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Why do you need an electrical maintenance program?

- Reliability, prevent business interruption
- Extended equipment life
- Reduce cost
- Safety
- Comply with applicable regulations
- Achieve Lowest Total Cost of Ownership (TCO) for an asset.

Extend Life
Extend Life

Lowest Total Cost of Ownership

Which costs more?

Emergency or Planned procurement and replacement?
Cost Saving

Comply With Regulations
NEC Relationship with NFPA 70B

- NFPA 70B was created because several requests were sent to NEC (NFPA 70) Committee to include maintenance recommendations in the NEC.
- NEC scope (from 90.2) covers the installation.
- Installed equipment will work as intended only if maintained to an acceptable level of performance.
- NEC extracts used in NFPA 70B, essentially directs maintenance to ensure equipment remains installed as originally specified.
NFPA 70E Relationship to NFPA 70B

- NFPA 70E makes conditions of maintenance critical.
- 70E allows normal operation of equipment only when maintained to manufacturers instructions or applicable industry codes or standards.
- Everything completely fastened and secured, no signs of impending failure.
- Incident energy depends on proper operation of overcurrent protection; devices must be tested.
- NFPA 70E extracts used in NFPA 70B.

70B 2.4, 70E 130.2(A)(4)

NFPA 70E Relationship to NFPA 70B

- Increased clearing time of an overcurrent device through neglected maintenance, will increase the exposure a worker will receive should an arc flash occur, rendering the Arc-Flash labels worthless.
## NFPA 70B Relationship to Other Standards

- 70B is exhaustive reference with recommended practices from other standards, List in Chapter 2:
  - 2.2 NFPA Publications
    - 2.3.1 ASTM
    - 2.3.2 EASA
    - 2.3.3 IEEE
    - 2.3.4 ITI
    - 2.3.5 NEMA
    - 2.3.6 NETA
    - 2.3.7 OSHA
    - 2.3.8 UL
    - 2.3.9 US Govt.
    - 2.3.10 Other

## Intangible Benefits of EPM

“Intangible” = Not tracked by accounting
- Improved employee morale
- Better workmanship
- Increased productivity
- Reduced absenteeism
- Reduced interruption of production
- Improved insurance considerations
Structure of **NFPA 70B**

- **NFPA 70B** has 35 Chapters and 17 Annexes
  - Chapters 1-3: General Information
  - Chapters 4-6, 30, 31: Effective Electrical Preventive Maintenance (EPM) and REX
  - Chapter 7: Safety Recommendation
  - Chapter 8: Fundamentals
  - Chapter 9: System Studies

Structure of **NFPA 70B**

- Chapter 10: Power Quality
- Chapter 11: Testing and Test Methods
- Chapter 12: Equipment Subject to Long Intervals
- Chapters 13-29, 33, 34, 35: Specific Equipment and Systems
- Chapter 32: Electrical Disaster Recovery
Structure of *NFPA 70B*

- Annexes (A through Q) are not part of the recommendations, for informational purposes only, but helpful.
- Annex H: Examples of typical maintenance and testing forms; show how to satisfy the maintenance recommendations.
- Annex L: Interval Guidelines for the most asked question. Modify according to 6.4.4.

---

**NFPA Documents**

- **Code** — A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.
- **Recommended Practice** — An NFPA Standard similar in content and structure to a code or standard but that contains only nonmandatory provisions using the word “should” to indicate recommendations in the body of the text.
NFPA 70B To Change

• From “Recommended Practice” to “Code”

• Current goal of the Technical Committee (in which ES Squared is a member as well 70 &E).

• Committee wants to provide a solid document to help people meet, and AHJs enforce, NFPA 70E Maintenance Requirements for SAFETY.

• Two steps: 1) Separate all explanatory material and move to annexes - 2022, and 2) change all “should’s” to “shall’s” - 2025.

Scope

• Applies to Preventive and Predictive Maintenance

• Does not Supersede Instructions from Manufacturer

• Typical Electrical Equipment in Industrial and Commercial Locations

• Does not Apply to Residences other than Large Multifamily Complexes

70B 1.1.1
Purpose

• Reduce hazards to life and property resulting from failure or malfunction of electrical equipment

Can hazards be completely eliminated?

