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Guide for:

Arc-Flash Hazard Calculations

Based on IEEE 1584tm *Guide for Performing Arc-Flash Hazard Calculations – 2002 Edition and Jim Phillips' Complete Guide to Arc Flash Hazard Calculation Studies*

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The worksheets are derived from equations published in IEEE 1584-2002™. Using the results of the calculations from these equations does not insure that a worker will not face injury or death from an arc flash. Following NFPA 70E and IEEE 1584 procedures and wearing the proper protective equipment will greatly reduce the possibility of injury and death.

ALWAYS WORK ON SYSTEMS PLACED IN AN ELECTRICALLY SAFE CONDITION WHEN POSSIBLE PER NFPA 70E

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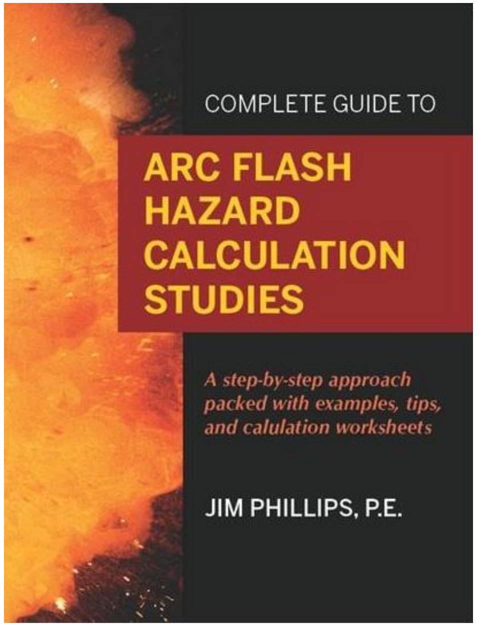
Complete Guide to Arc Flash Hazard Calculation Studies - $79.00



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This book takes Arc Flash to the next level by showing you how to perform the complete Arc Flash Hazard Calculation Study (AFHCS) including IEEE 1584 calculations, data collection, system modeling and details you need to perform the complete study..

Using a series of flow charts, examples and calculation worksheets, I break the study process down to a detailed step by step approach. Many important and helpful features are included in this book such as:

Step by Step Approach – This book takes the entire AFCS process and breaks it down into individual steps with one chapter for each step.

Solved examples – Dozens of solved example problems are provided to help illustrate the details of each equation and calculation method.

Calculation Work sheets – Solving complex equations such as those used for an AFHCS can seem overwhelming. However, I take each arc flash equation and breaks it down into simple steps laid out on a work sheet that you can use for solving the problems.

Tricks and Traps – Many questions and potential problem areas are frequently encountered when performing the AFHCS. I provides many tricks that can be used for the study and also warnings about the potential traps that could be encountered. You will also see how to successfully make assumptions and simplify the overall process.

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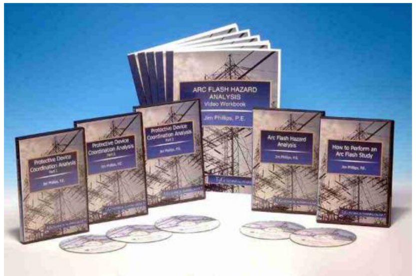
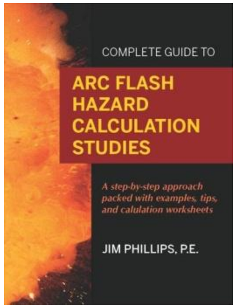
1.0 Introduction

This *Brainfiller Guide for Arc Flash Hazard Calculations* contains a series of worksheets that have been developed based on equations published in IEEE 1584-2002tm *Guide for Performing Arc-Flash Hazard Calculations* and Jim Phillips' book *Complete Guide to Arc Flash Hazard Calculation Studies.* The worksheets are designed to assist in manual arc flash calculations and are not intended as a replacement for the IEEE 1584 or NFPA 70E Standards or any other standards. The user must still comply with the requirements of these standards which contain additional details not shown here. The user should obtain a complete copy of the most current edition of both IEEE 1584 and NFPA 70E

It is assumed the user already has an understanding of arc flash calculations and related standards. The guide contains worksheets for estimating arcing short circuit current, calculating the incident energy and calculating the arc flash boundary.



For a better understanding of arc flash calculations, order Jim's arc flash video series and book at www.brainfiller.com

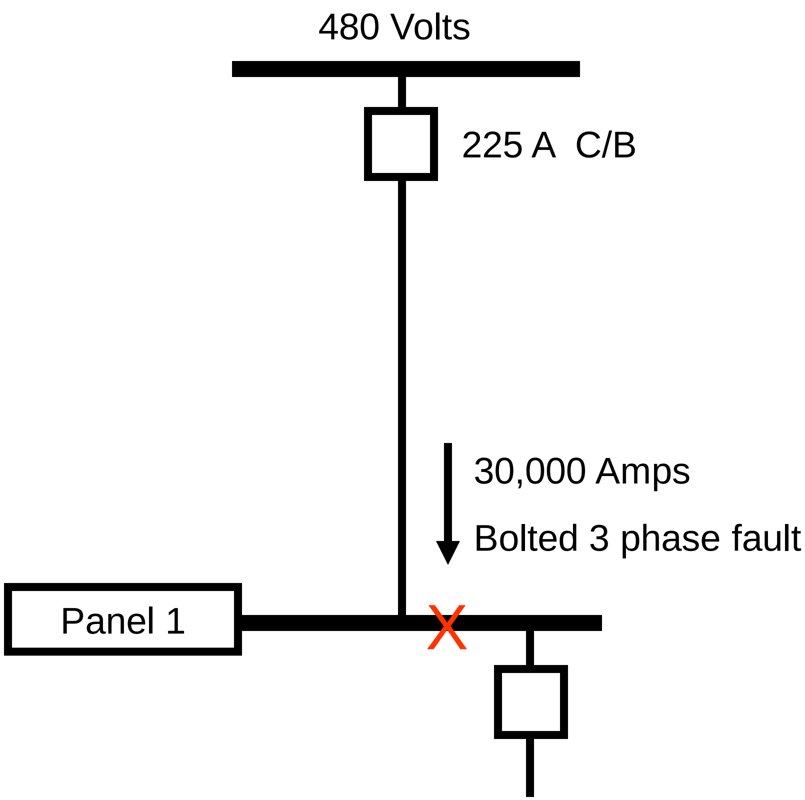


2.0 Arcing Short Circuit Current Calculations - Discussion

The first step in conducting arc flash calculations is to estimate the arcing short circuit current. The magnitude of an arcing fault will be less than a bolted fault due to the arc impedance.

