



**Shenandoah Valley  
Wastewater Treatment Plant Network**

**Pure H<sub>2</sub>O Forum**

**Safeguarding Operations Personnel –  
Understanding Arc Flash &  
Developing an Electrical Safety Program**

**September 25, 2015**



**Presenter:  
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Vice President  
Energy & MEP Group Leader**



# Objectives

- Why is Electrical Safety important and what is my responsibility?
- What is arc flash?
- What happens during an arc flash event?
- What is an arc flash analysis and does our organization need one?

# Objectives

- What should we require in the way of deliverables?
- How do we modify our behavior after the analysis?
- Why have an Electrical Safety Program and will it help prevent injuries?



# Importance of Electrical Safety

- Personal safety of employees/  
co-workers/friends
- Protection of property and assets
- OSHA regulatory requirements
- Expense associated with an arc flash event
- Civil liabilities

# Electrical Safety Statistics

- Electrocution is the 4<sup>th</sup> leading cause of death in the US industrial workplace
- 97% of electricians report having been shocked or injured on the job
  - Long term effects of shocks on human health unknown
- 80% of electrical injuries are related to arc flash incidents

# Arc Flash Hazard Statistics

- 5-10 arc explosions occur in the United States every day
- 2000 people are treated in burn trauma units every year resulting from arc flash incidents
- Someone dies from an electrical event in the United States every working day (and that includes significant improvement over the last decade)



# Cost of an Arc Flash Incident

- \$1.5M average cost of medical treatment
- 8-12 months away from work  
(on average)
- \$10-12M average litigation cost for general industry incident
- Human tragedy



# What is my Responsibility?

- Position of Authority
- Set the tone for work practices
- Define the importance of safety





# Importance of an Electrical Safety Program

- The goal is to minimize risk
  - Eliminate the hazard
  - Substitute lower hazards for higher hazards
  - Implement engineering controls to limit risk
  - Raise awareness of risks and their consequences
  - Establish administrative controls to regulate work practices
  - Mandate the use of personal protective equipment (PPE) as a last resort

# What is included in an Electrical Safety Program?

- Definition of the hazards that exist
- Acknowledgement of situational realities
- Tool to assess the work required
- Process to request electrical outage
- Process to request energized work permit
- Lock-out/Tag-out (LO/TO) procedures
- Description of available PPE

# Arc Flash

- Regulatory Compliance
  - OSHA – effective August 2007, regulations require that employers protect employees against arc flash hazards
  - Since 2002, NEC requires “field marking” of equipment requiring service while energized
  - NFPA 70E – industry standard for guidance on electrical safety in the workplace
  - IEEE 1584 defines a standard for calculating incident energy levels

# Arc Flash

## NFPA Definition

Electrical current that passes through air when insulation or isolation between electrified conductors is no longer sufficient to withstand the applied voltage

