Nothing Compares
NORTH CAROLINA

Hidden Risks of Aging Electrical Systems

STATE CONSTRUCTION OFFICE

Agenda

- What Is That Grey Box?
- Electrical Equipment Life Expectancy
- Electrical Equipment Life Risk Factors
- Arc Flash Awareness
- Potential Mitigation Actions

Electrical Systems Are Vital
But Often Unrecognized Infrastructure

- **What are those grey boxes anyway?**

Can you identify the electrical supply locations?

Improper Uses of Electrical Equipment Rooms

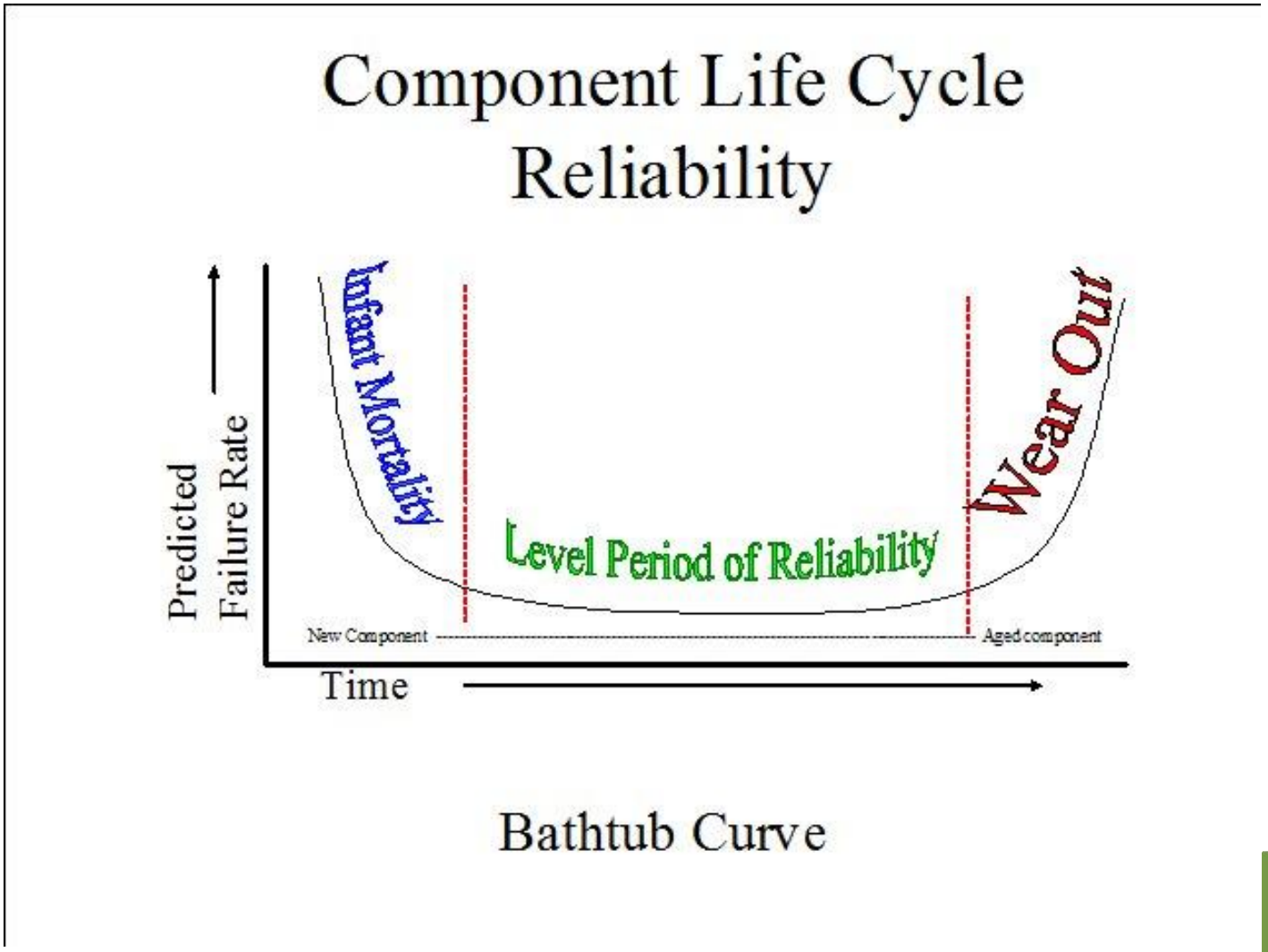
Break Room?

Storage Room?

- Lack of recognition and respect of electrical equipment has risks

Electrical Equipment Life Expectancy

How Long Does Electrical Equipment Last?



Typical Electrical Equipment Life Expectancies

EQUIPMENT	EXPECTED USEFUL LIFE, YEARS
Capacitors	17
LV molded case circuit breakers	20
LV power circuit breakers	15 - 20
MV power circuit breakers	15 - 20
MV vacuum circuit breakers	15 - 20
Ðry- type transformers and reactors	20
Liquid filled transformers	30
LV and MV cables	20
Protective relays	Not stated
Motors and motor starters	20 - 30
VFDs and UPSs	20

Reference IEEE Gold Book

(Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems)

Can Electrical Equipment Operate Reliably Beyond Normal Life Expectancy?

Administration Building
Downtown Raleigh
1966 Westinghouse
Low Voltage Switchgear

- Regular maintenance, optimal loading, and clean environment can extend equipment life.

