Forensic Analysis of Electrical Injury Using Burn Pattern to Predict the Incident Narrative

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The problem

A primary goal of investigating electrical incidents is to develop the most accurate narrative.

In a perfect world …

- You have audio/video of the incident from a perfectly aimed camera
- You have recorded “hard data” that tells the tale of voltage, current, duration, and energy.
- You have eyewitnesses with perfect recall and no agenda.

Then there is the real world…

- Cameras, if they exist, seem always to miss the most critical information
- There is little to no recorded data in most instances.
- Humans are notoriously unreliable eyewitnesses when placed in high stress situations.

Accuracy Hinges on Correct Electric Shock Parameterization

When trying to parameterize an electrical injury, we are looking for:

- Voltage (which is the most commonly available parameter.)
- Body Resistance (which is pretty much never known)
- Current (easily calculated if you know body resistance and voltage.)
- Duration (which is often more of a guestimate than an actual estimate.)
- Entry and exit points (often very hard to determine even when there are burns and harder to identify when there are no burns.)

Body Resistance:

- Absolutely never known at the instant of the electrical contact
- Often changes during the contact.
- “Typical” is 1000 ohms but can vary wildly from 300 ohms to beyond 100,000 ohms.
- **Any number that anyone comes up with is an educated guess at best and is probably just a guess**.

Duration:

- Often derived from eyewitness or victim narratives (time is easily distorted during witnessed traumatic events…)
- Best derived from hard data (reclosers, fault recordings, breaker trips, videos)
- Sometimes derived from expected human response (”can’t let go” or “getting the hell out of Dodge.”)

Getting to the Best Narrative of the Incident

How then do we develop an accurate narrative:

- Hard data (That which is known)
- Burn pattern analysis (where even a lack of burns can be informational)
- Use physical laws (which work as the best and most accurate witness) to provide irrefutable boundaries (with near 100% probability)
- Test and temper the narrative with probable human response.

Avoid pitfalls which increase narrative inaccuracy:

- Avoid establishing boundary conditions that can’t be validated.
- Avoid tainting the narrative with client bias.
- Don’t fill in what you don’t know -- Know AND ADMIT what you don’t know.
- Don’t create facts where there are none.

Avoid Zebras:

- “When you hear hoofbeats think horses … not zebras”
- ZEBRA THEORIES have very low probability of being correct.

Let the Burn Pattern tell the Story – Go where it takes you.

What do burns tell us?

1. Burns are a local effect and tell us about the conditions where the burn occurred.

2. A lack of burns is not predictive of a lack of injury but may be predictive of the probability of injury.

Burn Pattern Analysis

1. Identify each burn by type
2. Know the physics of each burn type
3. Set hard narrative boundaries based on burn type tempered with hard data and bounded by physical laws.

First Step – Identify all burn types:

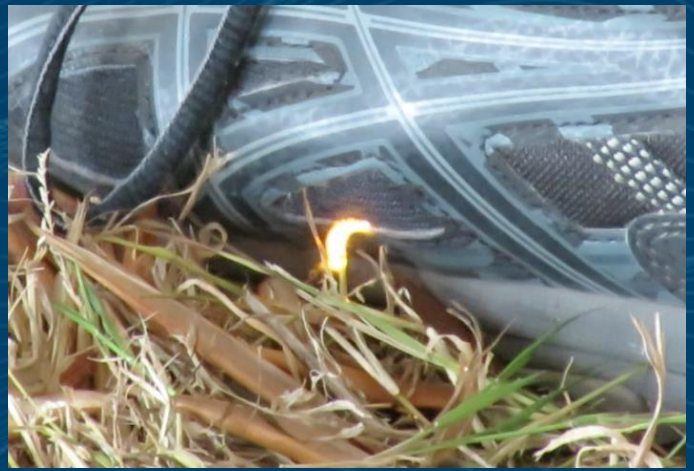
TABLE I
ELECTRICAL BURN TYPES AND THEIR FORENSIC IMPLICATIONS

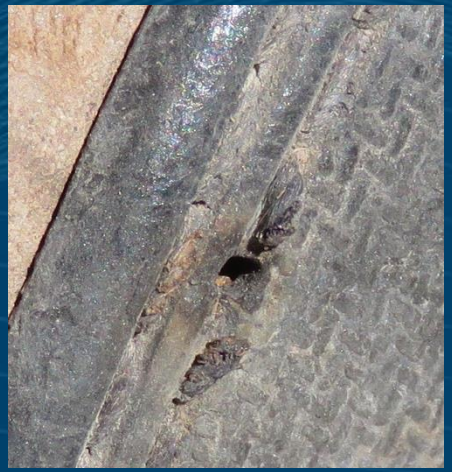
Burn Type	Voltage	Appearance	Burn Depth	Predicts
Resistive Burn	Both HV & LV	Sunburn to blistering and charring; often matches the shape of the contact.	Surface (contact burn) to deep resistive heating.	Entry point and shape of contact; for LV, often predicts duration.
Arc Entry/Exit Burn	Almost exclusively HV	Black, carbonized center with a surrounding margin of damaged tissue and healthy tissue beyond.	Surface burn with possible deeper resistive heating.	Proximity (with high probability) to source or ground; can predict body position or a grabbing action.
Flash Burn	Almost exclusively HV	Uniform pattern diminishing with distance from the arc source; ranges from sunburn-like erythema to surface charring.	Surface only.	Proximity to the arc; can predict orientation relative to nearby structures.
Flame Burn	Almost exclusively HV	Typically significant and matches the area of burnt clothing.	Surface only.	Often masks other burn types and reduces their predictive value.

