United States District Court
Northern District of New York

Matthew Avitabile Plaintiff, v. LT. COL. GEORGE BEACH, in his Official capacity as Superintendent of the New York State Police Defendants.	No. 1:16-CV-01447 (DNH)(CFH)

EXPERT REPORT OF MARK KROLL, PhD, FACC, FHRS, FIEEE, FAIMBE

I, Mark Kroll, being of legal age and under the penalties of perjury, state as follows:

1. I am a competent adult and have personal knowledge of the following facts or believe them to be true based on information and belief. Facts about which I do not have personal knowledge are of the type reasonably relied upon by experts in this field and have probative value to me in rendering my opinions.
2. What follows is a true and accurate copy of my expert report in this litigation.
3. The report summarizes my analysis and findings and includes a statement of my opinions. The report also includes data and other information considered by me in forming my opinions and sets out my qualifications (including a link to my Curriculum Vitae).
4. My opinions are expressed to a reasonable, or higher, degree of professional certainty.
5. I affirm under the penalties of perjury that the foregoing statements are true and correct.

Mark Kroll, PhD, FACC, FHRS, FAIMBE 29 March 2018

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Brief Summary of Qualifications

I am a Biomedical scientist with a primary specialty in bioelectricity or the interaction of electricity and the body. (My secondary biomedical science specialty is biomechanics.[1-3]) I have invested most of my career researching and developing electrical devices to diagnose and treat disease. The primary focus is the effect of electrical shocks on the human body.

This involves researching, lecturing, and publishing on electric shocks and their effects on the human body. It includes lectures throughout Europe, South America, and Asia (in 35 countries) as well as at many of the major universities and medical centers of the United States (U.S.). Usually, the typical audience member is a cardiologist electrophysiologist, or medical examiner. I have lectured at most of the major teaching hospitals in New York including Cornell, NYU, Columbia, and SUNY Buffalo. With 375 issued U. S. patents and numerous pending and international patents, I currently hold the most patents on electrical medical devices of anyone in the world. Over 1 million people have had devices with some of these patented features in their chest, monitoring every heartbeat. http://bme.umn.edu/people/adjunct/kroll.html.

In 2010 was awarded the Career Achievement Award by the Engineering in Medicine and Biology Society which is arguably the most prestigious award given internationally in Biomedical Engineering.
http://tc-therapeutic-systems.embs.org/whatsnew/index.html

Believed to be the only individual to receive the high "Fellow" honor from both Cardiology and Biomedical societies. To wit:

1997	Fellow, American College of Cardiology
2009	Fellow, Heart Rhythm Society
2011	Fellow, IEEE Engineering in Medicine and Biology Society
2013	Fellow, American Institute for Medical and Biological Engineering

Author of over 200 abstracts, papers, and book chapters and also the co-editor of 4 books including the only 2 scientific treatises on the Conducted Electrical Weapon (CEW):

1. TASER® Conducted Electrical Weapons: Physiology, Pathology and Law. Springer-Kluwer 2009.
2. Forensic Atlas of Conducted Electrical Weapons: Springer-Kluwer 2012.

Directly relevant paper publications include over 80 papers, books, book chapters, and indexed letters on CEWs and arrest-related death (ARD) as well as numerous scientific meeting abstracts.[1-84] For more details please see curriculum vitae at:
https://www.dropbox.com/sh/wju0hu6q3ca62xx/AAAlzTlLbKbxu5m34AsMfCrYa?dl=0

There have also been many presentations on CEWs to scientific and medical, as well as law enforcement, audiences. These include: 2007 American

Academy of Forensic Science (AAFS) conference major presentation in San Antonio, Texas[75] and the 2007 BEMS (Bio-electromagnetic Society) meeting Plenary Address in Kanazawa, Japan.[77]

1. Major invited lecture at the 2006 NAME (National Association of Medical Examiners) conference in San Antonio, Texas.[85]
2. Advanced Death Investigation Course of St. Louis University (2007) as faculty lecturer to full audience.[86]
3. Faculty lecturer to full audience at Institute for the Prevention of In-Custody Death Conferences (2006 and 2007), Las Vegas, Nevada.
4. Chair of special session on TASER CEW at 2006 Cardiostim meeting in Nice, France.
5. Guest lecture to U.S. Military on CEW in 2006.
6. "Presenting Rhythm in Sudden Custodial Deaths After Use of TASER® Electronic Control Device," was presented at the 2008 scientific conference of the Heart Rhythm Society.[87]
7. "Can Electrical-Conductive Weapons (TASER®) alter the functional integrity of pacemakers and defibrillators and cause rapid myocardial capture?" was presented at the 2008 scientific conference of the Heart Rhythm Society.[70]
8. "Weight-Adjusted Meta-Analysis Of Fibrillation Risk From TASER® Conducted Electrical Weapons" presented at the 2009 AAFS conference.[62]
9. "Meta-Analysis Of Fibrillation Risk From TASER® Conducted Electrical Weapons as a Function of Body Mass" presented at the 2009 scientific conference of the Heart Rhythm Society.[61]
10. Oral presentation at the 2014 NAME (National Association of Medical Examiners) conference in Portland, Oregon.
11. Pathophysiological Aspects of Electroshock Weapons. University of Salzburg Electroshock Weapon Symposium. Salzburg, Austria. July 2015.
12. Real and Imagined Risk of Electrical Weapons. University of Salzburg Electroshock Weapon Symposium. Salzburg, Austria. Dec 2016.

In addition to the major addresses above, there have been lectures at the United States Department of Justice (2007), AAFS (2006), and BEMS (2006) regarding the TASER CEW.

I have deployed and discharged TASER CEWs numerous times and have personally experienced an X26E CEW probe deployment discharge directly to the center of my chest. I have sat on the TASER corporate board since Jan 2003 and their Scientific and Medical Advisory Board (SMAB) since its inception in Aug 2004. Also sit on the International Electrotechnical Commission (IEC) (Geneva, Switzerland) TC64 Committee that provides the scientific input to the international electrical safety standards.

Summary of Case Specific Opinions

1. CEWs have contributed to arrest-related deaths because of fires and falls.

2. It is an urban myth that anyone has ever been electrocuted by a CEW.

3. There are no known cases of fatality or serious injury from a civilian TASER® CEW.

4. Suspect injury rates are cut by ≈ 2/3 with law-enforcement usage compared to alternatives such a OC spray, batons, or wrestling. In other words, the use of alternative force options tends to triple (3x) the injury rate compared to the CEW, including hands-on physical force.[88-99]

5. The number of law enforcement firearms shootings prevented has been estimated at over 100,000 based on the 3.66 million field uses.[66,100] In agencies using the CEW with minimal restrictions, the *fatal* officer shooting rate falls by ≈ 2/3.[101]

6. Modern CEWs deliver a safe level of electrical current as specified by the Underwriters Laboratory and International Electric Fence standards.[102] In fact, they satisfy all relevant electrical safety standards.[8,103] The X26E CEW delivers ≈ 1.8 watts (W) which satisfies the Underwriter's Laboratories (UL) electric fence safety limit of an equivalent of 5 W and even the more conservative 2.5 W IEC international limit.[104,105]

7. The X26E delivers ≈1.8 mA (milliamperes) of pulsed DC (Direct Current) which is equivalent to 13 mA of AC (Alternating Current). This is well below the 40 mA of AC considered safe by international electrical safety standards.[106]

8. The TASER® CEWs satisfy the ANSI CPLSO-17:2017 "Electrical Characteristics of ECDs and CEWs" standard. This standard is applicable to high voltage Electronic Control Devices (ECD), or Conducted Electrical Weapons, (CEW) used by law-enforcement agencies. This standard specifies the characteristic electrical requirements for effective and safe performance.

Definitions

There are many types of electrical weapons or electrical deterrent or defense devices. The earliest, and most common, is the electric fence and that has been the initial driver of electrical safety limits. Because of the common misuse of the federally registered trademark, TASER®, it is important to present accurate definitions and the taxonomy of these weapons.