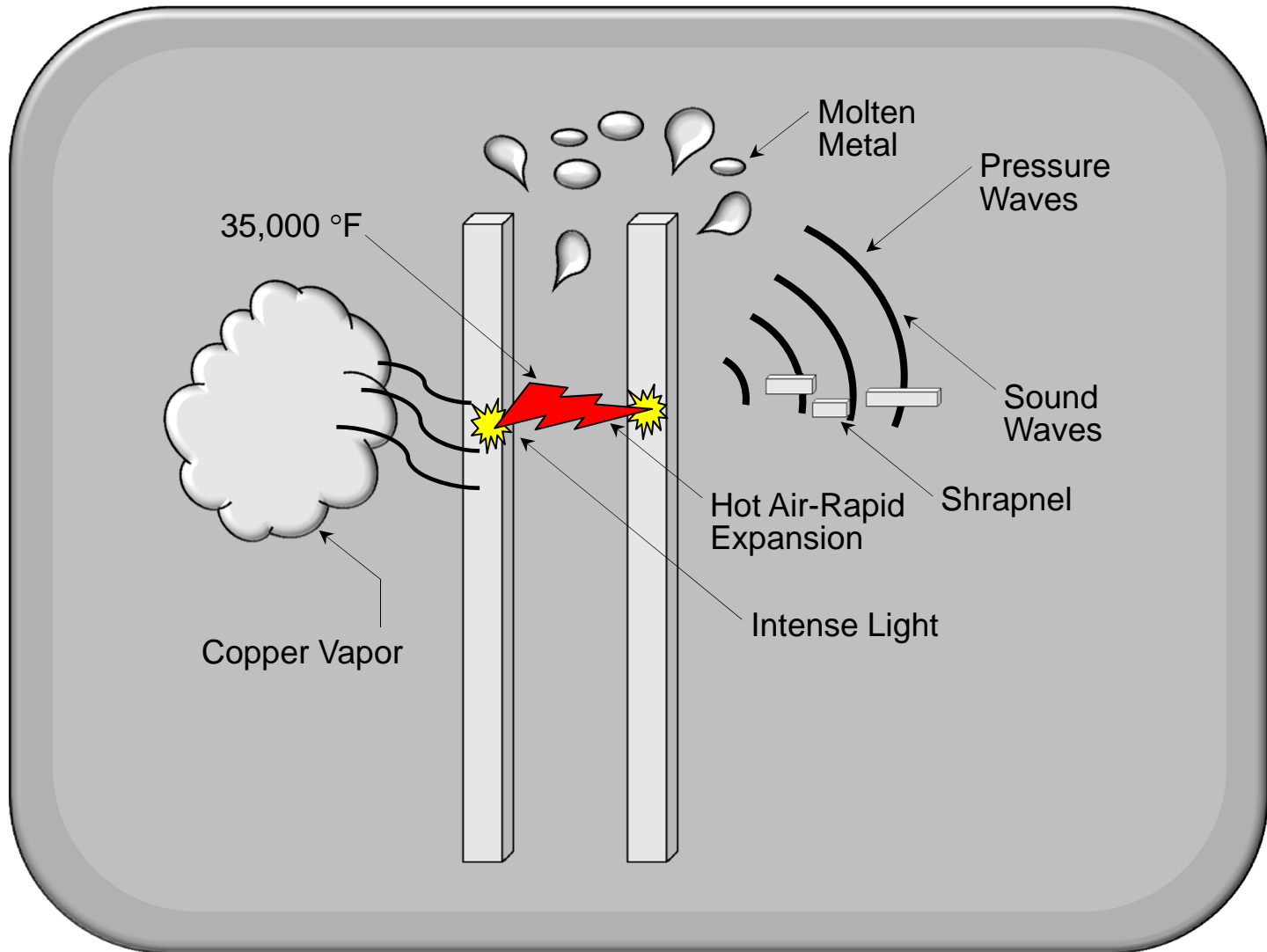
# Arc Flash

- Incident Energy
  - The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event
  - Often expressed in calories/cm<sup>2</sup>, which aligns with ratings given to PPE
  - Function of short circuit current and the length of time that the current is permitted to flow

# Arc Flash



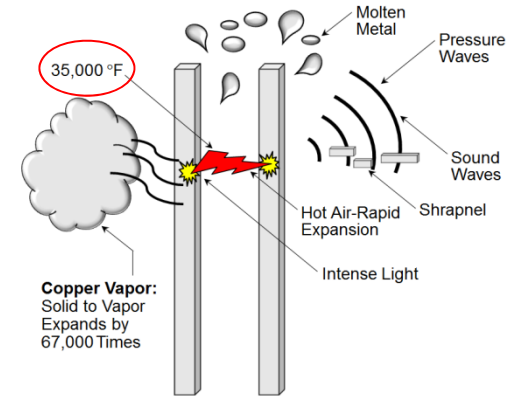
# Physical Impacts of an Arc Flash



## Nature of an Electrical Arc

# Heat

- Temperature within the arc can be up to 35,000 °F (4x hotter than surface of the sun)
- Fatal burns can occur several feet from arc
- Cotton clothing can ignite several feet from arc
- Non-cotton clothing can melt into the skin several feet from arc







# PPE Performance Test



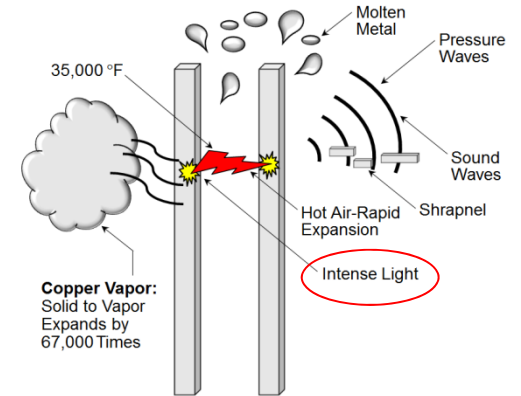
Photos of an arc flash (Courtesy of Westex)

