Second Revision No. 21-NFPA 70B-2018 [Global Comment]

Update all temperatures for consistent usage of primary and secondary units, which should be °C [°F].

Supplemental Information

File Name	Description	Approved
70B_SR21_Global_Temperature_1.docx	1 of 2	
70B_SR21_Global_Temperature_2.docx	2 of 2	

Submitter Information Verification

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State:
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Submittal Date: Wed Jan 31 13:12:02 EST 2018

Committee Statement

Committee Statement: Consistent use of primary and secondary units is a requirement of the Manual of Style.
Response Message:

Revise the following for consistent use of temperature units.

10.6.3.3 Motor Heating and Losses.

Insulation life is approximately halved for every 10°C (18°F (10°C) increase in winding temperature. Table 10.6.3.3 illustrates the typical percentage increases in motor losses and heating for various levels of voltage unbalance.

Table 10.6.3.3 Voltage Unbalance Versus Temperature Rise at Average Voltage of 230

Percent Unbalanced Voltage	Percent Unbalanced Current	Increased Temperature Rise (°C)	
		(°C)	(°F)
0.3	0.4	0	0
2.3	17.7	30	54
5.4	40	40	72

11.11.4.3

Maximum power-factor/dissipation-factor values of liquid-filled transformers corrected to 20°C (68°F) should be in accordance with the transformer manufacturer's published data.

11.17.5.6

Section 9 and Table 10.18 of the ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, suggest temperature benchmarks similar to those in the following list. The temperature differences in this list denote differences from the normal referenced temperature. The normal referenced temperature is determined by a qualified technician.

1. Temperature differences of 1°C to 3°C (1.8°F to 5.4°F) indicate possible deficiency and warrant investigation.
2. Temperature differences of 4°C to 15°C (7.2°F to 27°F) indicate deficiency; repairs should be made as time permits.
3. Temperature differences of 16°C (28.8°F) and above indicate major deficiency; repairs should be made immediately.

11.19 Insulating-Liquid Analysis.

Regular semiannual tests should be made on insulating oils and askarels. Samples should be taken from the equipment in accordance with ASTM D923, *Standard Test Method for Sampling Electrical Insulating Liquids*. The maintenance tests most commonly performed on used insulating liquids, together with the appropriate ASTM test methods, are shown in Table 11.19(a) through Table 11.19(g).

Table 11.19(a) Suggested Limits for Class I Insulating Oil

Test	ASTM Method	Mineral Oil[a]		
			Acceptable Values	
		69 kV and Below	Above 69 kV – Below 230 kV	230 kV and Above
Dielectric breakdown, kV minimum[b]	D877	26	26	26
Dielectric breakdown, kV minimum @ 1 mm (0.04 in.) gap	D1816	23	28	30
Dielectric breakdown, kV minimum @ 2 mm (0.08 in.) gap	D1816	40	47	50
Interfacial tension mN/m minimum	D971	25	30	32
Neutralization number, mg KOH/g maximum	D974	0.2	0.15	0.10
Water content, ppm maximum @ 60°C (140°F)[c]	D1533	35	25	20
Power factor at 25°C (77°F), %	D924	0.5	0.5	0.5
Power factor at 100°C (212°F), %	D924	5.0	5.0	5.0
Color[d]	D1500	3.5	3.5	3.5
Visual condition	D1524	Bright, clear, and free of particles	Bright, clear, and free of particles	Bright, clear, and free of particles
Specific gravity (relative density) @ 15°C (59°F) maximum[e]	D1298	0.91	0.91	0.91

[a]ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 7.
[b]IEEE STD 637-1985, *Guide for Reclamation of Insulating Oil and Criteria for Its Use*, Table 1.
[c]ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 5.
[d]In the absence of consensus standards, NETA's Standard Review Council suggests these values.
[e]ANSI/IEEE C57.106, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 1.

Table 11.19(b) Suggested Limit for Less-Flammable Hydrocarbon Insulating Liquid

Test	ASTM Method	Acceptable Values
Dielectric breakdown voltage, kV minimum	D877	24
Dielectric breakdown voltage for 0.04 in. gap, kV minimum	D1816	34
Dielectric breakdown voltage for 0.08 in. gap, kV minimum	D1816	24
Water content, ppm maximum	D1533 B	35
Dissipation/power factor, 60 Hz, % max. @ 25°C (77°F)	D924	1.0
Fire point, °C, minimum	D92	300
Interfacial tension, mN/m, 25°C (77°F)	D971	24
Neutralization number, mg KOH/g	D664	0.2

ANSI/IEEE C57.121-1998, *Guide for Acceptance and Maintenance of Less-Flammable Hydrocarbon Fluid in Transformers*, Table 4.
The values in this table are considered typical for acceptable service-aged LFH fluids as a general class. If actual test analysis approaches the values shown, consult the fluid manufacturer for specific recommendations.
If the purpose of the HMWH installation is to comply with *NFPA 70*, this value is the minimum for compliance with *NEC* Article 450.23.

Table 11.19(c) Suggested Limit for Service-Aged Silicone Insulating Liquid

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	25
Visual	D2129	Colorless, clear, free of particles

Water content, ppm maximum	D1533	100
Dissipation/power factor, 60 Hz, maximum @ 25°C (77°F)	D924	0.2
Viscosity, cSt @ 25°C (77°F)	D445	47.5–52.5
Fire point~~, °C~~, minimum	D92	340°C (644°F)
Neutralization number, mg KOH/g maximum	D974	0.2

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 3.

Table 11.19(d) Suggested Limits for Service-Aged Tetrachloroethylene Insulating Fluid

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	26
Visual	D2129	Clear with purple iridescence
Water content, ppm maximum	D1533	35
Dissipation/power factor, % maximum @ 25°C (77°F)	D924	12.0
Viscosity, cSt @ 25°C (77°F)	D445	0
Fire point~~, °C~~, minimum	D92	—
Neutralization number, mg KOH/g maximum	D974	0.25
Neutralization number, mg KOH/g maximum	D664	—
Interfacial tension, mN/m minimum @ 25°C (77°F)	D971	—

Instruction Book PC-2000 for Wecosol™ Fluid-Filled Primary and Secondary Unit Substation Transformers, ABB Power T&D.

Table 11.19(e) Insulating Fluid Limits

	Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment				
	Mineral Oil				
Test	ASTM Method	≤69 kV and Below	>69 kV – <230 kV	>230 kV – <345 kV	>345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1 mm (0.04 in.) gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08 in.) gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25°C (77°F), %	D924	0.05	0.05	0.05	0.05
Power factor at 100°C (212°F), %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	1.0
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 11.19(f) Test Limits for Silicone Insulating Liquid in New Transformers

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	Clear, free of particles

Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 Hz, % max. @ 25°C (77°F)	D924	0.1
Viscosity, cSt @ 25°C (77°F)	D445	47.5–52.5
Fire point~~, °C~~, minimum	D92	340°C (644°F)
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2.

Table 11.19(g) Typical Values for Less-Flammable Hydrocarbon Insulating Liquid in New Equipment

Table 100.4.3 Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Minimum	Results	Maximum
D1816	Dielectric breakdown voltage for 0.08 in. gap, kV	40	34.5 kV class and below	
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in. gap, kV	20	34.5 kV class and below	
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g			0.03
D877	Dielectric breakdown voltage, kV		30	
D924	AC loss characteristic (dissipation factor), % 25°C (77°F) 100°C (212°F)			0.11
D1533B	Water content, ppm			25
D1524	Condition-visual		Clear	
D92	Flash point ~~(°C)~~		275°C (527°F)	
D92	Fire point ~~(°C)~~		300~~a~~°C (572°F)	—
D971	Interfacial tension, mN/m, 25°C (77°F)		38	
D445	Kinematic viscosity, mm^2/s, (cSt), 40°C (104°F)		1.0 × 102 (100)	1.3 × 102 (130)
D1500	Color			L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers*, Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

11.20.1.2

Insulation resistance readings taken for purposes of correlation should be made at the end of a definite interval following the application of a definite test voltage. For purposes of standardization, 60-second applications are recommended where short-time single readings are to be made on windings and where comparisons with earlier and later data are to be made. Recommended minimum acceptable insulation values without further investigation are as shown in Table 11.20.1.2.

Table 11.20.1.2 Rotating Machine Insulation Testing

Rotating Machinery Voltage	Insulation Resistance (at 40°C [104°F])
1000 volts and below	2 megohms
Above 1000 volts	1 megohm per 1000 volts plus 1 megohm

11.21.3.1 Insulation Resistance.
Measure the insulation resistance individually on each conductor with all other conductors and shields grounded. Apply dc voltage in accordance with the manufacturer's published data. Insulation resistance values should be in accordance with the manufacturer's published data. In the absence of manufacturer's published data, use Table 11.21.3.1(a). See Table 11.21.3.1(b) for temperature correction factors.

Table 11.21.3.1(a) Insulation Resistance Test Values Electrical Apparatus and Systems

Nominal Rating of Equipment (Volts)	Minimum Test Voltage (dc)	Recommended Minimum Insulation Resistance (Megohms)
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
34,500 and above	15,000	100,000

Notes: (1) Test results are dependent on the temperature of the insulating material and the humidity of the surrounding environment at the time of the test.
(2) Insulation resistance test data can be used to establish a trending pattern. Deviations from the baseline information permit evaluation of the insulation.
Source: ANSI/NETA MTS-2011, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, Table 100.1.

Table 11.21.3.1(b) Insulation Resistance Conversion Factors (20°C [68°F])

Temperature		Multiplier for Apparatus Containing Solid Insulation
°C	°F	
−10	14	0.25
−5	23	0.32
0	32	0.40
5	41	0.50
10	50	0.63
15	59	0.81
20	68	1.00
25	77	1.25
30	86	1.58
35	95	2.00
40	104	2.50
45	113	3.15

50	122	3.98
55	131	5.00
60	140	6.30
65	149	7.90
70	158	10.00
75	167	12.60
80	176	15.80
85	185	20.00
90	194	25.20
95	203	31.60
100	212	40.00
105	221	50.40
110	230	63.20

Source: ANSI/NETA MTS-2011, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, Table 100.14.

23.5.3 High-Intensity Discharge Lamps.
High-intensity discharge (HID) lamps include metal halide, mercury vapor, and high-pressure sodium lamps. These lamps typically are constructed of an outer bulb with an internal arc tube. Metal halide arc tubes operate at higher pressures and temperatures (approximately 1100°C [2012°F]). Metal halide arc tubes and outer bulbs can rupture, particularly if the lamp is misapplied. Metal halide lamp types are as follows:

1. O-type lamps are designed for open fixtures. They contain a shrouded arc tube strong enough to prevent lamp shattering.
2. E-type lamps are intended for use in enclosed fixtures. Such fixtures include integral containment barriers that enclose the lamp.
3. S-type lamps can be used in either open or enclosed fixtures. These lamps have no shroud. The design is limited to certain lamps between 350 watts and 1000 watts. The lamps must be operated vertically if they are used in open fixtures. S-type lamps in open fixtures offer the least protection in the event of a rupture.

25.6.2.1
Apparatus that has been clogged with mud from dust storms, floods, or other unusual conditions require a thorough water washing, usually with a hose with pressure not exceeding 1.72 kPa (25 psi). Initial cleaning should be made with hot nonsaline water plus detergent, followed by a rinse with hot nonsaline water (no detergent). Chemical tests should be made to verify that the water is nonsaline. The machine should be completely dismantled, terminal boxes opened, and all corroded parts identified for repair or replacement. All components that are to be reused should be washed in a tank of hot, fresh, nonsaline water for at least four hours. The water tank should have a water inlet and outlet such that the water is constantly changing at a minimum rate of 38 lpm (10 gpm). All washed components should be dried at 85°C (185°F), or less, for 2 hours with continuous air circulation. Electrical insulation should be dried at 85°C (185°F) for an additional 4 hours, followed by 105°C to 120°C (221°F to 248°F) for at least four more hours. The winding insulation resistance should be measured with a 500 volt insulation test instrument every 2 hours until the insulation resistance has stabilized. Allow the insulation to cool in a dry environment to avoid moisture absorption. Before being placed in service, the minimum recommended insulation resistance levels should be in

accordance with ANSI/IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery*. Sleeve bearings and housing should be cleaned, and antifriction bearings should be replaced with the same type as originally supplied.

Annex H (See separate attachment)

P.1.1
The identification letters are:
(1) First letter: Internal cooling medium in contact with the windings:
O: mineral oil or synthetic insulating liquid with fire point ≤300°C (572°F)
K: insulating liquid with fire point > 300°C (572°F)
L: insulating liquid with no measurable fire point
Fire point — The lowest temperature at which a specimen will sustain burning for 5 s. (ASTM D92, "Cleveland Open Cup" test method.)
(2) Second letter: Circulation mechanism for internal cooling medium:
N: *natural* convection flow through cooling equipment and in windings
F: *forced* circulation through cooling equipment (i.e., coolant pumps), natural convection flow in windings (also called nondirected flow)
D: forced circulation through cooling equipment, *directed* from the cooling equipment into at least the main windings
(3) Third letter: External cooling medium:
A: air
W: water
(4) Fourth letter: Circulation mechanism for external cooling medium:
N: natural convection
F: forced circulation [fans (air cooling), pumps (water cooling)]

Q.8 Refrigeration Compressor Fails Unexpectedly as a Result of Improper Maintenance.
A 25-story office building located in a major metropolitan, warm-climate city was constructed in the early 1920s. The building's air-conditioning system (with one central compressor) was installed in the 1960s. During the hottest time of the year, the compressor motor failed due to a shorted coil winding. The windows of the building were sealed shut, so there was no conditioned air for the building. Internal temperatures of the building reached over 32°C (90°F). The timeline for repairs to the air-conditioning system was three months. Tenants fled the building and revenue losses initially increased to over $250,000 (U.S.). Long-term revenue losses could not be tracked. The repair costs of the air-conditioning system and compressor motor approached $200,000 (U.S.) due to the emergency service.
The following is the preventative maintenance schedule that was used when the failure occurred:
Resistive measurements of the motor windings was performed and recorded for only six years. Examples of resistive measurements recorded were: "good," "not performed," "0.5," and "3." Oil sampling was only performed for the past three years. The oil sampling revealed evidence of increasing metal wear, but under a predetermined action level.
Ignoring trending data from the oil sampling and not accurately documenting resistive measurements from testing allowed this failure to occur at an unscheduled downtime.

SR 21, Global, Attachment #1 of 2

Annex H Forms

This annex is not a part of the recommendations of this NFPA document but is included for informational purposes only.

H.1

Figure H.1 shows a typical work order request form.

Figure H.1 Typical Work Order Request Form.

WORK ORDER REQUEST

Work Order No.	Craft
___|___|___|___ —	

Plant Department

Directions to Requester: Complete Section I ONLY. Submit four copies to the Plant Department. Maintain last copy for your files. Prepare a separate request for each job. This request will be returned to you and becomes a work order only when approved and assigned a work order number by the Plant Department. Allow sufficient time for completion. Please TYPE your request.

I. To be completed by requester: Date ______ / ______ / ______

Summary of work request ________________________

Location of work: Room(s) ________________ Building ____________

Details of work request ________________________

Typical work order request form consists of five parts — includes copies for plant department (or plant engineer), data processing, receiving stores, requester, and requester's department. Work to be done is spelled out in detail.

Special time requirement: Date needed ______ / ______ / ______ Indicate reason ____________

Department ____________ Tel. ext. ________ ❑ Plan attached ❑ Info. attached

Authorized signature ____________ Title ________ Approval if required ________

II. For plant department use only: Date Received ______ / ______ / ______

A. Your request has been ❑ Approved ❑ Disapproved ❑ Forwarded to ____________ for action. Use the assigned work order number when referring to this request.

B. Instructions: ________________________

Job Estimates	Craft	Total Hours	Total Labor	Material	Grand Total
	Hours		$	$	$

Assigned to ________________ Craft ____________ ❑ Day ❑ Night

Foreman —

C. Completed per plant instructions? ❑ Yes ❑ No

Can recurrence be prevented? ❑ Yes ❑ No

If yes, indicate ____________

Actual hours used	Tot. reg.	Tot. O/T	Tot. equiv. hrs.

Requester —

Completed per your request? ❑ Yes ❑ No

Plant and requester note variations ____________

Date ________ Foreman's signature ____________ Requester's signature ____________

III. For data processing use only:

Dept.	Bldg.	Class	Category	Cause	Pay	O/T $

Total Labor $	+	Total Material $	=	Total $

Work description (alphabetic) ________________________

Work Order No. — Craft

Plant Department

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H.2

Figure H.2 shows a typical air circuit breaker inspection record.

Figure H.2 Typical Air Circuit Breaker Inspection Record.

AIR CIRCUIT BREAKER INSPECTION RECORD

Plant ______________________ Date ______________________

Location ______________________ Serial No. ______________________

Mfr. ______________________ Type or Model ______________________

Drawout ❑ Non-drawout ❑ Switchboard ❑ Metal clad ❑

Rating: Volts __________ Amperes __________ Interrupting Amperes __________

Operation: Manual ❑ Electrical ❑ Remote Control ❑

Volts close __________ ac ❑ dc ❑ Volts trip __________ ac ❑ dc ❑

Protective Devices: Induction Relays ❑ Direct Trips ❑ Direct Trips ❑

CL Fuses ❑ TD Setting __________ Inst. Setting __________

Annual Inspection

Date										
Inspector's Initials										
	Aux.	Main	Aux.	Main	Aux.	Main	Aux.	Main	Aux.	Main
Contact Condition										
Good — Surface Smooth										
Fair — Minor Burns										
Poor — Burned and Pitted										
Contact Check										
Pressure (Good, Weak, Bad)										
Drawout Contacts										
Pressure (Good, Weak, Bad)										
Alignment (Good, Bad)										
Lubricate (Must Do — Use a No-Oxide Lubricant by Mfr.)										
Arcing Assemblies										
Clean and Check the Arc-Splitting Plates Surface Conditions										
Bushings										
Clean and Check Surface Condition										

Date					
Inspector's Initials					
Operating Mechanisms					
Checks					
Positive Close and Trip					
Bushing and Pin Wear					
Set Screws and Keepers					
Protective Devices					
Lubricate Wear Points					
Clean Pots and Replace Oil with Equipment Mfrs. Recommended Oil					
Insulation Condition					
Loose Connections					
Discolored Areas					
Corona Tracking					
Clean Surfaces					
Insulation Tests					
Phase to Phase (Megohm)					
Phase to Ground (Megohm)					
Test Operation					
Close and Trip					
Counter Reading (No. of Ops.)					
Electrical Load					
Peak Indicated Amperes					

Remarks (record action taken when indicated by inspection or tests):

____

____

Other repairs recommended:

____

____

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H.3

Figure H.3 shows a typical air circuit breaker test and inspection report.

Figure H.3 Typical Air Circuit Breaker Test and Inspection Report.

AIR CIRCUIT BREAKER TEST AND INSPECTION REPORT

Customer ______ Date ______ Work Order No. ______

Address ______ Air Temp. ______ Rel. Humidity ______

Breaker Owner/User ______ Date Last Inspection ______

Address ______ Last Inspection Report No. ______

Equipment Location ______

Owner Identification ______

Breaker Data:

Manufacturer ______ Voltage ______ Type ______ Amperes ______ Int. Rating ______

Serial No. ______ Type Oper. Mech. ______ Age ______ Other N.P. Data ______

Test Data:	**Tank 1**	**Tank 2**	**Tank 3**
Ins. Res. ______ kV, Megohms ______			
Contact Resistance, Microhms ______			
Closing Speed/Opening Speed ______			
Reference, P.F. Test Sheet No. ______			

Adjustments:	**Mfr's. Rec.**	**As Found**	**As Left**
Arcing Contact Wipe ______			
Main Contact Gap ______			
Main Contact Wipe ______			
Latch Wipe ______			
Latch Clearance ______			
Contact Travel ______			
Prop Clearance ______			
Stop Clearance ______			
______			
______			
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______			
______			
______			

Inspection and Maintenance:	**Insp.**	**Dirty**	**Cleaned/ Lubed**	**See Remarks**
Overall Cleanliness ______				
Insulating Members ______				
Mech. Connections ______				
Structural Members ______				
Cubicle ______				
Pri. Contact Fingers ______				
Shutter Mech. ______				
Relays ______				
Auxiliary Devices ______				
Racking Device ______				
Arc Chutes ______				
Blow Out Coil ______				
Puffers ______				
Liner ______				
Arc Runners ______				
Main Contacts ______				
Cubicle Wiring ______				
Breaker Wiring ______				
Heaters ______				
Panel Lights ______				
Bearings ______				
______				
______				
______				
Contact Sequence ______				
Ground Connection ______				
Counter Reading ______				

Remarks: ______

Inspections and Test by: ______ Equipment Used: ______ Sheet No.: ______

 NFPA 70B

H.4

Figure H.4 shows a typical medium-voltage vacuum breaker form.

Figure H.4 Typical Medium-Voltage Vacuum Breaker Form.

MEDIUM VOLTAGE VACUUM BREAKER

SHEET NO. ________ OF ________

CUSTOMER ________________ DATE ________________ PROJECT NO. ________________
ADDRESS ________________ AIR TEMP. ________________ REL. HUMIDITY ________________
OWNER/USER ________________ DATE LAST INSPECTION ________________
ADDRESS ________________ LAST INSPECTION REPORT NO. ________________
EQUIPMENT LOCATION ________________
OWNER IDENTIFICATION ________________

BREAKER DATA:

Manufacturer ________ Voltage ________ Type ________ Amps ________ Age ________
Serial No. ________ Type Oper Mech ________ Int. Rating ________ Other ________

TEST DATA:

Ins Res @ ______ kV

	A to G	B to G	C to G
Results In	A to B	B to C	C to A
Gigaohms ______			
Megohms ______	A-L to L	B-L to L	C-L to L
Contact Resistance			
Microhms - As Found			
Microhms - As Left			
	A-L to L	B-L to L	C-L to L
HiPot Test @			

ADJUSTMENTS:

	MFR'S. REC.	AS FOUND	AS LEFT
Erosion Indicator			
Main Contact Gap			

INSPECTION AND MAINTENANCE:

	INSP	NA	CLEAN LUBE	SEE REMARKS
Overall Cleanliness				
Insulating Members				
Mech. Connections				
Structural Members				
Cubicle				
Pri. Contact Fingers				
Shutter Mech.				
Relays				
Auxiliary Devices				
Racking Device				
Main Contacts				
Cubicle Wiring				
Breaker Wiring				
Heaters				
Panel Lights				
Bearings				
Contact Sequence				
Ground Connection				
Counter Reading				

Remarks ________________

Equipment Used ________________
Submitted By ________________

Courtesy of Northeast Electrical Testing NFPA 70B

H.5

Figure H.5 shows a typical oil circuit breaker test report.

Figure H.5 Typical Oil Circuit Breaker Test Report.

OIL CIRCUIT BREAKER TEST

SHEET NO. ________ OF ________

CUSTOMER ____________________ DATE ____________ PROJECT NO. ____________
ADDRESS ____________________ AIR TEMP. ____________ REL. HUMIDITY ____________
OWNER/USER ____________________ DATE LAST INSPECTION ____________
ADDRESS ____________________ LAST INSPECTION REPORT ____________
EQUIPMENT LOCATION ____
OWNER IDENTIFICATION ____

BREAKER DATA:

Manufacturer ____________ Voltage ________ Type ____________ Amps ________ Age ________

Serial No. ____________ Type Oper Mech ____________ Int. Rating ____________ Other ____________

Bushing Data ____

TEST DATA:

Ins Res @ ______ kV

Results In

Gigaohms ______

Megohms ______

A to G	B to G	C to G
A to B	B to C	C to A
A-L to L	B-L to L	C-L to L

Contact Resistance

Microhms - As Found			
Microhms - As Left			
Reference PF Test Sheet			

ADJUSTMENTS:

	MFR'S. REC.	AS FOUND	AS LEFT
Stop Clearance			
Contact Travel			
Overtravel			
Contact Wipe			
Trip Roller			
Latch Wipe			
Latch Clearance			
Prop Wipe			
Prop Clearance			
Cut-off Switch			
AA Switch			

INSPECTION AND MAINTENANCE:

	INSP	NA	CLEAN LUBE	SEE REMARKS
Tank Liners				
Insulating Members				
Oil Gauges				
Opening Spring				
Bushings				
Main Contacts				
Secondary Contacts				
Interrupters				
Linkage				
Dashpots				
Shutter Mechanism				
Elevating Mechanism				
Compressor Air Strainer				
Unload Valve				
Check Valve				
Compressor Belt				
Air Leaks				
Compressor Oil				
Gaskets				
Nuts, Bolts, Pins				
Closing Sequence				
Heater				
Oil Level				
Ground Connection				
Counter Reading As-Found				
Counter Reading As-Left				

Remarks ____

Equipment Used ____
Submitted By ____

Courtesy of Northeast Electrical Testing

NFPA 70B

H.6

Figure H.6 shows a typical disconnect switch test report.

Figure H.6 Typical Disconnect Switch Test Report.

DISCONNECT SWITCH TEST REPORT

SHEET NO. ________ OF ________

CUSTOMER ____________________ DATE ____________ PROJECT NO. ____________
ADDRESS ____________________ AIR TEMP. ____________ REL. HUMIDITY ____________
OWNER/USER ____________________ DATE LAST INSPECTION ____________
ADDRESS ____________________ LAST INSPECTION REPORT NO. ____________
EQUIPMENT LOCATION ____________________
OWNER IDENTIFICATION ____________________

Fused ____________ Non-Fused ____________

SWITCH DATA:

Manufacturer ____________ Voltage ________ Type ____________ Amps ________ Age ________

Serial No. ____________ Type Oper Mech ________ Int. Rating ________ Other ____________

TEST DATA:

Ins Res @ ______ kV	A to G	B to G	C to G
Results In	A to B	B to C	C to A
Gigaohms ______			
Megohms ______			
Contact Resistance			
Microhms-As Found			
Microhms-As Left			

INSPECTION AND MAINTENANCE:

	INSP	NA	CLEAN LUBE	SEE REMARKS
Overall Cleanliness				
Insulating Members				
Mech. Connections				
Structural Members				
Cubicle				
Pri. Contact Fingers				
Main Contacts				
Arc Chutes				
Arc Runners				
Manual Operation				
Contact Lube				
Mechanical Lube				
Paint				
Door Interlock				
Ground Connection				

FUSE DATA:

	A	B	C
Manufacturer			
Size			
Catalog No.			
I.C. Rating			
Contact Resistance			
Microhms-As Found			
Microhms-As Left			

Remarks ____

Equipment Used ____________________

Test Technician ____________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.7

Figure H.7 shows a typical low-voltage circuit breaker 5-year tests form.

Figure H.7 Typical Low-Voltage Circuit Breaker 5-Year Tests Form.

LOW-VOLTAGE CIRCUIT BREAKER 5-YEAR TESTS FORM

Plant ______________________ Date ______________________

Substation ______________ Feeder ______________ Load Reading ______________

Breaker Data

Mfr. ______________ Type ______________ Serial No. ______________

Trip Coil Rating ________ Amperes Characteristic ______________ Mfr's. Time Curve ______________

Trip Devices: Long Time Delay ❑ Short Time Delay ❑ Instantaneous Trip ❑

Time Delay Type: Oil Sucker Dashpot ❑ Air Bellows ❑ Air Orifice ❑ Oil Orifice ❑ Other ❑

Settings:

LT Delay — Amperes ________ Adjustable Range ________ Time Adjustable? Yes ❑ No ❑

ST Delay — Amperes ________ Adjustable Range ________ Time Adjustable? Yes ❑ No ❑

Instantaneous Trip — Amperes ______________ Adjustable? Yes ❑ No ❑

Test Data

Date of Test / Inspector's Initials		Left Pole	Center Pole	Right Pole	Time Range from Curve
As Found Test (Trip Time in Seconds) % Pickup ________ Amperes ________					
Time Delay	(As Found — Amperes)				
Minimum Pickup (Nullify Time Delay)	(Adjusted — Amperes)				
Time Delay Tests (Trip Time in Seconds) % Pickup Amperes					
Long Time ________ ________					
________ ________					
Short Time ________ ________					
________ ________					
Resettable Delay	(Satisfactory)				
(___ % for ___ sec)	(Tripped)				
Instantaneous Trip	(As Found — Amperes)				
	(Adjusted — Amperes)				

Remarks (record unusual conditions, corrections, needed repairs, etc.; use separate form to record annual breaker inspection details):

____

____

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H.8

Figure H.8 shows a typical electrical switchgear–associated equipment inspection record.

Figure H.8 Typical Electrical Switchgear–Associated Equipment Inspection Record.

ELECTRICAL SWITCHGEAR–ASSOCIATED EQUIPMENT INSPECTION REPORT

Plant ______________________ Date ______________________

Location ______________________ Serial No. ______________________

Mfr. ______________________ Year Installed ______________________

Rating: Volts ______________________ Bus Capacity Amperes ______________________

Type: Switchboard ❑ Indoor Metal Clad ❑ Outdoor Metal Clad ❑

Annual Inspection (Disregard items that do not apply.)

Date					
Inspector's Initials					
Switchboards					
Clean					
Check Wiring					
Inspect Panel Insulation					
Exposed Bus and Connections					
Clean and Check Porcelain					
Check Insulators for Cracks or Chips					
Check and Tighten Connections					
Inspect Potheads for Leaks					
Check for Environmental Hazards					
Test Insulation (Megohms)					
Metal Clad Enclosures					
Clean					
Check for Openings That Permit Dirt, Moisture and Rodent Entrance — Repair					
Check Hardware for Rust or Corrosion					
Paint Condition					
Check Heaters and Ventilators					
Metal Clad Bus and Connections					
Clean Insulators and Supports					
Check and Tighten Connections					
Check for Corona Tracking					
Inspect Potheads for Leaks					
Test Insulation (Megohms)					

Date					
Inspector's Initials					
Disconnect Switches					
Check Contact Surfaces					
Check Insulation Condition					
Lubricate per Mfr's. Instructions					
Test Operate					
Fuses and Holders					
Check Contact Surfaces					
Lubricate per Mfr's. Instructions					
Meters and Instruments					
Check Operation					
Test Meters per Eng. Std.					
Test Relays per Mfr's. Instructions					
Interlocks and Safety					
Check for Proper Operations					
Check Lightning Arresters					
Check Ground Detectors					
Check Equipment Grounds					
Station Battery					
Periodic Routine					
Maintenance is performed					

Remarks (record action taken when indicated by inspection or tests):

____

____

Recommendations:

____

____

____

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H.9

Figure H.9 shows a typical current or potential transformer ratio test report.

Figure H.9 Typical Current or Potential Transformer Ratio Test Report.

