**THE INVESTIGATION OF ELECTRICAL INJURIES AND DEATHS**

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**INTRODUCTION**

Since there were humans, the occasional electrical injury or death occurred as the result of lightning. With the development of generated electrical current in 1839, the possibility of death or injury from man-made electricity was created. This potential appears to have been first realized in Lyon, France in 1879 when a carpenter was killed by current produced by a Simon’s alternating generator1-3

Subsequently, thousands of persons have been injured or killed by generated current as the consumption of power has risen during the latter part of the nineteenth and twentieth centuries. Currently, approximately 1,100 such incidents occur per year in the United States and Canada.

Our understanding of the physics of electricity was fairly well established by the end of the nineteenth century. Our understanding of the physiology of electrical injury and death has expanded greatly during the twentieth century.a4-8

In addition, during this time, the standardization of electrical wiring and appliances, guided by the National Electrical Code (NEC), the National Electric Safety Code (NESC), the Underwriter’s Laboratory and the American Society for Testing and Materials, to name but a few organizations involved in these matters, has resulted in a much safer environment. Understanding of the past and current status of these codes and standards can guide in the unraveling of the puzzle presented to the person investigating electrical injuries or death.

This presentation shall provide an overview of the physics, biology and a bit of practical electrical generation, transmission, distribution and domestic wiring. The purpose of this presentation is to describe the how and why of electrical injury and death. The goal will be to prepare you for, or to hone your skills and knowledge in investigating these events.

But first*,* let us go back and review a little history, both because it is interesting, but also because a fair amount may be learned from this exercise.

**HISTORY**

The term electricity comes from the Greek word for amber, electros. Thales appears to have first used this term in the sixth century BC when he wrote of his experiments concerning the ability of amber, after it was rubbed with fur, to attract dried materials. This attraction force he called electricity. Subsequently, a device invented by Otto Von Guericke in 1663, generated static electricity. At Leyden University, Professor Pieter van Musschenbroek invented the “electric phial” or “Leyden Jar” which could store static electricity whether made with a generator or by rubbing amber. Benjamin Franklin, of the English Colonies in North America, was the first to properly identify that electrical charges were but excessive amounts of “electrons” which were transferred either by Von Guericke’s generator or by rubbing amber. Franklin’s experiments in 1752 with the Leyden jar and lightning tended to prove that lightning and static electricity were the same.[[1]](#footnote-1)As mentioned above, the first person thought to have been killed was a carpenter in Lyon France. The first death in the United States is said to have been Samuel Smith, who touched a DC generator in Buffalo, New York in 1881.

Increasing generation of electricity caused increasing deaths and injuries. Although commercial generators were first employed in 1839, the use of these devices was primarily to energize large arc lamps used for theatrical lightning. It was not until 1879 that Thomas A. Edison perfected the incandescent lamp. That appliance created a demand for consumer electricity. Edison’s companies soon supplied the demand. Edison had also invented a generator that produced direct current and an electric motor that ran on DC current. During the 1880’s generating plants began to spring up in the cities in the United States. Initially, these were all DC and employed Edison’s patents.

George Westinghouse, another inventor, developed an alternating current generator and perhaps more importantly an alternating current electric motor.[[2]](#footnote-2) It quickly became apparent to all, that for domestic use, alternating current was the only reasonable way to generate electricity9. Unfortunately for Mr. Edison in the 1880’s this gave his archenemy Mr. Westinghouse a decided commercial advantage Mr. Edison, probably the foremost publicist the world has ever known, came up with a plan to derail the alternating current competition. He labeled it dangerous. Indeed, as the State of New York at this time was seeking a more humane way to have the State kill persons, Mr. Edison’s agents suggested using AC current (as it was so dangerous). Indeed the Commission on the Execution of the Death Penalty decided to provide for electrical death. The word ***ELECTROCUTION*** is a contraction of ***electros*** from electricity and ***cution*** from execution. Westinghouse, of course was reluctant to have his equipment become involved and refused to sell to the State of New York. Edison’s agents procured the devices by subterfuge and provided them to the State. On August 6, 1890, William Kimmler achieved the distinction of being the first person electrocuted as Mr. Edison meant the word10-13

As time went on, indeed before the electrocution debut, Mr. Edison recognized the folly of his clinging to DC and he too moved to AC current. This was in part driven by a fantastic rise in the price of copper that occurred in the late 1880’s. Unfortunately, Edison was right about the danger of alternating current The relatively low frequency of 50 or 60 Hz which was standardized in Europe and North and South America is extremely efficient at producing injury and death.

Investigations into the cause of death of persons exposed to electrical current led to the discovery of ventricular fibrillation, or the uncontrolled quivering of the heart that is one of the mechanisms of death from electricity.

As time went on, more and more electrical energy was used. With this use came a declining rate of injury and death expressed as both per power consumed and to persons exposed as important improvements in electrical wiring and appliance manufacturing were made. In spite of these improvements, electrical injuries and deaths continue to occur. In addition, and often perplexingly, deaths and rarely injuries occur which are ascribed to electrical causes that are not in fact due to electricity.

***ELECTRICAL THEORY***

The underlying concept that needs to be grasped in understanding electrical injury and deaths, and thus to be able to effectively investigate them, is the concept of a circuit. A circuit is, for our purposes, something through which electrons are flowing from a place where they are in excess to where they are relatively non-abundant. Generally, most folk use as an example a plumbing system with water being the electrons and the pipes being the circuit. We will come back to this example in a moment.

Once we have a circuit, we can define some characteristics of the circuit. All of this is important in understanding how to approach an electrocution scene. The current-flow formula is called “Ohms Law” and works as follows. [[3]](#footnote-3)

IMPEDANCE (OHMS IMPEDANCE) – Resistance plus capacitance impedance plus inductive impedance.

RESISTANCE (OHMS) ----The resistance to the flow of electricity. This is a value that can be determined by directly measuring or by calculating. It is a measure of electrical conductivity, such that the smaller the number the more conductive the material is. Copper wire of 18 gauge 10 feet in length has nearly 0 ohms resistance. A dry pine 2x4 may have 100 million ohms resistance. A wet pine 2x4 may have as little as 50 ohms resistance. Humans have resistances as high as millions of ohms to as little as 190 ohms. Between 25V and 1000VAC, human resistance ranges from 6100 to 650 ohms.

