Arc Flash Calculations for Consulting Engineers

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IEEE-SF-IAS
November 16, 2004

Outline

- History
- Hazard
- Codes & Standards
- Calculations
- Enforcement

History

- Shock / Electrocution Major Hazard
- Ralph Lee 1982
  - “The Other Electrical Hazard: Electric Arc Blast Burns”
  - Electrical Arc Burns Are a Common Injury
  - Electrical Arcing is Term Applied to Current Passing Thru a Vapor of Conductive Material
  - Established Relationship Between Temperature and Skin Burns & Human Tissue Cell Death
- IEEE 1584 Expanded Lee’s Work

Recent Local Incident

Stanford University

Technician injured at linear accelerator

-Ulysses Torassa

Thursday, October 12, 2004

A technician suffered second and third degree burns Monday after a 480 volt electrical arc erupted during the installation of a circuit breaker at the Stanford Linear Accelerator Center, authorities said.

The man, who was not identified, was installing the device at 11:18 a.m. next to an electrical panel in a section of the 2 mile long accelerator located just west of Interstate 280, said center spokesman Neil Calder.

The arc ignited his clothes and threw him backward, but two co-workers who were nearby were able to put out the flames quickly. He was being treated in the burn unit at Santa Clara Valley Medical Center in San Jose.

Calder said officials had suspended operations at the accelerator for a few days while the accident is investigated but that the halt was unlikely to affect any research work.

SFGate.com

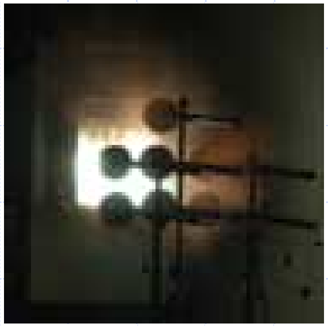
Hazards of Electrical Work

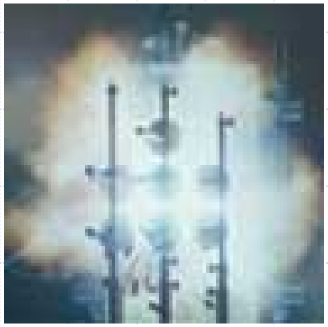
- Electrical Shock – Direct Contact
- Electrical Shock – Vaporized Metal in Arc Plasma
- Arc Flash Burns (Heat, Fire)
- Arc Blast (Pressure, Shrapnel, Sound)

Secondary hazards include

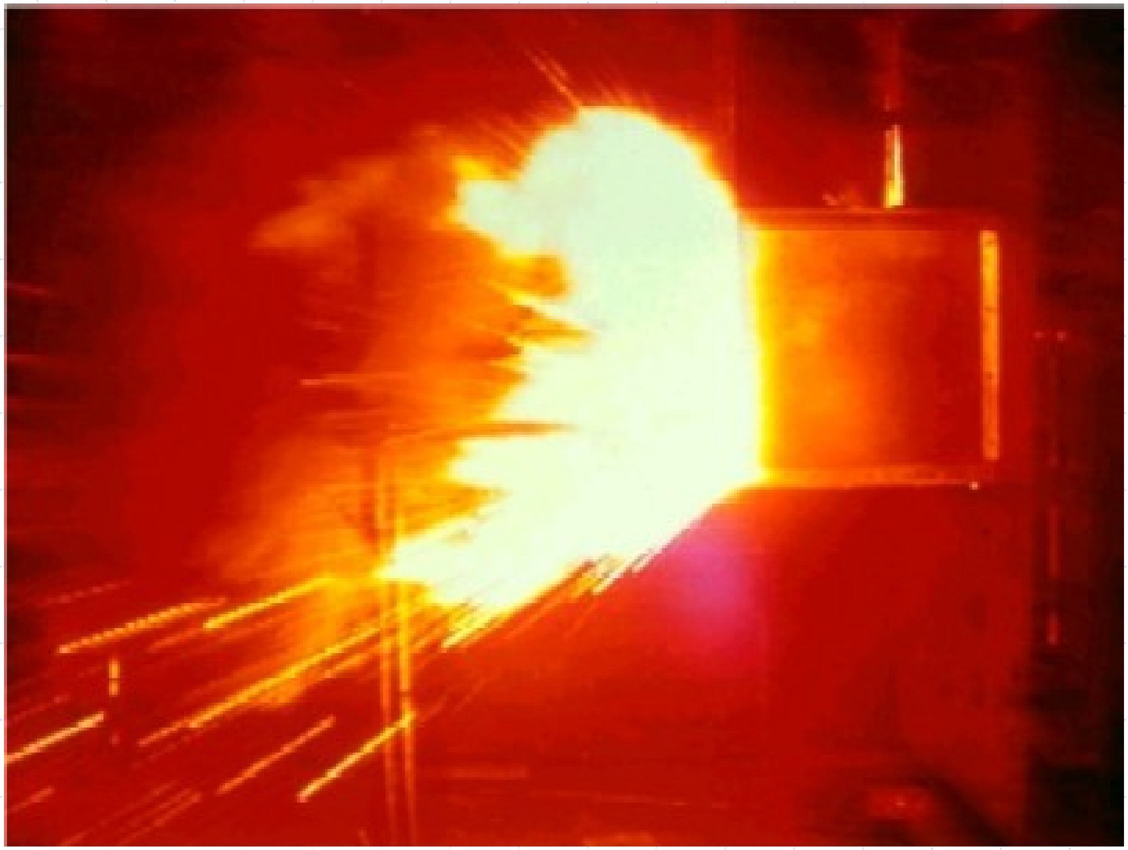
- Falls
- Fire

Photos of Arc Flash Hazard

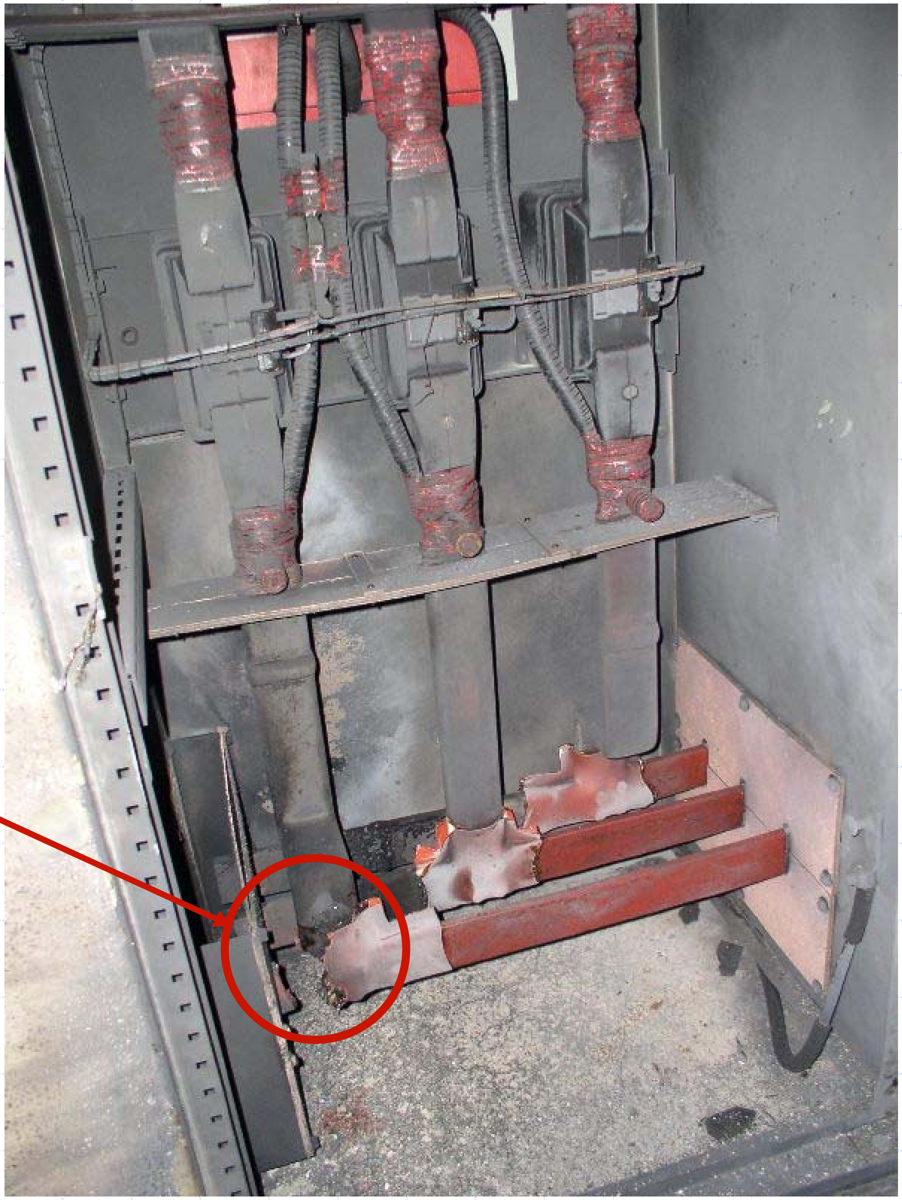




Photos of Arc Flash Hazard



7:30am Nov. 8, 2004 in SF



Vaporized copper

Arc Flash Hazard Comparison

- Steam (water to vapor) (Heat of Vaporization) at 212° F.
- Vaporized copper at 5000° F.

Arc Flash Hazard Comparison

Skin Temperature	Duration of Exposure	Damage Caused
110° F	6 Hours	Cell breakdown begins
158° F	1 Sec.	Total cell destruction
176° F	0.1 Sec.	Curable burn
200° F	0.1 Sec.	Incurable 3rd degree burns

Flash Hazard Analysis

- A **Flash Hazard Analysis** must be performed before a person approaches any exposed electrical conductor or circuit part that has not been placed in an electrically safe work condition.
- The **Flash Protection Boundary** will establish the need for PPE to cross that boundary.
- **Flame Resistant (FR) clothing** and **PPE** are used by the employee based upon the incident energy associated with the task.

Alternate Methods of Analysis

- Method 1: NFPA 70E Tables
- Method 2: Calculations per formulas in NFPA 70E based on available fault current and fault clearing time
- Method 3: Calculations per formulas in IEEE 1584, based on empirical test data.

