EFCOG Best Practice - #48

Electrical Severity Measurement Tool Rev. 06

Facility: DOE Complex

Best Practice Title: Electrical Severity Measurement Tool (ESMT)

Points of Contact:

Tommy Martinez, LANL tmartinez@lanl.gov
Richard Waters, INL richard.waters@inl.gov
Jennifer Martin, PNNL jennifer.l.martin@pnnl.gov
Heath Garrison, NREL heath.garrison@nrel.gov
Drew Thomas, HMIS drew_a_thomas@rl.gov

Brief Description of Best Practice: The purpose of the Electrical Severity Measurement Tool (ESMT) is to provide a standardized approach for tracking and trending personnel exposures to hazardous electrical energy. Specifically, the tool provides a consistent method to score the severity of exposure and a means to measure performance over time by tracking an Electrical Severity Index (ESI).

Why the best practice was used: Prior to 2006 there was no standardized approach to measure and monitor the performance of an individual electrical safety program. Since 2005 a host of electrical safety best practices have been created as part of an overall electrical safety improvement plan within the Department of Energy (DOE). The ESMT was created to provide a means to measure performance over time as part of the electrical safety improvement plan.

What are the benefits of the best practice:
This Best Practice provides DOE sites with a standardized means to actively assess their electrical safety performance over time and evaluate the need for corrective actions when performance does not meet expectations.

What problems/issues were associated with the best practice: No Standardized means within the DOE complex to assess electrical safety program improvement.

How the success of the Best Practice was measured: The ESMT has been used by a multitude of sites since 2006 and is currently being used at nineteen sites. The ESMT has also undergone five revisions since 2006 to make improvements based on user feedback and changes to electrical safety standards. The revisions have improved severity scoring consistency and clarified use of the tool in areas that were open to interpretation.

Description of process experience using the Best Practice: The ESMT has been successfully implemented at many DOE sites and is being effectively used to monitor and track electrical safety performance.

Revision ID: 6.
Effective Date: 06/27/2024.

Electrical Severity Measurement Tool

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Electrical Severity Measurement Tool

1. Purpose

1.1 This tool is intended to measure the severity of exposure to hazardous electrical energy based on an evaluation of contributing factors. The factors include electrical hazard, environment, shock proximity, arc flash proximity, thermal proximity, use of personal protective equipment and any resulting injury(s) to affected personnel.

2. 2.0 Scope

2.1 This tool establishes a standardized approach for tracking and trending exposures to hazardous electrical energy. Specifically, this tool provides a consistent method to measure the severity of personnel exposure to hazardous electrical energy and may be used to measure performance over time. The Electrical Severity (ES) calculation is to be performed by an Electrical Safety Subject Matter Expert (SME) with a working knowledge of NFPA 70E.

3. Limitations

3.1 This tool is not intended to evaluate events that do not involve personnel exposure to hazardous electrical energy.

NOTE 1: *Discoveries made by absence of voltage/energy verifications in the process of establishing an electrically safe work condition does not necessarily indicate exposure to hazardous energy as defined by NFPA 70E. Although NFPA 70E considers an incomplete isolation an exposure, it is possible that an incomplete isolation does not expose personnel to hazardous electrical energy. If an incomplete isolation or other event involves a conductor or circuit part that is suitably **insulated**, **isolated**, or **guarded** (See def. NFPA 70E) then for the purposes of this tool it is not **exposed** (See def. NFPA 70E) and therefore is not a shock hazard.*

3.2 This tool establishes a metric that can be consistently applied to allow an organization to compare relative performance against itself. Comparison of one organization's performance to another is considered inappropriate without further normalization due to anomalies and variables that may exist in work scope (e.g., D&D vs. Research), environmental conditions, etc.

4. User Guidelines

4.1 The tool is not intended to cover all factors that contribute to an electrical safety event or be the sole measure of the significance of an electrical safety event. For example, the tool does not consider work control (except establishing an electrically safe work condition and wearing proper PPE), equipment condition of maintenance, additional hazards (e.g., confined space, radiological), other issues (e.g., lack of training, lack of engineering controls), and other similar management concerns. The tool is intended to give a relative measure of the severity of personnel exposure to hazardous electrical energy including injuries sustained from the event. It does not consider "What if" questions or scenarios that did not occur in the event.

4.2 The tool is intended to give a quantitative, reproducible measure of the severity of personnel exposure to hazardous electrical energy. Ideally, the tool should give the same result regardless of the user.

NOTE 2: *Consider only the data required by the Electrical Severity (ES) Equation. If the event involves exposure to more than one source of hazardous electrical energy the electrical severity of the event is the one that scores highest.*

4.3 The tool produces a medium significance score for a dry hand 120 VAC shock. (See example in Appendix 3) There are varying opinions on this result, and considerable thought went into the tool development and pilot results. Consider that, across the United States, there are estimated to be hundreds of dry hand 120 VAC shocks daily while performing everyday activities such as inserting a plug into a receptacle, especially across the fingers of one hand. It is very rare that such shocks result in injury or fatality in the workplace, but it is important to record them to monitor for adverse trends that raise concerns. The tool does consider the factors that can cause such shocks to be harmful or fatal, namely a wet environment.

4.4 Equipment failures that contain the electrical hazard and do not result in personnel injury, fatality, or exposure to an electrical hazard score a severity of zero. If electrical energy escapes, such as when no equipment ground is in place, or inadequate arc flash/blast containment, which results in personnel exposure to an electrical hazard or injury then the tool may be utilized to measure the severity of the event.

NOTE 3:

- *Hearing protection is required to be worn within the arc flash boundary. There is no boundary for coincidental noise generated from an arc blast when personnel are not interacting with the equipment.*
- *Equipment failures may not result in personnel being exposed to an electrical hazard.*

5. Electrical Severity (ES)

5.1 Each electrical event is scored based on the following factors:

- Electrical Hazard (See Appendix 1 for the classification of electrical hazard(s))
- Environment
- Shock Proximity
- Arc Flash Proximity
- Thermal Proximity
- Injury
- PPE/Equipment Mitigation

Electrical Severity (ES) is calculated using the following equation:

Electrical Severity (ES) = (Electrical Hazard) * (1 + Environment + Shock Proximity[1] + Arc Flash Proximity[1,2] + Thermal Proximity[1,2]) * (Injury)

[1]When the proper Personal Protective Equipment (PPE) is used while performing the work then these factors may be reduced to zero (refer to section 5.7 PPE Mitigation).