ELECTROMOTIVE FORCE -PRESSURE (VOLTS) --The amount of force that causes the electrons to move in the Circuit. Generally, household voltages are either 120 volt or 240 volt. Electrical distribution lines, the rather ubiquitous overhead-un­insulated wires found in the United States and Canada, have 2400 - 44000 volts measured from conductor to conductor (phase to phase). Transmission lines, the tall towers seen crisscrossing the countryside, have voltages in excess of 69000 volts measured from conductor wire to wire. The phase to ground voltage is calculated by dividing the phase to phase conductor voltage by 1.732.

CURRENT (AMPS)---The amount of electrons flowing per unit of time. This is the calibration value for overload protectors of electrical circuits. Generally in the United States, household circuits are rated at 15 AMPS.

If you know any two of the values above you can calculate the other one.

CURRENT (AMPS) *=* PRESSURE (VOLTS) / RESISTANCE (OHMS) or I=V/R or RESISTANCE (OHMS) *=* PRESSURE (VOLTS) / CURRENT (AMPS) Or R=I/V or PRESSURE (VOLTS) *=* RESISTANCE (OHMS) **\*** CURRENT (AMPS) or V=R\*I

There are some other concepts to look at here while we are doing the formulas. One is WATTS (Instantaneous Power).

For our purposes we will use as a measure of electromotive power a unit called a WATT

WATT-- as in 100-WATT bulbs, or 6.5 cents per kilo-WATT Hour. As we will see later, the amount of WATTS is the primary determinate of the mechanism of death and injury from electricity.

JOULE (ENERGY)—Watt Second, i.e. a 100-watt bulb on for 10 hours consumes one CALORIE—4.18 joules = the energy required to raise 1 gram of water 1° C.

At any rate:

WATTS *=* VOLTS **\*** AMPS

However, as you remember from the OHMS law formula above an AMP is equal to VOLTS / OHMS. Thus you can replace AMPS in the above formula with VOLTS / OHMS to give you

*V* 2

WATT *=* VOLTS **\*** VOLTS / OHMS = \_\_\_\_

*R*

The importance of the above is to show that the amount of power in a circuit goes up

at the square of the voltage. Or to put it another way, if you have a circuit which goes from 100 to 1000 volts the power will go up one hundred times. (10 squared**).** This is why the power companies use high voltage circuits to transmit power because they can get huge increases of power transmission from fairly modest increases in voltage. This is also why Edison abandoned DC.

The limiting factor in circuits is the amount of amperes. This is why huge wires are required for car batteries as peak-starting power may pull over 100 amps. However, 100 amps at 12 VAC is only 1200 watts, compare this with only about 10 amps being required to produce 1200 watts at 117 volts and at 7680 volts only

O.156 amps are required.

Which brings us to another concept and that is heat. When you have a resistive current carrying electrical circuit, you have heat. The amount of heat is a direct function of the amount of power. Heat is measured in joules or calories and the actual formula is:

JOULE = WATT \* SECOND

*V* 2

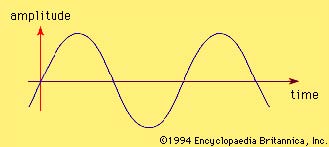
CALORIE *=* 4.18 Joules – 4.18 Watt \* Seconds – 4.18 = 4.18 I2RS

*RS*

Using the previous formula you can substitute VOLTS squared divided by OHMS to figure out the amount of heat. Obviously, as with power, the amount of heat increases at the square of the voltage or current. Thus, one calorie is the amount of energy required to raise one gram of water one-centigrade degree.

Now we are almost done with the physics, just one other small matter, the difference between alternating and direct current. Direct Current (DC) is the sort of thing that you get from a battery. There is a plus and minus side, and the minus side is the place where the electrons flow from, due to a mistake made by Benjamin Franklin and continued to this day. Thus electricity flows from minus to plus. Oh well.

Alternating Current has no real minus or plus, as it varies very rapidly overtime. In North and South America it cycles 60 times per second or times per minute. (In England and Europe it alternates 50 times per second or 3000 times per minute; from a hazard standpoint there is no difference both are disastrous, as we shall see). If you read the voltage of a wall outlet using a DC meter the reading is 0 volts. The voltage changes from negative to positive (from –170 volts to + 170 volts) by the square root of the root mean squared (RMS) of 120 volts 120 times a second, but on average it is 0 volts. The peaks will not record on a DC voltmeter that measures net or average voltage. An AC RMS voltmeter should read about 120 volts when you check the outlet from the wall. This is because an AC voltmeter measures the RMS voltage. RMS voltage stands for root mean square of the voltage and is the best approximation of the equivalent amount of voltage that would be delivered if the voltage were non-alternating (i.e., 120VDC). If you measure the instant voltages very fast and plot them you get a figure like FIGURE A which is a Sine Wave. When we deal with voltage in an alternating current we generally talk of the RMS voltage. The peak voltage is actually reached 60 times a second negative and 60 times a second positive.[[4]](#footnote-4)



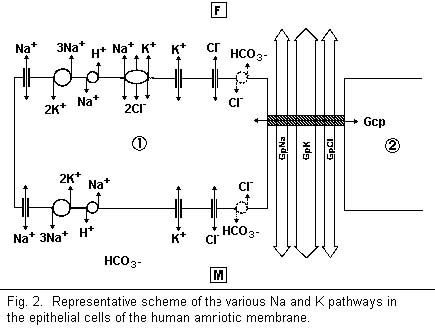
**Figure A**

All of this is done because of the problem associated with transmitting power. If you transmit power as DC you end up having to literally move huge amounts of electrons. If you transmit power by AC you only move them out one way for 0.0083 seconds (1/60 of a second divided by 2) during the negative part of the cycle and then back for 0.0083 seconds. The lack of actual movement allows the transmission of power over exceedingly great distances with less loss of the power.

**PHYSIOLOGIC ELECTRICAL EFFECTS**

Having quickly reviewed the theory of electricity we have to look at the electrical effect upon humans (or animals generally). All of the cells that we are made of act as tiny electrical batteries. The voltage on the inside is minus 0.09 volts (or 90 millivolts). This voltage is produced by work which the cell does pumping sodium and potassium salts across the cell membrane. This voltage is maintained when the cell is just sitting there and is called the resting membrane potential. If you short out the battery eg make the voltage go to zero, then the cell does whatever it does. In the case of the muscle cell it contracts. In the case of the nerve it fires off to its connecting nerves. If the nerve happens to be a pain nerve then it makes either a tingle, or at higher amounts of current, it makes pain.

Figure B shows the stylized drawing of a cell with its resting membrane potential.