The calculation is based on using the bolted three phase short circuit current obtained from a standard short circuit study. This value along with other variables such as arc gap distance is input into the equation on the next page.

The worksheet in this section provides a step-by-step process for estimating the arcing current.



2.0 Arcing Short Circuit Current Calculations - Discussion

IEEE 1584-2002[tm] Equation For Estimating the Arcing Short Circuit Current

$$\log I_a = k + 0.662\log I_{bf} + 0.0966V + 0.000526G + 0.5588V(\log I_{bf}) - 0.00304G(\log I_{bf})$$

$$I_a = 10^{\log I_a}$$

$\log = \log_{10}$
I_a = arcing current in kA
k = - 0.153 for open air and - 0.097 for arcs in a box
I_{bf} = bolted three-phase available short-circuit current (symmetrical rms kA)
V = system voltage in kV
G = conductor gap in millimeters (mm)

2.0 Arcing Short Circuit Current Calculations - Discussion

Table 1 Factors for Equipment and Voltage Classes - From IEEE 1584-2002tm

System Voltage (kV)	Type of Equipment	Typical Conductor Gap (mm)	Distance X-Factor
0.208 to 1	Open-air	10 – 40	2.000
	Switchgear	32	1.473
	MCC's and panels	25	1.641
	Cables	13	2.000
>1 to 5	Open-air	13 – 102	2.000
	Switchgear	102	0.973
	Cables	13	2.000
>5 to 15	Open-air	13 – 153	2.000
	Switchgear	153	0.973
	Cables	13	2.000

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2.0 Arcing Short Circuit Current Calculations - Worksheet

Three Phase Arcing Short Circuit Current Work Sheet System Voltage $\leq$ 1kV		
I_{bf} = Bolted 3 Phase Short Circuit Current in kA	V = system voltage in kV G = Conductor gap (mm)	K = - 0.153 for open air arcs = - 0.097 for arcs in a box

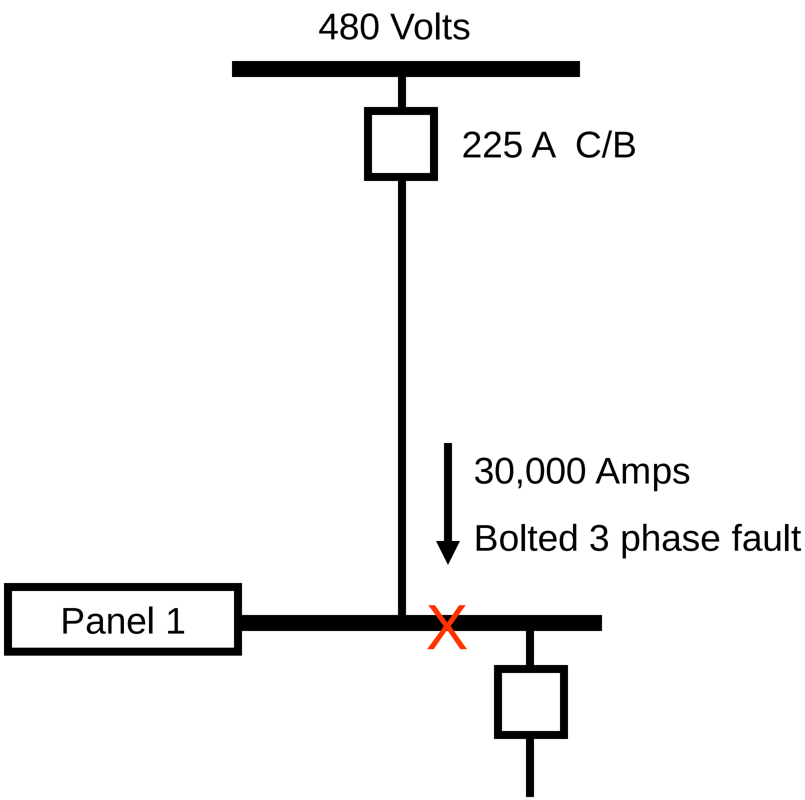
Step 1	0.662 x log (I_{bf})	0.662 x Log ( )	
Step 2	0.0966 x V	0.0966 x ( )	
Step 3	0.000526 x G	0.000526 x ( )	
Step 4	0.5588 x V x log (I_{bf})	0.5588 x ( ) x log ( ) 0.5588 x ( ) x ( )	
Step 5	- 0.00304 x G x log (I_{bf})	-0.00304 x ( ) x log ( ) -0.00304 x ( ) x ( )	-
Step 6	Add K	K = - 0.153 for open air arcs K = - 0.097 for arcs in a box	-
Step 7	log (I_a) = Step 1 + Step 2 + Step 3 + Step 4 + Step 5 + Step 6		
Total I_{arcing}	$10^{\log(Ia)}$ for many calculators enter 10 [Y^X] (Answer from Step 7)		kA

2.0 Arcing Short Circuit Current Calculations – Example Problem

The following example illustrates how to perform arc flash calculations using the worksheets. The one line diagram to the right shows a 480 Volt panel protected by an upstream 225 Amp circuit breaker.

A short circuit study indicates the available "bolted" three-phase fault current at Panel 1 is 30,000 Amps. This example illustrates how to estimate the arcing short circuit current.

The power system is considered to be solidly grounded and the arc flash is in a box representative of an enclosure.