[2]An electrical event cannot have both an Arc Flash Proximity Factor and a Thermal Proximity Factor, as the presence of an arc flash hazard includes the thermal hazard.

6. Electrical Hazard

6.1 The Electrical Hazard is determined by classifying the source(s) of electrical energy personnel were exposed to during an event and then assigning a value based on the Electrical Hazard Classification Charts[3] found in Appendix 1 of this document and color coded as shown in Table 1.

[3]The hazard classification charts cover six broad categories, ac 50/60 Hz (Chart 2), dc (Chart 3), capacitors (Chart 4 and Chart 5), batteries (Chart 6), rf (Chart 7) and sub-rf (Chart 8). These charts, taken collectively, represent almost all of the electrical hazards found in electrical equipment. Consequently, all category classes should be considered when identifying the hazards associated with any piece of electrical equipment. A single piece of equipment may have multiple electrical hazard classifications, and personnel may have been exposed to a combination of electrical hazards. To aid hazard identification, each chart has cross-reference notes. For example, the dc chart has cross-reference notes to capacitance, battery, and ac 50/60 Hz. Event evaluators should have a thorough understanding of the equipment involved in the electrical event. Consulting manuals and schematics and speaking with factory service representatives and SMEs are ways to ensure that all of the hazards are fully understood and that all the pertinent areas/classifications are considered.

Table 1. Electrical hazard classification color codes.

Electrical Hazard	green - no hazard	0
	yellow - moderate hazard	10
	red - high hazard	50
	maroon - very high hazard	100

7. Environment

7.1 The Environment is determined by analyzing the environmental condition found in the area at the time of the event. The environment can play a major role in the severity of an event, especially where shock is a concern. Human skin resistance can vary considerably from a dry location to one that contains conductive fluids (e.g., end mill misters present in a machine shop).

NOTE 4: *The environmental condition for an event is somewhat subjective, and the condition used in the electrical severity score is based on an evaluation of the area where and when the event occurred and is determined at the discretion of the SME. Generally, Dry is indoors, Damp is outdoors, Wet is when standing water, snow conditions, or other conductive liquids contribute to the severity of the event. Examples: Outdoors can be dry in arid climates and certain snow conditions, indoors can be damp or wet, in work conditions involving conductive fluids or high humidity.*

Table 2. Environment

Environmental Condition	Dry	0
	Damp	5
	Wet	10

8. Shock Proximity

8.1 Shock Proximity is determined by performing a Shock Risk Assessment. Determine whether the energy source exceeds the shock hazard thresholds in Table 3, then determine the approach boundaries in Table 4 (ac 50/60 Hz) or Table 5 (dc), from NFPA 70E. Assign the shock proximity based on the approximate distance of the personnel to the exposed hazardous energy source. All dimensions are distance from the exposed energized part to the personnel.

Table 3. Thresholds for defining shock hazards.

Source	Includes	Thresholds
ac	50/60 Hz	≥ 50 V and > 5 mA
dc	all	> 100 V and > 40 mA (short circuit)
Capacitors	all	< 100 V and > 100 J, or > 100 V and > 1 J, or > 400 V and > 0.25 J
Batteries	all	> 100 V
Sub rf	1 Hz to 3 kHz	> 50 V and > 3 mA
rf	3 kHz to 100 MHz	A function of frequency

1. It is possible for personnel to be exposed to more than one shock hazard at any given location.
2. There may be other electrical hazards below the shock thresholds that pose a hazard to personnel e.g., a thermal burn hazard. Refer to the Hazard Classification Charts in Appendix 1.
3. Injuries may result from startle reactions due to contact with energized components, even though there is no shock hazard, especially a high-voltage, low-energy shock.
4. Shock and burn hazards from induced and contact rf currents become negligible above 100 MHz.

8.2 Shock Boundary Analysis for 50/60 Hz

8.2.1 The determination of the Limited and Restricted Shock Boundaries, is based on the nominal system voltage range, phase to phase with the distance being from the exposed energized electrical conductor or circuit part to personnel. Table 4 is extracted from the 2021 NFPA 70E. The notes help to explain the content and use of the table.

Table 4. Shock protection approach boundaries to exposed energized electrical conductors or circuit parts for alternating current 50/60 Hz.

Nominal System Voltage Range, Phase to Phase[1]	Limited Approach Boundary		Restricted Approach Boundary, Includes Inadvertent Movement Adder
	Exposed Movable Conductor[3]	Exposed Fixed Circuit Part	
< 50	Not specified	Not specified	Not specified
50–150[5]	3.0 m (10’0”)	1.0 m (3’6”)	Avoid contact
151–750	3.0 m (10’0”)	1.0 m (3’6”)	0.3 m (1’0”)
751–15 kV	3.0 m (10’0”)	1.5 m (5’0”)	0.7 m (2’2”)
15.1–36 kV	3.0 m (10’0”)	1.8 m (6’0”)	0.8 m (2’9”)
36.1–46 kV	3.0 m (10’0”)	2.5 m (8’0”)	0.8 m (2’9”)
46.1–72.5 kV	3.0 m (10’0”)	2.5 m (8’0”)	1.0 m (3’6”)
72.6–121 kV	3.3 m (10’8”)	2.5 m (8’0”)	1.0 m (3’6”)
138–145 kV	3.4 m (11’0”)	3.0 m (10’0”)	1.2 m (3’10”)
161–169 kV	3.6 m (11’8”)	3.6 m (11’8”)	1.3 m (4’3”)
230–242 kV	4.0 m (13’0”)	4.0 m (13’0”)	1.7 m (5’8”)
345–362 kV	4.7 m (15’4”)	4.7 m (15’4”)	2.8 m (9’2”)
500–550 kV	5.8 m (19’0”)	5.8 m (19’0”)	3.6 m (11’8”)
765–800 kV	7.2 m (23’9”)	7.2 m (23’9”)	4.9 m (15’11”)

1. All dimensions are distance from exposed energized electrical conductor or circuit part to worker.
2. For single-phase systems above 250V, select the range that is equal to the system’s maximum phase-to-ground voltage multiplied by 1.732.
3. Exposed Movable Conductor describes a condition in which the distance between a conductor and a person is *not* under the control of the person. The term is usually applied to overhead line conductors supported by poles or structures.(e.g., an overhead transmission line conductor or service drop).
4. Exposed Fixed Circuit Part means the bare conductor or other circuit part is stationary and will not move. This is the most common Limited Approach Boundary value used.
5. This includes circuits where the exposure does not exceed 120V.