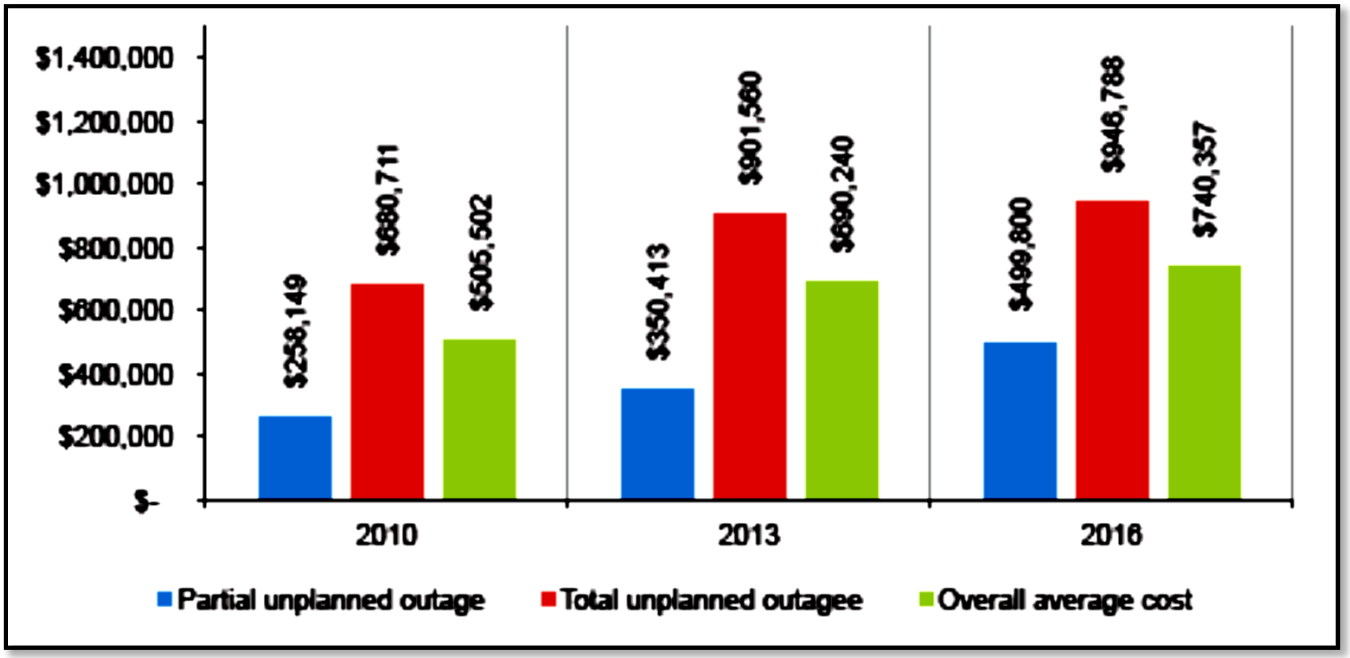
Aging Electrical Infrastructure Risks

- Reduced equipment reliability
  - Equipment operating at available fault levels exceeding equipment rating
- Equipment damage & personnel injury
  - Unrecognized hazard or hazard greater than anticipated
  - Electrical shock, electrocution, or arc flash
- Unscheduled outages
- Financial costs of emergency repairs, rental equipment, regulatory fines, and liability awards

- **Yes, it is still in operation!**

Risks are unfortunately not realized until actual failure occurs.

Data Centers Electrical Outage Financial Impact



Ponemon Institute *2013-2016 Survey:*
Cost of Data Center Outages

Greatest root cause of unplanned data center outages?
- UPS system equipment failure

Electrical Equipment Life Risk Factors

Aging Electrical Equipment Failure Causes

- Utility available fault current changes
- Excessive loading, harmonics, surges
- Inadequate documentation
- Improper operation under current electrical codes, standards, regulations
- Lack of preventative maintenance
- Environmental degradation

- Electrical equipment asset management should be a priority for facility owners.

OSHA 46 CFR 183.210
Protection From Wet/Corrosive Environments

- Electrical equipment use in the following spaces must be dripproof:
  - Machinery spaces
  - Space exposed to splashing, washdown
- Electrical equipment exposed to weather must be watertight
- Electrical equipment exposed to corrosive environments must be of suitable construction and resistant to corrosion

- **Rainproof?**

Corrosion Coupon Measurements

Prior to installation

After 7 Days

After 30 Days

After 60 Days

Example Adverse/Corrosive Contaminants

- Hydrogen Sulfide
- Sulfur Dioxide
- Ammonia
- Chlorine
- Chlorinated Compounds
- Salts
- Moisture/Water

Corrosion is *accelerated* by increased concentration of contaminants, elevated temperature and high humidity.

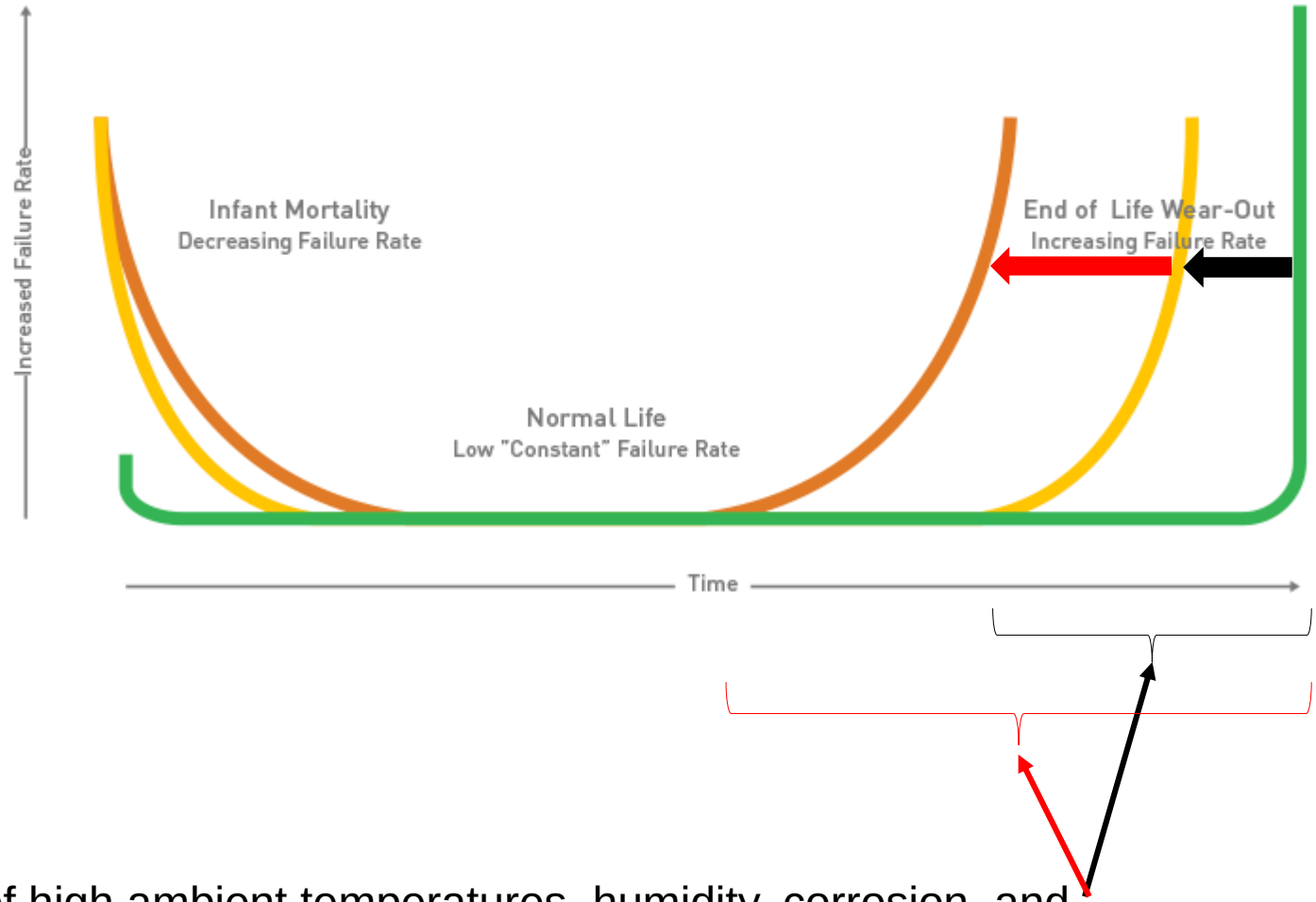
Components/Wiring Internal To "Protected" Enclosure

