BY RICHARD CADENA

Protecting the stage:
How many more singers have to die?

ON NOVEMBER 23, 2014, Augustin Briolini, the lead singer of a band called Krebs, was on stage in Argentina and committed a deadly act: he grabbed a microphone. It was an ordinary mic, except that there was enough voltage, possibly between his guitar strings and the microphone, that the simple act of touching the mic allowed deadly current to flow through his body. Attempts to resuscitate him were unsuccessful and he was pronounced dead on arrival at the hospital.

Unfortunately, this is a scenario that is too often repeated. You don't have to look too hard to find stories and videos online of singers being badly shocked or electrocuted, such as Nolberto Alkalá, Frankie Palmeri of Emmure, or Chad Gilbert of New Found Glory. That's just in the last two years, and it doesn't include countless backline techs who have horror stories to tell about their shock experiences.

What if there was a device that could fit in the palm of your hand, cost less than a good microphone cable, and was quick and easy to install, that prevents these types of accidents? Would you, as a trained live event professional, use it? Before you answer No, please read the rest of this article.

These accidents are preventable. Had Briolini been using a ground fault circuit interrupter (GFCI) or a residual current device (RCD) with the device producing the contact voltage (probably his guitar amp), he would more than likely be alive today. GFCIs are commonly used in North America, especially where electricity is used in the proximity of water or moisture because wet skin has less resistance, making current flow through the body more readily. RCDs are commonly used in Europe, Australia, and other parts of the world.

Current Level (milliamperes)	Probably Effect on Human Body
1 mA	Perception level. Slight tingling sensation. Still dangerous under certain conditions.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries.
6 mA – 16 mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or "let-go" range.
17 mA – 99 mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible.
100 mA – 2,000 mA	Ventricular fibrillation (uneven, uncoordinated pumping of the heart.) Muscular contraction and nerve damage begins to occur. Death is likely.
> 2,000 mA	Cardiac arrest, internal organ damage, and severe burns. Death is probable.

Figure 1 – From OSHA.gov, How Electrical Current Affects the Human Body

A GFCI and an RCD both work by detecting the difference between the current flowing to a load and the current coming back from the same load. If there is a difference between the two, it's because some of the current has leaked from the circuit, which means that either someone is being shocked, or there is a potential for someone to be shocked. Either way, current is being diverted away from the circuit and back to the supply through a ground fault path, because current always returns to its source. If there is enough leakage current, then the GFCI or RCD will trip and interrupt the flow of current.

How much is enough current to trip these devices? Therein lies the main difference between a GFCI and an RCD. A Class A GFCI must open the circuit within 5.59 seconds if the current is 6 mA of leakage current. If the leakage current is higher, it will trip faster, and if it is less than 4 mA, it should not trip at all. An RCD, on the other hand, must trip within 30 milliseconds if there is 30 milliamps of leakage, or faster if there is more leakage. As you can see, there is quite a difference between a GFCI and an RCD.

I've always been taught that 20 or 30 mA can be lethal, and it can be if it flows for a long enough period of time. When someone gets shocked, how badly they are injured depends not only on the amount of current, but also the time, and which part of the body the current flows through. You've probably seen the charts showing the threshold of current that will cause your muscles to seize anywhere from 8 mA to 90 mA. (See **Figure 1**.) But those charts leave out the time factor. So what they really mean is that if 20 or 30 mA is flowing through your body *long enough,* then you could lose muscle control, which can be fatal.

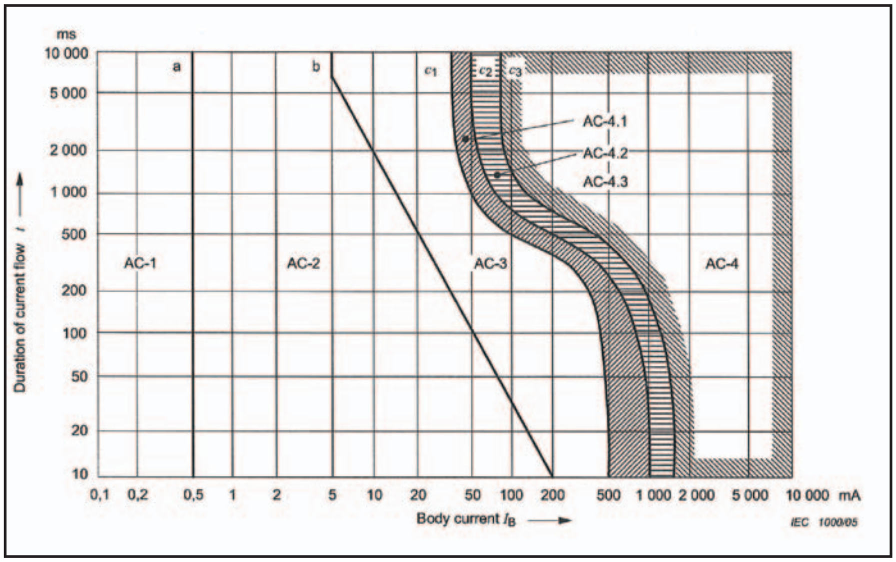
On the other hand, in *IEC 60479-1: 2005 – Effects of current on human beings and livestock*, there is a more detailed chart (**Figure 2** from IEC TS 60479-1) that shows the effects of current passing through the human body verses the amount of time it flows. It says that the results of a shock of 30 mA for 30 milliseconds will be "involuntary muscular contractions . . . but usually no harmful electrical physiological effects." So a GFCI and an RCD are both designed to protect against the probability of muscle reaction and ventricular fibrillation, either of which can be lethal.