EPM Program Planning

• Four Basic Steps
  1) Compile Listing of Equipment
  2) Determine Which is “Critical”
  3) Develop Monitoring System
  4) Identify Needed Personnel
      • Internal
      • External
EPM Program Resources

- Resource Work Center
  1) Inspection and Test Procedures
  2) Previous Reports
  3) Single-Line Drawings
  4) Schematic Diagrams
  5) Nameplate Data
  6) Vendors’ Catalogs
  7) Facility Stores’ Catalogs
  8) Forms
  9) Codes & Standards References

EPM Data Collection

Single Line Drawings
Arc Flash Hazard Analysis
Equipment Location Plan
Vendor Data
Maintenance Records

70B 6.1.5
70B 6.2.1
EPM Program Set-up

• Point is...

• NFPA 70B Provides guidance on setting up an Electrical Preventive Maintenance program.

Identification of Critical Equipment

• Considered Critical If Failure Would Cause Serious Threat To:
  – People
  – Property
  – Product

• Must Consider Normal Operation and Complete Loss of Control

70B 6.3
Establishing a Systematic Program

• Purpose
  − Establish Condition of Equipment
  − Determine What Work Necessary
  − Verify it will Continue to Operate Until Next Scheduled Servicing

• Inspection/Testing In Concert with Routine Maintenance
  − Small Corrections can be made immediately
  − Maintenance Department hasOwnership

Establishing a Systematic Program

• Inspection Frequency
  − Start with Manufacturers’ O&M Manuals
  − Annex L
  − Adjust for environment, duty, criticality

But how much should we adjust for these factors?
Frequency Adjustments

- Located in clean AC room – extend by 30%
- High dust or corrosive vapors – reduce by 50%
- Continuously operated – extend by 10-20%
- Stand-by operation – reduced by 20-40%
- Double frequency upon failures.

**Do Not Reduce Before 4 Maintenance Cycles**
- Monitor Trends and Make Decisions on Data
- Consider Cost vs. Risk/Benefit

Personnel Safety

- Grounding of Equipment
- 70B Contains some good guidance on when and how.
- Decision to Apply Personnel Grounding Based on Circumstances
  - Induced Voltages
  - Switching Errors Possible
  - Contact with Energized Circuit
  - Lightning Strikes
  - Stored Energy
Apply Grounds Where Necessary

Place Grounds with Care
EPM Fundamentals

• Impact of Maintenance on Protective Devices
  – In the following slides, an arc flash occurs until the overcurrent protective device interrupts the circuit. With proper maintenance, the device will operate as design, limiting the amount of energy released and resulting damage.

Fast (8.3ms) Clearing Time

Voltage:
  480V, 3 phase
Fault current available:
  22.6 kA
Clearing time:
  < 1/2 cycle
Device:
  Class L, current limiting fuse
  601 A

Estimated (Calculated) Incident Energy: ~ 0.3 – 0.5 cal/cm² @ 18 in. work distance
Estimated (Calculated) Arc Flash Boundary: ~ 7 - 9 in.
Arc Flash – Half Cycle

Measured Results

144°F  133 dB

> 437°F

504 psf

No temp. data (under shirt)
EPM Fundamentals

- Impact of Maintenance on Protective Devices
  - Now, the same event will be observed but with extended time. This simulates what could happen if protective devices are not maintained to ensure adequate performance.

Arc Flash 6 Cycle Stop Motion
Arc Flash 6 Cycle Stop Motion

Arc Flash 6 Cycle Stop Motion
6 Cycle (100ms) Clearing Time

Measured Results

141.5 dB

> 437° F

> 2160 psf

122° F
under shirt
EPM Fundamentals

Acceptance Testing
• Develop Functional Performance Tests
• Confirms the installation – “first maintenance”
• Establishes the baseline

Chapter 9  System Studies

• Engineering Studies Critical to Maintenance
  − Coordination
  − Short-Circuit
  − Arc-Flash
  − Load-Flow
  − Reliability

• Single-Line Drawings and Copies of Studies Provided to Maintenance
The Old and New Order of Studies

OLD:
- Starts with raw Load and individual protections.
- Double-ends unit substation and transformers for redundancy.
- Calculates fault currents to specify gear.
- Calculates arc-flash currents to specify PPE.
- No attempt to design to minimize.

NEW:
- Considers all together to limit arc-flash & blast energy. Typically keep bus loads down to 2000 amps and utilizes N-1 for redundancy, not just where N=2 (double).

