



## Letter to the Editor

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## Letter to the Editor

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### CLARIFICATION TO “PILOT MEASUREMENTS OF ELF CONTACT CURRENTS IN SOME ELECTRIC UTILITY OPERATIONS”

We wish to offer several clarifications to our recently published article on measurements of contact currents on electric utility workers.<sup>(1)</sup> This article used a recently developed contact current meter (CCM) that logs voltage differences between the extremities<sup>(2)</sup> in order to assess personal exposures to contact currents in a sample of electric utility occupations.

After our article was accepted for publication, an investigation of the CCM's accuracy in various electric utility environments was published as a report.<sup>(3)</sup> This report identified several sources of error that affect the results in our article. In this letter, we discuss the implications of Bracken's findings on the results in our article and the future use of the CCM for assessing exposures to contact currents and electric fields.

#### Calibration Factor

The meter's raw output, extremity-to-extremity voltage difference, was converted to current by using Ohm's Law ( $V = IR$ ) with published values of the body's resistance.<sup>(1,2)</sup> Bracken<sup>(3)</sup> reported that the CCM's calibration factor overestimated the voltage differences by 10–11%. However, this positive bias in our results was more than canceled by using published values for the body resistance between hands and feet. In our case, the electrodes were placed on the upper arms and legs, which resulted in lower path resistances than the full extremity-to-extremity values used in our calculations. As we discussed earlier, accurate values for a person's body resistance with any electrode placement can be measured before and after a shift with the CCM and a current injection device.<sup>(1)</sup> The CCM's calibration errors have been corrected by reprogramming the meter with the constants determined by Bracken.

#### Bias Channel Saturation

For the CCM to operate properly, the potential difference between the body of the subject wearing the meter and the voltage reference point within the meter (its local ground) cannot deviate from a narrow range. To maintain this control, the meter introduces a small current through a “bias” cable extending from the meter to a nearby point on the body. Field

tests conducted by Bracken<sup>(3)</sup> showed that the reference voltage was not adequately controlled in electric fields above about 1 kV/m, causing the meter's output to saturate (plateau). This malfunction was due to a 3-megaOhm resistor that we installed in the bias channel lead for our study in order to prevent accidental injection of dangerous currents during work with energized lines.

This saturation effect would probably not affect much of our data because most subjects were not in high electric fields. The exceptions would be people working below the high-voltage transmission lines (200–500 kV) that serve substations. In our sample, 60-Hz contact currents were measured on seven people working in substations—one administrative technical support employee, and six control room operators (Table III). Based on the timing of the contact current events (Figure 3), we conjecture that the exposure to the substation control room operators occurred not in the control room (where the electric fields are shielded) but in the substation yard where the electric fields could have been high enough to saturate the bias channel. Therefore, the reported measurements for these employees working in substations are not reliable. Since then, the resistor in the bias channel was substantially lowered for the CCM measurements conducted by Bracken<sup>(3)</sup> with consequent elimination of the saturation problem.

#### CCM Readings in High Electric Fields

Maxwell's Laws predict that the electric field gradient under an electric line will induce voltage differences over the body. The field tests by Bracken<sup>(3)</sup> revealed that electric fields above ~500 V/m can induce inter-electrode voltages in the CCM that could be interpreted as contact current events. This is especially true when motion of extremities in a field results in rapid changes in the potentials between electrodes. The meter cannot distinguish these extremity-to-extremity potential differences due to electric field coupling from those due to direct contact with surfaces at different voltages. Without careful observation of the subject at the time of measurement, it would be difficult to distinguish between the contact currents and electric field induction.

Nonetheless, our study was confined to workers who did not work with energized lines, and, with perhaps the exception of the seven workers in substations (discussed above), we do not believe that the exposures logged in this study occurred in the presence of electric fields strong enough to confound the

reported data. We cannot say for sure that instances of electric field confounding did not occur with other subjects.

### Reported Contact Currents and Internal Electric Fields

After analyzing the results from Bracken,<sup>(3)</sup> we believe that the data reported in Table III, Figure 4, and Figure 5 generally represent contact currents flowing through the body—with the inaccuracies due to the calibration factor, body resistance, and electric field effects on substation employees discussed above. The same conclusions apply to the internal electric field estimates reported in Tables IV and VI except for the substation employees where the external electric fields might again affect these results.

During high-voltage work, both contact current exposures and induced internal currents will be reflected in the CCM measurements. Even if the two types of exposure had been distinguished, the currents involved could not be easily distinguished. Therefore, extension of the measurements reported here for low-voltage workers to high-field environments will require further research on CCM response and careful observations during measurements.

We believe these clarifications set an improved context for the data reported and their interpretation. They do not alter our conclusion that imperceptible contact current exposures can occur in the workplace, and we believe they need to be characterized so as to have a fuller understanding of occupational electric and magnetic field environments.

We thank Dr. T. Dan Bracken for his assistance in writing this letter.

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health (NIOSH).

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