**Figure B Electron Pumps in cell membranes maintain a 90mv resting potential**

Electricity causes its physiologic effect, as opposed to its heat effect, by causing cells to depolarize or to in effect loose the resting membrane potential across the cell membrane or in effect shorting out the battery**.**

Some experiments into the effect of all of this have been made and Table 1 gives the results of these experiments. 14-18

**Table A Representative current flow and effect on humans**

|  |  |
| --- | --- |
| 0.001 Amp | Threshold of Sensation |
| 0.017 Amp | No-Let go threshold |
| 0.050 Amp | Respiratory Paralysis death if sustained |
| 0.100 Amp | Low Threshold for ventricular fibrillation |
| 1.000 Amp | Low Threshold of AC defibrillation |

Basically, in humans, going from hand to hand, we can feel about 0.001 amps (1 milliamp) of current. At about 0.017 amps (17 milliamps) traveling from hand to hand or hand to foot, enough of the muscles contract in the forearm that a person cannot let go of an energized pipe (this is therefore called the “no-let-go” threshold). At a level of about

0.100 amps the heart may go into ventricular fibrillation. At a level above about 1.000 amps the heart does not fibrillate but goes into complete contraction or may actually defibrillate.

The no let go and tingle threshold are nearly the same for DC as for AC current. This is solely a function of simply depolarizing (shorting the battery) of the cell.

The way folk behave when there is a circuit through them also works the same for AC or DC. All persons behave differently within a range. The variations are partly a function of fatty tissue and skin resistances.

The first rule is:

* ALL of the muscles in a circuit at or above 50 milliamps will contract.

The second rule is:

* The muscle contraction from current is more or less the same for everyone. Such that current through the entire body results in the person in the circuit:
* Standing on the toes
* Knees straight
* Hip straight
* Arms rotated inward
* Elbows flexed
* Fists made
* Back and Neck arched backwards.

The third rule is:

* If the current passes through the chest, there is usually a scream, or at least a noise

Thus a person standing with a circuit from hand to foot will fall over backwards. A person squatting with a circuit from foot to foot will shoot forward or somersault backwards depending upon the exact squatting posture. A person with something in their hand which can be grasped and which makes up one side of the circuit, will hold it until the circuit is broken if the current is above “no-let-go”

*A* quick aside is probably needed here to describe the phenomena of “instant *rigor mortis.”*

*Rigor mortis* is the stiffening of the body *after* death. It occurs when the muscles are completely depleted of their glycogen post mortem. *Rigor mortis* can be accelerated by muscular contraction. With electrocution, muscle contraction often occurs for a protracted time period, producing near instant *rigor.* This is often unilateral, so you can make the diagnosis of electrocution, or be very suspicious that it has occurred if there is unilateral, or oddly advanced *rigor.*

Another aside is that the contraction caused by electrical current will result, if the circuit is continued for 0.02 seconds or minutes while the person stays alive, in a massive rise in serum Creatine Phosphokinase (CPK). This is an enzyme that restores the high-energy phosphate bonds that are required to make muscles contract. When muscles contract violently for a period of time CPK leaks into the blood stream. In addition, with long term contraction of the muscles+, there is release of myoglobin into the blood. Myoglobin is the muscle equivalent of hemoglobin in the red blood cells.

The effect of the current on contracting muscles occurs regardless whether it is AC or DC current. Further, it doesn’t really matter what the voltage is as long as the current flow is above 5O milliamps. However, Professor Dalziel was not able to explore the effects of DC current completely, as his paid volunteers refused to participate after the first experience because of the pain of DC.

Although there is no difference in skeletal muscle contraction between AC and DC, there is a huge difference in the lethal effects at low voltages. For practical purposes, DC low voltage deaths do not occur. At high voltages, the difference between DC and AC disappears again.

***Determining Whether Electrical Injury has occurred***

The rules are:

**Table B Voltage/Power Effects**

|  |  |
| --- | --- |
| LOW VOLTAGE-LOW POWER AC | Asphyxial Injury or rarely death Minor Skin injury |
| LOW VOLTAGE-LOW POWER AC | Kills by Ventricular Fibrillation |
| HIGH VOLTAGE-LOW POWER AC | Kills by Ventricular Fibrillation |
| HIGH VOLTAGE HIGH POWER AC | Injures and Occasionally kills by Heating |
| HIGH-VOLTAGE-ARCING DC or AC | Ignites Materials and Causes Burning |
| LOW VOLTAGE DC | Kills rarely at high current levels |
| HIGH VOLTAGE DC | Kills by heat effect rarely by Fibrillation |

The reason that low voltage AC kills by ventricular fibrillation is that with the current flowing skin to skin at about 100 milliamps up to 1000 milliamps, the heart tries to follow the alternating current as its pace maker. To understand this we need to see how the heart works. Ifyou cut out a person’s heart and put it into warm water containing sugar and salt (Warm Gatorade will do) while bubbling oxygen through, the heart will beat 50-70 times per minute for a long time. The reason the heart does this is that it has a place up near the top where the heart muscle polarizes itself (sets up the little battery) and then automatically depolarizes firing off the rest of the heart in turn which causes it to contract and thus pump. It does this automatically in humans about 1.2 times per second (72 times per minute). With about 100 milliamps of current and up there is enough for the heart to start trying to beat at the rate of the alternating current or 120 times per second (7200 times per minute). This the heart cannot do. It just starts to quiver instead of beating. This is called ventricular fibrillation (fibrillation mean quiver) and in humans once fibrillation is started the heart will never beat again unless it is artificially defibrillated, which is done by stopping the fibrillation so the heart can go back on automatic.

Above 1000 milliamps, the current density is strong enough that it will stop the heart and if the current stops the heart, it will automatically restart. Which brings us to high voltage AC.[[5]](#footnote-5)

High voltage AC almost always results in current flows of more than 1 AMP. The reason for this is because of the resistance of people. Humans with intact skin have as little as 1000 OHMS resistance and as much as 1 million OHMS or more at 120 volts. At voltages over 1,000 you get arcing discharge through the skin and thus the resistance tends to be in the 200 OHMS range, or less. At 1000 Ohms resistance 120 volts gives 120 milliamps of current. At 200 Ohms resistance at 1000 volts you get 5 amps that is defibrillatory not fibrillatory.

High Voltage kills primarily by joule heating and by poration whether the current is AC or DC. There is no difference between AC and DC in a high voltage situation. However, high voltage DC circuits are rarely encountered.