CURRENT OR POTENTIAL TRANSFORMER RATIO TEST REPORT

SHEET NO. ________ OF ________

CUSTOMER ____________________ DATE ____________________ PROJECT NO. ____________________

ADDRESS ____________________ AIR TEMP. ________ °C REL. HUMIDITY (%) ____________________

OWNER/USER ____________________ DATE LAST INSPECTION ____________________

ADDRESS ____________________ LAST INSPECTION REPORT NO. ____________________

EQUIPMENT LOCATION ____________________

CIRCUIT IDENTIFICATION ____________________

LOCATION OF C.T. OR P.T. ____________________

C.T. OR P.T. IDENTIFICATION	C.T. OR P.T. SECONDARY TAPS	NAMEPLATE RATIO	APPLIED VOLTAGE OR CURRENT	MEASURED VOLTAGE OR CURRENT	PERCENT (%) ACCURACY	POLARITY PRIMARY	POLARITY SECONDARY
POLE #1 (A)	X1-X2						
BURDEN TEST							AMPS / VOLTS
SATURATION TEST							VOLTS / MA
MEGGER TEST							MEGOHMS
POLE #2 (B)	X1-X2						
BURDEN TEST							AMPS / VOLTS
SATURATION TEST							VOLTS / MA
MEGGER TEST							MEGOHMS
POLE #3 (C)	X1-X2						
BURDEN TEST							AMPS / VOLTS
SATURATION TEST							VOLTS / MA
MEGGER TEST							MEGOHMS

REMARKS ____________________

SUBMITTED BY ____________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.10

Figure H.10 shows a typical overload relay test report.

Figure H.10 Typical Overload Relay Test Report.

OVERLOAD RELAY TEST REPORT

SHEET NO. ________ OF ________
TEST REPORT NO. ________

CUSTOMER ________ DATE ________ PROJECT NO. ________
ADDRESS ________ AIR TEMP. ________ °C REL. HUMIDITY ________
OWNER/USER ________ DATE LAST INSPECTION ________
ADDRESS ________ LAST INSPECTION REPORT ________
EQUIPMENT LOCATION ________
OWNER IDENTIFICATION ________

MOTOR PROTECTED ________
MOTOR FLA ________ MOTOR VOLTAGE ________

OVERLOAD INFORMATION

OVERLOAD MANUFACTURER ________ CATALOG NUMBER ________
OVERLOAD RELAY HEATER COIL ________ HEATER POSITION ________
MANUFACTURERS CURVE NO. ________ AMBIENT TEMP. ________
FULL LOAD CURRENT AMPERES ________ MIN. ________ MAX. ________

TEST RESULTS

PHASE	HEATER CURRENT	TEST CURRENT		TEST TIME
		PERCENTAGE	AMPS	SECONDS
PHASE 1				
PHASE 2				
PHASE 3				

STARTER INFORMATION

STARTER MANUFACTURER ________
STARTER SIZE ________ STARTER CATALOG NO. ________
STARTER ________ OTHER INFORMATION ________

CONDUCTOR ________ CONDUCTOR INSULATION ________

DATE ________

INSULATION RESISTANCE RESULTS:

Aø - GND ________ Aø - Bø ________
Bø - GND ________ Bø - Cø ________
Cø - GND ________ Cø - Aø ________

DATE ________

MEGGER MOTOR ø-GND: (1/2 MIN) ________ (1 MIN) ________

DATE ________

MEGGER MOTOR ø-GND W/CONDUCTOR INCLUDED: ________ (1 MIN) ________

REMARKS: ________

EQUIPMENT USED ________ SERIAL NUMBER ________
QUALITY CONTROL REP. ________ TITLE ________
SUBMITTED BY ________ TEST CREW ________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.11

Figure H.11 shows a typical ground-fault system test report.

Figure H.11 Typical Ground-Fault System Test Report.

GROUND FAULT SYSTEM TEST

SHEET NO. ________ OF ________

CUSTOMER ____________ DATE ____________ PROJECT NO. ____________

ADDRESS ____________ AIR TEMP. ____________ REL. HUMIDITY ____________

OWNER/USER ____________ DATE LAST INSPECTION ____________

ADDRESS ____________ LAST INSPECTION REPORT NO. ____________

EQUIPMENT LOCATION ____________

CIRCUIT IDENTIFICATION ____________

FIELD DATA

MAIN OVERCURRENT DEVICE:

☐ CIRCUIT ☐ FUSED SWITCH

MANUFACTURER ____________

TYPE ____________

MODEL/CAT. # ____________

CURRENT RATING ____________

SYSTEM VOLTAGE ____________

VOLTAGE RATING ____________

GROUND FAULT SYSTEM:

☐ NEUT-GND STRAP ☐ ZERO SEQUENCE

MANUFACTURER ____________

MODEL ____________

CAT. NO. ____________

PICK-UP RANGE ____________

TIME RANGE ____________

SENSOR/ C.T. ____________

INSPECTION

CORRECT	INCORRECT	INSPECTION POINT	SIZE - REMARKS
		NEUT.-GRD LOCATION	
		CONTROL POWER	
		MONITOR OR TEST PANEL OPERATION	
		OTHER ____________	

ELECTRICAL TESTS

1. BREAKER/SWITCH REACTION TIME (RT) ____________ ☐ SEC. ☐ CYC.
2. PICK UP CURRENT ____________ AMPS
3. PICK UP CURRENT MINUS 10% (____________) A. ☐ TRIP ☐ NO TRIP
4. SHUNT TRIP COIL PICK-UP VOLTAGE ____________ VOLTS
5. SYSTEM NEUTRAL INSULATION RESISTANCE TO GND ____________ MEGOHMS
6. TIME-CURRENT CALIBRATION TESTS:

PRIMARY CURRENT AMPERE-TURNS	% PICKUP	TOTAL TIME	RT	RELAY TIME	MFG. TOLERANCE

REMARKS: ____________

SUBMITTED BY: ____________

Courtesy of Northeast Electrical Testing

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H.12

Figure H.12 shows a typical instrument/meter calibration and test report.

Figure H.12 Typical Instrument/Meter Calibration and Test Report.

INSTRUMENT/METER CALIBRATION AND TEST REPORT

SHEET NO. ________ OF ________

CUSTOMER ____________________ DATE ____________ PROJECT NO. ____________

ADDRESS ____________________ AIR TEMP. ____________ °C

OWNER/USER ____________________ DATE LAST INSPECTION ____________

ADDRESS ____________________ LAST INSPECTION REPORT NO. ____________

EQUIPMENT LOCATION ____________________

CIRCUIT IDENTIFICATION ____________________

LOCATION/FUNCTION OF INSTRUMENT/METER ____________________

TYPE ____________ MANUFACTURER ____________ MODEL ____________

FULL SCALE ____________ ACTUAL INPUT ____________

P.T. RATIO ____________ C.T. RATIO ____________ CAL. WATTS ____________

FULL SCALE CARDINAL POINTS							
BASIC RANGE CALCULATED VALUE							
STANDARD "AS FOUND"							
STANDARD "AS LEFT"							
"AS LEFT" ACCURACY (%)							

REMARKS ____________________

LOCATION/FUNCTION OF INSTRUMENT/METER ____________________

TYPE ____________ MANUFACTURER ____________ MODEL ____________

FULL SCALE ____________ ACTUAL INPUT ____________

P.T. RATIO ____________ C.T. RATIO ____________ CAL. WATTS ____________

FULL SCALE CARDINAL POINTS							
BASIC RANGE CALCULATED VALUE							
STANDARD "AS FOUND"							
STANDARD "AS LEFT"							
"AS LEFT" ACCURACY (%)							

REMARKS ____________________

SUBMITTED BY: ____________________ EQPT. USED: ____________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.13

Figure H.13 shows a typical watt-hour meter test sheet.

Figure H.13 Typical Watt-Hour Meter Test Sheet.

WATT-HOUR METER TEST SHEET

SHEET NO. ________ OF ________

CUSTOMER ______________________ DATE ______________ PROJECT NO. ______________

ADDRESS ______________________ AIR TEMP. ______________

OWNER/USER ______________________ DATE LAST INSPECTION ______________

ADDRESS ______________________ LAST INSPECTION REPORT NO. ______________

EQUIPMENT LOCATION ______________________

CIRCUIT IDENTIFICATION ______________________

TEST LOCATION ______________________ CIRCUIT METERED ______________________

METER MANUFACTURER ______________________ TYPE ______________ SER. NO. ______________

VOLTS ______________ AMPS ______________ ______________ PHASE ______________ WIRE INTERVAL ______________

C.T. RATIO ______________ P.T. RATIO ______________ TEST K ______________ PRI. TEST K ______________

	AS FOUND	AS LEFT		AS FOUND	AS LEFT
KWH REGISTER READING			POTENTIAL IND LAMPS		
DEMAND REGISTER READING			CHECK AND VERIFY REGISTER RATIO		
DISC R.P.M.			SYNCHRONOUS MOTOR		
WORM WHEEL MESH			CHECK KW PTR AGAINST KWH PTR		
MAGNET CLEANLINESS			CREEP CHECK		
MAGNET TIGHTNESS			TIME INTERVAL		

	ACCURACY CHECK (% REG.)		COIL BALANCE CHECK					
			COIL NO. 1		COIL NO. 2		COIL NO. 3	
TEST FUNCTION	AS FOUND	AS LEFT	AS FOUND	AS LEFT	AS FOUND	AS LEFT	AS FOUND	AS LEFT
LIGHT LOAD								
FULL LOAD								
POWER FACTOR								

REMARKS: ____

CUSTOMER REPRESENTATIVE ______________________ TITLE ______________

TEST EQUIPMENT USED ______________________ SERIAL # ______________

SUBMITTED BY ______________________ TEST ______________

Courtesy of Northeast Electrical Testing

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H.14

Figure H.14 shows a typical panelboard/circuit breaker test report.

Figure H.14 Typical Panelboard/Circuit Breaker Test Report.

PANELBOARD/CIRCUIT BREAKER TEST REPORT

SHEET NO. ________ OF ________

CUSTOMER ______________________ DATE ______________ PROJECT NO. __________
ADDRESS ______________________ AIR TEMP. ______________ REL. HUMIDITY __________
OWNER/USER ______________________ DATE LAST INSPECTION ______________
ADDRESS ______________________ LAST INSPECTION REPORT ______________
EQUIPMENT LOCATION ______________________
OWNER IDENTIFICATION ______________________

PANEL BUS INSULATION RESISTANCE IN MEGOHMS

A-G ________ B-G ________ C-G ________ A-B ________ B-C ________ A-C ________

PANEL BOARD RATINGS: AMPS: ______________ VOLTAGE: ______________

TEST VOLTAGE: ______________ MODEL NO: ______________ CATALOG ______________

MFG. ______________ CURVE NO. ______________ CURVE RANGE: ______________

MFG. ______________ CURVE NO. ______________ CURVE RANGE: ______________

MFG. ______________ CURVE NO. ______________ CURVE RANGE: ______________

MFG. ______________ CURVE NO. ______________ CURVE RANGE: ______________

CIRCUIT #	CKT. BKR. SIZE	TEST AMPS	TRIP TIME	INST. TRIP	CONTACT RESIS.	CIRCUIT #	CKT. BKR. SIZE	TEST AMPS	TRIP TIME	INST. TRIP	CONTACT RESIS.

REMARKS: ____

CUSTOMER REPRESENTATIVE ______________________ TITLE ______________
TEST EQUIPMENT ______________________ SERIAL # ______________
SUBMITTED BY ______________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.15

Figure H.15 shows a typical transformer test and inspection report.

Figure H.15 Typical Transformer Test and Inspection Report.

TRANSFORMER TEST AND INSPECTION REPORT

SHEET NO. ________ OF ________

CUSTOMER ____________________ DATE ____________ PROJECT NO. ____________

ADDRESS ____________________ AIR TEMP. ________ °C REL. HUMIDITY (%) ________

OWNER/USER ____________________ DATE LAST INSPECTION ____________________

ADDRESS ____________________ LAST INSPECTION REPORT ____________________

EQUIPMENT LOCATION ____

OWNER IDENTIFICATION ____

NAMEPLATE INFORMATION:

MANUFACTURER ____________ KVA ________ PHASE ________ CYCLE ________

SERIAL NO. ____________ TYPE ____________ CLASS ________

PRI. VOLTAGE ____________ △ ☐ OR Y ☐ RATED CURRENT ____________ AMPERES

SEC. VOLTAGE ____________ △ ☐ OR Y ☐ RATED CURRENT ____________ AMPERES

COOLANT ☐ OIL ☐ ASKAREL ☐ AIR ☐ NITROGEN ☐ OTHER ________

COOLANT CAPACITY ________ TEMP. RISE (°C) ________ IMPEDANCE (%) ________

NO LOAD TAP CHANGER VOLTAGES ________________________________

GAUGES AND COUNTERS

TEMP. ________ TEMP. RANGE ________ RESET GAUGE ________

PRESSURE ________ OIL LEVEL ________ TAP SETTING ________

VISUAL INSPECTION

BUSHING ________ CONNECTIONS ________ PAINT ________ OTHER ________

LOAD TAP CHANGER ________ LEAKS ________

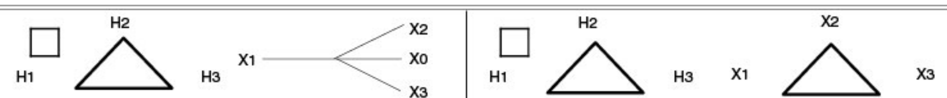
FANS & CONTROLS ________ GAS REGULATOR ________ GROUNDS ________

WINDING INSULATION RESISTANCE TEST (MEGOHMS)

		30 SEC.	1 MIN.	10 MIN.	D.A.	P.I.
PRIMARY TO GROUND, SEC. GUARDED	________ KVDC					
SECONDARY TO GROUND, PRI. GUARDED	________ KVDC					
PRIMARY TO SECONDARY, GROUND GUARDED	________ KVDC					

EQUIPMENT USED ________________________

TURNS RATIO TEST ☐ ☐



NAMEPLATE PRIMARY VOLTS	TAP POSITION	CONNECTION H__H__X__X__	CONNECTION H__H__X__X__	CONNECTION H__H__X__X__	CALCULATED RATIO
	A1				
	B2				
	C3				
	D4				
	E5				

REMARKS: ________________________________

EQUIPMENT USED ________________ SUBMITTED BY ________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.16

Figure H.16 shows a typical transformer (dry type) inspection record.

Figure H.16 Typical Transformer (Dry Type) Inspection Record.

TRANSFORMER (DRY TYPE) INSPECTION RECORD

Plant ______________________ Date ______________________

Location ______________________ Serial No. ______________________

Year Purchased ____________ Year Installed ____________ Mfr. ____________

kVA ____________ Voltage ____________ Impedance ____________

Phase ____________ Taps ______________________

Cooling System: Room Vent Fan ❑ Trans. Fan ❑ Gravity ❑

Annual Inspection

Date					
Inspector's Initials					
Electrical Load					
Secondary Voltage					
No Load Volts					
Full Load Volts					
Dust on Windings					
Minor Collection					
Major Collection					
Cleaned					
Connections					
Checked					
Tightened					
Cooling Systems					
Fan Operation					
Filter Cleanliness					
System Adequate					

Date					
Inspector's Initials					
Bushings					
Cracks or Chips					
Cleanliness					
Equipment Ground					
Check Connections					
Measured V					
Resistance					
Temperature Alarms and Indicators					
Operation					
Accuracy					
Case Exterior					
Covers Intact					
Paint Condition					
Lighting Arresters					
Check Connections					
Check Bushings					

Complete Internal Inspection

Report of Conditions Found:

Cooling System ______________________

Coil Insulation ______________________

Other ______________________

Description of Work Performed:

____

____

Other Repairs Recommended: ______________________

____

____

Shop or Contractor: ______________________ Cost: ____________

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H.17

Figure H.17 shows a typical transformer (liquid filled) inspection record.

Figure H.17 Transformer (Liquid Filled) Inspection Record.

TRANSFORMER (LIQUID FILLED) INSPECTION RECORD

Plant ______________________ Date ______________________

Location ______________________ Serial No. ______________________

Year Purchased ____________ Year Installed ____________ Mfr. ____________

kVA ____________ Voltage ____________ Taps ____________

Check type: Free Breathing ❑ Conservator ❑ Sealed ❑ Fan Cooled ❑

Phase ____________ Weight ____________ Impedance ____________

Insulating Fluid: Type ______________________ Gallons ______________________

Annual Inspection

Date					
Inspector's Initials					
Tank — Liquid Level					
Normal					
Below					
Added Fluid					
Entrance Compartment Liquid Level					
Normal					
Below					
Added Fluid					
Electrical Load					
Peak Amperes					
Secondary Voltage					
Full Load					
No Load					
Gaskets and Case Exterior					
Liquid Leaks					
Paint Condition					

Date					
Inspector's Initials					
Exposed Bushings					
Cracks or Chips					
Cleanliness					
Equipment Ground Connection					
Good					
Questionable					
Tested					
Temperature Indicator					
Highest Reading					
Reset Pointer					
Pressure–Vacuum Indicator					
Pressure					
Vacuum					
Ventilators, Dryers, Gauges, Filters, and Other Auxiliaries					
Operation OK					
Maint. Req'd.					

Remarks (record action when inspection data or tests are out of limits, etc.):

____

____

Reports of Conditions Found: ____

____

Description of Work Performed: ____

____

Other Repairs Recommended: ____

____

Shop or Contractor: ______________________ Cost: ____________

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H.18

Figure H.18 shows a typical transformer oil sample report.

Figure H.18 Typical Transformer Oil Sample Report.

TRANSFORMER OIL SAMPLE REPORT

CUSTOMER ____________________ TOTAL NO. OF SAMPLES ________

LOCATION ____________________ PROJECT NO. ________

DATE ________

LOCATION ________ ☐ OIL ________ SAMPLE NO. ________

IDENTIFICATION ________ ☐ ASKAREL ________

MFG. ________ ☐ NO GAUGE ________ PAINT ________ ☐ GOOD

SERIAL NO. ________ KVA ________ ☐ PRESSURE ________ ☐ POOR

CLASS ________ TYPE ________ ☐ VACUUM ________

INSUL. CLASS ________ PHASE ________ ☐ INDOOR ________ GASKETS ________ ☐ OK

VOLTAGE ________ ☐ OUTDOOR ________ ☐ LEAK

INSTR. BOOK ________ ☐ TEMP. GA. ________

AVG. DIELECTRIC ________ KV ________ BUSHINGS ________ ☐ OK

ACIDITY NO. ________ KOH ________ ☐ LEAK

ASTM COLOR NO. ________ LIQUID CAPACITY ________

PARTICLES ☐ YES ☐ NO TEMP ________ °C ________ OIL LEVEL ________ ☐ OK

WEATHER ________ ☐ LOW

RECOMMENDATIONS ____________________

LOCATION ________ ☐ OIL ________ SAMPLE NO. ________

IDENTIFICATION ________ ☐ ASKAREL ________

MFG. ________ ☐ NO GAUGE ________ PAINT ________ ☐ GOOD

SERIAL NO. ________ KVA ________ ☐ PRESSURE ________ ☐ POOR

CLASS ________ TYPE ________ ☐ VACUUM ________

INSUL. CLASS ________ PHASE ________ ☐ INDOOR ________ GASKETS ________ ☐ OK

VOLTAGE ________ ☐ OUTDOOR ________ ☐ LEAK

INSTR. BOOK ________ ☐ TEMP. GA. ________

AVG. DIELECTRIC ________ KV ________ BUSHINGS ________ ☐ OK

ACIDITY NO. ________ KOH ________ ☐ LEAK

ASTM COLOR NO. ________ LIQUID CAPACITY ________

PARTICLES ☐ YES ☐ NO TEMP ________ °C ________ OIL LEVEL ________ ☐ OK

WEATHER ________ ☐ LOW

RECOMMENDATIONS ____________________

LOCATION ________ ☐ OIL ________ SAMPLE NO. ________

IDENTIFICATION ________ ☐ ASKAREL ________

MFG. ________ ☐ NO GAUGE ________ PAINT ________ ☐ GOOD

SERIAL NO. ________ KVA ________ ☐ PRESSURE ________ ☐ POOR

CLASS ________ TYPE ________ ☐ VACUUM ________

INSUL. CLASS ________ PHASE ________ ☐ INDOOR ________ GASKETS ________ ☐ OK

VOLTAGE ________ ☐ OUTDOOR ________ ☐ LEAK

INSTR. BOOK ________ ☐ TEMP. GA. ________

AVG. DIELECTRIC ________ KV ________ BUSHINGS ________ ☐ OK

ACIDITY NO. ________ KOH ________ ☐ LEAK

ASTM COLOR NO. ________ LIQUID CAPACITY ________

PARTICLES ☐ YES ☐ NO TEMP ________ °C ________ OIL LEVEL ________ ☐ OK

WEATHER ________ ☐ LOW

RECOMMENDATIONS ____________________

EQUIPMENT USED ____________________ SUBMITTED BY ____________________

Courtesy of Northeast Electrical Testing NFPA 70B

H.19

Figure H.19 shows a typical transformer oil trending report.

Figure H.19 Typical Transformer Oil Trending Report.

TRANSFORMER OIL TRENDING REPORT

CUSTOMER ______________________ PROJECT NO. ____________

LOCATION ______________________ DATE ____________

LOCATION ______________ ☐ OIL ______________ SAMPLE NO. ____________

IDENTIFICATION ______________ ☐ ASKAREL ______________

MFG. ______________ ☐ GAUGE ______________ PAINT ____________ ☐ GOOD

SERIAL NO. ____________ KVA ____________ ☐ PRESSURE ______________ ☐ POOR

CLASS ____________ TYPE ____________ ☐ VACUUM ______________

INSUL. CLASS ____________ PHASE ____________ ☐ INDOOR ______________ GASKETS ____________ ☐ OK

VOLTAGE ______________ ☐ OUTDOOR ______________ ☐ LEAK

INSTR. BOOK ______________ ☐ TEMP. GA. ______________

DIELECTRIC FLUID ANALYSIS

YR - JOB#	DIELE. (KV)	ACIDITY (mgKOH/g)	IFT (dynes/cm2)	COLOR	VISUAL	SPECIFIC GRAVITY	WATER (PPM)	POWER FACTOR (%)	PCB (PPM)

ACCEPTABLE DIELECTRIC TEST VALUES:

DIELECTRIC (ASTM D877) 30KV MIN. NEW OIL / 26KV MIN. USED OIL / 30KV MIN. NEW SILICONE/ 25kV MIN. USED SILICONE

ACID (ASTM D974) 0.03 mgKOH/g MAX. NEW OIL / 0.20mgKOH/g MAX. USED OIL / 0.1mgKOH/g MAX. NEW SILICONE/ 0.2mgKOH USED SILICONE

IFT (ASTM D971) 35 dynes/cm2 MIN. NEW OIL / 24 dynes/cm2 MIN. USED OIL / 31 dynes/cm2 MIN. SILICONE

COLOR (ASTM D1500) 1 MAX. NEW OIL / 4 MAX. USED OIL / CLEAR FOR SILICONE

WATER (ASTM D1533B) 25PPM MAX. NEW OIL / 35PPM MAX. USED OIL / 50PPM MAX. NEW SILICONE/ 100PPM MAX. USED SILICONE

DISSOLVED GAS ANALYSIS

YEAR	HYDROGEN (H2) (<100PPM)	OXYGEN (O2)	NITROGEN (N2)	METHANE (CH4) (<120PPM)	CARBON MONOXIDE (CO) (<350PPM)	CARBON DIOXIDE (CO2) (<2500PPM)	ETHYLENE (C2H4) (<50PPM)	ETHANE (C2H6) (<65PPM)	ACETYLENE (C2H2) (<1PPM)	TOTAL GAS CONTENT (%)	TOTAL COMBUST. GAS

REMARKS: ______________________________

SUBMITTED BY ______________________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.20

Figure H.20 shows a typical transformer insulation resistance record.

Figure H.20 Typical Transformer Insulation Resistance Record.

TRANSFORMER INSULATION RESISTANCE RECORD

Plant ______________________ Date ______________

Scope: Power transformers of 150 kVA and greater capacity with primary voltage of 2300 volts or higher. Direct reading — recorded and plotted.

Transformer Serial No. ______________ Phase ______________

Location ______________ Instrument Used ______________

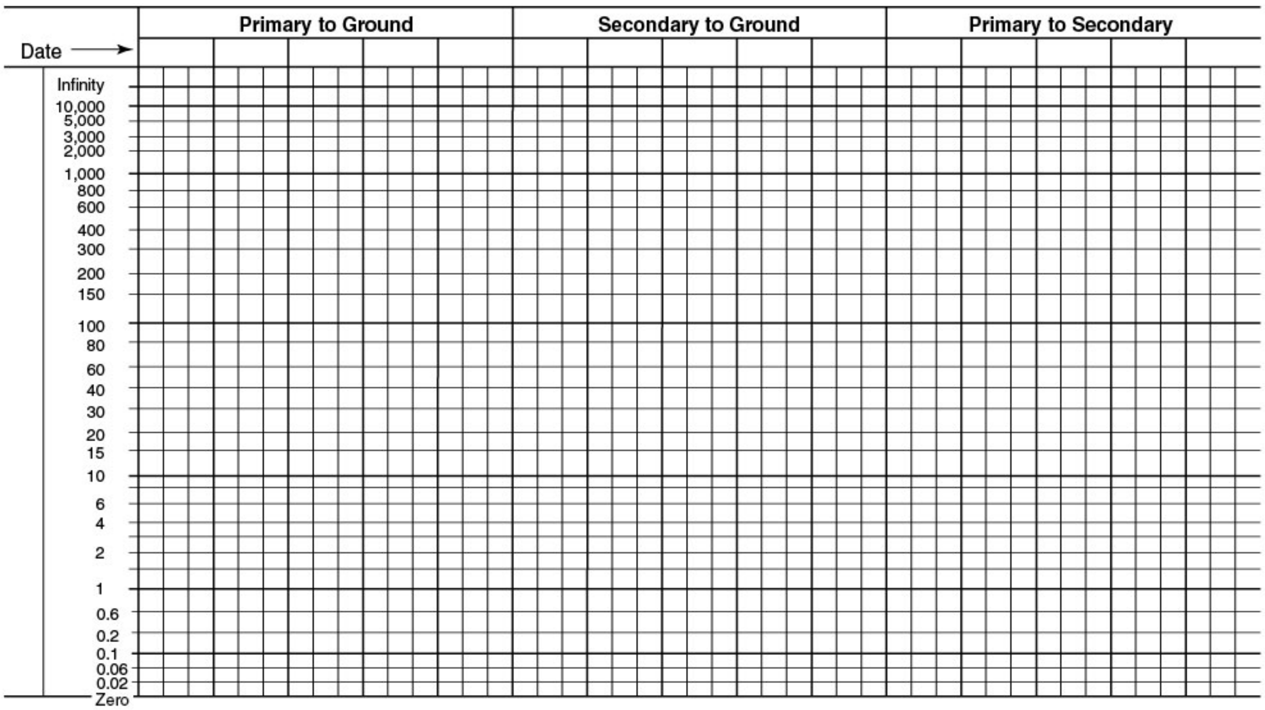
Equipment Included in Test ______________

____

____

I I*	Date	Primary to Ground	Secondary to Ground	Primary to Secondary	Internal Temp.	Ambient Temp.

*Inspector's Initials



Remarks: ______________

____

____

____

____

 NFPA 70B

H.21

Figure H.21(a) shows an example of a VRLA battery inspection report. Figure H.21(b) shows an example of a VRLA maintenance work sheet.

Figure H.21(a) Typical Battery Record.

VALVE-REGULATED LEAD-ACID (VRLA) STATIONARY BATTERIES AND CHARGERS INSPECTION REPORT

Inspected by: ______________________________

Inspection date: ____________________________

User's Name:	Authorized Site Contact:
Installation Location:	Phone No.:
	Other:
System OEM:	Installation by:

BATTERY AND CHARGER SYSTEM INFORMATION

VENDOR INSPECTION	USER INSPECTION
Order Number	Appearance of Following Battery Items
Ship Date	Positive Posts
Date Installed	Negative Posts
Battery Model	Cell Covers
Cells x Strings	Presence of Lubricant on Cells ❐ Yes ❐ No
Application	
Bus Voltage, Portable Meter	
Bus Voltage, Equipment, Final	
Charger Size, Type, Serial No. & Mfg.	
Ambient Room Temperature	
Last Discharge	
Peak Load Current Amp. or KW	
Typical Load Current/KW	
Cell Arrangement	

COMMENTS AND RECOMMENDATIONS

 NFPA 70B

Figure H.21(b) Example of a VRLA Maintenance Worksheet.

VALVE-REGULATED LEAD-ACID (VRLA) MAINTENANCE WORKSHEET

BATTERY CHARGE STATUS ❐ OPEN CIRCUIT ❐ FLOAT ❐ EQUALIZE

BATTERY BUS VOLTAGE ________ Vdc ________ Vdc ________ Vdc

Location: **Model:** **Date:**

Cell No.	Volts +2.000	Serial No.	Connection Resistance	Internal Cell Conductance /Impedance/ Resistance

Cell No.	Volts +2.000	Serial No.	Connection Resistance	Internal Cell Conductance /Impedance/ Resistance

 NFPA 70B

H.22

Figure H.22 shows a typical engine generator set inspection checklist.

Figure H.22 Typical Engine Generator Set Inspection Checklist.

ENGINE GENERATOR INSPECTION

SHEET NO. ________ OF ________

CUSTOMER ____________________ DATE ____________ PROJECT NO. ____________
ADDRESS ____________________ AIR TEMP. ____________ REL. HUMIDITY ____________
OWNER/USER ____________________ DATE LAST INSPECTION ____________________
ADDRESS ____________________ LAST INSPECTION REPORT ____________________
EQUIPMENT LOCATION ____
CIRCUIT IDENTIFICATION ____

ENGINE TYPE: ☐ GASOLINE ☐ DIESEL ☐ GAS TURBINE

MAKE ____________ MODEL ____________ SERIAL NO. ____________ KS # ____________
KVA ____________ KW ____________ VOLTAGE ____________ F.L.A. ____________
RPM ____________ HZ ____________ HP ____________ TECH. BULL. # ____________

1. ☐ Change oil and lube oil filters.
2. ☐ Remove unused oil from premises.
3. ☐ Change fuel oil elements.
4. ☐ Service crankcase breather.
5. ☐ Inspect air cleaner element, clean if required. If replacement is required, element(s) will be billed separately. Price of element(s) not included in contract price.
6. ☐ Check coolant level and maintain safe degree of protection. Engine mounted radiators only. (Remote radiators, cooling towers & heat exchangers serviced at user's request on a time and material basis.)
7. ☐ Check manifolds, brackets, mountings and flex connections.
8. ☐ Inspect fan belts, adjust if required.
9. ☐ Check pulley hub, bearings, lubricate if required.
10. ☐ Check operation of auxiliary water pump or fan motor.
11. ☐ Check operation of automatic louvers.
12. ☐ Repair minor fuel, coolant and lube oil leaks.
13. ☐ Check operation of jacket water heater(s).
14. ☐ Inspect generator, perform any routine maintenance as required.
    ☐ Megger
15. ☐ Inspect governor/actuator linkage.
16. ☐ Check battery electrolyte level and maintain to include:
    ☐ Temperature ☐ Specific Gravity ☐ Voltage
17. ☐ Check operation of charger and/or alternator.
18. ☐ Inspect fuel supply system for leaks or low level, inform owner of any discrepancies.
19. ☐ Drain condensation from day tank and check for any contamination. ONLY if day tank is equipped with a drain valve.
20. ☐ Check operation of transfer pump.
21. ☐ Check for correct generator output voltage & frequency, adjust if required.
22. ☐ Simulate & check operation of each safety shutdown and alarm device, relay type control panels only.
23. ☐ Check operation of generator control instrumentation; volts, amps, etc.
24. ☐ Test fault lamps & replace bulbs as required, panels with lamp test only.
25. ☐ Tank crankcase oil sample, owner to be notified of any discrepancies.
26. ☐ Submit report to owner
27. ☐ Auto start test.

