COUNTY OF ERIE
DIVISION OF PURCHASE
MEMORANDUM

To: All Using Departments

From: Jamie Kucewicz, Buyer

Date: June 17, 2021

Subject: ELECTRICAL PREVENTIVE MAINTENANCE

Bid No.: 221107-002

Effective Dates: June 1, 2021 through May 31, 2024

Vendor #: 134781

Vendor: O'CONNELL ELECTRIC COMPANY, INC.
830 Phillips Road
Victor, NY 14564

Telephone: 585-924-2176

Contact: Victor E. Salerno

Pricing: per attached documents

EXHIBIT "F"

County of Erie

MARK C. POLONCARZ
COUNTY EXECUTIVE

DIVISION OF PURCHASE

STANDARD AGREEMENT

This AGREEMENT, made as of the 4th DAY OF JUNE, 2021

by and between O'CONNELL ELECTRIC COMPANY, INC.

of 830 PHILLIPS ROAD, VICTOR, NY 14564

herein after referred to as the Contractor, and the County of Erie, a municipal corporation of the State of New York, hereinafter referred to as the County:

WHEREAS, in accordance with public open competitive bidding, sealed proposals were received and publicly opened by the County of Erie, Division of Purchase

on JUNE 3, 2021 at 11:00AM

for: ELECTRICAL PREVENTIVE MAINTENANCE

WHEREAS, the bid of the Contractor submitted in accordance therewith, the sum of $60,218.00, was the lowest responsible bid submitted; and

WHEREAS, a contract is hereby awarded to the Contractor by the County, in accordance with the provisions therein contained; and

WHEREAS, the Notice to Bidders and Specifications make provisions for entering into a proper and suitable contract in connection therewith;

NOW, therefore, the Contractor does hereby for its heirs, executors, administrators and successors agree with the County of Erie that, the Contractor shall for the consideration mentioned, and in the manner set forth in Accepted Invitation to Bid No. 221107-002, Specifications and Provisions of Law annexed hereto and forming a part of this contract, furnish the equipment and materials and perform the work and services described in the Accepted Bid for the above sum.

$60,218.00 Paid monthly upon presentation of invoices.

_____ Upon delivery, completion and approval of the work, as per specifications.

Please refer to the Invitation to Bid (Page 1) and the Instructions to Bidders which are part of this agreement.

IN WITNESS THEREOF, the parties hereto have hereunto set their hands and seals the day and year first above written.

COUNTY OF ERIE

by _____
Director of Purchase

Date_____

CONTRACTOR: O'CONNELL ELECTRIC COMPANY, INC.

by _____
Victor E. Salerno

Title Chief Executive Officer

Date June 14, 2021

APPROVED AS TO FORM

Electronically Approved

_____
Assistant County Attorney
County of Erie, New York

Date_____

COUNTY OF ERIE

MARK C. POLONCARZ
COUNTY EXECUTIVE

DIVISION OF PURCHASE

INVITATION TO BID

Bids, as stated below, will be received and publicly opened by the Division of Purchase in accordance with the attached specifications. FAX bids are unacceptable. Bids must be submitted in a sealed envelope to:

County of Erie
Division of Purchase
Attention: JAMES D. KUCEWICZ, BUYER (716) 858-6336
95 Franklin Street, Room 1254
Buffalo, New York 14202-3967

NOTE: Lower left-hand corner of envelope MUST indicate the following:

BID NUMBER: 221107-002

OPENING DATE: MAY 25, 2021 TIME: 11:00AM

FOR: ELECTRICAL PREVENTIVE MAINTENANCE

NAME OF BIDDER: _____

If you are submitting other Invitations to Bid, each bid must be enclosed in a separate envelope.

Following EXHIBITS are attached to and made a part of the bid specifications, and part of any agreement entered into pursuant to this Invitation to Bid:

X	EXHIBIT "A"	- Assignment of Public Contracts
X	EXHIBIT "B"	- Purchases by Other Local Governments or Special Districts
	EXHIBIT "C"	- Construction/Reconstruction Contracts
	EXHIBIT "D"	- Bid Bond (Formal Bid)
N/A	EXHIBIT "E"	- Bid Bond (Informal Bid)
X	EXHIBIT "EP"	- Equal Pay Certification
X	EXHIBIT "F"	- Standard Agreement
X	EXHIBIT "G"	- Non-Collusive Bidding Certification
X	EXHIBIT "H"	- MBE/ WBE Commitment
X	EXHIBIT "IC"	- Insurance CLASSIFICATION "A"
	EXHIBIT "P" & EXHIBIT "PBI"	- Performance Bond
	EXHIBIT "Q"	- Confined Space Program Certification
X	EXHIBIT "PW"	- NYS Prevailing Wage
X	EXHIBIT "V"	- Vendor Federal Compliance Certification

(Rev. 1/00)

County of Erie

DIVISION OF PURCHASE

NON-COLLUSIVE BIDDING CERTIFICATION

By submission of this bid, each bidder and each person signing on behalf of any bidder certifies, and in the case of a joint bid each party thereto certifies as to its own organization, under penalty of perjury, that to the best of his knowledge and belief:

(1) the prices in this bid have been arrived at independently without collusion, consultation, communication, or agreement, for the purpose of restricting competition, as to any matter relating to such prices with any other bidder or any competitor;

(2) unless otherwise required by law, the prices which have been quoted in this bid have not been knowingly disclosed by the bidder and will not knowingly be disclosed by the bidder prior to opening, directly or indirectly, to any other bidder or to any competitor; and

(3) no attempt has been made or will be made by the bidder to induce any other person, partnership or corporation to submit or not to submit a bid for the purpose of restricting competition.

NOTICE

(Penal Law, Section 210.45)

IT IS A CRIME, PUNISHABLE AS A CLASS A MISDEMEANOR UNDER THE LAWS OF THE STATE OF NEW YORK, FOR A PERSON, IN AND BY A WRITTEN INSTRUMENT, TO KNOWINGLY MAKE A FALSE STATEMENT, OR TO MAKE A FALSE STATEMENT, OR TO MAKE A STATEMENT WHICH SUCH PERSON DOES NOT BELIEVE TO BE TRUE

BID NOT ACCEPTABLE WITHOUT FOLLOWING CERTIFICATION:

Affirmed under penalty of perjury this 25th day of May, 20 21

TERMS _____ DELIVERY DATE AT DESTINATION _____

FIRM NAME O'Connell Electric Company, Inc.

ADDRESS 830 Phillips Road

Victor, New York ZIP 14564

AUTHORIZED SIGNATURE Victor E Salerno

TYPED NAME OF AUTHORIZED SIGNATURE Victor E. Salerno

TITLE Chief Executive Officer TELEPHONE NO. 585-924-2176

County of Erie

DIVISION OF PURCHASE
BID SPECIFICATIONS

BID NO. 221107-002

Ship to:
Attention:
Address:

Ship Via:
Date Required at Destination:

ITEM NO.	QUAN -TITY	U/M	CATALOG NO./DESCRIPTION	UNIT PRICE	TOTAL PRICE
			Proposal to cover Electrical Distribution System		
			Preventive Maintenance at		
			Southtowns Wastewater Treatment Facility		
			S-3690 Lakeshore Road, Buffalo, NY 14219		
			Contract period is June 1, 2021 through April 30, 2024.		
			Please provide pricing on Pricing Page.		
			There will be a MANDATORY site visit		
			on Monday, May 10, 2021 at 9:00am		
			For questions regarding the specifications of the bid		
			please contact Chuck Yung at (716) 823-8188.		