Low Voltage AC usually kills primarily by producing heart fibrillation. At autopsy, the only changes in the heart are what ever the person had before the encounter with the current. If he or she had a normal heart, he or she will have a normal heart after getting electrocuted. If he or she had coronary artery disease, he or she will have coronary artery disease after getting electrocuted. In the latter case, it is awfully easy to call it a natural heart death and not an electrocution.

The difference between non-arcing current flow and arcing current flow is that non-arcing current flow is fairly invisible. You cannot see the electrons flow through the wires in your house, as the flow is non-arcing. You cannot see them flow through a person. An arcing circuit shows. When you bring two objects of different voltage close to each other, at some point, depending on the shape of the objects, the humidity arid the voltage, an arc will form between the objects. The arc occurs when electrons flow through the air. Air is non- conductive to the flow of electrons and the way arcing occurs is by a burst that is associated with fairly impressive heating, and light, and sound.

When humans are in the circuit, arcing is not generally a feature at low voltages. Arcing is often a feature with high voltages. Indeed, a special kind of arcing can occur through the skin with high voltage, although it is not as impressive to view as with air arcing.

***LIGHTNING***

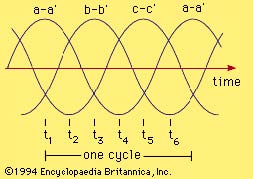
The most impressive arcing is seen with lightning. Lightning is a special form of DC high voltage. There are some special attributes of lightning that makes it unique. First, although it is an arc, arcing burns are not generally seen, as the whole person is in the arc and the vast majority of the current flows external to the body. Second, as with any DC high voltage, if there is a death, it is nearly always due to heat effect, although ventricular fibrillation may be seen, very rarely. Third, the heat effect generally produces explosive changes in the clothing, rupture of one or both tympanic membranes and very rarely produces arborizing lividity. Finally, ferrous metals are often magnetized by the passage of the electricity19-25

***ELECTRICAL GENERATION, TRANSMISSION and WIRING***

The Power Company generates electrical power using generators that convert mechanical energy into electrical energy by the principal of electromagnetism. If you pass current through a wire it creates a magnetic field. If you pass a magnetic field along a wire you create an electrical current.

The former is the principal for electric motors the latter is that for generators. Indeed, with minor modifications, any motor can be made to be +a generator and a generator a motor.

The power company creates alternating current in their generator, and characteristically they create three phases, or alternatively there are three separate outputs from the generator. If you look at a cross section of the generator you will see three collectors. If you spin the generator 60 times per second, you will get three separate AC outputs, each separated in time by 1/20th of a second.



**Figure C**

See FIGURE C to view the three phases called A, B and C. The net effect of this is that the AC voltage measured from A to B or B to C or C to A is nearly twice the AC voltage measured from any of the phases to ground.

A short aside, as power is generated as alternating current or AC. there is no need to pump electrons out, you just move them out and back, out and back. You can use the ground or earth as the relative source of electrons or a sink for excess electrons. The earth can act as neutral and ground or both.

We will examine the consequences of this in a moment.

Leaving the generator there are three phases and the voltage from phase to phase may be stepped up as high as 735 kilovolts or kV. (The phase to ground is 1.732 or 425 kV). Another nice quality of AC current is that it can be transformed to another voltage using a transformer. The principal is the same; magnetism and electrical power are interchangeable. Via transformers, the current from the power company will be dropped down to successive lower voltages (distribution voltages) until it gets to approximately 15kV phase to phase or nominally 7680VAC phase to ground.

The 7680 lines are the most ubiquitous. These are the distribution lines which are found nearly everywhere in cities and towns and which are seen in rural areas as well. In general, the NESC code requires these lines to be insulated by over 18 feet of air. These lines are a common source for high voltage electrocution and these occur when the 18 feet of insulating air is breached, either that the wire breaks or something conductive of electricity is held by a person such as an antenna or sail boat mast and completes a circuit with a person in the circuit.

There are overload protectors (fuse, circuit breakers, or reclosers) attached to the power lines, some of which can also be remotely activated. First a word about overload protection:

As we stated above, passing electricity through something makes heat. This is directly proportional to the power of the circuit. In transmitting power, there are limits to the amount of power that can be conducted by the wires.

If that power is exceeded, the conductor will burn down. As it is expensive to burn down one’s conductors, very early on power companies came up with fused links that were designed to burn out before the conductors did. Thus if you had a conductor which was rated at 100 amps continuous, it could actually carry 1000 fault amps momentarily. If it is protected by a 100 amp fuse, then all you have to do is replace the fuse, not the conductor. Blown fuses, however, must be replaced which is expensive, not to mention time consuming. Thus an invention was made called a recloser. A recloser is an oil-filled device that contains two current sensing contacts and a timer. If you have a fault, and if the current flow gets to, say, 1000 amps, the recloser will open and interrupt the circuit. Reclosers generally protect fused distribution sub-circuits. They are oil enclosed generally to prevent the arcing that occurs in air, and they are set to automatically reclose, restoring the circuit, and thus getting their name (OCR – Oil Circuit Recloser). In a closed circuit there is electrical current flow. An open switch in a circuit stops the current. A recloser can be set to reclose four times before they will open if there is a sustained fault or overload. They can also be opened and closed remotely for switching purposes. Recloser operations cause lights to flicker during thunderstorms. After some number of reclosures, if the fault persists, the recloser will not reclose, but stay open. This results in a power outage.

Common reasons for recloser operations in distribution systems are lightning[[6]](#footnote-6), trees, birds, and dirty insulators. Local changes in the ground state of the ground, which is associated with thunderstorms and lightning discharge back to ground, cause the neutral ground to become non-neutral when measured from a distant site. Although these changes are relatively short-lived, they can produce flashovers of insulators. These are the sources of flickering lights which one experiences during thunderstorms. Shorts, or overloads, will also open the recloser. But if all is working well, the recloser will stay open, at least eventually, say when a wire blows down and touches the ground.[[7]](#footnote-7)

All of the above is to explain that reclosures are designed, as all overload protectors are, to protect conductors. To give you an example, at 7680 volts 4/0 Aluminum wire (ACSR for Aluminum Clad Steel Reinforced) is rated for 310 amps in air. Going back to our formula this is for 7680\*310 Amps or 2,480,000 Watts, or a lot of light bulbs. A person who stands on the ground with an Aluminum pole and touches a 7680 VAC line has say a 1000 ohm resistance. This will result, using ohms law in a 8 AMP circuit, well below the value at which the recloser opens, (310 AMPS) but resulting in 64,000 WATTS that of course causes the person to be literally fried.