Definitions of Key Terms

- Incident Energy
- Flash Protection or Arc Flash Boundary
- Limited Approach Boundary
- Restricted Approach Boundary
- Prohibited Approach Boundary
- Qualified Person
- Working Distance

National Electrical Code

Article 110.16 Flash Protection

Switchboards, panelboards, industrial control panels, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

FPN No. 1: NFPA 70E-2000, *Electrical Safety Requirements for Employee Workplaces*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

FPN No. 2: ANSI Z535.4-1998, *Product Safety Signs and Labels*, provides guidelines for the design of safety signs and labels for application to products.

Sample Label

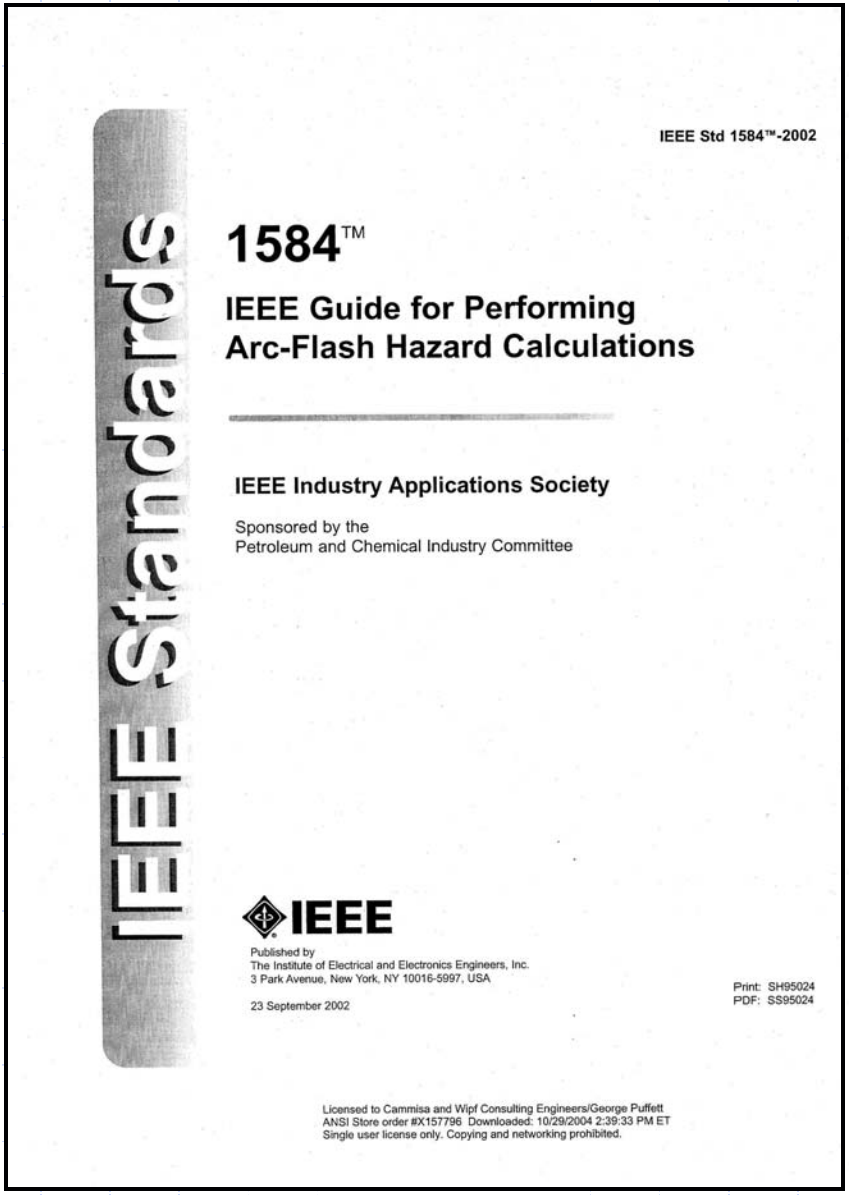
WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

56 inch	Flash Hazard Boundary
3.58	cal/cm^2 Flash Hazard at 18 inches
Class 1	FR Shirt & Pants
4160 VAC	Shock Hazard when cover is removed
60 inch	Limited Approach
26 inch	Restricted Approach
7 inch	Prohibited Approach

Bus: 012-TX3 TER Prot: R SWG3

IEEE & NFPA


IEEE Standards
IEEE Std 1584™-2002
1584™
IEEE Guide for Performing
Arc-Flash Hazard Calculations
IEEE Industry Applications Society
Sponsored by the
Petroleum and Chemical Industry Committee
IEEE
Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA
23 September 2002
Print: SH95024
PDF: SS95024
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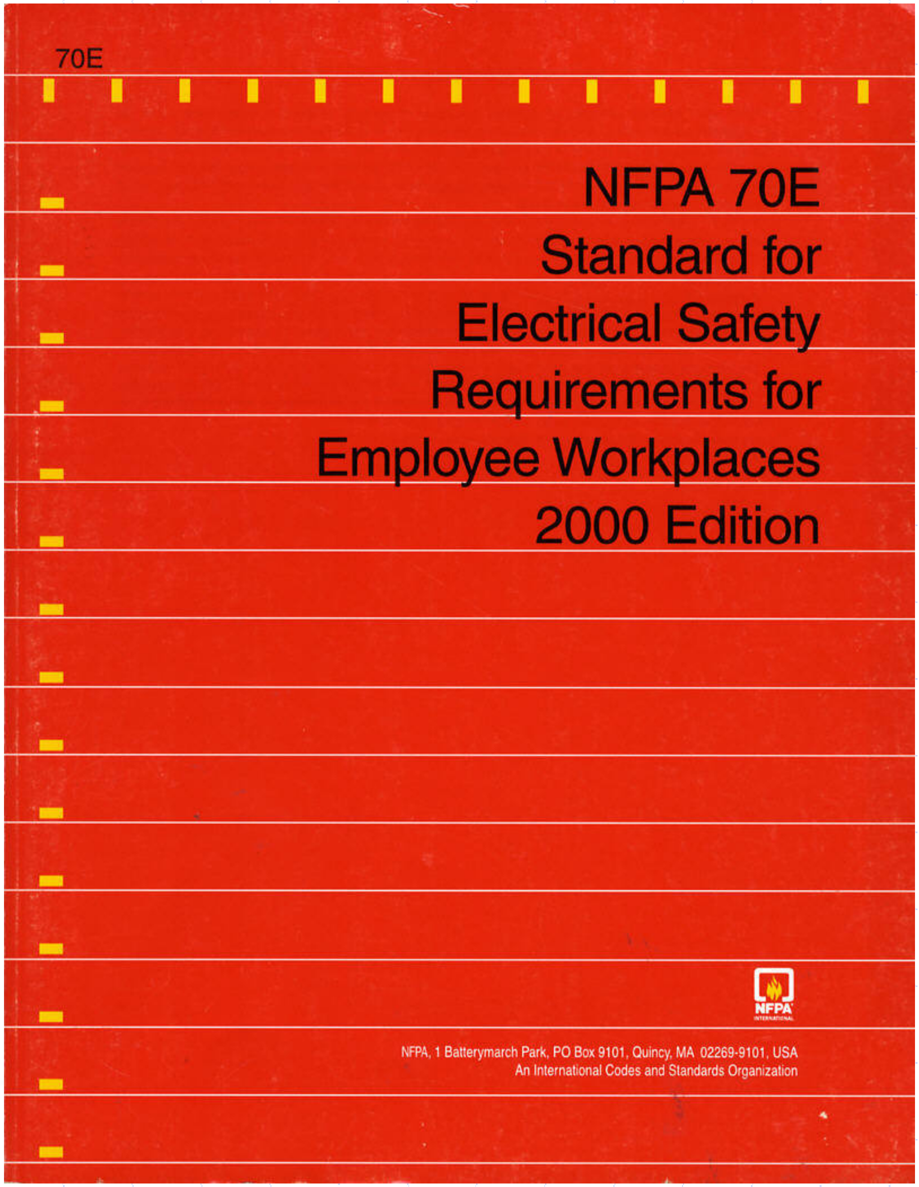

70E
NFPA 70E
Standard for
Electrical Safety
Requirements for
Employee Workplaces
2000 Edition
NFPA
NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101, USA
An International Codes and Standards Organization

NFPA 70E - 2004

Energized Electrical Work Permit

- Description of equipment and work
- Justification of why work energized
- Description of safe work practices
- Shock Hazard Analysis & Approach Boundaries
- Flash Hazard Analysis & FP Boundary
- Protective clothing and PPE
- Restriction of unqualified persons
- Job Briefing
- Management approval

Sample Energized Work Permit

ENERGIZED ELECTRICAL WORK PERMIT

PART I: TO BE COMPLETED BY THE REQUESTER: Job/Work Order Number: ____________

(1) Description of circuit/equipment/job location:
12KV MAIN SWGR

(2) Description of work to be done:

(3) Justification of why the circuit/equipment cannot be de-energized or the work deferred until the next scheduled outage:

Requester/Title ____________ Date ____________

PART II: TO BE COMPLETED BY THE ELECTRICALLY QUALIFIED PERSONS DOING THE WORK:

Check When Complete

(1) Detailed job description procedure to be used in performing the above detailed work: ☐

(2) Description of the Safe Work Practices to be employed: ☐

Flash Boundary	37 inch	Flash Hazard	1.23 cal/cm^2	Working Distance	36 inches
Shock Hazard	12470 VAC	Limited Approach	60 Inch	Glove Class	2
		Restricted Approach	26 Inch		
		Prohibited Approach	7 inch		
Requied PPE	Class 1	FR Shirt & Pants			

(3) Means employed to restrict the access of unqualified persons from the work area: ☐

(4) Evidence of completion of a Job Briefing including discussion of any job-related hazards: ☐

(5) Do you agree the above described work can be done safely? ☐ Yes ☐ No (If no, return to requester)

