Dealing with Electrical Hazards in the Workplace

Presented By:

Tom Norwood – Sr. Safety Specialist

AVO®
A SUBSIDIARY OF MEGGER

TRAINING INSTITUTE, INC.
Dallas, Texas

Introduction

- Several hundred electrical fatalities occur annually as a result of electrical shock
  - Over half are from 120-volts
- Electrical contacts result in (NIOSH):
  - 4,000 non-disabling injuries a year
  - 3,600 disabling injuries a year
  - One death every day

Introduction

- 10-15 employees per day are hospitalized from arc-flash burns
- Arc-flash injuries are catastrophic to the victim:
  - Physically
  - Psychologically
  - Financially

Introduction

- Electricity is a "Silent killer"
  - Cannot be tasted, seen, heard, or smelled
- Electricity exposes employees to:
  - Shock
  - Serious burns
  - Falls
  - Injury
  - Death
- Any and everyone is susceptible

Hazards of Electricity

Electrical Shock

Electrical Arc-Flash

Electrical Arc-Blast

Electrical Shock

- Shock caused by a difference in potential across the body
- Severity of shock depends on several factors:
  - Resistance of the body
  - Circuit voltage
  - Amount of current flowing through the body
  - Current path through the body
  - Area of contact
  - Duration of contact

Current Range and Effect

Current	Effect
1 mA	Barely perceptible
1-3 mA	Perception threshold (most cases)
3-9 mA	Painful sensations
9-25 mA	Muscular contractions (can't let go)
25-60 mA	Respiratory paralysis (may be fatal)
60 mA or more	Ventricular fibrillation (probably fatal)
4 A or more	Heart paralysis (probably fatal)
5 A or more	Tissue burning (fatal if vital organ)

Tissue Damage

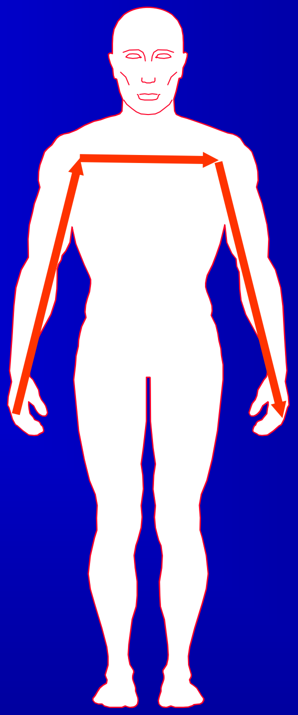
High current passing through the body can cause damage to:

- **Tissue**
- **Muscle**
- **Bone**
- **Nerves**
- **Blood vessels**

- **Heart**
- **Liver**
- **Lungs**
- **Kidneys**
- **Anything else it passes through**

Electrical Shock

- **Further demonstration of fatal shock**
  - Average working conditions with 120-volts
  - Person is perspiring
  - Average resistance is 1000-ohms from hand-to-hand



250 ohms

500 ohms

250 ohms

1000 ohms Total

Electrical Shock

- Further demonstration of fatal shock:
  - Ohm's law:

$$I = E/R \text{ or } I = 120/1000$$

$$I = 0.12 \text{ amps or } 120 \text{ ma}$$

  - Will probably cause ventricular fibrillation

Electrical Shock

- Some ways of prevention:
  - Insulation
  - Guarding
  - Grounding
  - Electrical protective equipment
  - Safe work practices
- STAY OUT OF THE CIRCUIT
- Perform a Shock Hazard Analysis
  - NFPA 70E–2004:
    - 110.8(B)
    - 130.2
  - CSA Z462 (Pending)

Electrical Arc-Flash

- A large number of serious electrical injuries involve burns from electric arcs
  - Primarily from ignition of clothing
- Product of:
  - Short-circuit current
  - Clearing time or arc duration
  - Proximity to the worker
- Misconception that the arc hazard is condition of only high voltage