**The bottom line is that overload protection, whether end user or transmission, protects conductors, not people. Do not expect overload protectors to protect people, they were not designed to and they will not.**

This brings us to end users of electrical power. Residential consumer voltage in the US and Canada is 120 VAC line to ground, 240 volts leg to leg. There may be other end user voltages between 240VAC to 480VAC line to ground, mostly only seen in industrial locations. The end user leg to leg voltage is 240 VAC which is from one leg of the transformer to the other but still 120 line to ground (and sometimes 440 VAC or 600 VAC in the industrial setting).

In the end user setting, 7680VAC (phase-ground) is stepped down by a pole top or pad mount transformer that usually has a single high voltage conductor going in, and one neutral. Generally, there is a fused link which is rated from 5-50 amps which is overload protection for the transformer. The transformer, usually has three wires going to the house or business. The wires to the house are typically insulated with a plastic insulation with high resistance to current flow, and the three wires are made up of the two legs plus neutral which is connected to ground back at the power pole. The voltage of each leg is 120 VAC from hot wire to ground or hot wire to neutral and 240 VAC from hot wire to hot wire.

These three wires generally are dropped down a service connection to the meter. It is important to note that the Electric Company’s responsibility stops at the meter or the connection point on the mast to the meter. Anything on the customer side of the meter usually is the customer’s responsibility. Generally, if you have a potential electrocution and the Power Company has been notified, they will only examine from the meter back to the transformer. If they say there is nothing wrong, they mean from the wire from the meter back to the transformer. If the trouble is on the customer’s side, the Power Company personnel generally will not investigate this.

Back to our story, we will describe a breaker panel and its circuits. The same effect is accomplished using a fuse panel, and fuse panels are still allowed by code, but rarely seen in new construction, for the same reason that reclosures are used in distribution. It is a pain to replace fuses, a lot easier to reset the breaker.

The term ‘breaker’ comes from the fact that the dielectric device used breaks the circuit. In individual end user circuits, either shorts or true overloads cause overload circuit interruption, true overloads occur when the circuit has more current

than the conductor can handle. Thus residential breakers do not automatically reclose, you have to manually reset them, presumably causing you to investigate for the short or correct the overload before resetting. They also do not have the oil quenching of the circuits, as arcs at less than 240 volts are minimal.

If you examine the interior of a typical breaker box, you will find four wires coming in. These are the two legs, which are 120 VAC leg to ground, and 240 VAC leg to leg (black and black). In addition, there is the neutral wire (usually white) that comes from the power company and a ground wire (green or bare) that is actually attached to a rod driven into the ground. (Historically ground was achieved by either a driven copper rod or by a connection to the cold water pipe, the latter is no longer code as today copper or steel are not always used for piping, and plastic pipe make a very ineffective ground). It should be noted that in most modern wiring, the neutral and ground are bonded together at the circuit box[[8]](#footnote-8).

Which brings us to color-coding; conductors in the United States and Canada are color coded. The black wire (or red if it is a secondary circuit) is hot. It is connected to one of the two phases coming into the house from the power company. White is neutral, it is connected to the neutral coming from the power company’s transformer or bonded at the box. Green is the safety ground. It is connected to the driven ground near the meter, and is generally also connected to the neutral in the main service panel in the house.[[9]](#footnote-9)

At the main service panel, each of the two hot wires are connected to two busses, large metal bars which are insulated from the panel. The neutral (and ground usually) is connected to a neutral bus. A branch breaker is snapped into place with its metal base making contact with one bus if it is a 120 circuit; or two busses if it is a 240 VAC circuit. From each breaker, one or two black or red wires exit. If the breaker is open, there will be no current on the wire. If it is closed there will be 120 VAC phase to neutral (and ground).

Again, breakers protect wires, not people. Most household circuits are designed to be 15 or 20 AMP. Thus the breakers are set to open if more than 15 amps or 20 amps travel down the conductor. Again, using a person with 1,000 Ohms resistance, we see that Ohms law gives us a person in the circuit of 120/1.000 *=* AMPS *=* .120 AMPS or 120 milliamps. In other words you can safely electrocute 120 people (120 **\*** .12 ***=*** 14.4 AMPS) simultaneously with one 15-amp circuit, and not overload the circuit. ***Do not expect the overload protector to open the circuit in an electrocution, unless you have electrocuted more than 120 people at once***.

There is a device called a GFCI that can either be a GFCI breaker, a GFCI outlet, or even a GFCI extension cord. GFCI stands for Ground Fault Circuit Interrupter, also called GFI that stands for Ground Fault Interrupter. The GFCI breaker looks much like the regular breaker, except it has a push button to test the GFCI part, as well as a way to reset the breaker. In addition, it has an extra wire, a white one that must be connected directly to the circuits white wire.

The reason for this, and the way the GFCI works, is that it continually monitors the amount of current that goes down the black and up the white. As you know this is not quite true, as the current goes back and forth 120 times per second, the GFCI actually monitors the comings and going but it is easier to think of it as two lanes each with one way traffic. If the amount going does not add up to amount coming back, leaving a 5 milliamp leeway, then the GFCI trips. Five milliamps was selected by a committee.. It is less than the ‘no-let-go’ current. It is fairly safe; we have not seen or heard of a death with an operating GFCI: However, it is low enough that so called “Nuisance Tripping” where there is a leak of 5 milliamps (Fig. 17) or more, occurs not infrequently, particularly if the environment is wet.

GFCI’s thus have to be directly connected to black and white. If there is 5 milliamps missing then there is a “Ground Fault” or a pathway of electricity from hot to ground not as it should be from hot to neutral. As with alternating current a ground fault on the neutral side will open a GFCI just as fast as one on the hot side. This can create some difficult to trouble shoot problems with GFCI’s as neutral ground faults are nor perceivable under ordinary operation without a GFCI. If you grab hold of a GFCI protected black wire then if you are 1,000 ohms resistant, you will have a 120-milliamp­ground fault through you that will nearly immediately open the circuit, *if the GFCI works!!*. You will barely be able to feel it. (Notice boys and girls, this stunt should not be done at home, leave it to trained professionals (who have more sense)).

GFCI protected circuits are required by the National Electric Code in outside outlets, plus the kitchen and bathroom outlets. This is because these are the places where it is easy to get grounded (such as to sinks, stoves and refrigerators) and thus get electrocuted when one makes a circuit. In my house, which has terrazzo floors (a kind of concrete with marble chips) all of the outlets are GFCI protected, as it is very easy to get electrocuted in such a house. Likewise, steel reinforced concrete buildings are also relatively well grounded. Wet carpets may also provide a ground to bare skin.

