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FUSE: A Surgeon's Guide To Understanding Energy Devices

By Pascal Fuchshuber

In a recent article in this publication, the electrosurgical device invented by William T. Bovie, PhD, was described as an "electrocautery device" *(General Surgery News* October 2015, *Surgeons' Lounge,* page 8). The fact is that the vast majority of surgical and endoscopic energy devices in use today, including the original and modern versions of the device invented by W.T. Bovie, are far from being cautery devices. Today, very few devices, such as the battery-powered cautery device for hemostasis used in minor surgical office procedures and a few new energy devices coming on the market recently, are based on cautery.

For millennia, medical devices that apply energy to tissue were known throughout the world. Cautery, which is the direct application of heat to tissue, best described by the application of a hot branding iron to the hide of a calf, was the first medical energy device and was used to destroy tumors and achieve hemostasis as early as 3,000 B.C. (Figure 1).

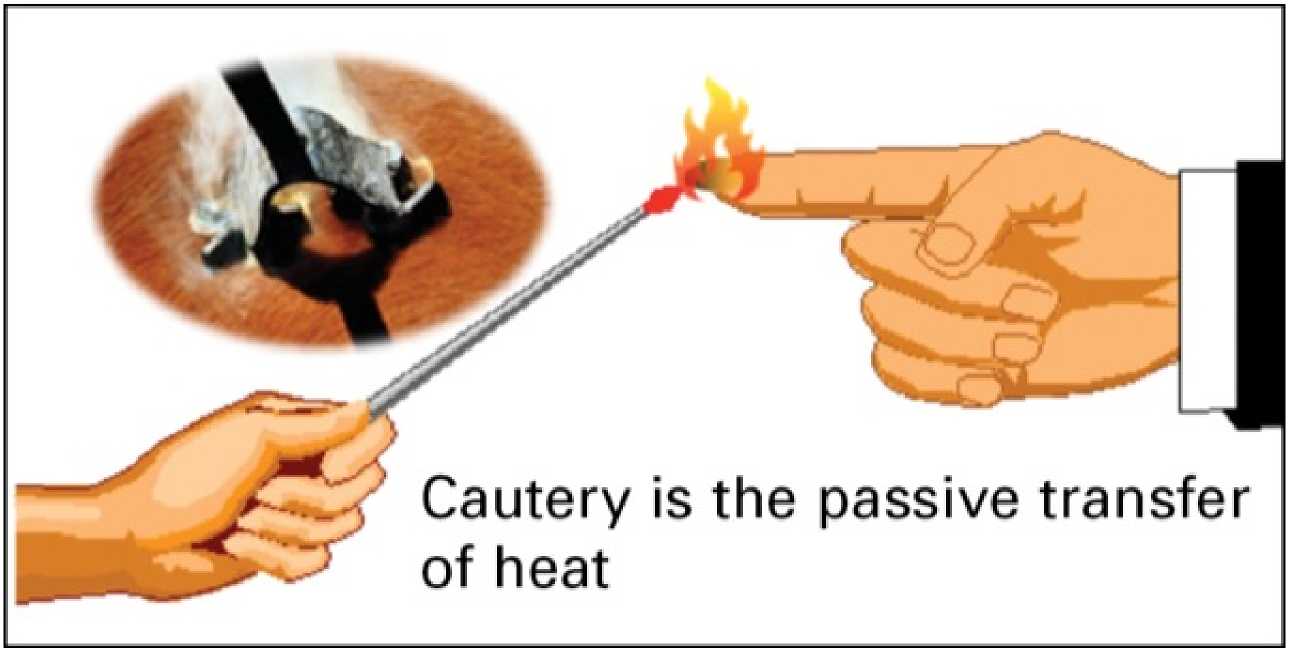

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Figure 1. The principle of cautery is the passive transfer of heat from an active object to a passive object. This type of energy was used for millennia in medicine until the development of electrosurgical devices that pass electrical current through tissue.
With permission, SAGES FUSE program 2012.