Electrically Qualified Person(s) ____________ Date ____________

Electrically Qualified Person(s) ____________ Date ____________

PART III: APPROVAL(S) TO PERFORM THE WORK WHILE ELECTRICALLY

Maintenance/Engineering Manager ____________ Manufacturing Manager ____________

Safety Manager ____________ Electrically Knowledgeable Person ____________

General Manager ____________ Date ____________

Definition

- **Flash Hazard Analysis**: A study investigating a worker's potential exposure to arc-flash energy, conducted for the purpose of injury prevention and the determination of safe work practices and the appropriate levels of PPE. [from NFPA 70E 2004]

Hazard Category Classification

- Table 3-3.9.1 Hazard Risk Category
  - Hazard Risk Category (0 to 4)
  - Voltage Rated Gloves (Yes or No)
  - Voltage Rated Tools (Yes or No)
- Table 3-3.9.2 Protective Clothing & PPE
  - Protective Clothing and Equipment
  - Hazard Risk Category
  - Protective Systems for Category (-1 to 4)

NFPA Table 3-3.9.1

Table 3-3.9.1 Hazard Risk Category Classifications

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary)	Hazard/ Risk Category	V-rated Gloves	V-rated Tools
Panelboards rated 240 V and below – Notes 1 and 3	—	—	—
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized parts)	1	N	N
Opening hinged covers (to expose bare, energized parts)	0	N	N
Panelboards or Switchboards rated >240 V and up to 600 V (with molded case or insulated case circuit breakers) — Notes 1 and 3	—	—	—
CB or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
600 V Class Motor Control Centers (MCCs) – Notes 2 (except as indicated) and 3	—	—	—
CB or fused switch or starter operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N

NFPA Table 3-3.9.2

Table 3-3.9.2 Protective Clothing and Personal Protective Equipment (PPE) Matrix

Protective Clothing & Equipment	Protective Systems for Hazard/Risk Category					
Hazard/Risk Category Number	−1 (Note 3)	0	1	2	3	4
Untreated Natural Fiber	—	—	—	—	—	—
a. T-shirt (short-sleeve)	X			X	X	X
b. Shirt (long-sleeve)		X				
c. Pants (long)	X	X	X (Note 4)	X (Note 6)	X	X
FR Clothing (Note 1)	—	—	—	—	—	—
a. Long-sleeve shirt			X	X	X (Note 9)	X
b. Pants			X (Note 4)	X (Note 6)	X (Note 9)	X
c. Coverall			(Note 5)	(Note 7)	X (Note 9)	(Note 5)
d. Jacket, parka, or rainwear			AN	AN	AN	AN
FR Protective Equipment	—	—	—	—	—	—
a. Flash suit jacket (2-layer)						X
b. Flash suit						X

Protective Clothing & PPE

- Untreated Natural Fiber (not synthetic)
  - T-shirt, Long-sleeve shirt, Pants
- FR Clothing [by employee per NECA]
  - Long-sleeve shirt, Pants, Coverall, Jacket
- FR Protective Equipment [by employer per NECA]
  - Flash suit jacket, Flash suit pants, Hard hat, FR hard hat liner, Safety glasses, Safety goggles, Face protection, Hearing protection, Leather gloves, Leather boots

Flash Suit

Safety Policy

- It is the policy of the Company to provide safe and healthful working conditions by acknowledging safety as the highest of priorities in all of our work activities. Knowledge of the job, the hazards involved, and the precautions to be taken are all critical factors in preventing accidents. It is our continual goal to eliminate occupational injuries and illness among our employees.
- It is the goal of the Company to have employees properly trained to meet the standards of a "Qualified Person" as set forth by OSHA (US) and OHSA (Canada) and to provide continual improvement of our employee's job skills and safety awareness through training and communication of vital safety information.
- Employees should never feel pressured to work in unsafe conditions or take unnecessary risks by working on equipment, which introduces additional or increased hazards.
- While the Company is committed to providing safe and healthful working conditions for each of its employees, in return the Company expects and insists that each employee recognize their obligation to conduct themselves in strict accordance with our safety policy and with due regard not only for their own safety but for the safety of their fellow employees, sub-contractors and customers as well.

Prerequisite to Analysis

- One-Line Diagram
- Short Circuit Study
- Coordination Study

Concept of Calculation

- Voltage, Current, Time
- “Flash Protection Boundary Calculation”:

- $D_C = (2.65 \times MVA_{BF} \times t)^{1/2}$

- D_C = distance in feet for 80° F
- MVA_{BF} = bolted fault at point involved
- t = time of arc exposure in seconds

[from NFPA 70E, Part II, Appendix B]

Concept of Calculation

- Voltage, Current, Time
- "Flash Protection Boundary Calculation":

- $D_C = (53 \times MVA_{TR} \times t)^{1/2}$

- D_C = distance in feet for 80° F
- MVA_{TR} = rating of transformer
  (For <0.75MVA multiply by 1.25)
- t = time of arc exposure in seconds

[from NFPA 70E, Part II, Appendix B]

IEEE 1584 Calculations

- Empirically derived formulas based on years of testing at four recognized testing laboratories
- Arcing current is calculated
- Incident energy is calculated using arcing current and arcing time
- Equations tailored for specific protective devices – fuses or circuit breakers and ampere rating

IEEE 1584 Formulas

5.2 Arcing current

The predicted three-phase arcing current must be found so the operating time for protective devices can be determined.

For applications with a system voltage under 1000 V solve the equation (1):

$$\lg I_a = K + 0.662 \lg I_{bf} + 0.0966\, V + 0.000526\, G + 0.5588\, V (\lg I_{bf}) - 0.00304\, G (\lg I_{bf}) \quad (1)$$

where

- lg is the $\log_{10}$
- I_a is arcing current (kA)
- K is –0.153 for open configurations and
  is –0.097 for box configurations
- I_{bf} is bolted fault current for three-phase faults (symmetrical RMS) (kA)
- V is system voltage (kV)
- G is the gap between conductors, (mm) (see Table 4)

For applications with a system voltage of 1000 V and higher solve the equation (2):

$$\lg I_a = 0.00402 + 0.983 \lg I_{bf} \quad (2)$$

The high-voltage case makes no distinction between open and box configurations.

IEEE 1584 Formulas

5.3 Incident energy

First find the $\log_{10}$ of the incident energy normalized. This equation is based on data normalized for an arc time of 0.2 seconds and a distance from the possible arc point to the person of 610 mm.

$$\lg E_n = K_1 + K_2 + 1.081 \lg I_a + 0.0011 G \quad (4)$$

where

E_n	is incident energy (J/cm^2) normalized for time and distance [13]
K_1	is –0.792 for open configurations (no enclosure) and
	is –0.555 for box configurations (enclosed equipment)
K_2	is 0 for ungrounded and high-resistance grounded systems and
	is –0.113 for grounded systems
G	is the gap between conductors (mm) (see Table 4)

Then:

$$E_n = 10^{\lg E_n} \quad (5)$$

Finally, convert from normalized:[14]

$$E = 4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{D^x}\right) \quad (6)$$

where

E	is incident energy (J/cm^2)
C_f	is a calculation factor
	1.0 for voltages above 1kV, and
	1.5 for voltages at or below 1kV
E_n	is incident energy normalized [15]
t	is arcing time (seconds)
D	is distance from the possible arc point to the person (mm)
x	is the distance exponent from Table 4.

The other cases are handled similarly.

IEEE 1584 Formulas

5.4 Lee method

For cases where voltage is over 15 kV, or gap is outside the range of the model, the theoretically derived Lee method can be applied and it is included in the IEEE Std 1584-2002 Incident Energy Calculators.[16] See 7.2 and 9.11.4.

$$E = 2.142 \times 10^6 V I_{bf} \left(\frac{t}{D^2}\right) \qquad (7)$$

where[17]

E is incident energy (J/cm²)
V is system voltage (kV)
t is arcing time (seconds)
D is distance from possible arc point to person (mm)
I_{bf} is bolted fault current

For voltages over 15 kV, arc fault current is considered to be equal to the bolted fault current.

5.5 Flash-protection boundary

For the IEEE Std 1584-2002 empirically derived model: [18]

$$D_B = \left[4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{E_B}\right)\right]^{\frac{1}{x}} \qquad (8)$$

For the Lee method: [19]

IEEE 1584 Formulas

$$D_B = \sqrt{2.142 \times 10^6 V I_{bf} \left(\frac{t}{E_B}\right)} \qquad (9)$$

where

D_B	is the distance of the boundary from the arcing point (mm)
C_f	is a calculation factor 1.0 for voltages above 1 kV, and 1.5 for voltages at or below 1 kV,
E_n	is incident energy normalized[20]
E_B	is incident energy in J/cm^2 at the boundary distance
t	is time (seconds)
x	is the distance exponent from Table 4.
I_{bf}	is bolted fault current

E_B can be set at 5.0 J/cm^2 for bare skin (no hood) or at the rating of proposed PPE.[21]