8.3 Shock Boundary Analysis for DC

8.3.1 Table 5 gives approach boundaries to exposed energized electrical conductor or circuit part for dc, which is applicable to dc circuits, batteries, and capacitors. Table 5 is extracted from the 2021 NFPA 70E. The notes help to explain the content and use of the table.

Table 5. Shock protection approach boundaries to exposed energized electrical conductors or circuit parts for direct current voltage systems.

Nominal Voltage[3] Conductor to Ground	Limited Approach Boundary		Restricted Approach Boundary, Includes Inadvertent Movement Adder
	Exposed Movable[4] Conductor	Exposed Fixed[5] Circuit Part	
<100	Not specified	Not specified	Not specified
100–300	3.0 m (10’0”)	1.0 m (3’6”)	Avoid contact
301–1 kV	3.0 m (10’0”)	1.0 m (3’6”)	0.3 m (1’0”)
1.1–5 kV	3.0 m (10’0”)	1.5 m (5’0”)	0.5 m (1’5”)
5.1–15 kV	3.0 m (10’0”)	1.5 m (5’0”)	0.7 m (2’2”)
15.1 kV–45 kV	3.0 m (10’0”)	2.5 m (8’0”)	0.8 m (2’9”)
45.1 kV–75 kV	3.0 m (10’0”)	2.5 m (8’0”)	1.0 m (3’6”)
75.1 kV–150 kV	3.3 m (10’8”)	3.0 m (10’0”)	1.2 m (3’10”)
150.1 kV–250 kV	3.6 m (11’8”)	4.0 m (11’8”)	1.6 m (5’3”)
250.1 kV–500 kV	6.0 m (20’0”)	6.0 m (20’0”)	3.5 m (11’6”)
500.1 kV–800 kV	8.0 m (26’0”)	8.0 m (26’0”)	5.0 m (16’5”)

1. In alignment with NFPA 70E 2021 Section 350.9, the hazard classification charts in appendix 1 the threshold for a direct current shock is set at > 100 Vdc and > 40 mA’s.
2. All dimensions are distance from an exposed energized electrical conductor or circuit part to personnel.
3. Voltage is conductor to ground.
4. Exposed Movable Conductor describes a condition in which the distance between a conductor and a person is *not* under the control of the person. The term is usually applied to overhead line conductors supported by poles or structures.(e.g., an overhead transmission line conductor).
5. Exposed Fixed Circuit Part means the bare conductor or other circuit part is stationary and will not move. This is the most common Limited Approach Boundary value used.

8.4 **Shock Proximity**

Table 6. Shock Proximity

Outside Limited Approach Boundary	0
Within Limited Approach Boundary	1
Within Restricted Approach Boundary	3
Tool/equipment contact with energized conductors or circuit parts	5*
Personnel contact with energized conductors or circuit parts	10

* If personnel contact hazardous electrical energy using an insulated (non-voltage rated) article such as a tool or remain inside the cab of heavy equipment such as a track hoe and do not receive a shock, then the worker was exposed but to a lesser degree than contact with a bare hand.

8.5 Arc Flash Proximity

8.5.1 Arc Flash Proximity is determined by performing an Incident Energy Analysis using one of the methods as described in NFPA 70E. The method used cannot differ from the method that the institution is using to determine Personal Protective Equipment (PPE) to protect against arc flash. The approximate distance of the personnel to the energy source is used again to determine the arc flash hazard.

NOTE 5: *An event cannot have both an Arc Flash Proximity and a Thermal Proximity.*

8.5.2 The ac arc flash hazards in Table 7 are based on IEEE 1584, which describes when an arc flash hazard is present. The balance of the table is based on IEEE paper ESW2009-23 and EFCOG Best Practice #232.

Table 7. Thresholds for arc flash hazards

Source	Includes	Thresholds
ac three-phase	50 and 60 Hz	An arc flash hazard to personnel exists when an arc flash risk assessment determines that the Incident Energy (IE) exposure level at the working distance is ≥ 1.2 cal/cm^2. The likelihood of an arc flash occurrence while interacting with electrical equipment is dependent upon several factors. Engineering evaluation per IEEE-1584 and EFCOG Best Practice #232 is necessary to determine the potential and level of arc flash exposure to personnel. **NOTE:** 120 VAC single phase systems are unlikely to result in an arc flash incident. [IEEE-1584, EFCOG BP #232]
dc	all	150-400 V and >500 A (short circuit) Or > 400 V and > 500 A
Capacitors	all	> 100 V and > 100 kJ
Batteries	all	> 100 V and > 500 A
sub rf	1 – 3 kHz	> 250 V and > 500 A
rf	NA	Not Applicable (NA)

Table 8. Arc Flash Proximity

Outside Arc Flash Boundary	0
Inside Arc Flash Boundary (No Arc Flash)	5
Inside Arc Flash Boundary (Arc Flash)	10

8.6 Thermal Proximity

8.6.1 Thermal Proximity is determined by performing a Thermal Hazard Analysis based on whether a conductive media came into contact with an energized source. The hazard to personnel in this case is a thermal one such as a burn received from holding a wrench or wearing conductive jewelry that came into contact with a high current energy source. Thresholds for thermal burns are noted in Table 9. The Thermal Proximity results from personnel contact with the conductive media and the power available to the contacting media.

Table 9. Thresholds for thermal burn hazards.

Source	Includes	Thresholds
dc	all	< 100 V and > 1000 W
Capacitors	all	< 100 V and > 100 J
Batteries	all	< 100 V and > 1000 W
Sub rf	1 – 3 kHz	< 50 V and > 1000 W
rf	NA	NA

Table 10. Thermal Proximity

Thermal Proximity	Power	
	1-30 kW	>30 kW
No contact	0	0
Contact	3	10

8.7 Injury

8.7.1 Injury is determined by the type of injury that occurred to the personnel involved in the event.

NOTE 6: *If an event involves multiple injuries to a person such as hearing loss and third degree burn that affects 5% of the body or more select the higher injury factor i.e., (20) for 3rd degree burn versus (7) for hearing loss.*

Table 11. Injury

None	1
Shock (no fibrillation) or burn (1st degree)	3
Burn (2nd degree)[1]	5
Permanent disability (hearing loss)[3]	7
Shock resulting in effects on heart[2]	10
Permanent disability due to burn (3rd degree)[1]	20
Fatality	100

[1]Assign the value if the burn injury is affecting more than five percent of the body surface.

