

DC Systems Working Group

EFCOG ESTG Workshop

**Pacific Northwest National
Laboratory**

July 24-28, 2017

DC WG - History

- **On the EFCOG ESTG website**
 - See [DC Working Group 20140714e.PPTX](#) for:
 - DC Arc Flash WG Phase I – 10/2010
 - DC Systems WG Phase II – 10/2012
 - DC Systems WG Phase III – 7/2014
 - See [DC Working Group 20150713d1.PPTX](#) for:
 - DC Systems WG Phase IV – 7/2015
 - See [DC Working Group 20160718b3.PPTX](#) for:
 - DC Systems WG Phase V – 7/2016

Accomplishments

- **Reviewed and revised EFCOG Best Practice BP194-DC Arc Flash Calculator from 2016 ESW**
 - Incorporated capacitor bank Arc Flash calculator into BP194
 - Improved convergence of arc current calculation
- **Readied for Release Battery Risk Assessment Flowchart as a BP**
- **Proposed a Ground Hook Design Recommendation based upon practices of SNL and LBNL**

DC Arc Flash WG 2017 Members

new members in 2017

- Kyle Carr, Gary Dreifuerst, Adam Green, Peter McNutt, Lynn Ribaud, Kyle Roberts, Justin Tokash, Dwight Clayton, Nasser Dehkordi, Matt Strandy, Rodney Wolfe
- Facilities-ANL, DOE, Hanford, LANL, LBNL, LLNL, NREL, NNSS, ORNL, PNNL, SNL

BP194 tab 4 - Capacitor Calculator

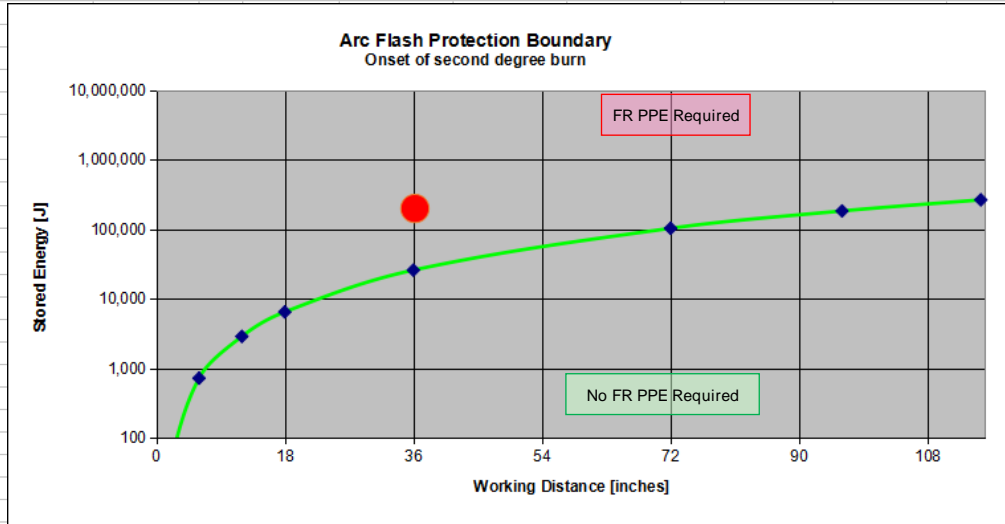
Arc Flash Energy - Capacitor - Stored Energy			
Enter data in blue cells - Read answers in orange cells			
<p>This is a physics estimate only. It is not based on experimental data but has been verified to be a conservative calculation of incident energy. Please note that this will show the maximum incident energy possible based on the inputs. This method also uses the conservative rounding of coefficients used by Doan [1] and NFPA 70E-2015 Section D.5.1 [2]. Closed box approximations based on NFPA 70E-2015 Section D.5.1 or the calculated closed box approximation from Wilkins, et. al. [3] as described by Ammerman, et. al. [4] are available using the radio buttons</p>			
<p>Also included for capacitor calculation is an estimated damage radius for ear or lung damage at the 1% susceptibility threshold. Calculation is based on the Army Research Lab (ARL) estimate from blast modeling of equivalent energy using Air_Blast_Lethality code as described in reference [5]. 1% ear damage corresponds to 3 psi overpressure or 180dB SPL. 1% lung damage corresponds to 10 psi overpressure</p>			
<p> <input type="radio"/> Open Air <input checked="" type="radio"/> Closed Box - NFPA 70E 2015 D.5.1 <input type="radio"/> Closed Box - Wilkins - Large Switchgear (MV) (1143mm x 762mm x 762mm) <input type="radio"/> Closed Box - Wilkins - Medium Switchgear (LV) (508mm x 508mm x 508mm) <input type="radio"/> Closed Box - Wilkins - Small Panel (LV) (305mm x 356mm x 191mm) </p>			
V _{sys}	20000	V	[system open circuit voltage]
C	1000	uF	[capacitance in microfarads]
E	200.0000	kJ	[stored energy in kilojoules]
D	92	cm	[working distance]
	36	in	
CF _{WD}	3.00		[configuration factor at working distance]
CF _{AFB}	3.00		[configuration factor at arc flash boundary]
I _{Em}	1.42	cal/cm ²	
AFB	100.0	cm	39.4 in
Lung 1%	24.5	cm	9.6 in
Ear 1%	278.1	cm	109.5 in