5.6 Current limiting fuses

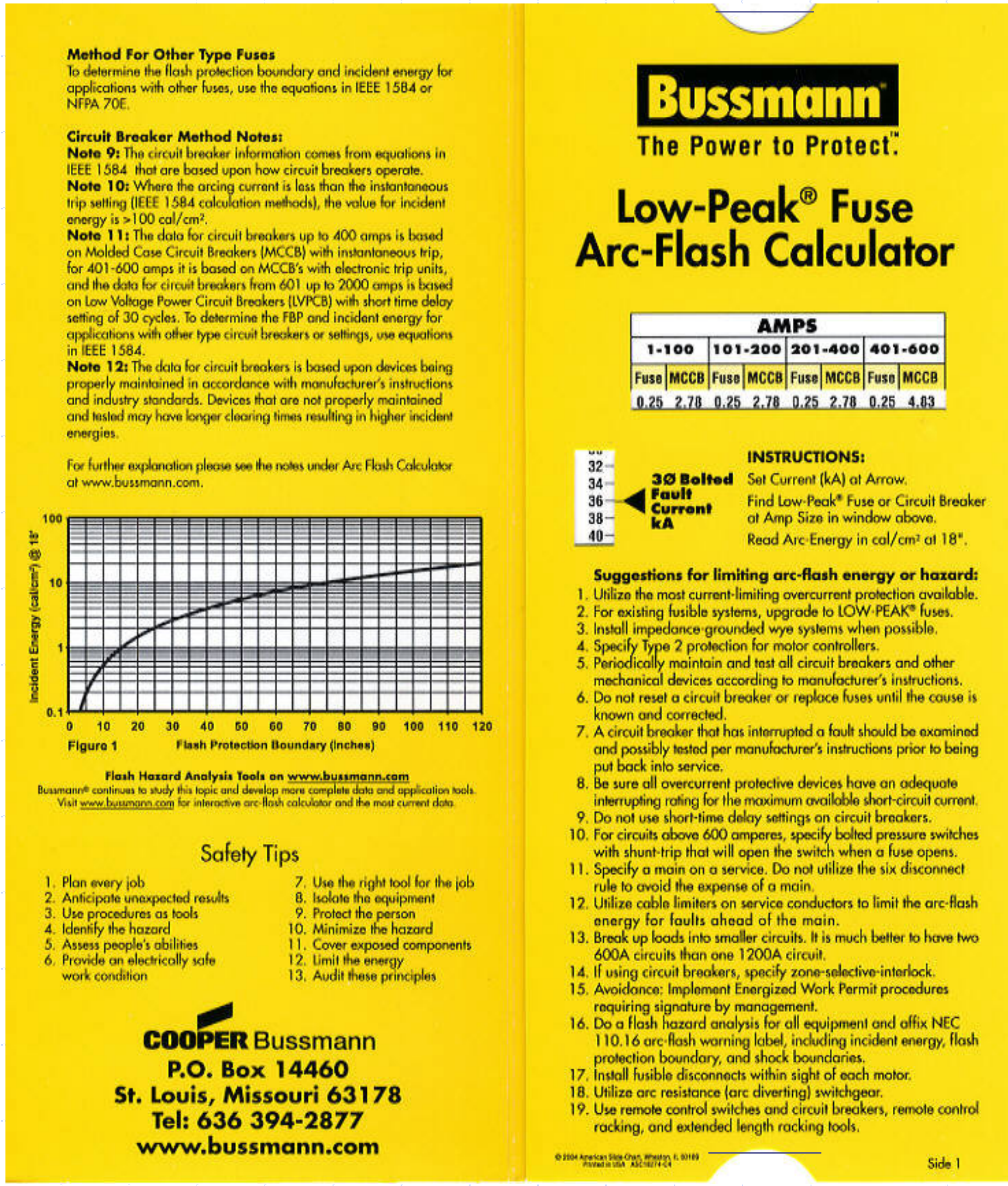
Formulae for calculating arc-flash energies for use with current-limiting Class L and Class RK1 fuses have been developed. These formulae were developed based upon testing at 600 V and a distance of 455 mm using one manufacturer's fuses. The variables are as follows:

I_{bf}	is bolted fault current for three-phase faults (symmetrical RMS) (kA)
E	is incident energy (J/cm^2).

How to Compute

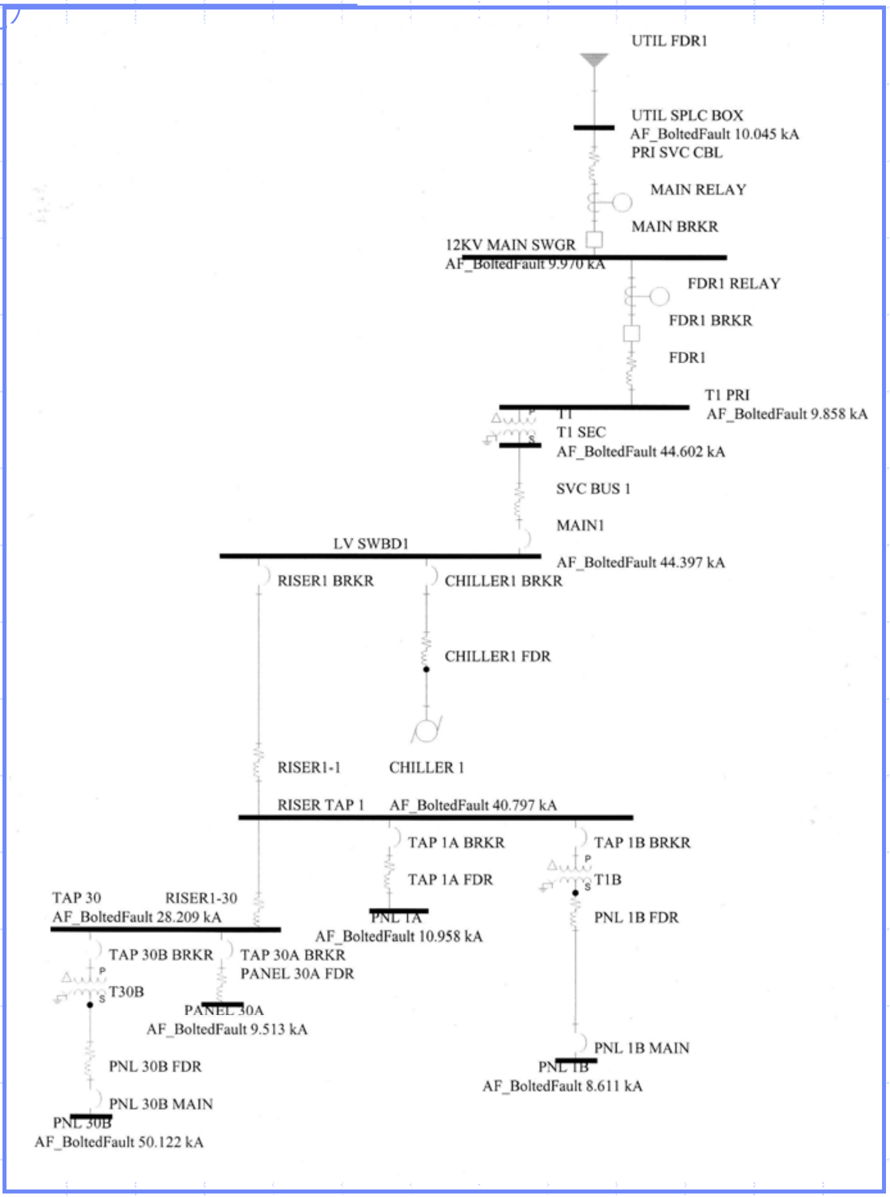
- Slide calculator [from fuse manuf.]
- Look-up Table [from NFPA 70E]
- Spreadsheet using IEEE 1584 formulas, included with the standard
- Computer program

