5.5 COMPANY TASK-SPECIFIC ELECTRICAL SAFETY PROCEDURES

The Company's task-specific electrical safety procedures are just one component of the Company's site-specific safety procedures. The Site Superintendent, Safety Coordinator, and Foremen will formulate the electrical safety procedures to address the following job factors:

- Purpose of job task.
- Qualification and number of employees to be assigned.
- Hazardous nature and duration of each job task.
- Limits of approach.
- Testing devices.
- Task-specific safe work practices to be utilized.
- Personal protective equipment required.
- Insulating materials and tools involved.
- Special precautionary techniques.
- Electrical diagrams, plans, and specifications.
- Equipment details and manufacturers' installation instructions.
- Employee safety training requirements.

Copies of applicable sections of NFPA 70E, OSHA, consensus electrical safety codes/standards and pertinent parts of the Company's site-specific safety procedures, sketches or drawings of unique features should be attached.

6.0 ELECTRICAL HAZARDS

6.1 WHAT CAUSES ELECTRICAL HAZARDS

Construction electrical hazards can include poor work conditions, equipment or practices. It may also include careless, inadvertent actions made on the part of individuals. Avoiding hazards requires that the Foreman first identify the electrical safety hazard and take every reasonable precaution to provide crew members with a safe work environment. This includes the review of designs and specifications of the electrical components and equipment to be installed, checked-out, tested, started-up, or maintained.

Many electrical circuits do not directly pose serious shock or burn hazards by themselves. However, many of these circuits are found adjacent to circuits with potentially lethal levels of energy. Even a minor shock can cause a qualified electrician to rebound into a lethal circuit or cause the electrician to drop a tool into the circuit. Involuntary reaction to a shock may also result in bruises, bone fractures, and even death from collisions or falls.

6.2 THREE TYPES OF HAZARDS

There are three basic electrical hazards that cause injury and death - *shock, arc flash* and *arc blast*.

a. *Shock* - Current can pass through the human body's nervous or vascular systems, and across the surface of the body.

- The current required to light a 7.5 watt, 120-volt lamp, passing through the chest can cause death.
- Of those killed while working on voltages below 600 volts, half were performing work on "hot" energized equipment.
- Most electrocutions can be avoided with proper training, planning, job preparation, procedures and proper equipment.

b. *Arc Flash* - Extremely high temperature conductive plasma and gases.

- As much as 80% of all electrical injuries are burns resulting from an arc flash contact and ignition of flammable clothing.
- Arc temperatures can reach 35,000ºF - four times hotter than the sun's surface.

.1 second exposure to an arcing fault can cause incurable third degree burns to a person's body a distance of 2 feet. (Consider the damage to human skin exposed to near 35,000ºF.)
No material on earth can withstand temperatures of 35,000ºF without vaporizing.
Copper expands to 67,000 times its original volume, when vaporized, and can be inhaled into human lungs with debilitating or fatal results.

- Skin temperature of 200ºF for more than one-tenth of a second will cause incurable damage.
- An arc-flash in excess of 3,632ºF (2,000ºC) may extend to 10 ft.

c. *Arc Blast* - The pressure wave caused by the rapid expansion of gases and conducting material with high flying molten materials.

- An arc-blast may result in a violent explosion of circuit components and thrown shrapnel.
- At 25 kA, arc-blast energy can exert 480 lbs. of force on a person's body at a distance of 2 feet.
- The blast can destroy structures and knock electricians from ladders or across a room.

6.3 ELECTRICAL SHOCK

a. *Effects on the Human Body*

Qualified electricians are aware that there is always a danger of electrical shock, and how little current is required to cause injury, even death and the fact that the current drawn by a 7.5 watt, 120 volt lamp, passing across the chest, from hand to hand or foot, is enough to cause fatal electrocution.

The effects of electric current on the human body depend on:

- Circuit characteristics (current, resistance, frequency and voltage).
- Contact and internal resistance of the body.
- The current's pathway through the body, determined by contact location and internal body chemistry.
- Duration of contact.
- Environmental conditions (dry or wet) affecting the body's contact resistance.

