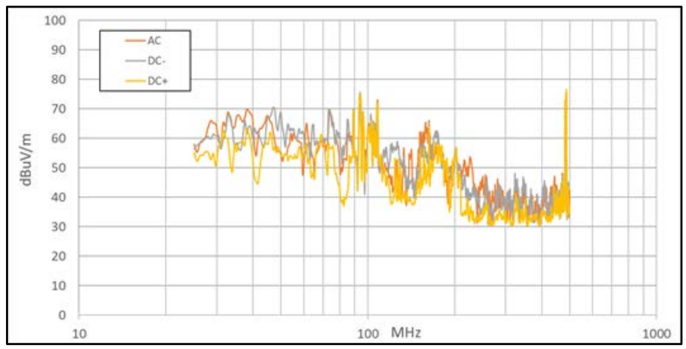
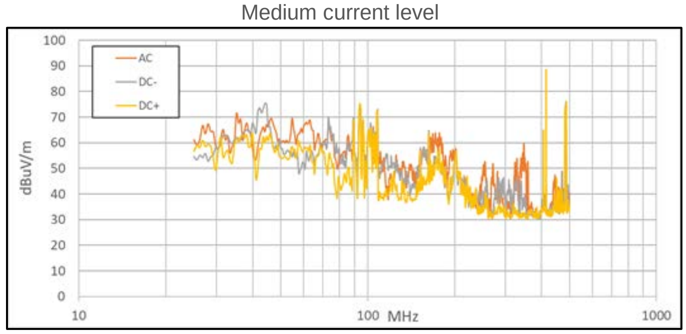


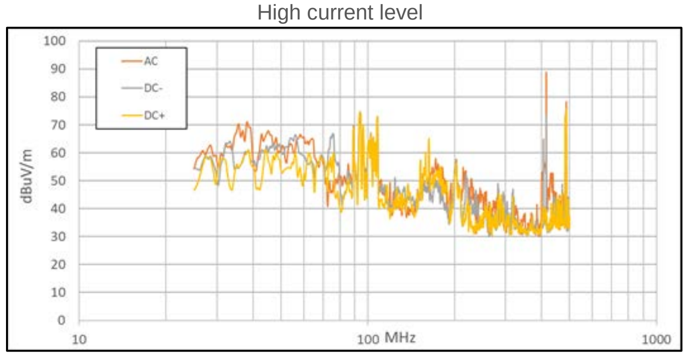
Figure 5. The emissions from welding and the ambient noise compared with RE102 limit level for ground applications.



Medium current level

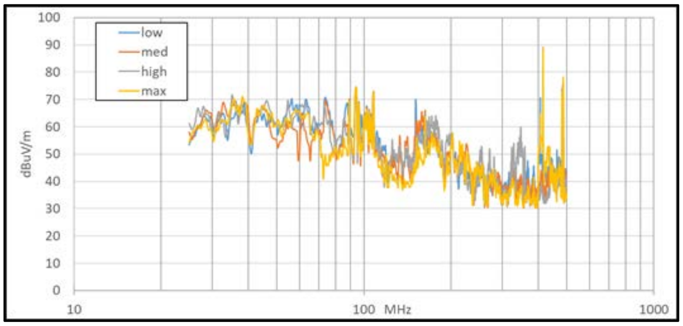


High current level

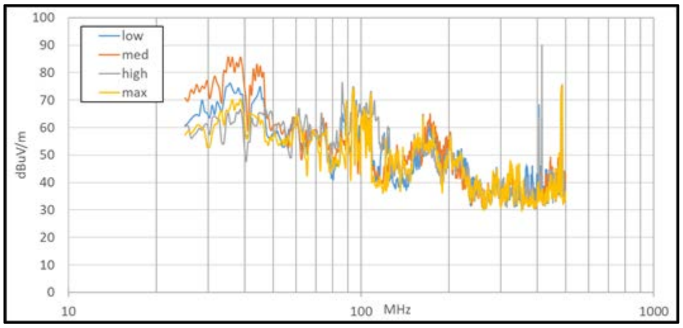


Maximum current level

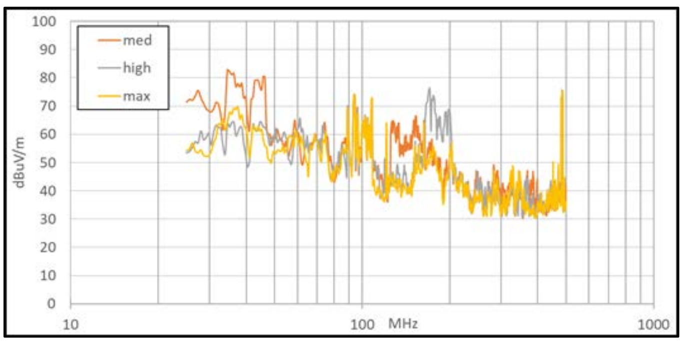
Figure 6. Comparison of operating modes for medium (top), high (middle), and maximum (bottom) current level. Configuration A, Stick #1.