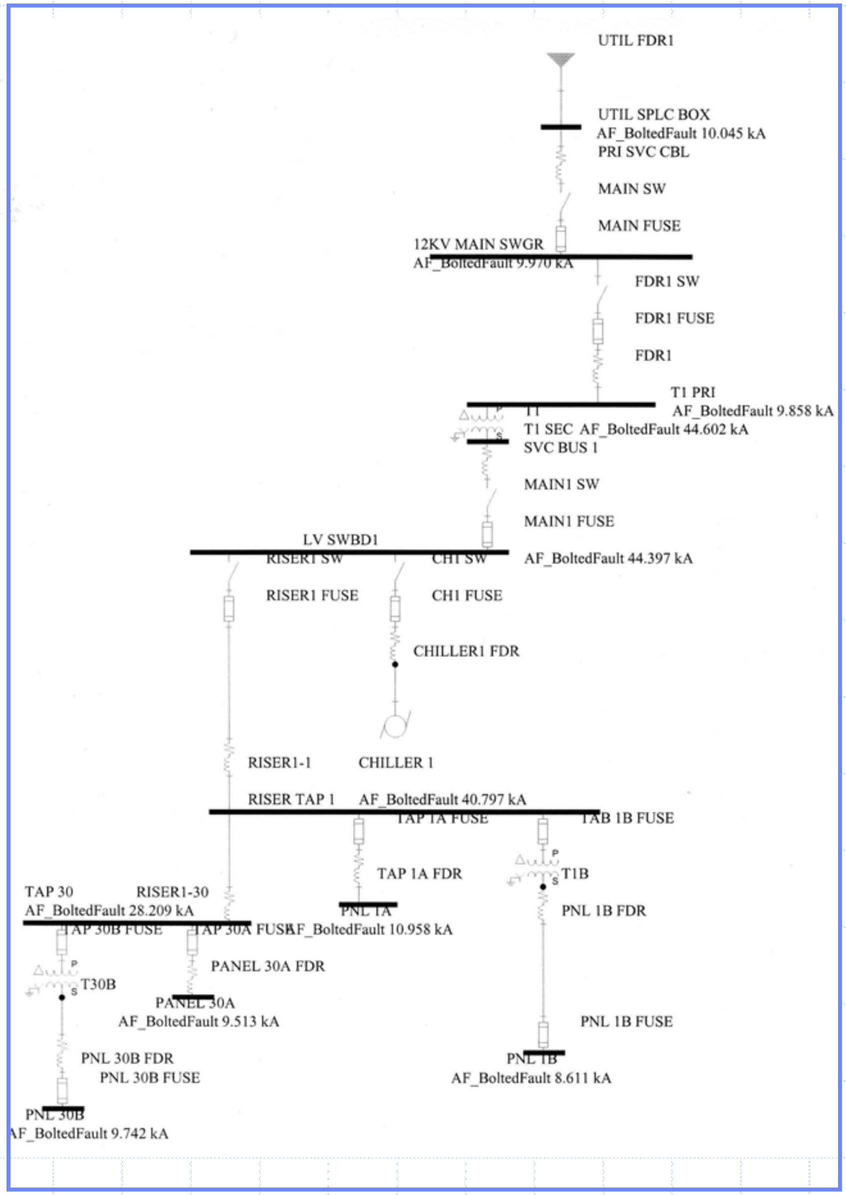
Slide Calculator



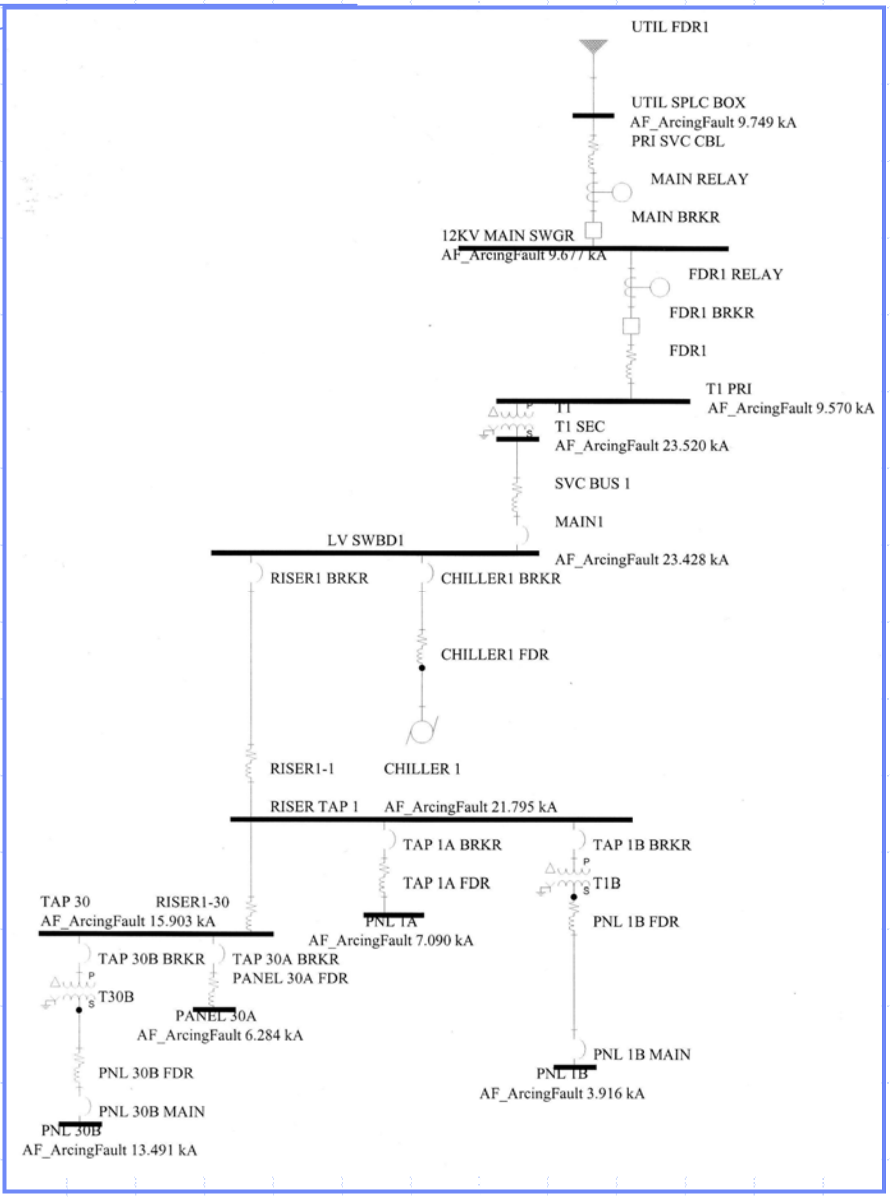
Example Computer Programs

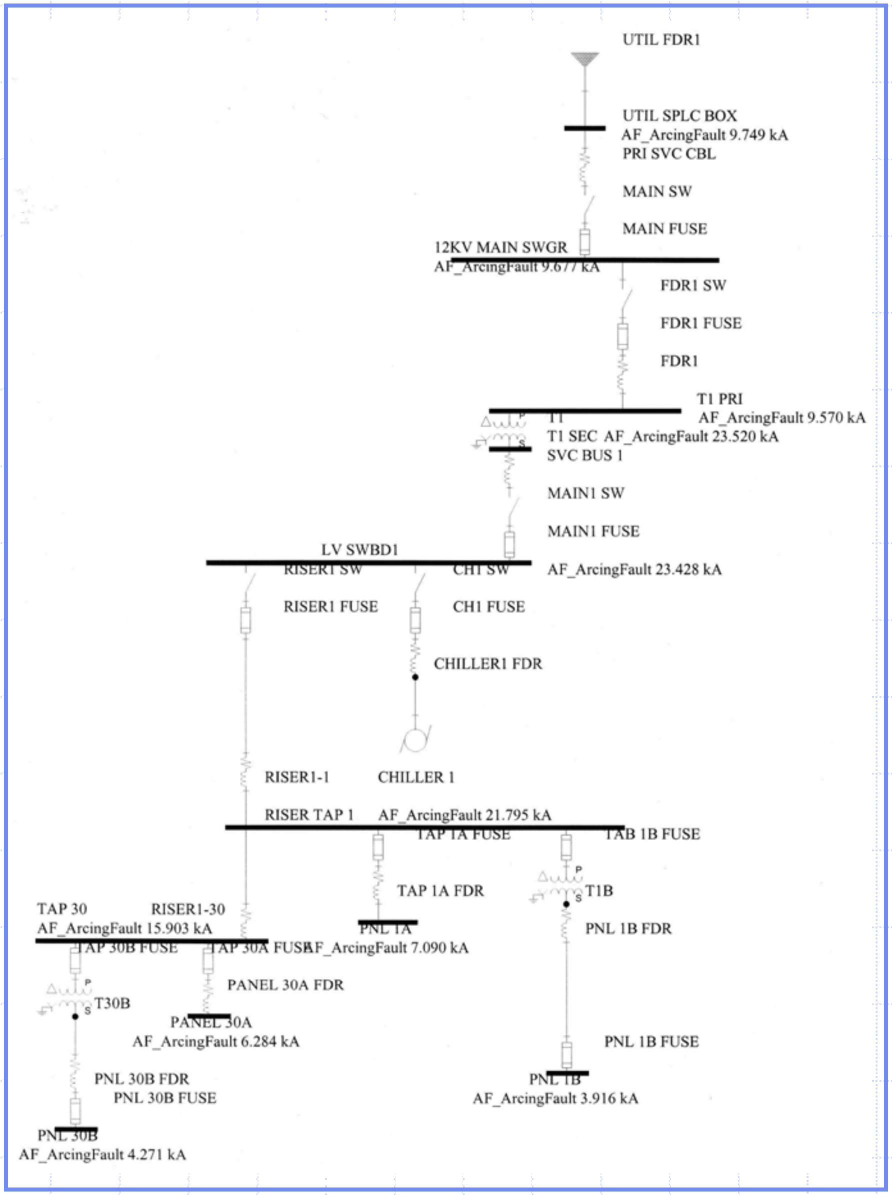
Sample One-Line Diagram-BF



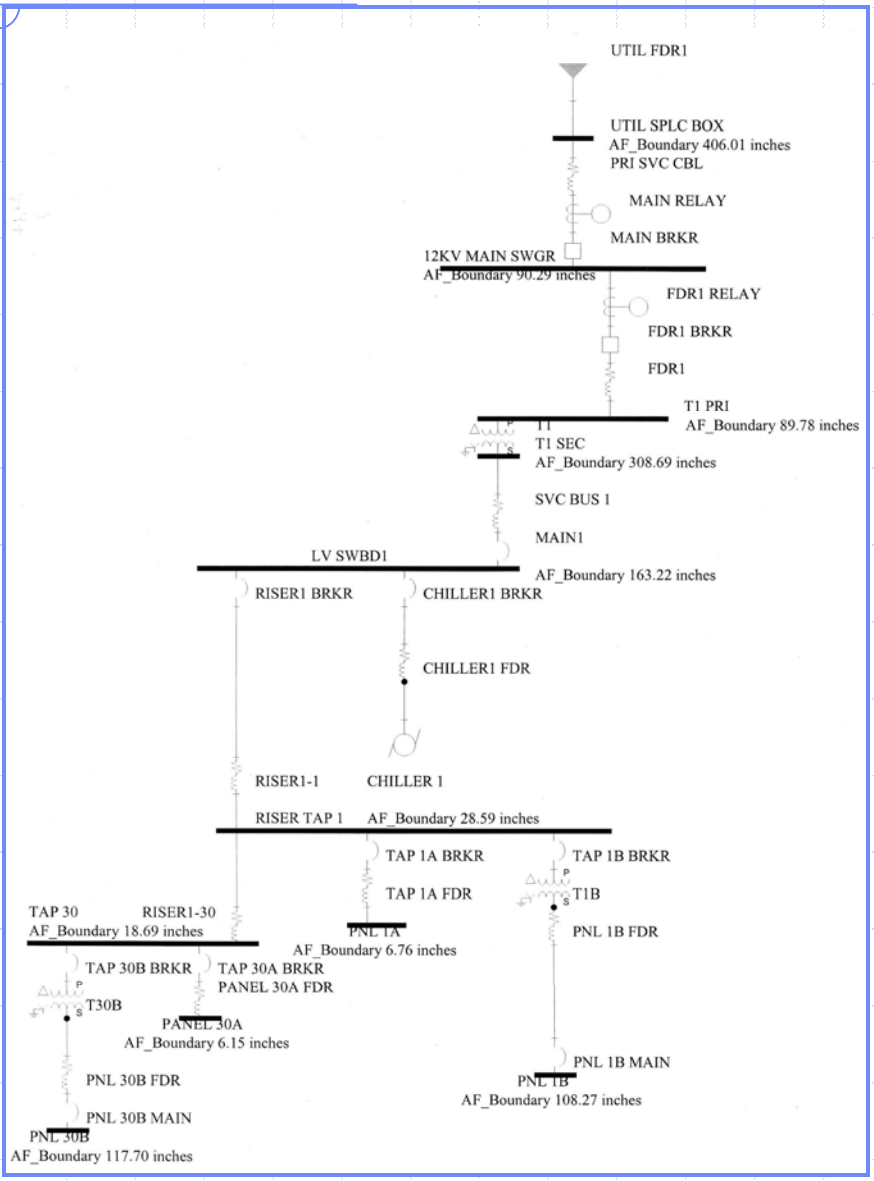


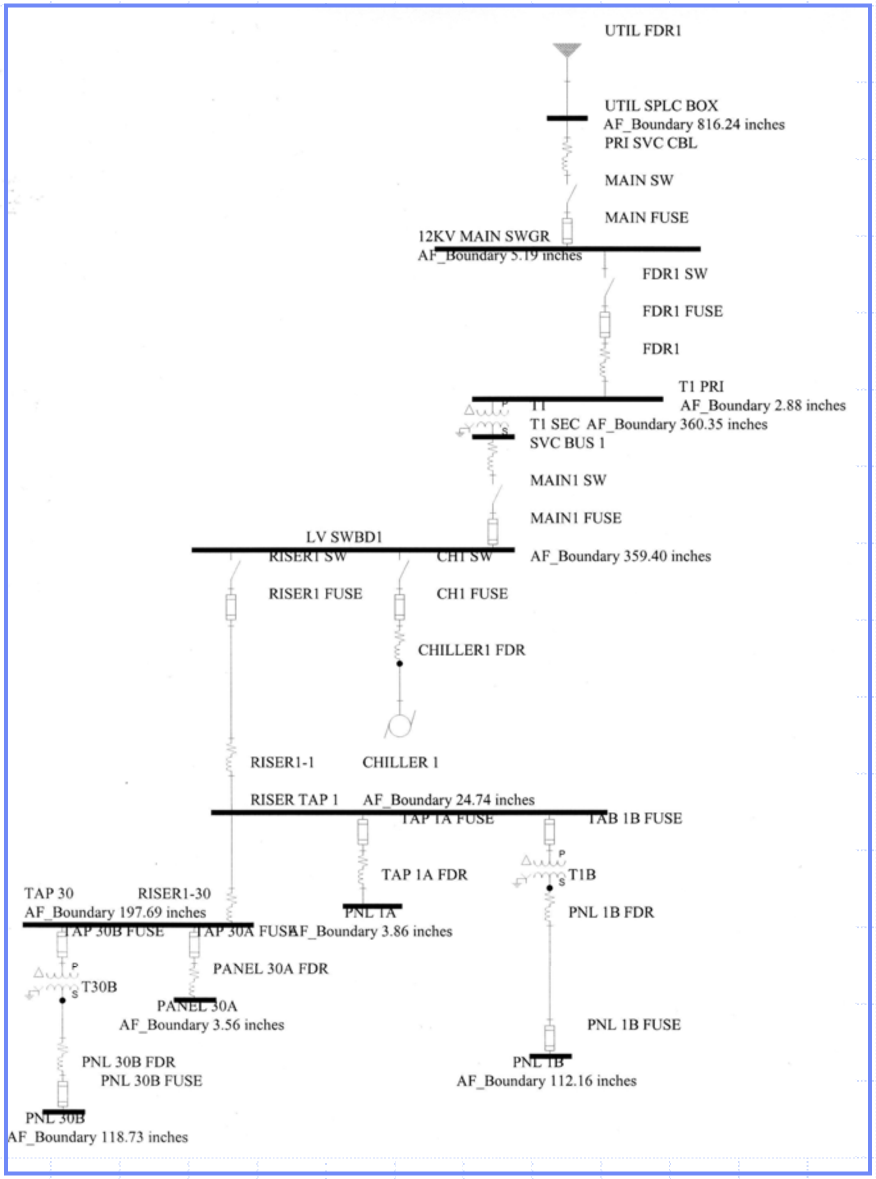
Sample One-Line Diagram-AF



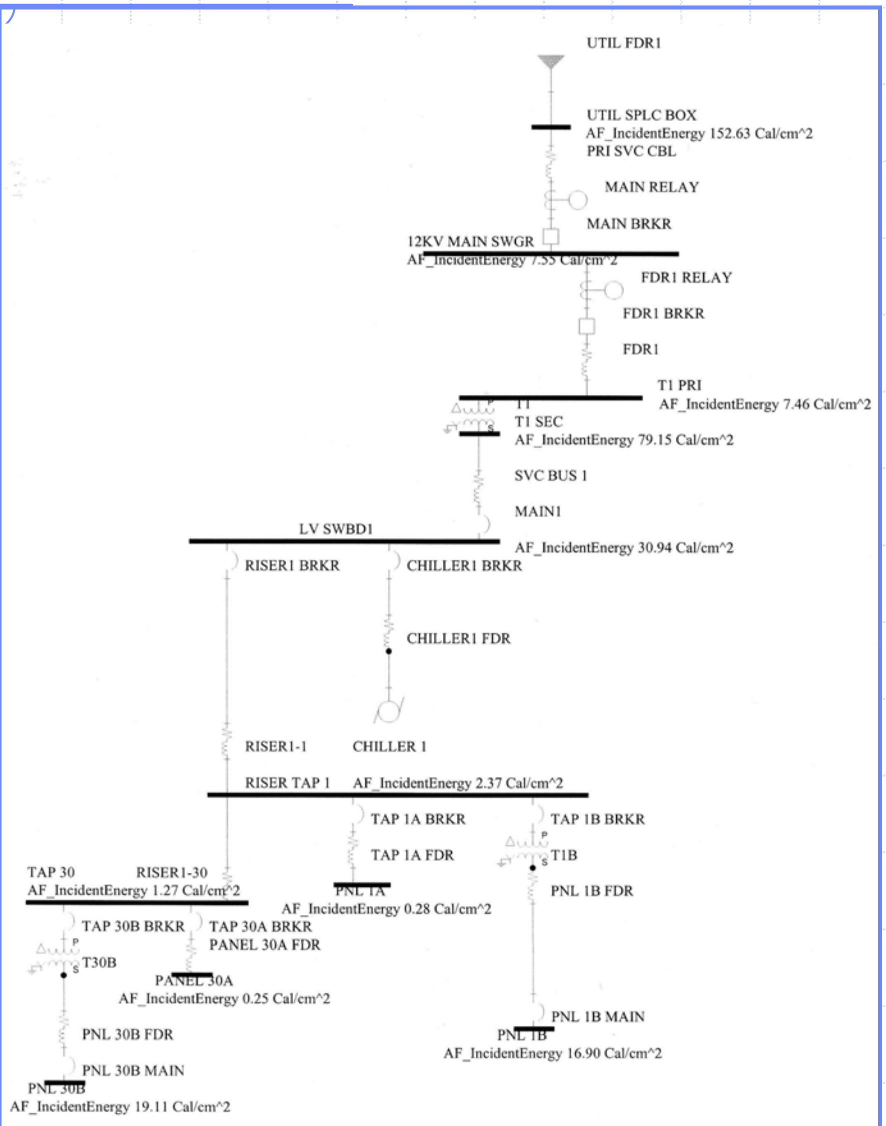


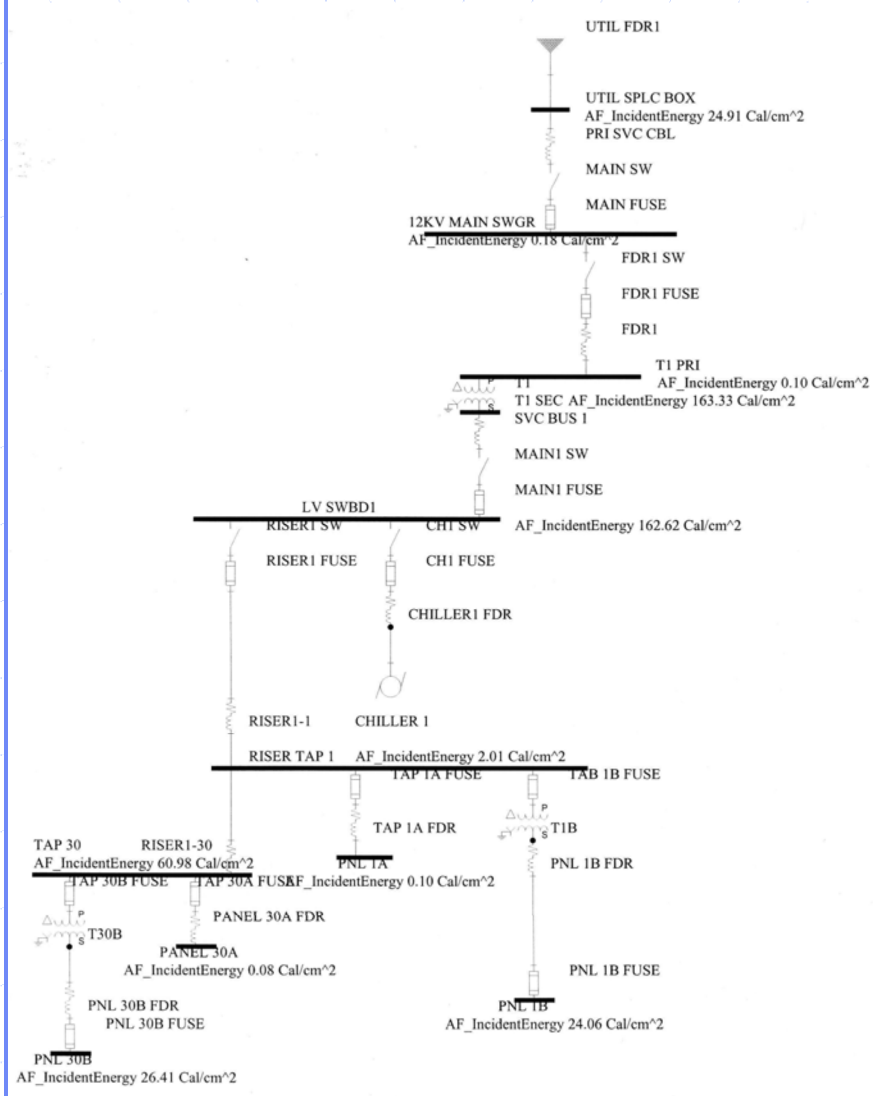
Sample One-Line Diagram-AFB





Sample One-Line Diagram-IE





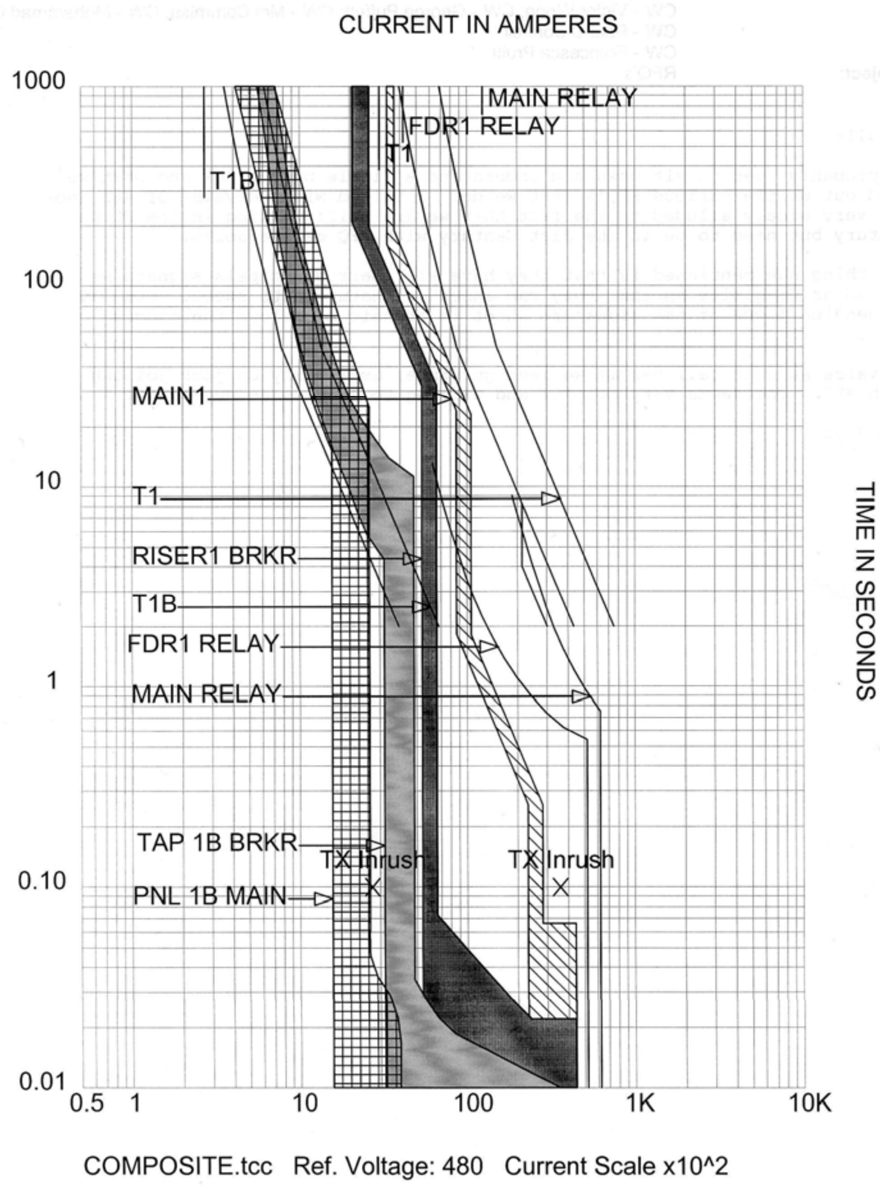
Sample Short Circuit Study

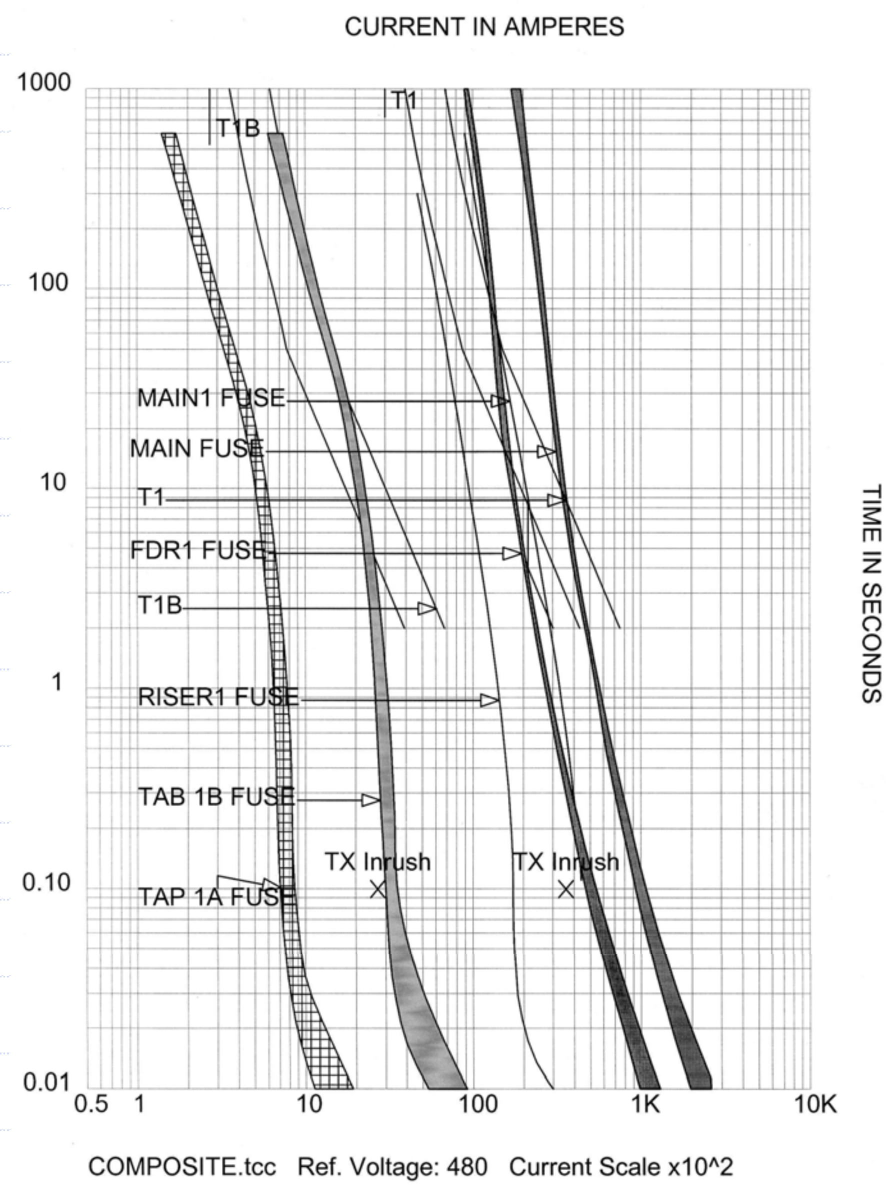
***************** F A U L T   A N A L Y S I S   S U M M A R Y **************

BUS NAME	VOLTAGE L-L	AVAILABLE FAULT CURRENT 3 PHASE	X/R	LINE/GRND	X/R
12KV MAIN SWGR	12470.	9970.5	7.5	3987.24	7.8
LV SWBD1	480.	44397.3	5.6	44798.68	4.5
PANEL 30A	480.	9512.8	0.6	3415.30	0.5
PNL 1A	480.	10957.8	0.6	5947.18	0.4
PNL 1B	208.	8610.8	2.3	8007.60	2.1
PNL 30B	208.	9742.0	2.2	9997.66	2.2
RISER TAP 1	480.	40797.0	3.5	22031.34	1.2
T1 PRI	12470.	9857.6	6.3	3962.22	7.1
T1 SEC	480.	44602.0	5.8	46902.50	5.8
TAP 30	480.	28208.8	1.6	5961.59	0.7
UTIL SPLC BOX	12470.	10045.5	8.0	4004.83	8.0