2.0 Arcing Short Circuit Current Calculations – Example Problem

<table>
<tr><th colspan="4">Three Phase Arcing Short Circuit Current Work Sheet
System Voltage $\leq$ 1kV</th></tr>
<tr><td colspan="2">I_{bf} = Bolted 3 Phase Short Circuit Current in kA</td><td>V = system voltage in kV
G = Conductor gap (mm)</td><td>K = - 0.153 for open air arcs
= - 0.097 for arcs in a box</td></tr>
<tr><td>Step 1</td><td>0.662 x log (I_{bf})</td><td>0.662 x Log (30)</td><td>0.97785</td></tr>
<tr><td>Step 2</td><td>0.0966 x V</td><td>0.0966 x (0.48)</td><td>0.04637</td></tr>
<tr><td>Step 3</td><td>0.000526 x G</td><td>0.000526 x (25)</td><td>0.01315</td></tr>
<tr><td>Step 4</td><td>0.5588 x V x log (I_{bf})</td><td>0.5588 x (0.48) x log (30)
0.5588 x (0.48) x (1.47712)</td><td>0.39620</td></tr>
<tr><td>Step 5</td><td>- 0.00304 x G x log (I_{bf})</td><td>-0.00304 x (25) x log (30)
-0.00304 x (25) x (1.47712)</td><td>- 0.11226</td></tr>
<tr><td>Step 6</td><td>Add K</td><td>K = - 0.153 for open air arcs
$\boxed{\text{K = - 0.097 for arcs in a box}}$</td><td>- 0.09700</td></tr>
<tr><td>Step 7</td><td colspan="2">log (I_a) = Step 1 + Step 2 + Step 3 + Step 4 + Step 5 + Step 6</td><td>1.22431</td></tr>
<tr><td>Total I_{arcing}</td><td colspan="2">$10^{\log(Ia)}$ for many calculators enter 10 [Y^X] (Answer from Step 7)</td><td>16.761 kA</td></tr>
</table>

2.0 Arcing Short Circuit Current Calculations – Example Problem

Worksheet - Estimate Arcing Short Circuit Current:

Step 1: Enter the bolted three phase short circuit current as 30 kA

Step 2: Enter the voltage in kV as 0.48 kV

Step 3: Select a conductor gap of 25 mm from Table 1 for a panel

Step 4: Enter 0.48 kV and 30 kA

Step 5: Enter 25 mm gap and 30 kA

Step 6: Select k = - 0.097 for the arc occurring in a box (represents a panel)

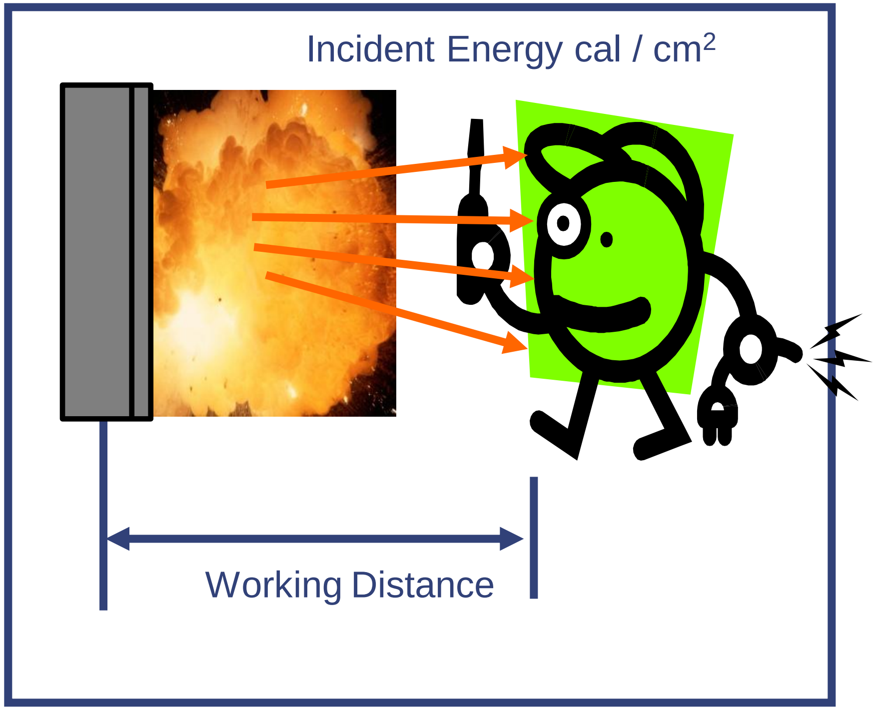
Step 7: Total Steps 1 through 6

Step 8: Take 10 and raise it to the power of Step 7. This is the estimated arcing current in kA

3.0 Incident Energy Calculations - Discussion

The next step is to calculate the incident energy in calories/centimeter^2 (cal/cm^2). Incident energy is defined as "the amount of energy impressed on a surface, a certain distance from the source" The distance from the source is referred to as "working distance".

Two equations are used for this step. The first equation is used to determine the incident energy based on a normalized working distance of 24 inches and a clearing time of 0.2 seconds. The second equation is used to adjust the normalized data to specific conditions. The clearing time is normally determined from the upstream protective device's time current curve using the estimated arcing current.



3.0 Incident Energy Calculations - Discussion

Since lower fault currents can cause overcurrent devices to respond more slowly, a second calculation is also performed based on 85% of the estimated current to account for unknowns. The greater of the two incident energy calculations is used for the results. Caution must be used since parts of the body closer than the working distance can receive an increased incident energy exposure requiring greater personal protective equipment (PPE).