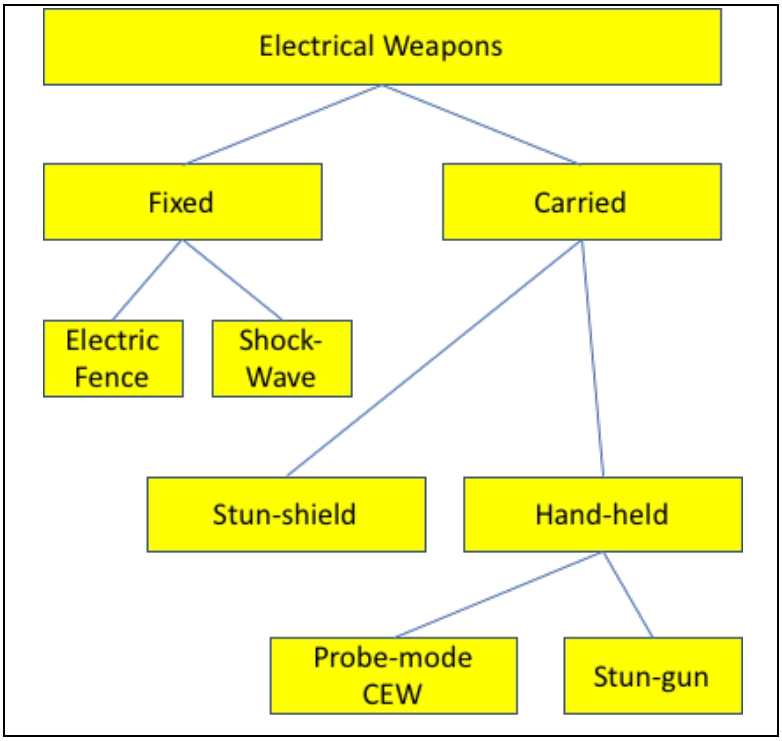

Figure 1. Taxonomy of electrical weapons.

The most scientifically accepted term for probe-mode electrical weapons is "conducted electrical weapon" or "CEW." This term is used in 52 papers on the National Library of Medicine (MedLine). Also common is "Electronic Control Device" or "ECD" which appears 39 times. Earlier proposed terms such as conducted energy device, conducted electrical device, or electro-shock weapon do not appear anywhere in MedLine as they are not accepted scientifically.

For simplicity, this report will use "CEW" to specifically refer to a probe-mode CEW to the exclusion of non-probe stun-guns. The New York penal code 265.00 15-a refers to the CEW as an "electronic dart gun."

Benefits and Risks of Electronic Control

Electronic control benefits are well-established in the peer-reviewed literature and explain why these weapons are so widely adopted throughout the industrialized world (107 countries). Suspect injury rates are cut by ≈ 2/3. In other words, the use of alternative force options tends to triple (3x) the injury rate compared to the CEW, including hands-on physical force.[88-99] The number of law enforcement firearms shootings prevented has been estimated at over 100,000 based on the 3.66 million field uses.[66,100] In agencies using the CEW with minimal restrictions, the *fatal* officer shooting rate falls by ≈ 2/3.[101]

Table 1. Primary risks from CEW probe-mode applications.

	Findings	Notes
Primary (Direct) Risks		
Electrocution	Theoretical possibility with probe directly over heart in subjects under 46 lbs.[51] In general, electrocution events in adults is an urban legend.[17,35,107]	Present CEWs satisfy all world electrical safety standards.
Loss of vision	Demonstrated with probes penetrating the eye.[5,108-110]	
Secondary (Indirect) Risks		
Head injury from fall.	Fatalities demonstrated.[18] Non-fatal injuries demonstrated.[98,111]	
Fume ignition.	Fatalities demonstrated.[11,112]	

The primary demonstrated and theoretical risks supported by the existing literature are outlined in Table 1. The most common contribution to fatality is a secondary injury from a head impact from an uncontrolled fall. If the subject is running, or above a hard surface and receives a CEW probe deployment, with sufficient probe spread inducing broad neuromuscular incapacitation (NMI) the unbroken fall can cause a serious head injury and there have been 16 deaths due to this. [18] This has not been reported with the drive (or contact or touch)-stun mode as there is no muscle lock-up. There have been a handful of secondary injury fatalities in which flammable fumes were ignited by an electrical spark from the CEW. [11,112] This has not been reported with drive-stuns although that remains a very unlikely theoretical possibility. There are no such reported civilian CEW-induced head impact deaths or flammable fume ignition, or probe-eye impalements.

The most misunderstood and exaggerated theoretical risk is that of electrocution. This is extremely unlikely as the delivered output of existing CEWs satisfy all relevant world electrical safety and effectiveness standards including those for the ubiquitous electric fence. [102,103] The conservative IEC (International Electrotechnical Commission) standard allows up to 2.5 W (watts) for an

electric fence and all present TASER CEWs deliver less than 2 W.[104] Underwriters Laboratories (UL) allows 5 W for narrow pulse such as those of TASER CEWs.[105] The primary driver of this myth appears to be the fundraising material of Amnesty International that lists Arrest-Related Deaths (ARDs) with electronic control along with the innuendo that the electronic control somehow directly caused the death by delivery of sufficient electrical current to the heart to induce ventricular fibrillation (VF). Notably, they have never attempted to explain how a CEW that satisfies all world electrical safety standards could ever electrocute anyone.

Swine are 3 times as sensitive to electrical current as humans.[113] The largest swine electrocuted by an X26E CEW was that of Valentino and it weighed 36 kg) (79 lbs).[114] Nanthakumar also electrocuted a *single* 50 kg swine with a 15 second CEW discharge but he used a drug trick which made the swine's weight equivalent to ≈ 30 kg.[115] Hence the largest swine ever directly electrocuted by a normal CEW output weighed only 36 kg.

The levels of dangerous electrical current scale with body mass just like most drug dosage. Since Walcott has shown that swine are 3 times as sensitive to electrical current (as humans) we can translate the Valentino 36 kg pig to a 12 kg (26 lb) human.[113] This calculation uses a direct proportion relationship of dangerous current levels to the body mass. Some authorities have published that the danger level scales with the square root of body mass.[116] With such a relationship the Valentino pig is equivalent to a larger 21 kg (46 lb) human. If we take the more conservative calculation, it is clear that the best evidence suggests that the risk of CEW electrocution is limited to humans with a body mass under 46 lbs.

Most authorities agree that electrocution is a theoretical possibility with an extremely thin individual and a fully penetrating CEW dart directly over the heart in a very thin person.[50,62,117]

Table 2. Summary of benefits and risks of CEWs.

	Item	Rate
Benefits:	Subject injury	2/3 reduction
	Subject death	2/3 reduction
Risks:	Fatal fall	1:200,000
	Fatal or nonfatal major burn	1:360,000
	Blindness from probe	1:200,000

The very rare risks of CEW complications are swamped by the lives saved from the reductions of ARDs (arrest-related deaths). For every ARD from a CEW complication (fatal fall or fire) there are 50 ARDs prevented by reducing firearm shootings and over-exertional deaths.

A Brief Primer on Electrocution.

Low-power electrocution is death from an electrical current from a source under 1000 watts (W).[44] This is contrasted from "high-power" electrocution from power lines or lightning strikes. The death is almost always the result of the electrical current inducing VF (ventricular fibrillation). The electrical induction of VF takes a few seconds at most. [118-129] (A massive electrical injury such as a lightning strike can also kill by brain and nerve damage but that is not relevant here.) Modern CEWs fall in the "low-power" category. The X26E CEW delivers 1.8 W and the X2 CEW delivers 1.7 W.