# Personal Protective Equipment

- NFPA 70E, Table H.3(b) provides guidance
  - Less than or equal to 1.2 calories/cm<sup>2</sup>
  - Greater than 1.2 to 12 calories/cm<sup>2</sup>
  - Greater than 12 calories/cm<sup>2</sup>

## Nature of an Electrical Arc Light

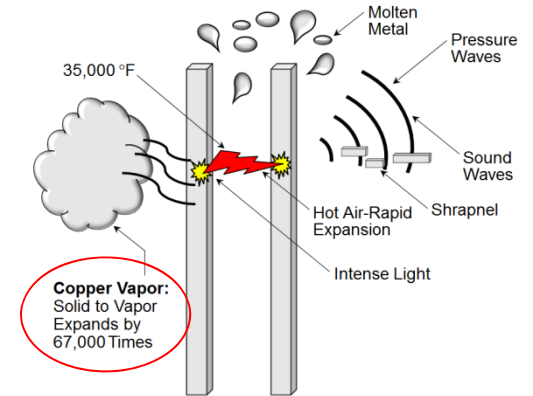
- Intense light can cause immediate and permanent eye damage
- Intense light can cause early development of cataracts



## Nature of an Electrical Arc

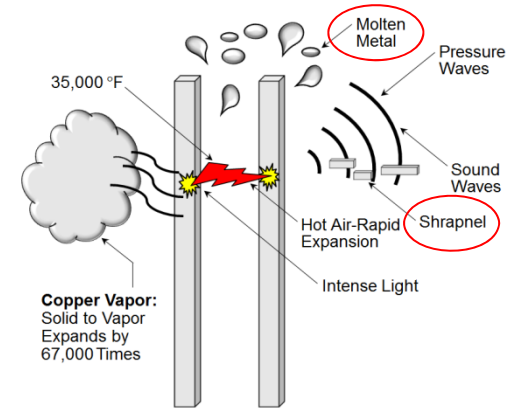
# Hot Vapor Expansion

- Solid copper to copper vapor expands at a rate of 67,000/1
- Water to vapor expands at a rate of 1670/1
- Lung damage can readily occur



## Nature of an Electrical Arc Molten Debris

- Droplets of molten metal may be propelled several feet and lodge in clothing or skin and then solidify again
- Blast shrapnel can penetrate the body with speeds in excess of 700 mph

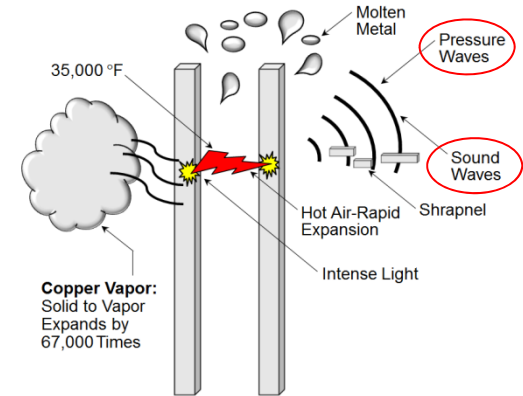




## Nature of an Electrical Arc

# Pressure and Sound Waves

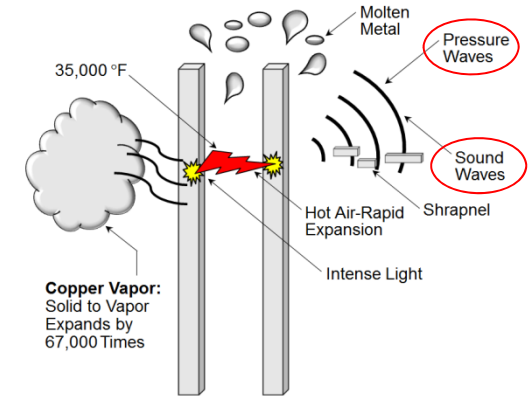
- Blast pressure of up to 2000 lbs/ft<sup>2</sup> on a body
- Deafening explosion