REMARKS ____

SUBMITTED BY ____________________ EQUIPMENT USED ____________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.23

Figure H.23 shows a typical automatic transfer switch form.

Figure H.23 Typical Automatic Transfer Switch Report.

AUTOMATIC TRANSFER SWITCH

SHEET NO. ________ OF ________

CUSTOMER ________ DATE ________ PROJECT NO. ________
ADDRESS ________ AIR TEMP. ________ REL. HUMIDITY ________
OWNER/USER ________ DATE LAST INSPECTION ________
ADDRESS ________ LAST INSPECTION REPORT NO. ________
EQUIPMENT LOCATION ________
OWNER IDENTIFICATION ________

Mfg. ________ Type: ________ Bul #: ________
Cat. # ________ Serial # ________ Voltage: ________
Amps: ________ Phase: ________ Op. Coil: ________
Inst. Bk: ________ Parts Bk. ________ Wire Diag: ________

Time Range "Transfer to Emergency" From ________ To ________
Time Range "Retransfer to Normal" From ________ To ________

TEST OPERATIONS

Transfer Time to Emergency As Found ________ As Left ________
Retransfer Time to Normal As Found ________ As Left ________

	NORMAL			EMERGENCY		
Contact Resistance in Microhms:	A ____	B ____	C ____	A ____	B ____	C ____
Voltage Drop in Millivolts:	A ____	B ____	C ____	A ____	B ____	C ____
Voltage Readings:	A-N ____	B-N ____	C-N ____	A-N ____	B-N ____	C-N ____
	A-B ____	B-C ____	C-A ____	A-B ____	B-C ____	C-A ____
Amperage Readings:	A ____	B ____	C ____	A ____	B ____	C ____

Undervoltage Relay:

	1V	2V	3V
Pickup	____	____	____
Dropout	____	____	____

________ Relay: Pickup ________ Dropout ________

________ Relay: Voltage Pickup ________ Dropout ________
Frequency Pickup ________ Dropout ________

Arc Chutes: ________
Contacts: ________
Megger: ________
Cleaned: ________
Lubrication: ________

Circuit Properly Tagged: ________
Bolted Connections: ________
Mechanical Operation: ________
Unusual Conditions: ________

Remarks: ________

Test Crew: ________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.24

Figure H.24 shows a typical uninterruptible power supply system inspection checklist.

Figure H.24 Typical Uninterruptible Power Supply System Inspection Checklist.

UNINTERRUPTIBLE POWER SUPPLY (UPS) SYSTEM INSPECTION CHECKLIST

For use of this form see TM 5-694: the proponent agency is COE.

SECTION A – CUSTOMER DATA

1. PLANT/BUILDING	2. LOCATION	3. JOB NUMBER
4. EQUIPMENT	5. CIRCUIT DESIGNATION	6. DATE *(YYYYMMDD)*
7. TEST EQUIPMENT		8. TESTED BY

SECTION B – VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

9. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING			ENERGIZE AND TEST SYSTEM		
INSTALLATION INSPECTION/TESTING			UTILITY TRIP TEST		
WIRING VISUAL VERIFICATION			LOADED TRANSFER TEST (NORMAL, EMERGENCY & RETURN)		
GENERATOR CONTROL FUNCTIONS			TIGHTNESS OF BOLTED CONNECTIONS		
LOADING UPS TEST			BATTERY DISCHARGE TEST		
DISCONNECT RECTIFIERS & INVERTERS SEPARATELY. DOES SYSTEM OPERATE CORRECTLY?			TEST ALL UPS DIAGNOSTIC FAULT INDICATORS		

SECTION C – ELECTRICAL TESTS**

10.	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
UPS INPUT											
UPS OUTPUT	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
UPS SWITCHBOARD HARMONIC (THD)	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

11. NOTES

* CONDITION: A = ACCEPTABLE; R = NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C = CORRECTED; NA = NOT APPLICABLE
** NOTE VALUE AND PHASING

NFPA 70B

H.25

Figure H.25 shows a typical back-up power system inspection checklist.

Figure H.25 Typical Back-Up Power System Inspection Checklist.

BACK-UP POWER SYSTEM INSPECTION CHECKLIST

For use of this form see TM 5-694: the proponent agency is COE.

SECTION A – CUSTOMER DATA

1. PLANT/BUILDING	2. LOCATION	3. JOB NUMBER
4. EQUIPMENT	5. CIRCUIT DESIGNATION	6. DATE *(YYYYMMDD)*
7. TEST EQUIPMENT AND CALIBRATION DATE		8. TESTED BY

SECTION B – EQUIPMENT DATA

9. MANUFACTURER	10. STYLES/S.O.	11. VOLTAGE RATING	12. CURRENT RATING
13. EQUIPMENT CLASSIFICATION	14. FREQUENCY	15. WET BULB TEMPERATURE	16. DRY BULB TEMPERATURE

SECTION C – VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

17. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING			WIRING VISUAL VERIFICATION		
ENERGIZE AND TEST SYSTEM			UTILITY TRIP/GENERATOR BUILDING LOAD TEST		
INSTALLATION INSPECTION/TESTING			TIGHTNESS OF BOLTED CONNECTIONS		
GENERATOR CONTROLS AND FUNCTIONS			CHECK FOR PROPER SIZE BREAKER		
WIRING CONTINUITY TESTING			REFERENCE DRAWINGS		
WORKING CLEARANCE			PROPER PHASING CONNECTIONS AND COLOR CODE		
SWITCHGEAR CONTROL FUNCTIONS					
PERFORM AUTOMATIC TRANSFER SYSTEM (ATS) FUNCTIONS UNDER THE ADJACENT CONTROLLER	A. OPERATE NORMAL POWER				
	B. ALL GENERATORS OPERATE				
	C. GENERATORS 1 AND 2 OPERATE				
	D. GENERATORS 2 AND 3 OPERATE				
	E. GENERATORS 1 AND 3 OPERATE				
	F. RETURN TO NORMAL POWER AFTER EACH OF THE ABOVE TESTS				
	G. PARALLEL WITH UTILITY UPON RETURN TO NORMAL POWER (ITEMS B THROUGH E)				

SECTION D – ELECTRICAL TESTS

18. MEASUREMENT DESCRIPTION	VOLTAGE AND CURRENT MEASUREMENTS										
	VOLTAGE**						CURRENT**				
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

19. NOTES

1. CHECK FOR PROPER GROUNDING CONNECTIONS PRIOR TO ENERGIZING.

* CONDITION: A = ACCEPTABLE; R = NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C = CORRECTED; NA = NOT APPLICABLE
** NOTE VALUE AND PHASING

NFPA 70B

H.26

Figure H.26 shows a typical insulation resistance–dielectric absorption test sheet for power cable.

Figure H.26 Typical Insulation Resistance–Dielectric Absorption Test Sheet for Power Cable.

INSULATION RESISTANCE–DIELECTRIC ABSORPTION TEST SHEET FOR POWER CABLE

Test No. ______________________

______________________ Company   Date ______________________

______________________ Location   Time ______________________

Circuit	Circuit Length	Aerial Duct Burned	
Number of Conductors	Conductor Size AWG MCM (kcmil)	Belted Shielded	
Insulating Material	Insulating Thickness	Voltage Rating	Age
Pothead or Terminal Type		Location Indoors Outdoors	
Number and Type of Joints			
Recent Operating History			
		Mfr.	
State if Potheads or Terminals Were Guarded During Test			
List Associated Equipment Included in Test			
Misc. Information			

Test Data — Megohms

Part Tested					Test Made	Hours Days	After Shutdown
Grounding Time					Dry-Bulb Temp.		°F
Test Voltage					Wet-Bulb Temp.		°F
Test Connections	To Line	To Line	To Line	To Line	Dew Point		°F
	To Earth	To Earth	To Earth	To Earth	Relative Humidity		%
	To Guard	To Guard	To Guard	To Guard	Absolute Humidity		Gr./#
¼ minute					Equipment Temp.		°F (°C)
½ minute					How Obtained		
¾ minute							
1 minute							
2 minutes					"Megger" Inst.		
3 minutes					Serial No.		
4 minutes					Range		
5 minutes					Voltage		
6 minutes							
7 minutes							
8 minutes							
9 minutes							
10 minutes							
10:1 min. Ratio							

Remarks ______________________

Tested by:

 NFPA 70B

H.27

Figure H.27 shows a typical cable test sheet.

Figure H.27 Typical Cable Test Sheet.

CABLE TEST SHEET

Company ______ Date ______ Job No. ______

Test Location ______ Circuit ______ Air Temp. ______ °C ______ % Hum. ______

Test Type: Acceptance ❑ Periodic ❑ Special ❑ Date Last ______ Sheet No. ______ Weather ______

Cable Mfr.	
Rated kV	(Gnd., Ungnd.)
Oper. kV	(Gnd., Ungnd.)
Length	
Age	
No. Cond.	
No. Size	
Insul. Material	
Insul. Thickness	
Insul. Type	
Covering	
Installed in	
Factory Test kV	
% Factory Test kV	
Max. Test kV	
Voltmeter kV	

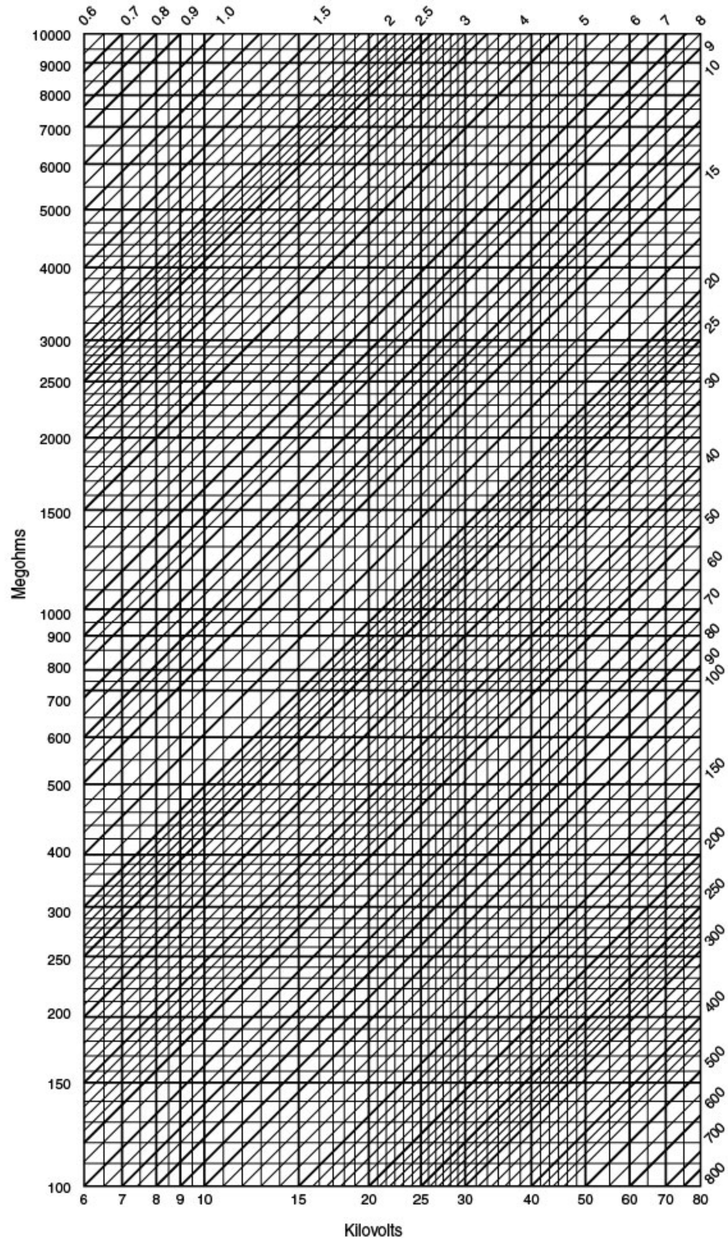
Time Min.	Volts kV	Leakage Current-Microamps		
		Φ1 – ⊙	Φ2 – △	Φ3 – ⊡

Insulation Resistance Test 1 Minute @ 2.5 kV — 1000 Megohms			
Φ TO GND.			
Φ 1 TO Φ	—		
Φ 2 TO Φ	—	—	

Authorization of Max.
Test kV and Verifying Voltmeter kV

______
Signature

Remarks: ______



Test Set No.: ______ Tested by: ______ Sheet No.: ______

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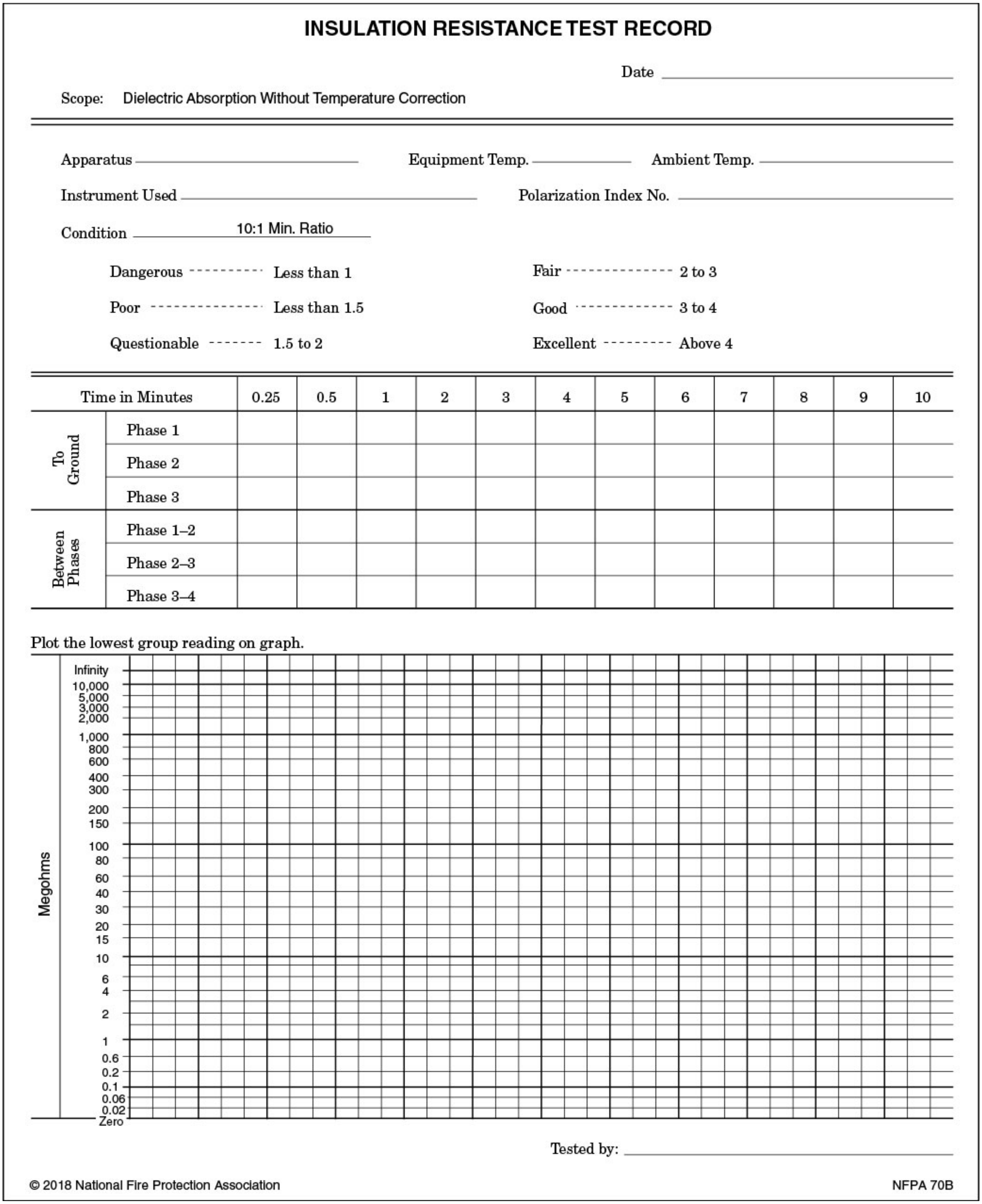
H.28

Figure H.28 shows a typical insulation resistance test record.

Figure H.28 Typical Insulation Resistance Test Record.



INSULATION RESISTANCE TEST RECORD

Date ______________________

Scope: Dielectric Absorption Without Temperature Correction

Apparatus ______________________ Equipment Temp. __________ Ambient Temp. __________

Instrument Used ______________________ Polarization Index No. ______________________

Condition 10:1 Min. Ratio

Dangerous	Less than 1	Fair	2 to 3
Poor	Less than 1.5	Good	3 to 4
Questionable	1.5 to 2	Excellent	Above 4

	Time in Minutes	0.25	0.5	1	2	3	4	5	6	7	8	9	10
To Ground	Phase 1												
	Phase 2												
	Phase 3												
Between Phases	Phase 1–2												
	Phase 2–3												
	Phase 3–4												

Plot the lowest group reading on graph.

Tested by: ______________________

 NFPA 70B

H.29

Figure H.29 shows a typical insulation resistance test record for rotating machinery.

Figure H.29 Typical Insulation Resistance Test Record for Rotating Machinery.

INSULATION RESISTANCE TEST RECORD FOR ROTATING MACHINERY

Reference: ANSI/IEEE 43, *Recommended Practice for Testing Resistance of Rotating Machinery*

Scope:

Dielectric Absorption — Temperature Corrected

ac machines 1000 kVA or more
dc machines 100 kW or more

Date ____________________

Apparatus ____________________ Voltage __________ Rating __________

Test Conditions:

List Associated Test Equipment Included in Test ____________________

Winding Grounding Time __________ Test Made __________ Hours After Shutdown

Ambient Temperature __________ °F Relative Humidity __________ % Weather __________

Equipment Temperature __________ How Obtained __________

Instrument __________ Range __________ Voltage __________

Test Data:

Minutes	0.25	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Reading												
Correction												

Megohms: Infinity, 10,000, 5,000, 3,000, 2,000, 1,000, 800, 600, 400, 300, 200, 150, 100, 80, 60, 40, 30, 20, 15, 10, 6, 4, 2, 1, 0.6, 0.2, 0.1, 0.06, 0.02, Zero

Polarization No. (10:1 min. ratio) __________ Tested by __________

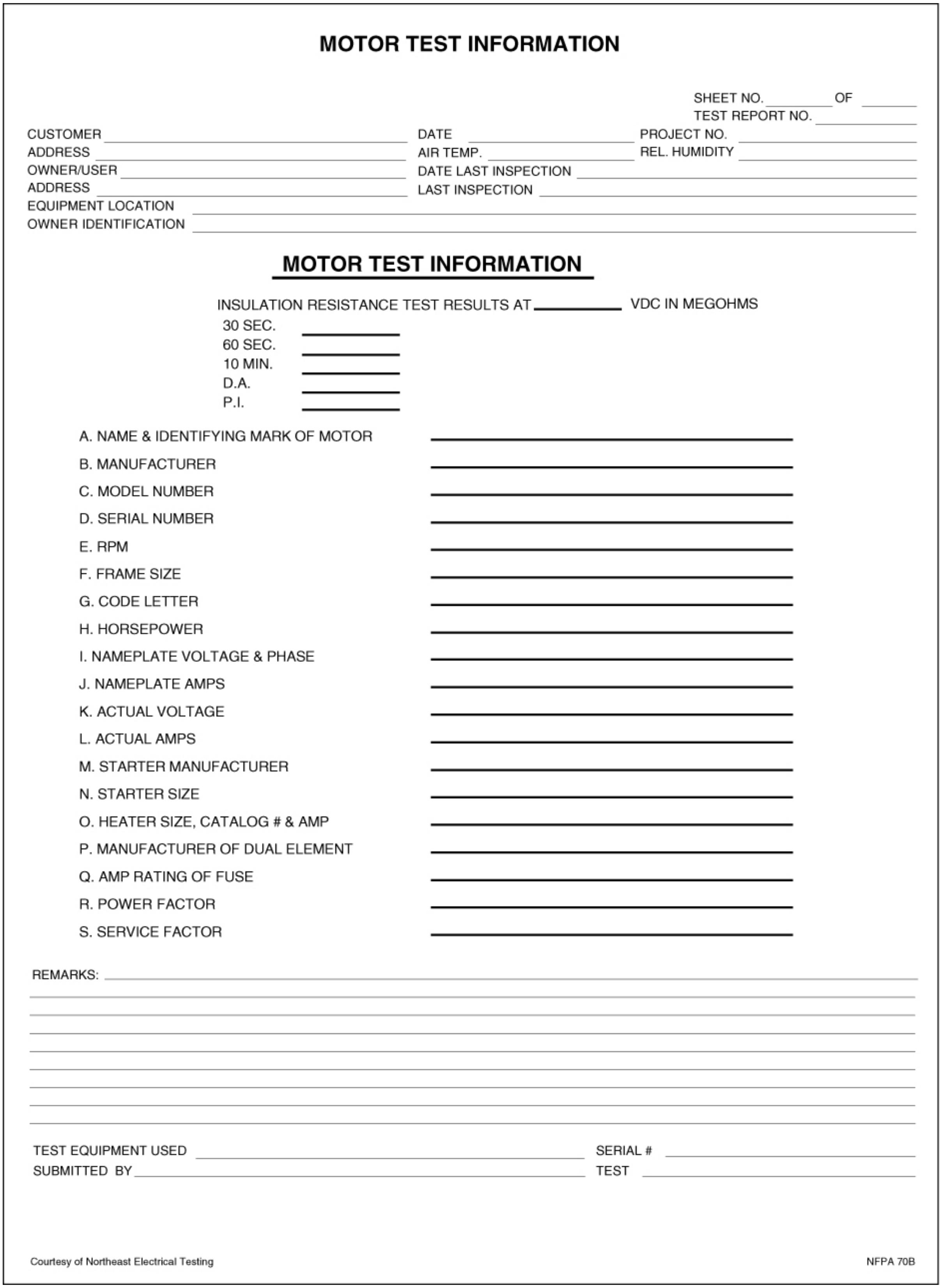
Remarks: ____________________

 NFPA 70B

H.30

Figure H.30 shows a typical motor test information form.

Figure H.30 Typical Motor Test Information Form.



MOTOR TEST INFORMATION

SHEET NO. ________ OF ________
TEST REPORT NO. ________

CUSTOMER ________ DATE ________ PROJECT NO. ________
ADDRESS ________ AIR TEMP. ________ REL. HUMIDITY ________
OWNER/USER ________ DATE LAST INSPECTION ________
ADDRESS ________ LAST INSPECTION ________
EQUIPMENT LOCATION ________
OWNER IDENTIFICATION ________

MOTOR TEST INFORMATION

INSULATION RESISTANCE TEST RESULTS AT ________ VDC IN MEGOHMS
30 SEC. ________
60 SEC. ________
10 MIN. ________
D.A. ________
P.I. ________

A. NAME & IDENTIFYING MARK OF MOTOR ________
B. MANUFACTURER ________
C. MODEL NUMBER ________
D. SERIAL NUMBER ________
E. RPM ________
F. FRAME SIZE ________
G. CODE LETTER ________
H. HORSEPOWER ________
I. NAMEPLATE VOLTAGE & PHASE ________
J. NAMEPLATE AMPS ________
K. ACTUAL VOLTAGE ________
L. ACTUAL AMPS ________
M. STARTER MANUFACTURER ________
N. STARTER SIZE ________
O. HEATER SIZE, CATALOG # & AMP ________
P. MANUFACTURER OF DUAL ELEMENT ________
Q. AMP RATING OF FUSE ________
R. POWER FACTOR ________
S. SERVICE FACTOR ________

REMARKS: ________

TEST EQUIPMENT USED ________ SERIAL # ________
SUBMITTED BY ________ TEST ________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.31

Figure H.31 shows a typical ground system resistance test report.

Figure H.31 Typical Ground System Resistance Test Report.

GROUNDING SYSTEM RESISTANCE TEST

SHEET NO. ________ OF ________

CUSTOMER ______________________ DATE ______________ PROJECT NO. ______________

ADDRESS ______________________ AIR TEMP. ______________ REL. HUMIDITY ______________

OWNER/USER ______________________ DATE LAST INSPECTION ______________________

ADDRESS ______________________ LAST INSPECTION REPORT NO. ______________________

LOCATION ____

SEASON	
SOIL TYPE	
SOIL CONDITION	
SINGLE ROD DEPTH	
MULTIPLE RODS (Y/N)	
LONGEST DIMENSION	
BURIED WIRE/STRIPS (Y/N)	
LONGEST DIMENSION	
DIST. TO AUX. ELECTRODE	
OTHER	

AUXILIARY POTENTIAL ELECTRODE

DISTANCE (FEET)	RESISTANCE (OHMS)

DISTANCE (FEET)

RESISTANCE (OHMS)

REMARKS ____

SUBMITTED BY ______________________ EQUIPMENT USED ______________________

Courtesy of Northeast Electrical Testing

NFPA 70B

H.32

Figure H.32 shows a typical ground test inspection report for health care facilities.

Figure H.32 Typical Ground Test Inspection Report — Health Care Facilities.

GROUND TEST INSPECTION REPORT — HEALTH CARE FACILITIES

SHEET NO. ________ OF ________

CUSTOMER ______________________ DATE ______________ PROJECT NO. ____________

ADDRESS ______________________ AIR TEMP. ______________ REL. HUMIDITY ____________

OWNER/USER ______________________ DATE LAST INSPECTION ______________________

ADDRESS ______________________ LAST INSPECTION REPORT ______________________

EQUIPMENT LOCATION ____

OWNER IDENTIFICATION ____

MAXIMUM TEST INTERVALS:
GENERAL CARE: 12 MONTHS
CRITICAL CARE: 6 MONTHS
WET LOCATIONS: 12 MONTHS

*NOTE: MAXIMUM READINGS PERMITTED:
20mV NEW CONSTRUCTION
40mV CRITICAL EXISTING CONSTRUCTION
500mV GENERAL CARE EXISTING CONSTRUCTION
0.1 ohm NEW CONSTRUCTION
0.2 ohm QUIET GROUNDS AND EXISTING CONSTRUCTION

ROOM NO.	DESCRIPTION (C) CRITICAL (G) GENERAL	VOLTAGE MEASUREMENT			IMPEDANCE MEASUREMENT	
		NUMBER OF RECEPTABLES	NUMBER OF OTHER	MAX READING (MILLIVOLTS)	NUMBER OF RECEPTACLES	MAX READING (OHMS)

REMARKS ____

CUSTOMER REPRESENTATIVE ______________________ TITLE ______________________

TEST EQUIPMENT ______________________ SERIAL # ______________________

SUBMITTED BY ____

Courtesy of Northeast Electrical Testing

NFPA 70B

H.33

Figure H.33 shows a typical line isolation monitor test data report for health care facilities.

Figure H.33 Typical Line Isolation Monitor Test Data Report — Health Care Facilities.

LINE ISOLATION MONITOR TEST DATA — HEALTH CARE FACILITIES

SHEET __________ OF __________

CUSTOMER ______________________ DATE ______________________ PROJECT NO. ______________________

ADDRESS ______________________ AIR TEMP. __________ °C REL. HUMIDITY ______________________

OWNER/USE ______________________ DATE LAST INSPECTION ______________________

ADDRESS ______________________ LAST INSPECTION REPORT NO. ______________________

EQUIPMENT LOCATION ______________________

CIRCUIT ______________________

INSTRUMENT OR METER UNDER TEST

TYPE ______________ MANUFACTURER ______________ VOLTAGE ______________

SERIAL NO. ______________ MODEL NO. ______________

CATALOG NO. ______________ STYLE NO. ______________

TEST OPERATIONS

CAUTION: NO TEST EQUIPMENT NEEDED FOR THIS SECTION. REMOVE ALL PLUGS FROM MONITOR DURING THESE TESTS. PATIENT MUST NOT BE SUBJECTED TO HARMFUL TEST VOLTAGES.

		AS FOUND		AS LEFT	
1. AUDIBLE AND VISUAL INDICATORS	SELF TEST				
	SILENCE (MUTE)				
2. CHECK APPROPRIATE BOX IF INDICATOR IS OPERATIONAL	RED				
	GREEN				
	YELLOW				
3. LIM	MANUFACTURER'S SPECIFIED ALARM POINT		MA		MA
	METER READING		MA		MA

TEST OPERATIONS USING TEST EQUIPMENT:

TEST SET ______________________

		AS FOUND	AS LEFT
4. LINE LEAKAGE TO GROUND	ONE mA		
	TWO mA		
	THREE mA		
	FOUR mA		
	FIVE mA		
5. ARE ALL BREAKERS OPERATIONAL AND CIRCUITS LABELED?			

REMARKS ____

CUSTOMER REPRESENTATIVE ______________________ TITLE ______________________

TEST EQUIPMENT ______________________ SERIAL # ______________________

SUBMITTED BY ______________________ TEST CREW ______________________

Courtesy of Northeast Electrical Testing NFPA 70B

H.34

Figure H.34 shows a typical torque value record.

Figure H.34 Typical Torque Value Record.

