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AEM® LAPAROSCOPIC INSTRUMENTS

# White Paper

## Capacitive Coupling with Unshielded Laparoscopic Electrodes

*By Kurt Aronow, P.E.*

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**Encision Inc.**
**6797 Winchester Circle**
**Boulder, CO USA 80301**

**www.encision.com**

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## Introduction

During laparoscopic surgery, unshielded monopolar electrodes can cause unintended stray energy burns because of insulation failure or capacitive coupling. Destructive capacitive current can flow even if the shaft insulation is perfectly intact. This paper explains how capacitive coupling works and how to solve the problem of stray burns.

## Capacitive Current

A capacitor is formed by two conductors separated by an insulator. If you connect a battery between the two conductors, negative charge (excess electrons) will appear on one plate and positive charge (lack of electrons) will appear on the other plate. If the battery is removed, the capacitor retains the battery voltage until the charge leaks away.

If the capacitor's plates are larger, they can store more charge and more energy. The energy is stored as an electric field so the closer the plates are to each other, the stronger the field. Another feature of capacitors is the electrical insulation or dielectric between the two plates. Better dielectrics can withstand stronger electric fields without excess leakage.

When a battery is connected across a capacitor, continuous current does not flow through the capacitor. On the other hand, if a capacitor is connected in series with a speaker (so that current flows from the audio amplifier, through the capacitor, then to the speaker), current still flows, and the speaker still works. This is because the capacitor only fully blocks continuous current, which is also called direct current (DC). At higher frequencies, for example with alternating current (AC), the capacitor offers progressively less impedance or restriction to the current.

*How does current flow through a capacitor?*
As charge builds up on one plate of the capacitor, the electric field pushes charge away from the other plate. If the voltage changes from positive to negative or vice versa, the electric field changes and alternately attracts or repulses charge on the other plate. This causes an AC current to flow through the capacitor.

At higher frequencies, the electric field polarity switches faster. Therefore, less time exists to accumulate charge on the capacitor plates allowing for current to flow with less impedance. Similarly, turning up the speed (frequency) of the windshield wipers allows more water (current) to be swept away. Increased current flow through capacitive coupling increases the likelihood of stray burns.

## Unshielded Laparoscopic Instruments

An interesting experiment can be done with a conventional, unshielded monopolar electrode designed for laparoscopic surgery. Examine the electrode to be sure that there are no breaks in the insulation on its shaft. Then drape a piece of thin, damp lunchmeat over the shaft of the electrode without letting it touch the exposed tip. Plug the electrode into an electrosurgical generator. Let an end of the lunchmeat touch a metal pad attached to the patient return side of the generator. Key the generator at 40 Watts and you will see current sparks through the lunchmeat. The lunchmeat will continue to cook until it dries out and ceases to conduct current.

*Why does the lunchmeat cook?*
When you drape the lunchmeat over the shaft of the electrode, you create a capacitor. One of the plates is the monopolar electrode and the other plate is the damp lunchmeat. The insulation around the electrode prevents it from shorting to the lunchmeat. But, the high frequency current from the electrosurgical generator flows through this capacitor and cooks the lunchmeat.

## Low & High Frequency Current

Electric utilities in the United States deliver power at 60 Hertz (Hz or cycles per second). In contrast, high frequency electrosurgical generators operate near 500 KHz *or at half a million cycles per second*. The impedance of the capacitor created with the electrode and the lunchmeat is over 8000 times smaller and able to conduct much larger currents than if the electrosurgical generator were operating at 60 Hz. The high frequencies necessary for electrosurgery create the special problem of significant conduction through the electrode capacitance.

## Stray Burns

With unshielded laparoscopic electrodes, some capacitance always exists between the insulated electrode and the patient tissue. With sufficient salinity and proximity, the capacitance between the electrode and the tissue will be large enough to allow stray burns. Stray burns generally go unnoticed since the surgeon only has a view of the tip of the electrode. (This discussion is limited to stray burns from an insulated electrode shaft not from the electrode tip which the surgeon can see and control.)