Consider the human body as a resistor with a resistance R (hand to hand) of just 1,000 ohms. The voltage V will determine the amount of current passing through the body. While 1,000 ohms may appear to be rather low, even lower levels can be approached by someone having sweat-soaked cloth gloves on both hands, and a full hand grasp of a large energized conductor and a grounded pipe or conduit. Moreover, cuts, abrasions, or blisters on hands can negate skin resistance, leaving only internal body resistance to oppose current flow. A circuit in the range of 50 volts could be dangerous in this instance.

Ohm's Law: I (Amperes) = V (Volts)/R (Ohms)   Example: I = 480/1000   480 mA (or 0.480 amps)

Product standards consider 4 to 6 mA to be the safe upper limit for children and adults (hence, the reason a 5 milliamp rated GFCI circuit. *Note*: GFCI's do not protect against a line-to-neutral or a line-to-line shock.)

Electrical currents can cause muscles to lock up. This results in an inability to release the hand's grasp from the current source. This is known as the "let go" threshold current. At 60 Hz, most males have a "let go" limit above 9 milliamps and most females have a "let go" limit of about 6 milliamps. Sensitivity and potential injury will also increase with time. A victim, who cannot "let go" of a current source, is much more likely to be electrocuted than someone whose reaction removes them from the circuit more quickly. The victim, who is exposed for only a fraction of a second, is less likely to sustain an injury.

The most damaging path for electrical current is through the chest cavity and head. In short, any prolonged exposure to 60 Hz current of 10mA or more may be fatal. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milliamperes (mA). These injuries can cause fatalities resulting from either direct paralysis of the respiratory system, failure of the rhythmic heart pumping action, or immediate heart stoppage.

During fibrillation, the victim may become unconscious or he or she may be conscious, deny needing help, walk a few feet and then collapse. Death may occur within a few minutes or take hours.

Prompt medical attention is needed for anyone receiving electrical shock. Many of these victims can be saved provided they receive proper medical treatment including cardiopulmonary resuscitation (CPR) quickly.

Electrical shöck injuries usually have entrance and exit wounds, coagulated areas and may have some charring, or these areas may be missing having exploded away from the body due to the level of energy present. The smaller the area of contact, the greater the heat produced. For a given current, damage in the limbs may be the greatest, due to the higher current flux per unit of cross-sectional area.

Within the body, the current can burn internal body parts in its path. This type of injury may be difficult to diagnose, as the only initial sign of injury is the entry and exit wounds. Damage to the internal tissues, while not apparent immediately, may cause delayed internal tissue swelling and irritation. Prompt medical attention will minimize possible loss of blood circulation and the potential for amputation of the affected extremity as well as avoid death.

The Effects of Electrical Current on the Body at 60Hz Alternating Current

	Men	*Women*
1. Tingling sensation	1.0 mA	0.7 mA
2. Slight shock	1.8 mA	1.2 mA
3. Painful shock - can "let go"	9 mA	6 mA
4. Painful shock - cannot "let go"	16 mA	10 mA
5. Severe shock	23 mA	15 mA
6. Possible ventricular fibrillation - 3 second shock	100 mA	100 mA
7. Possible ventricular fibrillation - 1 second shock	200 mA	200 mA
8. Heart muscle activity stops	500 mA	500 mA
9. Tissue and organs burn	1500 mA	1500 mA

b. *Safe Approach Distances*

Several standards offer guidance regarding safe approach distances to minimize the possibility of shock from exposed electrical conductors of different voltage levels. The most recent and probably the most authoritative guidance is presented in NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces - 2000 Edition in Part II, Appendix A, Limit of Approach on page 70E-67.

6.4 ARC FLASH HAZARDS

Recent studies of reported electrical injuries have indicated that as many as 80% of documented injury cases were burns result from exposure to radiant energy from electrical arcs. In addition, each year more than 2,000 people are admitted to burn centers with severe electrical burns. NFPA 70E was the first consensus standard to identify arc flash as a hazard to be dealt with by electrical professionals. OSHA than issued their 29 CFR 1910.269 standard, which contained some recognition of the existence of a potential injury from an electrical arc. While all electricians are aware of the hazards of electrocution, many construction electricians are not aware of the extreme dangers posed by electrical arc flash and arc blast.