Cautery remained the only surgical energy device until the beginning of the 20th century, when Dr. Bovie (and others) developed a surgical device in which a high-frequency alternating current was used to create tissue effects. The frequencies of around 300,000 Hz used by these devices are equivalent to the frequency of radio waves, and thus the name, radiofrequency electrosurgery (Figure 2).

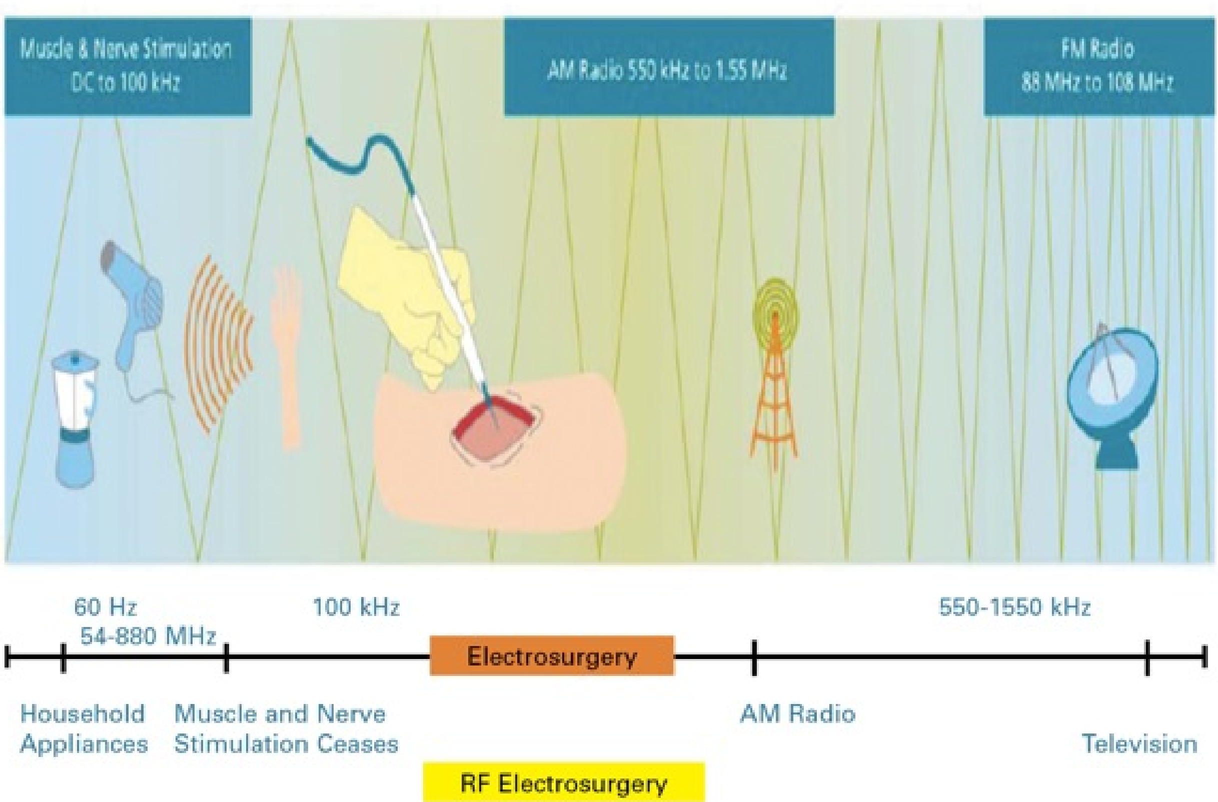

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Figure 2. Frequency range of modern electrosurgical devices based on alternating current. Note that it corresponds to the frequency of radio waves, hence the term "radiofrequency" (RF).

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These high frequencies are necessary to avoid lethal muscle depolarization, which can occur at up to 100,000 Hz.

The heat created in tissues from the application of a Bovie electrosurgical pencil results from the agitation of ions that oscillate at the frequency of the applied alternating current, around 300,000 times per second, and not from direct transfer of heat as in cautery (Figure 3).