[2]Effects on the heart are determined through medical evaluation by a physician.

[3]Assign the value if the standard threshold shift (hearing loss) is ≥ 10 dB at 2000, 3000, and 4000 Hz in one or both ears.

8.8 PPE/Equipment Mitigation

8.8.1 Appropriately rated and donned PPE and/or equipment reduces the associated factor(s) to zero when used. Appropriately rated PPE and equipment is designed and manufactured to protect the worker from the electrical hazard associated with that factor and has been tested and certified (if applicable) to do so. The type and ratings (if applicable) of PPE must be determined.

NOTE 7: *Meltable fibers are not permitted to be worn in the fabric underlayers with the exception of incidental amounts of elastic found in underwear and socks. Reduction of the arc flash hazard factor to zero cannot be applied if meltable fibers are known or discovered to have been worn in the underlayers. Examples of meltable fibers include but are not limited to acetate, nylon, polyester, polypropylene, and spandex.*

8.8.2 GFCI's are an engineering control that operate in an electrical event reducing personnel exposure to hazardous electrical energy. If a GFCI is verified to be functioning correctly after tripping in an electrical event, the shock hazard can be reduced to zero.

Table 12. PPE/Equipment Mitigation.

Correct for Environment hazard	Reduces the Environment to 0.
Correct for Shock hazard	Reduces the Shock Proximity to 0.
Correct for Arc Flash hazard	Reduces the Arc Flash Proximity to 0.
Correct for Thermal hazard	Reduces the Thermal Proximity to 0.

8.9 Electrical Severity

8.9.1 The Electrical Severity (ES) equation generates scores from 0–310,000. This range provides an exponentially rising severity that, when based on a logarithmic scale, breaks down into three categories of significance: high, medium, and low, as shown in Table 13.

Table 13. Electrical Severity Categories.

Category	Electrical Severity (ES)
High	≥ 1750
Medium	31 – 1749
Low	0 - 30

8.9.2 Low category scores (0–30) include events where the electrical hazard classification is low and may not pose a risk of electrical injury to personnel such as a static shock or a shock that occurs on a circuit protected by a functioning GFCI (limited current and duration). These events must be thoroughly evaluated by an SME to determine if personnel were exposed to hazardous electrical energy or not. If personnel are not exposed to hazardous electrical energy, then the event may score between 0-30 but it is not considered an electrical safety event.

9. Electrical Severity Index (ESI)

9.1 The Electrical Severity Index (ESI) performance metric was developed to normalize electrical events against organizational work hours.

9.2 The ESI should be calculated monthly.

9.3 The rolling twelve month ESI average should also be calculated monthly to limit the effect of small period fluctuations.

9.4 Both the monthly ESI and the rolling twelve-month ESI average should be tracked graphically.

9.5 The ESI is calculated when each event is weighted for severity and then averaged with other events to obtain a result representing performance.

9.6 The Electrical Severity (ES) is used as the weighting factor for each event in the Electrical Severity Indicator (ESI) metric below.

NOTE 8: *The ESI uses a similar approach to calculating OSHA Recordable Case Rate RCR (source of work hours is same). It assigns a numerical weighting factor to each event, the more risk or consequence associated with the event, the higher the weighting factor. ES = the Electrical Severity calculated for a specific event.*

$$ESI = \frac{200{,}000\left[(ES_{event1}) + (ES_{event2}) + (ES_{eventN})\ldots\right]}{(\text{hours worked})}$$

where:

ESI = Electrical Severity Index

200,000 = constant (man hours for a 100 person work force for a full year)

event # = electrical safety event label

hours worked = actual work hours for work population

9.7 An evaluation should be performed to determine if continuous improvement is being achieved.

Appendix 1

Electrical Hazard Classification Charts

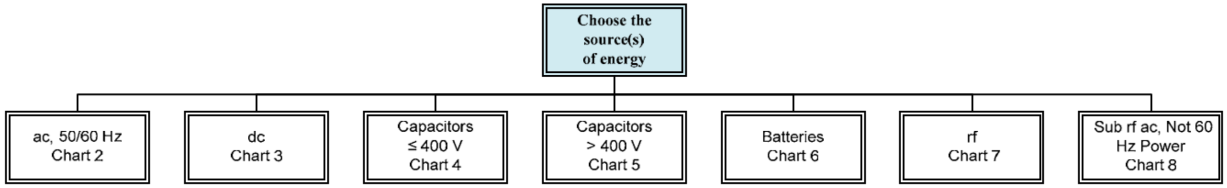

Chart 1. Overview of Electrical Hazards

These charts, taken collectively, represent most of the electrical hazards found in electrical equipment. Consequently, all charts should be considered when identifying the hazards associated with any piece of electrical equipment. Where a single piece of equipment has multiple energy sources, the worker may have been exposed to a combination of hazards. To aid hazard identification, each chart has cross-reference notes. For example, the dc chart (Chart 3) has cross-reference notes to capacitance, battery, and 50/60 Hz hazard tables. Event evaluators should have a thorough understanding of the equipment involved in the electrical event. Referencing manuals and schematics, speaking with factory service representatives, and consulting with SMEs are methods to ensure that all of the hazards are fully understood and that all of the pertinent sources are considered. Some guidelines on the use of the hazard classification charts are given. The guidelines are general, and there may be exceptions to each one:

- If you do not understand these guidelines and your equipment, consult an electrical SME.
- Most all equipment gets its power from the facility (Chart 2) or batteries (Chart 6). Thus, equipment starts with one of those sources. Exceptions are wind and solar generated power sources. You should use the appropriate ac or dc chart.
- Most small appliances, hand tools, and portable electrical equipment plugs into receptacles. In general, if you can carry it, most likely it uses 120 to 240 VAC.
- Larger equipment may use up to 480 VAC.
- Direct current power supplies may have hazards associated with 50/60 Hz (chart 2), dc (Chart 3), and capacitance (Charts 4/5), therefore, all hazards must be evaluated.
- Uninterruptable power supplies may have hazards associated with batteries (Chart 6), and/or 50/60 Hz power (Chart 2), since they are usually powered by a 50/60 Hz source (input) and produce 50/60 Hz power (output).