When short circuits or electrical faults happen, high-energy power sources can seriously injure electrical personnel. The heat created by an electric arc can lead to extensive burns or even a fatality. An arc can produce temperatures of more than 15,000ºF with more than 80% of the thermal radiation present to induce burns. Radiated thermal energy associated with an arc not only generates exceptionally high heat, but also creates other destructive energy. This energy is often very intense, resulting in high thermal radiation, high noise levels, explosive expansion of surrounding air, and decomposition of conductors and metal components. Tests simulating an arc flash during the performance of routine work on some motor control panels, starter units and busways have resulted in the following data:

Measured Indicators	Findings
Temperatures (Hands & Face)	86ºF to >437ºF
Infrared:	302ºF to 392ºF
Pressure (Chest)	108 lbs. sq. ft. to > 2160 lbs. sq. ft.
Sound	133dB @ 2ft to 164 dB @ 2ft.

These flash temperatures take on more meaning if one considers what happens when the heat comes into contact with exposed body parts or clothing. At the higher temperature levels, copper is vaporized and deteriorating electrical equipment produces streams of molten metal droplets. The droplets then contact skin and clothing at temperatures that can approach 1,800°F.

The pressure wave created by the heated, expanding air has at times saved lives by instantaneously heaving victims from the source of the heat generated by the high-energy arc fault. However, most of the time the force causes other injuries including impacting other objects, causing falls from platforms, and damaging hearing. Pressure as low as 108 lbs. per square foot could cause an employee balanced on a ladder to fall off. Higher pressures could send a person hurtling several yards or blow a panel cover into a worker at flash force.

a. *Burns*

Burns suffered in electrical accidents are of three basic types:

- Electrical burns - tissue damage (whether skin deep or deeper) occurs, because the body is unable to dissipate the heat from the current flow. Typically, electrical burns are slow to heal.
- Arc burns - caused by electric arcs and are similar to heat burns from high temperature sources. Temperatures generated by electric arcs can melt nearby material, vaporize metal in close vicinity, and burn flesh and ignite clothing at distances of 10 ft. or more.
- Thermal contact burns - normally experienced from skin contact with the hot surfaces of overheated electric conductors or clothing once ignited.

The human body survives in a relatively narrow temperature range around 97.7ºF. Studies show that when the skin temperature is as low as 110ºF, the body's temperature equilibrium begins to break down in about 6 hours. At 158ºF, only one-second duration is sufficient to cause total cell destruction. Exposure of the skin to temperatures of 200ºF for more than one tenth (1/10th) of a second will cause incurable "third degree" burns.

b. *Skin Temperature Tolerance Relationship*

Skin Temperature	Time of Skin Temperature	Damage Caused
110º F	6 hrs.	Cell breakdown starts
158º F	1 sec.	Total cell destruction
176º F	0.1 sec.	Curable burn
200º F	0.1 sec.	Incurable burn

c. *High Noise Hazard*

The resulting noise produced by the flash is also a problem, commonly causing decibel readings in the 164dB range. As a comparison, the sound level generated by a siren at 100 ft. is 135dB; a jet plane taking off is about 125dB; and a motorcycle accelerating can hit levels near 110dB. This sudden impact noise can have a detrimental effect on any personnel working nearby.

d. *Eyesight Hazard*

Although there is little data currently available to indicate the actual consequences, it should also be remembered that the high levels of ultraviolet radiation produced from an arc flash could lead to damage to an employee's eyes.

e. *Pre-Job Planning Factors*

- The arcing ground fault is very unpredictable, producing different results under the same test conditions. For example, the arcing fault event will not always create an arc blast.
- The arcing fault can be a real hazard in actual work conditions, where a phase to ground contact can soon become phase to phase as insulation barriers are decomposed physically as well as electrically.
- If the available current and/or duration of time of a fault event is limited, the potential for damage to personnel and equipment is reduced.
- Power system design and equipment that diminish available fault current through smaller transformers, high impedance transformers, reactors, and fault isolation through fault-current limiting overcurrent devices will considerably decrease worker exposure to injury and cut down on equipment downtime.
- Additional consideration must be taken by Foremen in selecting crew members' personal protective equipment, when there are arc fault hazard exposures.
- More training on arc fault and arc blast hazards will need to be provided to Foremen and employees.

The Company's safety & loss control manual and site-specific safety procedures should comply with the NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces - 2000 Edition Part II, Appendix A, Limit of Approach guidelines to help protect Foremen and employees against arc flash and arc blast hazards.