BP194 tab 5-Capacitor Arc Flash Graphics

Arc Flash Protection Boundary is the onset of a second degree burn at a flux of (1.2 cal/cm² --- 5 J/cm²)

This approach follows the method from the DOE Electrical Safety Workshop July 16-20 2007. It uses a 3x factor (to accommodate the focusing of energy due to a deep enclosure) of the 3d symmetrically propagated energy solved for a 2nd degree burn energy density of 5J/cm²: $D_c = \sqrt{0.05 \times E}$



If the Flash Protection Boundary (Dc) calculated by this method results in a distance that is greater than the distance at which the worker must approach the energy storage element, scale the distance using the Step 2 table below to find the energy density exposure for the worker at the working distance.

(Step 2) Enter the distance from the worker's body to the hazard into the light green cell (Working Distance Dw [in]). Appendix E data is duplicated in the formula to determine the Risk Category as a function of Energy Density (ATPV). The table also shows the clothing label information that is appropriate for the required ATPV.

Step 1	E [J]	Arc-in-a-Box			no-Arc-in-a-Box			
	200000	Dc [in]	Dc [ft]		Dc [in]	Dc [ft]		
	Working Distance Dw [in]	ATPV [cal/cm ²]	Risk Category	Clothing Label [cal/cm ²]	ATPV [cal/cm ²]	Risk Category	Clothing Label [cal/cm ²]	
Step 2	36	9.1	3	25	3.0	1	4	
	Working Distance Dw min [in]	ATPV [cal/cm ²]	Risk Category	Clothing Label [cal/cm ²]	Working Distance Dw min [in]	ATPV [cal/cm ²]	Risk Category	Clothing Label [cal/cm ²]
	100.0	1.2	0	1.2	57.7	1.2	0	1.2
	54.8	4	1	4	31.6	4	1	4
	38.7	8	2	8	22.4	8	2	8
	21.9	25	3	25	12.6	25	3	25
	17.3	40	4	40	10.0	40	4	40
	17.2	> 40	No Hot Work	No Hot Work	9.9	> 40	No Hot Work	No Hot Work