In VF, the heart muscle cells continue to contract but at nearly random times. This is a common cause of cardiac arrest. Hence, there is no coordination among the cells and no blood is pumped from the heart. Loss of consciousness occurs in 13 ± 4 seconds if the person is supine (laying down).[130] If someone is standing or sitting then the collapse occurs within 1-5 seconds.[131,132] Also, the person's blood pressure drops quickly, and immediately loses their pulse. Once VF is induced there is no pulse. There are 6 primary, there are others, diagnostic criteria required to diagnose an electrocution as shown in Table 3.

Electrocution has been extensively studied since the first US case occurred in 1881. Samuel W. Smith, while drunk, placed his hands across a DC generator terminal in Buffalo, NY. His death appeared quick, painless, and simple, and led local Thomas Edison to suggest electrocution as a method of capital punishment for that State. The first legal electrocution took place in 1890 in Auburn, NY, using an AC Westinghouse alternator.

Table 3. Diagnostic criteria for electrocution.

	Criterion	Timing
1	Sufficient current delivered to heart.	1–5 seconds of duration. [129] See Background section: *Electricity Does Not Build Up Like Poison.*
2	Loss of pulse.	Instant[133]
3	Loss of consciousness.	13 seconds if laying down.[130] Only 5 seconds if sitting up.[130-132]
4	Loss of normal breathing.	15–60 seconds. [133,134] Agonal breathing (typically 3 minutes) with a maximum of 6 minutes.[135-137]
5	Successful defibrillation.	14 minutes with any CPR; 9.5 minutes without.[45]
6	VF rhythm.	30–40 minutes after which the VF typically deteriorates to asystole or PEA.[42,138-141]

Electrocution has also been well-studied as it was used for decades to test implantable cardiac defibrillators.[142]

A final note on electrocution is that it is a stand-alone cause of death. Electrocution is not like a soup recipe where salt and pepper both contribute to the flavor. It does not "contribute" to other causes of death.[28] For example, if someone with late-stage cancer were to receive sufficient current, they would be dead within seconds and the cancer had nothing to do with it. However, if the same person received a lower level of current and died 30 days later, that person was not electrocuted. People have been killed by falls from ladders after being startled by an electrical shock. The shock certainly contributed to the death but this is not an electrocution. With rare partial exceptions — generally not salient to arrest-related-deaths — the presence of other disease states does not make someone significantly harder or easier to electrocute. Conversely, low-power electrical currents do not hasten deaths from other diseases.

The effects of metabolic and adrenergic stress on the electrocution threshold have been extensively studied. The effects, while statistically measurable, are immaterial in the arrest-related death scenario. Adrenergic stress will temporarily lower the ventricular fibrillation threshold for a few minutes after which point the threshold actually increases.[143,144] The impact for electrical weapons is that the critical dart-to-heart distance could increase temporarily to 4–5 mm. Metabolic acidosis also has a similar immaterial effect.[145] Cocaine intoxication increases the VF threshold (VFT), because it is a sodium channel blocker, and hence makes electrocution even more difficult.[146,147]

The Electrocution Myth

There have been 25 ARDs caused indirectly by the CEW from fatal falls and fires.[11,18] Surprisingly, these demonstrated linkages are rarely discussed in the mass medias as the mass media apparently prefers to promulgate the myth of electrocution by CEWs; effectively inducing electrophobia (unreasonable fear of electricity) in many people. This myth survives because reporters are unable to understand different levels of electrical current and do not appreciate that the modest output of a modern CEW is much less than that allowed for the ubiquitous electric fence.

The CEW has reduced the death rate from resisting arrest by 2/3 which is a dramatic result and explains why the vast majority of law enforcement officers in North America have access to this weapon. However, 2/3 is not 100% but rather how about 67% and there still are residual ARDs even with this sophisticated tool. Imagine that someone discovered a drug that reduced the death rate from prostate cancer by 2/3. They would be nominated for a Nobel prize. No one would argue that the unfortunate 1/3 — of patients that still died — were poisoned by the drug. Nevertheless, that is exactly what some media sources attempt to argue when it comes to the modern CEW.

This myth had also been promoted by excessive-force and wrongful-death litigation. This is much less common today as the science and independent reviews are clearly showing that the CEW does not electrocute people. There have been 11 lawsuits that were published as a causally unreliable case series by a plaintiff's expert and his retaining attorney in most of those litigations as if they are scientific evidence of electrocution. The majority of these 11 cases arose from the litigation partnership of 2 California attorneys and their expert, a controversial ex-cardiologist who opined that these residual ARDs were due to electrocution (induction of ventricular fibrillation). To add to the confusion, the cardiologist published his expert witness cases in the journal *Circulation*.[148]

The journal then received many letters explaining the facts of these cases which they were obliged to publish with some embarrassment.

Defendant's Allegations

It is hard to find a better evidence of these mythical beliefs than the Defendants' Memorandum of 7 March 2017 and their Response to Interrogatories dated 24 Jan 2018.

On page 14 of the Memorandum we read:

> For example, there are numerous instances in which Taser use was linked to the death of the individual struck with the Taser probes. The following is a small sample of cases over the past several years that discuss these types of fatalities:

Table 4. Allegedly linked deaths from Defendants' Memorandum

#	Decedent	Cause of Death	Causality Score
1	Armstrong	ME COD: Complications of Excited Delirium Syndrome.	
2	Mitchell	Zipes #7 from Kroll et al.[36]	-3
3	Harlan (Bachtel)	Zipes #8 from Kroll et al.[36]	-7
4	Williams	ME COD: Ventricular Fibrillation from Taser electrical device: Homo-cide[sic]	
5	Turner (Fontenot)	Zipes #2 from Kroll et al.[36]	-3
6	Piskura	Zipes #4 from Kroll et al.[36]	-5
7	Russell	ME: VF caused by severe cardiac disease with a high level of alcohol and the excitement of being re-strained.	
8	Marquez	ME COD: Excited delirium.	
9	Rosa	ME COD: Ventricular arrhythmia due to methamphetamine intoxication.	
10	Rich	Zipes #5 from Kroll et al.[36]	-4
11	Barnes (McKenney)	Fatal traumatic brain injury… exclu-sion #4 from Kroll et al.[18]	

Note: The Plaintiff is listed in parentheses if a different surname from the decedent.

First, there are no documented or known alleged incidents of electrocution in a legal use of a civilian CEW or electric weapon. A quick look at these cases clearly demonstrates how pathetic the scientific evidence is that supposedly shows any deaths directly caused by CEWs. The death certificate for #4 had major scientific errors and my comments on the special case of Mr. Williams are below. The following comments are thus reserved for the other 10 cases.

In none of the cited cases did the Medical Examiner (ME) find the CEW as the primary Cause-of-Death (COD).

Let's begin with #1. A minor point is that Mr. Armstrong never received any probes. While a minor technical point, it demonstrates the due diligence that went into the Defendants' memorandum as this list was introduced with the phrase, "…death of the individual struck with the Taser probes."

Cases 2,3 5,6, and 10 were from the infamous expert-witness anecdotes of Zipes that were discussed earlier. They are all covered in detail in the attached refutation that was invited by the American Heart Association's flagship journal, *Circulation* published on 7 January 2014. The cross-reference works like this: Defendant's case #2 (Mitchell) is Zipes #7 and is listed as Z7 in the *Circulation* article.[35] There is a narrative and also a table for the linkage scoring. Each of these cases was scored for 7 accepted factors for an electrocution so that a score of +7 meant a probable electrocution. A score of -7 meant definitely not an electrocution. None of these cases even had a positive score.

Case #7 (Piskura) is especially illustrative of the evidentiary value of this listing. The Defendants quote from the Magistrate's denial of a Daubert motion in which she stated "Dr. Zipes, a preeminent scholar in the field of electrophysiology…" as if that established some sort of causation. However, Dr. Zipes' impressive CV could not change the fact that at least the top probe missed Mr. Piskura and thus zero electrical current was delivered to him. This fact was established with no less than 3 lines of forensic evidence, namely:

1. Video taken by the CEW itself showing no probes on the body
2. Microscopic analysis of the probe showing no current had been delivered
3. Autopsy photographs showing complete absence of the characteristic probe markings on the body.