TORQUE VALUE RECORD

SHEET NO. ________ OF ________

CUSTOMER ______________________ DATE ______________ PROJECT NO. ____________
ADDRESS ______________________ AIR TEMP. ______________ REL. HUMIDITY ____________
OWNER/USER ______________________ DATE LAST INSPECTION ______________
ADDRESS ______________________ LAST INSPECTION REPORT NO. ______________
EQUIPMENT LOCATION ______________________
OWNER IDENTIFICATION ______________________

GENERAL INFORMATION:

Equipment ID: ______________ Performed By: ______________
Location: ______________ Torque Marked: ☐ Yes ☐ No Color: ________
Date Performed: ______________ Verified By: ______________
Torque Wrench Information: ☐ IN-LBS ☐ FT-LBS Verification Marked: ☐ Yes ☐ No Color: ________
Manufacturer: ________ Model: ________ Approved By: ______________

TORQUE AND VERIFICATION

No.	No. of Items	Item Description/Location	Vendor Specification		NETA Specification		Torque		Note
			NO.	FT-LB / IN-LB	NO.	FT-LB / IN-LB	NO.	FT-LB / IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	
				☐ FT-LB		☐ FT-LB		☐ FT-LB	
				☐ IN-LB		☐ IN-LB		☐ IN-LB	

REMARKS ____

CUSTOMER REPRESENTATIVE ______________________ TITLE ______________
TEST EQUIPMENT ______________________ SERIAL # ______________
SUBMITTED BY ____

Courtesy of Northeast Electrical Testing NFPA 70B

H.35

Figure H.35 shows a typical main power energization checklist.

Figure H.35 Typical Main Power Energization Checklist.

MAIN POWER ENERGIZATION CHECKLIST

For use of this form see TM 5-694: the proponent agency is COE.

SECTION A – CUSTOMER DATA

1. PLANT/BUILDING	2. LOCATION	3. JOB NUMBER	
4. CIRCUIT DESIGNATION	5. CIRCUIT FED FROM	6. CIRCUIT FED TO	7. DATE *(YYYYMMDD)*
8. TEST EQUIPMENT TYPE/BRAND AND CALIBRATION DATE		9. TESTED BY	

SECTION B – VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

10. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING COMPLETED			VERIFY SWITCHGEAR CONTROL FUNCTIONS		
WIRING VISUAL VERIFICATION			CHECK FOR WORKING CLEARANCE		
VERIFY WIRING DIAGRAMS			ENERGIZE AND TEST SYSTEM		
VERIFY CIRCUIT SWITCHER CONTROL FUNCTIONS			TRANSFORMER TRANSFER CONTROL FUNCTIONS		
ENERGIZE AND TEST SYSTEM FOR ALL CONDITIONS			CHECK FOR UNUSUAL SOUNDS AFTER ENERGIZING		
CHECK BUSHING OR TERMINALS			CHECK ANCHORING OF TRANSFORMER SWITCHGEAR AND SWITCHES ENCLOSURE		
CHECK FOR REMOVAL OF PAINT OR HEAVY DENTS			CHECK FOR NORMAL/ABNORMAL SWITCHING OPERATION		

SECTION C – ELECTRICAL TESTS

11. MEASUREMENT DESCRIPTION	VOLTAGE AND CURRENT MEASUREMENTS										
	VOLTAGE**						CURRENT**				
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

12. NOTES

* CONDITION: A = ACCEPTABLE; R = NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C = CORRECTED; NA = NOT APPLICABLE
** NOTE VALUE AND PHASING

H.36

Figure H.36 shows instructions to contractor.

Figure H.36 Instructions to Contractor.

Facility Identification **Job No.**

INSTRUCTIONS TO CONTRACTOR

Date: ____________________

Contractor Name: ____________________

Address: ____________________

City, State, Zip Code: ____________________

Subject: Project Title: ____________________

Project No.: ____________________

Enclosed is one complete set of the following bid documents covering work for the subject project.

1. Project Scope of Work, Dated: ____________________
2. Proposal Forms for:
   General Maintenance of Electrical Power Equipment, and/or
   Infrared Surveying of Electrical Power Equipment, and/or
   Circuit Breaker Overhaul and Trip Unit Retrofit
3. Plant Electrical Power Equipment Documentation:
   - **Plant one line diagrams** **Dwg. Nos.** ________________ , **Dated** ________________
   - **Plant layout drawings** **Dwg. Nos.** ________________ , **Dated** ________________
   - **Plant equipment list** **Doc. No.** ________________ , **Dated** ________________
   - **Short circuit analyses and time-current coordination studies**
   - **Equipment manufacturers' requirements will be available at the plant for your use.**

We would appreciate receiving a quote from you for this work on the enclosed Project Scope of Work in strict accordance to the quote documents. Please respond in writing if you do not intend to submit a quote for this project.

One original and copy(s) of your quote will be due not later than __________ at __________ local time.

Fax and send one original of your proposal to: ***(Enter Project Engineer's Name, Address, and Fax No. here)***

We welcome suggestions regarding changes in specifications and/or modifications in design or production methods that will aid in reducing costs without impairing quality or that will improve the quality, safety, and/or performance of the product on which you are quoting. However, your base bid price must be submitted on the basis of the bid documents. All voluntary alternates are to be presented as a separate price from the base bid.

Pre-Quote Walk Through (if applicable)

You are invited to attend a pre-quote walk through meeting scheduled for:

Time: ____________________

Day: ____________________

Date: ____________________

Location: ____________________

If you desire further information addressing the technical specifications or site visitation, please contact ***(project engineer)*** at ***(phone no.)***.

Sincerely,

(Enter Project Engineer's Name and Location here)

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H.37

Figure H.37 shows project scope of work template.

Figure H.37 Project Scope of Work Template.

Facility Identification **Job No.**

PROJECT SCOPE OF WORK

Introduction

This Scope of Work document will define the maintenance activities to be included in this project. The contractor shall provide all labor, materials, and equipment necessary to perform requested electrical power equipment maintenance. All maintenance activities will be performed in accordance with the applicable Technical Specification and other pertinent portions of facility's Electrical Power Equipment Maintenance Manual. *The costs of premium time, if required, shall be included in this quote.*

If electrical power equipment is found to be within the Manufacturer's specifications for continued service and the required maintenance is unnecessary, clean, adjust, and reassemble the electrical power equipment and perform all Manufacturer recommended procedures for continued service.

If the contractor discovers that the electrical power equipment cannot be brought into compliance with the Manufacturer's specifications for continued service, advise the Owner of the "as found" condition and await further direction. *Save all component parts for Owner inspection.*

General Task Description

____

____

____

____

____

____

____

____

____

____

____

____

____

Schedule

Time to complete all tasks: ______________________

Time equipment is available: ______________________

Time/day to begin work: ______________________

Time/day to complete work: ______________________

Facility Identification **Job No.**

PROJECT SCOPE OF WORK *(continued)*

Specific Task Description

Contractor will perform the specific tasks described in this section.

General Maintenance

The following maintenance activities will be performed in accordance with the Technical Specifications for General Maintenance or Electrical Power Equipment.

Circuit Breaker Overhaul and Trip Unit Retrofit

The following maintenance activities will be performed in accordance with the Technical Specifications for Circuit Breaker Overhaul and Trip Unit Retrofit.

Infrared Surveying

The following maintenance activities will be performed in accordance with the Technical Specifications for Infrared Surveying of Electrical Power Equipment.

Work Not Included (Listed Owner furnished services)

Exceptions to Specifications

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H.38

Figure H.38 shows project scope of work form.

Figure H.38 Project Scope of Work Form.

PROJECT SCOPE OF WORK QUOTE FORM

Location: ____________________ Project No. ____________________ Purch. Req. No. ____________________

Contractor: ____________________ MBO No. ____________________

The Contractor shall perform the work in strict accordance with the facility's Electrical Power Equipment Maintenance Manual EMM-1 General Maintenance Technical Specification, the Circuit Breaker Overhaul and Trip Unit Retrofit Technical Specification, the plant equipment list, single line diagrams and drawings, and the Project Scope of Work. All alternates shall be fully described with exceptions listed by Item Number, and priced separately. When applicable, General Maintenance Technical Specification (GMTS) codes shall be used on this Proposal Form as they are used in the Project Scope of Work.

Item No.	Maintenance Activity Description and Location of Equipment	GMTS Code	Quantity	Item/Unit Price	Item Total Price
				Page Total	

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H.39

Figure H.39 shows project scope of work modification form.

Figure H.39 Project Scope of Work Modification Form.

PROJECT SCOPE OF WORK MODIFICATION QUOTE FORM

Location: ____________ Project No. ____________ Purch. Req. No. ____________

Contractor: ____________ MBO No. ____________ Modification No. ____________

All modifications shall be fully described with reference to the original Item Number, and priced separately. The Contractor shall perform the work in strict accordance with the facility's Electrical Power Equipment Maintenance Manual EMM-1 General Maintenance Technical Specification, the Circuit Breaker Overhaul and Trip Unit Retrofit Technical Specification, the plant equipment list, single line diagrams and drawings, and the Project Scope of Work. When applicable, General Maintenance Technical Specification (GMTS) codes shall be used on this Proposal Form as they are used in the Project Scope of Work. Contractor shall not begin work until approved by the plant.

Item No.	Maintenance Activity Description and Location of Equipment	GMTS Code	Qty.	Labor	Mat'l	Item Total Price
					Page Total	

Submitted by: ____________ Date: ____________

Approved by: ____________ Date: ____________

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H.40

Figure H.40 shows cover and contents.

Figure H.40 Cover and Contents.

POWER QUALITY SURVEY DATA COLLECTION MANUAL

Installation: ____________________________

Location: ______________________________

Collection Date: __________________

Courtesy of U.S. Army Corps of Engineers NFPA 70B

H.41

Figure H.41 shows point of contact.

Figure H.41 Points of Contact.

POINTS OF CONTACT

Installation: ______________________________

Address: ______________________________

____

Names	Titles	Office Symbols	Phones

Contractor's Name: ______________________________

Address: ______________________________

____

Names	Titles	Office Names	Phones

Utilities: ______________________________

Address: ______________________________

____

Names	Titles	Office Names	Phones

Courtesy of U.S. Army Corps of Engineers

NFPA 70B

H.42

Figure H.42 shows power distribution unit (PDU) survey.

Figure H.42 Power Distribution Unit (PDU) Survey.

POWER DISTRIBUTION UNIT (PDU) SURVEY

Date: ____________________

Installation: ____ Location: ____

Power Distribution Unit (PDU) Identification: ________________

Manufacturer: ______________________________________ Model/Serial #: ____________________________________

Size: __________ kVA 3-Phase: ______ Single-Phase: ______ Frequency: __________ Hz

Input Voltage Rating: __________ V Input Current Rating: __________ A Tap Changing Range: __________

Output Voltage Rating: __________ V Output Current Rating: __________ A

Measured Input Volts	$V_{(IN)A\text{-}B}$ = ________ V	$V_{(IN)B\text{-}C}$ = ________ V	$V_{(IN)C\text{-}A}$ = ________ V	
Input Voltage Harmonic Distortion	$V_{(IN)THD(A\text{-}B)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________	$V_{(IN)THD(B\text{-}C)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________	$V_{(IN)THD(A\text{-}C)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________	
Measured Input Amps	$I_{(IN)A}$ = ________ A	$I_{(IN)B}$ = ________ A	$I_{(IN)C}$ = ________ A	
Input Current Harmonic Distortion	$I_{(IN)THD(A)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________	$I_{(IN)THD(B)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________	$I_{(IN)THD(C)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________	
Measured Output Volts	$V_{(O)A\text{-}N}$ = ________ V $V_{(O)A\text{-}G}$ = ________ V	$V_{(O)B\text{-}N}$ = ________ V $V_{(O)B\text{-}G}$ = ________ V	$V_{(O)C\text{-}N}$ = ________ V $V_{(O)C\text{-}G}$ = ________ V	$V_{(O)N\text{-}G}$ = ________ V
Output Voltage Harmonic Distortion	$V_{(O)THD(A\text{-}N)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________	$V_{(O)THD(B\text{-}N)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________	$V_{(O)THD(C\text{-}N)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________	$V_{(O)THD(N\text{-}G)}$ = ____ % 3rd = ________ __ th = ________ __ th = ________
Measured Output Amps	$I_{(O)A}$ = ________ A	$I_{(O)B}$ = ________ A	$I_{(O)C}$ = ________ A	$I_{(O)N}$ = ________ A
Output Current Harmonic Distortion	$I_{(O)THD(A)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________	$I_{(O)THD(B)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________	$I_{(O)THD(C)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________	$I_{(O)THD(N)}$ = _____ % 3rd = ________ __ th = ________ __ th = ________
K Factor	Measured K Factor: ____________		Nameplate K Factor: ____________	
Ground System	Neutral bus of PDU is connected to ground? ❑ Yes ❑ No Ground bus of PDU is connected to upstream switchgear/switchboard/panel ground bus? _____ to building metal frame? _____ to raised floor frame? _____ Ground current measurement: __________ A Ground resistance measurement: __________ Ω			
Temperature	Transf winding temperature range: ______ °F CBs having temperature higher that 90°F: ________________________________		Bus temperature range: ______ °F	
Power Factor	PF: ____________		Displacement Power Factor (DPF): ____________	

than 32°C (90°F)

POWER DISTRIBUTION UNIT (PDU) SURVEY *(continued)*

Deficiencies found	
Problems in the past	
Customer's concerns	
Notes	

Courtesy of U.S. Army Corps of Engineers

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H.43

Figure H.43 shows generator set survey.

Figure H.43 Generator Set Survey.

GENERATOR SET SURVEY

Date: ____________

Installation: ____________ Location: ____________

Number of generator sets at this location: ________

Generator Set #1

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair ❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: ____________

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: ____________
- Model/Type: ____________ Rated Voltage: ____________
- Rated hp (or kW): ____________ Rated Current: ____________
- Power Factor: ____________ Frequency: ____________

Generator Data:

- Manufacturer: ____________
- Model/Type: ____________
- Generated Voltages: ________ V Generated Frequencies: ________ Hz
- Rated kVA: ________ Rated kW: ________
- Rated Currents: ________ A Efficiency Factor: ________
- Winding Connection (D/W/GW): ________ Power Factor: ________

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: ________
- Measured Voltages: ________ V Measured Temperatures: ________ °F

Generator Set #2

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair ❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: ____________

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: ____________
- Model/Type: ____________ Rated Voltage: ____________
- Rated hp (or kW): ____________ Rated Current: ____________
- Power Factor: ____________ Frequency: ____________

Generator Data:

- Manufacturer: ____________
- Model/Type: ____________
- Generated Voltages: ________ V Generated Frequencies: ________ Hz
- Rated kVA: ________ Rated kW: ________
- Rated Currents: ________ A Efficiency Factor: ________
- Winding Connection (D/W/GW): ________ Power Factor: ________

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: ________
- Measured Voltages: ________ V Measured Temperatures: ________ °F

GENERATOR SET SURVEY *(continued)*

Generator Set #3

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair
❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: ____________________

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: ____________________
- Model/Type: ____________________ Rated Voltage: ____________________
- Rated hp (or kW): ____________________ Rated Current: ____________________
- Power Factor: ____________________ Frequency: ____________________

Generator Data:

- Manufacturer: ____________________
- Model/Type: ____________________
- Generated Voltages: __________ V Generated Frequencies: __________ Hz
- Rated kVA: __________ Rated kW: __________
- Rated Currents: __________ A Efficiency Factor: __________
- Winding Connection (D/W/GW): __________ Power Factor: __________

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: ____________________
- Measured Voltages: __________ V Measured Temperatures: __________ °F

Generator Operation:

- Can these generators run in parallel with the utility power sources? ❑ Yes ❑ No
- The generators are being used as: ❑ Backup source ❑ Peak shaving ❑ Prime source
- Are the generators properly protected against overload? ❑ Yes ❑ No abnormal conditions? ❑ Yes ❑ No or reverse power flow (if generators can run in parallel with utility source)? ❑ Yes ❑ No
- Can the generators automatically start? ❑ Yes ❑ No and automatically shut off? ❑ Yes ❑ No
- How many times did generator fail to start or break down (with unknown reason) during the last few years? _____

Maintenance:

- Does the generator operation log book exist and is it up to date? ❑ Yes ❑ No
- How often does the generator run for maintenance? ______ times per week/month, ❑ with loads or ❑ without loads.
- How long did the generator run during each maintenance period? ______ minutes
- How often is the generator fuel system checked? ______ times per week/month

Generator Grounding System:

- ❑ Solidly grounded ❑ High resistance ❑ Low resistance ❑ Reactance
- Measured ground impedance in ohms: _______
- Is the generator's neutral bus connected to ground? ❑ Yes ❑ No
- Is the generator frame connected to ground? ❑ Yes ❑ No

Notes:

____

____

____

____

____

Courtesy of U.S. Army Corps of Engineers

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H.44

Figure H.44 shows electrical panel survey.

Figure H.44 Electrical Panel Survey.

ELECTRICAL PANEL SURVEY

Date: ____________

Installation: ______________________ Location: ______________________

Panel Identification: ______________________

Manufacturer Name: ______________________ Panel Type/Model: ______________________

Voltage Rating: ________ V Current Rating: ________ A Phases: ________ # of Wires: ________

Main Breaker: Type/Model: ____________ Rating: ________ A Adjustable Setting Range: ________

Measured Voltages	$V_{A\text{-}N}$ = ______ V $V_{A\text{-}G}$ = ______ V	$V_{B\text{-}N}$ = ______ V $V_{B\text{-}G}$ = ______ V	$V_{C\text{-}N}$ = ______ V $V_{C\text{-}G}$ = ______ V	$V_{N\text{-}G}$ = ______ V
Voltage Sine Waves	$V_{A\text{-}N}$	$V_{B\text{-}N}$	$V_{C\text{-}N}$	$V_{N\text{-}G}$
Harmonic Voltage Distortion	$V_{THD(A\text{-}N)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %	$V_{THD(B\text{-}N)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %	$V_{THD(C\text{-}N)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %	$V_{THD(N\text{-}G)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %
Measured Currents	I_A = ________ A	I_B = ________ A	I_C = ________ A	I_N = ________ A
Current Sine Waves	I_A	I_B	I_C	I_N
Harmonic Current Distortion	$I_{THD(A)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %	$I_{THD(B)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %	$I_{THD(C)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %	$I_{THD(N)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %

Power Factor	PF: ______________ Displacement Power Factor (DPF): ______________
Grounding System	Ground bus isolated from frame? ____ or bonded to frame? ____ Ground by metal conduits? ____ or by ground conductors? ____ Ground bus bonded to neutral bus? ❑ Yes ❑ No Each branch circuit has separated neutral ❑ Yes ❑ No and ground conductor? ❑ Yes ❑ No Ground current measurement: ______ A Ground resistance measurement: ______ Ω Sketch the existing grounding system (on the back sheet) when it is necessary.
Temperature	Bus temperature range: ______ °F Conductor temperature range: ______ °F CBs having temperature higher that 90°F: ______________
Entrance Conductor	Phases: ________ MCM Number of conductors per phase: ________
Sizes	Neutral: ________ MCM Number of conductors per phase: ________ Ground: ________ MCM Number of conductors per phase: ________
Lightning Protection	Manufacturer: ______________ Type: ________ Voltage rating: ________

→ than 32°F (90°F)

ELECTRICAL PANEL SURVEY *(continued)*

Other Circuit Breakers in the Panel	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
	Circuit breaker rating: _________ A	3 Ph or Single:_____	How many CB:_____
Deficiencies Found			
Problems in the Past			
Customer's Concerns			
Notes			

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H.45

Figure H.45 shows inverter survey.

Figure H.45 Inverter Survey.

INVERTER SURVEY

Date: ______________

Installation: ________________________________ Location: ________________________________

Inverter Identification: ______________________

Number of inverters at this location: ________ Do they all have the same size and characteristics? ❑ Yes ❑ No

Manufacturer: ______________________ Model: ________ Type: ________ Phases: _____ Wires: _____

Input Voltages	Rated: ________ Measured: ________
Input Currents	Rated: ________ Measured: ________
Output Voltages	Rated: ________ Measured: ________
Output Currents	Rated: ________ Measured: ________
kVA	Rated: ________ Measured input: ______ Measured output: ______ PF: ______
kW	Rated: ________ Measured input: ______ Measured output: ______ DPF: ______
Conductor Sizes	Phases: ( )_______ Neutral: ( )_______ Ground: ( )_______
Measured Temperatures	Bus temperature range: ________°F Conductor temperature range: ________°F
Grounding System	Terminal of inverter bonded to ground? ❑ Yes ❑ No Ground bus of inverter bonded to the frame? ❑ Yes ❑ No Ground current measurement: ______ A Ground resistance measurement: ______ Ω Sketch the existing grounding system (on the back sheet) when it is needed.
Batteries	Manufacturer: ______________ Model: __________ Type: __________ Cell voltage: ______________ Number of cells: ______________ Total battery voltages: ________ V Total battery currents: ________ A Conductor sizes: Phases: ( ) ______ Neutral: ( ) ______ Ground: ( ) ______ Physical conditions: ❑ Damage ❑ Corrosion ❑ Leakage Fluid fill level: ________ Proper mounting: ________ Proper clearance: ________ Battery rack condition: ____________ Battery rack grounded? ❑ Yes ❑ No Battery bank terminal grounded? ❑ Yes ❑ No Battery fluid specific gravity last checked: ______________

Measured Cell Battery Voltages and Fluid Temperatures

Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F
Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F
Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F
Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F
Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F	Cell #____ ____V ____°F

insert row: "All temperatures are in □°C □°F"

INVERTER SURVEY *(continued)*

Deficiencies Found	
Problems in the Past	
Notes	

H.46

Figure H.46 shows building lightning protection survey.

Figure H.46 Building Lightning Protection Survey.

BUILDING LIGHTNING PROTECTION SURVEY

Date: ____________

Installation: ____________ Building #: ____________

Physical Conditions	❑ Good Condition ❑ Rust/Corrosion ❑ Damaged
Roof	Materials: ❑ Metal ❑ Non-metal Types: ❑ Flat ❑ Gable ❑ Hip ❑ Gambrel ❑ Intermediate Ridges ❑ Domed ❑ Shed
Air Terminals	Size (diameter): ________ inches Height: ________ feet ________ inches Material: ❑ Copper ❑ Copper Alloys ❑ Aluminum Approximate distance between two consecutive air terminals: ________ feet Air terminals securely mounted on appropriate bases? ❑ Yes ❑ No Air terminal bases are of the same material as the air terminals? ❑ Yes ❑ No Air terminal bases properly fastened/anchored to the roof? ❑ Yes ❑ No An air terminal at each corner of the roof? ❑ Yes ❑ No Two paths for currents to flow (to ground) at each air terminal? ❑ Yes ❑ No
Lightning Conductors	Sizes: ________ AWG Material: ❑ Copper ❑ Copper Alloys ❑ Aluminum Approximate distance between two consecutive lightning conductors: ________ feet Interconnected lightning conductors properly bonded together? ❑ Yes ❑ No Any sharp bend curves (less than 8 inch radius and 90° angle)? ❑ Yes ❑ No Lightning conductor securely fastened every 4 feet? ❑ Yes ❑ No
Down Conductors	Size: ________ AWG Material: ❑ Copper ❑ Copper Alloys ❑ Aluminum Are the conductors electrically continuous running down to the ground? ❑ Yes ❑ No Approximate distance between two consecutive down conductors: ________ feet At least 2 down conductors installed at opposite corners of the building? ❑ Yes ❑ No Total number of down conductors installed: ________ Average resistance measurement at down conductors: ________ Ω
Objects on the Roof	Metal object has a thickness less than $\frac{3}{16}$ inch? ❑ Yes ❑ No Metal object is directly bonded to lightning conductors or through an air terminal to lightning conductors? ❑ Yes ❑ No The bonding surface has a contact area of not less than 3 sq-inches? ❑ Yes ❑ No Non-metal objects on the roof? ❑ Yes ❑ No Are they protected with air terminals? ❑ Yes ❑ No Does each air terminal provide a two-way path to the ground? ❑ Yes ❑ No For non-metal object, is the distance from the farthest corner of the object to the air terminal less than 2 feet? ❑ Yes ❑ No
Grounding System	Separate grounding loop for lightning protection system? ❑ Yes ❑ No Is the grounding loop for lightning protection system bonded to the electrical grounding system? ❑ Yes ❑ No Average ground resistance measurement (at the location where it is connected to electrical grounding system): ________ Ω

BUILDING LIGHTNING PROTECTION SURVEY *(continued)*

Deficiencies Found	
Problems in the Past	
Sketch the roof floor plan and mark down the location of air terminals, cross-roof lightning conductors, down conductors, and distances between them.	

H.47

Figure H.47 shows rectifier survey.

Figure H.47 Rectifier Survey.

RECTIFIER SURVEY

Date: ____________________

Installation: ____ Location: ____

Rectifier Identification: ____________________________

Number of units at this location: _________ Do they all have the same size and characteristics? ❑ Yes ❑ No

Manufacturer: __________________________ Model: __________ Type: __________ Phases: _____ Wires: _____

Input Voltages	Rated: __________ Measured: __________
Input Currents	Rated: __________ Measured: __________
Output Voltages	Rated: __________ Measured: __________
Output Currents	Rated: __________ Measured: __________
kVA	Rated: __________ Measured input: ______ Measured output: ______ PF: _______
kW	Rated: __________ Measured input: ______ Measured output: ______ DPF: ______
Conductor Sizes	Phases: ____________ Neutral: ____________ Ground: ____________ Number of conductors per phase: ____________
Measured Temperatures	Bus temperature range: _________°F Conductor temperature range: _________°F
Grounding System	Terminal of rectifier bonded to ground? ❑ Yes ❑ No Ground bus of rectifier bonded to the frame? ❑ Yes ❑ No Ground current measurement: _______ A Ground resistance measurement: _______ Ω Sketch the existing grounding system (on the back sheet) when it is needed.
Batteries	Manufacturer: ______________________ Model: ____________ Type: ____________ Cell voltage: ________________________ Number of cells: ____________________ Total battery voltages: __________ V Total battery currents: __________ A Conductor sizes: Phases: ( ) ______ Neutral: ( ) ______ Ground: ( ) ______ Physical conditions: ❑ Damage ❑ Corrosion ❑ Leakage Fluid fill level: __________ Proper mounting: __________ Proper clearance: __________ Battery rack condition: ____________ Battery rack grounded? ❑ Yes ❑ No Battery bank terminal grounded? ❑ Yes ❑ No Battery fluid specific gravity last checked: __________________

Measured Battery Cell Voltages and Fluid Temperatures

Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F
Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F
Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F
Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F
Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F	Cell #_____ _____V _____°F

See H.45

RECTIFIER SURVEY *(continued)*

Deficiencies Found	
Problems in the Past	
Customer's Concerns	
Notes	

H.48

Figure H.48 shows electrical panel survey.

Figure H.48 Electrical Panel Survey.

ELECTRICAL PANEL SURVEY

Date: ____________

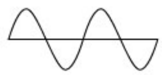
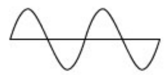
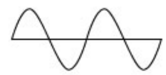
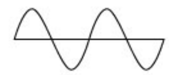
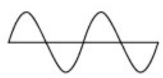
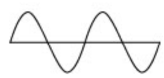
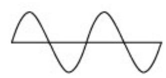
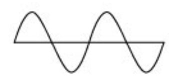
Installation: ______________________ Location: ______________________

Panel Identification: ______________________

Manufacturer Name: ______________________ Panel Type/Model: ______________________

Voltage Rating: ________ V Current Rating: ________ A Phases: ________ # of Wires: ________

Main Breaker: Type/Model: ____________ Rating: ________ A Adjustable Setting Range: ________

Measured Voltages	$V_{A\text{-}N}$ = ______ V $V_{A\text{-}G}$ = ______ V	$V_{B\text{-}N}$ = ______ V $V_{B\text{-}G}$ = ______ V	$V_{C\text{-}N}$ = ______ V $V_{C\text{-}G}$ = ______ V	$V_{N\text{-}G}$ = ______ V
Voltage Sine Waves	 $V_{A\text{-}N}$	 $V_{B\text{-}N}$	 $V_{C\text{-}N}$	 $V_{N\text{-}G}$
Harmonic Voltage Distortion	$V_{THD(A\text{-}N)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %	$V_{THD(B\text{-}N)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %	$V_{THD(C\text{-}N)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %	$V_{THD(N\text{-}G)}$ = ____ % 3rd = ______ % __th = ______ % __th = ______ %
Measured Currents	I_A = ________ A	I_B = ________ A	I_C = ________ A	I_N = ________ A
Current Sine Waves	 I_A	 I_B	 I_C	 I_N
Harmonic Current Distortion	$I_{THD(A)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %	$I_{THD(B)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %	$I_{THD(C)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %	$I_{THD(N)}$ = _____ % 3rd = ______ % __th = ______ % __th = ______ %

Power Factor	PF: ______________ Displacement Power Factor (DPF): ______________
Grounding System	Ground bus isolated from frame? ____ or bonded to frame? ____ Ground by metal conduits? ____ or by ground conductors? ____ Ground bus bonded to neutral bus? ❑ Yes ❑ No Each branch circuit has separated neutral ❑ Yes ❑ No and ground conductor? ❑ Yes ❑ No Ground current measurement: ______ A Ground resistance measurement: ______ Ω Sketch the existing grounding system (on the back sheet) when it is necessary.
Temperature	Bus temperature range: ______ °F Conductor temperature range: ______ °F CBs having temperature higher that 90°F: ______________________
Entrance Conductor	Phases: ________ MCM Number of conductors per phase: ________
Sizes	Neutral: ________ MCM Number of conductors per phase: ________ Ground: ________ MCM Number of conductors per phase: ________
Lightning Protection	Manufacturer: ______________ Type: ________ Voltage rating: ________

than 32°F (90°F)

ELECTRICAL PANEL SURVEY *(continued)*

Other Circuit Breakers in the Panel	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
	CB rating: ________ A	How many CB: ________	Conductor sizes: ________
Deficiencies Found			
Problems in the Past			
Customer's Concerns			
Notes			

H.49

Figure H.49 shows transfer switches survey.

Figure H.49 Transfer Switches Survey.