Electrical Arc-Flash

- Possible to generate higher energy from low-voltage sources than from high-voltage
- Arc temperatures can reach about 20,000^{0}C
  - Approximately 36,000^{0}F
- Three different issues with an arc:
  - Incident energy
    - 1.2 cal/cm^2 (173^{0}F or 78.3^{0}C @ 0.1 sec.) - onset of 2nd degree burn
  - Temperature
    - 203^{0}F or 95^{0}C @ 0.1 sec. (1.6 cal/cm^2)- incurable (3rd degree) burn
  - Blast or explosion

Video of Test Shot

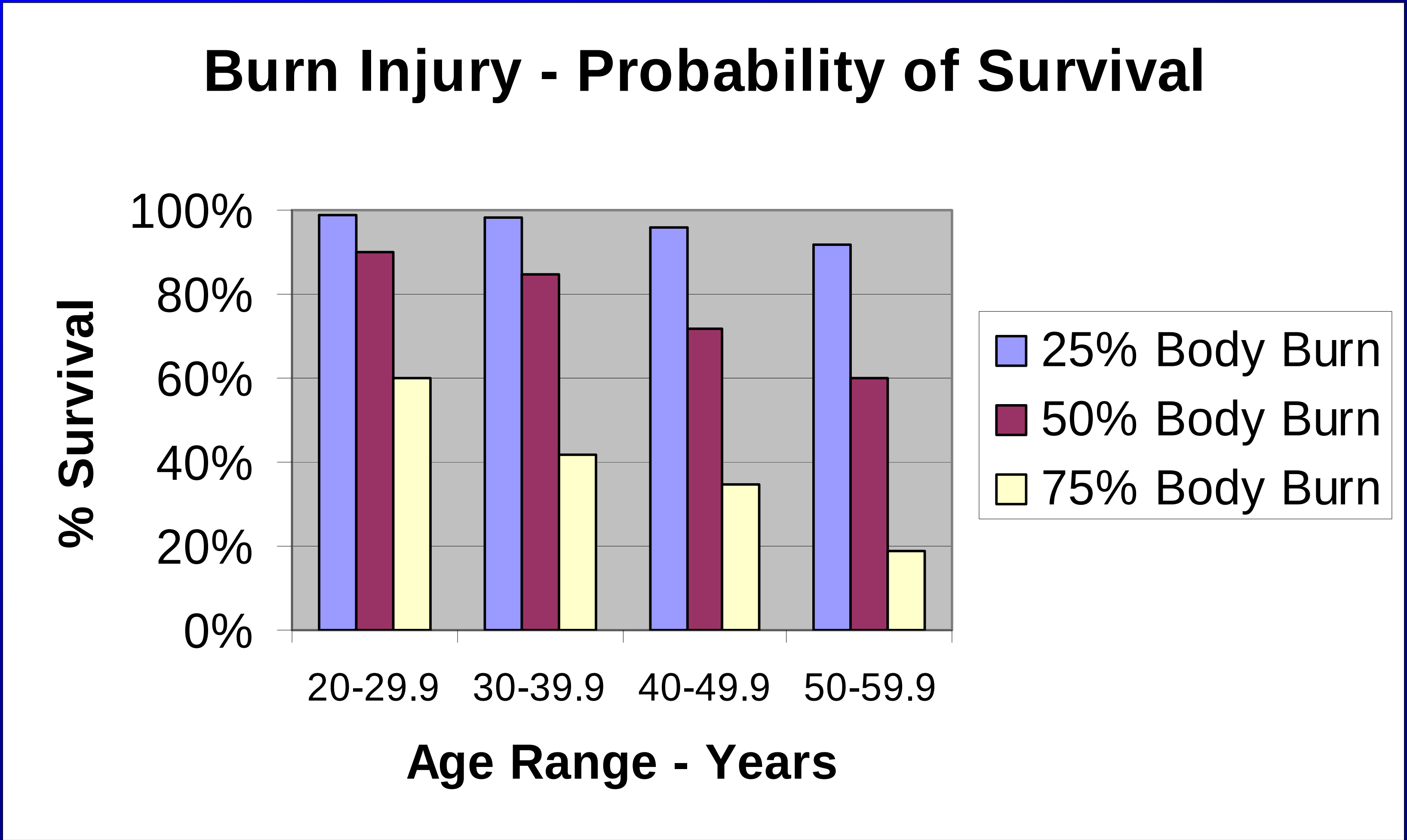
- **3 Phase, 600V Arc In 20 Inch Cubic Box**
- **1.25" Electrode Gap**
- **6 Cycle Arc**
- **Bolted Fault - 36.3 kA**
- **Arc Current - 28.6 kA**
- **Arc Power - 11.7 MW**
- **Incident Energy @ 2 Feet - 6.1 cal/cm^2**