GFCIs save lives. According to an article in the January-February 2014 issue of the *IAEI (International Association of Electrical Inspectors)* magazine by Nehad El-Sherif, the Consumer Product Safety Commission

> "... if 20 or 30 mA is flowing through your body *long enough*, then you could lose muscle control, which can be fatal."

says that electrocutions in the household were down from 270 in 1990 to 180 in 2001. The implication is that Class A GFCIs are responsible. The National Electrical Manufacturers Association (NEMA) also has an eye-opening chart showing how household electrocutions have fallen in inverse proportion to the number of GFCIs being used from about 1976 to about 2001. (See **Figure 3**.)

Portable GFCI adapters can be very small and inexpensive, yet rarely, if ever, do we find them on stages unless they are outdoors. And even then, it's hit and miss—mostly miss—despite the fact that *ANSI E1.19-2009: Recommended Practice for the use of Class A Ground-Fault Circuit Interrupters (GFCIs) intended for personnel protection in the Entertainment Industry* says that Class A GFCI protection "shall be used on all 15 to 100 ampere 120-240 VAC maximum single and three phase outdoor receptacles and circuits feeding utilization equipment in wet and damp locations, regardless of the application,



Zones	Boundaries	Physiological effects
AC-1	Up to 0,5 mA curve a	Perception possible but usually no 'startled' reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilization may occur. Effects increasing with current magnitude. Usually no organic damage to be expected
AC-4[1]	Above curve c1	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time.
	c1-c2	AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %
	c2-c3	AC-4.2 Probability of ventricular fibrillation up to about 50 %
	Beyond curve c3	AC-4.3 Probability of ventricular fibrillation above 50 %

[1] For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

Figure 2 – Taken from *IEC TS 60479-1:2005, Effects of current on human beings and livestock – Part 1: General aspect*

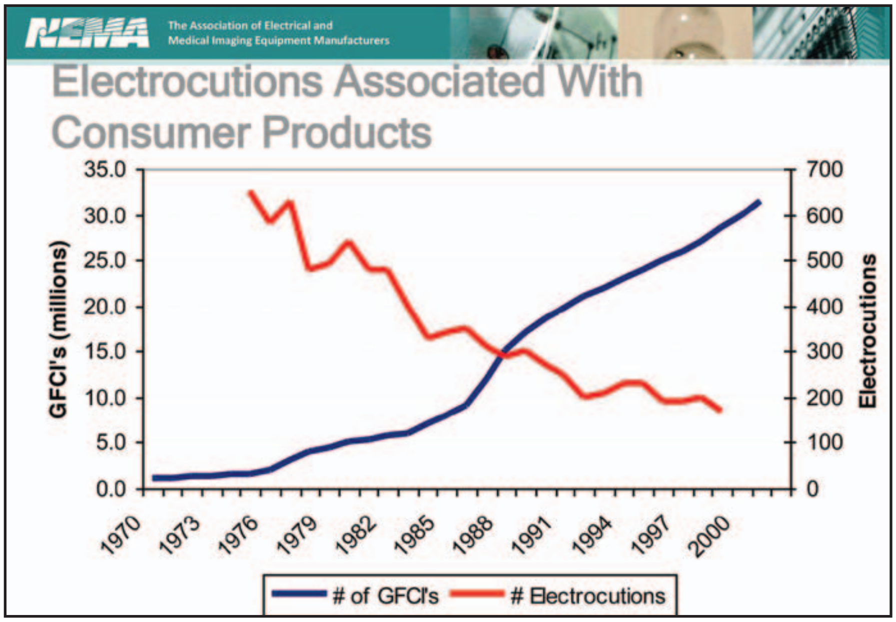


Figure 3 – From NEMA.org: Understanding GFCIs

unless specifically exempted by succeeding clauses in this document." Still, musicians and backline techs are not known for using them. Why is that?

One of the main complaints is that GFCIs are somewhat unpredictable. A circuit breaker will reliably trip at (or very near) a known value, and you can easily measure the current and know if you're close to tripping it. A GFCI, on the other hand, might trip for unknown reasons. And the first time it trips in the middle of a show and the guitar amplifier turns off is probably the last time that musician or tech will want to use it for that purpose. Even worse, if a GFCI trips and causes an audio processor to turn off, that could create a very loud popping sound that could destroy speakers, costing hundreds or thousands of dollars.