The Medical Examiner COD is listed for each of the cases 1, and 7-9.

The last listed case, Barnes, is also highly illustrative of the desperation of the Defendants in trying to establish the reality of the mythical electrocution causation. This case was considered in our paper on actual causations from fatal head injuries.[18] It is listed in the Appendix (of that paper) as excluded case #4. Here is the summary as published in this peer-reviewed article:

> Officers went to the home of a 21-year-old man [Barnes] to arrest him on warrants. As the officers approached him, the man dove through a closed 2nd story window. To prevent his escape, an officer deployed a CEW, striking him in the back as he was diving through the window. The probes were only 6 cm apart and thus achieved no muscle control. He struck his head on the pavement below and died 4 days later. The autopsy was not released, but litigation allegations cited multiple skull fractures and brain injury. An appeals-court decision noted that the death was due to "massive brain trauma."

Thus, far from the CEW electrocuting Mr. Barnes, the only connection was that the Officer was so close that the probe-spread was insufficient for control. Therefore, Mr. Barnes was able to dive thru a 2nd story window and kill himself from the fall to the pavement below.

The autopsy report and Mississippi death certificate of Mr. Jermain Williams has numerous factual, scientific, and spelling errors. It is, indeed, the only case in the listing above where the M.E. opined electrocution (induction of VF) by a CEW. However, that is immediately vetoed by the EMS records showing that Mr. Williams was never in VF but rather in asystole (flat-line) which is the expected cardiac arrest rhythm with Mr. Williams excited delirium and cocaine intoxication. [149-156] EMS recorded asystole 9 minutes after the collapse and it takes over 30 minutes for VF to deteriorate to asystole. [42]

On page 14 of the Memorandum we also read:

> These devices have already been used in holdups and robberies.

The relevance this statement is not explained. Virtually everything, including personal weapons, sticks, force tools of convenience, chemical aerosols, and firearms, have all been "used in holdups and robberies." Thus, to desperately attempt to single out the CEWs is confusing at best.

Also, this quote is highly misleading and obsolete to the point of being dishonest. Criminals are loath to use TASER CEWs as the tiny AFIDs (Anti-Felon Identification tags) confetti are almost impossible to clean up and lead law enforcement to the purchaser of the CEW cartridge. Before this fact was widely known, criminals occasionally used CEWs but not after the AFIDs were used to solve some major crimes. There are no such AFIDs or discharged evidentiary tracking and subject identification capabilities with ANY other force option often "used in holdups and robberies."

Example: Washington v Kozol (Crime: 2000, State Appeals Decision: 2003)

> It is unlikely that Kozol would have been identified as a suspect at all, but for the evidence that Wolter had been shot with a taser gun, including the AFIDS that police were able to trace to a taser gun purchased by Kozol.

I would much prefer to be robbed by someone threatening me with a CEW than with a club, knife, or firearm. Those can kill. And they leave no record identifying the purchaser of the weapon. We should hope that the Defense speculation of criminal usage was, in fact, true. There would be far less people killed in robberies. Sadly, this speculation is far from true.

In the Defendants Response to Interrogatories (dated 24 Jan 2018) we learn:

> In light of the fact that Tasers and stun guns have been determined to cause and/or contribute to death, they 'can be lethal in certain circumstances.

This inappropriately broad statement conflates actual secondary fatality contributions (due to falls and fires) with the mythical electrocution. It is well established that these weapons have contributed to some rare deaths in some very difficult law-enforcement scenarios involving falls and explosive fumes. No such deaths have been reported in the lawful use of civilian CEWs. The misleading innuendo here is that there are other fatalities beyond these — i.e. electrocutions.

Differences Between Civilian and Law-Enforcement Usage

There are dramatic differences between civilian self-defense and law-enforcement use of arrest-related control tactics.

Law-enforcement use of arrest-related control tactics.

The reality of law enforcement is that well-adjusted and sober members of society do not tend to be involved in forceful arrests as 79% of recipients of force have a history of mental illness or substance abuse and 66% have a documented history of mental illness.[96] More specifically to drug abuse, a large study found that 71% of electronic control subjects had drugs in their urine and 73% had a substance abuse history.[157] A large Canadian forceful-arrest study found that 82% of the subjects were being affected by alcohol, drugs, or emotional disturbance.[158] *Sober and rational people generally do not resist arrest.*

Sober and rational people do not resist emergency medical treatment. This issue looms large for the most dangerous law-enforcement activity which is an attempt to control a violent and psychotic individual so that he can receive emergency medical care.

Because of these comorbidities, Field recipients of law-enforcement force have a small but nonzero risk of death during encounter. This death rate has been estimated at about 1:1000 without electrical weapons and about 1:3000 with the use of electrical weapons.

Civilian self-defense.

The civilian is typically trying to defend against a fairly rational financial or sexual predator. The predator does not have the comorbidities that the typical recipient of law enforcement force does. Importantly, the civilian merely wants to stop the aggression and escape. In stark contrast the law-enforcement officer is obligated to continue the struggle until the suspect is under control. This, unfortunately, adds stress to the suspect and is a major cause of arrest related death.

This probably explains why there are no known fatalities or injuries even temporally linked to the civilian use of a CEW.

Urban Myths and Google Experts

Further evidence of Tthe prevalence of mythical false knowledge (surrounding the CEW) lies in the writings of "Google experts." These are individuals with minimal knowledge of the CEW that simply go to the Internet for a quick education on these weapons. Since there are so many urban myths on the Internet, these Google experts end up repeating some very silly things. This can be somewhat excused as the peer-reviewed scientific papers typically cost $30 to download and thus someone without academic library privileges is tempted to ignore the scientific literature in favor of the free education via Google.

The most common myth of all is the "50,000 volts" myth which continues to be promulgated by mass media stories. Of course, the actual pulse voltage is 600 volts for the standard X26.[43,53,54,59] Thus, this particular myth features a quantitative exaggeration of nearly100 times. The silver lining of this myth is that it allows for the immediate exposure of an unqualified expert.

We need look no further than this court to find such an example. In the case of Hulett v Syracuse et al (5:14-CV-0152) a self-identified expert by the name of Michael Lyman, PhD submitted an expert report. On page 8 of his expert report, Dr. Lyman has this sentence.

> A single pull and release of the trigger will deliver five seconds of current (50,000 volts), with the device delivering uninterrupted current as long as the trigger is pulled and the battery has energy.

Background:

A. The Electrophobia Myth

Many people, both lay and professional, have an illogical emotional fear of electricity, *electrophobia*. From an early age in life it is drilled into young children that 110 V (volt) electrical outlets cause death, Thus, most people have deeply absorbed the urban myths that voltage itself is dangerous and 110 V causes death. While this is scientifically incorrect most people, including most media, hold these myths to be undeniable truths.

Some people subscribe to a myth that since the human body is 97% water and since water transmits electricity that electricity delivered anywhere on the body is carried by the water to the heart and thus causes electrocution. This too is scientifically silly for many reasons. Life itself could not exist without electricity. Trying to say that all electricity is dangerous is equivalent to saying that all balls are dangerous. There are marked differences in the effects of being struck a ping-pong ball, baseball, bowling ball, and wrecking ball. Getting hit with a ping-pong ball is not equivalent to getting hit by a wrecking ball. In this analogy, the electrical impact from a CEW is approximately equivalent to a tennis ball while a 110 V wall outlet would be a bowling ball and a high-power transmission line or lightning strike would be a wrecking ball.

Table 5. AC Currents and Their Typical Effects

AC Current (mA)	Effect
1500	Nerve Damage
1000	
500	Cardiac Arrest Probable
200	
100	Cardiac Arrest Possible
50	Interference w Breathing
16	Male No-let-go threshold
13	TASER ® Weapon (AC Equivalent)
10	Muscle Contractions Begin
5	Pain Sensation
1.1	Male Hand Perception
0.7	Female Hand Perception

The typical effects of various AC currents are shown in Table 5. The < 2 mA of pulsed DC current (for the TASER® CEWs) is not directly comparable so their 13 mA AC equivalent is used.