Not in text for example only

Electrical Arc-Flash

- Perform a Flash Hazard Analysis
  - Establish the Flash Protection Boundary
    - NFPA 70E-2004: 110.8(B) & 130.3
    - IEEE 1584
    - CSA Z462 (Pending)
- Treatment of arc burns is lengthy
  - Debridement
  - Skin grafting
  - Reconstructive surgery
  - Physical trauma
  - Infection is common

Electrical Arc-Flash

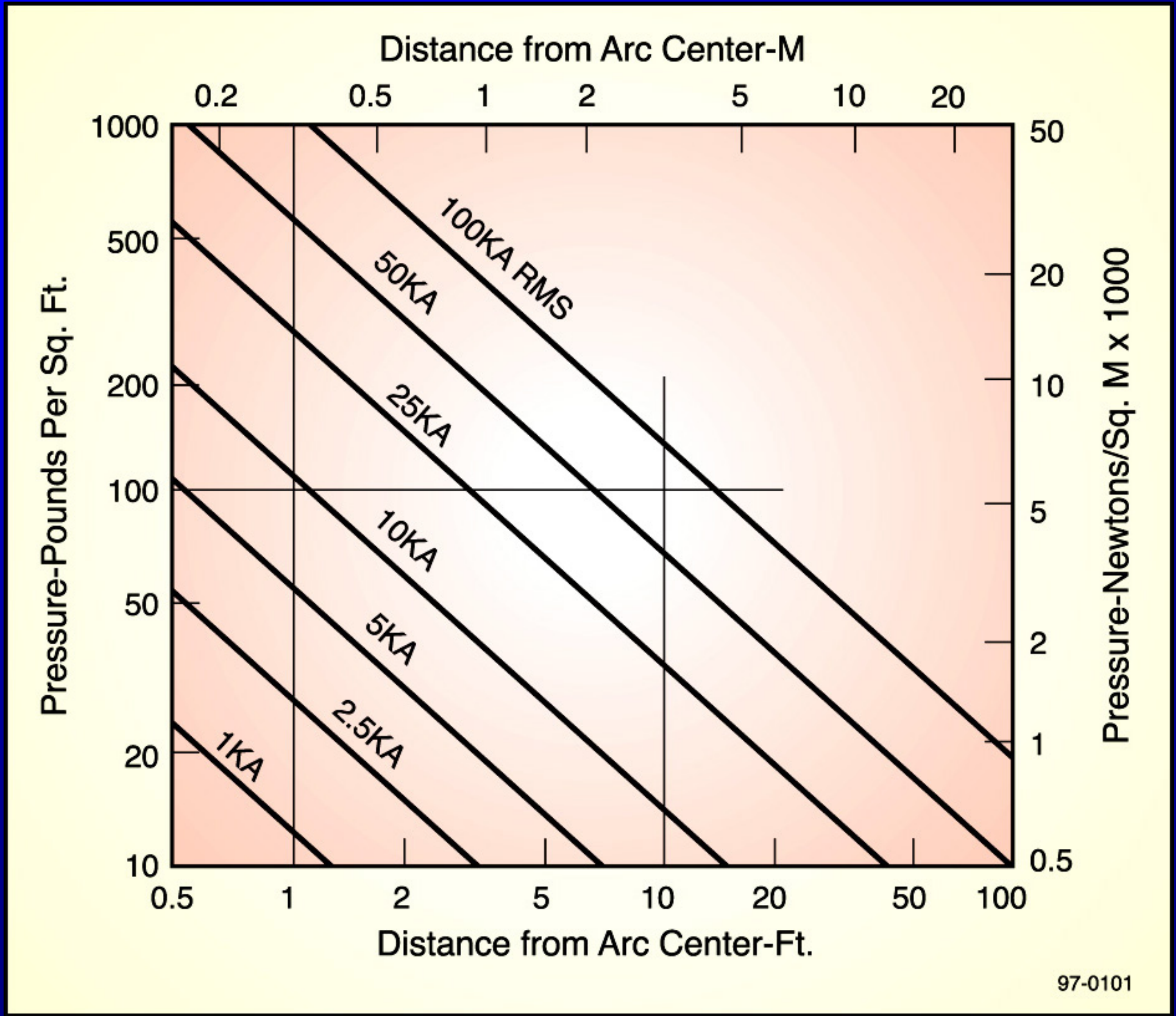


American Burn Association 1991-1993 Study

Electrical Arc-Blast

- Copper vaporized by electrical arc expands 67,000 times (1 $in.^3$ copper = 1.44$yds.^3$ vapor)
- Expansion produces explosion with:
  - Droplets of molten metal
  - Plasma
  - Fragmented metal
  - High temperatures
  - Pressure on the body

Pressure vs. Distance from Arc



Electrical Arc-Blast

- Pressures from a 25,000 amp fault: (human body is approximately 3 sq. ft.)
- 1-foot - 325 lbs./sq. ft. = 975 on body
- 2-feet - 160 lbs./sq. ft. = 480 on body
- 5-feet - 70 lbs./sq. ft. = 210 on body
- 50-feet - no pressure = 0 on body

Electrical Arc-Blast

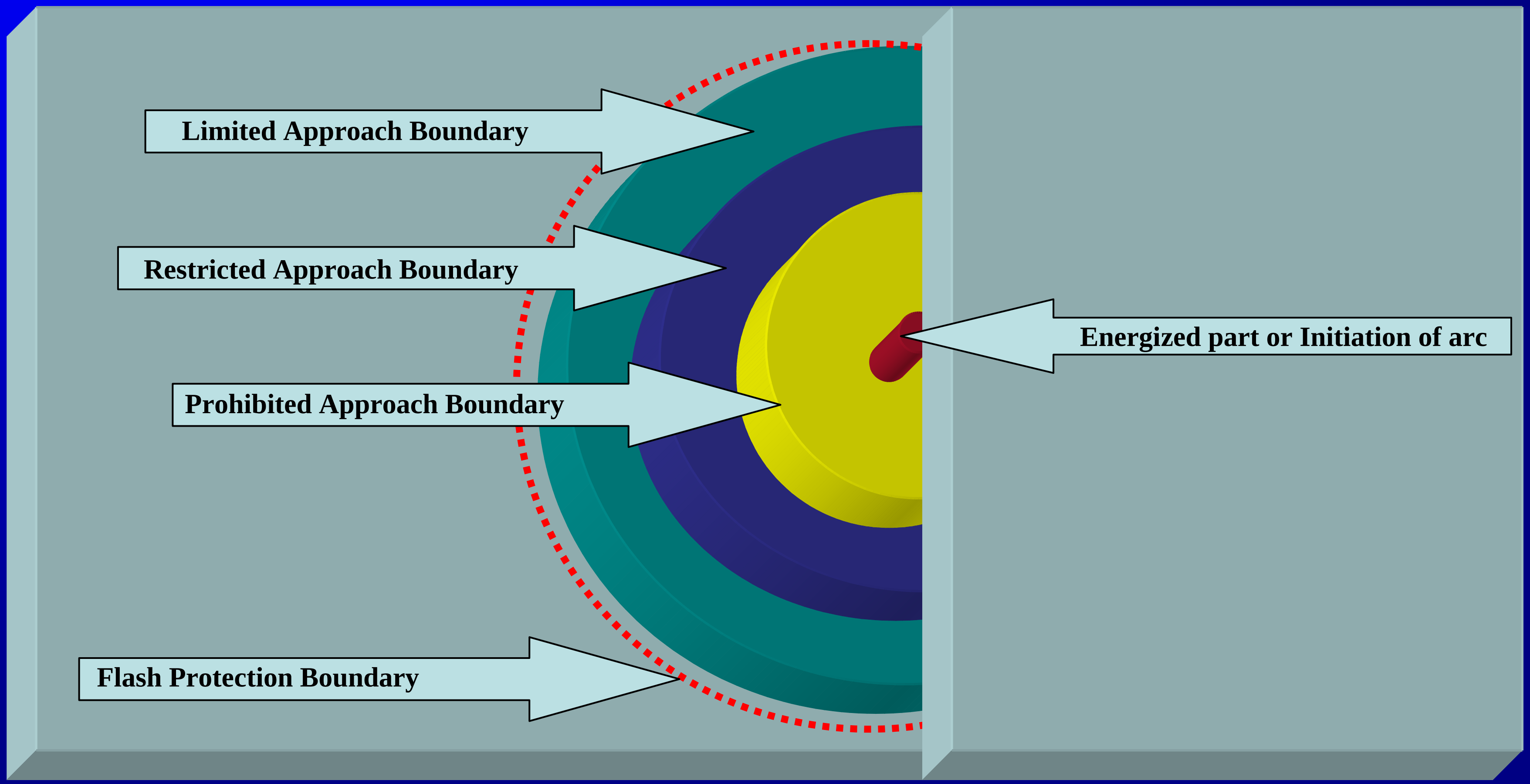
- <u>DO NOT USE</u> electrical equipment rooms for:
  - Offices
  - Walkways
  - Storage rooms
  - Break rooms
  - Maintenance shops