NOTE: Bid results cannot be given over the phone. All requests for bid results should be submitted in writing or faxed to:

ERIE COUNTY DIVISION OF PURCHASE
Freedom of Information Officer
95 Franklin Street, Rm. 1254
Buffalo, NY 14202
FAX #: **716/858-6465**

NAME OF BIDDER _____

COUNTY OF ERIE

MARK C. POLONCARZ
COUNTY EXECUTIVE

DIVISION OF PURCHASE

TO: ALL BIDDERS

FROM: James D. Kucewicz, Buyer
Erie County Division of Purchase

DATE: May 13, 2021

SUBJECT: ADDENDUM NO. 1 Erie County Bid #221107-002
Electrical Preventive Maintenance

The attention of all bidders is directed to the following changes in the above bid:

****

In 1. General Scope

In Year #1, Year #2 and Year #3, the third bullet point in each should read

- Three (3) transformer oil sample and analysis. Analysis will include:...

In year #1, for the De-energized preventive maintenance:

- Add, 2.4kV / 480 volt VPSA Dry transformer and disconnect switch inspection and testing.

In Year #1, Year #2 and Year #3, for the infrared inspections

- Add, 2.4kV / 480 volt VPSA Dry transformer and disconnect switch inspection and testing.

****

COUNTY OF ERIE

MARK C. POLONCARZ
COUNTY EXECUTIVE

DIVISION OF PURCHASE

TO: ALL BIDDERS

FROM: James D. Kucewicz, Buyer
Erie County Division of Purchase

DATE: May 24, 2021

SUBJECT: **ADDENDUM NO. 2** Erie County Bid #221107-002
Electrical Preventive Maintenance

The attention of all bidders is directed to the following changes in the above bid:

****

- Contract term is June 1, 2021 through May 31, 2024
- Please provide pricing on the attached pricing page.
- The bid opening date/time has been changed to June 3, 2021 at 11:00am.

****

PRICE SHEET
BID #221107-002

This contract will be in effect from June 1, 2021 through May 31, 2024.
Please provide a price for each year of the contract:

June 2021 - May 2022 $ 22,084.00

June 2022 - May 2023 $ 20,568.00

June 2023 - May 2024 $ 17,566.00

TOTAL $ 60,218.00

NAME OF BIDDER **O'Connell Electric Company, Inc.**

CONTENTS

CONTENTS (cont.)

TABLES

Standard Specification Form

Electrical Maintenance Tests

1. GENERAL SCOPE

1. The owner shall engage the services of a recognized independent testing firm for the purpose of performing inspections, tests and test data evaluation as herein specified.

2. The testing firm shall provide all material, equipment, labor and technical supervision to perform such tests and inspections.

3. It is the purpose of these specifications to assure that all tested electrical equipment and systems are operational and within industry and manufacturer's tolerances. All lists of equipment to be maintained has been attached and should be included as part of this specification.

4. Communication between the owner and service provider is of utmost importance. Plant uptime is required 24/7. Any power outage must be planned and approved by the owner. Where power down conditions cannot be avoided and required for the maintenance specified, specific time intervals and durations of work will be required to complete the task..

(3) YEAR ELECTRICAL PREVENTIVE MAINTENANCE SCOPE

Year #1

- Infrared Thermographic Inspection of the Southtowns Wastewater Treatment Plant Electrical Distribution System (2 days plus report generation). Southtowns Waste Water Treatment Plant will provide qualified electricians to remove and replace equipment covers as required.
- Visual Inspection of Southtowns Waste Water Treatment Plant Electrical Distribution System.
- Two (2) transformer oil sample and analysis. Analysis will include
  - Gas in Oil Analysis
  - Water Content
  - Acid Content
  - Interfacial Tension
  - Color Analysis
  - Dielectric Strength
  - Specific Gravity
  - PCB Content
- Inspection, testing of the batteries and charger located in the main outdoor switchgear, and generator switchgear.

- De-energized preventive maintenance of the main 15kV outdoor switchgear including:
  - All switchgear sections
  - All 15kV circuit breakers
  - All current and potential devices
  - All auxiliary devices
- De-energized preventive maintenance of the (2) main 15/2.4kV transformers.
- De-energized preventive maintenance of the 2.4kV outdoor switchgear including:
  - All switchgear sections
  - (2) Main 2.4kV circuit breakers
  - (1) Tie 2.4kV circuit breaker
  - (2) Feeder 2.4kV circuit breakers (1) spare, (1) Gen
- De-energized preventive maintenance of the 2.4kV switchgear including:
  - All switchgear sections
  - (4) 2.4kV circuit breakers
  - (2) 2.4kV Generator Switchgear
  - Capacitor Bank
  - All current and potential devices

Year #2

- Infrared Thermographic Inspection of the Southtowns Wastewater Treatment Plant Electrical Distribution System (2 days plus report generation). South Towns Waste Water Treatment Plant will provide qualified electricians to remove and replace equipment covers as required.
- Visual Inspection of your facilities Electrical Distribution System.
- Two (2) transformer oil sample and analysis. Analysis will include
  - Gas in Oil Analysis
  - Water Content
  - Acid Content
  - Interfacial Tension
  - Color Analysis
  - Dielectric Strength
  - Specific Gravity
  - PCB Content
- Inspection, testing of the batteries and charger located in the main outdoor switchgear, and generator switchgear.
- Inspection, testing and calibration of all of the protective relays in the main 15kV switchgear, 2.4kV outdoor switchgear, 2.4kV generator switchgear and 2400 volt Motor Control Centers.
- De-energized preventive maintenance of the 2400 volt motor control centers including:
  - (2) Main disconnect switches
  - (9) 2400 volt starters and accessories
  - All current and potential devices
- De-energized preventive maintenance of the (2) 2.4kV circuit breakers in the 2.4kV switchgear that feed the Motor Control Centers.

Year #3

- Infrared Thermographic Inspection of the Southtowns Wastewater Treatment Plant Electrical Distribution System (2 days plus report generation). South Towns Waste Water Treatment Plant will provide qualified electricians to remove and replace equipment covers as required.
- Visual Inspection of your facilities Electrical Distribution System.
- Two (2) transformer oil sample and analysis. Analysis will include
  - Gas in Oil Analysis
  - Water Content
  - Acid Content
  - Interfacial Tension
  - Color Analysis
  - Dielectric Strength
  - Specific Gravity
  - PCB Content
- Inspection, testing of the batteries and charger located in the main outdoor switchgear, and generator switchgear.
- De-energized preventive maintenance of the 2.4kV/480 volt substations including:
  - (2) Fused load interrupter switches
  - (2) Dry type 1500kVa transformers
  - Lot 480 volt switchgear
  - (17) Draw-out circuit breakers.
  - All current and potential devices

Notes:

1. The coordination for the required utility line outages is the responsibility of the testing firm.
2. Power outages to accommodate maintenance must be done to accommodate the schedule and requirements of Southtowns Waste Water Treatment Plant. Power outages may be limited in duration.
3. All equipment switching for preventive maintenance will be the responsibility of the testing firm.