B. CEW Probe Mode

In probe mode, the TASER handheld CEW uses compressed nitrogen to fire 2 small probes at typical distances of up to 7.7 m (meters) or 25 feet.[159,160] (Other TASER cartridge models can reach a distance of 11 m or 35 feet.) When the

CEW trigger is pulled, the high voltage first serves to open the nitrogen cartridges to release the nitrogen to propel the probes as directed. These probes themselves are designed to pierce or become lodged in most light clothing (which is usually overcome by the 50,000 V-arcing capability). The sharp portion of the probe is typically 9-13 mm (millimeters) long and will typically penetrate the epidermis and dermis to a depth of ~6 mm for a good electrical connection.

Even as a strong static electrical shock will temporarily incapacitate someone, a series of 19 very short duration shocks per second can cause temporary muscle incapacitation. The ultra-short duration electrical pulses applied by TASER CEWs are intended to stimulate Type A-α motor neurons, which are the nerves that control skeletal muscle contraction, but without a high-risk of stimulating cardiac muscle. This typically leads to a loss of regional muscle control and a fall to the ground to end a violent confrontation or suicide attempt.

Small swine of 30 kilograms (65 pounds) can occasionally, but rarely, be put into VF when the CEW probes are put within a few mm of the heart.[114] One study used a custom long plunging probe to deliver the CEW current almost directly (within 6 mm) to the heart of a pig in order to induce VF.[161] Pigs are extremely sensitive to electrical currents due to their hearts being literally wired "outside-in" compared to a human's (being wired "inside-out").[162-167] The swine heart needs 2/3 less current to go to VF (ventricular fibrillation) comparison to the human heart from external stimulation. I.e. the swine is 3 times as sensitive to electrocution as is the human.[21] There are numerous problems with the swine model that significantly exaggerate the electrocution risk.[32] This CEW-electrocution effect is also confined to *small* swine.[62] In stark contrast, human studies consistently show no demonstrated risk of VF with a CEW application.[168-176]

This is clearly the consensus of the scientific and medical community as shown by various position papers. For example: the June 2009 American Medical Association White (Position) Paper concluded:[177]

> Furthermore, no evidence of dysrhythmia or myocardial ischemia is apparent, even when the barbs are positioned on the thorax and cardiac apex.

On May 24, 2011, the National Institute of Justice, after a 5-year study, concluded:[178]

> Current research does not support a substantially increased risk of cardiac arrhythmia in field situations, even if the CED darts strike the front of the chest. There is currently no medical evidence that CEDs pose a significant risk for induced cardiac dysrhythmia in humans when deployed reasonably.

Finally, in June 2012, Bozeman stated:[179]

> The risk of such dysrhythmias, even in the presence of a transcardiac CEW discharge, is low, and suggest that policies restricting anterior thoracic discharges of CEWs based on cardiac safety concerns are unnecessary.

No danger or harm has been associated with the CEW probe-mode application, in human studies.

C. CEW Drive-Stun Mode: Skin Rub vs. Injection

Alternatively, the CEW may be used in a "drive-stun" mode by pushing the front of the weapon into the skin to function as a higher charge stun gun. With the fixed electrodes, only 4 cm (centimeters) or 1.6 inches apart — and the lack of skin penetration — the current flow is primarily through the dermis and fat layer between the electrodes and there is no significant penetration beyond the subdermal (or subcutaneous) fat layer. See Figure 2. Since there is insufficient depth of current flow to capture muscles, the drive-stun mode serves only as a compliance technique.

To make an analogy to medicine, drive-stun is like rubbing an ointment on the skin compared to the probe mode, which is like an injection. They have significantly different effects.

As mentioned above, small swine (30 kg or 65 pounds) can occasionally be put into VF when fully-embedded CEW *probes* are nearly touching the heart.[180,181] *However, it is impossible to fibrillate even small swine with a transcutaneous CEW drive-stun application.*[182-185] The electrical current simply does not penetrate deeply enough to affect any human muscles or organs. In fact, with a CEW drive-stun application directly over the human phrenic nerves (the nerves that control breathing) there is no effect.[186]

The American Academy of Emergency Medicine (AAEM) has the following guideline on drive-stun applications:[187]

> For patients who have undergone drive stun or touch stun ECD exposure, medical screening should focus on local skin effects at the exposure site, which may include local skin irritation or minor contact Allen. This recommendation is based on a literature review in which thousands of volunteers and individuals in police custody have had drive stun ECDs used with no untoward effects beyond local skin effects.

The National Institute of Justice, 5-year study of CEWs, found:[178]

> Risk of ventricular dysrhythmias is exceedingly low in the drive-stun mode of CEDs because the density of the current in the tissue is much lower in this mode.

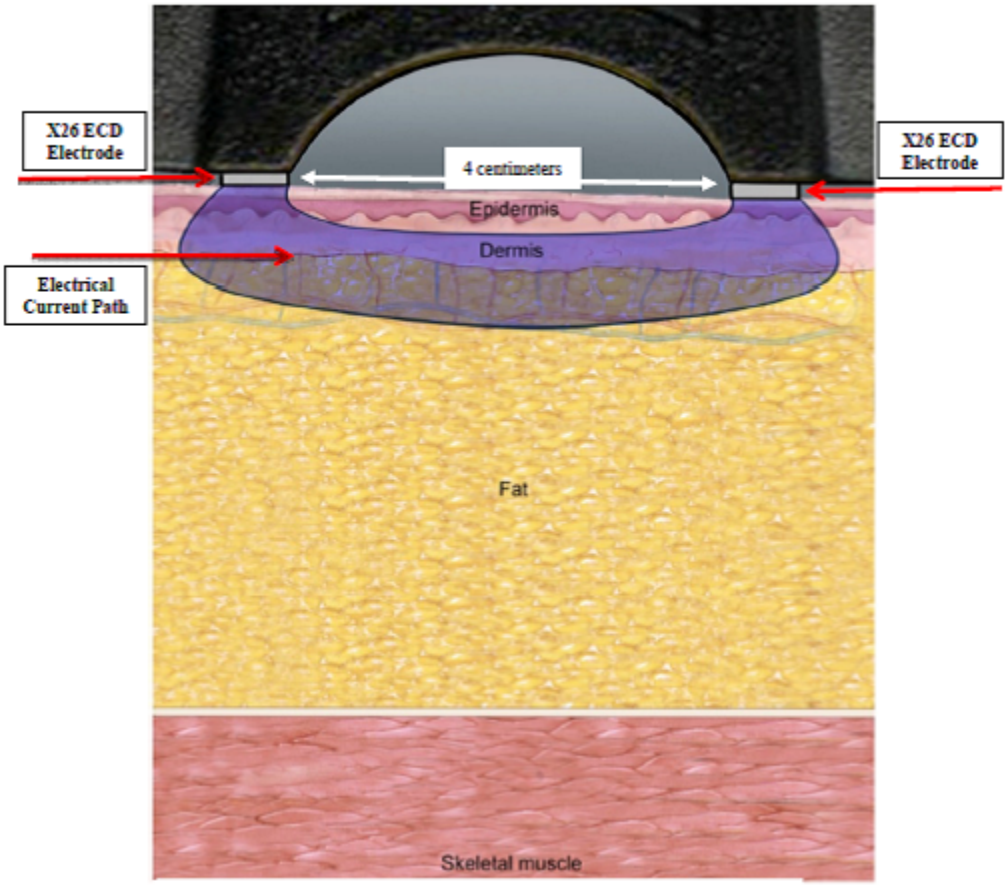

Figure 2. The majority of the drive-stun current is confined to the fat and dermis layer.