To determine the incident energy at the worker location:

$$\log Ei_n = k_1 + k_2 + [1.081 \text{ x } (\log I_a)] + 0.0011G$$

$$Ei_n = 10^{\text{Log Ein}}$$

Ei_n is normalized for 0.2 s and 610 mm working distance (24 inches)
To calculate Ei for specific condition:

$$E_i = 4.184 \text{ x } C_f \text{ x } Ei_n \left[(t / 0.2) \text{ x } (610 / D_w)^x \right]$$

I_a = arcing current in kA
k_1 = open air or in a box factor
C_f = calculation factor
t = arcing time in seconds from time current curves
Metric conversions: 1 Inch = 25.4 millimeters

G = conductor gap in millimeters (mm)
k_2 = ground / ungrounded factor
X = distance exponent
D_w = working distance
0.24 cal / cm^2 = 1 Joule/cm^2

3.0 Normalized Incident Energy Calculations - Worksheet

Normalized Incident Energy Ei_n - Worksheet A Normalized to a 24 inch Working Distance and 0.2 Second Clearing Time System Voltage $\leq$ 15kV			
I_a= 3 Ph. Arcing Short Circuit Current (kA) G = Conductor gap (mm)		K_1 = - 0.792 for open air arcs K_1 = - 0.555 for arcs in a box	K_2 = 0 for ungrounded or hi Z K_2 = -0.113 for grounded
Step 1	1.0811 x log (I_a)	1.0811 x log ( )	
Step 2	0.0011 x G	0.0011 ( )	
Step 3	Add K_1	K_1 = - 0.792 for open air arcs K_1 = - 0.555 for arcs in a box	-
Step 4	Add K_2	K_2 = 0 for ungrounded or hi Z K_2 = -0.113 for grounded	-
Step 5	log (Ei_n) = Step 1 + Step 2 + Step 3 + Step 4		
Total Ei_n (1)	$10^{\log(Ein)}$ for many calculators enter 10 [Y^X] (Answer from Step 5)		

(1) Energy is normalized for arcing time of 0.2 Seconds and working distance of 24 inches (610 mm)

Ei_n must be adjusted for other than 0.2 Seconds and working distance of 24 inches (610 mm) by using Worksheet B

3.0 Adjusted Incident Energy Calculations – Worksheet

Adjusted Incident Energy Ei - Worksheet B Normalized Incident Energy Adjustment to Specific Working Distance and Clearing Time System Voltage < 15kV			
D_w = working distance in mm mm = Inches x 25.4 t = arcing time (Seconds)		C_f = 1.0 for V > 1kV C_f = 1.5 for V $\leq$ 1kV	X = distance exponent factor Ei_n = normalized incident energy
Step 1	$(610 / D_w)^X$	[( ) / ( )]^X	
Step 2	t / 0.2	( ) / 0.2	
Step 3	Cf x Ei_n	( ) x ( )	
Step 4	Total Ei = Step 1 x Step 2 x Step 3		cal/cm^2
Step 5 (1)	To convert from cal/cm^2 to $Joules/cm^2$ multiply Step 4 X 4.184		J/cm^2

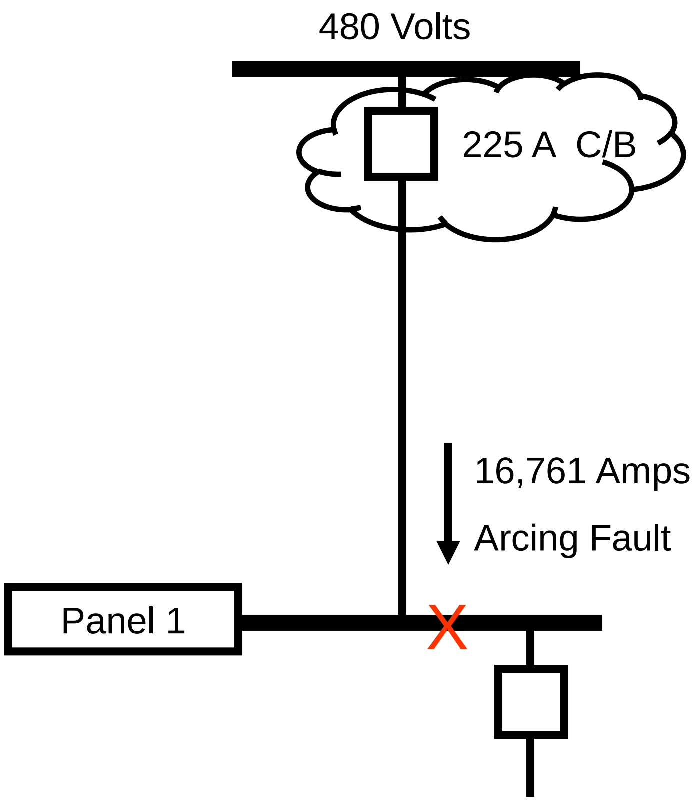
(1) The units in Step 4 are cal/cm^2 Step 5 is optional and is used to convert from cal/cm^2 to $Joules/cm^2$.

3.0 Incident Energy Calculations – Arc Flash Duration

This example illustrates how to calculate the incident energy in cal/cm^2 based on the estimated arcing short circuit current found in the previous example. A time current curve of the upstream 225 Amp circuit breaker is provided and is used to define the arc flash duration.

The breaker clearing time is 1 cycle for both 100% and 85% of the estimated arcing current. Therefore 100% will be used as the worst case.