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (cont).

All inspections and field tests shall be in accordance with the latest edition of the following codes, standards, and specifications except as provided otherwise herein.

1. American National Standards Institute – ANSI

2. American Society for Testing and Materials - ASTM

ASTM D 92 *Test Method for Flash and Fire Points by Cleveland Open Cup*

ASTM D 445 *Test Method for Kinematic Viscosity of Transparent and Opaque Liquids*

ASTM D 664 *Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

ASTM D 877 *Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes*

ASTM D 923 *Test Method for Sampling Electrical Insulating Liquids*

ASTM D 924 *Test Method for A-C Loss Characteristics and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids*

ASTM D 971 *Test Method for Interfacial Tension of Oil against Water by the Ring Method*

ASTM D 974 *Test Method for Acid and Base Number by Color-Indicator Titration*

ASTM D 1298 *Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

ASTM D 1500 *Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)*

ASTM D 1524 *Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field*

ASTM D 1533 *Test Methods for Water in Insulating Liquids (Karl Fischer Reaction Method)*

ASTM D 1816 *Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes*

ASTM D 2029 *Test Methods for Water Vapor Content of Electrical Insulating cases by Measurement of Dew Point*

ASTM D 2129 *Test Method for Color of Chlorinated Aromatic Hydrocarbons (Askarels)*

ASTM D 2284 *Test Method of Acidity of Sulfur Hexafluorid*

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (cont).

ASTM D 2285 *Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method*

ASTM D 2477 *Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies*

ASTM D 2685 *Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography*

ASTM D 2759 *Method for Sampling Gas from a Transformer under Positive Pressure*

ASTM D 3284 *Test Method for combustible Gases in Electrical Apparatus in the Field*

ASTM D 3612 *Test Method of Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography*

ASTM D 3613 *Methods of Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content*

3. Association of Edison Illuminating Companies - AEIC

4. Canadian Standards Association - CSA

5. Electrical Apparatus Service Association - EASA

ANSI/EASA AR 100 *Recommended Practice for the Repair of Rotating Electrical Apparatus*

6. Institute of Electrical and Electronic Engineers - IEEE

ANSI/IEEE C2 *National Electrical Safety Code*

ANSI/IEEE C37 *Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses*

ANSI/IEEE C57 *Distribution, Power, and Regulating Transformers*

ANSI/IEEE C62 *Surge Protection*

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

ANSI/IEEE Std. 48 *Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV through 765 kV*

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (cont).

IEEE Std. 81 IEEE *Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Part I)*

ANSI/IEEE Std. 81.2 IEEE *Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems (Part 2)*

ANSI/IEEE Std. 95 IEEE *Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage*

IEEE Std. 100 The IEEE *Standard Dictionary of Electrical and Electronics Terms*

IEEE Std. 141 IEEE *Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book)*

ANSI/IEEE Std. 142 IEEE *Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)*

ANSI/IEEE Std. 241 IEEE *Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)*

ANSI/IEEE Std. 242 IEEE *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)*

IEEE 386 IEEE *Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V*

ANSI/IEEE Std. 399 IEEE *Recommended Practice for Industrial and Commercial Power Systems Analysis (Brown Book)*

ANSI/IEEE Std. 400 IEEE *Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field*

ANSI/IEEE Std. 421B IEEE *Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines*

ANSI/IEEE Std. 446 IEEE *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)*

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

ANSI/IEEE Std. 493 IEEE *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)*

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (cont).

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

ANSI/IEEE Std. 602 IEEE *Recommended Practice for Electric Systems in Health Care Facilities (White Book)*

ANSI/IEEE Std. 637 IEEE *Guide for the Reclamation of Insulating Oil and Criteria for Its Use*

ANSI/IEEE Std. 739 IEEE *Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)*

ANSI/IEEE Std. 902 IEEE *Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems (Yellow Book)*

IEEE Std. 1015 IEEE *Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)*

IEEE Std. 1100 IEEE *Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)*

ANSI/IEEE Std. 1106 IEEE *Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Storage Batteries for Generating Stations and Substations*

ANSI/IEEE Std. 1159 *Recommended Practice for Monitoring Electric Power Quality*

ANSI/IEEE Std. 1188 *Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*

7. Insulated Cable Engineers Association - ICEA

8. InterNational Electrical Testing Association - NETA

ANSI/NETA ETT *Standard for Certification of Electrical Testing Technicians*

NETA ATS *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

9. National Electrical Manufacturer's Association - NEMA

NEMA AB4 *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*

ANSI/NEMA 84.1 *Electrical Power Systems and Equipment Voltage Ratings (60 Hz)*

NEMA MG1 *Motors and Generators*

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (cont).

10. National Fire Protection Association - NFPA

    ANSI/NFPA 70 *National Electrical Code*

    ANSI/NFPA 70B *Recommended Practice for Electric Equipment Maintenance*

    ANSI/NFPA 70E *Electrical Safety Requirements for Employee Workplaces*

    ANSI/NFPA 99 *Standard for Healthcare Facilities*

    ANSI/NFPA 101 *Life Safety Code*

    ANSI/NFPA 110 *Emergency and Standby Power Systems*

    ANSI/NFPA 780 *Installation of Lightning Protection Systems*

11. Occupational Safety and Health Administration - OSHA

12. Scaffold Industry Association - SIA

    ANSI/SIA A92.2 *Vehicle Mounted Elevating and Rotating Aerial Devices*

13. State and local codes and ordinances

14. Underwriters Laboratories, Inc. - UL

3. QUALIFICATIONS OF TESTING ORGANIZATION AND PERSONNEL

3.1 Testing Organization

3.1. The testing firm shall be an independent testing organization.

3.2. The testing firm shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.

3.3. The testing firm must have a full-time Field Safety Inspector that is an employee of the company The Field Safety Inspector is to perform safety inspections while the Electrical Preventive Maintenance is taking place. A signed copy of every field safety inspection must be made part of the final report each year.

3.4 The testing firm must have a full-time Electrical Professional Engineer that is an employee of the company. The Professional Engineer will be required to review, approve and stamp the final test data and recommendations that will be provided each year.

3.5 The testing firm shall utilize technicians who are regular full-time employees employed by the firm for testing services. Hiring 3rd party test firms that are not regular employees of your company is not acceptable.

3.6 The testing firm shall submit proof of the above qualifications with bid documents. The Lead Service Technician, Field Safety Inspector and Professional Engineer must be listed by name in the proposal. Failure to submit proof of the qualifications called for here in will result in disqualification of the bid.