TRANSFER SWITCHES SURVEY

Date: ____________

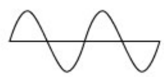
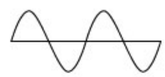
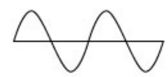
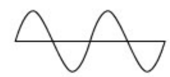
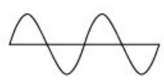
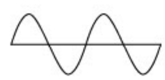
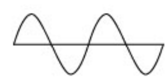
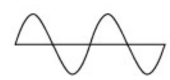
Installation: ______________________ Location: ______________________

Transfer Switch Identification: ______________________

Manufacturer Name: ______________________ Model/Type: ____________ Serial #: ____________

Voltage Rating: ________ V Current Rating: ________ A Fuse sizes: ____________

Automatic or Manual: ______________________ Phases: ______ # of Poles: _____ # of Wires: _____

Measured Voltages	$V_{A\text{-}G}$ = ______ V $V_{A\text{-}N}$ = ______ V	$V_{B\text{-}G}$ = ______ V $V_{B\text{-}N}$ = ______ V	$V_{C\text{-}G}$ = ______ V $V_{C\text{-}N}$ = ______ V	$V_{N\text{-}G}$ = ______ V
Voltage Sine Waves	 $V_{A\text{-}G}$	 $V_{B\text{-}G}$	 $V_{C\text{-}G}$	 $V_{N\text{-}G}$
Harmonic Voltage Distortion	$V_{THD(A\text{-}G)}$ = ____ % 3rd = ______ % 5th = ______ % __th = ______ %	$V_{THD(B\text{-}G)}$ = ____ % 3rd = ______ % 5th = ______ % __th = ______ %	$V_{THD(C\text{-}G)}$ = ____ % 3rd = ______ % 5th = ______ % __th = ______ %	$V_{THD(N\text{-}G)}$ = ____ % 3rd = ______ % 5th = ______ % __th = ______ %
Measured Currents	I_A = ________ A	I_B = ________ A	I_C = ________ A	I_N = ________ A
Current Sine Waves	 I_A	 I_B	 I_C	 I_N
Harmonic Current Distortion	$I_{THD(A)}$ = _____ % 3rd = ______ % 5th = ______ % __th = ______ %	$I_{THD(B)}$ = _____ % 3rd = ______ % 5th = ______ % __th = ______ %	$I_{THD(C)}$ = _____ % 3rd = ______ % 5th = ______ % __th = ______ %	$I_{THD(N)}$ = _____ % 3rd = ______ % 5th = ______ % __th = ______ %

Grounding System	Neutral bus exists? ❑ Yes ❑ No Ground bus exists? ❑ Yes ❑ No Neutral bus bonded to ground bus at the transfer switch? ❑ Yes ❑ No Neutral conductors just run through transfer switch? ❑ Yes ❑ No Ground bus bonded to the frame? ❑ Yes ❑ No Ground bus connected to upstream source ground? ❑ Yes ❑ No Ground bus connected to downstream load ground? ❑ Yes ❑ No Ground resistance measurement: ________ Ω Ground current measurement: ________ A Sketch the existing grounding system (on the back sheet) when it is necessary.
Temperatures	Bus temperatures: ________ °F Conductor temperatures: ________ °F
Power Factor	PF: ______________ Displacement Power Factor (DPF): ______________
Conductor Sizes	Normal source: Phases: ( ) _____ Neutral: ( ) _____ Ground: ( ) _____ Emerg/Standby source: Phases: ( ) _____ Neutral: ( ) _____ Ground: ( ) _____ Load side: Phases: ( ) _____ Neutral: ( ) _____ Ground: ( ) _____

TRANSFER SWITCHES SURVEY *(continued)*

Operation Scheme of Transfer Switch	Make before break? ❑ Yes ❑ No Break before make? ❑ Yes ❑ No Time delay available? ❑ Yes ❑ No
Deficiencies Found	
Problems in the Past	
Customer's Concerns	
Notes	

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H.50

Figure H.50 shows power transformers survey.

Figure H.50 Power Transformers Survey.

POWER TRANSFORMERS SURVEY

Date: ____________________

Installation: ____ Location: ____

Transformer Identification: ___________________________________

Type: ❑ Isolation ❑ Shielded Isolation ❑ Dry ❑ Oil ❑ Pad or Pole Mounted

Number of units: _________ kVA Rating of each unit: _________ Phases: _________ Impedance: _______ %

Load Tap Changing: ❑ Automatic ❑ Manual ❑ None

Cooling System (O/A/FA/etc.): _____________ Nameplate Power Factor: _________ Nameplate "k" Factor: _________

Measured Power Factor: ________ Measured Displacement Power Factor: ________ Measured "k" Factor: ________

	High Voltage Sides				***Low Voltage Sides***			
Voltage Rating	____________ V				____________ V			
Current Rating	____________ A				____________ A			
Wiring Connection	(D/Y/GY): ____________				*(D/Y/GY):* ____________			
Measured Voltages	$V_{A\text{-}B}$	$V_{B\text{-}C}$	$V_{A\text{-}C}$		$V_{a\text{-}n}$	$V_{b\text{-}n}$	$V_{c\text{-}n}$	$V_{n\text{-}g}$
Harmonic Voltages	THD							
	3rd							
	5th							
	_th							
	_th							
Measured Currents	I_A	I_B	I_C		I_a	I_b	I_c	I_n
Harmonic Currents	THD							
	3rd							
	5th							
	_th							
	_th							
Conductor Sizes	Phases: ____ # of Conductors/phase: ____ Neutral: ____ # of Conductors/phase: ____ Ground: ____ # of Conductors: ____				*Phases: ____ # of Conductors/phase: ____* *Neutral: ____ # of Conductors/phase: ____* *Ground: ____ # of Conductors: ____*			

POWER TRANSFORMERS SURVEY *(continued)*

Temperature	Winding temperature range: ________ °F Bus temperature range: ________ °F Enclosure temperature: ________ °F
Physical Conditions	❑ Good condition ❑ Damage ❑ Corrosion ❑ Fluid leakage Proper mounting: _______ Proper clearance: _______ Need maintenance: _______ Sight of burning/overheat (color change): _______
Grounding System	Ground bus connected to transformer frame? ❑ Yes ❑ No Ground bus connected to upstream source ground? ❑ Yes ❑ No Ground bus connected to downstream load ground? ❑ Yes ❑ No Ground bus connected to building metal frame? ❑ Yes ❑ No Ground current measurement: _________ A Ground resistance measurement: _________ Ω
Deficiencies Found	
Problems in the Past	
Customer's Concerns	
Notes	

H.51

Figure H.51 shows uninterruptible power system survey.

Figure H.51 Uninterruptible Power System Survey.

UNINTERRUPTIBLE POWER SYSTEM SURVEY

Date: ____________________

Installation: ____ Location: ____

UPS System Identification: ________________________

Number of modules: ________ Do these modules have the same sizes and characteristics? ❑ Yes ❑ No

Module #1

Manufacturer: ____

Model/Type: ____

Frequencies: Input: ____________ Hz Output: ____________ Hz

Power Factor: Input: ____________ Output: ____________

Wiring Connection: Input: ❑ 3-Phases/3 Wires ❑ 3-Phases/4 Wires ❑ Single-Phase

Output: ❑ 3-Phases/3 Wires ❑ 3-Phases/4 Wires ❑ Single-Phase

Grounding System: Ground Current: ____________ A Ground Resistance: ____________ Ω

Input Voltages: Rated: ______ V Measured $V_{A\text{-}B}$ = ______ V $V_{B\text{-}C}$ = ______ V $V_{A\text{-}C}$ = ______ V

Input Currents: Rated: ______ A Measured I_A = ________ A I_B = ________ A I_C = ________ A

DC Link Voltages: Rated: ______ V Measured $V_{A\text{-}B}$ = ______ V $V_{B\text{-}C}$ = ______ V $V_{A\text{-}C}$ = ______ V

DC Link Currents: Rated: ______ A Measured I_A = ________ A I_B = ________ A I_C = ________ A

Output Voltages: Rated: ______ V Measured $V_{A\text{-}B}$ = ______ V $V_{B\text{-}C}$ = ______ V $V_{A\text{-}C}$ = ______ V

Output Currents: Rated: ______ A Measured I_A = ________ A I_B = ________ A I_C = ________ A

kVA: Rated: ______ Measured Input: ______ ______ ______ Measured Output: ______ ______ ______

kW: Rated: ______ Measured Input: ______ ______ ______ Measured Output: ______ ______ ______

Module #2 (If they are of different sizes/characteristics)

Manufacturer: ____

Model/Type: ____

Frequencies: Input: ____________ Hz Output: ____________ Hz

Power Factor: Input: ____________ Output: ____________

Wiring Connection: Input: ❑ 3-Phases/3 Wires ❑ 3-Phases/4 Wires ❑ Single-Phase

Output: ❑ 3-Phases/3 Wires ❑ 3-Phases/4 Wires ❑ Single-Phase

Grounding System: Ground Current: ____________ A Ground Resistance: ____________ Ω

Input Voltages: Rated: ______ V Measured $V_{A\text{-}B}$ = ______ V $V_{B\text{-}C}$ = ______ V $V_{A\text{-}C}$ = ______ V

Input Currents: Rated: ______ A Measured I_A = ________ A I_B = ________ A I_C = ________ A

DC Link Voltages: Rated: ______ V Measured $V_{A\text{-}B}$ = ______ V $V_{B\text{-}C}$ = ______ V $V_{A\text{-}C}$ = ______ V

DC Link Currents: Rated: ______ A Measured I_A = ________ A I_B = ________ A I_C = ________ A

Output Voltages: Rated: ______ V Measured $V_{A\text{-}B}$ = ______ V $V_{B\text{-}C}$ = ______ V $V_{A\text{-}C}$ = ______ V

Output Currents: Rated: ______ A Measured I_A = ________ A I_B = ________ A I_C = ________ A

kVA: Rated: ______ Measured Input: ______ ______ ______ Measured Output: ______ ______ ______

kW: Rated: ______ Measured Input: ______ ______ ______ Measured Output: ______ ______ ______

UNINTERRUPTIBLE POWER SYSTEM SURVEY *(continued)*

Batteries	Manufacturer:______________ Model:_______ Type:_______ Number of battery banks:________ Number of cells per bank:________ Measured total voltage of each bank:____ ____ ____ ____ ____ V Measured total current of each bank:____ ____ ____ ____ ____ A Battery rack condition: ________ Battery rack properly grounded? ❑ Yes ❑ No Battery bank terminal grounded? ❑ Yes ❑ No Battery bank switch (3 or 4 poles):______ Switch properly grounded? ❑ Yes ❑ No Conductor sizes: Phases: ( ) ____ Neutral: ( ) ____ Ground: ( ) ____ Ground current measurement:____ A Ground resistance measurement:____ Ω Batteries properly mounted? ❑ Yes ❑ No Proper ventilation? ❑ Yes ❑ No Fluid level checked:______ Battery fluid specific gravity last checked: ______ Battery physical conditions: ❑ Damage ❑ Corrosion ❑ Leakage ❑ Need maintenance

Measured Battery Cell Voltages and Fluid Temperatures

See H.45

Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F
Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F
Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F
Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F
Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F
Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F	Cell #___ ___V ___°F

Deficiencies Found	
Notes	

H.52

Figure H.52 shows low-voltage breaker data record.

Figure H.52 Low-Voltage Breaker Data Record.

LOW VOLTAGE BREAKER DATA RECORD

Site: ______ Date: ______ Page: ______

No.	Location	Breaker					Relay								
									Long Time Delay		Short Time Delay		Instant	Ground	
		Mfgr.	Type	Rated Voltage	Frame Rating	Interr. Time	Mfgr.	Type	Range	Bands Avail.	Range	Bands Avail.	Range	Range	Bands Avail.

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H.53

Figure H.53 shows recloser data record.

Figure H.53 Recloser Data Record.

RECLOSER DATA RECORD

Site: ____________ Date: ____________ Page: ____________

No.	Location	CT Ratio	Nominal Voltage	Mfgr.	Type	BIL	Continuous Current Rating	Interruption Rating	Minimum Trip	Hydrau or Electro	Operation Sequence Available	Reclosing Times Available	Tripping Curves Available

NFPA 70B

H.54

Figure H.54 shows generator data record.

Figure H.54 Generator Data Record.

GENERATOR DATA RECORD

Site: ____________________ Date: __________ Page: __________

No.	Location	Type	kVA Rating	Generated Volts	Rated Current	Speed in RPM	Wiring Connections	Subtrans. Impedance	Ground Impedance	Power Factor

Second Revision No. 22-NFPA 70B-2018 [Global Comment]

Revise the following sections to remove usage of the term "nationally recognized testing laboratory (NRTL)":

6.10.4 If it is suspected that the goods are counterfeit, contact the manufacturer ~~or~~ and where labeled, contact the listing organization ~~nationally recognized testing laboratory (NRTL)~~ .

13.2.3.4 Separate test instruments are available that can be used for testing and troubleshooting GFCIs. Such testers should be listed ~~by a nationally recognized testing laboratory~~ to UL 1436, Outlet Circuit Testers and Similar Indicating Devices. Separate GFCI test instruments should not be used to test GFCIs protecting 2-wire circuits — doing so can result in electric shock.

18.1.4.3 Listing. It is important that the fuses bear the ~~listing mark~~ label of a ~~nationally recognized testing laboratory~~ listing organization . Testing laboratories ~~test~~ certify fuses for both ac and dc performance characteristics, and the ratings are marked on the fuse label. Be sure to select the proper fuse for the specific application.

27.2.9 Field modifications of equipment and parts replacement should be limited to those changes acceptable to the manufacturer and approved by the authority having jurisdiction. ~~Normally, modifications to equipment void any listing by nationally recognized testing laboratories.~~

Submitter Information Verification

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Submittal Date: Wed Jan 31 13:30:14 EST 2018

Committee Statement

Committee Statement: "Nationally recognized testing laboratory (NRTL)" is not a term used by NFPA. It is an OSHA term that does not have a clear meaning outside the United States.

Response Message:

Second Revision No. 23-NFPA 70B-2018 [Global Comment]

1) Move Annex D Informational References to a new Annex R (last annex).

2) Merge the content of Annex C Bibliography into D.2 (will be R.2, after the move in item 1).

3) Leave Annex C and Annex D as reserved chapters.

4) Update all references.

Supplemental Information

File Name	Description	Approved
70B_SR23_NEW_Annex_R.docx		

Submitter Information Verification

Submitter Full Name: Barry Chase
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Submittal Date: Wed Jan 31 13:42:04 EST 2018

Committee Statement

Committee Statement: Per the Manual of Style, the Informational References annex is required to be the last annex in the document. In addition, the MOS defines a location for providing a list of useful documents that are not referenced within the document text. Therefore, the content of Annex C is more appropriately located as the X.2 section of the Informational References chapter.

Response Message:

SR 23, NEW Annex R

Changes:

- **Combine content from existing Annex C and Annex D into a new Annex R and update references, as indicated**
- **Annex C and Annex D to be RESERVED, so that existing annex chapters are not renumbered**

~~~~**

Annex ~~D~~ R Informational References

~~D~~R.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this recommended practice and are not part of the recommendations of this document unless also listed in Chapter 2 for other reasons.

~~D~~R.1.1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70®, *National Electrical Code®*, 2017 edition.

~~D~~R.1.2 Other Publications.

~~D~~R.1.2.1 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*, 2016b.

ASTM D1933, *Standard Specification for Nitrogen Gas as an Electrical Insulation Material,* 2003 (revised 2017).

~~D~~R.1.2.2 IEEE Publications.

IEEE, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

ANSI/IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery,* 2013.

IEEE 100CD, *Authoritative Dictionary of IEEE Standards Terms,* 2013.

IEEE 315, *Graphic Symbols for Electrical and Electronics Diagrams,* 1975 (1993).

IEEE 450, *Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2010.

IEEE 1106, *Recommended Practice for Installation, Maintenance, Testing and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2015.

IEEE 1188, *Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 2005 (2010 with 2014 amendment).

IEEE C57.12.00, *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers,* ~~2015~~2016.

R.1.2.3 International Electrotechnical Commission (IEC).

3 rue de Varembé, P.O. Box 131, 1211 Geneva 20, Switzerland. (In the United States, IEC Publications are available from American National Standards Institute, ANSI.)

IEC 60076-2, *Power Transformers — Part 2: Temperature Rise for Liquid-Immersed Transformers,* ~~, 3rd edition,~~ 2011.

~~D~~R.1.2.~~3~~ 4 NETA Publications.

InterNational Electrical Testing Association, 3050 Old Centre Ave., Suite 102, Portage, MI 49024.

ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems,* 2015.

~~D~~R.1.2.~~4~~ 5 Other Publications.

~~IEC 60076-2, *Power Transformers — Part 2: Temperature Rise for Liquid-Immersed Transformers,* , 3rd edition, 2011.~~

Leiter, David, *Distributed Energy Resources,* U.S. Department of Energy for Fuel Cell Summit IV, Washington, DC, May 10, 2000.

MIL-HNDK-508, *Wiring and Wiring Devices for Combat and Tactical Vehicles, Selection and Installation of*, April 21, 1998, available from DLA Document Services, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. (Supersedes MIL-STD-339)

~~RAC Publications,~~ *Reliability Tool~~-~~Kit,* RAC Publications, ~~page 12~~1995.

~~D~~R.2 Informational References.

The following documents or portions thereof are listed here as informational resources only. They are not a part of the recommendations of this document.

~~**C.1.1**~~

This bibliography lists some of the more widely recognized sources of maintenance and testing information. Because they are so numerous, many excellent textbooks by individual authors are not listed; information on them is available from the various publishers.

~~**C.1.2**~~

For those who are interested in implementing an effective EPM program or improving an existing one, a suitable reference library should be readily available. The size of the plant and the extent of its maintenance and servicing operations will determine the desired publications for the reference library.

~~**C.1.3**~~

The need to use the manufacturer's service manuals and instructions furnished with specific equipment or apparatus has been previously mentioned and cannot be overemphasized. Additionally, there are many sources of helpful information on general and specific maintenance, troubleshooting, test methods, test instruments, and their use. Some of these are available without cost, but most entail a nominal charge. Publishers of technical and trade magazines are another important source of pertinent literature. Some can provide, without charge, reprints of specific articles, or, for a nominal fee, a compilation of reprints of articles on a particular subject.

~~C.1.3~~R.2.1 American Petroleum Institute (API).

1220 L St. NW, Washington, DC 20005-4070.

Guide for Inspection of Refinery Equipment, Chapter XIV, Electrical Systems, Third edition, ~~1978~~1982 (withdrawn).

~~C.1.3~~R.2.2 Eaton's **Crouse-Hinds Division.**

~~P.O. Box 4999~~1201 Wolf Street, Syracuse, NY ~~13221~~13208.

Crouse-Hinds 2017 Code Digest, ~~*Suggestions for Installation and Maintenance of Electrical Equipment for Use in Hazardous Areas*~~*Article 500-516 of the National Electrical Code with product recommendations for use in hazardous (classified) areas*, ~~2011~~2017.

~~C.1.3~~R.2.3 ~~Factory Mutual Engineering Corporation~~FM Global.

1151 Boston-Providence Turnpike, Norwood, MA 02061.

~~*Handbook of Industrial Loss Prevention*~~*FM Global Data Sheets*, ~~Chapter 32, 1968~~www.fmglobal.com/datasheets.

~~D.2.1~~R.2.4 IEEE Publications.

IEEE, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

ANSI/IEEE 1100, *Recommended Practice for Powering and Grounding Electronic Equipment,* 2005.

~~**C.1.3.4 IEEE.**~~

~~445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.~~

ANSI/IEEE 67, *Guide for Operation and Maintenance of Turbine Generators,* 2005.

ANSI/IEEE 315 (ANSI Y32.2-75), *Graphic Symbols for Electrical and Electronics Diagrams,* 1975, reaffirmed 1993.

ANSI/IEEE 432, *Guide for Insulation Maintenance for Rotating Electrical Machinery (5 HP to less than 10,000 HP),* 1992 (withdrawn).

IEEE 1458, *Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded Case Circuit Breakers for Industrial Applications*, 2017.

IEEE 1250, *IEEE Guide for Identifying and Improving Voltage Quality in Power Systems*, 2011.

IEEE 1409, *Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV Through 38 kV,* 2012.

IEEE 1453, *IEEE Recommended Practice — Adoption of IEC 61000-4-15:2010, Electromagnetic compatibility (EMC) — Testing and measurement techniques — Flickermeter — Functional and design specifications*, 201~~1~~5.

IEEE 1564, ~~*Draft*~~ *Guide for Voltage Sag Indices, 2014.* ~~*Power Quality Analysis, NJATC*, 2011.~~

IEEE C37.41, *Standard Design Tests for High-Voltage (>1000 V) Fuses*~~*, Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Fuse Links*~~ *and Accessories*~~*Used with These Devices*~~, ~~2008~~2016.

ANSI/IEEE C37.95, *Guide for Protective Relaying of Utility-Consumer Interconnections*, ~~2002~~2014.

IEEE C37.96, *Guide for AC Motor Protection,* 2012.

IEEE C57.94, *Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type* ~~*General Purpose*~~ *Distribution and Power Transformers,* ~~1982, reaffirmed 1987~~2015.

ANSI/IEEE C57.106, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment,* ~~2006~~2015.

IEEE C57.111, *Guide for Acceptance and Maintenance of Silicone Insulating Fluid and Its Maintenance in Transformers,* ~~1989~~2009.

ANSI/IEEE C57.121, *Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* 1998 (2009).

~~C.1.3~~R.2.5 International Electrotechnical Commission (IEC).

3 rue de Varembé, P.O. Box 131, 1211 Geneva 20, Switzerland. (In the United States, IEC Publications are available from American National Standards Institute, ANSI.)

IEC No. 60417-DB-HS, *Graphical Symbols for Use on Equipment,* 2008.

~~C.1.3~~R.2.6 McGraw-Hill Publishing Co.

1221 Avenue of the Americas, New York, NY 10020.

D. Beeman, *Industrial Power Systems Handbook*.

E. W. Boozer, *Motor Applications and Maintenance Handbook*.

C. I. Hubert, *Preventative Maintenance of Electrical Equipment*.

Dugan, R. C., M. F. McGranaghan, S. Santoso, and H. W. Beaty, *Electrical Power Systems Quality*~~, McGraw Hill~~, 3rd Edition, 20~~02~~12.

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~~C.1.3~~R.2.7 National Electrical Contractors Association (NECA).

3 Bethesda Metro Center, Suite 1100, Bethesda, MD 20814-5372.

Total Energy Management — A Practical Handbook on Energy Conservation and Management, Index No. 2095.

~~C.1.3~~R.2.8 National Electrical Manufacturers Association (NEMA).

1300 North 17th Street, Suite 1847, Rosslyn, VA 22209.

NEMA 280, *Application Guide for Ground-Fault Circuit Interrupters* (see Section 7, Field Test Devices, and Section 8, Field Troubleshooting), 1990.

NEMA AB 3, *Molded Case Circuit Breakers and Their Application*, ~~2012~~2013.

NEMA ICS 1.3, *Preventive Maintenance of Industrial Control and Systems Equipment*, 1986~~, reaffirmed 2009~~ (R2015).

NEMA ICS 2.3, *Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers Rated Not More Than 600 Volts,* 1995~~, reaffirmed 2008~~ (R2008).

NEMA ICS 7, ~~*Industrial Control and Systems*~~ *Adjustable ~~—~~Speed Drives,* ~~2006~~2014.

ANSI/NEMA MG 2, *Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators* (see Section 8.3, Maintenance), ~~2001, reaffirmed 2007~~2014.

NEMA PB 1.1, *General Instructions for Proper Installation, Operation~~,~~ and Maintenance of Panelboards Rated ~~at~~ 600 V~~olts~~ or Less,* ~~2012~~2013.

NEMA GD 1, *Evaluating Water-Damaged Electrical Equipment,* ~~2011~~2016.

~~C.1.3~~R.2.9 National Safety Council (NSC).

60611 1121 Spring Lake Drive, Itasca, IL 60143.

~~NSC 129.46,~~ *Electrical Inspection~~s~~ Illustrated*, 3rd edition, 2011.

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~~NSC 635, *Lead-Acid Storage Batteries.*~~

~~C.1.3~~R.2.10 U.S. Department of the Army.

U.S. Army Corps of Engineers, 441 G Street NW, Washington, D.C. 20314-1000.

TM-5-682, *Electrical Safety, Facilities Engineering U.S. Army,* November 1999.

TM-5-683, *Electrical Interior, Facilities Engineering U.S. Army,* November 1995.

TM-5-684, *Electrical Exterior, Facilities Engineering U.S. Army,* November 1996.

TM-5-685, *Operation, Maintenance and Repair of Auxiliary Generators U.S. Army,* August 1996.

TM 5-686, *Power Transformer Maintenance and Acceptance Testing,* November 1998.

TM 5-688, *Foreign Voltages and Frequencies Guide,* November 1999.

TM 5-691, *Utility Systems Design Requirements for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities,* December 2000.

TM 5-692-1, *Maintenance of Mechanical and Electrical Equipment at Command, Control Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities-Recommended Maintenance Practices,* April 2001.

TM 5-692-2, *Maintenance of Mechanical and Electrical Equipment at Command, Control Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities-System Design Features,* April 2001.

~~C.2~~R.2.11 ~~Power Quality~~Other References.

~~*Electrical Power Systems Quality*, McGraw Hill, 2002.~~

~~IEEE 1250, *IEEE Guide for Identifying and Improving Voltage Quality in Power Systems*, 2011.~~

~~IEEE 1409, *Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV Through 38 kV*, 2012.~~

~~IEEE 1453, *IEEE Recommended Practice — Adoption of IEC 61000-4-15:2010, Electromagnetic compatibility (EMC) — Testing and measurement techniques — Flickermeter — Functional and design specifications*, 2011.~~

~~IEEE 1564, *Draft Guide for Voltage Sag Indices, 2014. Power Quality Analysis, NJATC*, 2011.~~

Power Quality Analysis, NJATC, ~~2011~~2010.

~~D~~R.3 References for Extracts in Informational Sections.

NFPA 70®, *National Electrical Code®*, 2017 edition.

Second Revision No. 6-NFPA 70B-2018 [Sections 2.2, 2.3]

2.2 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70®, *National Electrical Code®*, 2017 edition.

NFPA *70E®*, *Standard for Electrical Safety in the Workplace®*, 2018 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems,* 2019 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2017 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2017 edition.

NFPA 791, *Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation,* 2018 edition.

NFPA 1600®, *Standard on Disaster/Emergency Management and Business Continuity/Continuity of Operations Programs,* 2019 edition.

2.3 Other Publications.

2.3.1 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester,*~~2016a~~ 2016b .

ASTM D445, *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids and Calculation of Dynamic Viscosity,*~~2015a~~ 2017a .

ASTM D664, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration,*~~2011e1~~ 2017 .

ASTM D877/D877M, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes,* 2013.

ASTM D923, *Standard Practices for Sampling Electrical Insulating Liquids,* 2015.

ASTM D924, *Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids,* 2015.

ASTM D971, *Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method,* 2012.

ASTM D974, *Standard Test Methods for Acid and Base Number by Color-Indicator Titration,* 2014e2.

ASTM D1298, *Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method,* 2012b (2017) .

ASTM D1500, *Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale),* 2012 (2017) .

ASTM D1524, *Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field,* 2015.

ASTM D1533, *Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration,* 2012.

ASTM D1816, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes,* 2012.

ASTM D2129, *Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale),*~~2005 (2010)~~ 2017 .

ASTM D2472, *Standard Specification for Sulfur Hexafluoride,* 2015.

ASTM D3284, *Standard Practice for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters,* 2005 (2011).

ASTM D3612, *Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography,* 2002 (2009).

2.3.2 EASA Publications.

Electrical Apparatus Service Association, Inc., 1331 Baur Blvd, St. Louis, MO 63132.

ANSI/EASA AR100, *Recommended Practice for the Repair of Rotating Electrical Apparatus,* 2015.

2.3.3 IEEE Publications.

IEEE, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery,* 2013.

IEEE 80, *Guide for Safety in AC Substation Grounding,* 2013.

IEEE 81, *Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Ground System,* 2012.

IEEE 95, *Recommended Practice for Insulation Testing of AC Electric Machinery (2300 V and Above) with High Direct Voltage,*2002 , reaffirmed 2012.

IEEE 141, *Recommended Practice for Electric Power Distribution for Industrial Plants,* 1993, revised 1999.

IEEE 142, *Recommended Practice for Grounding of Industrial and Commercial Power Systems,* 2007, Errata, 2014.

IEEE 241, *Recommended Practice for Electric Power Systems in Commercial Buildings,* 1990.

IEEE 242, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems,* 2001, Errata, 2003.

IEEE 399, *Recommended Practice for Industrial and Commercial Power Systems Analysis,* 1997.

IEEE 400, *Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems,* 2012.

IEEE 400.1, *Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage,*~~2007~~ 2017 .

IEEE 400.2, *Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) Less Than 1 Hertz,* 2013.

IEEE 400.3, *Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment,*~~2015~~ 2006 .

ANSI/IEEE 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications,* 1995, revised 2000.

ANSI/IEEE 450, *Recommended Practice for Maintenance, Testing and Replacement of Vented Lead-Acid Batteries for Stationary Applications,* 2010.

ANSI/IEEE 493, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems,* 2007.

ANSI/IEEE 519, *Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems,* 2014.

~~IEEE 637, *Guide for Reclamation of Insulating Oil and Criteria for Its Use,* 1985. (Superseded by IEEE C57.637.)~~

IEEE 1100, *Recommended Practice for Powering and Grounding Electronic Equipment,* 2005.

IEEE 1106, *Recommended Practice for Installation, Maintenance, Testing and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications,* 2015.

~~ANSI/IEEE 1125, *Guide for Moisture Measurement and Control in* SF_6 *Gas-Insulated Equipment* , 1993, revised 2000. (Superseded by IEEE C37.122.5.)~~

IEEE 1159, *Recommended Practice on Monitoring Electric Power Quality*, 2009.

IEEE 1188, *Recommended Practice for Maintenance, Testing and Replacement of Valve-Regulated Lead Acid (VRLA) Batteries for Stationary Applications,* 2005 (r2010 with 2014 amendment).

IEEE 1578, IEEE *Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management*, 2007.

IEEE 1584™, *Guide for Performing Arc Flash Hazards Calculations*, 2002 (with Amendment 1 and 2).

IEEE 1657, *IEEE Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries*, 2009 (2015 amendment).

IEEE 3007.1, *IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems* , 2010.

IEEE 3007.2, *IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems*, 2010.

IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems* , 2012.

IEEE C2, *National Electrical Safety Code®(NESC®),* 2017.

ANSI/IEEE C37.13, *Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures*, 2015.

IEEE C37.20.1, *Standard for Metal-Enclosed Low-Voltage (1000 Vac and Below, 3200 Vdc and Below) Power Circuit Breaker Switchgear*, 2015.

IEEE C37.23, *Standard for Metal-Enclosed Bus*, 2015.

IEEE C37.122.1, *IEEE Guide for Gas-Insulated Substations Rated Above 52 kV*, 2014.

IEEE C37.122.5, *Guide for Moisture Measurement and Control* SF_6 *Gas-Insulated Equipment*, 2013.

ANSI/IEEE C57.104, *Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers*, 2008.

ANSI/IEEE C57.106, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment,* 2015.

ANSI/IEEE C57.110, *Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents,* 2008.

ANSI/IEEE C57.111, *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers,*~~1995 (~~ 2009~~)~~ .

ANSI/IEEE C57.121, *Guide for Acceptance and Maintenance of Less-Flammable Hydrocarbon Fluid in Transformers,* 1998 (2009) .

IEEE C57.637, *Guide for the Reclamation of Mineral Insulating Oil and Criteria for its Use*, 2015.

2.3.4 ITI Publications.

Information Technology Industry Council, 1101 K Street, NW, Suite 610, Washington, DC 20005. http://www.itic.org.

ITI (CBEMA) Curve Application Note, 2000.

2.3.5 NEMA Publications.

National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209.

Evaluating Water-Damaged Electrical Equipment, ~~2014~~ 2016 .

Evaluating Fire- and Heat-Damaged Electrical Equipment, ~~2013~~ 2016 .

ANSI/NEMA AB 4, *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*, ~~2009~~ 2017 .

ANSI/NEMA C84.1, *Electric Power Systems and Equipment, Voltage Ratings (60 Hertz),*~~2011~~ 2016 .

~~ANSI/NEMA KS 3, *Guidelines for Inspection and Preventive Maintenance of Switches Used in Commercial and Industrial Applications,* 2010.~~

NEMA MG 1, *Motors and Generators*, ~~2016~~ 2017 .

ANSI/NEMA PB 2.1, *General Instructions for Proper Handling, Installation, Operation, and Maintenance of Dead Front Distribution Switchboards Rated 600 Volts or Less,* 2013.

ANSI/NEMA WD 6, *Wiring Devices — Dimensional Specifications*, 2016.

2.3.6 NETA Publications.

InterNational Electrical Testing Association, 3050 Old Centre Ave., Suite 102, Portage, MI 49024.

ANSI/NETA ATS, *Standard for Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*, 2017.

ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, 2015.

2.3.7 OSHA Publications.

Occupational Safety and Health Administration, 200 Constitution Ave., NW, Washington, DC 20210.

OSHA Safety & Health Information Bulletin (SHIB), "Certification of Workplace Products by Nationally Recognized Testing Laboratories," 02-16-2010.

2.3.8 UL Publications.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures*, ~~Twelfth edition, 2013~~ 2016 .

~~ANSI/UL 943, *Standard for Ground-Fault Circuit Interrupters* , 5th edition, 2016.~~

UL 1066, *Standard for Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures* , 2012.

UL 1436, *Outlet Circuit Testers and Similar Indicating Devices*, ~~Fifth edition, 2014~~ 2016 .

UL Firefighter Safety and Photovoltaic Installations Research Project, November 2011.

2.3.9 U.S. Government Publications.

U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Energy Policy Act of 1992, HR 776, 102nd Congress, 10/24/1992.

Federal Emergency Management Agency (FEMA), FEMA P-348, *Protecting Building Utilities from Flood Damage*, 1999 updated 2012.

~~Title 29, *Code of Federal Regulations,* Part 1910.~~

Title 15, *United States Code,* Chapter 53, Toxic Substances Control Act, Environmental Protection Agency.

Title 29, *Code of Federal Regulations,* Part 1910.~~94(a), "Occupational Health and Environmental Control — Ventilation."~~

Title 29, *Code of Federal Regulations,* Part 1910.94(a), "Occupational Health and Environmental Control — Ventilation."

Title 29, *Code of Federal Regulations,* Part 1910.146, "Permit-Required Confined Spaces."

Title 29, *Code of Federal Regulations,* Part 1910.242(b), "Hand and Portable Powered Tools and Other Hand Held Equipment."

Title 29, *Code of Federal Regulations,* Part 1910.269, "Electric Power Generation, Transmission, and Distribution," Paragraph (e), Enclosed Spaces.

~~Title 29, *Code of Federal Regulations* , Part 1910.331 through Part 1910.335, "Safety Related Work Practices."~~

Title 29, *Code of Federal Regulations*, Part 1926.

Title 40, *Code of Federal Regulations*, Part 761, "Protection of Environment — Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions."

TM 5-694, *Commissioning of Electrical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities,* 2006.

TM 5-698-1, *Reliability/Availability of Electrical and Mechanical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*, 2007.

TM 5-698-2, *Reliability-Centered Maintenance (RCM) for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities,* 2006.

TM 5-698-3, *Reliability Primer for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities,* 2005.

~~Toxic Substances Control Act, Environmental Protection Agency, www.epa.gov/agriculture/lsca.html.~~

U.S. General Services Administration and U.S. Department of Energy, *Building Commissioning Guide,* 2009.

2.3.10 Other Publications.

ABB Power T & D Company, Inc., *Instruction Book PC-2000 for Wecosol ^{TM} Fluid-Filled Primary and Secondary Unit Substation Transformers*.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

Penn-Union Catalog, http://www.penn-union.com/Services/Literature.

PowerTest Annual Technical Conference, Flood Repair of Electrical Equipment, Pat Beisert, Shermco Industries, March 12, 2009.

Square D Catalog, Schneider Electric, www.schneider-electric.com/us.

Square D Services, *Procedures for Startup and Commissioning of Electrical Equipment*, PDF available at http://www.schneider-electric.us/en/download/document/0180IB0001/

Submitter Information Verification

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Submittal Date: Mon Jan 29 16:22:17 EST 2018

Committee Statement

Committee Statement: The referenced publications have been updated, per the Manual of Style.

Response Message:

Second Revision No. 7-NFPA 70B-2018 [Section No. 3.3.1]

3.3.1 Arc Flash Hazard.

A ~~dangerous condition~~ source of possible injury or damage to health associated with the possible release of energy caused by an electric arc. [***70E***, 2018]

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Committee Statement

Committee Statement: The extracted text is updated.
Response Message:

Second Revision No. 24-NFPA 70B-2018 [Section No. 3.3.63]

3.3.63 Risk Assessment.

~~A study investigating a worker's potential exposure to arc flash energy, conducted for the purpose of injury prevention and the determination of safe work practices, arc flash boundary, and the appropriate levels of personal protective equipment (PPE).~~ An overall process that identifies hazards, estimates the likelihood of occurrence of injury or damage to health, estimates the potential severity of injury or damage to health, and determines if protective measures are required. [***70E*, **2018]

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Committee Statement

Committee Statement: The extracted definition is updated per the 2018 edition of NFPA 70E.
Response Message:

Second Revision No. 11-NFPA 70B-2018 [Section No. 7.1.2]

7.1.2

NFPA *70E*; ~~ANSI/Accredited Standards Committee~~ IEEE C2, *National Electrical Safety Code*; IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems* ; and OSHA 29 CFR 1926 and 1910 are among the references that should be utilized for the development of programs and procedures associated with maintenance activities, and are necessary to be used in conjunction with this document.

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Committee Statement

Committee Statement: The additional referenced IEEE standard is a complement to NFPA 70E.
Response Message:

Second Revision No. 12-NFPA 70B-2018 [Section No. 8.1.1 [Excluding any Sub-Sections]]

Equipment should be deenergized for inspections, tests, repairs, and other servicing. Where maintenance tasks must be performed when the equipment is energized, provisions are to be made to allow maintenance to be performed safely. Refer to NFPA *70E*, IEEE 3007.1, *IEEE Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems* ; IEEE 3007.2, *IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems* ; and IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems* . For the purposes of this chapter, *deenergized* means the equipment has been placed in an electrically safe work condition in accordance with 7.1.3.2. See Chapter 7 for examples of typical safety-related work practices that might need to be implemented.

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Committee Statement

Committee Statement: The additional referenced IEEE standards are complements to NFPA 70E.
Response Message:

Second Revision No. 9-NFPA 70B-2018 [Section No. 9.3.1.2]

9.3.1.2

NFPA 70 and various IEEE standards contain the requirements and suggested practices to coordinate electrical systems. The IEEE standards include ANSI/IEEE 242, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)*; ANSI/IEEE 141, *Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book)*; ANSI/IEEE 241, *Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book)*; and ANSI/IEEE 399, *Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book)*. *(See A.9.2.1.2 .)*

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Committee Statement

Committee Statement: The references to the IEEE "color book" standards have been retained in the main body text, because the "dot" standards available at this time do not cover the entire scope of the existing "color book" standards. This annex material has been updated to alert the user to the availability of some of the "dot" standards.

Annex A.9.3.1.2 has been deleted.

Response Message:

Second Revision No. 13-NFPA 70B-2018 [Section No. 9.6.1.1]

9.6.1.1

A risk assessment study is an important consideration for electrical safe work practices. Refer to NFPA *70E*and IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems* , for guidance on risk assessment and selection of PPE.

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Committee Statement

Committee Statement: The additional referenced IEEE standard is a complement to NFPA 70E.
Response Message:

Second Revision No. 5-NFPA 70B-2018 [Sections 9.7.1, 9.7.2, 9.7.3]

9.7.1

A maintenance-related design study ~~uses~~ should develop design options that eliminate or reduce hazards or reduce risk for maintenance or daily operations. This study should use input that can include the electrical system design, the equipment maintenance instructions, and the company's historical maintenance data, as well as results of other available studies such as reliability and risk assessment studies. The study ~~as input and evaluates~~ should evaluate design and operational concepts for electrical equipment and installations that impact the safety of maintenance practices~~. The objective is to develop design options that eliminate or reduce hazards or reduce risk.~~ and then make recommendations for improvement. Facilities management ~~can~~ should use this study to ~~assist in making~~ make implementation decisions ~~on implementing changes~~ . Design considerations to enhance operations should include the entire life cycle cost of the building or system. The initial cost for efficient use of energy and for providing an efficient maintenance environment should be considered as valuable long-term investments that support daily operations. Workspaces and systems should be designed to ~~the electrical equipment~~ allow safe maintenance or urgent repair while other operations continue. System-monitoring equipment can be used for planning predictive maintenance and help prevent unplanned outages .

9.7.2

A maintenance-related design study should include an evaluation of various maintenance-related design element options such as, but not limited to, the following:

(1) Sufficient clearances to remove and install drawout circuit breakers

(2) Remote operating controls and remote racking for circuit breakers

(3) Lift mechanisms to allow safe removal of drawout circuit breakers

(4) Motor control centers having the capability to rack individual buckets in or out remotely

(5) Permanently mounted absence-of-voltage testers

(6) Perform an incident energy analysis in addition to short circuit and coordination studies

(7) Design redundancy into the electrical power system to facilitate personnel to perform maintenance on equipment in an electrically safe work condition and still power the loads

(8) Motor overload relays that can be reset without exposing the worker to energized conductors or circuit parts

(9) Infrared windows to allow for testing and inspection without exposing workers to energized parts

(10) Thermal sensors for critical terminations, ultrasonic sensors in medium-voltage equipment, and partial discharge monitoring of critical cables and equipment

(11) Automatic transfer switches having maintenance bypass switches

9.7.3

After the risk assessment study in Section 9.6 is ~~completed, a maintenance-related design study should be performed~~ complete. Annex O of NFPA *70E* should be referenced for additional items that could be evaluated in the maintenance-related design study .

~~**9.7.4**~~

~~For more information, see the safety-related design requirements in Informative Annex O of *NFPA 70E* .~~

Supplemental Information

File Name	Description	Approved
Sections_9.7.1_through_9.7.3_track_changes.docx	legislative changes - for staff use	

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Committee Statement

Committee Statement: The revised text clarifies what constitutes a maintenance-related design study and provides examples of what should be evaluated.

Response Message:

Public Comment No. 6-NFPA 70B-2017 [Sections 9.7.1, 9.7.2, 9.7.3]

Second Revision No. 18-NFPA 70B-2018 [Section No. 10.8.5]

10.8.5 Solutions.

Once the nature of noise disturbance is determined, the best solution is to isolate and eliminate the source. Unfortunately, the source of the noise cannot always be located or the offending piece of equipment removed. In these cases, the noise should be attenuated or filtered out of the system. Some methods of attenuating or filtering out noise ~~are listed below.~~ <u>could include the following:</u>

(1) ~~This is a~~ <u>A</u> special type of grounding system designed for data processing installations. When properly installed, it provides the lowest possible ground impedance across the widest spectrum of frequencies. The grid places the entire data processing ground system at a common potential.

(2) Transformers equipped with multiple electrostatic shields <u>that</u> can significantly attenuate transverse and common mode noise.

(3) Filtering can be low-pass, high-pass, band-pass, or notch type. Once the frequency and amplitude of the noise signal is determined, a filter can be tuned to “trap” the unwanted noise signal.

~~Transformers equipped with multiple electrostatic shields can significantly attenuate transverse and common mode noise.~~

(4) The use of twisted pair and shields in low-power signal cables can effectively reduce noise.

(5) Plane shielding mounted on walls, floors, or ceilings can reduce radiated noise if properly grounded.

~~**10.8.5.1** Elimination.~~

~~Once the nature of noise disturbance is determined, the best solution is to isolate and eliminate the source. Unfortunately, the source of the noise cannot always be located or the offending piece of equipment removed. In these cases, the noise should be attenuated or filtered out of the system. Some methods of attenuating or filtering out noise are listed below.~~

~~**10.8.5.2** Signal Reference Grid.~~

~~This is a special type of grounding system designed for data processing installations. When properly installed, it provides the lowest possible ground impedance across the widest spectrum of frequencies. The grid places the entire data processing ground system at a common potential.~~

~~**10.8.5.3** Isolation Transformers.~~

~~Transformers equipped with multiple electrostatic shields can significantly attenuate transverse and common mode noise.~~

~~**10.8.5.4** Filters.~~

~~Filtering can be low-pass, high-pass, band-pass, or notch type. Once the frequency and amplitude of the noise signal is determined, a filter can be tuned to “trap” the unwanted noise signal.~~

~~**10.8.5.5** Signal Cable.~~

~~The use of twisted pair and shields in low-power signal cables can effectively reduce noise.~~

~~**10.8.5.6** Shielding.~~

~~Plane shielding mounted on walls, floors, or ceilings can reduce radiated noise if properly grounded.~~

Supplemental Information

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Committee Statement

Committee Statement: The section is reformatted as a numbered list to correlate with the format of the previous paragraphs in this section.

Response Message:

Second Revision No. 20-NFPA 70B-2018 [Section No. 11.10.1]

11.10.1 Low-Voltage Circuit Breakers — General.

Low-voltage circuit breakers generally can be divided into the following two categories depending on the applicable industry design standards:

(1) Insulated-case/molded-case circuit breakers are designed, tested, and evaluated in accordance with ANSI/UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures*.

(2) Low-voltage power circuit breakers are designed, tested, and evaluated in accordance with ~~NEMA SG 6,~~ ~~*Power Switching Equipment*~~ ANSI/UL 1066, *Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures* , and ANSI/IEEE C37.13, *Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures*.

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Committee Statement

Committee Statement: NEMA SG 6 has been rescinded and is replaced with UL 1066.
Response Message:

Second Revision No. 1-NFPA 70B-2018 [Section No. 11.10.2.3]

11.10.2.3

~~The testing of electromechanical trip devices or solid-state devices~~ If testing by the primary injection method ~~requires the use of~~ is performed, utilize a high-current test set capable of producing sufficient current at low voltage to operate each of the elements of the trip device. This test should have means of adjusting the amount of current applied to the trip device and a cycle and second timer to measure the amount of time to trip the breaker at each current setting. At least one test should be made in the range of each element of the trip device. The long time-delay element ordinarily should be tested at approximately 300 percent of its setting. The short time-delay element should be tested at 150 percent to 200 percent of its setting. The instantaneous element should be tested for pickup. For the test of the instantaneous element, the applied current should be symmetrical without an asymmetrical offset, or random errors will be introduced. As-found and as-left tests should be performed if any need of adjustments is found.

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Committee Statement

Committee Statement: The section addresses how primary current injection is to be performed, not "if" it is required. This section is not intended to provide guidance on when such testing, or any other type, is to be used.

Response Message:

Public Comment No. 4-NFPA 70B-2017 [Section No. 11.10.2.3]

Second Revision No. 2-NFPA 70B-2018 [Section No. 11.10.5.1.1]

11.10.5.1.1

Insulated-case/molded-case circuit breakers are available in a wide variety of sizes, shapes, and ratings. Voltage ratings~~, by standard definitions, are limited to 600 volts, although special applications have been made to 1000 volts. Current ratings are available from 10 amperes through 4000 amperes~~ <u>up to 1000 volts ac or 1500 volts dc and current ratings up to 6000 amperes are available</u> . Insulated-case/molded-case circuit breakers can be categorized generally by the types of trip units employed as described in Section 17.5.

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Committee Statement

Committee Statement: The paragraph is revised to be more technically accurate with respect to modern circuit breakers available in the market.

Response Message:

Second Revision No. 3-NFPA 70B-2018 [Section No. 11.10.5.2.6]

11.10.5.2.6

Testing the instantaneous (magnetic) element of a trip unit requires the use of elaborate constant rate-of-rise the appropriate test equipment coupled with accurate current-monitoring instrumentation, preferably with digital readouts , for accurate confirmation of manufacturers' test results. Unless this type of equipment is available, it is recommended that these breakers be referred to the manufacturer, electrical contractor, or other competent service organization when calibration is required. Instantaneous pickup values of insulated-case/molded-case circuit breakers should fall within the manufacturer's published tolerances. In the absence of manufacturer's published tolerances, refer to Table 11.10.5.2.6 with values as recommended in Table 4 of ANSI/NEMA AB4, *Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications*.

Table 11.10.5.2.6 Instantaneous Trip Tolerances for Field Testing of Circuit Breakers

		Tolerances of Manufacturers' Published Trip Range	
Breaker Type	**Tolerances of Settings**	**High Side**	**Low Side**
Electronic trip units*	+30%	—	—
	−30%	—	—
Adjustable*	+40%	—	—
	−30%	—	—
Nonadjustable†	—	+25%	−25%

*Tolerances are based on variations from the nominal settings.

†Tolerances are based on variations from the manufacturer's published trip band (i.e., −25 percent below the low side of the band, +25 percent above the high side of the band).

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Committee Statement

Committee Statement: The reference to "elaborate constant rate-of-rise" test equipment was deleted because not all test equipment is constant rate-of-rise and "elaborate" is not a defined term.

