

NFPA 70B

Recommended Practice for Electrical Equipment Maintenance

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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

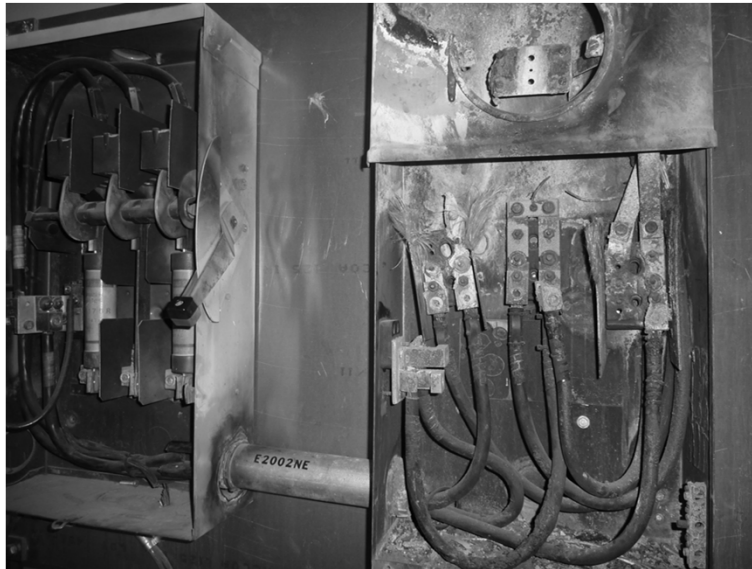


Lowest Total Cost of Ownership

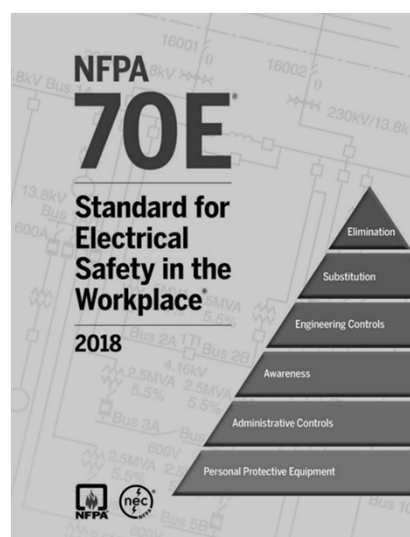
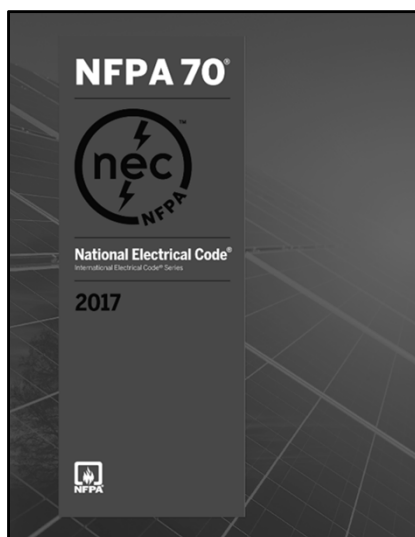
Which costs more?