- Internal corrosion conditions occur undetected unless routine inspections are implemented

Silver Plated Terminals/Bus

Corrosion can affect protective equipment clearing time including “no trip” failure mode

How Many Installations Are Gambling Upon "Wear Out" Time?

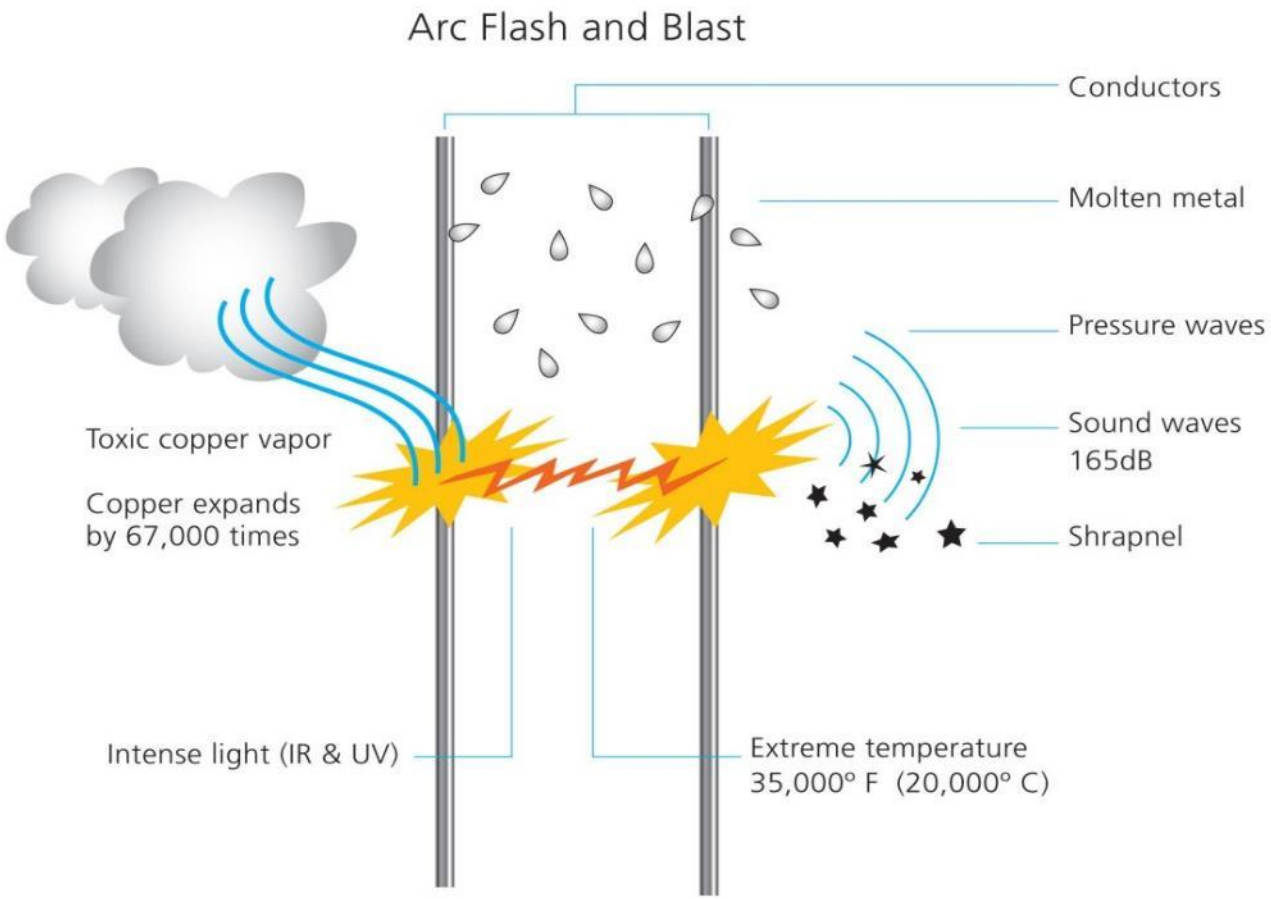


- Affects of high ambient temperatures, humidity, corrosion, and lack of maintenance upon hastening end-of-life.