Power Quality

Power Quality Problems are Deviations from Ideal Sign Wave of Voltage and/or Current with Power Factor of 1.0 (no lead or lag) which could result in:
- Electrical Faults
- Impacts to Personnel Safety
- Reduced Life of Equipment or Reduced Performance
- Fire Hazard
- Interrupted communications

70B 10.1.2
Power Quality

Examples of Power Quality Disturbances
• Harmonics
• Transients
• Voltage Sags and Swells
• Sustained Interruptions
• Unbalanced Voltages
• Noise
• Fluctuations

Power Quality
• Power Quality Audit
• Portable quality monitor meters are available to collect data.
Testing and Test Methods

The true beginning of 70B: WHAT to do.

- Determine Need for Corrective Maintenance
- Ascertain Ability of Element to Perform Adequately
- Trend Degradation of Equipment

Testing and Test Methods

- Acceptance Tests
  - New Equipment.
  - Factory Acceptance Tests for proper design and workmanship.
  - Site Acceptance Tests for shipping damage and installation workmanship.
  - Electrical Tests per NETA ATS
  - Includes Visual Inspection
  - Complete operational checks
Testing and Test Methods
• Test Operators Should Be Qualified
  – NETA Certification of Contractors

• Test Equipment Maintained to Safe Condition
  – Calibrated for good comparative data results.

• Proper Forms for recording test results
  – Annex H, List on pg. 51

Electricians Favorite Test Tools
• Multimeter (with proving unit)
• Clamp-on ammeter (if not part of multimeter)
• Insulation Resistance Tester (Megger)
• Microhmeter
• Voltage phasing
• HV detector
Insulation Testing

- Insulation will naturally break down with age and normal voltage stresses.
- Accelerated by heat. Half the life for every 10°C rise.
- Chemical attack, moisture, dirt, mechanical damage, sunlight and other environmental exposures also destroy insulation.

70B 11.9, 11.9.2.3

---

Insulation Testing

A word about fear of damaging through the potential testing methods....

Don’t test if you are not prepared with spare parts and cable to replace. What will you do if you find a problem? ORDER THE SPARES.

If the test does cause a failure, this is finding a very weak spot. Time to replace (should have been tested sooner). At least you planned the downtime (extended?).

70B 11.9, 11.9.2.3
Invest in Test Equipment

Molded-Case Circuit Breakers
LV Circuit Breaker Testing

- Molded Case Circuit Breaker – UL 489
- Low Voltage Power Circuit Breaker – ANSI/UL 1066 and IEEE C37.13
- Field Testing is NOT Calibration Testing
- Follow Manufacturer’s Instructions or NETA MTS
- Primary Injection to Verify Long-Term (Thermal) and Short-Term (Magnetic) Pickup Values
- Insulation Resistance & Contact Resistance

MCCB: UL 489

- Breakers are tested twice at rated short circuit current.

- Rated for ONLY ONE fault clearing.

- How about overloads and endurance?
### MCCB Overload Test Operations – UL 489 Table 7.1.3.1

<table>
<thead>
<tr>
<th>Frame size, Amperes</th>
<th>Number of operations</th>
<th>Switches</th>
<th>Number of cycles of operation per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Close and open manually&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Close manually, open automatically</td>
<td></td>
</tr>
<tr>
<td>100 or less</td>
<td>35</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>101 – 150</td>
<td>50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–</td>
<td>50</td>
</tr>
<tr>
<td>151 – 225</td>
<td>50</td>
<td>–</td>
<td>50</td>
</tr>
<tr>
<td>226 – 1600</td>
<td>50</td>
<td>–</td>
<td>50</td>
</tr>
<tr>
<td>1601 – 2500</td>
<td>25</td>
<td>–</td>
<td>25</td>
</tr>
<tr>
<td>2501 – 6000</td>
<td>28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>–</td>
<td>28&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

### MCCB Endurance Test Operations – UL 489 Table 7.1.5.1

<table>
<thead>
<tr>
<th>Maximum frame size in amperes</th>
<th>Number of cycles of operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per minute&lt;sup&gt;a&lt;/sup&gt;</td>
<td>With current</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>6,000</td>
</tr>
<tr>
<td>150</td>
<td>5</td>
<td>4,000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>225</td>
<td>5</td>
<td>4,000</td>
</tr>
<tr>
<td>600</td>
<td>4</td>
<td>1,000</td>
</tr>
<tr>
<td>800</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>1200</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>2500</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>6000</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>400</td>
</tr>
</tbody>
</table>

<sup>a</sup> In general, the number of cycles of operation per minute is determined by the frame size of the MCCB.