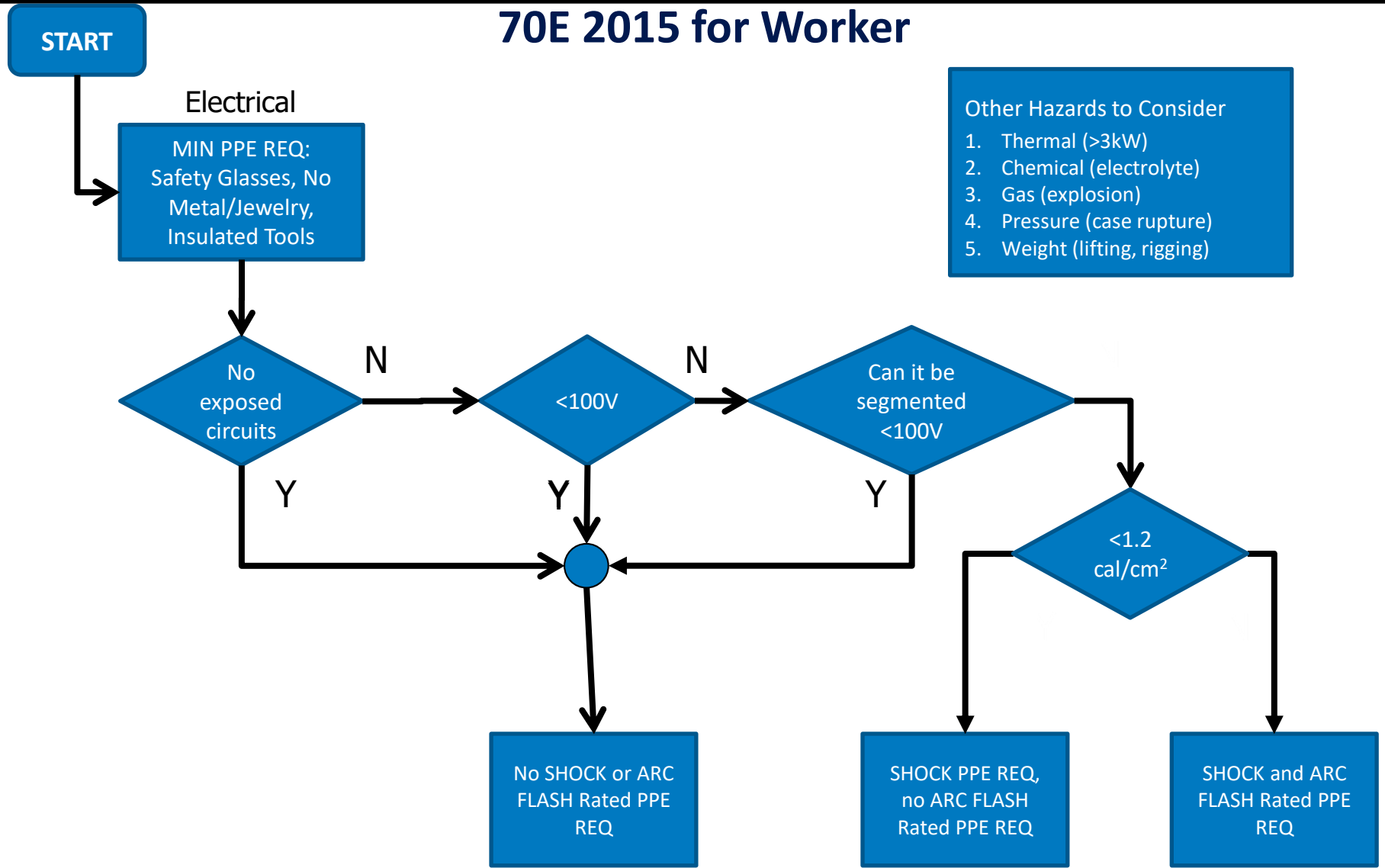


Prepare Battery Flow Chart as BP

- **See next slide**

Battery Risk Assessment Flowchart

70E 2015 for Worker



Ground Hook (Stick) Safety

July 2017 Update Developed

- Reviewed LBNL and SNL Ground Hook Safety documents.
- Developed a combined draft design document as guidance for sites that have no design criteria in place.
- This is a design/assembly consideration document.

Ground Hook (Stick) Safety

- **Document is for guidance only and is not intended to be a detailed construction or procurement specification.**
- **Detailed design and procurement information will be provided by the user.**

Actions prior to next ESTG Winter Meeting

- **Review and post changes to BP194 including capacitor calculations and graphics as well as add input for battery link impedance**
- **Review and Post Battery Risk Assessment Flow Chart as new BP**
- **Complete, Review and Post Ground Stick Design Recommendations as new BP (we need volunteers for reviews)**

Path Forward for DC Working Group

- **Develop additional worksheet to BP194 to include Inductor Arc Flash Calculation (inductor users for next year please)**
- **Improve Battery Bank Short Circuit Calculation Worksheet in BP194 spreadsheet (battery bank users for next year please)**
- **If time allows, discuss and develop DC clearing time guidance to DC arc flash calculation as a new BP**

QUESTIONS?