FIGURE 12
Switchgear Room
Post Arc Flash and Fire

Electrical Hazards Analysis

- NFPA 70E-2004 requirements
  - Shock hazard analysis [110.8(B) & 130.2]
    - Limited Approach Boundary
    - Restricted Approach Boundary
    - Prohibited Approach Boundary
  - Flash Hazard Analysis [110.8(B) & 130.3]
    - Flash Protection Boundary

Approach & Protection Boundaries



Flash Hazards Analysis

- A Key component of the Flash Hazard Analysis is the over-current protective device clearing time.
  - Primarily circuit breakers and relays
- Primary focus should be on the maintenance issues of circuit breakers and relays

Flash Hazards Analysis

- Molded case and low-voltage power circuit breakers (600-volts or less) will generally clear a fault condition in 3 to 8 cycles.
- The majority of older medium-voltage circuit breakers (2300-volts or greater) will clear a fault in around 8 cycles with the newer ones clearing in 3 to 5 cycles.

Flash Hazards Analysis

- Protective relays will generally add approximately 3 to 4 cycles to the clearing time of the medium-voltage circuit breaker.
- Where proper maintenance and testing are not performed, extended clearing times could occur creating an unintentional time delay that will effect the results of a flash hazard analysis.

Flash Hazards Analysis

- **All maintenance and testing of the electrical protective devices must be accomplished in accordance with the manufacturer's instructions.**
- **The NETA *"Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems"* 2001 Edition is an excellent source of information for performing the required maintenance and testing of these devices.**

Flash Hazards Analysis

- **Since most molded-case circuit breakers have riveted frames, maintenance is limited. We can help ensure appropriate clearing times through:**
  - **proper mechanical mounting**
  - **maintaining electrical connections**
  - **periodic manual operation**

Flash Hazards Analysis

- All other molded-case circuit breakers that are UL approved are factory-sealed to prevent access to the calibrated elements.
- Broken seals would indicate the integrity of the device could be questionable

Flash Hazards Analysis

- Molded case circuit breakers installed in a system are often forgotten.
- Without proper attention, there are several things that can go wrong.
  - Circuit breakers can fail to open due to a burned out trip coil, or
  - Fail because the mechanism is frozen due to dirt, dried lubricant, or corrosion.

Flash Hazards Analysis

- Most manufacturers recommend that if a molded-case circuit breaker has not been operated within as little as six months time, it should be removed from service and manually exercised several times.

Flash Hazards Analysis

- Manually exercising helps:
  - keep the contacts clean due to their wiping action
  - ensures that the operating mechanism moves freely
- This exercise DOES NOT operate the mechanical linkages in the tripping mechanism

Flash Hazards Analysis

- The only way to properly exercise the entire breaker operating and tripping mechanisms is to:
  – remove the breaker from service and test the overcurrent and short-circuit tripping capabilities
- A stiff or sticky mechanism can cause an unintentional time delay in its operation under fault conditions and increase the arc/flash incident energy level.