********************** FAULT ANALYSIS REPORT COMPLETED **********************

Sample Coordination Study





Sample Arc Flash Results-1

Arc Flash Evaluation NFPA 70E-2004 Bus Report (80% Cleared Fault Threshold, include Ind. Motors for 5.0 Cycles), mis-coordination checked

	Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Duration of Arc (sec.)	Arc Type	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	Required Protective FR Clothing Class
1	12KV MAIN SWGR	FDR1 RELAY	12.5	9.97	0.05	0.05	0.083	0.000	0.083	In Box	83	36.00	6.34	Class 2
2	12KV MAIN SWGR	MAIN RELAY	12.5	9.97	9.92	9.92	0.016	0.083	0.099	In Box	90	36.00	7.55	Class 2
3														
4	LV SWBD1	CHILLER1 BRKR	0.48	44.40	1.21	1.21	0.083	0.000	0.083	In Box	69	18.00	8.73	Class 3
5	LV SWBD1	MAIN1	0.48	44.40	43.19	16.41	0.753	0.000	0.753	In Box	163	18.00	30.9	Class 4 (*3)
6														
7	PANEL 30A	TAP 30A BRKR	0.48	9.51	9.51	9.51	0.01	0.000	0.01	In Box	6	18.00	0.25	Class 0
8														
9	PNL 1A	TAP 1A BRKR	0.48	10.96	10.96	10.96	0.01	0.000	0.01	In Box	7	18.00	0.28	Class 0
10														
11	PNL 1B	PNL 1B MAIN	0.21	8.61	8.61	3.27	2	0.000	2	In Box	108	18.00	16.9	Class 3 (*3)
12														
13	PNL 30B	PNL 30B MAIN	0.21	9.74	9.74	3.70	2	0.000	2	In Box	118	18.00	19.1	Class 3 (*3)