Stick #1

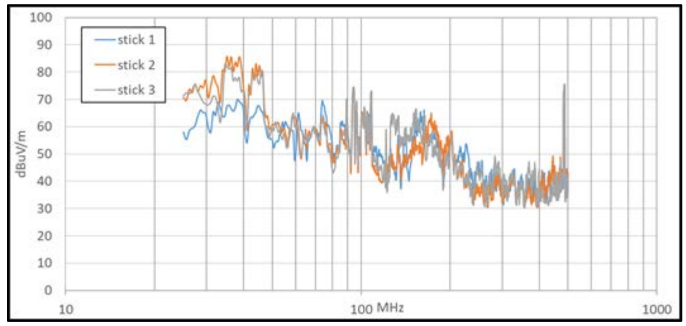


Stick #2

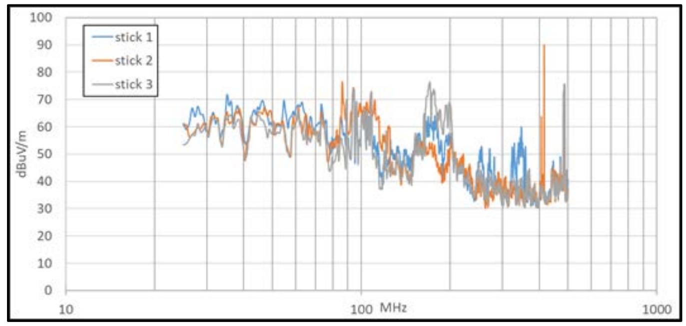


Stick #3

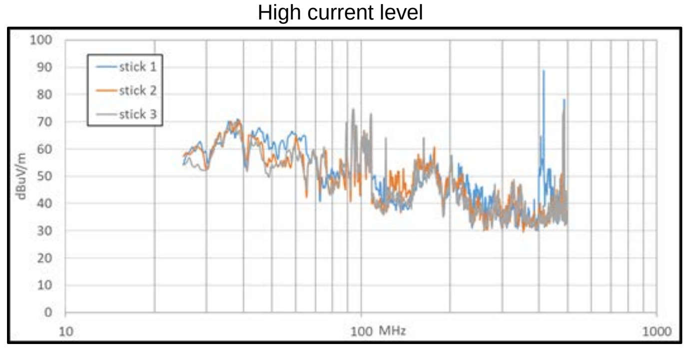
Figure 7. Comparison of current levels for Stick #1 (top), Stick #2 (middle), and Stick #3 (bottom)—Configuration A, AC mode.



Medium current level



High current level



Maximum current level

Figure 8. Comparison of stick type for medium (top), high (middle), and maximum (bottom) current level. Configuration A, AC mode.

B-FIELD EMISSIONS

To measure the B-field emissions, a Com-Power AL-RE101 loop antenna was positioned about 7cm away from the EUT and connected to an Anritsu portable spectrum analyzer (Anritsu MS2722C) via a RF cable. The B-fields due to the welding process were recorded at five locations: the upper portion of the welder (Figure 10), the lower portion of the welder, the cable coiled, the cable stretched, and the welding table (the arc). Ambient noise was also recorded while the welder was powered off. All the settings were kept the same (Stick #2, AC mode, medium current level).

Figure 9 shows the comparison at different locations for 9–200 kHz. Based on the plot, the cable had the strongest B-field emissions among all the locations when it was coiled. When stretched out, however, the B-field emissions from the cable decreased dramatically (up to 40 dBpT). The B-field emissions from the lower portion of the welder were slightly higher than that from the upper portion of the welder. The reason for that might be the emitting components were located at the lower portion of machine. It could also be caused by the coiled cable nearby (Figure 10). Another observation is that the arc had less B-field emissions than did other components. This contrasts to what was observed in the E-field measurements. The B-field emissions and the ambient noise are also compared with the susceptibility curve of a proximity detection system (PDS). The data shows that the emissions from the coiled cable and the welder exceed the susceptibility limit for the PDS device.

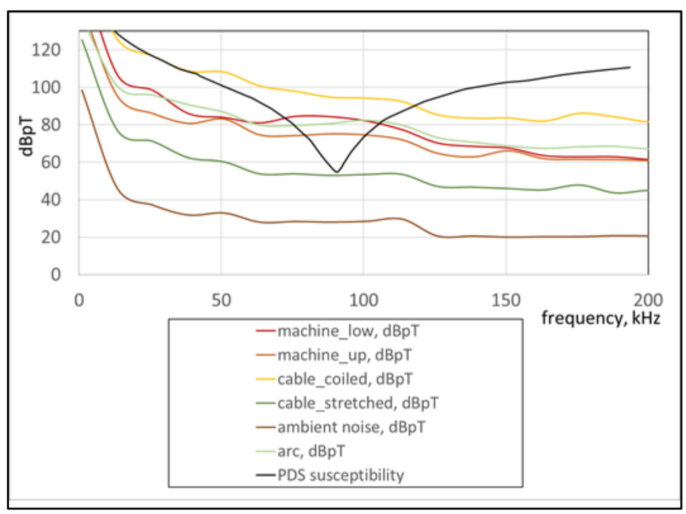


Figure 9. The B-field emissions due to the welding process at various locations, 9–100 kHz, Stick #2, AC mode, medium current level.

CONCLUSION

The shielded metal arc welding (SMAW) process can generate electromagnetic emissions. The tests in this study show that the E-field emissions due to the SMAW process were mainly from the arc. Among several factors investigated in the testing, it was found that the operating mode has more influence on E-field emission level than do the current setting and electrode type. The data suggests that the AC mode produced the higher emissions than the DC modes, given that the other settings were the same. The SMAW process can also generate B-field emissions that can be prominent to the environment noise. The coiled cable, however, has the strongest B-field emissions among all the components tested. However, it should be noted that only a limited range of welder settings and electrode types were tested, and all testing was conducted in a single operating environment. The generalizability of these measurements is therefore limited, but the data provides an indication of the type of emission that can be expected from the welding process.

Figure 10. The B-field was measured at the upper and lower portions of the front panel of the welder while cable was coiled nearby.

The information in this paper can be useful for the mining industry to better understand EM emissions from a SMAW welder.

DISCLAIMER

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

CONFLICTS OF INTERESTS

The authors declare that they have no conflict of interest.

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