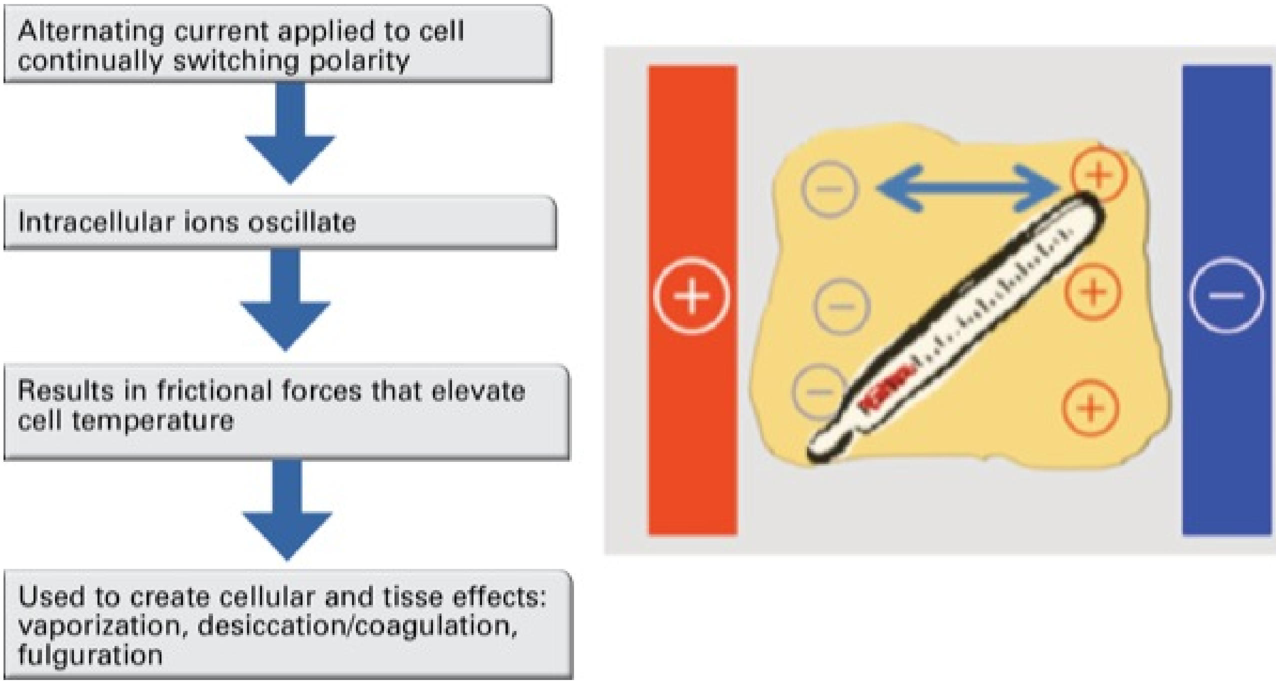

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Figure 3. Main principle of tissue effect due to the application of radiofrequency current to tissues. Heat is generated through ionic oscillation within tissue that eventually leads to frictional heating with effects described as coagulation, vaporization, dessication and fulguration.

So, to better convey the true nature of electrosurgery and avoid mistaking it for cautery and other unrelated mechanisms, it is important to observe the appropriate designation and language when discussing, teaching and explaining electrosurgical devices. Many terms used by surgeons should be avoided and replaced with the correct terminology (Table 1). Any provider using electrosurgical devices should also be familiar with the most fundamental physical concepts and terms, described in Table 2. Understanding these principles is the basis for the safe and appropriate use of these devices.

Table 1. Terminology To Avoid and To Use When Describing Electrosurgical Energy Devices

No	Yes
~~‘Bovie’~~	Electrosurgical Generator/Unit
~~‘Hot Bovie’~~	Techniques/Tissue Effects
~~‘Cautery’~~	• Vaporize
~~‘Hot Bovie cautery’~~	

~~‘Cauterize’~~ ~~‘Burn’~~ ~~‘Ground pad’~~ ~~‘Return electrode’~~ ~~Monopolar energy~~ ~~Bipolar energy~~	• Cut (linear vaporization) • Desiccate/coagulate • Fulgurate Electrodes • Active • Dispersive Instruments • Monopolar • Bipolar