# Nature of an Electrical Arc

## Pressure and Sound Waves

- Blast pressure of up to 2000 lbs/ft<sup>2</sup> on a body
- Deafening explosion



### Case Study

–Will Tyree,  
Lynchburg  
Electrician



# What is Arc Flash Analysis?

- Thorough and accurate data collection and system modeling
- Incident energy calculations
- Protective device coordination study
- Scope of the study should be limited only if administrative procedures are in place to restrict energized work
- Licensed professional engineer

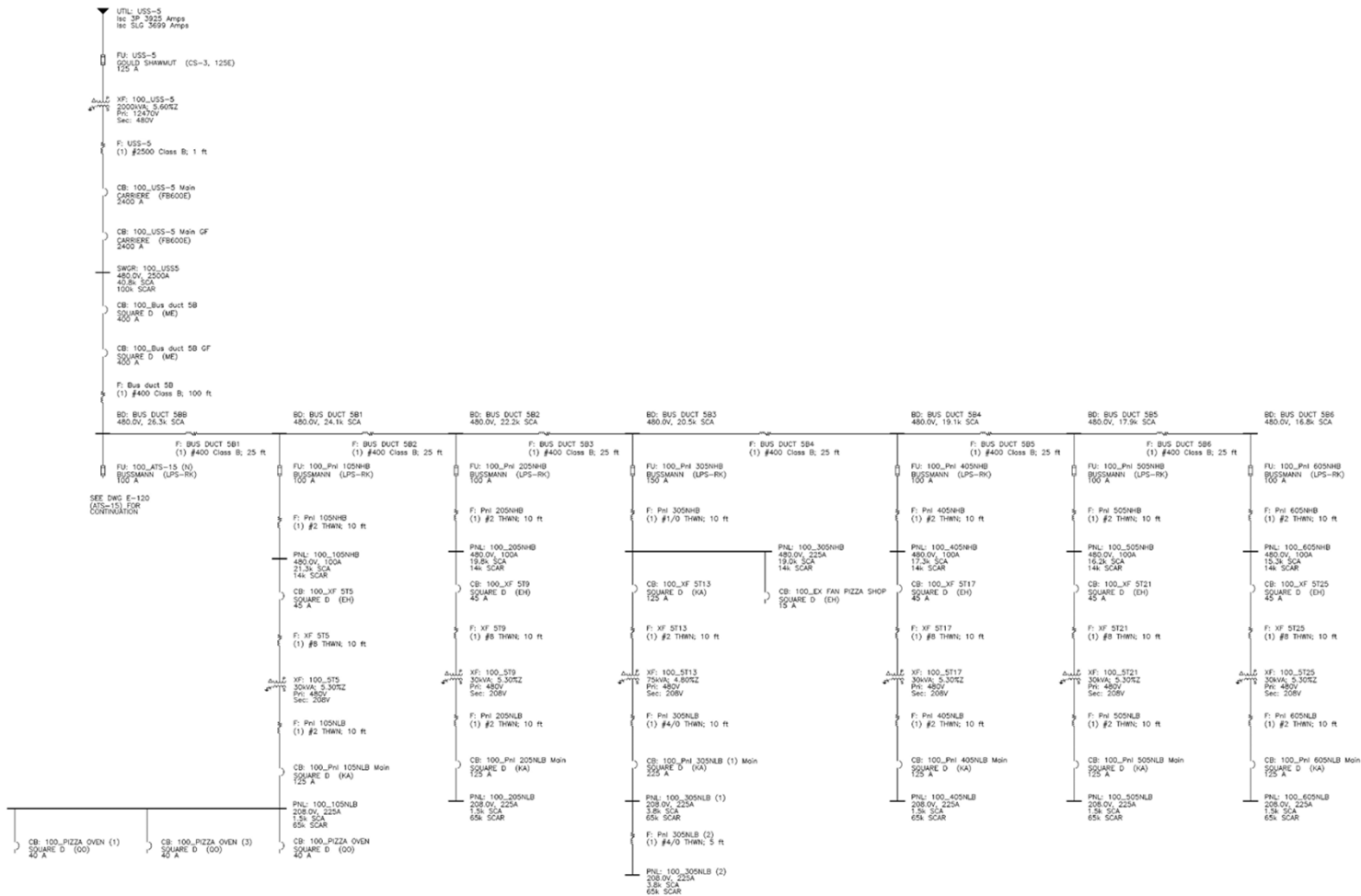


# Protective Device Coordination

## NEC Definition

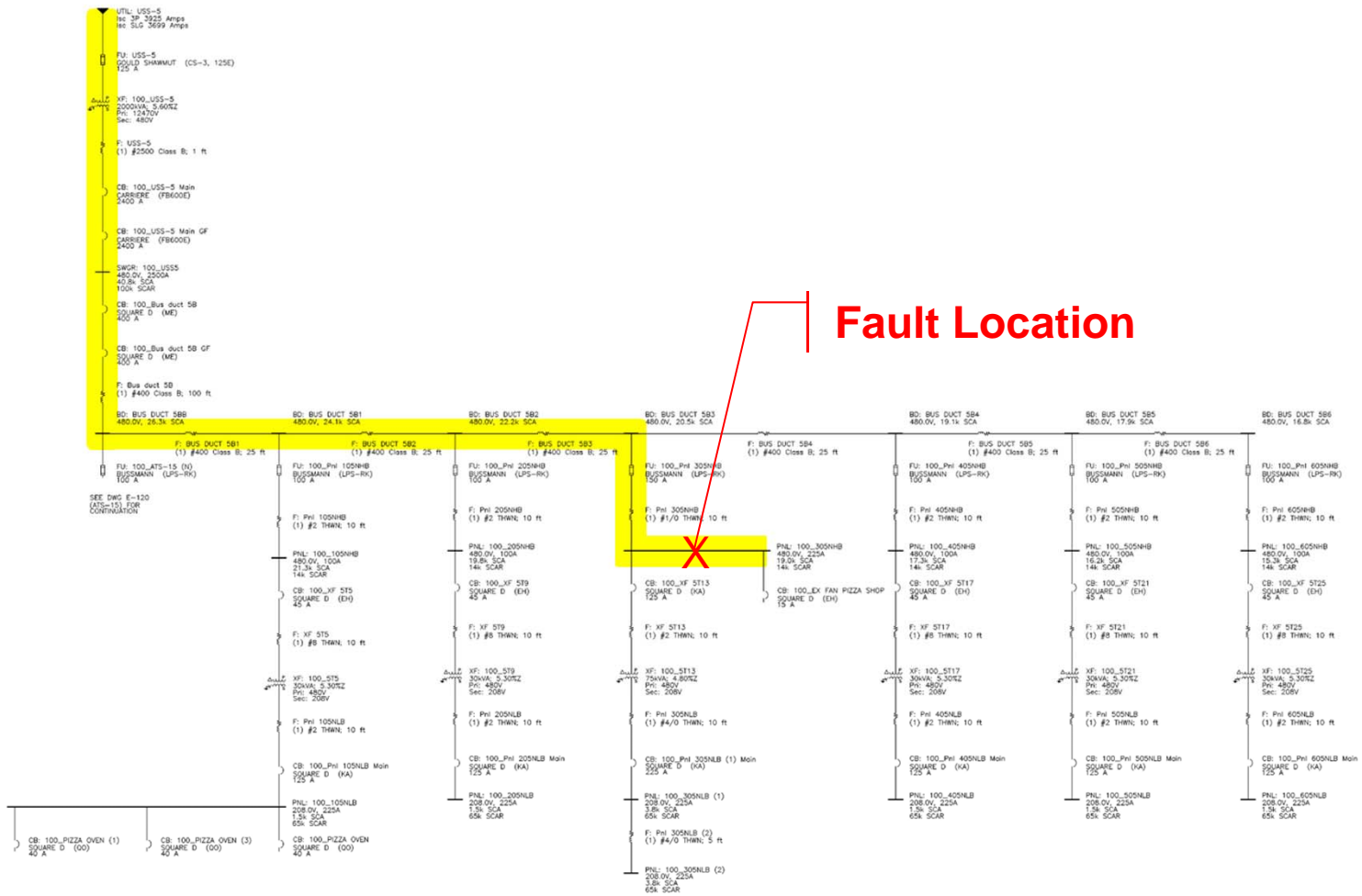
Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings

# One-Line Diagram

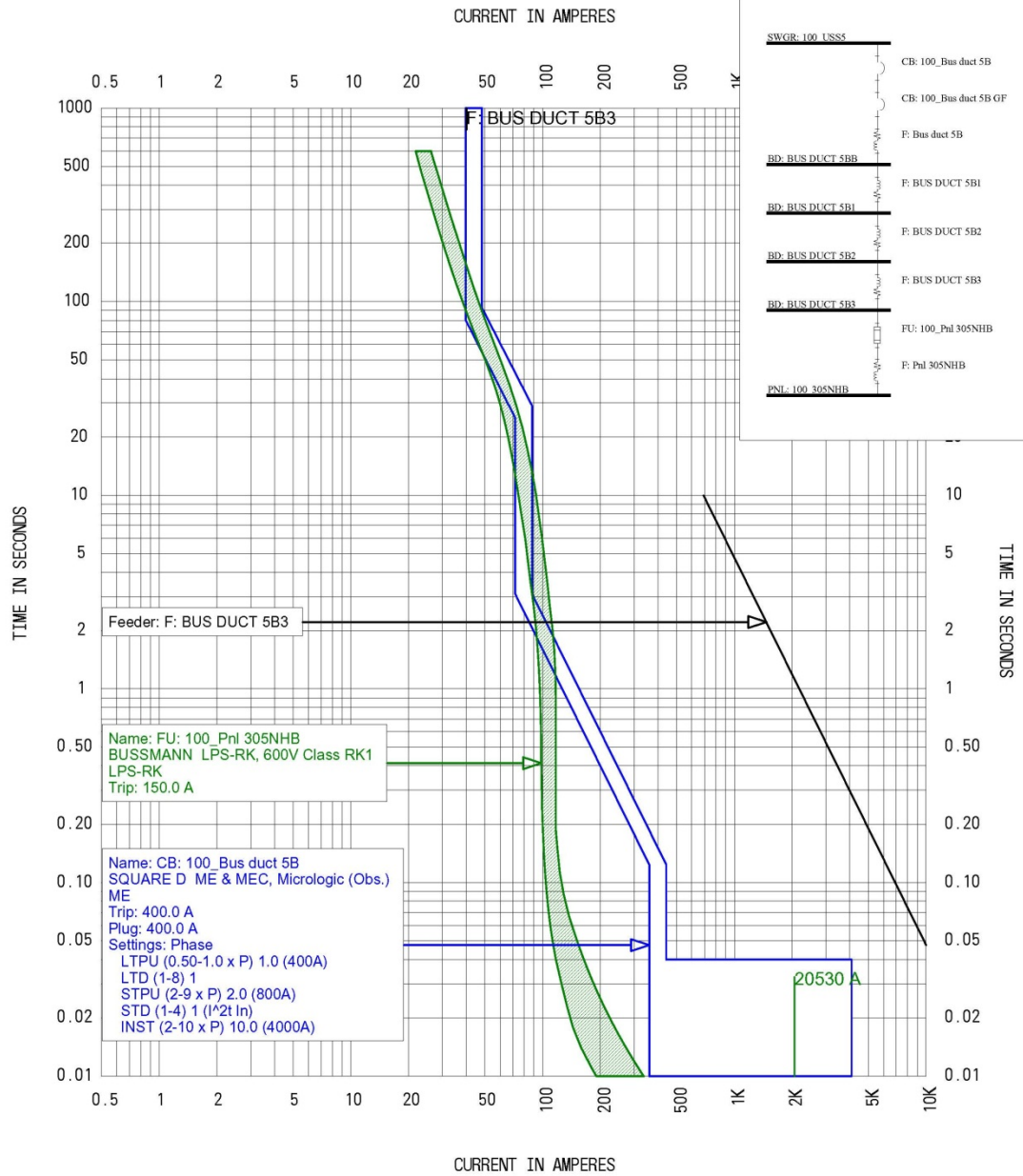


AREA F - USS-5 BUSDUCT B - ONE-LINE DIAGRAM  
 NO SCALE

# One-Line Diagram

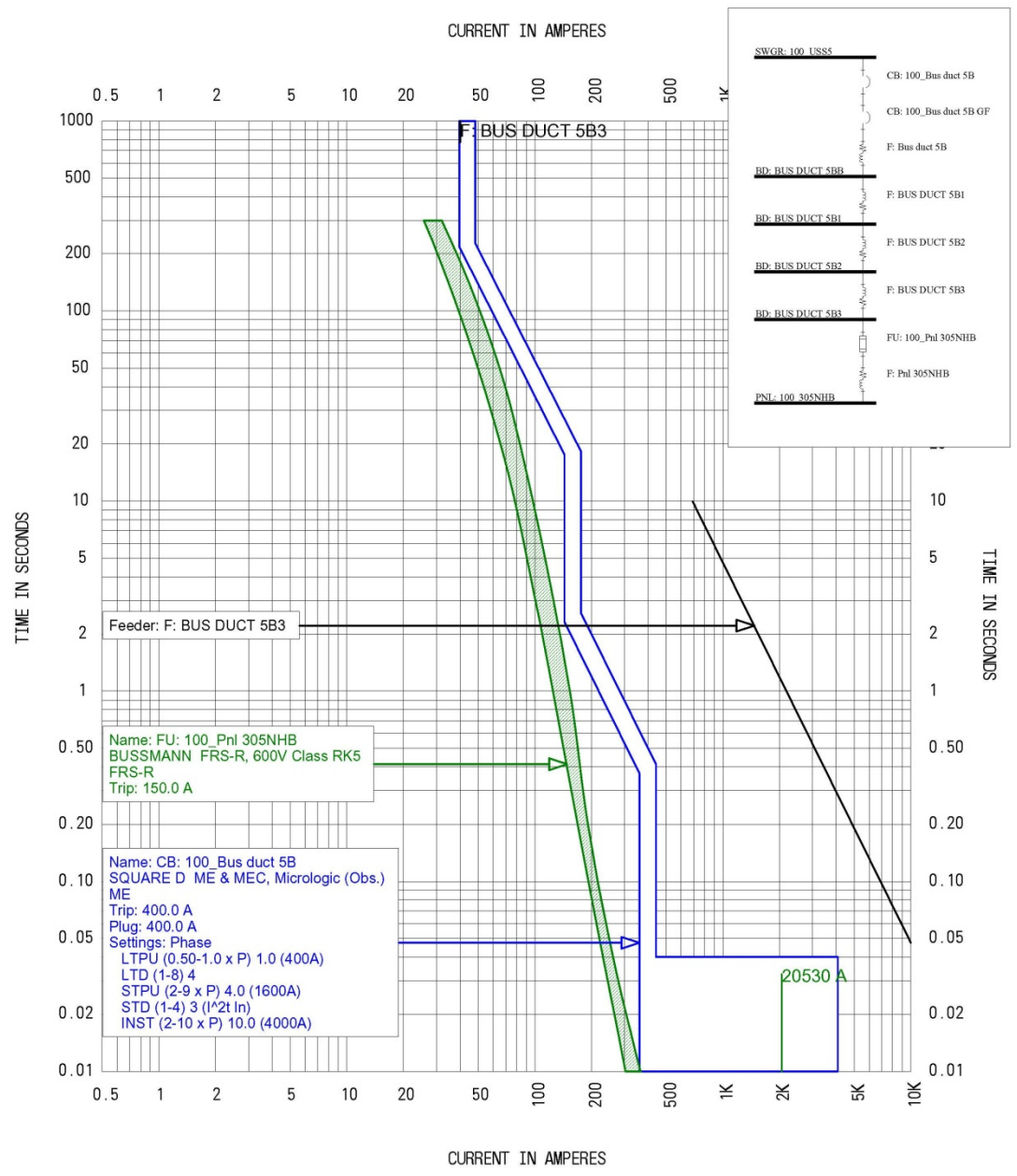


AREA F - USS-5 BUSDUCT B - ONE-LINE DIAGRAM  
 NO SCALE



# Existing Conditions

TCC Name: USS5B\_31\_CB 100\_BD 5B\_FU 100\_Pnl 305NHB  
 Reference Voltage: 480  
 Current Scale x 10  
 July 10, 2010 1:06 PM VAMC Houston (Existing) SKM Systems Analysis, Inc.