*Emergency or Planned procurement
and replacement?*

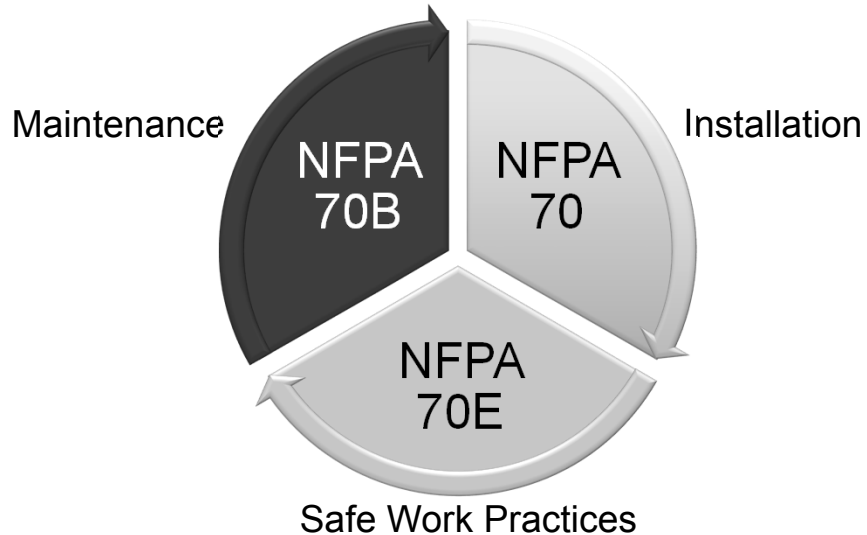
Cost Saving



Comply With Regulations



Electrical Safety Wheel



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.**

70B 2.4

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**

70B Chapter 2

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**

70B 4.2.2

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

70B TOC

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

70B TOC

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.**

70B Annexes

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 Regulations, 70B 3.2.4

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?

70B 1.2

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**

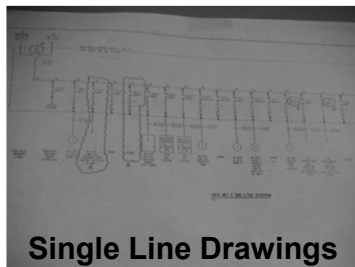
70B 6.1.2

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**

70B 6.1.5

EPM Data Collection

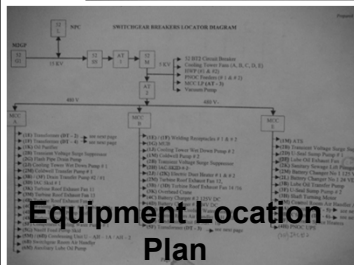


Single Line Drawings

A table showing the results of an Arc Flash Hazard Analysis. The table includes columns for equipment ID, voltage, available fault current, clearing time, and the resulting incident energy in cal/cm². The data is organized into rows for different pieces of equipment.

Equipment ID	Voltage (kV)	Available Fault Current (A)	Clearing Time (s)	Incident Energy (cal/cm²)
SW-1	15.0	10,000	0.05	1.2
SW-2	15.0	10,000	0.05	1.2
SW-3	15.0	10,000	0.05	1.2
SW-4	15.0	10,000	0.05	1.2
SW-5	15.0	10,000	0.05	1.2
SW-6	15.0	10,000	0.05	1.2
SW-7	15.0	10,000	0.05	1.2
SW-8	15.0	10,000	0.05	1.2
SW-9	15.0	10,000	0.05	1.2
SW-10	15.0	10,000	0.05	1.2
SW-11	15.0	10,000	0.05	1.2
SW-12	15.0	10,000	0.05	1.2
SW-13	15.0	10,000	0.05	1.2
SW-14	15.0	10,000	0.05	1.2
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SW-98	15.0	10,000	0.05	1.2
SW-99	15.0	10,000	0.05	1.2
SW-100	15.0	10,000	0.05	1.2

Arc Flash Hazard Analysis



Equipment Location Plan

A table showing maintenance records for various pieces of equipment, including dates, descriptions of work performed, and the names of the technicians who performed the work.

Equipment ID	Date	Description of Work	Technician
SW-1	10/15/2018	Oil change and filter replacement	John Doe
SW-2	10/15/2018	Oil change and filter replacement	John Doe
SW-3	10/15/2018	Oil change and filter replacement	John Doe
SW-4	10/15/2018	Oil change and filter replacement	John Doe
SW-5	10/15/2018	Oil change and filter replacement	John Doe
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SW-98	10/15/2018	Oil change and filter replacement	John Doe
SW-99	10/15/2018	Oil change and filter replacement	John Doe
SW-100	10/15/2018	Oil change and filter replacement	John Doe

Maintenance Records

Hazard Analysis

Hazardous Materials	Quantity	Location	Notes
1. Acetone	1000	Room 101	Flammable
2. Benzene	500	Room 102	Flammable
3. Chloroform	250	Room 103	Flammable
4. Ethanol	1000	Room 104	Flammable
5. Hydrochloric Acid	500	Room 105	Corrosive
6. Nitric Acid	250	Room 106	Corrosive
7. Sulfuric Acid	1000	Room 107	Corrosive
8. Toluene	500	Room 108	Flammable
9. Xylene	250	Room 109	Flammable
10. Other	1000	Room 110	Flammable