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Table 2. Fundamental Terminology of Electrosurgical Devices

Variable	Definition	Units
Current (I)	Flow of electrons past a point in the circuit/unit time	Amperes (coulombs/second)
Voltage (V)	Difference in electrical potential between two points in the circuit; force required to push a charge along the circuit	Volts (joules/coulomb)
Impedance (resistance) ®	Degree to which the circuit, or a portion of the circuit impedes the flow of electrons	Ohms
Energy	Capacity of a force to do work; cannot be created or destroyed	Joules (watts/second)
Power (P)	Work; amount of energy per unit time. Product of “V” and “I”	Watts (joules/second)

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After the astonishing success of Harvey Cushing, MD, who was the first to use Dr. Bovie’s device in clinical practice, surgeons were quick to follow. The tissue effects of a modern electrosurgical pencil can best be compared with cutting with a knife that at the same time can coagulate to stop bleeding and desiccate to destroy tissue. To this day, it remains the most widely used surgical energy-based device. However, modern electrosurgical pencils are a far cry from Dr. Bovie’s invention. Today, they are controlled by a computer from an electrosurgical unit (ESU) in a closed circuit, either in monopolar or bipolar application (Figure 4).

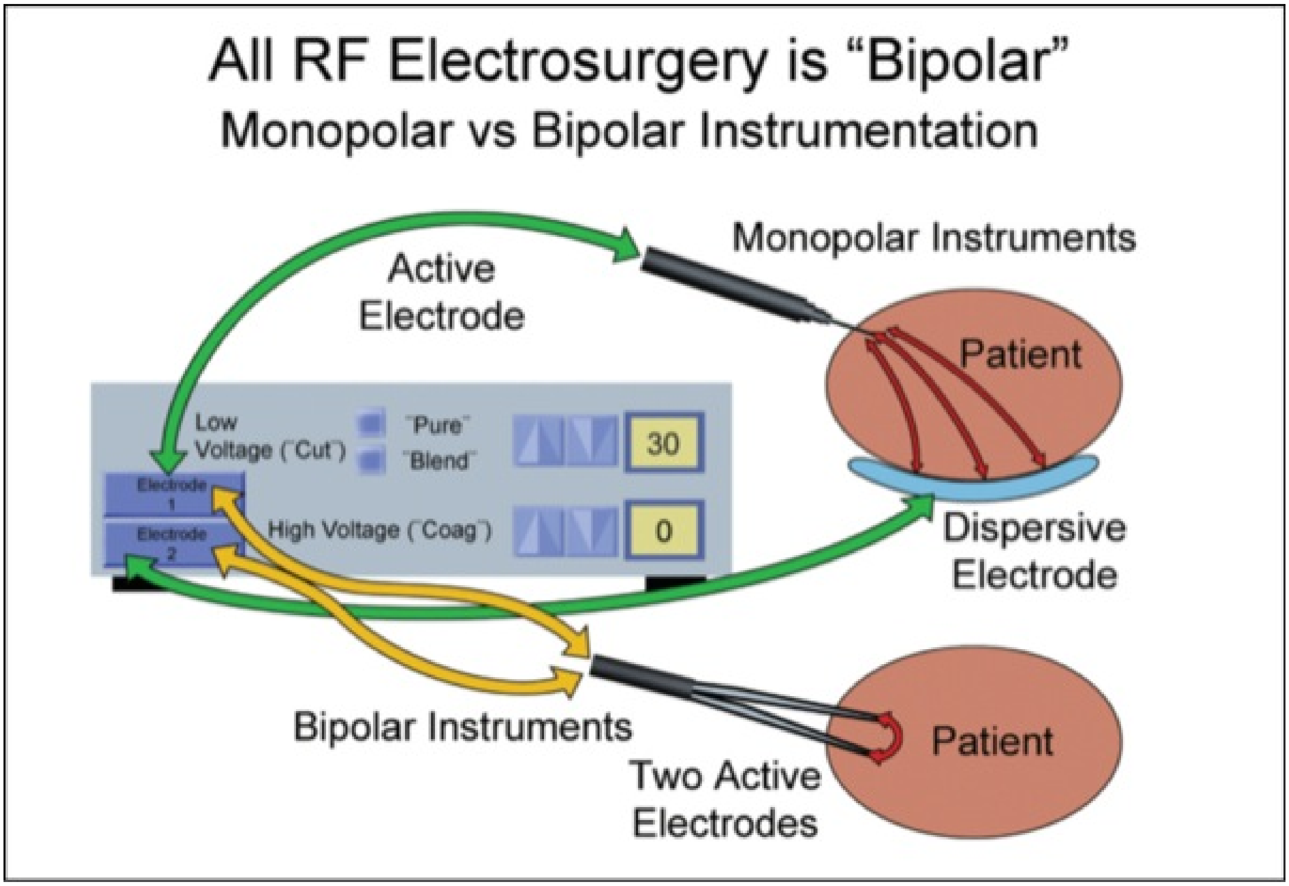

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Figure 4. Schematic of a modern electrosurgical unit (ESU) using a closed circuit, whereby the current is returned to the ESU either via a dispersive electrode (monopolar device) or the second electrode (bipolar device). This reduces the possibility of injury through current diversion with ground reference units such as the one developed by William T. Bovie, PhD.

With permission, The SAGES Manual The Fundamental Use of Surgical Energy (FUSE). New York, NY: Springer; 2012.

Modern ESUs allow adaptation of the current waveform to modulate the tissue effects in many ways, thus increasing the spectrum of possible tissue effects and applications (Figure 5).