<sup>b</sup> The number of cycles with current is calculated based on the maximum current rating of the MCCB.

<sup>c</sup> The number of cycles without current is calculated based on the desired number of cycles for the endurance test.

<sup>d</sup> These values are subject to change based on specific test conditions and equipment used.

<sup>e</sup> Additional testing may be required to ensure compliance with UL 489 standards.

<sup>f</sup> These values are for test standard compliance purposes and may not reflect normal operating conditions.

<sup>g</sup> The number of cycles of operation per minute is determined by multiplying the number of operations by the maximum current rating of the MCCB.

<sup>h</sup> These values are subject to change based on specific test conditions and equipment used.

<sup>i</sup> Additional testing may be required to ensure compliance with UL 489 standards.

<sup>j</sup> These values are for test standard compliance purposes and may not reflect normal operating conditions.

<sup>k</sup> The number of cycles without current is calculated based on the desired number of cycles for the endurance test.
Molded-Case Circuit Breakers

- Potential Failure or Delay to Open Faulted Circuit
- Increased Opening Time Increases Arc-Flash Incident Energy
- Clean and Inspect for Overheating, Loose Connections
- Exercise Mechanical Linkage
- Insulation & Contact Resistance, 300% Injection per 11.10

*How long can a healthy 200 amp breaker conduct 600 amps before tripping?*

70B Chapter 17

<table>
<thead>
<tr>
<th>Rated Current Amperes</th>
<th>Maximum Trip Time in Seconds*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤250V</td>
</tr>
<tr>
<td>0–30</td>
<td>50</td>
</tr>
<tr>
<td>31–50</td>
<td>80</td>
</tr>
<tr>
<td>51–100</td>
<td>140</td>
</tr>
<tr>
<td>101–150</td>
<td>200</td>
</tr>
<tr>
<td>151–225</td>
<td>220</td>
</tr>
<tr>
<td>225–400</td>
<td>300</td>
</tr>
<tr>
<td>401–600</td>
<td>—</td>
</tr>
<tr>
<td>601–800</td>
<td>—</td>
</tr>
<tr>
<td>801–1000</td>
<td>—</td>
</tr>
<tr>
<td>1001–1200</td>
<td>—</td>
</tr>
<tr>
<td>1201–1600</td>
<td>—</td>
</tr>
<tr>
<td>1601–2000</td>
<td>—</td>
</tr>
<tr>
<td>2001–2500</td>
<td>—</td>
</tr>
<tr>
<td>2501–5000</td>
<td>—</td>
</tr>
<tr>
<td>6000</td>
<td>—</td>
</tr>
</tbody>
</table>

**Table 11.10.5.2.5**

Values for Inverse Time Trip Test

(at 300% of Rated Continuous Current of Circuit Breaker)
MCCB Failure Case

- Electrician reset the breaker.
- Operator pressed the start/run button.
- A fault (at least one phase) to ground existed.
- Insulation Resistance Test
- Contacts had pitted badly prior to this event.
- Contact Resistance Test (micro-ohmmeter)
- Contacts welded closed upon this in-rush. *What tests could have determined the problems prior to re-closing?*

Molded-Case Circuit Breakers

- NFPA 70E 130.6(M) requires determination of cause of trip prior to reclosing.
- Non-qualified personnel are not allowed to reset, although many found resetting without any precaution – a “household” carry-over?
- If frequent trips experienced breaker must be replaced and/or design changes made. Only tested for 50 overload operations.
Molded-Case Circuit Breakers

• 70B refers to NEMA AB4: Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications.

• Insulated-face thermography: temperature rises of 35°C on metal or 60°C on plastic surfaces (above ambient) are considered excessive.

70B Chapter 17

Molded-Case Circuit Breakers

• IR scan for any difference between phases of more than 15°C.

• Most conditions of elevated temperature are related to terminal connection issues – improper tightness.

• Check & clean surfaces of dust, dirt, soot, grease, or moisture.