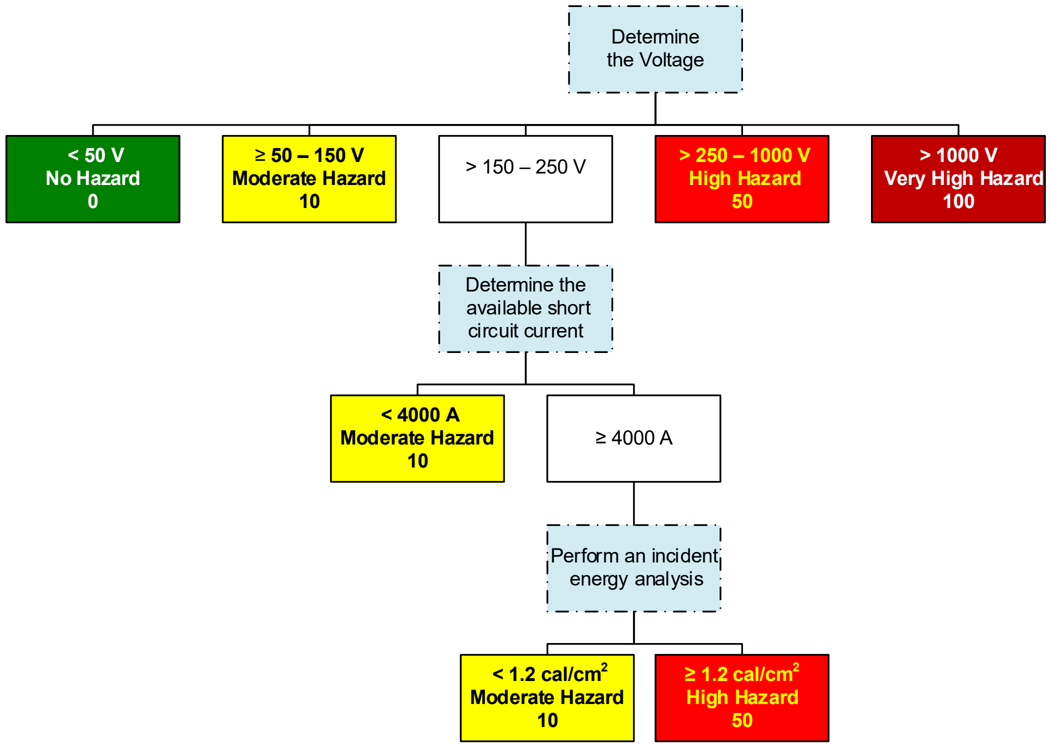

Chart 2.ac, 50/60 Hz.

NOTES:

- The likelihood of an arc flash occurrence while interacting with electrical equipment is dependent upon several factors. Engineering evaluation per IEEE-1584 and EFCOG Best Practice #232 is necessary to determine the potential and level of arc flash exposure to personnel.
- 120 VAC single phase systems are unlikely to result in an arc flash incident. [IEEE-1584, EFCOG BP #232] The voltage is the root mean square (rms) voltage for 50/60 Hz power.
- For 250 – 1000 volts, if the incident energy analysis determines the incident energy at the working distance to be less than 1.2 cal/cm^2, the electrical hazard can be lowered from high to moderate (50 to 10).
- For current limited 50/60 Hz circuits (≤ 5mA), use Chart 8.
- Evaluate all energy sources that the worker was exposed to.
  - For dc, use Chart 3
  - For Capacitors, less than 400 Volts, use Chart 4
  - For Capacitors, greater than 400 Volts, use Chart 5
  - For Batteries, use Chart 6, unless V > 100 Volts, then use Chart 3 for dc shock and arc flash.
  - For rf, use Chart 7
  - For Sub-rf ac, use Chart 8

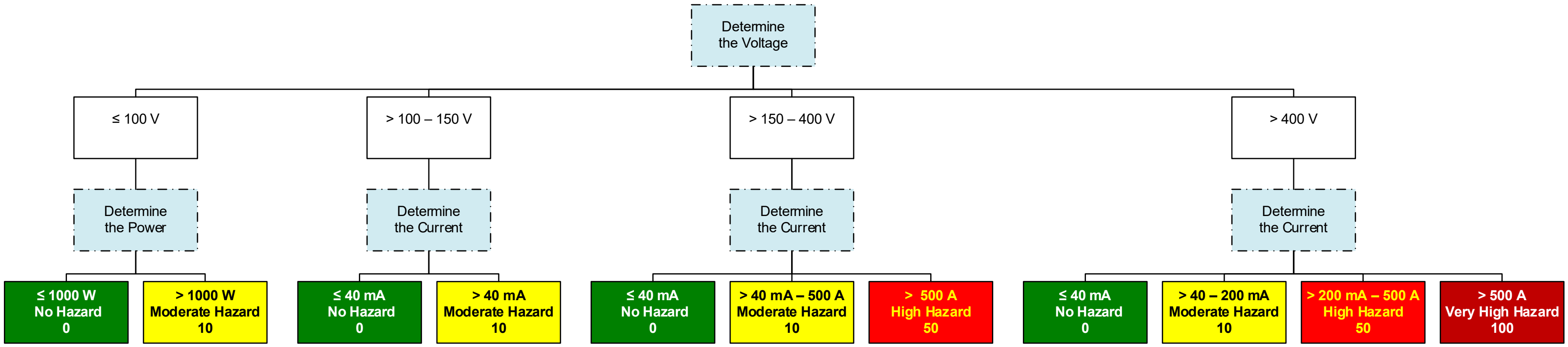

Chart 3. dc

NOTES:

- The voltage is the dc voltage.
- The power is available short-circuit power.
- The current is available short-circuit current.
- Evaluate all energy sources that the worker was exposed to.
  - For ac 50/60 Hz, use Chart 2
  - For Capacitors, less than 400 Volts, use Chart 4
  - For Capacitors, greater than 400 Volts, use Chart 5
  - For Batteries, use Chart 6, unless V > 100 Volts, then you must use Chart 3 for dc shock and arc flash
  - For rf, use Chart 7
  - For Sub-rf ac, use Chart 8