14														
15	RISER TAP 1	RISER1 BRKR	0.48	40.80	40.80	40.80	0.022	0.000	0.022	In Box	29	18.00	2.37	Class 1
16														
17	T1 PRI	MAIN1	12.5	9.86	0.05	0.05	0.083	0.000	0.083	In Box	82	36.00	6.27	Class 2
18	T1 PRI	FDR1 RELAY	12.5	9.86	9.81	9.81	0.016	0.083	0.099	In Box	90	36.00	7.46	Class 2
19														
20	T1 SEC	MAIN1	0.48	44.60	1.21	1.21	0.083	0.000	0.083	In Box	81	18.00	11.1	Class 3
21	T1 SEC	FDR1 RELAY	0.48	44.60	43.40	43.40	0.58	0.050	0.63	In Box	309	18.00	79.2	Dangerous!!!
22														
23	TAP 30	RISER1 BRKR	0.48	28.21	28.21	10.72	0.046	0.000	0.046	In Box	19	18.00	1.27	Class 1 (*3)
24														
25	UTIL SPLC BOX	MAIN RELAY	12.5	10.05	0.05	0.05	0.083	0.000	0.083	In Box	83	36.00	6.39	Class 2
28	Class 1: FR Shirt & Pants													Current
29	Class 2: Cotton Underwear + FR Shirt & Pants													
30	Class 3: Cotton Underwear + FR Shirt & Pant + FR Coverall													
31	Class 4: Cotton Underwear + FR Shirt & Pant + Multi Layer Flash Suit	Device with 80% Cleared Fault Threshold												NFPA 70E-2004 Bus Report (80% Cleared Fault Threshold, include Ind. Motors for 5.0 Cycles), mis-coordination checked