Arc Flash Awareness

Arc Flash Video - Molten Metal, Intense light

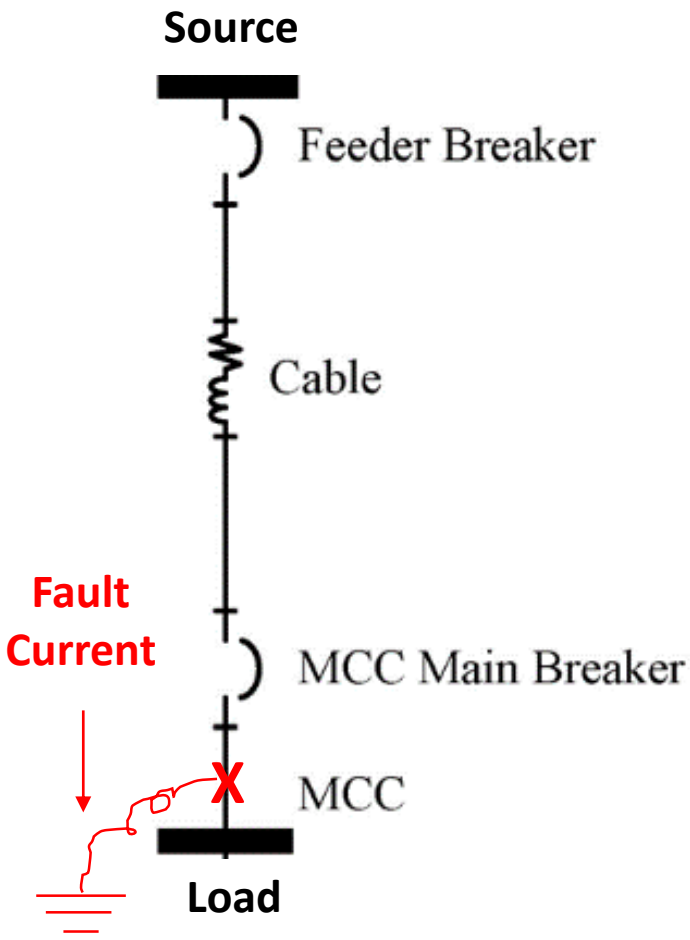
Arc Flash Basics



An arc flash produces shock wave, molten metal, intense light, and heat exposure

Arc flash Examples – Shock Wave, Molten Metal, Intense Light, Heat

Calculating Arc Flash Incident Energy



- Incident Energy based on:
  - Available fault current
  - **Protective device clearing time**
  - Working distance away from the equipment

- Accurate available utility fault current level and actual protective device settings are critical.

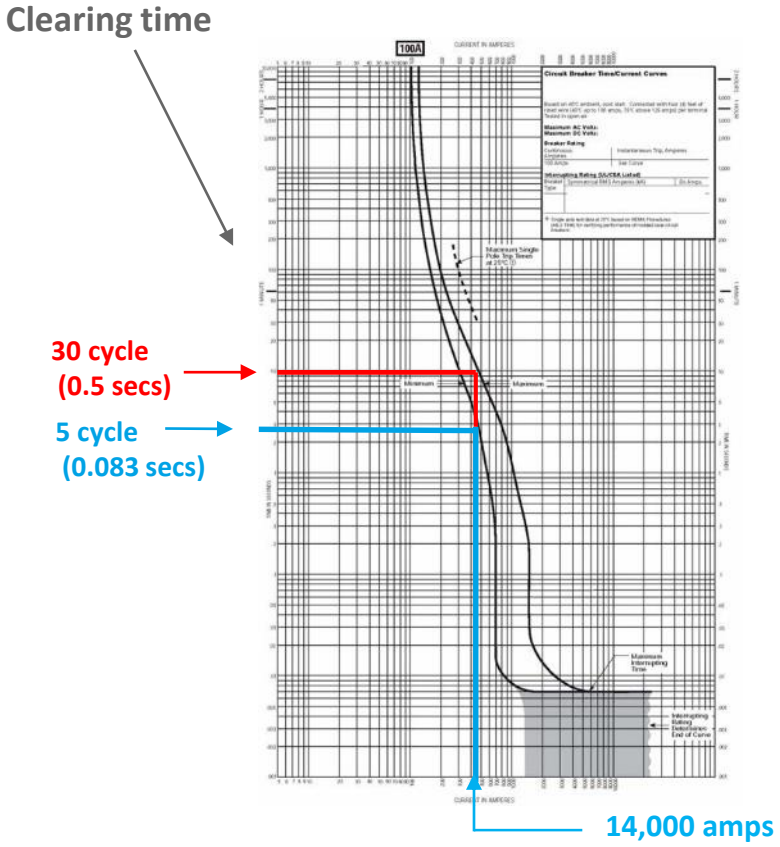
Personal Protective Equipment (PPE)

Hazard/Risk Category 4 cal/cm² **1**	Arc-rated long-sleeve shirt Arc-rated pants or overall Arc-rated face shield with hard hat Safety glasses Hearing protection Leather & voltage rated gloves (as needed) Leather work shoes	
Hazard/Risk Category 8 cal/cm² **2**	Arc-rated long-sleeve shirt Arc-rated pants or overall Arc-rated face shield & balaclava or Arc flash suit with hard hat Safety glasses, Hearing protection Leather & voltage rated gloves (as needed) Leather work shoes	
Hazard/Risk Category 25 cal/cm² **3**	Arc-rated long-sleeve jacket Arc-rated pants Arc-rated flash hood with hard hat Safety glasses, Hearing protection Leather & voltage rated gloves (as needed) Leather work shoes	
Hazard/Risk Category 40 cal/cm² **4**	Arc-rated long-sleeve jacket Arc-rated pants Arc-rated flash hood with hard hat Safety glasses, Hearing protection Leather & voltage rated gloves (as needed) Leather work shoes	

80% electrical injuries are burns from exposure to arcing fault

Reference IEEE Report

Improperly Installed or Maintained Equipment May Increase OCPD Fault Clearing Time



$E_{MB} = D_B \times t_A \times F$

Where:

E_{MB} = incident energy

D_B = distance from arc

t_A = arc duration, seconds

F = fault current (thousands)

Example:

5 cycle (0.083 secs) t_A= 3.5 cal/cm^2 E_{MB}

30 cycle (0.5 secs) t_A = 25 cal/cm^2 E_{MB}

- *"PPE selection based upon incident energy analysis may not provide adequate protection from actual arc flash hazard. "* NFPA 70E Section 130.5

Federal Register Vol 79 #70 4/11/2014

OSHA estimates on average, 74 fatalities and 444 serious injuries occur annually among employees performing work involving electric power generation, transmission, and distribution.