3.7 Final payment will be held on this project until all of the above criteria are met including copies of safety inspections and P.E. stamps on the reports.

4. DIVISION OF RESPONSIBILITY

4.1. The owner shall supply a suitable and stable source of electrical power to each test site. The testing firm shall specify the specific power requirements.

4.2. The owner shall notify the testing firm when equipment becomes available for maintenance tests. Work shall be coordinated to expedite project scheduling.

4.3. The testing firm shall notify the owner prior to commencement of any testing.

4.4. Any system, material, or workmanship which is found defective on the basis of maintenance tests shall be reported including recommended corrective actions.

4.5. The testing firm shall maintain a written record of all tests and shall assemble and certify a final test report. The certification must be done by an Electrical P.E. (See Section 3.4 of this specification).

5. GENERAL

All parties involved must be cognizant of industry-standard safety procedures. This document does not include any procedures, including specific safety procedures. It is recognized that an overwhelming majority of the tests and inspections recommended in this standard are potentially hazardous. Individuals performing these tests shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved.

5.1 Safety and Precautions

1. Safety practices shall include, but are not limited to, the following requirements:
    1. All applicable provisions of the Occupational Safety and Health Act, particularly OSHA 29CFR 1910.
    2. Accident Prevention Manual for Industrial Operations, National Safety Council.
    3. Applicable state and local safety operating procedures.
    4. Owner's safety practices.
    5. ANSI/NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces.
2. A safety lead person shall be identified prior to commencement of work.
3. A safety briefing shall be conducted prior to the commencement of work.
4. All tests shall be performed with the apparatus de-energized and grounded except where otherwise specifically required to be ungrounded or energized for certain tests.
5. The testing organization shall have a designated safety representative on the project to supervise operations with respect to safety. This individual may be the same person described in 5.1.2 Documentation testifying to the qualifications must be submitted with the bid documents.

5.2 Suitability of Test Equipment

1. All test equipment shall be in good mechanical and electrical condition.
2. Split-core current transformers and clamp-on or tong-type ammeters require careful consideration of the following in regard to accuracy:
    1. Position of the conductor within the core
    2. Clean, tight fit of the core pole faces
    3. Presence of external fields
    4. Accuracy of the current transformer ratio in addition to the accuracy of the secondary meter.

3. Selection of metering equipment should be based on a knowledge of the waveform of the variable being measured. Digital multimeters may be average or rms sensing and may include or exclude the dc component. When the variable contains harmonics or dc offset and, in general, any deviation from a pure sine wave, average sensing, rms scaled meters may be misleading.

4. Field test metering used to check power system meter calibration must have an accuracy higher than that of the instrument being checked.

5. Accuracy of metering in test equipment shall be appropriate for the test being performed but not in excess of two percent of the scale used.

6. Waveshape and frequency of test equipment output waveforms shall be appropriate for the test and the tested equipment.

5.3 Test Instrument Calibration

1. The testing firm shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

2. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST).

3. Instruments shall be calibrated in accordance with the following frequency schedule:

    1. Field instruments: Analog, 6 months maximum. Digital, 12 months maximum.

    2. Laboratory instruments: 12 months

4. Dated calibration labels shall be visible on all test equipment

5. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date and must be part of the yearly field service report.

6. Up-to-date instrument calibration instructions and procedures shall be maintained for each test instrument.

7. Calibrating standard shall be of higher accuracy than that of the instrument tested.

5. GENERAL

5.4 Test Report

i. The test report shall include the following:

1. Summary of project.

2. Description of equipment tested.

3. Description of tests.

4. Test data.

5. Analysis and recommendations.

ii. Test data records shall include the following minimum requirements:

1. Identification of the testing organization.

2. Equipment identification.

3. Humidity, temperature, and other conditions that may affect the results of the tests/calibrations.

4. Date of inspections, tests, maintenance, and/or calibrations.

5. Identification of the testing technician.

6. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.

7. Indication of expected results when calibrations are to be performed.

8. Indication of "as-found" and "as-left" results, as applicable.

9. Sufficient spaces to allow all results and comments to be indicated.

iii. The testing organization shall furnish a copy or copies of the complete report to the owner as specified in the maintenance testing contract.

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

1. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
2. Inspect anchorage, alignment, grounding, and required area clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using one of the following methods:
    1. Use of low-resistance ohmmeter in accordance with Section 7.1.2.3.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
    3. Perform thermographic survey in accordance with Section 9.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
    1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
    2. Make key exchange with devices operated in off-normal positions.
9. Lubrication requirements
    1. Use appropriate lubrication on moving current-carrying parts.
    2. Use appropriate lubrication on moving and sliding surfaces.
10. Perform as-left tests.
11. Inspect insulators for evidence of physical damage or contaminated surfaces.
12. Verify correct barrier and shutter installation and operation.
13. Exercise all active components.
14. Inspect mechanical indicating devices for correct operation.

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (cont.)

15. Verify that filters are in place and/or vents are clear.

16. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.

17. Inspect control power transformers.

    1. Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.

    2. Verify that primary and secondary fuse ratings or circuit breakers match drawings.

    3. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.

2. **Electrical Tests**

    1. Perform electrical tests on instrument transformers in accordance with Section 7.10.

    2. Perform ground-resistance tests in accordance with Section7.13.

    3. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.1.1.

    4. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute in accordance with Table 10.1.

    5. Perform system function tests in accordance with Section 8.

    6. Control Power Transformers

        1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 10.1 unless otherwise specified by manufacturer.

        2. Verify correct function of control transfer relays located in switchgear with multiple power sources.

    7. Voltage Transformers

        1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 10.1 unless otherwise specified by manufacturer.

        2. Verify secondary voltages.

    8. Verify operation of switchgear/switchboard heaters.

3. **Test Values**

    1. Compare bus connection resistances to values of similar connections.

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (cont.)

2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar bus by more than 50 percent of the lowest value.

4. Insulation-resistance values for bus and control power transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 10.1. Values of insulation resistance less than this table or manufacturer's minimum should be investigated. Overpotential tests should not proceed until insulation-resistance levels are raised above minimum values.

5. Bus insulation shall withstand the overpotential test voltage applied.

6. Control wiring minimum insulation-resistance values should be comparable to previously obtained results but not less than two megohms.

7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (cont.)

NOTE: This category consists of power transformers with windings rated higher than 600 volts and low-voltage transformers larger than 167 kVA single-phase or 500 kVA three-phase.

1. **Visual and Mechanical Inspection**
    1. Inspect physical and mechanical condition including evidence of moisture and corona.
    2. Inspect anchorage, alignment, and grounding.
    3. Prior to cleaning the unit, perform as-found tests, if required.
    4. Clean the unit.
    5. Verify that control and alarm settings on temperature indicators are as specified.
    6. Verify that cooling fans operate.
    7. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.2.1.2.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    8. Perform specific inspections and mechanical tests as recommended by manufacturer.
    9. Perform as-left tests.
    10. Verify that as-left tap connections are as specified.
    11. Verify the presence of surge arresters.
2. **Electrical Tests**
    1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.2.1.
    2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground with test voltage in accordance with Table 10.5. Calculate polarization index.
    3. Perform turns-ratio tests at the designated tap position.
    4. Perform an excitation-current test on each phase.
    5. Measure the resistance of each winding at the designated position.
    6. Measure core insulation-resistance at 500 volts dc if core is insulated and if the core ground strap is removable.