Sample Arc Flash Results-2

Arc Flash Evaluation NFPA 70E-2004 Bus Report (80% Cleared Fault Threshold, include Ind. Motors for 5.0 Cycles), mis-coordination checked

	Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Duration of Arc (sec.)	Arc Type	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	Required Protective FR Clothing Class
1	12KV MAIN SWGR	MAIN FUSE	12.5	9.97	9.92	9.92	0.011	0.000	0.011	In Box	31	36.00	0.86	Class 0
2	12KV MAIN SWGR	FDR1 FUSE	12.5	9.97	0.05	0.05	0.083	0.000	0.083	In Box	31	36.00	0.89	Class 0
3														
4	LV SWBD1	CH1 FUSE	0.48	44.40	1.21	1.21	0.083	0.000	0.083	In Box	81	18.00	11.0	Class 3
5	LV SWBD1	MAIN1 FUSE	0.48	44.40	43.19	16.41	2	0.000	2	In Box	317	18.00	82.3	Dangerous!!! (*3)
6														
7	PANEL 30A	TAP 30A FUSE	0.48	9.51	9.51	9.51	0.004	0.000	0.004	In Box	3	18.00	0.10	Class 0
8														
9	PNL 1A	TAP 1A FUSE	0.48	10.96	10.96	10.96	0.004	0.000	0.004	In Box	4	18.00	0.12	Class 0
10														
11	PNL 1B	PNL 1B FUSE	0.21	8.61	8.61	3.27	2	0.000	2	In Box	108	18.00	16.9	Class 3 (*3)
12														
13	PNL 30B	PNL 30B FUSE	0.21	9.74	9.74	3.70	2	0.000	2	In Box	118	18.00	19.1	Class 3 (*3)
14														
15	RISER TAP 1	RISER1 FUSE	0.48	40.80	40.80	15.50	0.449	0.000	0.449	In Box	112	18.00	17.7	Class 3 (*3)
16														
17	T1 PRI	FDR1 FUSE	12.5	9.86	9.81	9.81	0.008	0.000	0.008	In Box	26	36.00	0.63	Class 0
18	T1 PRI	MAIN1 FUSE	12.5	9.86	0.05	0.05	0.083	0.000	0.083	In Box	27	36.00	0.65	Class 0
19														
20	T1 SEC	MAIN1 FUSE	0.48	44.60	1.21	1.21	0.083	0.000	0.083	In Box	81	18.00	11.1	Class 3
21	T1 SEC	FDR1 FUSE	0.48	44.60	43.40	16.49	2	0.000	2	In Box	317	18.00	82.2	Dangerous!!! (*3)
22														
23	TAP 30	RISER1 FUSE	0.48	28.21	28.21	10.72	2	0.000	2	In Box	240	18.00	54.6	Dangerous!!! (*3)
24														
25	UTIL SPLC BOX	MAIN FUSE	12.5	10.05	0.05	0.05	0.083	0.000	0.083	In Box	83	36.00	6.39	Class 2
26	UTIL SPLC BOX	MaxTripTime @2.0s	12.5	10.05	10.00	10.00	2	0.000	2	In Box	406	36.00	153	Dangerous!!!
27	Class 0: Untreated Cotton													(*3) - 38% Bolted Fault Used as Arcing Fault Current
28	Class 1: FR Shirt & Pants													
29	Class 2: Cotton Underwear + FR Shirt & Pants													
30	Class 3: Cotton Underwear + FR Shirt & Pant + FR Coverall													
31	Class 4: Cotton Underwear + FR Shirt & Pant + Multi Layer Flash Suit	Device with 80% Cleared Fault Threshold												NFPA 70E-2004 Bus Report (80% Cleared Fault Threshold, include Ind. Motors for 5.0 Cycles), mis-coordination checked

Sample Arc Flash Results-3

Arc Flash Evaluation IEEE 1584-2002 Bus Report (80% Cleared Fault Threshold, include Ind. Motors for 5.0 Cycles), mis-coordination checked

	Class 0: Untreated Cotton	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Ground	Equip Type	Gap (mm)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	Required Protective FR Clothing Class
1	12KV MAIN SWGR	FDR1	12.5	9.97	0.05	0.04	0.083	0.000	Yes	SWG	153	31	36	1.03	Class 0
2	12KV MAIN SWGR	MAIN RELAY	12.5	9.97	9.92	9.63	0.016	0.083	Yes	SWG	153	37	36	1.23	Class 1
3															
4	LV SWBD1	CHILLER1 BRKR	0.48	44.40	1.21	0.64	0.083	0.000	Yes	PNL	25	53	18	6.94	Class 2
5	LV SWBD1	MAIN1	0.48	44.40	43.19	19.37	0.54	0.000	Yes	PNL	25	146	18	37.0	Class 4 (*3)
6															
7	PANEL 30A	TAP 30A BRKR	0.48	9.51	9.51	6.28	0.01	0.000	Yes	PNL	25	6	18	0.20	Class 0
8															
9	PNL 1A	TAP 1A BRKR	0.48	10.96	10.96	7.09	0.01	0.000	Yes	PNL	25	7	18	0.23	Class 0
10															
11	PNL 1B	PNL 1B MAIN	0.21	8.61	8.61	3.92	2	0.000	Yes	PNL	25	112	18	24.1	Class 3
12															
13	PNL 30B	PNL 30B MAIN	0.21	9.74	9.74	4.27	2	0.000	Yes	PNL	25	119	18	26.4	Class 4
14															
15	RISER TAP 1	RISER1 BRKR	0.48	40.80	40.80	21.79	0.023	0.000	Yes	PNL	25	23	18	1.80	Class 1
16															
17	T1 PRI	MAIN1	12.5	9.86	0.05	0.04	0.083	0.000	Yes	SWG	153	31	36	1.02	Class 0
18	T1 PRI	FDR1 RELAY	12.5	9.86	9.81	9.53	0.016	0.083	Yes	SWG	153	37	36	1.22	Class 1
19															
20	T1 SEC	MAIN1	0.48	44.60	1.21	0.64	0.083	0.000	Yes	PNL	25	53	18	6.97	Class 2
21	T1 SEC	FDR1 RELAY	0.48	44.60	43.40	22.88	0.969	0.050	Yes	PNL	25	239	18	83.3	Dangerous!!!
22															
23	TAP 30	RISER1 BRKR	0.48	28.21	28.21	15.90	0.031	0.000	Yes	PNL	25	23	18	1.72	Class 1
24															

Sample Arc Flash Results-4

Arc Flash Evaluation IEEE 1584-2002 Bus Report (80% Cleared Fault Threshold, include Ind. Motors for 5.0 Cycles), mis-coordination checked

	Class 0: Untreated Cotton	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Ground	Equip Type	Gap (mm)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	Required Protective FR Clothing Class
1	12KV MAIN SWGR	MAIN FUSE	12.5	9.97	9.92	8.19	0.017	0.000	Yes	SWG	153	5	36	0.18	Class 0 (*3)
2	12KV MAIN SWGR	FDR1 FUSE	12.5	9.97	0.05	0.04	0.083	0.000	Yes	SWG	153	5	36	0.18	Class 0 (*3)
3															
4	LV SWBD1	CH1 FUSE	0.48	44.40	1.21	0.64	0.083	0.000	Yes	PNL	25	53	18	6.94	Class 2
5	LV SWBD1	MAIN1 FUSE	0.48	44.40	43.19	22.79	2	0.000	Yes	PNL	25	359	18	163	Dangerous!!!
6															
7	PANEL 30A	TAP 30A FUSE	0.48	9.51	9.51	6.28	0.004	0.000	Yes	PNL	25	4	18	0.08	Class 0
8															
9	PNL 1A	TAP 1A FUSE	0.48	10.96	10.96	7.09	0.004	0.000	Yes	PNL	25	4	18	0.10	Class 0
10															
11	PNL 1B	PNL 1B FUSE	0.21	8.61	8.61	3.92	2	0.000	Yes	PNL	25	112	18	24.1	Class 3
12															
13	PNL 30B	PNL 30B FUSE	0.21	9.74	9.74	4.27	2	0.000	Yes	PNL	25	119	18	26.4	Class 4
14															
15	RISER TAP 1	RISER1 FUSE	0.48	40.80	40.80	18.53	0.031	0.000	Yes	PNL	25	25	18	2.01	Class 1 (*3)
16															
17	T1 PRI	FDR1 FUSE	12.5	9.86	9.81	9.53	0.008	0.000	Yes	SWG	153	3	36	0.10	Class 0
18	T1 PRI	MAIN1 FUSE	12.5	9.86	0.05	0.04	0.083	0.000	Yes	SWG	153	3	36	0.11	Class 0
19															
20	T1 SEC	MAIN1 FUSE	0.48	44.60	1.21	0.64	0.083	0.000	Yes	PNL	25	53	18	6.97	Class 2
21	T1 SEC	FDR1 FUSE	0.48	44.60	43.40	22.88	2	0.000	Yes	PNL	25	360	18	163	Dangerous!!!
22															
23	TAP 30	RISER1 FUSE	0.48	28.21	28.21	13.52	1.346	0.000	Yes	PNL	25	198	18	61.0	Dangerous!!! (*3)
24															
25	UTIL SPLC BOX	MAIN FUSE	12.5	10.05	0.05	0.04	0.083	0.000	Yes	SWG	153	31	36	1.04	Class 0

Enforcement

ENGINEERS

- NEC 2002, Art. 110.16
- California Electrical Code 2004 based on NEC 2002
  - Published early 2005
  - Effective 180 days later 2005

EMPLOYERS

- OSHA 1990 recognizes NFPA 70E as a national consensus standard

Obligations and Opportunities

ENGINEERS

Perform Arc Flash Analysis

EMPLOYERS

Comply with OSHA and NFPA 70E

The End