Resistive Burn:

- Identify by context in the environment. Surface resistive burns match the dimensions of the contact and extend outward and into deep tissues over time.
- Physics – A function of voltage, current, and time. (E=VIT)
- Indicates entry or exit points and duration of contact. Deep resistive burning indicates contact duration and current path.
- Can be used to delineate grab versus glancing contact.

Arc Entry/Exit Burn:





The key to all arc burns is knowing that arcs are initiated by proximity to source or pathway to ground and initiation distance is bounded by the breakdown of air (Typical: 30Kv / cm.)

Arc Entry/Exit Burn:

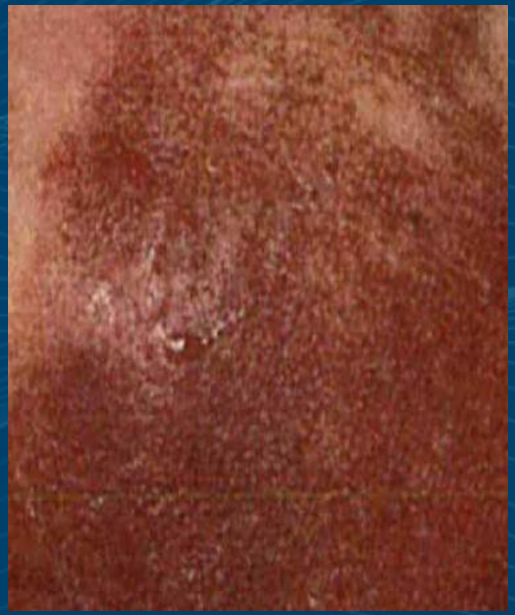
Know the life cycle of an electric arc:

1. Initiation (controlled by breakdown of air)
2. Growth/Propagation (lots of randomness)
3. Extinction (occurs with the arc can no longer be sustained… possibly bookended by a breaker/recloser/fuse operation.

Arc Entry/Exit Burn:

- Identified by carbonized center and proximate healthy tissue. Often circular.
- Physics: Extreme focused heat, instantaneous tissue burning, can be associated with high current flow, arc initiation is controlled by breakdown limitations of air.
- Can be used with very high probability to establish proximity to source or ground, standing or walking, body position, grab versus glancing contact.

Flash Burn:



- Identified by broad and uniform surface burning. Can be any be any degree burn.
- Physics – Proximity to intense radiant and convective heat of an electric arc.
- Used to identify body location relative to location of arc flash as well as body orientation and environmental shadowing.

Flame Burn:

- Identified in context. Surface burn only. Can mask other burn types and often occurs after the electrical incident is over. Can appear identical to a flash burn or a resistive burn but tends to match with burned clothing.

- Physics – Heat is related to composition of clothing and capacity to ignite and burn. Flame burns occur much slower than flash burns but have the same effect.

- Flame burns can be used with limited value to identify body position post incident. They are more apt to confuse the narrative but must be identified so as to be properly excluded.

What does it mean when there are no burns?

1. Might indicate brevity of contact.
2. Might indicate local sub-injurious current density.
3. Might indicate that there was no shock.
4. Always indicates that not enough energy was imparted locally to cause tissue damage in the form of a burn.

Lack of burns should NEVER be ignored. The absence of burns becomes a valuable part of the narrative ESPECIALLY when the physics predicts burns.

Go Where the Burn Pattern Takes You.