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (cont.)

7. Perform an overpotential test on all high- and low-voltage windings-to-ground. See ANSI/IEEE C57.12.91, Sections 10.2 and 10.9.

8. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

9. Test surge arresters in accordance with Section 7.19.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.

4. Insulation-resistance test values at one minute should be in accordance with Table 10.5.

5. The polarization index shall be compared to previously obtained results and should not be less than 1.0.

6. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.

7. Temperature corrected winding-resistance test results should compare within one percent of previously obtained results.

8. Core insulation-resistance values should be comparable to previously obtained results but not less than one megohm at 500 volts dc.

AC overpotential test shall not exceed 65 percent of factory test voltage for one minute duration.

DC overpotential test shall not exceed 100 percent of the ac rms test voltage specified in ANSI C57.12.91, Section 10.2 for one minute duration. The insulation should withstand the overpotential test voltage applied.

7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (cont.)

1. Visual and Mechanical Inspection
    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding.
    3. Verify the presence of PCB labeling.
    4. Perform as-found tests, if required.
    5. Clean bushings and control cabinets.
    6. Verify that alarm, control, and trip settings on temperature indicators are as specified.
    7. Verify that cooling fans and/or pumps operate correctly.
    8. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay, if applicable.
    9. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.2.2.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    10. Verify correct liquid level in tanks and bushings.
    11. Verify that positive pressure is maintained on gas-blanketed transformers.
    12. Perform inspections and mechanical tests as recommended by the manufacturer.
    13. Test load tap-changer in accordance with Section 7.12, if applicable.
    14. Verify the presence of transformer surge arresters.
    15. Perform as-left tests.

7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (cont.)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.2.1.
2. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground, with test voltage in accordance with Table 10.5. Calculate polarization index.
3. Perform turns-ratio tests at the designated tap position.
4. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment manufacturer's published data.
5. Perform power-factor or dissipation-factor tests or hot collar watts-loss tests on bushings in accordance with test equipment manufacturer's published data.
6. Perform excitation-current tests in accordance with test equipment manufacturer's published data.
7. Measure the resistance of each winding at the designated tap position.
8. If core ground strap is accessible, remove and measure core insulation resistance at 500 volts dc.
9. Measure the percentage of oxygen in the gas blanket, if applicable.
10. Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested for the following.
    1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
    2. Acid neutralization number: ANSI/ASTM D 974
    3. Specific gravity: ANSI/ASTM D 1298
    4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
    5. Color: ANSI/ASTM D 1500
    6. Visual Condition: ASTM D 1524
    7. Water in insulating liquids: ASTM D 1533. (Required on 25 kV or higher voltages and on all silicone-filled units.)
    8. Measure power-factor or dissipation-factor in accordance with ASTM D 924.
11. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.
12. Test instrument transformers in accordance with Section 7.10.
13. Test surge arresters in accordance with Section 7.19.
14. Test transformer neutral grounding impedence devices, if applicable.

7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (cont.)

3. Test Values

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by the manufacturer.
3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.
4. Insulation-resistance test values at one minute should be in accordance with Table 10.5.
5. The polarization index should be compared to previously obtained results and not be less than 1.0.
6. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.
7. Maximum power factor of liquid-filled transformers corrected to 20°C shall be in accordance with transformer manufacturer's published data. Representative values are indicated in Table 10.3.
8. Investigate bushing power factors and capacitances that vary from nameplate values by more than ten percent. Investigate any bushing hot collar watts-loss results that exceed the test equipment manufacturer's published data.
9. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
10. Temperature corrected winding-resistance measurements should compare within one percent of previously obtained results.
11. Core insulation values should be comparable to previously obtained results but not less than one megohm at 500 volts dc.
12. Investigate presence of oxygen in the nitrogen gas blanket.
13. Insulating liquid test results shall be in accordance with Table 10.4.
14. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.
15. Compare grounding impedance device results to previously obtained results. In the absence of previously obtained results, compare to manufacturer's published data.

7. INSPECTION AND TEST PROCEDURES

7.5.1.2 Switches, Air, Medium-Voltage, Metal-Enclosed

1. **Visual and Mechanical Inspection**
    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, grounding, and required area clearances.
    3. Prior to cleaning the unit, perform as-found tests, if required.
    4. Clean the unit.
    5. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
    6. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
    7. Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements.
    8. Verify that each fuseholder has adequate mechanical support and contact integrity.
    9. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.5.1.2.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    10. Test all interlocking systems for correct operation and sequencing.
    11. Compare switchblade clearances with industry standards.
    12. Verify all indicating and control devices for correct operation.
    13. Lubrication requirements
        1. Use appropriate lubrication on moving current-carrying parts.
        2. Use appropriate lubrication on moving and sliding surfaces.
    14. Perform as-left tests.

7. INSPECTION AND TEST PROCEDURES

7.5.1.2 Switches, Air, Medium-Voltage, Metal-Enclosed (cont.)

2. **Electrical Tests**

   1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.2.1.

   2. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 10.1.

   3. Perform an overpotential test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 10.2.

   4. Measure contact resistance across each switchblade and fuseholder.

   5. Measure fuse resistance.

   6. Verify operation of cubicle heaters.

3. **Test Values**

   1. Compare bolted connection resistances to values of similar connections.

   2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by manufacturer.

   3. Microhm or millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

   4. Insulation resistance values should be in accordance with manufacturer's published data or Table 10.1.

   5. The insulation shall withstand the overpotential test voltage applied.

   6. Investigate fuse resistance values that deviate from each other by more than 15 percent.

7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power

1. Visual and Mechanical Inspection

    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding.
    3. Verify that all maintenance devices are available for servicing and operating the breaker.
    4. Prior to cleaning the unit, perform as-found tests, if required.
    5. Clean the unit.
    6. Inspect arc chutes.
    7. Inspect moving and stationary contacts for condition, wear, and alignment.
    8. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
    9. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism in accordance with manufacturer's published data.
    10. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.6.1.2.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    11. Verify cell fit and element alignment.
    12. Verify racking mechanism operation.
    13. Lubrication requirements
        1. Use appropriate lubrication on moving current-carrying parts.
        2. Use appropriate lubrication on moving and sliding surfaces.
    14. Perform as-left tests.
    15. Record as-found and as-left operation counter readings, if applicable.

7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power (cont.)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.1.2.1.

2. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 10.1.