The Federal Court of Appeals for the 9th Circuit [*Brooks v Seattle*], and others, have concluded:

> The [TASER CEW]'s use in "touch" or "drive-stun" ... involves touching the [TASER CEW] to the body and causes temporary, localized pain only. ... this usage was considered a Level 1 tactic, akin to "pain compliance applied through the use of distraction, counter-joint holds, hair control holds, [and pepper spray]" and used to control passively or actively resisting suspects.

CEW drive-stun applications have no clinically significant physiological or pathological effects.

D. Current Flow in the Body

The flow of electrical current in the body is well understood and has been the subject of 100's of scientific papers.[31,57,67,81,82,188-192] The simplest analogy is the 1st to 2nd baseline in baseball. See Figure 3. The runners can go directly between the bases but they typically curve out a bit. Similarly, with 2 electrodes in the skin, the current flow "dives" in somewhat just like a runner's path in baseball. The further the electrodes are apart, the deeper the "dive" of the current. This analysis is accurate for a homogenous conductor like saltwater or fat.

However, the body's skeletal muscle layer preferable directs current around the outside of the body since electrical current vastly prefers to follow the grain of the muscle instead of going transverse and penetrating the body.

A runner might deviate somewhat from a straight line but would never run out into the outfield or wander into the bleachers. Similarly, with 2 CEW electrodes on the chest, no current passes into the legs or brain. That would be like a runner going into the outfield and then climbing up into the seats and then back to 2nd base.

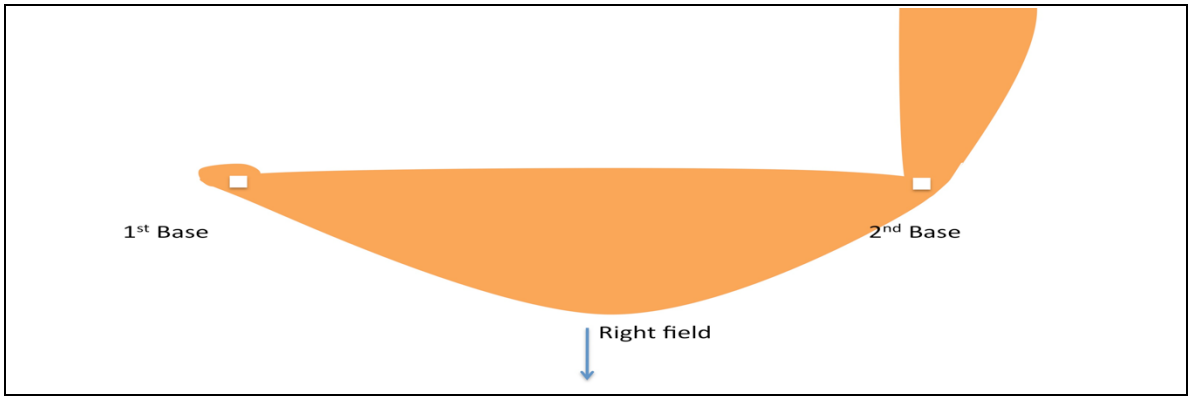

Figure 3. Graphic of electrical current flow in the body analogized to baseball.

An important exception occurs around bone. Mature calcified bone is an insulator and can thus not conduct electrical current.[193] A CEW probe landing in the sternum will pass very little current. What current is passed will be defused around the surface of the chest and will last tend to not affect the heart even though parts of the heart are directly beneath the sternum.[31]

Electrical current in the body tends to follow muscle fiber and only deviates slightly.

E. CEW Comparison to TENS Units

TASER CEWs deliver less current than some models of TENS (Transcutaneous Electronic Nerve Stimulator) units. For example, the popular EMPI® Select™ unit delivers up to 4.5 mA (milliamperes) of average current which is more than the 2.1 mA of the TASER X26 CEW. It is very popular in Europe to use TENS units for treating angina with the electrodes placed across the cardiac silhouette.[194-196] No deaths have been reported.

The X26 CEW delivers less average current than some transcutaneous nerve stimulators, which are often used directly across the heart without problems.

F. ANSI CPLSO-17 Standard

All present TASER brand electrical weapon outputs exceed the minimum requirements for effectiveness under the ANSI CPLSO-17 standard. These output levels are also below the maximum safety limits under the ANSI CPLSO-17 standard.

G. CEW Comparison to the Electric Fence

It is helpful to discuss the most common and longest existing electronic control device — which controls humans and other mammals by giving short painful electrical stimuli — namely the electric fence.

The IEC (International Electrotechnical Commission)and UL (Underwriters Laboratories) have long had standards for electric fences.[104,105] These are the Particular Requirements for Electric Fence Energizers. IEC 60335-2-76, edn 2.1, and the UL Standard for Electric-Fence Controllers in: Laboratories U, ed. UL 69. Independent testing has verified that the TASER X26 CEW satisfies both the IEC and UL electric fence standards.[102] The X2 and the X26P also satisfy these standards.

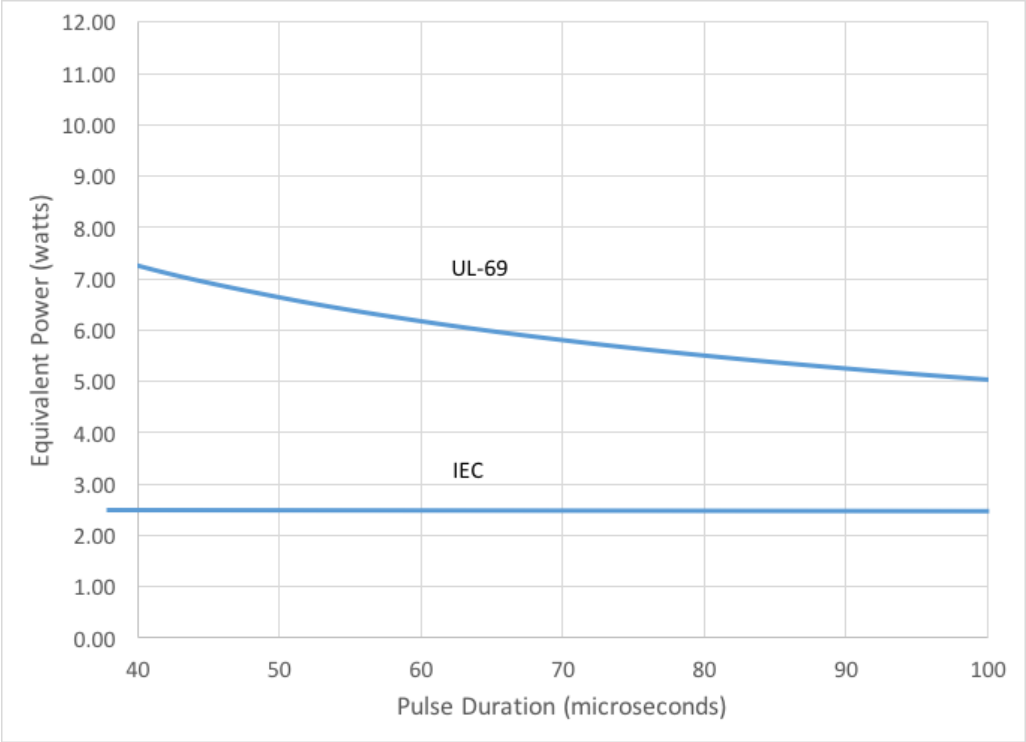

Figure 4. UL 69 electric fence equivalent power safety limit.

The X26 CEW satisfies the electric fence standards by a very wide margin.[102] The conservative IEC standard allows up to 2.5 watts for an electric fence and all present TASER CEWs deliver less than 2 watts. The UL high-rate limits are found in section in 23.2.4 of the UL standard 69.[105] This limit is shown in Figure 4 which allows 5 watts for the wider-pulse X26 and 6 watts for the narrow-pulse

X2. The electric fence standards have evolved from almost 100 years of experience with documented fatalities from earlier high-powered devices. The UL carefully collected data on these units to find out what was a safe limit. The typical accidental exposure to an electric fence is based on someone walking into it and thus is a frontal exposure. Depending upon the relative heights of the fence and the individual this exposure could be anywhere from the face to the thighs and could include skin penetration from barbs on barbed wire. These limits are very stringent and now fatalities from electric fences are almost unheard of in spite of there being on the order of 100,000 miles of electric fence in the United States alone.