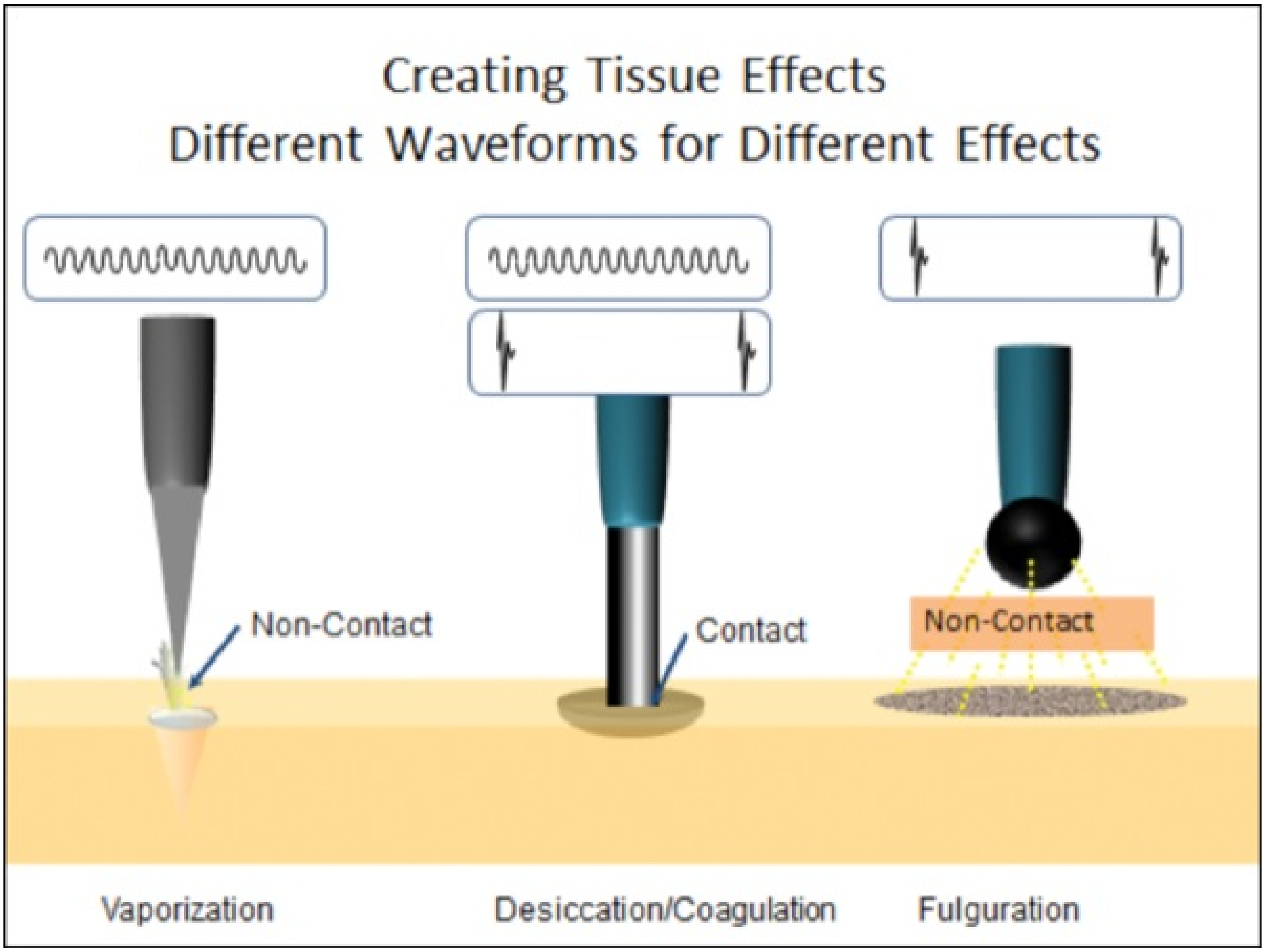

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Figure 5. The use of different waveforms, essentially continuous and interrupted waves, has increased the spectrum of tissue effects that can be obtained with a simple monopolar surgical pencil, originally invented by W. T. Bovie, PhD. Examples shown are coagulation, desiccation, vaporization and fulguration.

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Further refinements of electrosurgical devices such as cutting blades and real-time impedance measurement and a myriad of adaptations for different operations and laparoscopic procedures have led to an explosion of energy-based devices in the operating room in the past two decades. There is no question that these technical innovations, together with other energy devices not based on radiofrequency current, have enabled the minimally invasive and endoscopic revolution in the surgical treatment of patients. Without it, we would still need to apply ligatures and ties for the safe transection of blood vessels and dissection of tissues.

Despite this success, this technological bonanza has also created a large variety of energy device platforms, configurations, generators, cost points and vendors, and this complexity has increased the potential for injury. Today's surgeon will use a complex energy system on a patient only after a brief introduction by a vendor specialist, without necessarily understanding the fundamental principles of function and safety of that device. With the rapid increase in number, types and forms of energy applications to tissue, the potential for complications and harm to the patient and the operating team has become part of daily practice. Injury and harm from electrosurgical devices in laparoscopic surgery are estimated to occur at a rate of one to two incidents per 1,000 patients.[1] These complications include bowel and vascular injuries. Because these injuries are difficult to detect, particularly in minimally invasive procedures, many go unrecognized at the time of the injury. The delayed diagnosis often increases the damage and associated mortality.[2-5]