3. Perform a contact/pole-resistance test.

4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

5. Make adjustments to the trip settings in accordance with the coordination study.

6. Determine minimum pickup current by primary current injection.

7. Determine long-time delay by primary current injection.

8. Determine short-time pickup and delay by primary current injection.

9. Determine ground-fault pickup and delay by primary current injection.

10. Determine instantaneous pickup value by primary current injection.

11. Test functions of the trip unit by means of secondary injection.

12. Activate auxiliary protective devices, such as ground-fault or undervoltage trip devices, to insure operation of shunt trip devices. Check the operation of electrically-operated breakers in their cubicles.

13. Perform minimum pickup voltage test on shunt trip and close coils in accordance with Table 10.20.

14. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, antipump function, trip unit battery condition, and reset all trip logs and indicators.

15. Verify operation of charging mechanism.

7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power (cont.)

3. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by the manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.

4. Circuit breaker insulation resistance should be in accordance with Table 10.1.

5. Control wiring minimum insulation-resistance values should be comparable to previously obtained results but not less than two megohms.

6. Trip characteristics of breakers should fall within manufacturer's published time-current tolerance bands.

7. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table10.20.

7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage

1. **Visual and Mechanical Inspection**
    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding.
    3. Verify that all maintenance devices are available for servicing and operating the breaker.
    4. Prior to cleaning the unit, perform as-found tests, if required.
    5. Clean the unit.
    6. Inspect arc chutes.
    7. Inspect moving and stationary contacts for condition, wear, and alignment.
    8. If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, and penetration. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to ANSI C37.04.
    9. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
    10. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.6.1.3.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    11. Verify cell fit and element alignment.
    12. Verify racking mechanism operation.
    13. Inspect puffer operation.
    14. Perform time-travel analysis.
    15. Lubrication requirements
        1. Use appropriate lubrication on moving current-carrying parts.
        2. Use appropriate lubrication on moving and sliding surfaces.

7.6.1.3 Circuit Breakers, Air, Medium-Voltage (cont.)

16. Perform as-left tests.

17. Record as-found and as-left operation-counter readings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. See Section 7.6.1.3.1.

2. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with circuit breaker closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data or Table 10.1.

3. Perform a contact/pole-resistance test.

4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that can not tolerate the applied voltage, follow manufacturer's recommendation.

5. With breaker in the test position, make the following tests:

    1. Trip and close breaker with the control switch.

    2. Trip breaker by operating each of its protective relays.

    3. Verify trip-free and antipump functions.

    4. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 10.20.

6. Perform power-factor or dissipation-factor test with breaker in both the open and closed positions.

7. Perform an overpotential test in accordance with manufacturer's published data.

8. Measure blowout coil circuit resistance.

9. Verify operation of heaters.

10. Test instrument transformers in accordance with Section 7.10.

7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage (cont.)

3. Test Values

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by the manufacturer.
3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Circuit breaker insulation resistance should be in accordance with Table 10.1.
5. Control wiring minimum insulation-resistance values should be comparable to previously obtained results but not less than two megohms.
6. Power-factor or dissipation-factor test results shall be compared with previous tests of similar breakers or manufacturer's published data.
7. The insulation shall withstand the overpotential test voltage applied.
8. Minimum pickup for trip and close coils should be in accordance with manufacturer's published data. In the absence of manufacturer's data, refer to Table 10.20.
9. Circuit breaker operation times should conform to manufacturer's published data.

7. INSPECTION AND TEST PROCEDURES

7.9 Protective Relays

1. Visual and Mechanical Inspection

1. Inspect relays and cases for physical damage.
2. Prior to cleaning the unit, perform as-found tests.
3. Clean the unit.
4. Tighten case connections. Inspect cover for correct gasket seal. Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches. Remove any foreign material from the case. Verify target reset.
5. Inspect relay for foreign material, particularly in disk slots of the damping and electromagnets. Verify disk clearance. Verify contact clearance and spring bias. Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Burnish contacts. Inspect bearings and/or pivots.
6. Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.
7. Perform as-left tests.

2. Electrical Tests

1. Perform insulation-resistance test on each circuit-to-frame. Determine from the manufacturer's published data the allowable procedures for this test for solid-state and microprocessor-based relays.
2. Inspect targets and indicators.
    1. Determine pickup and dropout of electromechanical targets.
    2. Verify operation of all light-emitting diode indicators.
    3. Set contrast for liquid-crystal display readouts.

7. INSPECTION AND TEST PROCEDURES

7.9 Protective Relays (cont.)

3. Functional Operation

1. 2/62 Timing Relay
    1. Determine time delay.
    2. Verify operation of instantaneous contacts.
2. 21 Distance Relay
    1. Determine maximum reach.
    2. Determine maximum torque angle.
    3. Determine offset.
    4. Plot impedance circle.
3. 24 Volts/Hertz Relay
    1. Determine pickup frequency at rated voltage.
    2. Determine pickup frequency at a second voltage level.
    3. Determine time delay.
4. 25 Sync Check Relay
    1. Determine closing zone at rated voltage.
    2. Determine maximum voltage differential that permits closing at zero degrees.
    3. Determine live line, live bus, dead line, and dead bus set points.
    4. Determine time delay.
    5. Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.
5. 27 Undervoltage Relay
    1. Determine dropout voltage.
    2. Determine time delay.
    3. Determine the time delay at a second point on the timing curve for inverse time relays.
6. 32 Directional Power Relay
    1. Determine minimum pickup at maximum torque angle.
    2. Determine closing zone.

7. INSPECTION AND TEST PROCEDURES

7.9 Protective Relays (cont.)

3. Determine maximum torque angle.
4. Determine time delay.
5. Verify the time delay at a second point on the timing curve for inverse time relays.
6. Plot the operating characteristic.

7. 40 Loss of Field (Impedance) Relay
   1. Determine maximum reach.
   2. Determine maximum torque angle.
   3. Determine offset.
   4. Plot impedance circle.

8. 46 Current Balance Relay
   1. Determine pickup of each unit.
   2. Determine percent slope.
   3. Determine time delay.

9. 46N Negative Sequence Current Relay
   1. Determine negative sequence alarm level.
   2. Determine negative sequence minimum trip level.
   3. Determine maximum time delay.
   4. Verify two points on the $(I_2)^2t$ curve.

10. 47 Phase Sequence or Phase Balance Voltage Relay
    1. Determine positive sequence voltage to close the normally open contact.
    2. Determine positive sequence voltage to open the normally closed contact (undervoltage trip).
    3. Verify negative sequence trip.
    4. Determine time delay to close the normally open contact with sudden application of 120 percent of pickup.
    5. Determine time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.

7. INSPECTION AND TEST PROCEDURES

7.9 Protective Relays (cont.)

11. 49R Thermal Replica Relay
    1. Determine time delay at 300 percent of setting.
    2. Determine a second point on the operating curve.
    3. Determine pickup.
12. 49T Temperature (RTD) Relay
    1. Determine trip resistance.
    2. Determine reset resistance.
13. 50 Instantaneous Overcurrent Relay
    1. Determine pickup.
    2. Determine dropout.
    3. Determine time delay.
14. 51 Time Overcurrent
    1. Determine minimum pickup.
    2. Determine time delays at two points on the time current curve.
15. 55 Power Factor Relay
    1. Determine tripping angle.
    2. Determine time delay.
16. 59 Overvoltage Relay
    1. Determine overvoltage pickup.
    2. Determine time delay to close the contact with sudden application of 120 percent of pickup.
17. 60 Voltage Balance Relay
    1. Determine voltage difference to close the contacts with one source at rated voltage.
    2. Plot the operating curve for the relay.
18. 63 Transformer Sudden Pressure Relay
    1. Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer's specifications.