Inspecting the electrode before use (always a good idea) does not prevent stray burns since capacitive coupling occurs when the insulation is intact (see Figure 1). If the insulation of an unshielded electrode has a hole, then the patient may receive a direct or arcing burn. Significant stray burns appear to occur in somewhere between 0.1 and 0.5% of all laparoscopic surgeries![1]

[1] This is a loose figure from multiple sources. For example, a presentation at the 2004 meeting of Society of American Gastrointestinal Endoscopic Surgeons (SAGES) reported that 0.1 to 0.5% of laparoscopic operations produce a thermal injury.

  

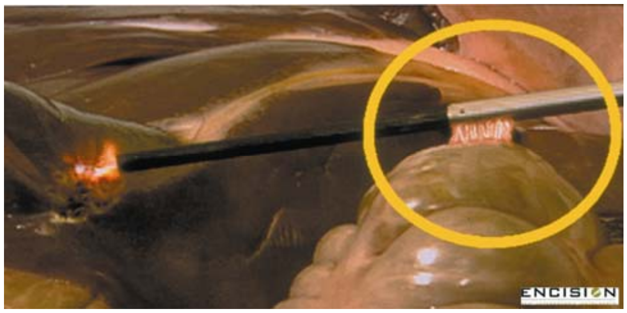


Figure 1. Example of Capacitive Coupling from Metal Cannula

### Shielded Electrode Solution

Stray burns during laparoscopic surgery from the electrode shaft can be prevented with shielded monopolar electrodes. A small amount of capacitive coupling does occur between the electrode and its shield. However, the shield is connected to patient potential near the generator preventing capacitive current from flowing through the patient. Only Encision's patented active electrode monitoring technology has monopolar electrosurgical instruments that are shielded as shown below in Figure 2.

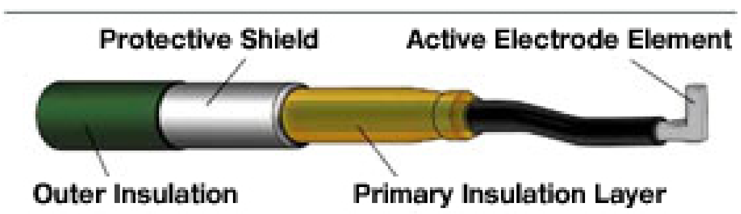


Figure 2. Illustration of an AEM Instrument

  

**Appendix of Formulae for the Mathematically Inclined:**

| Item | Comments | Formula | Definitions |
|---|---|---|---|
| Parallel Plate Capacitor | *C* is proportional to *A* and inversely proportional to *d*. | $C = \frac{\varepsilon_o \varepsilon_r A}{d}$ | *C* = Capacitance (Farads) |
| | | | *A* = Area of either plate (meters$^2$) |
| | | | *d* = Separation between the plates (meters) |
| | | | $\varepsilon_o$ = Permittivity of free space (8.85 x $10^{-12}$ Farads/meter) |
| | | | $\varepsilon_r$ = Relative permittivity between the plates (≥ 1) |
| Coaxial Cable Capacitor (e.g., lunchmeat over electrode) | *C* inversely increases as the natural logarithm of *a*/*b* (much slower than for *d* above). | $C = \frac{2\pi \varepsilon_o \varepsilon_r L}{\ln(b/a)}$ | $\pi$ ~ 3.14159 |
| | | | *b* = Outside diameter of center conductor (meters) |
| | | | *a* = Inside diameter of outer conductor (meters) |
| | | | L = Cable length (meters) |
| | | | Natural Logarithm: ln(2.71828$^X$) ≡ X |
| Capacitor Impedance | \|*z*\| is inversely proportional to both *f* and *C*. | $\lvert z \rvert = \frac{1}{2\pi f C}$ | \|*z*\| = Magnitude of capacitor impedance (ohms) |
| | | | *f* = Frequency (Hertz or cycles/second) |