6.5 ARC BLAST HAZARDS

Most qualified employees are aware of stories of a piece of an electrical equipment that blew up when it was turned on, but unless they have witnessed first-hand an actual arc flash and resulting arc blast wave, it is difficult to grasp the amount of physical force and the devastating impact on the injured electricians and their family members.

High-energy arcing faults generate a tremendous amount of heat. This heat causes melting, vaporization and expansion of conducting material as well as expansion of air creating a pressure wave. This pressure wave blast is a serious electrical hazard that is often not recognized. While it has been known to save many lives by rapidly hurling victims away from the arc heat source, more often it causes serious falls and other injuries. Physical injuries include:

- Impact with objects.
- Hearing damage.
- Concussion.

Flying shrapnel from damaged electrical and mechanical components, as well as molten conductive metals, may cause injuries. Individuals in close proximity to these severe pressures are also likely to suffer short-time loss of memory or may not remember the intense explosion of the arc itself.

The main sources of this pressure wave coming from an electrical arc include:

- Heating of the air passage of the arc through it (much like lightning).
- Expansion from melting, boiling and vaporizing of the conducting metal.

expands by a factor of 67,000 times as it vaporizes, in the same way that water expands about 1,670 s when it becomes steam. This accounts for the expulsion of near-vaporized droplets of molten metal in an arc. It also generates plasma (ionized vapor) that moves outward from the arc for distances proportional to the arc energy. This heat, with the addition of molten metal droplets emanating from the arc, can cause serious burns to nearby crew members.

Another consequence of arcs is damage to equipment and nearby structures. One study found that the pressure from a 100 kA, 10 kV arc reached a pressure level of about 400 lb/ft^2 at a distance of just over three feet. This force could easily destroy a conventional wall at a distance up to 40 feet away. A smaller 25 kA arc blast could destroy a wall or equipment at a distance of nearly 10 feet. This same 25 kA arc can create as much as 160 lb/ft^2 of pressure on an individual two feet from the arc source. This would place 480 lbs. of force upon an average person's body. It is certainly enough energy to knock an electrician from a ladder or throw him/her across the room.

This level of pressure has also been found to cause ear damage. At a 2-foot distance from an arc blast the noise level is 142 dBA. OSHA noise standard requires the wearing of hearing protective devices starting at 85/90 dBA noise levels. Company employees should be issued earmuffs for hearing protection, since the use of the disposal insert hearing protection devices may expose employees to these ear protection inserts being driven into their ears by the arc blast pressure wave.

Electrical equipment must sometimes be worked on while energized. This means that Company employees could be exposed to energized circuits during a fault. The risk of a fault occurring while employees are in close proximity to equipment must be taken into account by the Foreman when conducting the job hazard survey and crew members' safety requirements addressed in the job task electrical safety action plan.

7.0 WORK SITE ACCESS CONTROL

7.1 APPROACH BOUNDARIES

Foremen can follow the NFPA 70E Table 2-1.3.4 - 2000 Edition to set up approach distances to exposed energized electrical conductors (see page 22). This table identifies boundaries for limited approach, restricted approach and prohibited approach. The table establishes satisfactory distances between a qualified and unqualified person and conductors that have not been placed in an electrically safe work condition.

The Limited Approach Boundary (columns 2 and 3) is the limit of approach distance for unqualified persons to a live part. In concept, unqualified people are less capable of recognizing a shock and flash hazard. Therefore, these site workers should remain at a safer distance from open, energized conductors. When there is a need for an unqualified person to cross the limited approach boundary to perform a minor task, or look at equipment, a qualified person should advise him/her of the possible hazards and ensure the unqualified person is safeguarded. Under no circumstances should an unqualified person be permitted to cross the restricted approach boundary.

The Exposed Movable Conductor (column 2) is intended to mean that either the conductor might move (as in an overhead line) or the worker might move (as in an articulating support platform). A fixed circuit part (column 3) refers to a task where the conductor is not expected to move, such as, within a unit substation.

The Restricted Approach Boundary (column 4) is the closest distance for an "unqualified person". Under no circumstances should an unqualified person be permitted to cross the restricted approach boundary. To cross this boundary, a person must:

- Be a qualified person.
- Have an approved plan.
- Use personal protective equipment approved for the conditions.
- Position his or her body in a way that minimizes risk of inadvertent contact.