The TASER X26 CEW satisfies the International and UL electric fence standards by a wide margin and can be thus deemed very safe.

H. Comparison to General International Safety Standards

The IEC has set 40 mA as a safe level of utility (50/60 Hz) electrical current for avoiding the risk of VF induction (electrocution).[104] BIEGELMEIER Rapid short-pulse stimulation has the same risk of VF induction as does utility power frequencies at a current of 7.4 times higher than the average current of the rapid pulses. The *TASER X26 CEW* delivers about 18 pulses per second at a charge of about 100 μC (microcoulombs) per pulse.[53] This gives an average current of 1.8 mA which corresponds to a utility power current of 13 mA. This is seen to be less than 1/2 of the IEC VF safety level.

The *TASER X2 CEW* delivers about 19 pulses per second at a charge of about 62 μC (microcoulombs) per pulse.[53] This gives an average current of 1.18 mA which corresponds to a utility power current of 8.7 mA = 1.18 mA • 7.4. This is seen to be less than 1/4 of the IEC VF safety level. The TASER X26 and X2 CEWs satisfy all relevant international electrical safety standards.[103]

The available TASER CEWs satisfy all relevant electrical safety standards.

I. Electricity Does Not Build Up Like Poison

It is often alleged that multiple CEW applications are somehow more dangerous than a single standard 5-second CEW application. This can seem to be very intuitively appealing as multiple baton strikes and multiple bullet wounds are more dangerous than single ones. This intuition is, however, completely wrong and contrary to decades of scientific research. Due to the prevalence of this false intuition — even among many scientists, clinicians, and pathologists — it is helpful to present a fairly lengthy discussion of the scientific facts below.

In fact, 1 second is the official implied value used by UL for their electrical safety standards. [129] The IEC uses a more gradual transition out to about

3 seconds as seen in Figure 6. Note that the UL has a slightly stricter safety limit for VF than does the IEC but that is not relevant to this discussion.

These standards are supported by numerous animal and human studies. The "transition time" is the number of seconds after which VF is either induced or not induced with a certain level of electrical current. A summary of studies of the transition time is given in Table 6.

Table 6. VF transition times from various studies

Author	Model	Transition Time (seconds)
Antoni[119]	guinea pig	0.8
Wegria[120]	exposed dog hearts	0.2
Ferris[121]	sheep	1.4
Jacobsen[122]	swine	4.0
Roy[123]	dog	2.0
Scott[127]	dog	< 3.0
Kiselev[128]	dog	< 5.0

Using calculations based on the human heart rate, Biegelmeir and Lee determined that the transition time for humans is 2-5 seconds.[124,125] See Figure 5. In a human study, Swerdlow et al showed that the VFT decreased by 47% with durations going from 1-5 seconds, consistent with the calculations of Biegelmeier.[126]

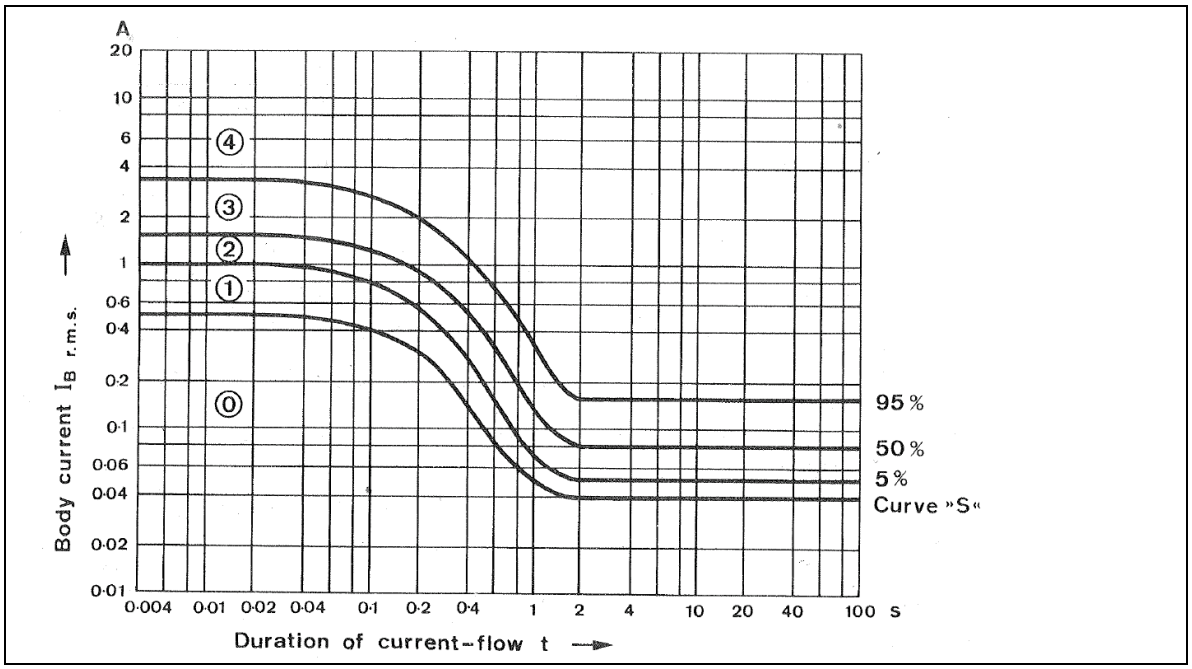

Figure 5. Original Biegelmeier curves showing safe (S) currents for humans.

In a canine study, Scott et al found that the VFT did not change with durations going from 3 out to 60 seconds.[127] Kiselev also found the VFT to be quite constant from 5 to 30 seconds.[128]
Scott states in his conclusions:

> Shocks of 3, 10, 30, and 60 seconds duration produced very similar mean [VFT] values. The stability of mean [VFT] over this wide range of shock duration suggests a basal threshold of fibrillation. Currents below this threshold seem unable to induce fibrillation regardless of shock duration.[127]

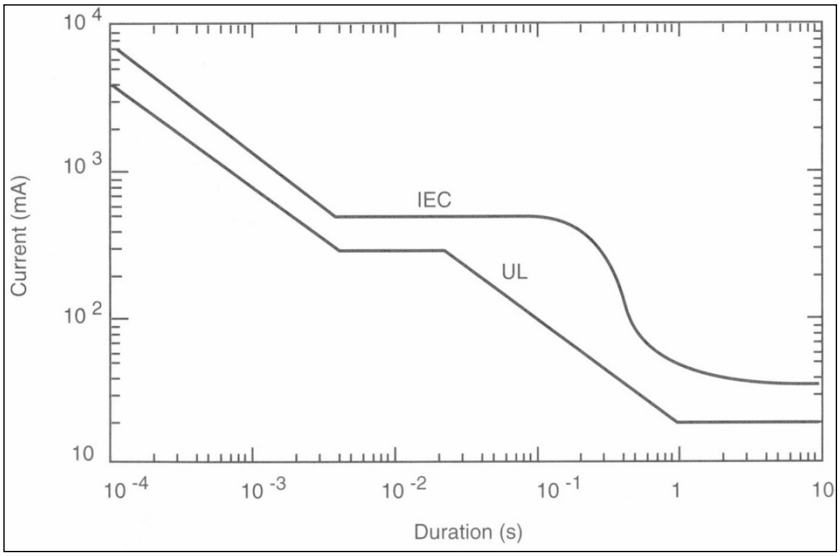

Figure 6. UL and IEC standards recognize that VF is induced or not within 1-5 seconds.

Scott's study showed that nothing happens between 3 and 60-second applications of current. Importantly he did this study in 16 canines, which have hearts that are electrically similar to humans — unlike pigs.[197-201]

The dogma of 3 strikes and 15 seconds.