70B Chapter 17
MV/HV ACB Testing

- Insulation Resistance
- Contact/Pole Resistance
- Power Factor
- DC Overpotential
- Operation of Blowout Coils and Heaters
- Time-Travel Analysis of Opening Mechanism

Notice that these two begin most component electrical tests.

Switchgear Testing

- Insulation Resistance
- Hi-potential testing
- Contacts/Connections Resistances
- Ground Resistance
- Function testing all connected devices
- Refer to NETA MTS
## Activity: Define Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonding</td>
<td>Isolated Ground</td>
</tr>
<tr>
<td>Counterpoise</td>
<td>Solidly Grounded</td>
</tr>
<tr>
<td>Down Conductor</td>
<td>Grounded Conductor</td>
</tr>
<tr>
<td>Effective Ground Path</td>
<td>Grounding Conductor</td>
</tr>
<tr>
<td>Ground Fault</td>
<td>High Impedance Ground</td>
</tr>
<tr>
<td>Ground Loop</td>
<td>Equipment Grounding Conductor</td>
</tr>
<tr>
<td>Grounding Electrode</td>
<td></td>
</tr>
<tr>
<td>Grounding Electrode Conductor</td>
<td></td>
</tr>
</tbody>
</table>

* MV Switchgear Buss With CORONA evidence at air-gap between insulating sleeve and cubicle barrier
Tracking that led to full discharge / failure

Tracking damage on circuit breaker to line side buss connection
Insulation damage detected by on-line Partial Discharge monitoring.

Motor Control Equipment
**Motor Control Equipment**

- Maintenance According to Table 16.2.2

- Troubleshooting According to Table 16.2.1

- Insulation and contact resistance tests for the gear and components also apply (electrical tests are not listed in Table 16.2.2).

**Cable Tray and Busway**
Cable Tray

Check for:
- Overfilled tray – every cable should be exposed to air.
- Illegal cables (not TC) and other items
- Dirt and debris build-up
- Proper spacing
- Cable or Tray damage
- Tray bonding and grounding
- Expansion joints

Insurance companies concern for tray fires.

70B Chapter 20
That’s why the professional men and women of

**ES Squared, Inc.**

*Electrical Safety Specialists*

are dedicated to safety in the workplace

...because one life saved means a successful career...
...because one life saved means a satisfied employer...
...because one life saved means a joyful family...

**Who are you saving today?**

---

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There Exists Electrical Safety for Every Site
No job is so urgent
nor any action so vital
that we cannot take time
to perform our work safely

Today’s Instructor

Michael Kovacic is a full-time Occupational Safety Instructor and Consultant and President of ES Squared, Inc., a Pittsburgh, PA based organization specializing in electrical safety and lockout/tagout.

Mr. Kovacic has over 20 years of experience in the electrical safety industry. He has participated in or managed teams for safety audits for literally millions of square feet of facility, representing over 150 heavy industrial facilities for major corporations and government organizations. Mr. Kovacic is involved in the development of several computer database applications which aid in the record keeping and reporting portions of the assessment function. He has participated in flash hazard analysis projects for numerous facilities, and has background in accident investigation and legal assistance, and has a strong knowledge of European safety requirements as well.

Mr. Kovacic has an extensive knowledge of various standards, including DOD/DOE requirements and Army, Navy and Air Force safety programs, which has allowed him to successfully conduct various standard and customized courses on the OSHA Standards, the National Electrical Code, and NFPA 70E for the U.S. Department of Labor at the OSHA Training Institute in Chicago, IL., various State OSHA Departments, Federal Aviation Administration (FAA), the American Society of Safety Engineers (ASSE), Bureau of Worker’s Compensation (Ohio) and numerous major private corporations such as Aluminum Company of America (Alcoa) and Heinz, and is a specialist in NFPA 70E, including arc flash hazard and safety-related work practices.

Additionally, this expertise in electrical safety and knowledge of standards has allowed for coauthoring and rewriting of complete electrical safety programs for major corporations and government entities around the country.

Due to his expertise and years of experience, Michael Kovacic also provides expert witness testimony both in pre-trial deposition and in court.

His unique experience in engineering, manufacturing, installation, and occupational safety allows him to relate extremely well to students from many different backgrounds.

In the time it takes you to listen to this presentation, there will be two preventable electrical-related workplace accidents