Vendor Data

Vendor Name	Address	Phone Number	Email Address
ABC Company	123 Main St, New York, NY 10001	(212) 555-1234	info@abc.com
DEF Company	456 Main St, New York, NY 10002	(212) 555-5678	info@def.com
GHI Company	789 Main St, New York, NY 10003	(212) 555-9012	info@ghi.com
JKL Company	101 Main St, New York, NY 10004	(212) 555-3456	info@jkl.com
MNO Company	202 Main St, New York, NY 10005	(212) 555-7890	info@mno.com
PQR Company	303 Main St, New York, NY 10006	(212) 555-2345	info@pqr.com
STU Company	404 Main St, New York, NY 10007	(212) 555-6789	info@stu.com
VWX Company	505 Main St, New York, NY 10008	(212) 555-0123	info@vwx.com
YZA Company	606 Main St, New York, NY 10009	(212) 555-4567	info@yza.com
BCD Company	707 Main St, New York, NY 10010	(212) 555-8901	info@bcd.com

Hazardous Materials	Quantity	Location	Notes
1. Acetone	1000	Room 101	Flammable
2. Benzene	500	Room 102	Flammable
3. Chloroform	250	Room 103	Flammable
4. Ethanol	1000	Room 104	Flammable
5. Hydrochloric Acid	500	Room 105	Corrosive
6. Nitric Acid	250	Room 106	Corrosive
7. Sulfuric Acid	1000	Room 107	Corrosive
8. Toluene	500	Room 108	Flammable
9. Xylene	250	Room 109	Flammable
10. Other	1000	Room 110	Flammable

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 has Ownership**

70B 6.4

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?

70B 6.4.4

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**

70B 6.4.4

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**

70B 7.2

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**



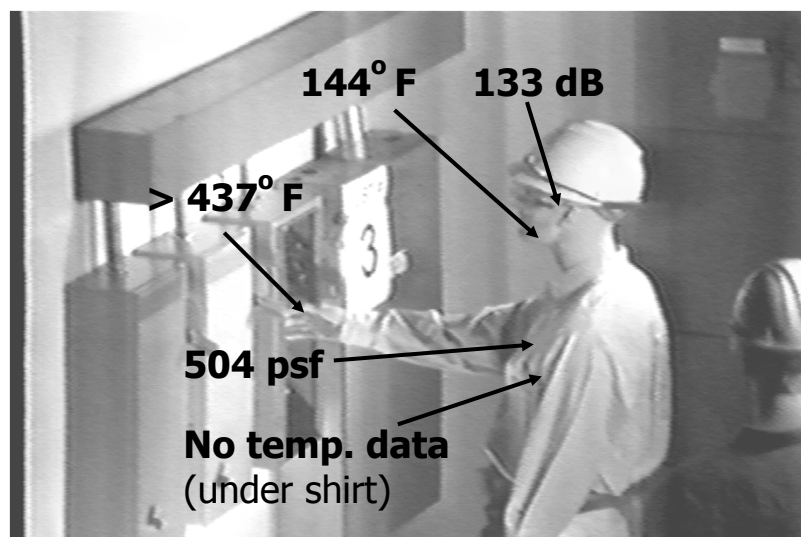
Estimated (Calculated) Incident Energy: ~ 0.3 – 0.5 cal/cm² @ 18 in. work distance

Estimated (Calculated) Arc Flash Boundary: ~ 7 - 9 in.

Arc Flash – Half Cycle



Measured Results



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.

70B 8.4

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



EPM Fundamentals



Acceptance Testing

- **Develop Functional Performance Tests**
- **Confirms the installation – “first maintenance”**
- **Establishes the baseline**

70B 8.5, 31.5

Chapter 9 System Studies

- **Engineering Studies Critical to Maintenance**
 - **Coordination**
 - **Short-Circuit**
 - **Arc-Flash**
 - **Load-Flow**
 - **Reliability****Must be studied together!**
- **Single-Line Drawings and Copies of Studies Provided to Maintenance**

70B 9.1

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

70B 10.1.2.6

Power Quality

- Power Quality Audit
- Portable quality monitor meters are available to collect data.