While anesthetized animals have been tested up to 30 minutes, human CEW testing has to be performed on volunteers. Law-enforcement trainees typically are required to take a 5-second CEW exposure but it is very difficult to find volunteers willing to expose themselves to more than 10 or 15 seconds. Therefore most clinical trials of the physiological effects of the TASER CEW, involve exposures of 5, 10, or 15 seconds. For example, there are a number of studies with continuous 15-second exposures.[202-205]

The independent review of Pasquier found:

> According to the available results, the physiologic changes from electronic control device exposure appear to be safe in healthy individuals who undergo an exposure duration of 5 to 15 seconds, i.e., the duration that corresponds to the majority of field exposures."[206]

Importantly, these clinical studies failed to find any trends for increased effects between 5, 10, and 15 seconds so there has been no evidence to motivate longer-duration studies. E.g. Dawes et al observed, "… the duration of the exposure does not appear to have a significant effect on CK [creatine kinase]."[207] There is certainly a false lay-intuition that electrical charge must build up like poison since baton strikes and bullet wounds do tend to injure in a cumulative fashion. However, over 100 years of electrical research has demonstrated that the direct effects of electricity do not build up like poison. Specifically, the US military has tested this in swine with continuous CEW exposures across the whole chest up to 30 minutes — not 30 seconds.[208] If someone is electrocuted this generally occurs within 1 second with an upper limit of about 2-5 seconds.[124,125] If an electrical current is strong enough to kill someone it will do so in the first few seconds of exposure and a longer exposure duration simply has no additional effect.[209] With a full-trunk human exposure, there is a slight pH shift (blood becomes less alkaline) in the first few seconds but then does not change.[171,210-217] For a given degree of subject resistance, the more the CEW is used, the better the outcome will tend to be since the use of more conventional force-option control options can be reduced. [89,90,97,160,218,219]

The epidemiological data unambiguously finds no increased risk with CEW exposures beyond 15 seconds.

1. Brewer studied 292 arrest-related-deaths (ARDs) where a CEW had been used.[66] He found that: (1) over 75% of the 292 deaths involved only 1 or 2 CEW exposures, (2) 85% of fatalities were preceded by 3 CEW exposures or less, and (3) concluded that there was no correlation between the number of CEW exposures and the mortality rate.

2. White studied 188 ARDs where a CEW had been used and similarly found that 87% of them had 3 trigger pulls or less which is the equivalent of 15 seconds of discharge or less.[220]

The widespread dogmatic urban myth that 15 seconds is safe while 16 seconds is dangerous is contradicted by all of the scientific studies and statistics.

The direct electrical induction of VF by electrical currents takes 1-5 seconds.

J. The TASER CEW Has Led to Dramatic Reductions in Injury.

Numerous published studies have now clearly demonstrated substantial injury reductions from the use of TASER CEWs compared to alternative control techniques.[88-98]

A partial list of these studies includes:

1. MacDonald which compared the CEW to pepper spray and "physical force."[90]
2. Taylor which compared the CEW to pepper spray, baton strikes, and "hands-on."[89]
3. Mesloh who studied CEW usage in comparison to many control options.[97]
   a. Gentle hold
   b. Handcuff
   c. Leg restraints
   d. Pepper spray
   e. Compliance holds
   f. Takedown
   g. Empty hand strike
   h. FN303/Pepperball
   i. Impact weapon
   j. Canine

The largest epidemiological study was the 2009 MacDonald study of 24,380 uses of force.[90] This study found that CEW usage dramatically reduced both suspect and officer injury (by 2/3) compared to alternative force options. Additional studies demonstrating injury reduction are memorialized in the papers of Taylor (13,983 subjects), Mesloh (n = 4303), Smith (n = 1645), Butler (n = 562), and White (n = 243).[89,90,97,160,218,219]

On average, the use of the CEW reduces suspect injuries by about 2/3. To put it another way, the use of alternative control techniques triples (3x) the risk of injury to subjects. Fatal suspect shootings are also reduced by 2/3 when electronic control is used without excessive restriction.[101]

a. The deployment and use of TASER CEWs has been shown to reduce injuries to officers and suspects over other force options, including physical force.
b. The deployment and use of TASER CEWs has been shown to reduce use-of-force citizen complaints and law enforcement internal affairs complaints against law enforcement officers.[221]
c. The deployment and use of TASER CEWs has resulted in the reduced need to use of deadly lethal force.

d. Rates of injury from TASER CEWs is comparable to, or less than, some collegiate contact and exertion sports.
e. Rates of injury from TASER CEWs is less than several other common law enforcement force options, including, but not limited to: physical force, batons, impact tools, canines, rubber bullets, and bean bags.
f. TASER CEWs are a safer alternative than other comparable law enforcement force options tools or techniques.
g. TASER CEWs are shown to reduce suspect injuries when compared to physical force options.
h. TASER CEWs have greater accountability features than any other force option.
i. TASER CEWs are the most studied force option available to law enforcement.
j. TASER CEWs are the most effective force option in accomplishing intended effects for U.S. law enforcement.
k. According to the peer-reviewed literature, the TASER CEW causes less-severe physiologic and metabolic effects than other force options.
l. According to the peer-reviewed literature, the TASER CEW is the safest force option available to law enforcement.

The TASER CEW reduces suspect injuries and fatalities.

General Comments

Previous Testimony

I have testified as an expert at trial or by deposition within the preceding 4 years in:

1. Criminal case of Crown v. Eric Lim, Damian Ralph, Scott Edmondson and Daniel Barling, Sydney, Australia (Nov 2014)
2. Excessive force case of van Raden v Mankato, MN (Jul 2015)
3. Excessive force case of Brossart v Nelson County, ND (Dec 2015)
4. Coroner's inquest in the death of Michael Langan, Manitoba (Jan 2016)
5. Criminal case of Illinois v. Brad McCaslin, Rockford, IL (May 2016)
6. Wrongful death case of Darden v Ft. Worth. Tarrant Cty, TX. (Jul 2016)
7. Criminal case of S Carolina v Michael Slager. Charleston, SC (Nov 2016)
8. Criminal case of Georgia v Eberhart & Weems. Atlanta, GA (Dec 2016)
9. Criminal case of Texas v Murray, Angleton, TX (Apr 2017)
10. Excessive force case of Khottavongsa v Brooklyn Center, MN (June 2017)
11. Electrical injury case of Rowan v Sunflower, Kansas City KS (Sept 2017)
12. Electrical injury case of Garcia v Natchitoches, LA (Sept 2017)

Fees:

My fees for this expert witness report are donated. My normal fees for testimony are $480 per hour with a minimum of $2400 and are due prior to the commencement of a deposition.

Right To Amend:

The opinions in this report are living opinions. Should additional discovery material be received, or additional research be completed, and then reviewed, these opinions may be altered or reinforced depending upon what information is obtained, reviewed, or studied. If new issues are opined, identified, or developed subsequent to submission of this report, I reserve the right to supplement, or further supplement, this report. *I especially reserve the right to amend my report after receiving other expert reports or new forensic evidence.*

Further Development:

Further, the opinions, which are expressed in this report, are not necessarily fully developed. Rather, they are listed to comply with current report requests. Each opinion may be further developed through research, investigation, during deposition or trial testimony.

Specific References:

Some of the opinions in this report may list specific references to some of the case specific documents reviewed or considered. These listings are not intended to be all-inclusive. I specifically reserve the right to supplement the support for each of the opinions in this report.

Opinion Methodology:

The enclosed opinions were developed using the disciplines of bioelectricity, electrophysiology, biomedical science, cardiovascular physiology, scientific methods, mathematics, and physics and are to a reasonable degree of professional, scientific, or medical certainty.

Additionally, the opinions provided in this case were developed using one or more qualitative and quantitative research methodologies, in addition to my education, training, experience, and literature review.

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