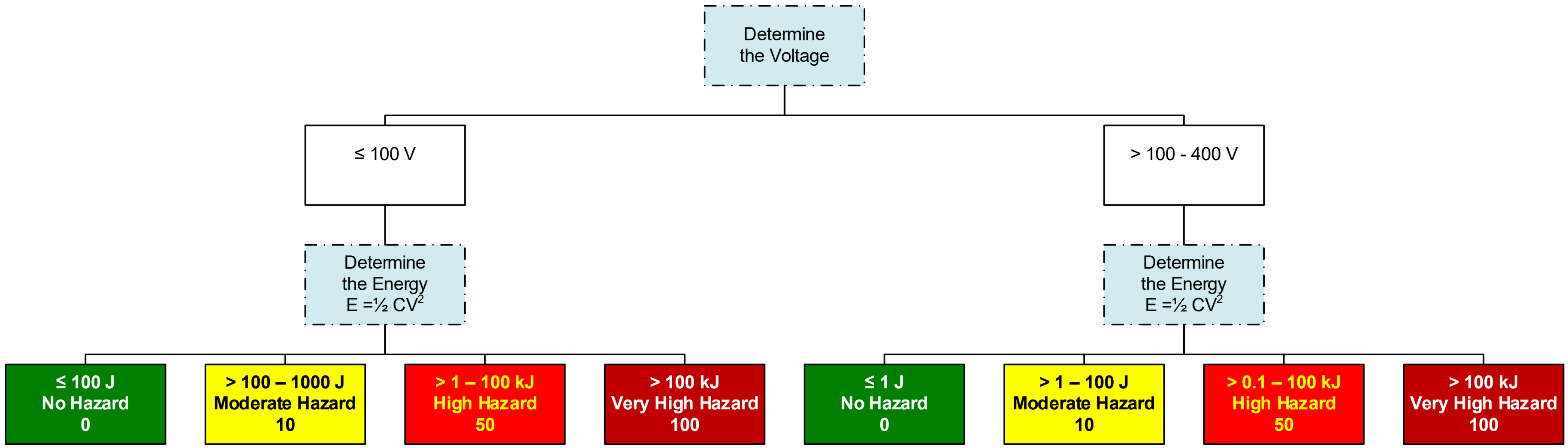

Chart 4. Capacitors, ≤ 400 V.

NOTES:

- The voltage is ac (rms) or dc maximum charge voltage on the capacitor.
- The energy is maximum energy stored in the capacitor as determined by $E = \frac{1}{2} CV^2$.
- Evaluate all energy sources that the worker was exposed to.
  - For ac 50/60 Hz, use Chart 2
  - For dc, use Chart 3
  - For Capacitors, greater than 400 Volts, use Chart 5
  - For Batteries, use Chart 6, unless V > 100 Volts, then you must use Chart 3 for dc shock and arc flash.
  - For rf, use Chart 7
  - For Sub-rf ac, use Chart 8

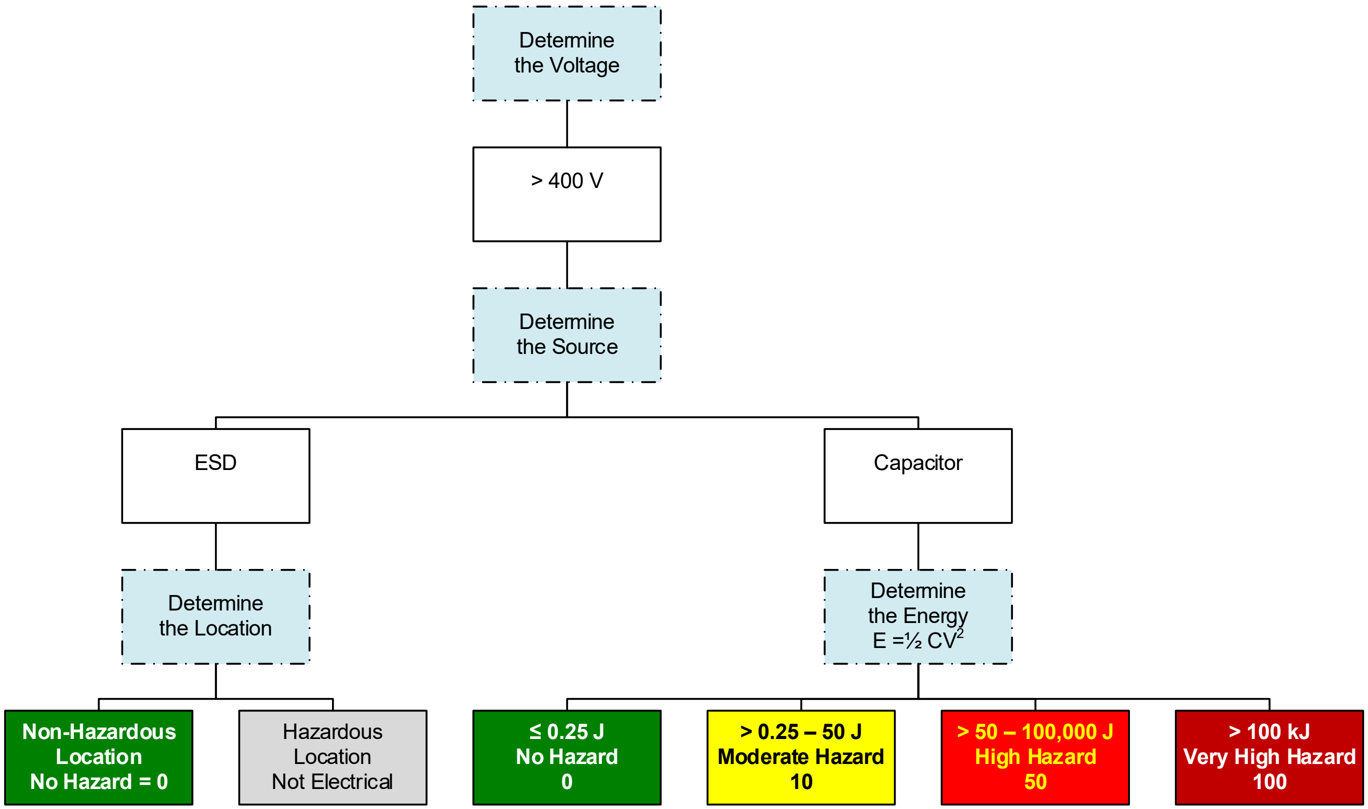

Chart 5. Capacitors, > 400 V.