The second sentence was deleted as it did not provide useful information in this context. The availability of appropriate equipment is an overarching concern throughout the document and should not be stated in individual sections.

Response Message:

Public Comment No. 2-NFPA 70B-2017 [Section No. 11.10.5.2.6]

Second Revision No. 4-NFPA 70B-2018 [Section No. 11.10.5.3]

11.10.5.3 Testing Instantaneous-Only Circuit Breakers.

The testing of instantaneous-only circuit breakers requires the use of ~~elaborate constant rate-of-rise~~ <u>the appropriate</u> test equipment ~~appropriate for the purpose~~ coupled with accurate current-monitoring instrumentation, preferably <u>with a</u> digital readout, for accurate ~~confirmation of manufacturers'~~ test results. ~~Unless this type of equipment is available, it is recommended that these breakers be referred to the manufacturer, electrical contractor, or other competent service organization when calibration is required.~~ Instantaneous pickup values of insulated-case/molded-case circuit breakers should fall within the manufacturer's published tolerances.

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Committee Statement

Committee Statement: The reference to "elaborate constant rate-of-rise" test equipment was deleted because not all test equipment is constant rate-of-rise and "elaborate" is not a defined term.

The second sentence was deleted as it did not provide useful information in this context. The availability of appropriate equipment is an overarching concern throughout the document and should not be stated in individual sections.

Response Message:

Public Comment No. 5-NFPA 70B-2017 [Section No. 11.10.5.3]

Second Revision No. 25-NFPA 70B-2018 [Section No. 11.19 [Excluding any Sub-Sections]]

Regular semiannual tests should be made on insulating oils and askarels. Samples should be taken from the equipment in accordance with ASTM D923, *Standard Test Method for Sampling Electrical Insulating Liquids*. The maintenance tests most commonly performed on used insulating liquids, together with the appropriate ASTM test methods, are shown in Table 11.19(a) through Table 11.19(g).

Table 11.19(a) Suggested Limits for Class I Insulating Oil

-	Mineral Oil[a]			
-	-	-	Acceptable Values	
Test	ASTM Method	69 kV and Below	Above 69 kV – Below 230 kV	230 kV and Above
Dielectric breakdown, kV minimum[b]	D877	26	26	26
Dielectric breakdown, kV minimum @ 1 mm (0.04 in.) gap	D1816	23	28	30
Dielectric breakdown, kV minimum @ 2 mm (0.08 in.) gap	D1816	40	47	50
Interfacial tension mN/m minimum	D971	25	30	32
Neutralization number, mg KOH/g maximum	D974	0.2	0.15	0.10
Water content, ppm maximum @ 60°C (140°F) [c]	D1533	35	25	20
Power factor at 25°C (77°F) , %	D924	0.5	0.5	0.5
Power factor at 100°C (212°F) , %	D924	5.0	5.0	5.0
Color[d]	D1500	3.5	3.5	3.5
Visual condition	D1524	Bright, clear, and free of particles	Bright, clear, and free of particles	Bright, clear, and free of particles
Specific gravity (relative density) @ 15°C (59°F) maximum[e]	D1298	0.91	0.91	0.91

[a]ANSI/IEEE C57.106-2002 , *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 7.

[b]IEEE STD C57. 637-1985 , *Guide for Reclamation of Insulating Oil and Criteria for Its Use*, Table 1.

[c]ANSI/IEEE C57.106-2002 , *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 5.

[d]In the absence of consensus standards, NETA's Standard Review Council suggests these values.

[e]ANSI/IEEE C57.106, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 1.

Table 11.19(b) Suggested Limit for Less-Flammable Hydrocarbon Insulating Liquid

Test	ASTM Method	Acceptable Values
Dielectric breakdown voltage, kV minimum	D877	24
Dielectric breakdown voltage for 0.04 in. gap, kV minimum	D1816	34
Dielectric breakdown voltage for 0.08 in. gap, kV minimum	D1816	24
Water content, ppm maximum	D1533 B	35
Dissipation/power factor, 60 Hz, % max. @ 25°C (77°F)	D924	1.0
Fire point, °C, minimum*	D92	300
Interfacial tension, mN/m, 25°C (77°F)	D971	24
Neutralization number, mg KOH/g	D664	0.2

ANSI/IEEE C57.121-1998, *Guide for Acceptance and Maintenance of Less-Flammable Hydrocarbon*

Fluid in Transformers , Table 4.

Note: The values in this table are considered typical for acceptable service-aged LFH fluids as a general class. If actual test analysis approaches the values shown, consult the fluid manufacturer for specific recommendations.

* If the purpose of the HMWH installation is to comply with *NFPA 70*, this value is the minimum for compliance with *NEC* Article Section 450.23 of the *NEC* .

Source: ANSI/IEEE C57.121, *Guide for Acceptance and Maintenance of Less-Flammable Hydrocarbon Fluid in Transformers* , Table 4.

Table 11.19(c) Suggested Limit for Service-Aged Silicone Insulating Liquid

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	25
Visual	D2129	Colorless, clear, free of particles
Water content, ppm maximum	D1533	100
Dissipation/power factor, 60 Hz, maximum @ 25°C (77°F)	D924	0.2
Viscosity, cSt @ 25°C (77°F)	D445	47.5–52.5
Fire point, °C , minimum	D92	340°C (644°F)
Neutralization number, mg KOH/g maximum	D974	0.2

Source: ANSI/IEEE C57.111-1989 (R1995) , *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 3.

Table 11.19(d) Suggested Limits for Service-Aged Tetrachloroethylene Insulating Fluid

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	26
Visual	D2129	Clear with purple iridescence
Water content, ppm maximum	D1533	35
Dissipation/power factor, % maximum @ 25°C (77°F)	D924	12.0
Viscosity, cSt @ 25°C (77°F)	D445	0
Fire point, °C , minimum	D92	—
Neutralization number, mg KOH/g maximum	D974	0.25
Neutralization number, mg KOH/g maximum	D664	—
Interfacial tension, mN/m minimum @ 25°C (77°F)	D971	—

Source: *Instruction Book PC-2000 for Wecosol*™ *Fluid-Filled Primary and Secondary Unit Substation Transformers*, ABB Power T&D.

Table 11.19(e) Insulating Fluid Limits

-	Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment				
-	Mineral Oil	-	-	-	-
Test	ASTM Method	≤69 kV and Below	>69 kV – <230 kV	>230 kV – <345 kV	>345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1 mm (0.04 in.) gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08 in.) gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971	38	38	38	38

-	Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment				
-	Mineral Oil	-	-	-	-
Test	ASTM Method	≤69 kV and Below	>69 kV – <230 kV	>230 kV – <345 kV	>345 kV and Above
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25°C (77°F) , %	D924	0.05	0.05	0.05	0.05
Power factor at 100°C (212°F) , %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	1.0
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

Source: ANSI/IEEE C57.106~~-2002~~ , *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 11.19(f) Test Limits for Silicone Insulating Liquid in New Transformers

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	Clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 Hz, % max. @ 25°C (77°F)	D924	0.1
Viscosity, cSt @ 25°C (77°F)	D445	47.5–52.5
Fire point~~, °C~~ , minimum	D92	340°C (644°F)
Neutralization number, mg KOH/g max.	D974	0.01

Source: ANSI/IEEE C57.111~~-1989 (R1995)~~ , *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2.

Table 11.19(g) Typical Values for Less-Flammable Hydrocarbon Insulating Liquid in New Equipment

-	Table 100.4.3 Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment			
ASTM Method	Test	Minimum	Results	Maximum
D1816	Dielectric breakdown voltage for 0.08 in. gap, kV	40	34.5 kV class and below	
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in. gap, kV	20	34.5 kV class and below	
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g			0.03
D877	Dielectric breakdown voltage, kV		30	
D924	AC loss characteristic (dissipation factor), % 25°C (77°F) 100°C (212°F)			0.11
D1533B	Water content, ppm			25

-	Table 100.4.3 Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment			
ASTM Method	Test	Minimum	Results	Maximum
D1524	Condition-visual		Clear	
D92	Flash point (°C)		275°C (527°F)	
D92	Fire point (°C)		300a °C (572°F)	—
D971	Interfacial tension, mN/m, 25°C (77°F)		38	
D445	Kinematic viscosity, mm^2/s, (cSt), 40°C (104°F)		1.0 × 102 (100)	1.3 × 102 (130)
D1500	Color			L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers* , Table 3.

Note: The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

Source: ANSI/IEEE C57.121, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers* , Table 3.

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Committee Statement

Committee Statement: The references are updated.
Response Message:

Second Revision No. 10-NFPA 70B-2018 [Section No. 15.8.5.2]

15.8.5.2 References.

The following should be considered for specific maintenance, repair considerations, and procedures:

(1) The equipment manufacturer's instructions

(2) ~~ANSI/IEEE 1125~~ IEEE C37.122.5 , *IEEE Guide for Moisture Measurement and Control in SF6 Gas-Insulated Equipment*

(3) ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, Section 7.5.4, SF_6 Switches, and Section 7.6.4, SF_6 HV Circuit Breakers

(4) Sections of IEEE C37.122.1, *IEEE Guide for Gas-Insulated Substations*, as follows:

(a) 4.2, Installation and equipment handling

(b) 4.4, Gas handling-SF_6 and GIS

(c) 4.5, Safe operating procedures

(d) 4.8, Partial discharge (PD) testing

(e) 4.10, Field dielectric testing

(f) 4.11, Maintenance and repair

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Submittal Date: Mon Jan 29 17:09:02 EST 2018

Committee Statement

Committee Statement: The document number of the reference has been updated to the current edition.

Response Message:

Second Revision No. 14-NFPA 70B-2018 [Section No. 15.9.4.3 [Excluding any Sub-Sections]]

Personnel should be aware of the types of hazards associated with stationary batteries, such as flammable/explosive gas hazards, chemical hazards, electric shock hazards, and arc flash/thermal hazards. Not all stationary batteries have the same types or degrees of hazards. Personnel must understand the potential hazards and do a risk assessment prior to any work per Section 7.1, of NFPA *70E* and ~~*NFPA 70E*~~ IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems* . Personnel should also follow the manufacturer's instructions. As a minimum, the safety precautions in 15.9.4.3.1 through 15.9.4.3.5 should be observed. IEEE 1657, *IEEE Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries*, provides recommended curriculum for various skill levels. *(See 15.9.4.1.2.)*

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Committee Statement

Committee Statement: The additional referenced IEEE standard complements NFPA 70E.
Response Message:

Second Revision No. 15-NFPA 70B-2018 [Section No. 15.9.4.3.2]

15.9.4.3.2 AC and DC Voltage Hazard.

Voltage is always present on battery systems, so the safety procedures in NFPA *70E* and IEEE 3007.3, *IEEE Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems* , for energized equipment should be followed. Voltages present on large systems, including chargers, can cause injury or death. Personnel should determine the voltages that are present, use insulated tools, and use PPE as appropriate. Conductive objects should not be used near battery cells.

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Committee Statement

Committee Statement: The additional referenced IEEE standard complements NFPA 70E.
Response Message:

Second Revision No. 16-NFPA 70B-2018 [Section No. 32.2.8]

32.2.8 Industry Standards and Guidelines.

Industry standards and guidelines should be referred to for information. Information is available from the following:

(1) Electrical Apparatus Service Association (EASA), ANSI/EASA AR100, *Recommended Practice for the Repair of Rotating Electrical Apparatus*

(2) Federal Emergency Management Agency (FEMA), FEMA P-348, *Protecting Building Utilities From Flood Damage: Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems*

(3) Institute of Electrical and Electronic Engineers (IEEE), IEEE 3007.1, *Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems*

(4) Institute of Electrical and Electronic Engineers (IEEE), IEEE 3007.2, *Recommended Practice for the Maintenance of Industrial and Commercial Power Systems*

(5) National Electrical Manufacturers Association (NEMA) NEMA, *Evaluating Water-Damaged Electrical Equipment*

(6) InterNational Electrical Testing Association (NETA) ANSI/NETA ATS, *Standard for Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

(7) ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*

(8) National Fire Protection Association (NFPA), *NFPA 70* and NFPA *70E*

(9) PowerTest Annual Technical Conference, 2009, *Flood Repair of Electrical Equipment; March 12, 2009, Pat Beisert, Shermco Industries*

(10) National Electrical Manufacturers Association (NEMA), *Evaluating Fire- and Heat-Damaged Electrical Equipment*

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Committee Statement

Committee Statement: IEEE 3007.1 is added as it covers the operation of electrical power systems.

Response Message:

Second Revision No. 8-NFPA 70B-2018 [Section No. A.9.2.1.2]

A.9.2.1.2

IEEE is incorporating the information in the color book series into the IEEE 3000 Standards. The content will be organized into approximately 70 IEEE "dot" standards as follows:

(1) IEEE 3000 Standards: Fundamentals

(2) IEEE 3001 Standards: Power System Design

(3) IEEE 3002 Standards: Power System Analysis

(4) IEEE 3003 Standards: Power System Grounding

(5) IEEE 3004 Standards: Protection and Coordination

(6) IEEE 3005 Standards: Energy and Standby Power Systems

(7) IEEE 3006 Standards: Power System

(8) IEEE 3007 Standards: Maintenance Operations and Safety

The user should refer to the IEEE website (www.ieee.org) for updated information regarding available standards.

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Committee Statement

Committee Statement: The references to the IEEE "color book" standards have been retained in the main body text, because the "dot" standards available at this time do not cover the entire scope of the existing "color book" standards. This annex material has been updated to alert the user to the availability of some of the "dot" standards.

Response Message:

Second Revision No. 19-NFPA 70B-2018 [Section No. A.30.4]

A.30.4

A metric used in the industry to compare levels of availability is often referred to as “the nines.” This reflects the number of 9s in the percentage of availability, as shown below in Table A.30.4(a).

Table A.30.4(a) “Nines,” Applications, and Expected Downtime

Number of 9s	Downtime/Year	Typical Application
3 Nines (99.9%)	~9 ~~Hours~~ hours	Typical ~~Desktop Computer~~ desktop computer Baseline ~~Power Delivery~~ power delivery General ~~Home Use~~ home use
4 Nines (99.99%)	~1 ~~Hour~~ hour	Enterprise ~~Server~~ server Desktop ~~Software~~ software General ~~Factory Use~~ factory use
5 Nines (99.999%)	~5 ~~Minutes~~ minutes	Carrier ~~Class Server~~ class server Airports
6 Nines (99.9999%)	~32 ~~Seconds~~ seconds	Carrier ~~Switching Equip.~~ switching equip.
9 Nines (99.9999999%)	30 ~~Milliseconds~~ milliseconds	Online ~~Markets~~ markets

The number of nines is often correlated to the cost of down time. The higher the cost of downtime, the greater the number of “nines” that is typically required for the availability. *[See Table A.30.4(b).]*

When parts of the system are in series, the availability is the product of the two numbers, whereas in paralleled systems, the availability is the lower of the two numbers, as shown in Figure A.30.4(a) through Figure A.30.4(e).

Table A.30.4(b) The Costs of Outage for Selected Commercial Customers

Industry	Average Cost of Downtime
Cellular communications	$41,000 per hour
Telephone ticket sales	$72,000 per hour
Airline reservations	$90,000 per hour
Credit card operations	$41,000 per hour
Telephone ticket sales	$41,000 per hour

Source: Leiter, David, “Distributed Energy Resources.”

Figure A.30.4(a) Calculation of Availability and Downtime Single Point Failure.

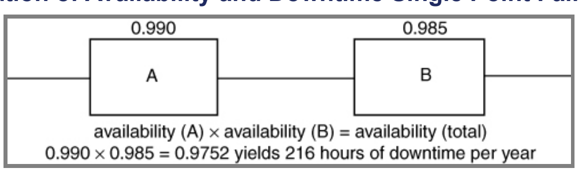


Figure A.30.4(b) Calculation of Availability and Downtime with Parallel Redundancy.

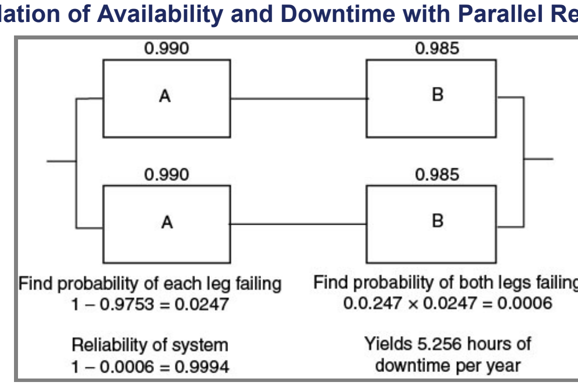


Figure A.30.4(c) Single Line Power System One Line and Availability Calculation.

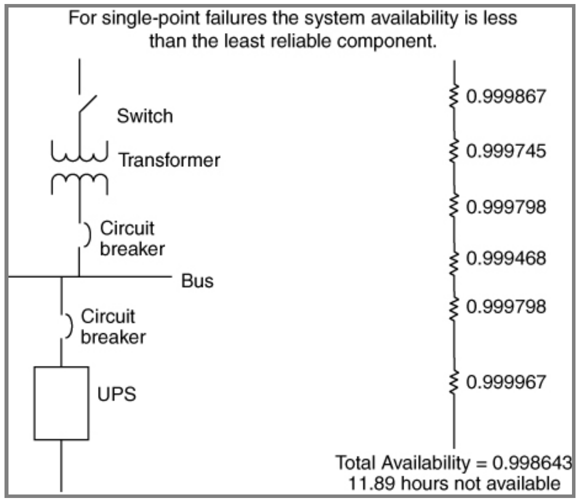


Figure A.30.4(d) Redundant Critical Power Distribution Paths Increase System Reliability.

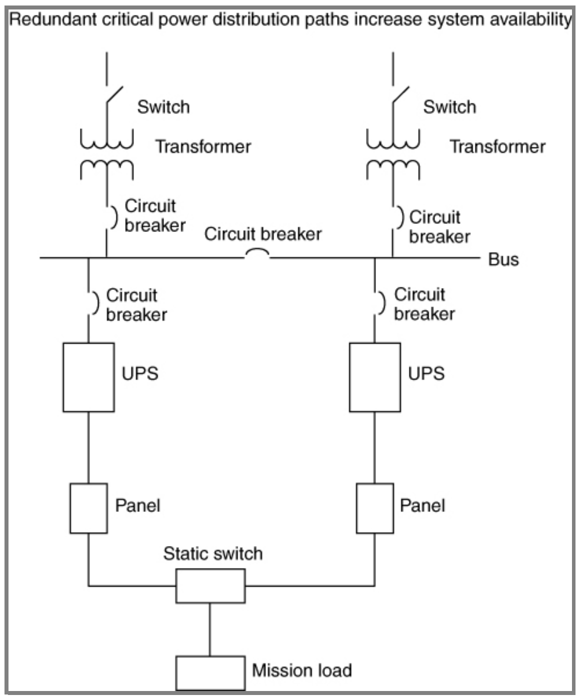
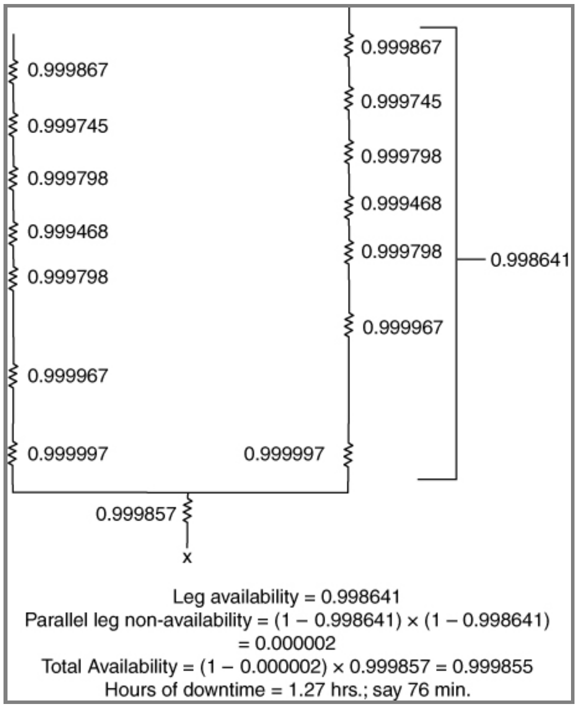


Figure A.30.4(e) Double Ended Substation Availability Calculation.



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Committee Statement

Committee Statement: The bold font is removed in the last column of Table A.30.4(a) because it is not necessary to highlight those applications.

Response Message:

Second Revision No. 17-NFPA 70B-2018 [Sections K.2, K.3]

K.2 Medium-Voltage Equipment.

Table K.2(a) through Table K.2(k) address equipment that should be considered items with long-term maintenance intervals, including the following equipment and techniques:

(1) Cables, terminations, and connections

(2) Liquid-filled transformers

(3) Dry-type transformers

(4) Metal-clad switchgear

(5) Circuit breakers

(6) Metal-enclosed switches

(7) Buses and bus ducts

(8) Protective relays

(9) Automatic transfer control equipment

(10) Circuit breaker overcurrent trip devices

(11) Fuses

(12) Lightning arresters

Table K.2(a) Medium-Voltage Equipment, Cables, Terminations, and Connections: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Solid Dielectric (Chapter 19)	**Inspections (while energized) (19.2.1):**	Annually.
	Conduit entrances (19.4).	Observe for deformation due to pressure and for bends with radius less than minimum allowed.
	Poles and supports.	Same as above.
	0+Binder tape terminations (aerial cables) (19.3).	Same as above.
	Ends of trays (19.4).	Same as above.
	Splices (19.2.3).	Same as above.
	Terminations (stress cones and potheads) (19.2.3, ~~19.2.5~~ 19.2.4).	Same as above plus dirt, tracking, water streaks, chipped porcelain, shield ground connections (where visible), and adequate clearances from grounded metal parts. Observe for continuity.
	Fireproofing (where required) (19.2.3). Loading.	Make certain loads are within cable ampacity rating.
Varnished Cambric Lead Covered and Paper Insulated Lead Covered	**Inspections (while energized) (19.2.1):**	
	Same as above.	Same as above.
	Lead sheath (19.2.3).	Observe for cracks or cold wipe joints, often indicated by leakage of cable oil or compound.
All Types	**Major Maintenance and Test (deenergized) (7.1, 19.2.1):**	3–6 years.
	Complete inspection same as above.	Same as above.
	Clean and inspect porcelain portions of potheads (~~19.2.5~~ 19.2.4 , 15.1.2.1).	For cracks and chips.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Clean and inspect stress cones and leakage sections (19.2.3, 15.2.14).	For soundness of stress cones.
		X-ray or disassemble, if soft spots are detected.
		For surface tracking.
	Check plastic jackets for longitudinal shrinkage from splices and terminations.	Jacket shrinkage might have damaged shielding tapes or stress cones.
	Check integrity of shield grounding (19.2.3).	Observe ground connections for stress cones. Suggest checking electrical continuity of shielding tape.
	Check general condition of cable (19.2.3).	Does insulating material appear to have been damaged by overheating?
	Observe connectors for overheating (~~19.2.5~~ 19.2.4 , 15.1.3, 15.2.15).	Discoloration or oxidation indicates possible problem.
		Check bolts for tightness, if accessible. If connectors are insulated with tape, deterioration or charring of tape is indicative of overheated connector, caused by loose bolts, etc.
		Infrared survey while conductors are energized and loaded to at least 40 percent of ampacity might be beneficial to detect overheated connections. Use good-quality infrared scanning equipment.
	Test cable insulation with high potential dc (19.5, 11.9.1).	Disconnect cables from equipment and provide corona protection on ends. Ground other conductors not being tested.
		Record leakage current in microamperes at each test voltage level.
		Record temperature and relative humidity.
	Determine condition of cable insulation (11.9.2.6).	Interpret test results, considering length of cable, number of taps, shape of megohm or leakage current curve, temperature and relative humidity.
	Reconnect cables to equipment.	Tighten connectors adequately.
	Aluminum conductors.	Make certain that connectors of the proper type are correctly installed.
		Use Belleville washers when bolting aluminum cable lugs to equipment.
		Advisable to determine conductivity of connection using microhmmeter or determine voltage drop under test load conditions.

Table K.2(b) Medium-Voltage Equipment, Liquid-Filled Transformers: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Oil and Askarel Sealed Tank, Conservator and Gas Sealed Systems (Chapter 21)	**Inspections (while energized):**	
	Top liquid temperature (21.2.4).	Weekly to monthly.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
		Record findings.
		Current temperature and highest indicated.
		Reset drag needle; 80°C (176°F) nominal max. permitted.
	Head space pressure (sealed-tank type) (21.2.5.2).	Should vary under changes in loading and ambient temperature.
		If gauge remains at zero, gauge is broken or leak exists in tank head space, which permits transformer to breathe and allows entrance of moisture.
	Nitrogen pressure (pressurized-tank type).	Check nitrogen bottle pressure and pressure in transformer head space.
	Liquid level in tanks (21.2.5.1).	Should be between min. and max. marks on gauge.
	Liquid levels in oil-filled bushings (if so equipped).	Should be between min. and max. marks on gauge.
	Evidence of oil leaks (21.2.7.4).	From tanks, fittings, cooling tubes, and bushings.
	Automatic load tap changer mechanism.	General condition; note and record number of operations.
	Tests (while energized):	
	Oil — draw sample and test in laboratory (~~21.2.8~~ 11.11.8).	Annually for normal service transformers, biannually for rectifier and arc furnace transformers.
		Dielectric strength, acidity, and color. If dielectric is low, determine water content.
	Askarel — draw sample and test in laboratory (~~21.2.8~~ 11.11.8). (Observe EPA regulations for handling and disposal.)	Same frequency as for oil.
		Dielectric strength, acidity, color, and general condition. If dielectric is low determine water content.
	Comprehensive liquid tests.	3–6 years.
		In addition to above, tests include interfacial tension, water content, refractive index power factor at 25°C (77°F) and 100°C (212°F) (20.9.3.2) corrosive sulfur (askarel), and inclusion of cellulose material.
		6 years or as conditions indicate.
		Draw sample in special container furnished by test laboratory.
	Dissolved gas content in liquid of transformers in critical service or in questionable condition as might be indicated by above liquid tests (11.11.10).	Spectrophotometer test detects gases in oil caused by certain abnormal conditions in transformer.
		A series of tests on samples drawn over a period of time might be necessary to determine if abnormal condition exists and to determine problem.
		Devices are available for installation on transformers to collect gases to be tested for combustibility to determine if internal transformer problem exists.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Major Maintenance and Testing (deenergized) (7.1, 21.2.7.2):	3–6 years or more often if above tests indicate.
	Make above tests well in advance of scheduled shutdown.	Determine possible problems that require attention.
	Inspect pressure-relief diaphragm for cracks or holes or mechanical pressure-relief device for proper operation (21.2.7.3).	Replace if defective. Possible cause of pressure in sealed-type transformers remaining at zero.
	Pressure test with dry nitrogen the head space areas of sealed-type transformers if pressure gauge remains at zero and pressure relief device is satisfactory.	Apply liquid along seams, etc., to locate leaks. Make necessary repairs.
	Clean bushings and inspect surfaces (21.2.7.3).	Consider application of silicone grease in badly contaminated areas; should be removed and reapplied at maximum 2-year intervals, preferably 1 year.
	Inspect load tap changer mechanism and contact.	Follow manufacturer's instructions on maintenance and number of operations between contact replacements.
	Paint tank as required.	Wire-brush and prime rust spots. Finish paint.
	Check ground system connections (21.2.7.5).	In each tap position; as an acceptance test and after major repairs.
	Perform turns ratio test (11.11.2).	
	Perform power factor tests (disconnect from equipment) (11.9.3.2).	Windings, bushings, and insulating liquid.
	Consider making winding/tap changer resistance tests.	Use microhmmeter in each tap position to detect abnormally high contact resistance.
	Make undercover inspection through manholes (provide positive protection to prevent entrance of moisture) (11.2.7). This inspection might not be necessary at 6-year intervals unless tests indicate problems.	6-year frequency should definitely be considered for rectifier and arc furnace transformers. Inspect for moisture or rust under cover, water on horizontal surfaces under oil, tap changer contacts (insofar as possible), trash, oil sludge deposits, loose bracing, and loose connections.
	Consider high-potential dc tests (11.9.2.6) (11.5 through 11.8).	dc in excess of 34 kV can polarize liquid and thereby increase leakage currents.
	If above inspections and/or tests indicate possible internal problems, it might be necessary to transport transformer to shop to untank the core and coil assembly for cleaning, inspecting, testing and making repairs as found necessary.	
	Filtering insulating liquid (deenergize transformer and ground windings).	Frequency as required. Remove moisture by heating and pumping liquid through cellulose filters, a centrifuge or a vacuum dehydrator. Thoroughly clean hose and filtering equipment before switching from oil to askarel or vice versa (21.2.1.2). Observe ANSI C107.1 for handling and disposal of askarel.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Re-refining insulating oil (deenergize transformer and ground windings).	Frequency as required.
		Filter through fuller's earth to remove polar compounds and acids.
		Add dibutylparacresol to replace oxidation inhibitors.
	Refilling transformer with insulating liquid (21.2.7.7, 21.2.7.8).	Refill under partial vacuum if transformer tank is so designed.
		Follow manufacturer's instructions.
		Always test insulating liquid for dielectric strength (min. 26 kV for oil) prior to pumping into transformer and pump through filter (min. 30 kV askarel).
	Special Testing (deenergized):	To test phase-to-phase and turn-to-turn insulation (200 Hz to 300 Hz for 7200-volt cycles).
	Induced potential test (11.11.2.1).	Proof test.
	ac high potential test (11.9.3.1)	Proof test.

Table K.2(c) Medium-Voltage Equipment, Dry-Type Transformers: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Ventilated (indoors) (21.1, 21.3)	**Inspections (while energized):**	Weekly to monthly. Record findings.
	Operating temperature (21.3.4).	Current temperature and highest indicated.
		Reset drag needle.
		150°C (302°F) is max. operating temperature for transformers rated 80°C (176°F) rise.
		220°C (428°F) is max. operating temperature for transformers rated 150°C (302°F) rise.
	Cleanliness of screens located over or behind ventilation louvers in enclosure (21.3.5.1).	Clogged screens restrict ventilation and thereby increase operating temperature of core and coil assembly.
		If dust and lint are on outside of screens, vacuum screens without deenergizing transformer. If dust and lint are on inside, transformer should be deenergized and enclosure sides removed to clean screens.
	Ventilating fan operation (if so equipped).	Check operation of fans with control switch in "Manual" position.
		Do not operate fans continuously with switch in "Manual"; leave in "Automatic" so temperature detectors will operate fans at temperatures above specified levels.
		Also check alarm contacts for proper operation at excessive temperature levels.
	Room ventilation (21.3.5.1)	Adequate ventilation system to admit and exhaust air. Air streams should not be directed toward upper vent louvers in transformer enclosure because doing so would restrict ventilation inside transformer and cause overheating.
	Evidence of condensation and water leaks in room (21.3.5.1).	Inspect top of transformer.
		Make necessary corrections.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Major Maintenance (deenergized) (7.1, 21.3.5):	3–6 years, more often if required.
	Remove enclosure covers and clean vent louvers and screens (21.3.5.5).	
	Clean insulators, core, and windings (21.3.5.5, 21.3.5.6).	Use bottle of dry nitrogen with pressure regulator, hose and small nozzle to blow off dust. Restrict pressure to 207 kPa (30 psi max).
		Clean with soft bristle brush as required.
	Inspect following components:	
	Interphase barriers (21.3.5.5).	Should not touch windings.
	Wedges and clamping rings (21.3.5.5).	For proper clamping of windings; tighten as required.
	Primary and secondary buses and conductors (15.1.3, 21.3.5.5).	For tightness of connections.
	Porcelain insulators (15.1.2).	For chips, cracks, and water streaks.
	Insulating materials (15.2.11 through 15.2.15, 21.3.5.5).	For surface tracking.
	Windings (15.2.15, 21.3.5.5, 21.3.5.6).	For damage to insulation, including overheating.
	Tap connections (21.3.5.5).	For tightness and correctness to provide proper voltage.
	Core assembly.	For loose or dislocated laminations, for localized or general overheating, and for integrity of ground strap, which is *only* place where core assembly is permitted to be grounded.
	Ventilating channels between core and windings and between windings (21.3.5.6).	For clogging with lint, dust, or tape used to hold spacers, etc., in place during assembly; clean as required to allow proper air flow.
	Space heaters for proper operation.	Used to keep windings dry when transformer is deenergized.
	Temperature detectors.	For proper location and proper support of leads.
	Temperature indicators.	For accuracy and operation of fan and alarm contacts at proper temperatures.
	Cooling fans.	For free turning and proper operation.
	Testing (deenergized) (11.1, 11.4 through 11.8):	3–6 years, more often if required.
	Turns-ratio test (11.11.2).	In each tap position as an acceptance test and after major repairs.
	Polarization index (PI) test (11.11.2, 11.11.9, 11.9).	Use 1000-volt insulation resistance tester. Low PI results often indicate moisture in winding; investigate cause and satisfactorily dry transformer before making high potential dc test and returning transformer to service.
	High-potential dc test (11.11.10, 11.9.2).	Record leakage currents in microamperes, temperature, and relative humidity.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Special Testing (deenergized):	
	Induced potential test (11.11.2).	To test phase-to-phase and turn-to-turn insulation (200 Hz to 300 Hz for 7200-volt cycles). Proof test.
	ac high-potential test (11.9.3).	Proof test.

Table K.2(d) Medium-Voltage Equipment, Metal-Clad Switchgear: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Indoor (Chapter 15)	**Inspections (while energized):**	3–6 months.
	Open external doors and inspect components:	
	Fronts of circuit breakers.	Record number of operations.
	Protective and control relays (15.9.7).	Wiring and connections, not internals.
	Auxiliary devices, wiring, and terminal blocks (15.4.6).	Proper indicating lights should light.
	Space heaters (15.2.8).	Operate continuously to overcome possible malfunction of thermostats. Consider installation of ammeters in heater supply circuits to monitor full load current of heaters on each circuit to ensure that all are operating.
	Ventilation (15.2.9).	Ventilation louvers should be open.
	Insulators and insulating materials (15.2.11 through 15.2.15).	
	Cable terminations (19.1 through 19.4).	Observe stress cones and leakage sections annually for cleanliness and tracking.
	Batteries (15.9.4).	
	Also inspect for following conditions:	
	Loading.	Record loads.
	Cleanliness (15.2.10).	Moderate amount of dry nonconductive dust not harmful.
	Dryness (15.2.6, 15.2.7).	Evidence of condensation or water leaks.
	Rodents and reptiles (15.2.5).	
	Overheating of parts (15.2.15).	Discoloration or oxidation indicates possible problem.
	Tracking on insulating surfaces (15.2.14).	Take necessary corrective action.
	Major Maintenance or Overhaul:	3–6 years, depending on ambient conditions.
	Deenergize (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.** Completely clean, inspect, tighten, and adjust all components (15.4.1):	Follow manufacturer's maintenance instructions.
	Structure and enclosure (15.2.4, 15.2.5).	Wire-brush and prime rust spots. Finish paint.
	Ventilating louvers and air filters (15.2.9).	Clean or replace filters as required.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Buses, splices, and bolts (15.1.3, 15.2.15).	Check bolts for tightness in accordance with 8.11. If inaccessible, check insulating tape, boot, or compound box over bus splices for heat deterioration due to loose bolts, etc.
	Insulators and insulating materials (15.1.2, 15.2.11 through 15.2.15).	Clean and inspect for surface tracking.
	Circuit breakers (15.4 through 15.6).	Refer to oil and air circuit breaker sections.
	Breaker disconnect studs and finger clusters (15.4.3.8).	Lubricate, unless manufacturer's instructions specify that they should not be lubricated.
	Drawout breaker racking mechanisms (15.1.7).	Alignment and ease of operation.
	Cable terminations and connections (19.1 through 19.4).	Clean and inspect for surface tracking.
		Check connections for tightness.
	Meters (15.9.7).	Test for accuracy.
	Controls, interlocks, and closing power rectifiers (15.9.8).	Make functional tests. Check voltages.
	CTs, PTs, and control power transformers (15.9.5).	
	Fuseclips and fuses (18.2).	Check clips for adequate spring pressure.
	Grounding (15.1.5, 15.9.9).	Proper fusing.
	Components and conditions in above block.	Make necessary repairs.
	Testing (7.1, Chapter 11):	3–6 years, depending on ambient conditions.
	Test buses, breakers, PTs, CTs, and cables with high-potential dc.	Record leakage currents in microamperes (19.5, 11.9.2.6).
	Calibrate and test protective relays (11.12).	Refer to protective relays section.
	Functionally trip breakers with relays (11.12.2).	Preferably, inject test current into CT and relay circuits.
	Test conductivity of aluminum cable connections (15.1.3).	Use microhmmeter or determine voltage drop under test load conditions.
	Test wiring for controls, meters and protective relays for insulation resistance (11.9.2.3).	1000-volt dc for control wiring.
		500-volt dc for meters and relays.
Outdoor	**Inspections (while energized):**	1–3 months.
	Same as for indoor gear except:	
	Special emphasis on evidence of condensation and water leaks (15.2.4, 15.2.6, 15.2.7).	Rust spots on underside of metal roof indicative of condensate.
	Special emphasis on space heater operation (15.2.8).	
	Ventilating louvers and air filters (15.2.9).	Clean or replace air filters as required.
	Major Maintenance or Overhaul:	3 years, more often if conditions require.
	Deenergize (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.** Same as for indoor gear.	Follow manufacturer's maintenance instructions.
	Testing (7.1, Chapter 11):	
	Same as for indoor gear.	3 years, more often if conditions require.

Table K.2(e) Medium-Voltage Equipment, Circuit Breakers: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Air-break, Drawout Type (15.4)	**Inspection and Maintenance (withdrawn from switchgear and deenergized) (7.1):**	Max. of 3 years or at manufacturer's maximum number of operations since previous maintenance, whichever occurs first.
		Immediately after breaker opens to interrupt a serious fault.
		Follow manufacturer's maintenance instructions. If breaker is stored-energy closing type, follow manufacturer's safety precautions, determine that closing springs are discharged, or mechanism is blocked to prevent personal injury. Keep hands away from contacts and mechanism while test operating breaker (15.4.1.1).
	Remove arc chutes. Inspect, adjust and clean where necessary:	
	Main contacts (15.4.3).	For pitting, spring pressure, overheating, alignment, overtravel, or wipe; adjust or replace accordingly.
	Arcing contacts (15.4.3.2).	For alignment, overtravel, or wipe and for arc erosion; adjust or replace accordingly.
	Moving parts and linkages (15.4.5.1 through 15.4.5.3).	For freedom of movement.
	Closing mechanism (15.4.5).	For quick and positive closing action.
	Tripping mechanism (15.4.5).	For freedom of movement and reliability to open breaker contacts.
	Interlocks and safety devices (15.4.6.2, 15.9.8).	Functionally test to prove proper operation.
	Primary disconnect finger clusters (15.4.3.8).	For proper adjustment and spring pressure; lubricate, unless manufacturer's instructions specify that they should not be lubricated.
	Secondary disconnect contacts (15.4.3.8).	For alignment and spring pressure. Lubricate.
	Closing and trip coils (15.4.6.1).	General condition and evidence of overheating.
	Spring charging motor and mechanism (stored energy type) (15.4.6.1).	Proper operation. Oil leaks from gear motor.
	Shunt trip device (15.4.6.1).	For freedom of movement. Functionally test.
	Undervoltage trip device.	For freedom of movement. Functionally test.
	Auxiliary contacts.	For proper operation with closing and opening of breaker.
	Closing (x and y) relays (electrically operated breakers).	Contact erosion. Dress or replace as required.
	Current transformers (15.2.11, 15.9.5.2).	General condition. Check nameplate ratio.
	Connection bolts (11.4.1 through 11.4.3).	Check for tightness.
	Structure or frame.	For proper alignment and loose or broken parts.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Fuses and mountings (18.1, 18.2).	General condition and tightness.
	Frame-grounding device.	Connect before and disconnect after primary fingers.
	Position indicators (15.4.6.2, 15.9.6.2).	For proper operation.
	Auxiliary wiring.	General condition and tightness of terminal screws.
	Arc chutes (15.4.4).	For broken parts, missing arc splitters, and amount of metal spatter and burning on interior surfaces.
		Snuffer screens should be clean.
		Repair or replace as necessary.
	Operation counter.	For proper operation.
		Record number of operations.
	Insulators and insulating materials (15.2.11, 15.2.13, 15.2.14, 15.4.2).	For cracks, breaks, corona, tracking, and overheating.
	Breaker auxiliary devices (15.4.6).	Make necessary repairs.