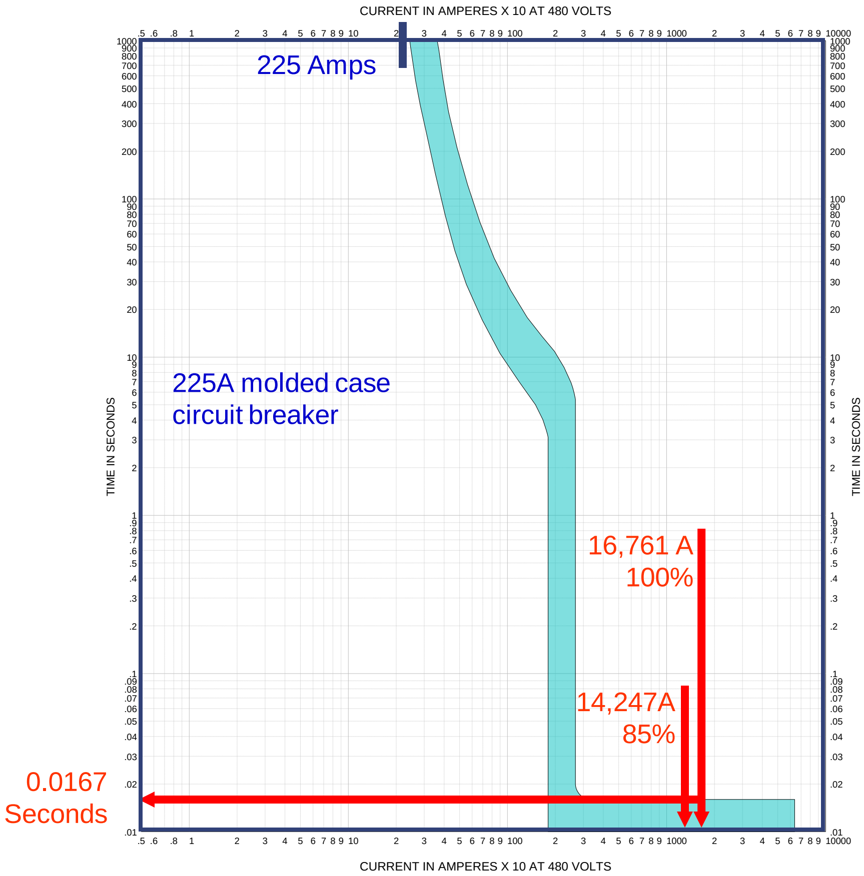
This calculation is considered to be an arc in the box case since it is a panel and it is also considered to be a solidly grounded system.



3.0 Incident Energy Calculations – Arc Flash Duration

The graph to the right illustrates the time current curve of the upstream 225 Amp circuit breaker. Based on the estimated arcing short circuit current of 16,761 amps, the clearing time would be 1 cycle or 0.0167 Seconds.

According to IEEE 1584 2002, an additional calculation using 85% of the estimated arcing current should also be evaluated to determine if the slightly lower current would yield a longer clearing time resulting in greater total incident energy. Both 100% and 85% of the arcing current should trip the breaker in 1 cycle based on this time current curve.



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3.0 Normalized Incident Energy Calculations – Example Problem

Normalized Incident Energy Ei_n - Worksheet A Normalized to a 24 inch Working Distance and 0.2 Second Clearing Time System Voltage $\leq$ 15kV			
I_a= 3 Ph. Arcing Short Circuit Current (kA) G = Conductor gap (mm)		K_1 = - 0.792 for open air arcs K_1 = - 0.555 for arcs in a box	K_2 = 0 for ungrounded or hi Z K_2 = -0.113 for grounded
Step 1	1.0811 x log (I_a)	1.0811 x log (16.761 kA)	1.32360
Step 2	0.0011 x G	0.0011 (25mm)	0.02750
Step 3	Add K_1	K_1 = - 0.792 for open air arcs $\boxed{K_1 = -0.555 \text{ for arcs in a box}}$	- 0.555
Step 4	Add K_2	K_2 = 0 for ungrounded or hi Z $\boxed{K_2 = -0.113 \text{ for grounded}}$	- 0.113
Step 5	log (Ei_n) = Step 1 + Step 2 + Step 3 + Step 4		0.68310
Total Ei_n (1)	$10^{\log (Ein)}$ for many calculators enter 10 [Y^X] (Answer from Step 5)		4.82059

(1) Energy is normalized for arcing time of 0.2 Seconds and working distance of 24 inches (610 mm)

Ei_n must be adjusted for other than 0.2 Seconds and working distance of 24 inches (610 mm) by using Worksheet B

3.0 Normalized Incident Energy Calculations – Example Problem

Worksheet A – Normalized Incident Energy Calculations

Step 1: Enter the estimated arcing short circuit current as 16.761 kA

Step 2: Select an arc gap of 25 mm from Table 1 for a panel

Step 3: Select k_1 = - 0.555 for the arc occurring in a box (represents a panel)

Step 4: Select k_2 = - 0.113 for a grounded system

Step 5: Add Steps 1 through 4

Step 6: Take 10 and raise it to the power of the answer found in Step 5. This is the normalized incident energy in calories / centimeter^2. This value needs adjusted to the actual working distance and clearing time by using the Adjusted Incident Energy Worksheet B on the next page.

3.0 Adjusted Incident Energy Calculations – Example Problem

Adjusted Incident Energy E_i - Worksheet B Normalized Incident Energy Adjustment to Specific Working Distance and Clearing Time System Voltage < 15kV			
D_w = working distance in mm mm = Inches x 25.4 t = arcing time (Seconds)		C_f = 1.0 for V > 1kV C_f = 1.5 for V $\le$ 1kV	X = distance exponent factor Ei_n = normalized incident energy
Step 1	$(610 / D_w)^X (610/457.2)^{1.641}$	[(12,670) / (8,286)]^X	1.60506
Step 2	t / 0.2	(0.01670) / 0.2	0.08350
Step 3	Cf x Ei_n	(1.5) x (4.82059)	7.23089
Step 4	Total Ei = Step 1 x Step 2 x Step 3		0.96910 cal/cm^2
Step 5 (1)	To convert from cal/cm^2 to Joules/cm^2 multiply Step 4 X 4.184		4.05473 J/cm^2

(1) The units in Step 4 are cal/cm^2 Step 5 is optional and is used to convert from cal/cm^2 to Joules/cm^2.

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3.0 Arcing Short Circuit Calculations – Example Problem

Worksheet B – Adjusting Incident Energy Worksheet Ei for Specific Conditions:

Step 1: Enter the working distance D in mm. 18 inches was selected which is commonly used for some low voltage distribution equipment assuming worker is standing back from the live bus or component.
18 inches = 457.2 mm. 610 mm = 24 inches which is the normalized distance calculated in Worksheet B. Choose x = 1.641 from table for a panel.