70B 10.11

Ch 11: 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**

70B 11.1

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**

70B 11.2.1

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**

70B 11.6, 11.7, 11.8

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**

70B 11.9, 11.9.2.3

Insulation Testing

- **Insulation will naturally break down with age and normal voltage stresses.**
- **Accelerated by heat. Half the life for every 10C 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**

70B 11.10

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

Frame size, Amperes	Number of operations			Number of cycles of operation per minute
	Circuit breakers		Switches	
	Close and open manually ^{b,c,d}	Close manually, open automatically		
100 or less	35	15	50	6
101 – 150	50 ^e	— ^e	50	5
151 – 225	50	—	50	5
226 – 1600	50	—	50	1 ^f
1601 – 2500	25	—	25	1 ^f
2501 – 6000	28 ^g	—	28 ^g	1 ^g

MCCB Endurance Test Operations – UL 489 Table 7.1.5.1

Maximum frame size in amperes	Number of cycles of operation			
	Per minute ^a	With current	Without current	Total
100	6	6,000	4,000	10,000
150	5	4,000 ^b	4,000	8,000 ^b
225	5	4,000	4,000	8,000
600	4	1,000	5,000	6,000
800	1	500	3,000	3,500
1200	1	500	2,000	2,500
2500	1	500	2,000	2,500
6000	1 ^c	400	1,100	1,500

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

Rated Current Amperes	Maximum Trip Time in Seconds*	
	≤250V	251–600V
0–30	50	70
31–50	80	100
51–100	140	160
101–150	200	250
151–225	230	275
226–400	300	350
401–600	—	450
601–800	—	500
801–1000	—	600
1001–1200	—	700
1201–1600	—	775
1601–2000	—	800
2001–2500	—	850
2501–5000	—	900
6000	—	1000

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.

70B 11.16.1

Switchgear Testing

- **Insulation Resistance**
- **Hi-potential testing**
- **Contacts/Connections Resistances**
- **Ground Resistance**
- **Function testing all connected devices**
- **Refer to NETA MTS**

70B 11.23

Activity: Define Terms

Bonding	Isolated Ground
Counterpoise	Solidly Grounded
Down Conductor	Grounded Conductor
Effective Ground Path	Grounding Conductor
Ground Fault	High Impedance Ground
Ground Loop	Equipment Grounding Conductor
Grounding Electrode	
Grounding Electrode Conductor	

*



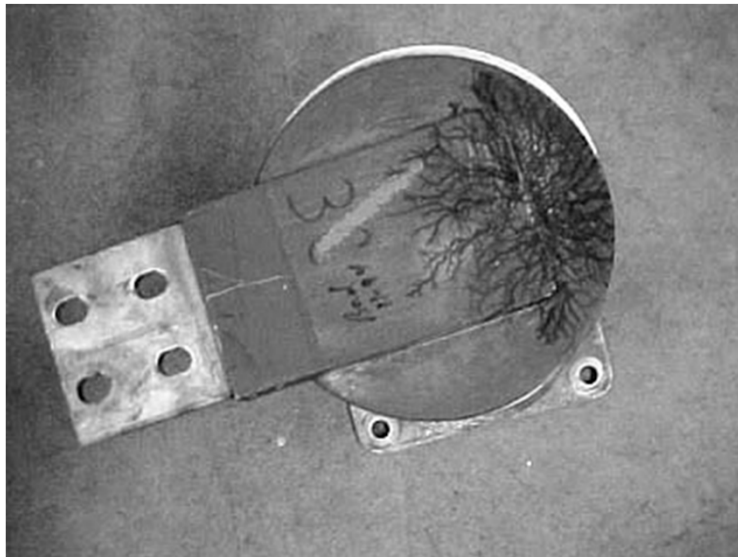
**MV Switchgear Buss With CORONA
evidence at air-gap between insulating
sleeve and cubicle barrier**

*



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).**

70B 16.2.1, 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

Last year in the United States, over
300 people were killed
by electricity in the workplace.

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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**