	Testing (withdrawn from switchgear and deenergized) (7.1, 11.5 through 11.8):	Max. of 3 years, etc., same as preceding block.
	Insulation (11.9.1, 11.9.2.3, 11.9.2.4, 11.9.2.6).	High-potential test each main contact with breaker open and all other main contacts and frame grounded. Record results. Use 1000-volt megohmmeter on auxiliary devices, controls, and associated wiring.
	Contact conductivity or resistance (11.16.1.2.2)	Use microhmmeter or determine voltage drop under test load conditions.
	System Testing (breaker installed):	
	Electrically operated breaker.	After above maintenance and testing have been satisfactorily completed, install electrically operated breaker in proper switchgear cell and rack it into “Test” position, or when test stand (station) is provided, connect breaker control contacts to same with cord and plug provided with breaker.
		Operate closing control devices to ensure that breaker closes and latches without trip-free operations.
		Operate trip control devices to ensure that breaker trips open in a reliable manner (15.4.6.3).
		Functionally test all electrical interlock and safety devices.
		After satisfactorily passing all operational tests, the breaker can be racked into the “Connected” position and placed in normal service.
Oil-immersed, Drawout Type (15.6)	**Inspection and Maintenance (withdrawn from switchgear and deenergized) (7.1):**	Max. of 3 years or at manufacturer's maximum number of operations since last previous maintenance, whichever occurs first; also immediately after breaker opens to interrupt a serious fault.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
		Follow manufacturer's maintenance instructions.
	Lower oil tank. Inspect, adjust, and clean where necessary:	
	Main contacts (15.6.3).	For pitting, spring pressure, overheating, alignment, overtravel, or wipe.
		Adjust or replace accordingly.
	Arc-quenching assemblies (15.6.4).	For alignment, overtravel, or wipe and for arc erosion.
		Adjust or replace accordingly.
	Moving parts and linkages (15.4.5.1 through 15.4.5.3).	For freedom of movement.
	Closing mechanism (15.4.5).	For quick and positive closing action.
	Tripping mechanism (15.4.5).	For freedom of movement and reliability to open breaker contacts.
	Interlocks and safety devices (15.4.6.2, 15.9.8).	Functionally test to prove proper operation.
	Primary disconnect finger clusters (15.4.3.8).	For proper adjustment and spring pressure.
		Lubricate, unless manufacturer's instructions specify that they should not be lubricated.
	Secondary (control) disconnect contacts (15.4.3.8).	For alignment and spring pressure.
		Lubricate.
	Closing and trip coils (15.4.6.1).	General condition and evidence of overheating.
	Shunt trip device (15.4.6.1).	For freedom of movement. Functionally test.
	Undervoltage trip device.	For freedom of movement. Functionally test.
	Bushings (15.6.2.1).	Cracked and chipped porcelain.
		Condition of surfaces.
	Auxiliary contacts.	For proper operation with closing and opening of breaker.
	Closing (x and y) relays (electrically operated breakers).	Contact erosion.
		Dress or replace as required.
	Current transformers (15.2.11, 15.9.5.2).	General condition. Check nameplate ratio.
	Connection bolts (11.4.1 through 11.4.3).	Check for tightness.
	Inspection and Maintenance (withdrawn from switchgear and deenergized):	
	Structure or frame.	For proper alignment and loose or broken parts.
	Fuses and mountings (18.1, 18.2).	General condition and tightness.
	Frame-grounding device.	Connect before and disconnect after primary fingers.
	Position indicators (15.4.6.2, 15.9.6.2).	For proper operation.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Auxiliary devices (15.6.6).	
	Auxiliary wiring.	General condition and tightness of terminal screws.
	Arc quenchers (15.6.4).	For broken and missing parts and amount of metal spatter and burning on interior surfaces.
		Repair or replace as necessary.
	Operation counter.	For proper operation.
		Record number of operations.
	Insulators and insulating materials (15.6.2.1).	For cracks, breaks, and chips.
	Insulating oil (15.6.2.2 through 15.6.2.4, 11.11.8, 11.19).	For level, general condition, dielectric strength, and acidity.
		Make necessary repairs.
	Testing (withdrawn from switchgear and deenergized) (7.1, 11.5 through 11.8):	Max. of 3 years, etc., same as preceding block.
	Insulation (11.9.1, 11.9.2.3, 11.9.2.4, 11.9.2.6).	High-potential test each main contact with breaker open and all other main contacts and frame grounded. Use 1000-volt insulation resistance tester on auxiliary devices and controls and associated wiring.
		Test oil for dielectric strength. Clean tank and breaker mechanism. Filter oil or replace as required (15.6.2.4).
	Contact conductivity or resistance (11.16.2.2.2).	Use microhmmeter or determine voltage drop under test load conditions.
	dc high-potential and/or power-factor test (11.9.1, 11.9.2, 11.9.3.2).	Record results.
	Overcurrent trip devices (electromechanical type) on breakers so equipped (15.4.6.4).	Pass specified currents from current test set through coils of trip devices to open breaker contacts within time limits according to manufacturer's or specially designed time–current coordination curves.
		Adjust trip devices as required to accomplish desired results.
		Test set should be equipped with cycle counter for accuracy of instantaneous trip tests.
		Record results.
	System Testing (breaker installed):	
	Electrically operated breaker.	After above maintenance and testing have been satisfactorily completed, connect electrically operated breaker to switchgear or test stand control wiring by means of the test cord and plug.
		Operate closing control devices to ensure that breaker closes and latches without trip-free operations.
		Operate trip control devices to ensure that breaker trips open in a reliable manner (15.4.6.3).

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
		Functionally test all electrical interlock and safety devices.
		After satisfactorily passing all operational tests, the breaker can be placed in its switchgear cell, racked into the "Connected" position, and placed in normal service.
Air-break and Oil-immersed, Fixed Type (15.4.1.2)	**Maintenance and Testing:**	Same frequency as similar drawout-type breaker in preceding blocks.
	Open all disconnect switches to isolate main contacts from electrical supply and load wiring (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.** Open closing and tripping power switches to deenergize control devices and wiring (15.1.4.1, 15.1.4.3).	Use adequate safety procedures.
	Perform maintenance and test work in accordance with applicable portions of preceding sections.	Follow manufacturer's instructions.
	Close switches to restore closing and tripping power.	
	Functionally test controls and protective relays for proper operation of breaker.	
Pneumatically and Hydraulically Operated Type (Usually Fixed, Outdoor Type)	**Inspection (while energized):**	Monthly. Follow manufacturer's instructions.
	Check for proper air or hydraulic pressure in storage tank for closing mechanism.	
	Operate motor-driven compressor.	
	Check interior of control cabinet for evidence of water leaks and condensation (15.2.6, 15.2.7).	
	Check space heater for proper operation (15.2.6, 15.2.8).	
	Check machined parts of mechanism for rust spots.	Should be covered with thin coat of lubricant.
	Check operation counter.	Record number of operations.
	Check control battery (15.9.4).	
	Check oil gauges on high-voltage bushings and breaker tanks (15.6.6).	For proper oil level.
	Porcelain bushings (15.6.2.1).	For cracks, chips, and breaks.
	Insulating oil (15.6.2.2 through 15.6.2.4, 11.11.8, 11.19).	For level, general condition, dielectric strength, and acidity.
	Check oil level in compressor crank case.	
	Inspect control wiring for evidence of damage.	
	Inspect breaker tanks for evidence of oil leaks.	
	Inspect breaker tanks for rust spots.	Make necessary repairs.
	Maintenance and Testing (while deenergized) (7.1):	Follow manufacturer's instructions and proper safety procedures.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Same as applicable portions of preceding sections plus:	
	Complete check of pneumatic or hydraulic operating mechanism.	
	Power factor test.	Record results.
	On some breakers, timing of contact closing and opening might be required (11.16.1.2.7).	Use circuit breaker time–travel analyzer or electronic timer.
	Measure contact resistance.	
	Measure contact penetration.	
	Measure resistance of internal resistors.	
	Check lever systems, stops, and adjustments.	
	Check dashpot or shock absorber operation.	
	Inspect contact interrupting plates.	
	Inspect gaskets, joints, conduit, and tank fittings.	
	Check pressure switch operation.	
	Check for loose bolts, tightness of joints, etc.	Make necessary repairs.
Vacuum and Gas-Filled Type (11.5)	**Inspections, Maintenance, and Testing:** Follow manufacturer's instructions.	Under certain conditions, high-potential testing can cause x-ray emission from vacuum bottles. Use manufacturer's recommended safety precautions.

Table K.2(f) Medium-Voltage Equipment, Metal-Enclosed Switches: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Indoor Air (15.1.4, 15.3, 15.7)	**Inspections:**	6 months.
	Observe components visible through inspection windows (if provided):	
	Switch contacts (15.2.15).	
	Auxiliary devices, wiring, and terminal blocks.	
	Fuseclips and fuses (18.2).	
	Insulators and insulating materials (15.1.2, 15.2.11 through 15.2.15).	
	Space heaters (15.2.8).	Operate continuously to overcome possible malfunction of thermostats.
		Consider installation of ammeters in heater supply circuits to monitor full load current of heaters on each circuit to ensure that all are operating.
	Cable terminations (19.1 through 19.4).	Observe stress cones and leakage sections annually for cleanliness and tracking.
	Adequate grounding (15.1.5, 15.9.9).	
	Also observe conditions:	
	Loading.	Record loads if gear is equipped with ammeters.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Cleanliness (15.2.10).	Moderate amount of dry nonconductive dust not harmful.
	Dryness (15.2.7).	Evidence of condensation or water leaks.
	Rodents and reptiles.	
	Overheating of parts (15.2.15).	Discoloration or oxidation indicates possible problem. Infrared survey might be beneficial. Use good-quality infrared scanning equipment. Switches should be loaded to at least 40 percent of rating while being scanned.
	Tracking on insulating surfaces (15.2.14).	Make necessary repairs.
	Major Maintenance or Overhaul:	3–6 years, depending on ambient conditions.
	Deenergize (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.** Completely clean, inspect, tighten and adjust all components (15.4.1):	Follow manufacturer's maintenance instructions.
	Structure and enclosure (15.2.4, 15.2.5).	Wire-brush and prime rust spots.
		Finish paint.
	Ventilating louvers and air filters (15.2.9).	Clean or replace air filters as required.
	Buses, splices, and bolts (15.1.3, 15.2.15).	Check bolts for tightness in accordance with 8.11.
	Insulators and insulating materials (15.1.2, 15.2.10 through 15.2.15).	Clean and inspect for surface tracking.
	Space heaters (15.2.7).	Operate continuously to overcome possible malfunction of thermostats. Consider installation of ammeters in heater supply circuits to monitor full load current of heaters on each circuit to ensure that all are operating. The ammeters permit frequent check of heater operation while switches are energized.
	Main switch blades and contacts (15.2.15, 15.4.1, 15.4.3).	Use safety precautions if switch is stored energy type.
		Lubricate.
	Arcing switch blades and contacts (15.4.3.2).	Dress or replace if arc eroded.
		Do not lubricate.
	Arc chutes or interrupter devices (15.4.4).	Check for condition, alignment, and proper operation.
	Switch-operating mechanism and linkage (15.4.5).	Adjust for adequate contact closure and overtravel. Lubricate.
	Switch/fuse door and other interlocks (15.9.8).	Make functional check for proper operation sequence.
	Switch disconnect studs and finger clusters (if switch is drawout type) (15.4.3.7).	Lubricate, unless manufacturer's instructions specify that they should not be lubricated.
	Cable terminations and connections (19.1 through 19.4).	Clean and inspect for surface tracking. Check connections for tightness.
	Meters (15.9.7).	Check for accuracy.
	Fuseclips and fuses (18.2).	Check clips for adequate spring pressure.
		Proper fuse rating.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Grounding (15.1.5, 15.9.9).	
	Potential and control power transformers (15.9.5).	
	Current transformers (15.9.5).	
	Auxiliary devices (15.4.6).	
	Components and conditions in preceding blocks.	Make necessary repairs.
	Testing (7.1, Chapter 20):	3–6 years, depending on ambient conditions.
	Test buses, breakers, PTs, CTs, and cables with high-potential dc.	Record leakage currents in microamperes (19.5, 11.9.2.6).
	Calibrate and test protective relays (11.12).	Refer to protective relays section.
	Functionally open electrically operated type switches with protective relays (11.12.2).	
	Test conductivity of switch contacts and aluminum cable connections.	Use microhmmeter or determine voltage drop under test load conditions.
	Test wiring for controls, meters, and protective relays for insulation resistance (11.9.2.3).	1000-volt megohmmeter for control wiring. 500-volt megohmmeter for meters and relays.
Outdoor Air	**Inspections (while energized):**	1–3 months.
	Same as for indoor gear except:	
	Special emphasis on evidence of condensation and water leaks (15.2.4, 15.2.6, 15.2.7).	Rust spots on underside of metal roof indicative of condensate.
	Special emphasis on space heater operation (15.2.8).	
	Ventilating louvers and air filters for cleanliness (15.2.9).	Clean or replace air filters as required.
	Major Maintenance or Overhaul:	3 years, more often if conditions require.
	Deenergize (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.** Same as for indoor gear (15.4.1).	
	Testing (7.1, Chapter 11):	
	Same as for indoor gear.	3 years, more often if conditions require.
Oil and Gas	**Exterior Inspection:**	Annually.
	Check oil level and gas pressure in switch.	
	Take oil or gas sample.	Test as recommended by manufacturer.
	Check for evidence of leakage.	Repair if necessary.
	Inspect exterior of switch for corrosion.	Paint as required.
	Major Maintenance or Overhaul:	After 500 operations.
	Deenergize (7.1, 15.4.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.**	
	Drain or vent insulating medium.	

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Check gaskets for cracks and flexibility.	Replace where necessary.
	Check cable entrances for mechanical damage or tracking.	
	Inspect all mechanical and electrical connections for tightness.	
	Clean switch interior.	
	Refill.	Use new or reconditioned oil or gas.
	Testing:	
	Actuate each operating mechanism.	Check for proper operation.
	Test with dc high-potential tester.	

Table K.2(g) Medium-Voltage Equipment, Buses and Bus Ducts: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Indoor	**Inspections (while energized):**	3–6 months.
	Open buses:	
	Condition of bus conductors (15.1.3).	
	Evidence of overheated joints (15.1.3, 15.2.15).	Discoloration or oxidation indicates possible problem. Infrared survey might be beneficial. Use good-quality infrared scanning equipment. Buses should be loaded to at least 40 percent of capacity while being scanned.
	Condition of insulators and insulated sleeving (15.1.2).	Cleanliness and breaks.
	Clearance from grounded metal surfaces and above floor.	
	Guards and caution signs.	Where required.
	Loading.	Make certain load is within ampacity rating.
	Bus duct (covers in place):	
	Condition of enclosures (15.2.4).	
	Evidence of water drips on enclosure.	Investigate and correct immediately.
	Adequate grounding (15.1.5, 15.9.9).	
	Loading.	Make certain load is within ampacity rating.
	Maintenance and Testing (deenergized):	1–6 years, depending on conditions.
	Deenergize (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.**	
	Open buses:	
	Check for evidence of overheated joints (15.1.3, 15.2.15).	Discoloration or oxidation of bare joints indicates possible problem. Charred tape or cover over insulated joint indicates problem.
	Check connection bolts for tightness where not covered (15.1.3).	Torque in accordance with 8.11.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Clean and inspect insulators (15.1.2).	For cracks, chips, breaks, and surface tracking.
	Clean and inspect insulated sleeving over buses, if provided.	For cracks, breaks, properly taped joints, and surface tracking.
	dc high-potential test (11.9.2).	Record results.
	Bus duct (covers removed):	
	Clean and check condition of sleeving over buses (15.2.1.3, 15.2.11 through 15.2.14).	For cracks, breaks, properly insulated joints, and surface tracking.
		Make necessary repairs.
	Clean and inspect insulators (15.1.2).	For cracks, chips, breaks and surface tracking or burning.
	Check for evidence of internal moisture (15.2.7).	From water leaks or condensation.
	Check for proper ventilation (15.2.9).	All ventilating louvers should be open.
	Check for proper space heater operation (15.2.8).	Operate continuously to overcome possible malfunction of thermostats. Consider installation of ammeters in heater supply circuits to monitor full load current of heaters on each circuit to ensure that all are operating. The ammeters permit frequent check of heater operation while buses are energized.
	Check space heater wiring.	For proper clearances from buses.
	Check condition of enclosure (15.2.4).	Close all unused holes.
	Check grounding connections (15.1.5).	For tightness.
	Check integrity of barriers.	
	dc high-potential test (11.9.2.6).	Record results.
Outdoor	**Inspections (while energized):**	3–6 months.
	Open buses:	
	Same as for indoor buses	
	Bus duct (covers in place):	
	Condition of enclosure (15.2.4):	Enclosure should be weatherproof type.
	Adequate grounding (15.1.5, 15.9.9).	
	Loading.	Make certain load is within ampacity rating.
	Maintenance and Testing (deenergized):	3–6 years.
	Deenergize (7.1). **Verify that no parts of the power or control circuitry are energized by "back feed" from alternate power or control sources.**	
	Open buses: Same as for indoor buses.	
	Bus duct (covers removed): Same as for indoor bus duct plus following:	

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Check condition of cover gaskets (15.2.6, 15.2.7).	For deterioration, breaks, and omissions.
	Check operation of space heaters (15.2.8).	Operate continuously to overcome the possible malfunction of thermostats. Consider installation of ammeters in heater supply circuits to monitor full load current of heaters on each circuit to ensure that all are operating. The ammeters permit frequent check of heater operation while buses are energized.
	Check enclosure ventilating louvers (15.2.9).	Clean or replace air filters, as necessary. Check for ability to exclude insects, rodents, reptiles, and metal rods.

Table K.2(h) Medium-Voltage Equipment, Protective Relays: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Induction Disk Relays (drawout type) (11.12)	**Inspection, Cleaning, Maintenance, Calibration, and Testing (while associated circuit breaker is closed and supplying load):**	2–3 years, more often where dust, moisture, corrosion, vibration, or wide temperature variation is present. Follow manufacturer's instructions for type of relay and test set.
	Brush or blow dust off top edge of relay cover and remove cover.	Use caution to not accidentally cause relay contacts to close, which would trip associated circuit breaker and shut down load.
	Remove relay disconnect device or open relay trip circuit switch and then open supply circuit switches in relay case.	Remove only one relay from service at a time. Leave other relays in service to provide protection for circuit.
	Release locking mechanisms, withdraw relay from case, and place on workbench in clean area adjacent to test equipment.	Handle with care to avoid damage to delicate mechanism.
	Clean mechanism with soft, long-bristle brush or very light air pressure from hose.	
	Tighten all screws and nuts. Inspect for broken or defective connections.	Do not overtighten. Repair defective connections.
	Inspect closely for dust and iron filings clinging to magnet and in air gap, which might restrict rotation of disk.	Thoroughly clean to remove dust and foreign matter.
	Inspect for correct alignment of disk and proper clearances from mechanism, magnet, etc.	Make necessary adjustments to provide proper clearances so disk does not drag on mechanism or magnet.
	Burnish contact surfaces and inspect contacts for burning and pitting.	Use relay contact burnishing tool. Replace badly burned or pitted contacts.
	Inspect disk restraint spring.	For proper shape, tension, and possible damage from overheating due to excessive current, flow through same.
	Record “as-found” time lever setting and temporarily set time lever adjustment on position 10. Turn disk	Check to detect if disk binds at any point.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	with thumb until relay contacts close.	Examine spring and contacts in closed position. Make necessary adjustments, repairs, or replacements.
	Release disk and allow it to reset until contact bracket is resting against "full-open" stop device.	Watch disk movement to detect if disk slows down or stops before contact bracket rests against the "full-open" stop device. If so, make necessary adjustments, repairs, or replacement.
	Reset time lever to "as-found" position or to the desired new position, if different one is specified on the applicable coordination or instruction sheet.	Refer to applicable time/current coordination sheet or setting instructions, which are necessary to obtain correct coordination with associated upstream or downstream protective devices.
	Check current tap plug for correct position and tightness. Reposition, if necessary, to agree with setting specified on applicable coordination sheet.	Same as preceding item.
	If precise relay operation accuracy is required, it might be necessary to test some types of relays in their own cases in switchgear or in an unwired duplicate case located on workbench.	For "in-case" testing, connect relay test set leads to proper type relay test jack and insert it into relay disconnect contacts, being careful to make connections in accordance with applicable instructions and diagrams. If relay is in its own case, make certain that it is disconnected from the switchgear wiring to the relay case by means of open switches in the case or by wiring to only the relay side of the test jack. Make certain that switchgear side of test has jumpers installed to short out the CT circuits.
	Some relays can be satisfactorily tested outside of case.	Place withdrawn relay on a clean workbench and connect test leads to proper terminals using alligator clips.
	Select test points from applicable coordination or instruction sheet and calculate amount of current or voltage to be applied to relay operating coil. Adjust test set to apply proper values of test current or voltage.	Consider switchgear PT or CT ratios in calculating proper amount of test current or voltage. Pass test current through current coils. Apply test voltage across potential coils.
	Test relay pickup point by applying test set voltage or current (determined from coordination curve) at which disk begins to turn very slowly.	After disk begins to turn slowly, lower test current or voltage slightly and check if disk stops turning and rests. Make necessary adjustments or repairs. Record results.
	Connect desired relay contact to timer circuit of test set. Adjust test set for current or voltage specified to test time contacts of relay. Push "Initiate" button on test set and check actual time required for relay	When contacts close, test set automatically removes applied test current or voltage, and its accurate timer will stop.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	time contacts to close.	
	Compare actual time with time specified on coordination curve.	If actual time is close enough to the specified time to satisfy the required coordination accuracy, record results and proceed to next step. If not, readjust time lever accordingly and repeat test. Continue until the desired timing accuracy is attained.
	If relay is equipped with instantaneous current attachment, adjust test set for current or voltage specified for testing same on coordination sheet. Apply and check accurate timer for time required for instantaneous contacts to close. Adjust instantaneous setting to close contacts at current value specified on coordination sheet.	After desired results are obtained, reduce test current slightly and check that relay contacts do not close at value below that specified. If they do, further adjustment and retesting at the specified current will be required until the close and no-close results are within the allowed tolerances.
	Test seal-in contacts for closing at specified values.	
	Check target flags for proper operation each time relay contacts close. Leave all targets in “dropped” position.	Reset target flags and check that moderate vibration does not cause a false operation.
	Record “as-found” and “as-left” settings, test current values and operating results, and maintenance and corrective action taken.	
	Clean and inspect interior of relay case located in switchgear.	Use soft-bristle brush or stream of low-pressure dry, clean air, being careful to not open current-shorting contacts or short potential contacts. Do not short trip circuit terminals, etc.
	Clean glass or plastic window in relay cover and check target reset mechanism for free movement.	Use cleaning materials that will not damage plastic.
	Insert relay into its case in switchgear and secure locking devices. Insert connection device or close switches inside relay case.	Observe that disk does not begin to rotate. If it does, remove connection device before contacts close and trip breaker, investigate reason, and make necessary correction. On relays with individual switches, close current or potential switches and observe that disk does not rotate before closing trip circuit switch.
	Replace relay cover and secure fastenings.	
	Operate target reset mechanism to determine that targets reset properly.	
	Seal relay cover to discourage unauthorized entry.	
Induction Disk Relays (nondrawout type) (11.12)	**Inspection, Cleaning, Maintenance, Calibration, and Testing:**	Same frequency and remarks as for drawout-type relays. Make certain that the connections to the test jack are correct before inserting test jack into test receptacle.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Same general procedures as for drawout type, except relays cannot be easily removed from their cases and switchgear. A test receptacle is usually provided in the switchgear adjacent to each relay to facilitate testing. A suitable isolating test jack is connected to the relay test set and inserted into the test receptacle. This disconnects the relay contacts from the breaker trip circuit in the switchgear and connects the test set current or potential leads to the proper operating coils in the relay.	
All Types (11.12)	**General Maintenance and Functional Testing (switchgear deenergized and associated breakers out of service) (7.3):**	3–6 years to coincide with major switchgear maintenance.
	Same as above, except checking condition of wiring and terminals.	Check wiring for condition of conductors and insulation.
		Check terminals for tightness.
	Functionally test by closing associated circuit breaker and injecting proper value of test current into associated CT circuit or applying proper value of test voltage to associated potential wiring after disconnecting same from its supply PTs.	Check to determine that contacts of proper relays close and that associated breaker trips open. If not, determine cause and make necessary corrections.

Table K.2(i) Medium-Voltage Equipment, Automatic Transfer Control Equipment: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Indoor and Outdoor	**Inspections (while energized):**	3–6 months.
	Protective, sensing, timing, and control relays.	For condition of contacts.
	Control wiring and terminals.	General condition.
	Control power batteries (15.9.4).	
	Enclosure (15.2.4, 15.2.6, 15.2.7, 15.2.10).	Cleanliness and evidence of condensation and leaks.
	Space heaters (outdoor enclosures) (15.2.8).	Operate continuously to overcome possible malfunction of thermostats. Consider installation of ammeter in heater supply circuit for frequent monitoring of full load current of heaters to ensure that all are operating. The ammeters permit frequent check of heater operation while buses are energized.
	Maintenance and Testing (while deenergized) (7.1):	3 years, more often if conditions require.
	Clean enclosure, relays, control devices, etc. (15.9.7).	
	Clean, inspect, and burnish contacts.	
	Test and calibrate protective relays (11.12).	Refer to protective relays section.
	Tighten terminals.	
	Test circuits and devices insulation.	Use 500-volt dc insulation resistance tester.
	Maintain enclosure.	Wire-brush and prime rust spots. Finish paint.

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Functionally test by placing selector switch in manual position and operating control switches to open and close associated circuit breakers.	Remove breakers from service.
	Functionally test by placing selector switch in automatic position and simulating conditions that should cause controls to operate associated breakers to effect transfer of power.	Remove breakers from service.

Table K.2(j) Medium-Voltage Equipment, Fuses: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
All Types (Chapter 18)	**Visual Inspections (while energized):**	3–6 months. Binoculars might be necessary to inspect fuses on overhead lines.
	Evidence of contact overheating.	Discoloration or oxidation indicates possible problem. Infrared survey might be beneficial. Use good-quality infrared scanning equipment. Fuses should be loaded to at least 40 percent of rating while being scanned.
	Cracked, chipped, or broken insulation of fuse barrels and mounting insulators (15.1.2, 18.2.3.1).	
	Cleanliness of insulation surfaces.	
	Overload.	Steady load should not exceed E rating of fuse.
	Proper oil level in barrel of oil-filled type.	
	Maintenance (while deenergized) (7.1, 18.2.2):	3–6 years, depending on ambient conditions.
	Remove fuses from mountings and inspect for:	
	Cleanliness (15.1.2, 18.2.3.1).	Clean insulating and contact surfaces.
	Cracked, chipped, or broken insulation (18.2.3.1).	Replace defective insulation.
	Evidence of overheating and arc erosion on fuse ferrules and spring clips on mountings (18.2.3.2).	Replace defective parts.
	Tension of spring clips and pressure against contact surfaces (18.2.3.3).	Replace weakened or annealed spring clips.
	Tightness of connections (18.2.3.3).	
	Ampere rating agreement with specified rating (18.1.4).	Disassemble refill-type fuses and check nameplate information on refill unit.
		Check contact surfaces for evidence of overheating.
		Reassemble and tighten securely.
	Interrupting rating adequacy for fault capability of system on which fuse is installed (18.1.4).	

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Testing (while deenergized):	3–6 years.
	Mounting insulators can be dc high-potential tested (11.9.2.6).	High-potential testing of fuse mountings is not a standard maintenance practice.

Table K.2(k) Medium-Voltage Equipment, Lightning Arresters: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Type	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
All Types	**Visual Inspection (while energized):**	3–6 months. Binoculars might be necessary to inspect arresters on overhead lines.
	Cleanliness of porcelain surfaces (15.9.2.1).	
	Cracked, chipped, or broken porcelain (15.1.2).	
	Disconnected line or ground connections.	
	Maintenance (while deenergized) (7.1):	3–6 years, depending on ambient conditions.
	Clean porcelain surfaces (15.9.2.1).	Consider application of silicone grease in badly contaminated areas; should be removed and reapplied at max. 2-year, preferably 1-year intervals.
		Wire-brush and prime rust spots. Finish paint.
	Check tightness of line and ground connections.	
	Inspect nameplate data for voltage rating suitability for system voltage and grounding.	
	Clean internal porcelain surfaces of nonsealed arresters if test results indicate contamination present.	
	Testing (while deenergized) (7.1):	3–6 years.
	Power factor test (15.9.2.2).	Record results.
	Test insulation resistance (15.9.2.2).	Record results.
		Compare resistances of all arresters of same rating and type, which should be approximately the same.

K.3 Medium- and Low-Voltage Equipment.

The medium- and low-voltage equipment that should be considered items for long-term maintenance intervals are outside overhead electric lines.

Table K.3 shows medium- and low-voltage equipment, outside overhead electric lines; maintenance of equipment subject to long intervals between shutdowns — electrical distribution.

Table K.3 Medium- and Low-Voltage Equipment, Outside Overhead Electric Lines: Maintenance of Equipment Subject to Long Intervals Between Shutdowns — Electrical Distribution

Equipment	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
Wood Poles	**Inspect from Ground Level for:**	4–6 months.
	Leaning.	Binoculars usually required.
	Washout.	
	Splitting.	
	Bird damage.	
	Lightning damage.	
Wood Crossarms	Twisting.	4–6 months.
	Splitting.	Binoculars usually required.
	Decay.	
	Loose or missing braces.	
	Loose pins.	
	Surface tracking or burning (15.2.14).	
Insulators and Bushings	Cracks (require careful inspection) (15.1.2.1).	4–6 months.
	Chips or bad breaks (15.1.2.1).	Binoculars usually required.
	Unscrewed from pin.	
	Leaning at bad angle.	
	Cleanliness (15.1.2.1).	If atmosphere is contaminated, annual or biannual cleaning and coating of porcelain insulator surfaces with silicone grease might be necessary. This can be done with lines energized by using special equipment, materials, and trained personnel.
Lightning Arresters	Cracked, chipped, and broken insulators (15.1.2.1, 15.9.2.1).	4–6 months.
		Binoculars usually required.
	Ground connection (15.1.5, 15.9.9).	
	Cleanliness.	If atmosphere is contaminated, annual or biannual cleaning and coating of porcelain insulator surfaces with silicone grease might be necessary. This can be done with lines energized by using special equipment, materials, and trained personnel.
Guys and Anchors	Broken strands.	4–6 months.
	Corrosion.	Binoculars usually required.
	Looseness and slippage.	
	Loose clamps.	
	Excessive tension.	
	Anchor eye above ground.	

Equipment	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Adequate clearance from conductors.	
	Insulators properly located.	
Conductors	Off insulator and resting on crossarms.	4–6 months.
	Broken strands.	Binoculars usually required.
	Blisters or burned spots.	
	Excessive or uneven sagging.	
	Loose connections (15.1.3, 15.2.15, 11.17).	
	Horizontal and vertical clearances.	
	Trees that touch or can fall across conductors.	
Hardware	Looseness.	4–6 months.
	Corrosion.	Binoculars usually required.
Switches and Fuses	General condition.	4–6 months.
	Broken arcing horns.	Binoculars are usually required.
	Bent or misaligned arms.	
Connections	Evidence of overheating (15.1.3, 15.2.15, 11.17).	4–6 months. Binoculars usually required. Infrared survey can be beneficial.
Ground Wires	~~Breaks~~ Open or missing (15.1.5).	Report on all conditions that require correction.
	Attachment to pole.	Make necessary repairs.
All Poles		3–5 years.
	Climbing or Bucket Truck Inspection for Detailed Inspection of Foregoing Items and Conditions	Tighten hardware and make necessary repairs and replacements. Wire-brush, prime, and finish-paint rusted areas of metal poles.
Wood Poles and Crossarms	**Ground-Line Inspection and Preservative Treatment:**	8–10 years in southern areas,
		10–15 years in northern areas.
	Sound pole with hammer to 1.83 m (6 ft) above ground.	
	Excavate to 0.46 m–0.51 m (18 in.–20 in.) belowground, wire-brush, inspect for surface decay.	Cut out moderate decay pockets.
	Test bore to determine internal decay; if found, determine extent.	If not too extensive, inject preservative fluid, and plug holes.
	Apply preservative to external surface from 0.51 m (20 in.) belowgrade to 0.15 m (6 in.) above.	
	Wrap treated area with protective film and backfill excavation.	If decay is excessive, reinforce or replace pole.
	Aboveground Inspection and Preservative Treatment:	
	Sound pole with hammer. Bore hollow areas and inject preservative fluid; plug holes.	

Equipment	Inspections, Maintenance, and Tests	Typical Frequency and Remarks
	Bore pole 0.15 m (6 in.) above bolts and inject preservative fluid; plug holes.	
	Inspect crossarms for decay pockets.	
	Apply preservative treatment.	Replace crossarm if decay is extensive.
	Inspect roof for decay. Apply preservative and cover.	If decay is present but does not extend below top crossarm, cut off pole to sound wood, treat with preservative, and install cover.
	Inspect all wood for termites.	Treat if not excessive.
	Tighten pole hardware.	
	Inspect for bird (woodpecker) damage.	Fill holes with compound if pole is not excessively weakened by damage. Weakened areas might be reinforced.
Current-Carrying Parts	**Thermal Scanning or Infrared Inspection** (11.17):	5–8 years, depending on ambient conditions.
	Scan all conductors, connectors, switches, fuses, etc., with special thermal detecting equipment to locate hot spots caused by loose connectors and bad contacts.	Conductors should be loaded to at least 40 percent of the rating while being scanned. Use good-quality infrared scanning equipment. Small gun-type thermal detectors not usually effective at overhead line distances and require too much time. Make repairs or replacements as indicated by results.

Supplemental Information

File Name	Description	Approved
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Committee Statement

Committee Statement: The cross-references in the tables have been updated to the correct sections.
Response Message:

Second Revision No. 26-NFPA 70B-2018 [Section No. N.1 [Excluding any Sub-Sections]]

These definitions are referenced in several reliability publications and the formulas can be verified in ~~MIL-STD339~~ MIL-HNDK-508 , *Wiring and Wiring Devices for Combat and Tactical Vehicles, Selection and Installation of*, or in IEEE 100, *Authoritative Dictionary of IEEE Standards Terms*.

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