Step 2: Enter the upstream device clearing time from time current curve
1 cycle from the graph = 0.0167 seconds.

Step 3: Select C_f of 1.5 since the voltage is $\leq$ 1 kV, enter Ei_n normalized incident energy from Worksheet A

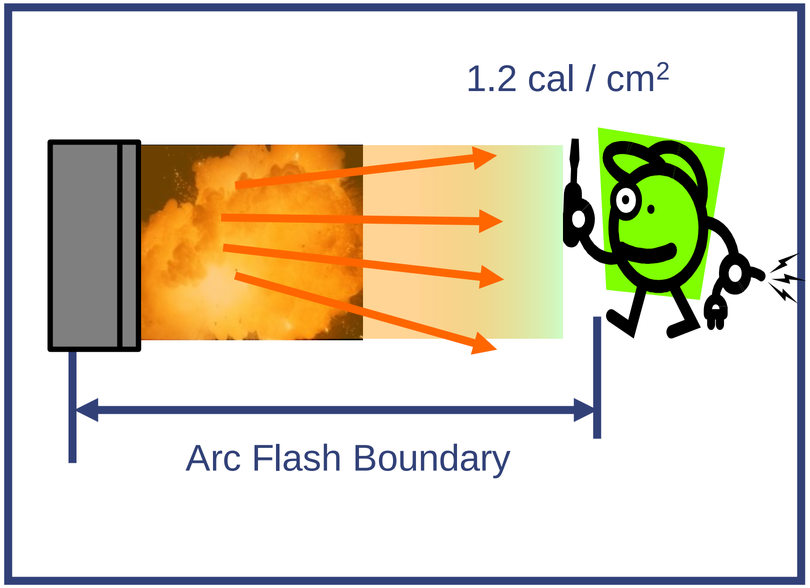
Step 4: Multiply Steps 1 through 3

Step 5: Multiply Step 4 X 4.184 to convert from cal/cm^2 to Joules/cm^2

4.0 Arc Flash Boundary - Discussion

The Arc Flash Boundary (AFB) known as Flash Hazard Boundary in IEEE 1584, is defined as an "approach limit at a distance from exposed live parts within which a person could receive a second degree burn if an electrical arc flash were to occur". This boundary is typically calculated as the distance where the incident energy falls off to 1.2 cal /cm^2.

Work performed within the AFB requires adequate PPE based on NFPA 70E requirements. It is always better to place the equipment in an electrically safe condition and not to perform live work.



4.0 Arc Flash Boundary - Discussion

To determine the Arc Flash Boundary:

$$D_B = [\ 4.184 \times C_f \times Ei_n \times (\ t / 0.2\ ) \times (610^x / E_B)]^{1/x}$$

D_B = distance from arc in mm
E_B = incident energy at the arc flash boundary, typically 1.2 cal/cm^2 or 5 Joules/cm^2
Ei_n = incident energy normalized from Worksheet A
C_f = calculation factor
t = arcing time in seconds from overcurrent device time current curve
X = distance exponent from Table 1
Metric conversions: 1 Inch = 25.4 millimeters 0.24 cal / cm^2 = 1 Joule/cm2

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4.0 Arc Flash Boundary - Worksheet

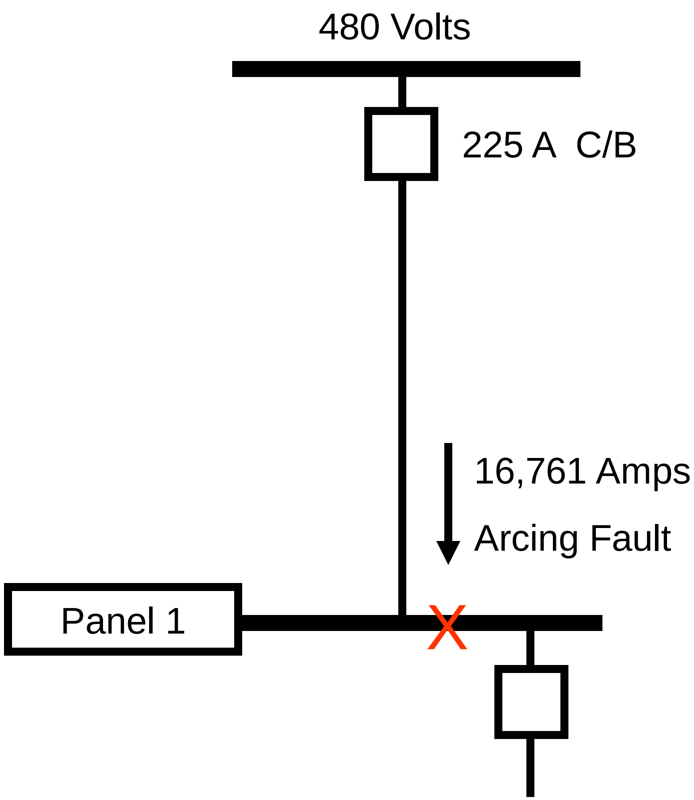
Arc Flash Boundary

Voltage $\leq$ 15 kV

D_n = normalized distance 24 in = 610 mm t = arcing time (Seconds)		C_f = 1.0 for V > 1kV C_f = 1.5 for V $\leq$ 1kV	X = distance factor Ei_n = normalized incident energy
Step 1	$D_n{}^x / E_B$	( ) / ( )	
Step 2	t / 0.2	( ) / 0.2	
Step 3	4.184 x C_f x Ei_n	4.184 ( ) x ( )	
Step 4	Step 1 x Step 2 x Step 3		
D_B (mm)	[Step 4] $^{(1 / x)}$	[ ] $^{(1/X)}$	mm
D_B (inches)	To convert to inches	D_b in mm / 25.4 mm/inch	Inches

4.0 Arc Flash Boundary – Example Problem

Based on the results of the *normalized* incident energy calculation from the previous example, this problem illustrates the calculation of the Arc Flash Boundary (in inches). The AFB is the distance from the arc flash where the incident energy falls to 1.2 cal/cm^2. This value is considered the threshold of a second degree burn (just curable burn).