7. INSPECTION AND TEST PROCEDURES

7.9 Protective Relays (cont.)

2. Verify operation of the 63 FPX seal-in circuit.

3. Verify trip circuit to remote breaker.

19. 64 Ground Detector Relay

1. Determine maximum impedance to ground causing relay pickup.

20. 67 Directional Overcurrent Relay

1. Determine directional unit minimum pickup at maximum torque angle.

2. Determine closing zone.

3. Determine maximum torque angle.

4. Plot operating characteristics.

5. Determine overcurrent unit pickup.

6. Determine overcurrent unit time delay at two points on the time current curve.

21. 79 Reclosing Relay

1. Determine time delay for each programmed reclosing interval.

2. Verify lockout for unsuccessful reclosing.

3. Determine reset time.

4. Determine close pulse duration.

5. Verify instantaneous overcurrent lockout.

22. 81 Frequency Relay

1. Verify frequency set points.

2. Determine time delay.

3. Determine undervoltage cutoff.

23. 85 Pilot Wire Monitor

1. Determine overcurrent pickup.

2. Determine undercurrent pickup.

3. Determine pilot wire ground pickup level.

7. INSPECTION AND TEST PROCEDURES

7.9 Protective Relays (cont.)

24. 87 Differential

1. Determine operating unit pickup.
2. Determine the operation of each restraint unit.
3. Determine slope.
4. Determine harmonic restraint.
5. Determine instantaneous pickup.
6. Plot operating characteristics for each restraint.

4. Control Verification

1. Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.
2. For microprocessor-based relays, verify all used inputs, outputs, and internal logic.

5. Test Values

1. When not otherwise specified, use manufacturer's recommended tolerances.
2. When critical test points are specified, the relay should be calibrated to those points even though other test points may be out of tolerance.

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers

1. **Visual and Mechanical Inspection**
    1. Inspect physical and mechanical condition.
    2. Prior to cleaning the unit, perform as-found tests, if required.
    3. Clean the unit.
    4. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.10.2 and 7.10.3.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    5. Verify that all required grounding and shorting connections provide contact.
    6. Verify correct operation of transformer withdrawal mechanism and grounding operation.
    7. Verify correct primary and secondary fuse sizes for voltage transformers.
    8. Lubrication requirements
        1. Use appropriate lubrication on moving current-carrying parts.
        2. Use appropriate lubrication on moving and sliding surfaces.
    9. Perform as-left tests.

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (cont.)

2. Electrical Tests - Current Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.

2. Perform insulation-resistance test of each current transformer and wiring-to-ground at 1000 volts dc. For units with solid-state components, follow manufacturer's recommendations.

3. Perform a polarity test of each current transformer.

4. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. 1 (IEEE *Guide for Field Testing of Relaying Current Transformers*).

5. Perform an excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1. (IEEE *Guide for Field Testing of Relaying Current Transformers*).

6. Measure current circuit burdens at transformer terminals.

7. When applicable, perform insulation-resistance and dielectric withstand tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Tables 10.5 and 10.9 respectively.

8. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3 (IEEE *Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases).*

3. Electrical Tests - Voltage Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.

2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute in accordance with Table 10.5. For units with solid-state components, follow manufacturer's recommendations.

3. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable.

4. Perform a turns ratio test on all tap positions, if applicable.

5. Measure voltage circuit burdens at transformer terminals.

6. Perform a dielectric withstand test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall be in accordance with Table 10.9. The test voltage shall be applied for one minute.

4. Electrical Tests - Coupling Capacitor Voltage Transformers

1. Perform all tests from 7.10.3 Voltage Transformers.

7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (cont.)

2. Measure capacitance of capacitor sections.

3. Measure power-factor or dissipation-factor in accordance with test equipment manufacturer's published data.

5. Test Values

1. Compare bolted connection resistances to values of similar connections.

2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by the manufacturer.

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.

4. Insulation-resistance measurement on any instrument transformer shall be not less than that shown in Table 10.5.

5. Polarity results shall agree with transformer markings.

6. Compare measured burdens to instrument transformer ratings.

7. Ratio accuracies shall be within 0.5 percent of nameplate or manufacturer's published data.

8. The insulation shall withstand the overpotential test voltage applied.

9. Capacitance of capacitor sections of coupling-capacitance voltage transformers shall be in accordance with manufacturer's published data.

10. Power-factor or dissipation-factor shall be in accordance with test equipment manufacturer's published data.

7. INSPECTION AND TEST PROCEDURES

7.11 Metering Devices

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Verify tightness of electrical connections.
3. Inspect cover gasket, cover glass, condition of spiral spring, disk clearance, contacts, and case-shorting contacts, as applicable.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Verify freedom of movement, end play, and alignment of rotating disk(s).
7. Perform as-left tests.

2. Electrical Tests

1. Verify accuracy of meters at all cardinal points.
2. Calibrate meters in accordance with manufacturer's published data.
3. Verify all instrument multipliers.

7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage

1. **Visual and Mechanical Inspection**
    1. Inspect physical and mechanical condition including evidence of moisture and corona.
    2. Inspect anchorage, alignment, and grounding.
    3. Prior to cleaning the unit, perform as-found tests, if required.
    4. Clean the unit.
    5. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.16.1.2.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform thermographic survey in accordance with Section 9.
    6. Test all electrical and mechanical interlock systems for correct operation and sequencing.
    7. Verify correct barrier and shutter installation and operation.
    8. Exercise all active components and confirm correct operation of all indicating devices.
    9. Inspect contactors.
        1. Verify mechanical operation.
        2. Inspect and adjust contact gap, wipe, alignment, and pressure in accordance with manufacturer's published data.
    10. Compare overload protection rating with motor nameplate to verify correct size. Set adjustable or programmable devices according to the protective device coordination study.
    11. Lubrication requirements
        1. Verify appropriate lubrication on moving current-carrying parts.
        2. Verify appropriate lubrication on moving and sliding surfaces.
    12. Perform as-left tests.

7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage (cont.)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.16.1.2.1.

2. Perform insulation-resistance tests on contactor(s), phase-to-ground, phase-to-phase, and across the open contacts for one minute in accordance with Table 10.1.

3. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500 volts dc for 300 volt rated cable and 1000 volts dc for 600 volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

4. Perform system function test in accordance with Section 8.

5. Test control power transformers in accordance with Section 7.1.2.8.

6. Perform an overpotential test in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 10.9.

7. Perform vacuum bottle integrity test (overpotential), if applicable, across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer's published data. Do not exceed maximum voltage stipulated for this test.