2,000 workers – number admitted annually to burn centers for extended injury treatment from arc fault energy exposure

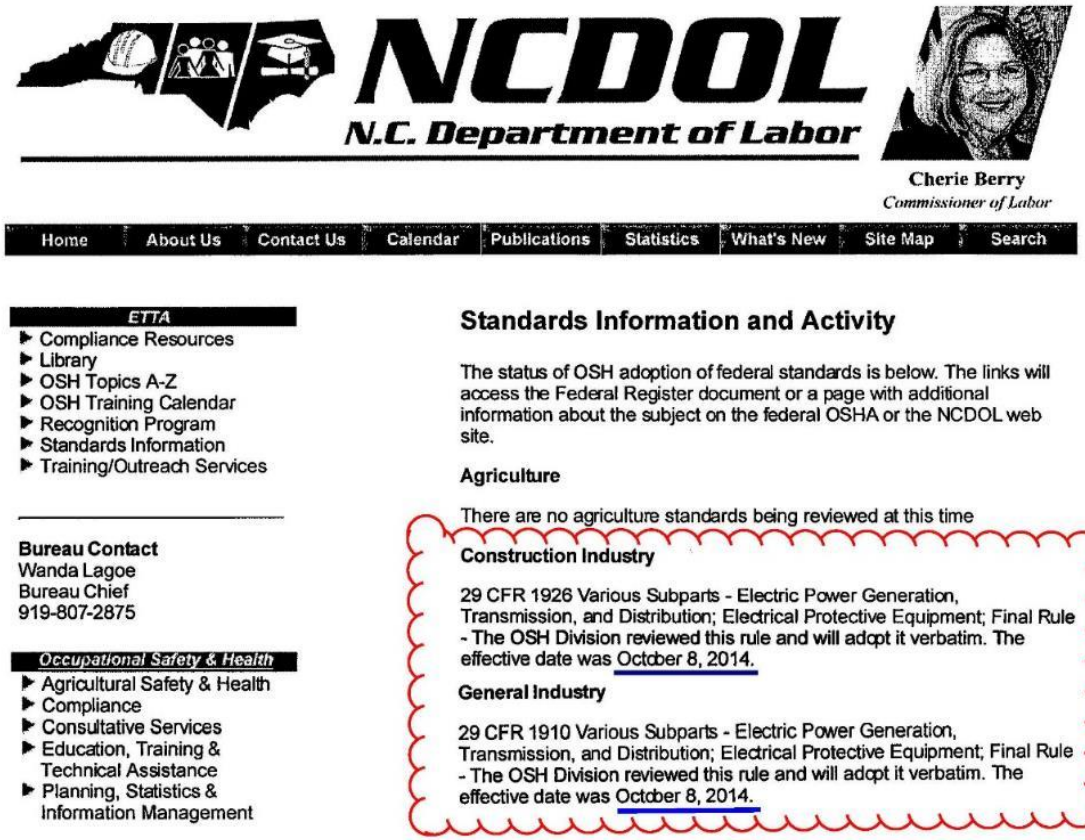
Reference IEEE Report

Governing Arc Flash Regulations and Standards

- OSHA Standards 29 Code of Federal Regulations,
  - Part 1910 General Industry
  - Part 1926 Construction Industry
- NFPA 70 - The National Electrical Code (NEC)
- NFPA 70E (2012) - *Standard for Electrical Safety in the Workplace*
- IEEE Standard 1584 (2002) *Guide to Performing Arc Flash Hazard Calculations*

- Arc flash regulations apply to existing facilities not just new construction

STATE OF NORTH CAROLINA ADMINISTERS OSHA APPROVED JOB SAFETY AND HEALTH PROGRAMS



NCDOL adopted 29 CFR 1910 effective *October 8, 2014*

Federal Civil Penalties
Inflation Adjustment Improvements Act of 2015

Maximum allowable penalties for OSHA citations:

	Prior to 2016	Effective 2016
• Other Than Serious	$1,000	**$1,500***
• Serious	$7,000	**$10,600***
• Willful	$70,000	**$106,000***

* OSHA penalties now indexed (CPI) for inflation

OSHA Standard 29 CFR Part 1910 General Industry – Electrical Power Generation, Transmission, & Distribution

All employers shall be responsible for:

- *Risk Assessments to Employees no later than January 1, 2015*
- *Electrical Hazard Classification no later than April 1, 2015*
- *Personal Protective Equipment no later than April 1, 2015*
- *Host – Contract Employer Responsibilities*
- *Information Transfer/Minimum Documentation*

Amongst Affected Industries Include Educational Facilities and Hospitals *Federal Register 4/11/2014*

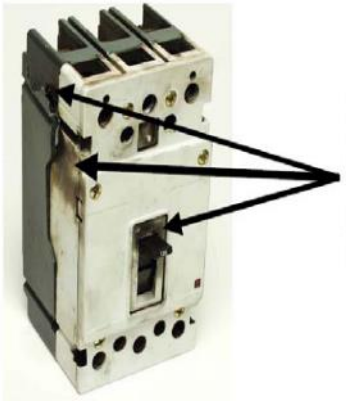
Potential Mitigation Measures

Implement Electrical Asset Management Program

- Identify installation age
- Collect O&M info
- Regular inspection
  - Signs of arcing or flash
  - Search broken parts, loose hardware (e.g. bolts on the floor)
- Cleaning and lubricating
- Confirm anchorage, alignment, grounding

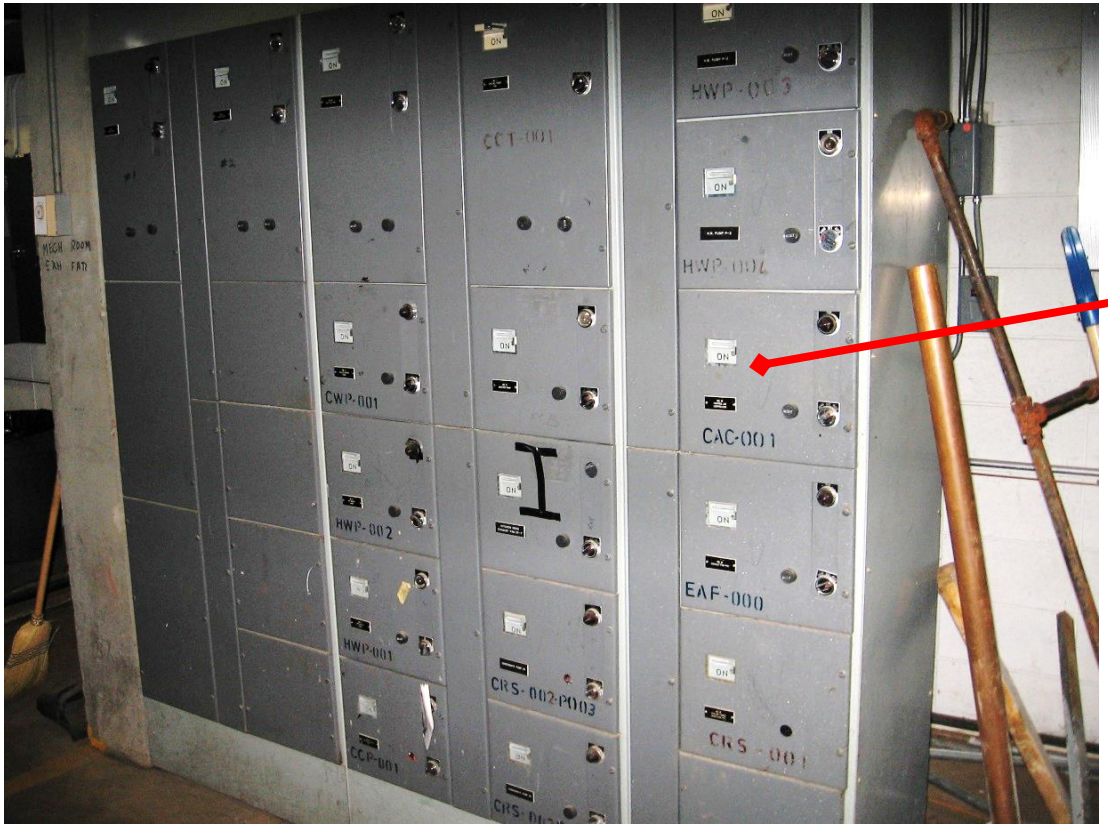
- Confirm organizational maintenance philosophy and contract for those tasks designated as undesireable