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4.0 Arcing Flash Boundary – Example Problem

Arc Flash Boundary Voltage $\leq$ 15 kV			
D_n = normalized distance 24 in = 610 mm t = arcing time (Seconds)		C_f = 1.0 for V > 1kV C_f = 1.5 for V $\leq$ 1kV	X = distance factor Ei_n = normalized incident energy
Step 1	$D_n^{\ x} / E_B$ $610^{1.641} / 5$	(37,215.7057) / (5 J/cm²)	7,443.1411
Step 2	t / 0.2	(0.0167) / 0.2	0.0835
Step 3	4.184 x C_f x Ei_n	4.184 (1.5) x (4.8206)	30.2541
Step 4	Step 1 x Step 2 x Step 3		18,802.9832
D_B (mm)	[Step 4] $^{(1 / x)}$	[18,802.9832] $^{(1/X)}$	400.9 mm
D_B (inches)	To convert to inches	D_b in mm / 25.4 mm/inch	15.8 Inches

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4.0 Arc Flash Boundary – Example Problem

Worksheet – Arc Flash Boundary:

Step 1: Enter the incident energy in Joules/cm^2 at the arc flash boundary. Typically 5 Joules/cm^2 is used (which represents the threshold of a 2nd degree burn.) 610 mm = 24 inches which is the normalized distance from the Normalized Incident Energy Calculation Worksheet A. Choose x = 1.641 from Table 1 which is for a panel.

Step 2: Enter the upstream device clearing time from the time current curve 1 cycle from the graph = 0.0167 seconds.

Step 3: Select C_f of 1.5 since the voltage is $\leq$ 1 kV, enter Ei_n normalized incident energy from Worksheet A

Step 4: Multiply Steps 1 through 3

Step 5: Raise Step 4 to the reciprocal of X

Step 6: Divide Step 5 by 25.4 inches/mm to convert to inches

References

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IEEE Std 1584atm, Guide for Performing Arc-Flash Hazard Calculations, 2004

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How to Perform an Arc Flash Study in 12 Steps, Jim Phillips, P.E., August 2007 NEC Digest

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ELECTRICAL SAFETY / NFPA 70E - 1 DAY PROGRAM
This 1 day class brings your staff up to date with OSHA and NFPA 70E requirements for performing a shock hazard and flash hazard assessment. Learn how to select proper PPE based on the hazard and risk as defined in the NFPA 70E tables. Examples of filling out energized work permits are also included.

ELECTRICAL SAFETY / NFPA 70E - 1/2 DAY PROGRAM The class provides an arc flash awareness overview of the NFPA 70E requirements including PPE selection and energized work permits. The ½ day format allows employers to divide their staff into two groups with on group attending the morning session and the other group attending the afternoon session.

GENERATOR AND UPS APPLICATIONS - I
With electric utility deregulation and large scale blackouts emergency and standby power systems are more important than ever. This class covers the requirements of sizing, operation, protection and planning a generator installation. Included is how to analyze the effect of harmonic producing loads and motor starting on the generator operation.

GENERATOR AND UPS APPLICATIONS - II
Power systems are facing a decrease in reliability yet mission critical systems must have 100% reliability. This class will show you how to properly size a UPS system, transfer switches selection, UPS heat loss, reliability, compatibility issues and more.

GROUNDING AND POWER QUALITY
Grounding is one of the more commonly mis-understood concepts of a power system. Poor or incorrect grounding can lead to safety and power quality problems. Learn the correct methods for grounding according to the NEC and IEEE. See how to locate and correct power quality problems including ground loops.

HOW TO PERFORM AN ARC FLASH STUDY - I
This class is based on OSHA and NFPA 70E and is designed to train students to understand electrical safety including shock and arc flash hazards as well as providing appropriate hazard assessment. Learn about NFPA 70E requirements, limited, restricted and prohibited approach boundaries, arc flash boundary, correct personnel protective equipment and many other topics.

HOW TO PERFORM AN ARC FLASH STUDY - II
The class is based on IEEE 1584 and shows how to perform the arc flash hazard calculation study including data collection and IEEE calculations. Jim discusses the effect of device settings and short circuit current magnitudes on arc flash as well as holes in the standards. Learn about the details such as Cf, distance exponents, system modeling and much more.

HOW TO STREAMLINE AND AUTOMATE ELECTRIC POWER DESIGN - I
Learn how to develop design tables to more easily and quickly design electrical power systems. Day 1 covers conductor / protection tables and motor circuit sizing tables. This course is based on the NEC and power system design concepts.

HOW TO STREAMLINE AND AUTOMATE ELECTRIC POWER DESIGN - II
Day 2 covers developing transformer tables, grounding, interfacing with the utility. Jim has developed design worksheets to aid in quick calculations and fewer errors. This class also has a demonstration of commercially available software to automate the design process.

MEDIUM VOLTAGE POWER SYSTEMS - I
The backbone of many electric power systems is the medium voltage distribution system. Typically operating at voltages ranging from 2,400 to 34,500 Volts, voltage stress, corona, surges and protection of equipment all create unique challenges in design, equipment selection, operation and engineering. Day 1 covers topics such as medium voltage cable, partial discharge, surge protection and substation transformers.

MEDIUM VOLTAGE POWER SYSTEMS - II
Day 2 focuses on protection of medium voltage power systems. The course includes the application of reclosers, medium voltage fuses, and relays for the protection of distribution feeders, rotating machinery and transformer thru fault protection.

NATIONAL ELECTRICAL CODE ® - 2 DAYS
This 2 Day class covers the major articles found in the NEC. Learn not only what the articles say, but also why and how to correctly use the articles in the design and installation of electric power systems.

POWER DISTRIBUTION EQUIPMENT - I
You will gain insight into the operation, selection and application of motors and variable frequency drives. You will also learn about transformer design, application and protection as well as transformer vault requirements.