By contrast, RCDs are almost always used on stages in the UK because it's mandated by codes and regulations. According to Rob Sayer, Senior Lecturer in Technical Theatre Production at Bath Spa University, RCDs really are used on stages in the UK, even with amplifiers.

> **GFCIs save lives.**

"All outlets will have a 30 mA RCD somewhere," he said, "either inline with the whole distribution board or individual outlets. Installed domestic sockets installed on stage often have an integral RCD built into the outlet."

Since an RCD has more headroom for leakage current, it's easier to get a non-linear load, like an amplifier, to work with it. GFCIs do work with some amplifiers. I tried using one with my Laney GC30 30 W solid-state amp and it never tripped the GFCI, not even at full volume. But tube amps and other equipment that produces high harmonic current distortion might be a different story. I sent a portable GFCI to a friend who has a Fender Deluxe Reverb Blackface edition (circa early 1960s), and he said it works at low volumes. (He promised to try it on a gig at a higher volume and get back to me.) But even RCDs, with a higher trip level than GFCIs, sometimes nuisance trip with some lighting equipment.

There is another class of GFCIs with a higher trip level than Class A. UL 943C includes Class C GFCIs with a must-trip value of 20 mA. These are only allowed if there is a reliable grounding conductor because without it, there would be no protection from loss of muscle control. With it, a Class C GFCI provides protection from let-go current and ventricular fibrillation. There are, however, no Class C GFCIs available for branch circuits (20 A) at this time, only for 100 A circuits and higher.

That leaves those of us in North America using high harmonic generating loads with a dilemma; we can choose between using GFCI protection with the possibility of stopping the show temporarily or using unprotected circuits with the possibility of shock. Since GFCIs are not mandated by the *National Electrical Code* to be used on indoor performance stages, the culture in our industry is such that they typically aren't used for that purpose. But that doesn't mean that you can't or shouldn't.

In show business, the show must go on—but the show stops when the performers get zapped. How can we insure the safety of performers using guitars and microphones?

For stage applications of handheld gear, like guitars, microphones, and keyboards, the best protection against shock is a well-trained crew who knows how to properly set up electrical power distribution and can recognize and mitigate hazards. Some of the steps you can take to help insure a safer stage include:

1. Visually inspect cables as you lay them out for signs of wear or damage. Cables with broken conductors or prongs, cracked or cut insulation, or any other damage that could cause faulty grounding/earthing or bonding should taken out of service until they are repaired.

2. Never, under any circumstances, lift the safety ground on an electrical supply. Those three prong-to-two prong adapters that we have in North America are not actually for lifting the ground/earth; they are intended to do just the opposite. They are designed to safely connect a three-wire device with a grounding/earthing conductor to a two-wire ungrounded/unearthed electrical system by connecting the grounding/earthing conductor to the building steel through the green tab on the adapter. When they are used incorrectly, they create a potentially lethal hazard.

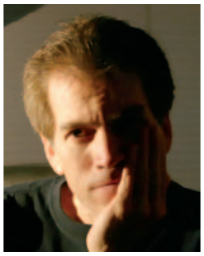
> **In show business, the show must go on—but the show stops when the performers get zapped.**

3. Using a volt meter or voltage detector, make sure there is no voltage on the grounding/earthing terminal of each receptacle before connecting a power cable. If you read more than a few volts, the receptacle could be mis-wired and could be hazardous. If you use a voltage detector instead of a meter, make sure it can read as low as 20 V or 30 V, like the Fluke 1LAC-A-II.

4. Use GFCI protection on any device with metal housing that will be handled by unqualified personnel. Test it beforehand for nuisance tripping. If it trips for no apparent reason and you suspect it's caused by high harmonic content, make sure the cable is as short as possible to minimize its contribution to leakage and try it again. If it continues to nuisance trip and the GFCI can't be used, test for contact voltage on the chassis before using the device. Find a good earth connection like a metal conduit or water pipe and measure the voltage between earth and the device. Even if there is no voltage, make sure anyone who might handle the device is wearing rubber-soled shoes and is not standing on bare concrete.

5. Make sure the metal parts of the stage are bonded to the grounding/earthing terminal of the electrical system.

There is a lot to know about electrical safety on the stage. The more you know and understand about electrical hazards, the better you can protect against them. As a production electrician or backline tech, it's your job to protect yourself, your crew, the talent, the audience, and anyone who might come in contact with the electrical system. Make an extra effort to make the gear safe and you'll never have to read about your boss being electrocuted. ■



Richard Cadena is Technical Editor of *Lighting&Sound America*, *Lighting&Sound International*, and *Protocol*. He is also an ETCP Certified Entertainment Electrician and an ETCP Recognized Trainer. Richard is the author of *Electricity for the Entertainment Electrician & Technician*, *Automated Lighting: The Art and Science of Moving Light*, and *Lighting Design for Modern Houses of Worship*.