Consider Thermal Inspection Program



Remove and replace equipment from service based upon infrared scan results

Implement Inspection and Maintenance Program



"Circuit breakers should be cycled ON-OFF at least every 6 months" – ANSI/NEMA AB 3

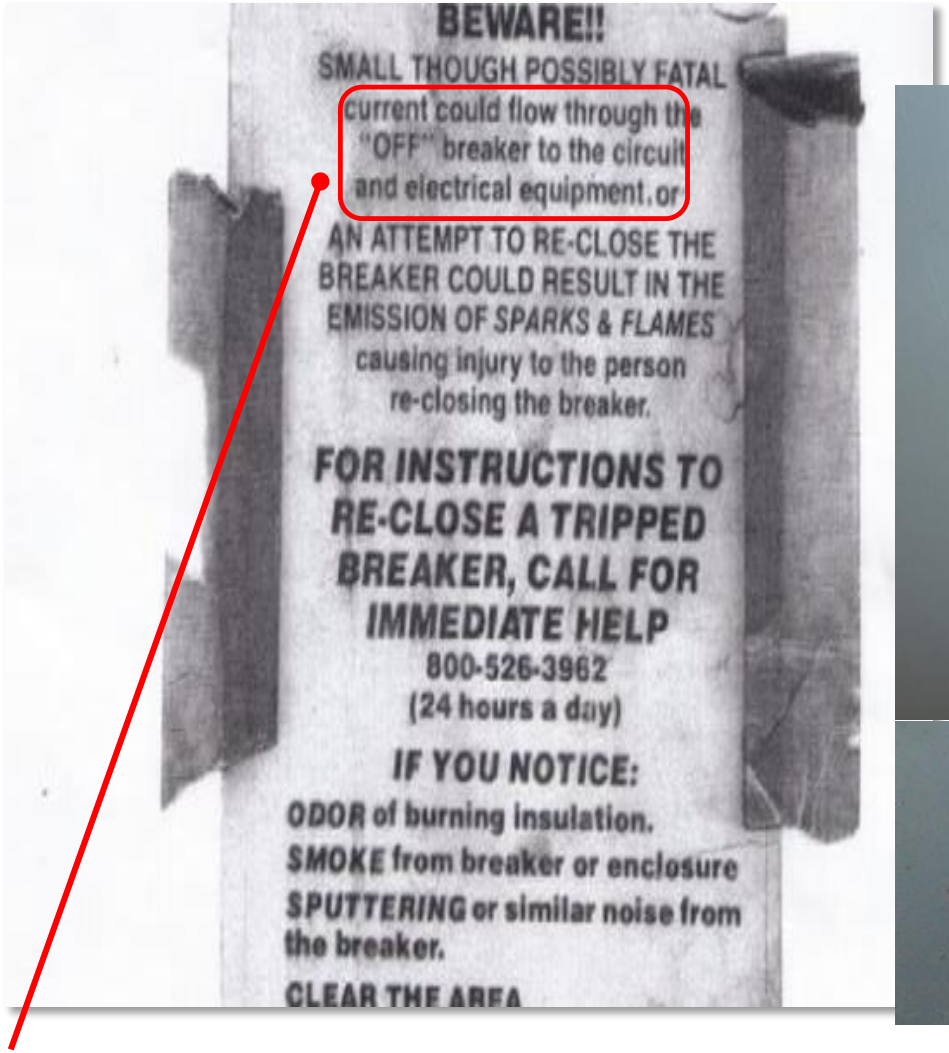
Corrosive Environment Mitigation
Example 1 of 2

Where unable to locate electrical equipment in “clean” areas then consider mitigating corrosive gas penetration

Corrosive Environment Mitigation
Example 2 of 2

Where unable to locate electrical equipment in “clean” areas then consider mitigating corrosive gas penetration

Replace Recalled and Legacy Equipment



- *"Do not reclose…current could flow through the 'OFF' breaker…"*

37

Upgrade In Place
Aging and Obsolete Electrical Equipment

- Economical upgrade for older switchgear
- Modernizes circuit breaker technology
- New operating and racking mechanisms
- Improved electrical system reliability