POWER DISTRIBUTION EQUIPMENT - II
The class includes the application and selection of circuit breakers, panelboards, switchboards, fuses, and relays. In addition, low & medium voltage switchgear and an introduction to short circuit and coordination studies is included.

MOTOR DESIGN, APPLICATION AND ANALYSIS - I
Learn how to design motor circuits as well as the fundamentals of motor design, variable frequency drive operation, analysis and motor starting techniques

MOTOR DESIGN, APPLICATION AND ANALYSIS - II
Modeling and analysis of motors and motor operation is the focus of this class. See how to model starting conditions, harmonics from drives, and the effect of source strength on voltage flicker and harmonics created by motor applications.

POWER FACTOR AND HARMONIC ANALYSIS
How do you manage harmonics? Learn how to analyze harmonics, perform resonance calculations, understand IEEE 519, perform THD calculations and design harmonic filters. In addition, learn what to do about neutral harmonics which often require oversized neutrals and K rated transformers. Understand the interaction between harmonics and power factor correction capacitors.

POWER SYSTEM ENGINEERING COURSE – 4 DAYS
This course has become the industry standard that defines the “Crash Course” in electrical power systems. People from all over the world have attended this course at Jim’s public sessions. The class is a combination of his five most popular courses rolled into a 4 day program. The five courses include: Design of Electric Power Systems I and II, Short Circuit Analysis, Protective Device Coordination Analysis and Harmonic Analysis.

PROTECTIVE DEVICE COORDINATION ANALYSIS
This course is designed to show you how to use time current curves and perform coordination studies with breakers, relays and fuses. The program provides an explanation of how to maximize reliability by developing a properly coordinated power distribution system.

PROTECTIVE RELAYING - I
It has been said that protective relay coordination is more of an art than science. This class introduces you to overcurrent relays, relay coordination, current transformer burden and saturation. Many relay examples are included.

PROTECTIVE RELAYING - II
A continuation of the basic class, this class shows how other relays operate and are set such as differential, synch check and reverse power relays. Various relay schemes for equipment protection are also covered.

SHORT CIRCUIT ANALYSIS
Learn how to perform short circuit calculations and equipment adequacy evaluations. Understand the importance of X/R ratios, symmetrical vs. asymmetrical faults and how series ratings work. Many calculation examples are used to illustrate how to perform an analysis. The methods are based on the IEEE Buff and Red books. This class can be paired with the Protective Device Coordination Class for 2 days of training.

CUSTOM CLASSES
Custom classes are also available. Pick and choose from any of the classes and Jim will put them together for a program designed to suit your specific needs.

TO RECEIVE A PROPOSAL
To receive a proposal to have Jim train at your location, contact Brenda at: 800.874.8883 or e-mail her at:

brenda@brainfiller.com

The Author

Jim Phillips, P.E.

Member of IEEE 1584 *IEEE Guide for Performing Arc Flash Hazard Calculations*

Vice - Chairman of Task Group - *IEEE 1584.1 Guide f or the specification of scope and deliverable requirements for an arc-flash hazard calculation.*

Member of IEC 61482-1-2 Determination of arc protection class of material and clothing by using a constrained and directed arc (box test)

U.S. representative to IEC TC 78 and WG 13 and member of various IEC committees

Member of NFPA, ANSI, ASTM, IEEE and several other organizations.

Author of the book: *Complete Guide to Arc Flash Hazard Calculation Studies*

Is a regular contributor to Electrical Contractor Magazine

Founder of the internationally known website:

www.ArcFlashForum.com

For over 30 years, Jim has been helping tens of thousands of people around the world understand electrical power systems design, safety, theory and applications. Having taught over 2000 seminars during his career to people from all seven continents (Yes Antarctica is included!), he has developed a reputation for being one of the best trainers and public speakers in the industry.

Jim does not just talk about arc flash and electrical safety - he is part of the development of the arc flash standards! He is also the instructor that has taught other instructors in the industry. Jim is a member of the IEEE 1584 Committee - *IEEE Guide for Performing Arc Flash Hazard Calculations.* He is Vice-Chairman of the IEEE Task Group - IEEE 1584.1 "Guide for the specification of scope and deliverable requirements for an arc-flash hazard calculation"

Jim literally wrote the book about arc flash studies with his book titled: ***Complete Guide to Arc Flash Hazard Calculation Studies*** available from brainfiller.com. He also wrote "How to Perform an Arc Flash Study in 12 Steps" published by NFPA.

Jim is a regular contributor to Electrical Contractor Magazine, has authored many articles published in Europe and is a speaker at conferences around the world.

Jim has served on many committees such as the Energy Policy Committee in Washington DC. He is a member of IEEE, NFPA, ASTM, ANSI, IEC and many others organizations.

Jim earned a BS Degree in Electrical Engineering from the Ohio State University. His career began with Square D Company's Power System Analysis Group where he was responsible for system studies, power system software development and training.

Later, Jim was in charge of the studies group of the System Protection Section of Ohio Edison Company. He was part of the adjunct faculty for Stark State College where he taught evening classes in electrical power systems.

Jim is a Registered Professional Engineer. with experience that includes everything from planning transmission systems, to design and analysis of industrial, commercial and utility power systems, cogeneration plant design, expert witness and forensic analysis.

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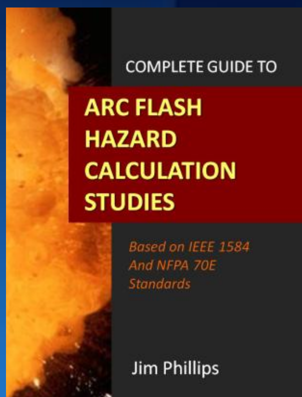

BOOKS - The "Complete Guide to Arc Flash Hazard Calculation Studies has many solved examples, worksheets, tips and tricks for performing the arc flash study. Order your copy today.

ARTICLES - Download many technical articles

VIDEOS - Many of Jim's training programs are available on DVD.

TRAINING PROGRAMS - Have Jim and any of his over 25 different programs at your location.

Join in the conversation with thousands of others at:

Arc flash FORUM.COM

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