In addition to the color code of the wires, switches and outlets are color coded as well. Brass colored screws or hardware is for the hot or black-red wire. Silver colored screws or hardware is for the white or neutral. Green screws or hardware are for the safety ground.

Which brings us to a discussion of the safety ground; all modern code approved circuits have (if leg to neutral) three wires, white and black plus a safety ground. If they are leg to leg they have four wires, one each for the two legs plus white for neutral and a safety ground. (Old leg wiring had only two wires, one each for the two legs).

The safety ground is just that. It provides a direct pathway back to the source should a short develop in an appliance. The idea is to have a pathway that has less than 2 ohms resistance to ground. If there is a short, it is in a 2-ohm pathway which results in 120/2 or 60 AMP current that should throw the overload protector open. As it is only for safety, some people defeat the system, either by using two wire conductors with no safety ground wire, or by just pulling the ground prong out of the plugs. In such a setting, you end up betting your life that there is never a short.

A couple other matters deserve some discussion. Double insulated hand tools and appliances have only two prongs on their factory installed electrical plugs. This is because the tool is encased in plastic with a high dielectric, or resistance to the flow of electricity. (This is the double insulation, the first is the insulation in the circuit supplying the switch and motor, the double is the extra that protects the housing). These tools are considered safe without a safety ground in the event of a breakdown of the primary insulation.

Finally, there is the matter of size and position coding of outlets. In a three-prong outlet, there is a large round hole, which is the safety ground. There are two slots. The small one is hot. The large one is neutral. If the ground hole is down, the hot is right, left is neutral. Many plugs that lack the safety ground are size coded to provide for proper connection of the switch. The hot side of the circuit should have the switch. If the prongs on the plug are the same size, then it is a 50-50 chance that a switch will open and close the hot side. Opening and closing the neutral side should cause the equipment to turn off and on, but everything is still energized when it is turned off, not the way one wants things.

Unfortunately unpolarized extension cords with only two slots and two prongs are available in the United States as are unpolarized replacement plugs. As long as these devices are available, someone will use them and end up with a low voltage electrocution.

***AUTOPSY FINDINGS in ELECTRICAL DEATHS***

The findings in electrical deaths are primarily caused by heat. The direct effects of electricity other than heat leave essentially no trace. Thus, in low voltage electrical deaths, where there is very little heat, there are often no findings. Indeed, in low voltage deaths, 50% of the electrocutions will have no autopsy findings indicating an electrocution.26-28

A quick word about all of the heat changes; if the circuit is produced soon after death, all of the changes seen in electrical burn can be created post-mortem. This includes charring, blistering, surrounding pallor, nuclear streaming microscopically, and even arborizing lividity. In addition, as well as occurring post mortem from electrical current passage, non-arcing burns and their microscopic nuclear streaming can be produced artificially by either heat from a non electrical source, or by post mortem pressure artifact.

Asphyxial findings, petechiae of heart, right ventricular dilatation, hemorrhagic pulmonary edema, are seen in all high voltage high and ultra-high power and lightning deaths and in low voltage low power deaths. The reason for this in high voltage high power is that death occurs by cooking the brain. When the heart restarts, as it usually does, then there are no further breaths and the person’s mechanism *of* death is asphyxial.

Non-clotted blood is a feature of immediate death from all types of electrocutions. It is mentioned, not because it is helpful, but just because some authors have described it as a hallmark of asphyxiation. In the case of electrocution, it is not; as ventricular fibrillation deaths give non-clotting blood as well. Non-clotting is just a sign of sudden death, natural, accidental, suicidal or homicidal.

Non-arcing burns have central charring and or redness. Surrounding this is an area of pallor, surrounding this is a rim of red. This is the stereotypic textbook electrical burn. Few are stereotypic. Many are very difficult to see, many are easily confused with artifact. Careful photography helps, but does not solve the identification problem with non-arcing electrical burns. They are not grossly or microscopically pathognomonic, but certainly are helpful in analysis.

Arcing burns are much more easily identified and are not easily confused with other lesions. Arcing burns occur almost exclusively with high voltage electrocutions, and then not always.

To produce an arc burn, you must have an arc. That means that the person must create a circuit by actually moving and closing the distance between him or herself and either the energized side or ground. Thus a person who has a 25 foot aluminum pole in his or her hands and touches a 7680 VAC line while standing in rubber soled leather shoes on concrete will likely have arcing burns on his feet but not his hands. The reason for this is that there is no air-gap between the aluminum pole and the hands, and thus no arc.

A word on arcing is probably in order. To initiate an arc, you have to exceed the dielectric strength of air. This varies with humidity and suspended material. Indeed, smoke will reduce the dielectric of air to lower values. All of South Florida was deprived of power one day when the 133 kV line to ground wires had a muck fire spread beneath them. They arced 50 feet and burned down the wires. Ordinarily, 133 kV will arc less than 12 inches. 7680 volts will arc about an inch. Electrode geometry plays a significant role in this.

***EXAMINATION OF EQUIPMENT AND SCENE (LOW VOLTAGE)***

As you can see from the above examining the body or injury, may or may not be very helpful in determining whether a death or shock was caused by electricity. What must be done is a careful examination of the scene and equipment from the scene. The examination of the items that could have been in the circuit must be done. Obviously, the person is examined. Likewise, the other parts of the circuit must be examined as well.

In death cases, if at all possible**,** forensic engineer and the pathologist should do the examination. He or she should be present when it is done, if at all possible. Whoever does the examination, hopefully they will be knowledgeable.

The circuit consists of what is energized, the person, and a pathway to ground or to neutral or to another leg or phase.

The initial source of the current may be an electric outlet, into which something is plugged. The outlet should be checked to see if it is properly wired. There is a test device available which is plugged into the outlet and which shows various combinations of lights to indicate proper or improper wiring. This is the easiest way to check the outlet. Below is how to do it using a VOM, which one has to have to check

To do proper testing of the low voltage circuit you need a fused VOM or voltmeter, ammeter, and an electric equivalent circuit of a human and suitable electrodes. You should also use rubber-insulated gloves with leather protectors and wear a Nomex suit and electrically rated shoes.

To check the outlet you should use a tester designed for this purpose. If you do not have one**,** you will be working with 120 VAC of electricity and should be very careful not to become part of the circuit. Avoid touching the test leads except by the plastic parts. Make sure no part of your body touches the ground, or concrete floors, or grounded appliances, or the carpet on concrete floors, of any water pipes or fixtures. If you cannot eliminate the possibility that you could be grounded you may be shocked or burned or killed. DO NOT PERFORM ANY TESTS ON ENERGIZED CIRCUITS without taking proper precautions!!!