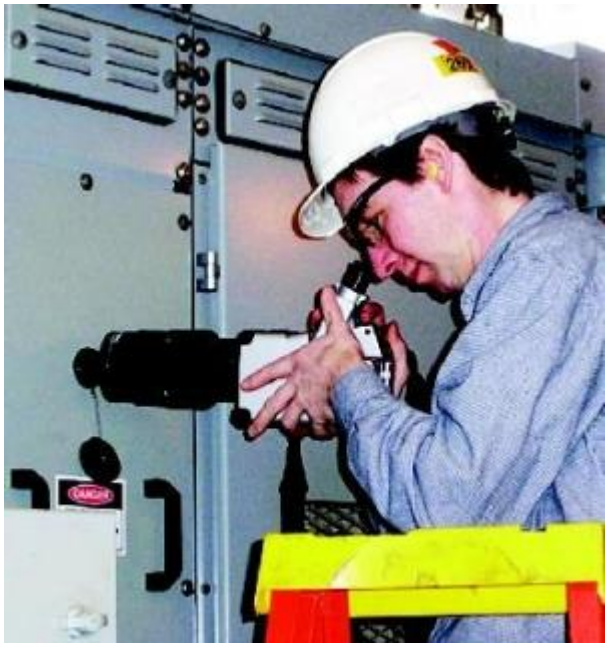
Switchgear Cubicle

Breaker Carriage

Before After

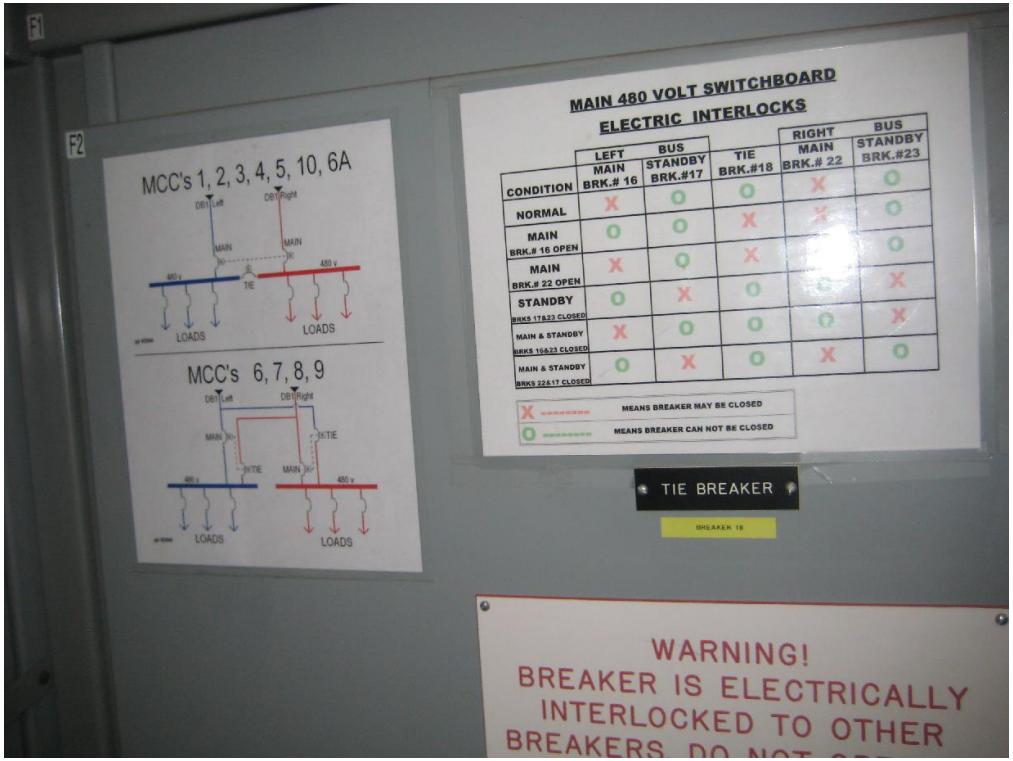
Passive **components (bus, terminals, structure) remain while replacing *active* components**

Optional Electrical Accessory Enhancements



Infrared viewing windows and remote breaker operating/racking mechanisms

Prominently Post Accurate Documentation Records



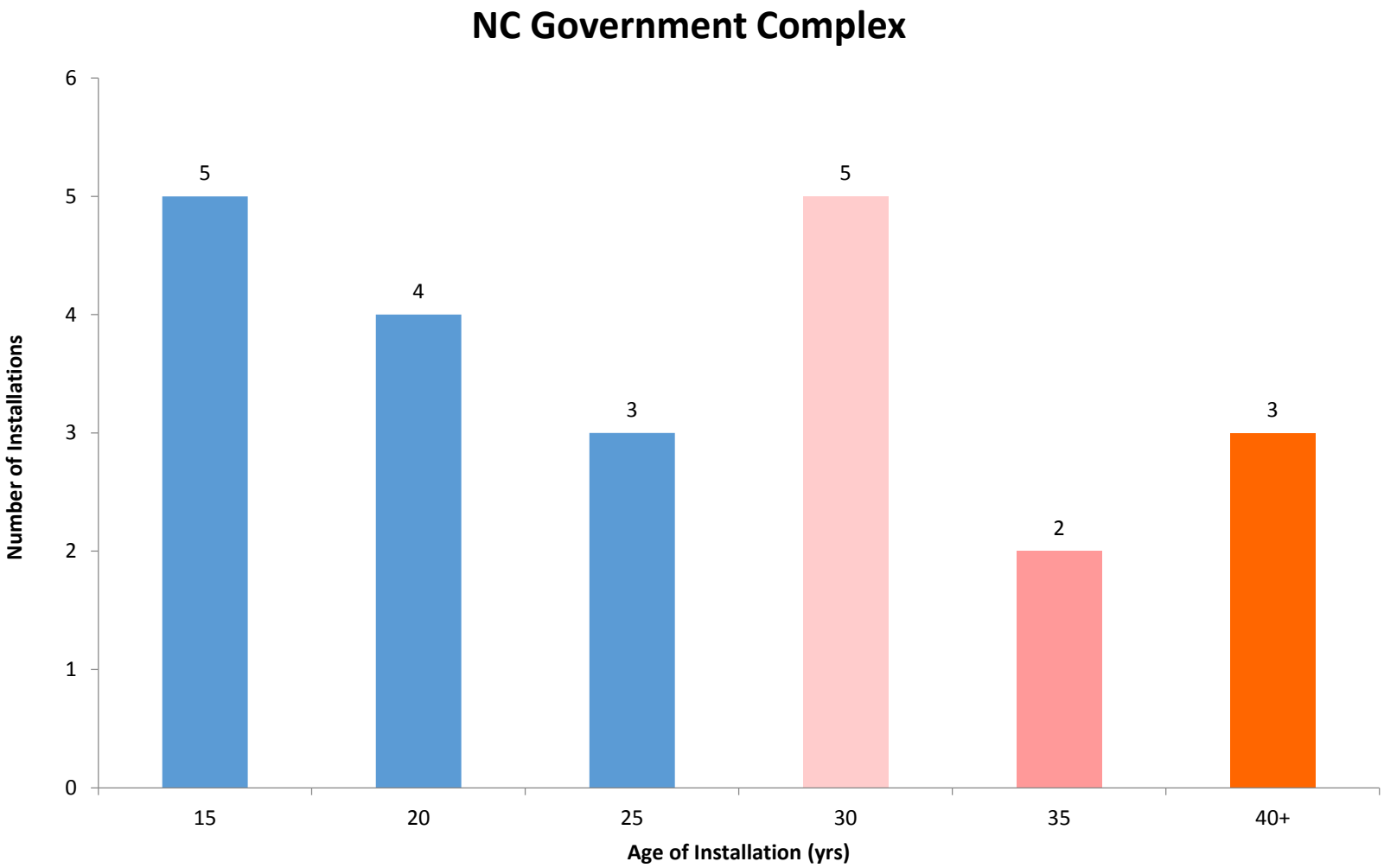
- **Commit to maintaining documentation accuracy subsequent to future modifications**