Procedure:

- Review all available narratives. (victim, witnesses, first responders.)
- Review all hard data (recloser data, fault recordings, circuit breaker trips, video)
- Establish hard incident parameters. (Know what you know.)
- Review all medical data and day 1 (pre-treatment) burn photos
- Identify all burn types
- Contextualize entry and exit points to be consistent with hard data and other narratives (to the greatest extent possible.)
- Use physical absolutes to establish hard narrative parameters

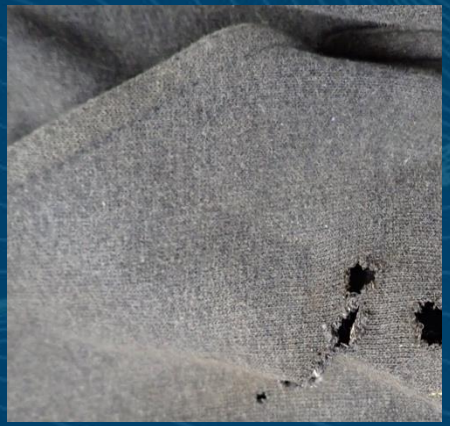
Procedure (continued):

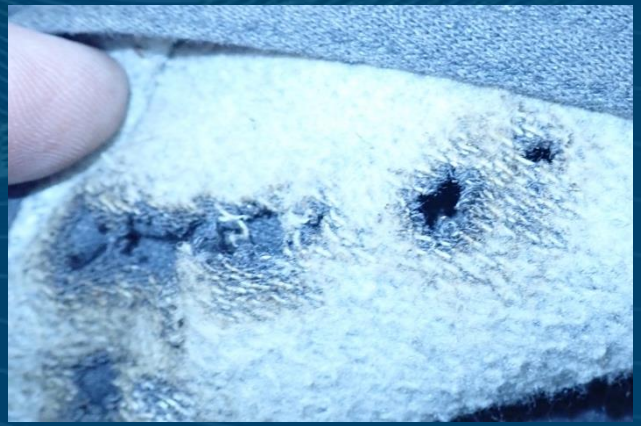
- Identify disconnects between other narratives and hard data.
- Identify disconnects between other narratives and laws of physics.
- Identify disconnects between other narratives and probable human response.

Develop the highest probability narrative in the context of absolutes (Go where the facts take you.)

Applying Burn Pattern Analysis

Example:





Scenario: Decedent found laying on his back with left hand in his hoody pocket. There are arc burns on the hoody pocket and on the back of the hand. No arc burns proximate to the hoody on the ground. Burned part of the hoody is several inches above the surrounding ground. There are no witnesses.

Basic Facts:

- Hard Data: Power line is 7KV.
- Totality of other burns tell the story of an individual who was somehow brought to the ground on his back (and did not roll over) and then was burnt repeatedly by a swinging downed power line.
- Most burns on the decedent are easily explained in the context of his final position except for the burn on the back of his left hand. It stood out as posing more questions than answers.

What we can derive from these very limited facts

1. The burns on the back of the hand approximate the burns in the hoody suggesting that the hand was in the hoody when the burns occurred.
2. Considering the breakdown of air (30Kv/cm) and the distance from the burns to ground, an arc could not be initiated from the back of his hand to ground suggesting it was not an exit wound.
3. The lack of proximate burns on the ground confirm the probability that the hoody and hand burn must have occurred prior to the fall to the ground.
4. The burn to the back of the hand (while in the hoody) is indicative of a glancing and passive (not grabbing) contact.
5. There were standing burns (not shown here) on decedent's feet indicating he received an event initiating shock while still standing.
6. CONCLUSION: The burns on his hand represent a glancing contact from a falling/swinging power line. They are entry burns and not exit burns and represent the event initiator.

Conclusion:

The burns on his hand represent a glancing contact from a falling/swinging power line.

They are entry burns and not exit burns

The burns tell the story that they represent the event initiator.

The decedent was standing or walking when he was contacted by a swinging or falling power line.

Use of Pattern and Irrefutables to Form Opinions

1. There are no witness narratives and no hard boundaries beyond known line voltage.
2. IRREFUTABLE: Some arc burns to feet could only have occurred while standing. (There were many other arc burns that were consistent with being on his back.
3. PROBABLE: Hand was in the hoody when initiating burn occurred
4. IRREFUTABLE: Burn to back of hand could not have occurred in the position he was found
5. PROBABLE: He was not on the ground when the hand/hoody burn occurred
6. IRREFUTABLE: Whatever caused the arc burn to his hand had to have been less than 1 cm. from his hand to initiate the arc.
7. PROBABLE: Burn to the back of the hand is resultant from a glancing, not grabbing, contact.
8. PROBABLE HUMAN RESPONSE: Passive contact with swinging or falling power line. (Defense disagreed with this one.)
9. PROBABLE HUMAN RESPONSE: Brief passive contact caused him to fall backwards onto the ground and was the initiating event.
10. CONCLUSION: Decedent was surprised by a swinging or falling power line.

In Conclusion:

1. Each burn tells a story that is part of the incident narrative.
2. Each burn has its own descriptive physics which becomes predictive of the narrative.
3. Physical rules can be used as inclusive or exclusive.
4. Physics can become the best witness to an electrical incident.
5. Physics taken in the greater context can be used to derive irrefutable truths.
6. Probable human response can be used as predictive of most probable narrative in the context of the information that is provided by the burn pattern.

For more information contact
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