NOTES:

- The voltage is ac (rms) or dc maximum charge voltage on the capacitor.
- The energy is maximum energy stored in the capacitor as determined by $E = ½ CV^2$.
- ESD in a hazardous location could potentially have a significant hazard. This tool cannot evaluate this hazard.
- Evaluate all energy sources that the worker was exposed to.
  - For ac 50/60 Hz, use Chart 2
  - For dc, use Chart 3
  - For Capacitors, less than 400 Volts, use Chart 4
  - For Batteries, use Chart 6, unless V > 100 Volts, then you must use Chart 3 for dc shock and arc flash
  - For rf, use Chart 7
  - For Sub-rf ac, use Chart 8

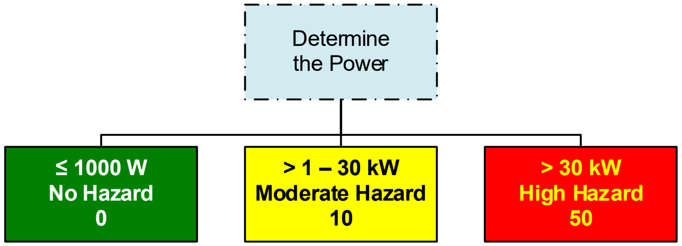

Chart 6. Batteries.

NOTES:

- The power is available short-circuit power.
- Note that if the battery voltage is greater than 100 Volts also refer to Chart 3 to classify the shock and arc flash hazards.
- Evaluate all energy sources that the worker was exposed to.
  - For ac 50/60 Hz, use Chart 2
  - For dc, use Chart 3
  - For Capacitors, less than 400 Volts, use Chart 4
  - For Capacitors, greater than 400 Volts, use Chart 5
  - For rf, use Chart 7
  - For Sub-rf ac, use Chart 8

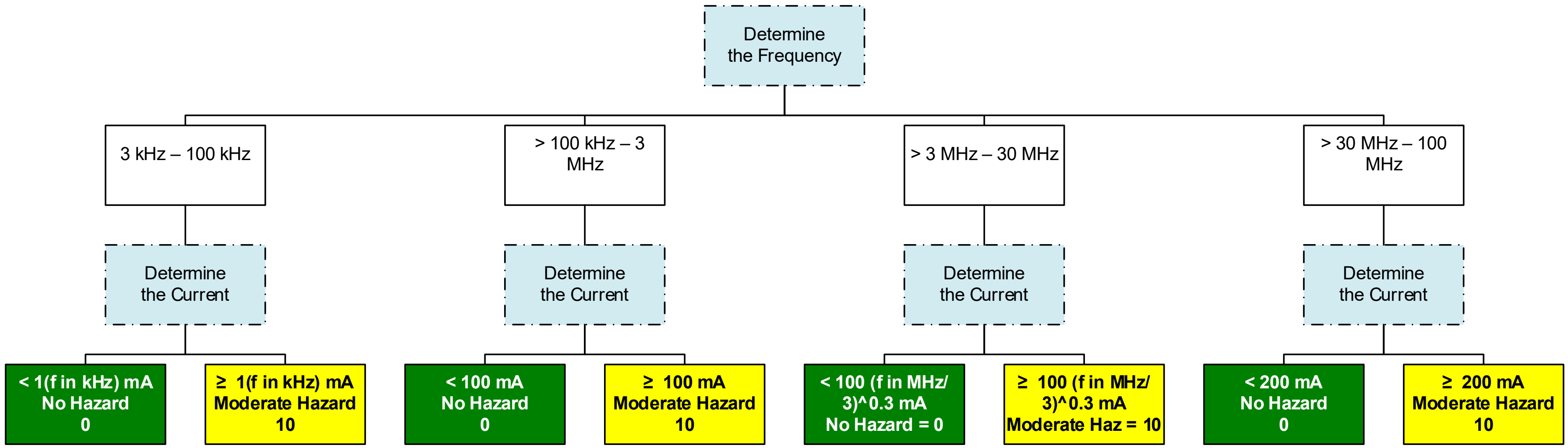

Chart 7. rf circuits, 3 kHz to 100 MHz.

NOTES:

- f in the chart is frequency
- This chart only addresses the rf shock hazard, it does NOT address exposure to electromagnetic fields.
- The allowable shock currents are much higher than 50/60 Hz (e.g., 100 mA is allowed for 100 kHz).
- Evaluate all energy sources that the worker was exposed to.
  - For ac 50/60 Hz, use Chart 2
  - For dc, use Chart 3
  - For Capacitors, less than 400 Volts, use Chart 4
  - For Capacitors, greater than 400 Volts, use Chart 5
  - For Batteries, use Chart 6, unless V > 100 Volts, then you must use Chart 3 for dc shock and arc flash
  - For Sub-rf ac, use Chart 8

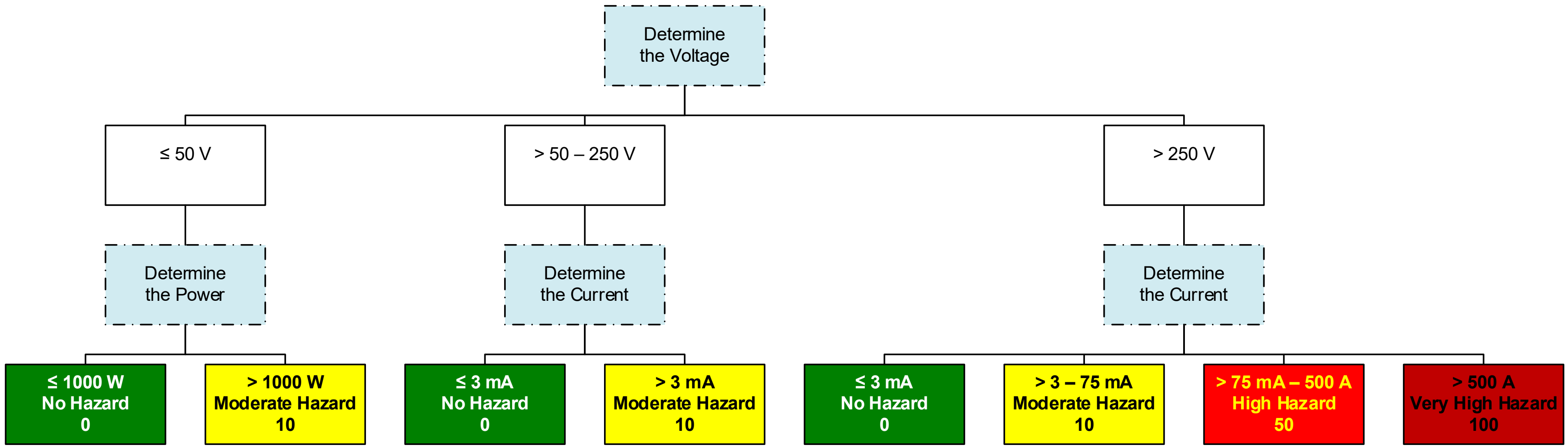

Chart 8. Sub-rf ac, 1 Hz to 3 kHz, NOT for 50/60 Hz Facility or Generator Powered Equipment.