# Recommended Modifications

TCC Name: USS5B\_31\_CB 100\_BD 5B\_FU 100\_Pnl 305NHB  
 Reference Voltage: 480  
 Current Scale x 10  
 July 10, 2010 1:07 PM VAMC Houston (Recommended) SKM Systems Analysis, Inc.

# Overcurrent Protective Device Coordination

- Required by the NEC for Emergency Systems (Life Safety and Critical Branches) and for Legally Required Standby Systems (Equipment Branch)

## Case Study

- Fault in motor windings at hospital resulted in disruption of the critical branch for five hours





# Correlation Between Arc Flash Hazard and Protective Device Coordination

- System adjustments to improve coordination will sometimes have an adverse effect on incident energy

# Mitigation Techniques to Reduce Incident Energy

- Make use of OCPD adjustments
- Replace basic OCPDs with more adjustable types
- Reconfigure the system
  - More branches, smaller transformers
  - Remove main devices to exterior of cabinets
- Maintenance mode on OCPDs
- Zone selective interlocking
- Optical sensors



# Analysis Deliverables

- One-line diagrams for systems studied
  - Medium-voltage distribution system
  - Low-voltage building systems
- TCC coordination sheets
- Recommendations for coordination improvement
- Arc flash incident energy calculations
- Arc flash mitigation recommendations
- Arc flash hazard labels

# Arc Flash Hazard Labels

Header Color:

Orange for incident energy values <40 cal/cm<sup>2</sup>

Red for values 40 cal/cm<sup>2</sup> and greater

PPE required,  
qualified person or  
continuously  
escorted  
unqualified person



**Arc Flash and Shock Hazards Appropriate PPE Required  
Failure to Comply Can Result in Death or Injury!**

Calculated  
energy at  
specified  
working distance

No unqualified  
persons

18 in  
480 VAC  
42 in  
12 in

Arc Flash Boundary

Shock Hazard

Limited Approach Boundary

Restricted Approach Boundary

Incident Energy  
**1.2 cal/cm<sup>2</sup>**  
Flash Hazard at  
18 in

**PPE Requirements:**  
Detailed guidance for personal protective clothing and equipment can be found in Table H.3(b), Annex H, NFPA 70E® 2012 edition. This table is also included in Section 6 of the Electrical Condition Assessment.

**Glove Class 00**

Voltage  
Insulation  
Class

Device: PNL: 147\_HA

Issued: June 2012

Calculation Date

Reference to PPE  
Guidance in NFPA  
70E, Annex H

Considered equivalent  
to making contact with  
energized parts

# Follow-up Steps

- There is a cost of ownership associated with an Arc Flash Analysis
  - NFPA 70E requires refreshing the study when a major modification or renovation takes place, not to exceed five years
  - Requires engineer to update the study and provide new labels with each significant alteration

# Follow-up Steps

- How do we change behavior after an analysis?
- Development or Enhancement of Electrical Safety Program
  - Energized Work
    - If? When? Who has authority?
- PPE for energized work

# What is included in an Electrical Safety Program?

- Definition of the hazards that exist
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# How Can I Protect Myself, My Co-workers, My Employees?



**DO NOT**  
Work on  
Energized  
Equipment!!!

# Justification for Energized Work

- Work on energized electrical equipment is permitted when:
  - Employer can demonstrate that deenergizing will create additional or **greater hazards**, or
  - Employer can demonstrate that the task to be performed is **infeasible** in a de-energized state due to equipment design or operational limitations, or
  - Energized conductors and parts operate at **less than 50 volts**, and there will be no increased exposure to electrical burns or arcs



# Infeasible vs. Inconvenient

- Infeasible
  - Not practical; not capable of being done or carried out
- Inconvenient
  - Inopportune; untimely; not suiting one's needs or purposes



# If Energized Work is Necessary...

- Know and abide by the requirements set forth in the NFPA 70E, including:
  - Obtain hot work permit (including justification)
  - Be a “qualified person”
  - Train, train, train!
  - Use lock-out/tag-out procedures
  - Follow your electrical safety program/procedures
  - Know the hazard and the risks
  - Wear your PPE!

# Qualified Person

- **NFPA Definition**

One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved

- **OSHA Definition**

Expands on the NFPA definition by expanding to say “demonstrated skills”

# Training

- Safety training
- Training on construction and operation on specific equipment
- First Responder / First Aid / CPR training
- Training must be documented

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