Flash Hazards Analysis

- **Several studies have shown that *low-voltage power circuit breakers*, which were not maintained within a 5-year period, have a 50% failure rate.**
- **Maintenance will generally consist of keeping them clean and properly lubricated.**
- **The environment can have an impact on maintenance intervals**

Flash Hazards Analysis

- Most of the inspection and maintenance requirements for low-voltage power circuit breakers also apply to medium-voltage power circuit breakers.
- Most manufacturers recommend that these breakers be removed from service and inspected at least once per year.
- Always follow the manufacturer’s instructions.

Flash Hazards Analysis

- Relays continuously monitor complex power circuit conditions, such as:
  - current and voltage magnitudes,
  - phase angle relationships,
  - direction of power flow, and
  - frequency.
- When an abnormal condition is detected, the relay responds and causes a portion of the system to be deenergized via the circuit breaker.

Flash Hazards Analysis

- The ultimate goal of protective relaying is to disconnect a faulty system element as quickly as possible.
- Sensitivity and selectivity are essential to ensure that the proper circuit breakers are tripped at the proper speed to:
  - clear the fault,
  - minimize damage to equipment, and
  - reduce the hazards to personnel.

Flash Hazards Analysis

- Several things may happen to prevent primary relaying from disconnecting a power system fault:
  - Current or voltage supplies to the relays are incorrect.
  - DC tripping voltage supply is low or absent.
  - Protective relay malfunctions.
  - Tripping circuit or breaker mechanism hangs up.
  - Relays not properly set per RFCS

Flash Hazards Analysis

- Most manufacturers recommend that periodic inspections and maintenance be performed at intervals of one to two years.

Flash Hazards Analysis

- The periodic inspections, maintenance, and testing are intended to ensure that the protective relays are functioning properly and have not deviated from the design settings.
- If deviations are found, the relay must be retested and serviced as described in the manufacturer’s instructions.

Flash Hazard Analysis

- All calculations for determining the incident energy of an arc and for establishing a flash protection boundary require the protective device clearing time.
- This clearing time is derived from the engineering coordination study, which is based on what the protective devices are designed to do.

Flash Hazard Analysis

- Maintenance is a very critical part of the flash hazard issue.
- The information provided here clearly indicates the need for a preventive maintenance program on these circuit protective devices.
- Evidence has proven that inadequate maintenance can cause unintentional time delays in the clearing of a short circuit condition.

Flash Hazard Analysis

- If, for example, a low-voltage power circuit breaker had not been operated or maintained for several years and the lubrication had become sticky or hardened, the circuit breaker could take several additional cycles, seconds, minutes, or longer to clear a fault condition.

Flash Hazard Analysis

A Flash Hazard Analysis is performed based on what the system is suppose to do. An unintentional time delay, due to a sticky mechanism on a breaker, can extend the clearing time from 5 cycles to 30 cycles, increasing the incident energy the worker would be exposed to. This could seriously injure or kill the worker because he/she would under protected.

Flash Hazard Analysis

Arc/Flash situation: 20,000-amp short-circuit, 480 volts, 3-inch arc gap, the worker is 18 inches from the arc, with a 5 cycle clearing time for a 3-phase arc in a box (enclosure).

Next slide illustrates this:

Conclusion

- Circuits operating at 50-volts or higher
- Three Hazards of Electricity
  - Electrical Shock
  - Electrical Arc-Flash
  - Electrical Arc-Blast
- Best way to avoid exposure to these hazards:
  - STAY OUT OF THE CIRCUIT

Conclusion

- With the proper mixture of common sense, training, manufacturers’ literature and spare parts, proper maintenance can be performed and power systems kept in a safe, reliable condition.

Conclusion

- Circuit breakers, if installed within their ratings and properly maintained, should operate trouble-free for many years.
- However, if operated outside of their ratings or without proper maintenance, catastrophic failure of the power system, circuit breaker, or switchgear can occur causing not only the destruction of the equipment but serious injury or even death of employees working in the area.