The outlet will have two slots and a round hole or just two slots. If the round hole is down, then the left slot should be neutral and the right slot is hot. Vice versa if the round hole is up. The round hole is the ground. Using the volt setting on the VOM measure from the hot to the neutral it should read 120 volts. From the hot to ground should read 120 volts. From ground to neutral should read 0 volts. Any reading different from this indicates a miswired outlet. If the deceased was using a grounded tool, such as a hand drill with a metal case, and was grounded, plugging the tool into a ground-hot reversed outlet can be expected to be the cause of death. Nothing else is required but to plug the appliance in, whether it is turned on or not. A ground-hot reversal gives 0 VAC from hot to neutral, 120 VAC from ground to neutral and ground to hot. Other miss-wirings are not as constantly dangerous but may lead to death. Insert the equivalent human circuit and measure the milliamps of current.

Not having a ground circuit, either by having it improperly wired, a reading of 0 volts from hot to ground and 0 volts from ground to neutral; or having an outlet with only two slots and no provision for grounding is not itself dangerous. However, for many types of equipment, the ground circuit (green wire) is designed to carry off any ground fault or short. (If the ground circuit has a resistance of 2 ohms and the voltage is 120, the ground circuit will have a current flow of 60 amps that will very shortly open a circuit breaker or fuse.) Many low voltage electrocutions are caused in part by the defeat of the ground circuit.

A note here is probably in order. Since 1975 Ground Fault Circuit Interrupters (GFI or GFCI) have been required in new construction where there is a high probability of a person being grounded (anywhere the outlet is within 2 feet of a water source or outside). These devices constantly measure the amount of current that flows down the hot side and compares that against what is flowing back the neutral side. If there is a 5-milliamp difference between the two then the circuit is broken (interrupted). These devices can and do fail. Often, people disable or wire past GFCI’s because of “nuisance tripping”. Current leaking to ground, usually by dangerous equipment, causes nuisance tripping. If a GFCI is in a circuit, and it works, it will reduce the probability of an electrocution to near zero. Always check to see that the GFCI works. The testing device made part of the receptacle or part circuit breaker is not an adequate test, if it passes. That is, pushing the test button and having the power disconnected is only a partial test. If that happens, then obtain a special GFCI tester and plug it into the suspected outlet. These devices are generally available from hardware stores..

Once one has finished evaluating the potential source of the current one has to look at the ground (or rarely neutral side of the circuit). The common grounds are the same as the warning above. Ground is probably obviously ground. If a person is touching dirt with bare skin, he/she is probably grounded. Anything which is a conductor and which touches the ground is a ground. Thus metal water pipes are nearly always grounded, as is anything metal which touches them. Concrete almost always will be grounded, as it conducts electricity. Many damp items become conductive. Thus a damp carpet on a concrete floor may be grounded. A dry carpet will not. Metal appliances will probably have their cases grounded. To test the ground state set the VOM on Ohms (or use a ground resistance meter) and measure the resistance between the functioning ground hole (tested as above), and the item which is suspected to be grounded. The reading of less than infinity should cause you to suspect a potential ground. A reading of less than 10 means that it is absolutely a ground.

Having established the ground and the source all one has to do is to finish analyzing the circuit. Some appliances develop a short to ground only upon being energized.

If there is a hand tool or extension cord test it using the VOM. All portable items should be x-rayed. Concentrate on the plugs and switches as these are the common sites of trouble and the trouble is shown in the radiographs by interruptions in the wires.

After x-rays and photographs then use the VOM on Ohms to test for conductivity. The extension cords should give 3 or fewer Ohms from the respective slot and prong. That is the hot slot (left with the ground down) will be less than 3 Ohms to the hot prong (right with the ground down with it pointing at you) likewise for the neutral and the ground. There should be infinite resistance with hot to neutral, hot to ground, neutral to ground measured in both the plug and outlet using an insulation resistance tester. Failure of any of the last tests, especially hot to ground, indicates a very serious potential problem. If the extension cord has two wires, the testing is a lot easier. It has no ground circuit and is ready to allow the electrocution of a person if a short develops to the case of a tool. Generally two wire extension cords and “cheaters” which allow plugging plugs with three prongs into two slot outlets are outlawed in civilized countries. They are legal in the United States.

After checking the extension cords, the device is tested. Again the resistance between the hot, neutral and ground is tested with any conductive part of the tool or appliance. Each is tested with each other and all tests are done switch on and switch off. There should be low resistance between hot and neutral and infinite between hot and ground, neutral and ground and between hot and neutral to anywhere that could be touched on the appliance. There should be less than 3 Ohms from the ground to the case.

Any circumstance where the hot side of the circuit is exposed to a person, who was grounded, suggests an electrocution.

***EXAMINATION OF BODY AND SCENE (HIGH VOLTAGE)***

With High Voltage situations, direct measurements are not safe, unless the power is off. If possible, the parts of the circuit should be examined and photographed, but only if they are safely disconnected from the power source. Generally, high voltage electrocutions are fairly easily determined by an examination of the body. However, it is possible to have low amperage high voltage electrocutions that involve the interposition of a high resistance in the circuit with the person, or a lower impedance pathway to ground than through the person. Thus it is possible to have electrical deaths from ventricular fibrillation with a circuit which begins as 7680V but which has a tree branch between the person and the high voltage source. Tree branches have resistances that will reduce the power to fibrillatory ranges. Unfortunately, disputes often arise following high voltage electrocutions; many of the controversies may be eliminated, or at least minimized, by careful documentation and conservation of the physical evidence. Photography is important (digital, video, infrared, slides, x-rays). First, an overall photo of the scene should be attempted. If multiple exposures are required, make sure that a plan is drawn and is photographed. Next, medium range and close up photographs should be made of all relevant areas. As much as possible, identifying background items should be included to orient the photographs. Arc marks, burns, smoke and soot should be photographed including close up’s with scales of measure and arrows or other items to orient the photographs. You may need telephoto lenses, binoculars and spotting scopes for observations on distribution poles and wires.

Remember; photograph first, before moving or altering anything. First photos should orient the scene. Use the widest lens *you* have and take the picture from an elevated bucket truck if possible. Then intermediate; then close up. You really should have a macro lens for this work and a good flash.