In response to this safety issue, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) has created the FUSE—Fundamental Use of Surgical Energy—program. Working in partnership with the Association of periOperative Registered Nurses, American Association of Gynecologic Laparoscopists and American Urological Association, the FUSE task force includes general surgeons with a variety of subspecialty practices, as well as nurses, anesthesiologists, engineers and gynecologists.

FUSE includes two components: a standardized continuing medical education and continuing education unit–accredited curriculum for surgeons and allied health professionals of all specialties available online, and a high-stakes certification exam that meets high psychometric and accreditation standards. Success on the certification exam will result in FUSE certification, documenting the acquisition of the basic knowledge that underlies the safe use of energy-based devices in the operating room. The FUSE curriculum includes 10 educational domains: physical principles of electrosurgery, fire and burn prevention, monopolar, bipolar, ultrasound and microwave devices and special circumstances on pediatric patients, endoscopic procedures and implantable devices.[6,7] The necessary knowledge to pass the FUSE certification exam can be obtained through the FUSE online curriculum, the FUSE manual[8] and participation in a FUSE postgraduate course held at both the American College of Surgeons and SAGES meetings every year.

The free FUSE online educational curriculum and information on taking the FUSE certification exam are available at **www.fuseprogram.org (http://www.fuseprogram.org).**

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