Commit to Implementing Arc Flash Hazard Awareness

- Target new employees as well as frequent refresher sessions scheduled regularly for all personnel
- Clearly identify “qualified” and “non-qualified” personnel

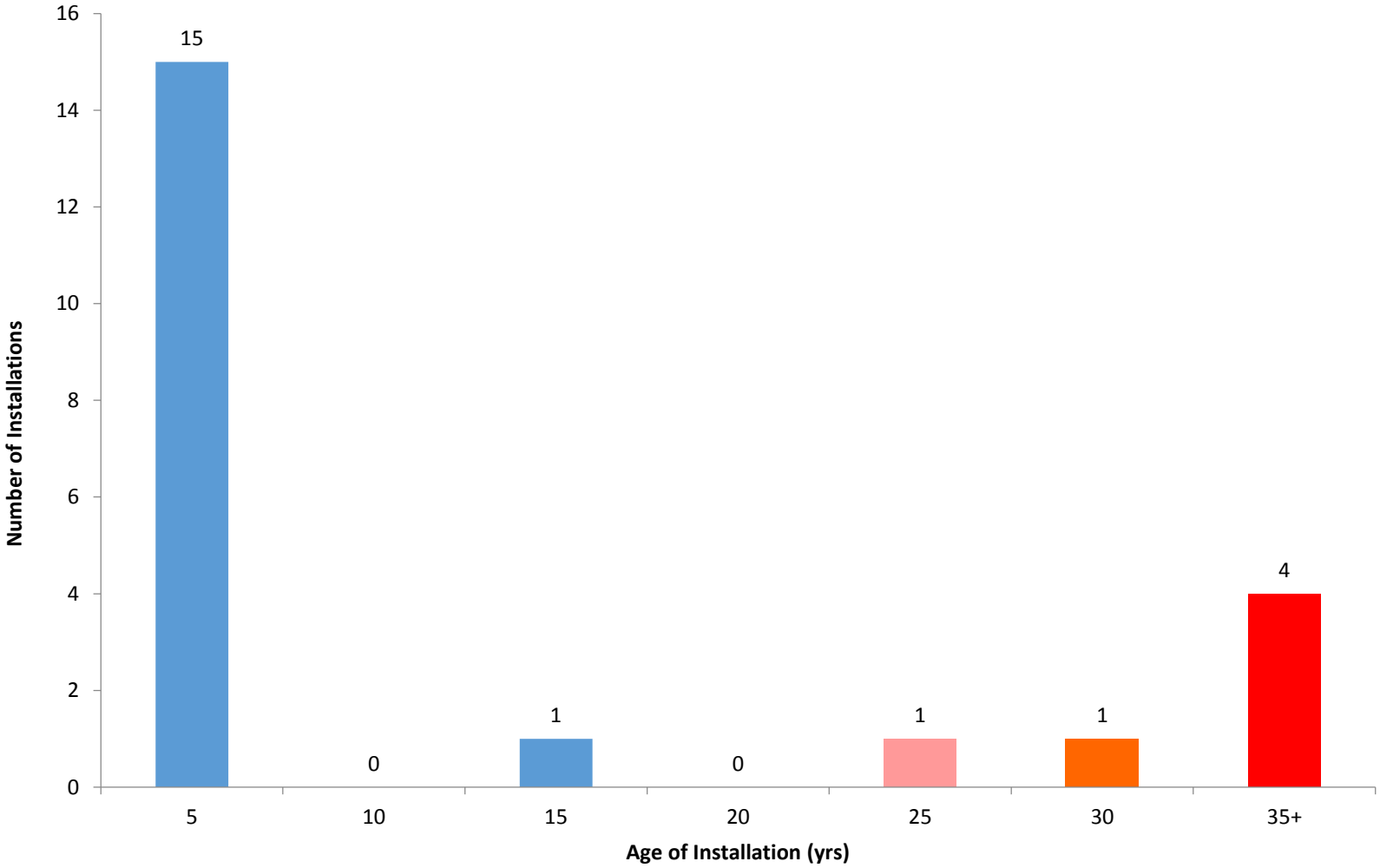
- Keep arc flash hazard analysis up to date with system modifications and utility changes.

Downtown Raleigh NC Government Complex
2004 Assessment



- **>80%** electrical facilities exceed 20 years of installation age

Downtown Raleigh NC Government Complex
2016 Assessment



- **< 25%** electrical facilities exceed 25 years of installation age

Conclusions & Recommendations

Considerations for Addressing Aging Electrical Infrastructure Systems

- Implement asset management program w/ electrical system focus
- Establish regular preventative maintenance program
- Maintain arc flash hazard analysis & protective device study
  - Update with system changes or service utility changes
- Maintain accurate system documentation
- Monitor electrical equipment environment
- Consider enhanced accessories infrared windows, remote racking

- Continuing to ignore the risks of aging electrical infrastructure should no longer be accepted practice!

Contacts

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- State Construction Office
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Thank You !

References

Slide 6 - Bathtub Reliability Curve	www.thereliableboat.com
Slide 16 – Photograph	EC&M Magazine “What’s Wrong Here-Hint:Rotten to the Core”, Nov 2015
Slide 20 - Video	www.youtube.com
Slide 21 - Image	www.arcflash-training.ca
Slide 22 – Photographs	www.huntelectric.com www.cablejoints.co.uk
Slide 24 – Chart	www.powerhawke.com
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Slide 33 – Photographs	www.martechnical.com
Slide 35 – Photographs	Water and Sewer Authority of Cabarrus County North Carolina
Slide 38 – Photographs	www.schneider-electric.com
Slide 39 – Photographs	www.eaton.com