NOTES:

- For 50/60 Hz facility or generator powered equipment use Chart 2.
- The voltage is the root mean square (rms) voltage.
- The power is available short circuit power.
- The current is available short circuit current.
- Evaluate all energy sources that the worker was exposed to.
  - For dc, use Chart 3
  - For Capacitors, less than 400 Volts, use Chart 4
  - For Capacitors, greater than 400 Volts, use Chart 5
  - For Batteries, use Chart 6, unless V > 100 Volts, then you must use Chart 3 for dc shock and arc flash.
  - For rf, use Chart 7

Appendix 2

List of Acronyms

ac	alternating current
D&D	Decontamination and Decommissioning
dc	direct current
EFCOG	Energy Facility Contractors Operating Group
ES	Electrical Severity
ESD	Electrostatic Discharge
ESMT	Electrical Severity Measurement Tool
IE	Incident Energy
NFPA	National Fire Protection Association
PPE	Personal Protective Equipment
R&D	Research and Development
rf	radio frequency
rms	root mean square
SME	Subject Matter Expert

Appendix 3

Electrical Severity Measurement Tool

Event Information Questionnaire

This questionnaire was developed by the EFCOG-ESCoP Hazardous Energy Control subgroup and is intended to aid SMEs in gathering information related to scoring an electrical event. The questions are designed to help the SME determine whether personnel were exposed to hazardous electrical energy or not and if exposure occurred, gather additional information needed to produce a consistent electrical severity score.

The following questions are used to determine if personnel were exposed to hazardous electrical energy and assign an electrical hazard factor. ***NOTE:*** *If personnel are not exposed to hazardous electrical energy, then the ESMT scores a zero and no further information is needed.*

Electrical Hazard Factor

- What was the source of energy?
- Was there more than one source of energy?
- What was the voltage, current, power, frequency, capacitance, phases, waveform of the energy source(s)?
- Was the source(s) of energy determined to be hazardous (exceeding established thresholds)?
- Was the source(s) of energy suitably isolated, insulated, or guarded such that inadvertent contact would not pose a shock hazard or arc flash hazard?
- What hazard(s) was the worker exposed to (e.g., shock, arc flash, arc blast, thermal)?
- Was the circuit energized at the time the event occurred?
- Did the overcurrent protection device trip?
- Was the circuit protected by a GFCI?
- Did the GFCI operate and open the circuit as designed?
- Was the GFCI tested after the event to verify it was still operable?

The following questions are used to gather additional information when determined that personnel were exposed to hazardous electrical energy.

Environment Factor

- Location (e.g., inside, outside)
- Dry? Damp? Wet? (Determined by SME judgment)
- Any conditions that added moisture or conductive liquids to the event?

Shock Proximity Factor

- How close was the worker to the source(s)?
- What tools if any were used?
- Were the tools voltage rated?
- What dielectric PPE was used?
    - Was the PPE rated for the voltage?
    - Was the PPE within the test date, if required?
- Was the risk of shock reduced or eliminated by PPE, engineering controls (GFCI), or by being inside the cab of mobile equipment?
- Was the cab enclosed or open? Did the worker get out of the cab? Did anyone approach the mobile equipment or source(s) of energy?

Arc Flash Proximity Factor

- What was the incident energy level of the exposure?
- What was the arc flash boundary for the source(s) of energy?
- Was the worker inside the arc flash boundary? How close did they get to the source of the IEL?
- What arc flash PPE was worn if any?
- Was the PPE adequate for the exposure?
- Did an arc flash occur?

Thermal Proximity Factor

- Was contact made with a conductive object (e.g., wrench, screwdriver, ring)?
- Was the worker in contact with the conductive object?
- What PPE, if any, was worn to protect the worker from burns?

Injury Factor

- Was the worker injured by the source(s) of energy?
- What did the worker feel?
- What did the worker hear?
- What did the worker see?
- If a shock occurred what was the path?
- Was the worker evaluated by medical?
- What were the results of the medical evaluation?

Appendix 4

Electrical Severity Scoring Example

The following example is provided to assist the user in the application of the tool. The electrical severity measurement tool is based on a 120 volt ac dry hand shock and scoring is illustrated by the following example.

- Refer to chart 1 of the hazard classification system in appendix 1 to choose the source of energy.
- The source of energy is ac 50/60 Hz which refers to chart 2.
- Referring to chart 2, find the voltage level and associated hazard classification number.
- The electrical hazard factor for 120 VAC is "10". Refer to section 5.2 to determine the environment factor.
- The environment for this example is dry or "0."
- Refer to the table section 5.3.1 to determine the shock approach boundary for the exposed circuit voltage.
- The restricted approach boundary for 120 VAC is avoid contact. Since the person received a shock, that person was in contact with the energized electrical conductor or circuit part. The shock proximity is "10" for entering the restricted approach boundary.
- Refer to section 5.4 to determine the arc flash proximity factor.
- There is no credible arc flash hazard associated with 120 VAC, therefore the arc flash proximity is "0", outside the arc flash boundary.
- Refer to section 5.5 to determine the thermal proximity factor.
- A dry hand shock, with no conductive tools to cause a thermal burn, the thermal proximity factor is "0".
- Refer to section 5.6 to determine the injury factor.
- A shock with no fibrillation or 1st degree burn occurred which results in an injury factor of "3".
- Refer to section 5.7 to determine whether the event involved the use of appropriate PPE for the hazard.
- Because a shock occurred proper PPE was not worn, and the hazard factor cannot be reduced to "0".
- Refer to section 5 and insert the event factors into the formula for calculating electrical severity (ES) = (10) * (1+0+10+0+0) * (3) for an electrical severity score of 330.