However, the first rule of electrical scene work is *Primum Non Nocere-;* first do no harm (particularly to you). When doing this photography seek the assistance of skilled and experienced linemen certified in the voltages involved.

If there was transmission or distribution line contact, every effort should be made to secure the wire and anything associated with it. However, make certain that itis marked as far as orientation in at least two planes, up and down and North-South (East West) before removing. Photograph, mark, re-photograph, remove, re-photograph. Tag all evidence, package it properly and store it properly. Maintain a chain of custody.

**Low Voltage Worksheet**

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ date time of injury \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Identifying number \_\_\_\_\_\_\_

Witness \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Witness \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date time of examination \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Street \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (Latitude, Longitude) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

City, State, County \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Electric Pathway Source \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ground\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Source wire gauge \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_AWG Type (solid/stranded) \_\_\_\_\_\_\_\_\_\_ (Cu/Al)\_\_\_\_\_\_\_\_\_\_\_\_\_

Overload Protection (fuse/breaker) \_\_\_\_\_\_\_\_\_\_\_ Rating \_\_\_\_\_\_\_\_AMPS Status (Open/Closed) \_\_\_\_\_\_\_ Manufacturer\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Serial Number \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

GFCI(yes/no)\_\_\_\_\_\_\_ Manufacturer \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Serial Number\_\_\_\_\_\_\_\_\_\_\_ Status(Open/Closed/Unsure)\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Tested Internal(Pass/Fail/Unsure) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Tested External(Pass/Fail/Unsure) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Test-Equipment \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Outlet Manufacturer\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Type(3 / 2/ Other) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Rating \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_AMPS

Wiring (Proper, Hot-Ground reverse, Hot-Neutral reverse, Open Ground, Open Neutral, Other)\_\_\_\_\_\_\_\_\_\_  
X-Ray all cords and equipment \_\_\_\_\_\_\_\_\_\_\_\_  
Photograph all cords and equipment \_\_\_\_\_\_\_\_\_\_

**HIGH Voltage Worksheet**

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ date time of injury\_\_\_\_\_\_\_\_\_\_\_ Identifying number\_\_\_\_\_

Witness \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ date time of examination \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Street\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (Latitude, Longitude) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

City, State, County \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Electric Pathway Source \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ground\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Source wire gauge \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_AWG Type (solid/stranded) \_\_\_\_\_\_\_\_\_\_ (Cu/Al)\_\_\_\_\_\_\_\_\_\_\_\_\_

Overload Protection (fuse/breaker) \_\_\_\_\_\_\_\_\_\_\_ Rating \_\_\_\_\_\_\_\_AMPS Status (Open/Closed)\_\_\_\_\_\_\_ Manufacturer\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Serial Number \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Voltage of source wire \_\_\_\_\_\_\_\_\_VAC line to ground \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_VAC line to line \_\_\_\_\_\_\_\_\_\_\_

Wire Seized? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_date/time

Wire Marked and Photographed \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_date]/time

**AUTOPSY/Examination Recommended Techniques**

1. On living patients make certain that Creatine Phosphokinase (CPK or CK) is drawn and urine and blood myoglobin if indicated.
2. On living patients make certain an Electrocardiogram 12 lead is obtained and if abnormal, serially repeated daily until normal.
3. Retain the clothing, examine, photograph and preserve
4. Photograph all skin areas using 35mm film or equivalent resolution with proper lighting and rule of scale
5. On living patients, repeat the photographs of lesions at the approximately 24 hours and then weekly.
6. If the body can be examined at the scene, evaluation of rapid or geographic rigor mortis should be made.
7. An ordinary “complete autopsy” should be performed on the deceased.
8. An ordinary “complete toxicology” screen should be performed and the specimens preserved.
9. In addition, the following should be done:
   1. Any suspected electrical mark should be photographed with a scale, good lighting and with digital camera at close up magnification.
   2. Urine should be analyzed for myoglobin if there is any reddish discoloration.
   3. The tympanic membranes should be examined if there is any possibility of lightning. Any possibility of lightning should include thunderstorms in the area around the time of injury/death if the person is inside, and all outdoor possible electrocutions.
   4. Any ferrous metal in the effects of the deceased should be checked for magnetization.
   5. Formalin fixed tissue should be retained of all suspected electrical marks, and appropriate H&E stained sections prepared.
   6. Scanning Electro-Microphotography may be done on the formalin fixed tissue at a later time to detect metal disposition.
10. Make certain that all of the possible physical evidence related to the injury or death is seized, marked, x-rayed, photographed and preserved.

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1. Unfortunately, Franklin gave us a negative charge to electrons. He had a 50/50 chance of getting this correct, but did not. Thus electrons have a negative charge and the flow is from negative to positive, backwards from the ordinary way of thinking of things. [↑](#footnote-ref-1)
2. Incandescent lamps will run on either DC or AC current, as long at the periodicity of the alternating current is sufficient to preclude flickering. This is achieved by somewhere in the vicinity of 60 Hz, or at least Westinghouse thought so. In Europe, 50 Hz was adopted as the standard, which also seems not to flicker incandescent lamps [↑](#footnote-ref-2)
3. G. S. Ohm (1827). [*Die galvanische Kette, mathematisch bearbeitet*](https://web.archive.org/web/20090326094110/http:/www.ohm-hochschule.de/bib/textarchiv/Ohm.Die_galvanische_Kette.pdf) (PDF). Berlin: T. H. Riemann. Archived from [the original](http://www.ohm-hochschule.de/bib/textarchiv/Ohm.Die_galvanische_Kette.pdf) (PDF) on 2009-03-26. [↑](#footnote-ref-3)
4. Thus although the standard in the United States is 60 Hz this is actually 120 alternations per second. When reading older literature this can sometimes be confusing. [↑](#footnote-ref-4)
5. It should be noted that these amperage numbers are for skin-to-skin contact for humans. [↑](#footnote-ref-5)
6. At least in the United States and Canada which are prone to thunderstorms [↑](#footnote-ref-6)
7. Actually, unless there is a good pathway to ground, the downed power line may not have enough current flow through it to cause an overload or protective device to open. [↑](#footnote-ref-7)
8. The wiring is called the “Edison System” which is the most commonly used today in the United States and Canada, and is promoted by the NEC. There is an industrial delta system which is allowed by code, but which is becoming increasingly unusual. One of the features of the delta system is that there is a strong possibility that the neutral may be energized relative to ground. [↑](#footnote-ref-8)
9. Actually white and green are the colors that are fixed by code. All other colors may be hot. [↑](#footnote-ref-9)