8. Perform contact resistance tests.

9. Measure blowout coil circuit resistance.

10. Measure resistance of power fuses.

11. Energize contactor using an auxiliary source. Adjust armature to minimize operating vibration where applicable.

12. Test motor protection devices in accordance with manufacturer's published data. In the absence of manufacturer's data, use Section 7.9.

13. Test starting transformers, if applicable, in accordance with Section 7.2.1.

14. Test starting reactors, if applicable, in accordance with 7.20.3.

15. Verify operation of cubicle space heater.

7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage (cont.)

3. Test Values

   1. Compare bolted connection resistances to values of similar connections.

   2. Bolt-torque values should be in accordance with Table 10.12 unless otherwise specified by manufacturer.

   3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.

   4. Starter insulation resistance shall be in accordance with Table 10.1.

   5. Control wiring minimum insulation-resistance values should be comparable to previously obtained results but not less than two megohms.

   6. The insulation shall withstand the overpotential test voltage applied.

   7. Resistance values shall not deviate by more than 15 percent between identical fuses.

   8. Motor protection parameters shall be in accordance with manufacturer's published data.

7. INSPECTION AND TEST PROCEDURES

7.18.1.1 Direct-Current Systems, Batteries, Flooded Lead-Acid

1. **Visual and Mechanical Inspection**
    1. Verify ventilation of battery room or enclosure
    2. Verify existence of suitable eyewash equipment.
    3. Inspect physical and mechanical condition.
    4. Inspect anchorage, alignment and grounding.
    5. Perform as-found tests, if applicable.
    6. Verify electrolyte level. Measure electrolyte specific gravity and temperature levels.
    7. Verify presence of flame arresters.
    8. Verify adequacy of batter support racks, mounting, anchorage, and clearances.
    9. Neutralize acid on exterior surfaces and rinse with water.
    10. Clean corroded/oxidized terminals and apply an oxide inhibitor.
    11. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.18.1.1.2
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
        3. Perform Thermographic survey under load in accordance with Section 9.
    12. Perform as-left tests.
2. **Electrical Tests**
    1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.1.1.1.
    2. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
    3. Verify all charger functions and alarms.
    4. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.
    5. Measure intercell connection resistances.
    6. Perform internal ohmic measurement tests.

7. INSPECTION AND TEST PROCEDURES

7.18.1.1 Direct-Current Systems, Batteries, Flooded Lead-Acid

7. Perform a load test in accordance with manufacturer's specifications or ANSI/IEEE 450, *Recommended Practice for Maintenance, Testing and Replacement of Large Lead Storage Batteries for Generating Stations and Substations.*

3. **Test Values**

1. Electrolyte level and specific gravity shall be within normal limits.

2. Compare bolted connection resistances to values of similar connections.

3. Bolt-torque levels shall be in accordance manufacturer's recommended data.

4. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.

5. Charger float and equalize voltage levels shall be in accordance with battery manufacturer's published data.

6. Cell voltages should be within 0.05 volt of each other or in accordance with manufacturer's published data.

7. Cell internal ohmic values (resistance, impedance or conductance) values should not vary by more than 25 percent between identical cells that are in a fully charged state.

7. INSPECTION AND TEST PROCEDURES

7.18.2 Direct Current Systems, Chargers

1. Visual and Mechanical Inspection

1. Inspect for physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect all bolted electrical connections for high resistance using one of the following methods:
    1. Use of low-resistance ohmmeter in accordance with Section 7.18.2.2.
    2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
    3. Perform thermographic survey under load in accordance with Section 9.
6. Inspect filter and tank capacitors.
7. Verify operation of cooling fans. Clean filters if provided.
8. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.2.1.
2. Verify float voltage, equalize voltage, and high voltage shutdown settings.
3. Verify current limits.
4. Verify correct load sharing (parallel chargers).
5. Verify calibration of voltmeter and ammeter.
6. Verify operation of alarms.
7. Measure and record input and output voltage and current.
8. Perform full load testing of charger.

3. Test Values

1. Compare bolted connection resistances to values of similar connections.
2. Bolt-torque levels shall be in accordance with manufacturer's published data or Table 10.12.

7. INSPECTION AND TEST PROCEDURES

7.18.2 Direct Current Systems, Chargers

3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.

4. Float and equalize voltage settings shall be in accordance with the battery manufacturer's published data.

5. Current limit shall be within manufacturer's recommended maximum.

6. Charger shall be capable of manufacturer's specified full load.

7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage Surge Protection Devices

1. **Visual and Mechanical Inspection**
    1. Inspect physical and mechanical condition.
    2. Inspect anchorage, alignment, and grounding.
    3. Prior to cleaning the unit, perform as-found tests.
    4. Clean the unit.
    5. Inspect bolted electrical connections for high resistance using one of the following methods:
        1. Use of low-resistance ohmmeter in accordance with Section 7.19.2.2.
        2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 10.12.
    6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
    7. Verify that stroke counter, if present, is correctly mounted and electrically connected.
    8. Perform as-left tests.
2. **Electrical Tests**
    1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.2.1.
    2. Perform an insulation-resistance test at voltage levels in accordance with Table 10.1.
    3. Test grounding connection in accordance with Section 7.13.
    4. Perform a watts-loss test.

7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage Surge Protection Devices (cont.)

3. Test Values

   1. Compare bolted connection resistances to values of similar connections.

   2. Bolt-torque levels should be in accordance with Table 10.12 unless otherwise specified by the manufacturer.

   3. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate any values which deviate from similar connections by more than 50 percent of the lowest value.

   4. Insulation-resistance values should be in accordance with Table 10.1.

   5. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm.

   6. Compare watts loss to similar units.

8. SYSTEM FUNCTION TESTS

8.1 System Function Tests

It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices.

Perform system function tests upon completion of the maintenance tests defined, as system conditions allow.

1. Develop test parameters and perform tests for the purpose of evaluating performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

2. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.

3. Verify the correct operation of all sensing devices, alarms, and indicating devices.

9. THERMOGRAPHIC SURVEY

9.1 Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Remove all necessary covers prior to thermographic inspection.

9.2 Equipment to be inspected shall include all current-carrying devices.

9.3 Provide report including the following:

1. Each reported Thermographic image must be date and time stamped.
2. The following items must be identified for each Thermographic image:
    1. Location of the equipment
    2. Description of the reported component including part numbers.
    3. Break, fuse or switch sized including all relevant values including voltage, amperage, phase, coil ratings, etc.
    4. Current readings at the time the image was taken
    5. Wire size on bus size to and from the device being reported component.
    6. An observation outlining what is specifically wrong with the reported component.
    7. Specific repair or replacement recommendations.
    8. Temperature differential between deficient areas and reference areas.
    9. Repair priority ratings.
    10. Photographs both thermal and digital of the reported areas with the deficiencies clearly identified.
    11. A summary sheet shall be supplied for management of repairs. The summary sheet must include:
        1. All deficient equipment.
        2. The location of each piece of equipment.
        3. The repair priority of each piece of equipment.
        4. An area for the signature of the repair electrician.
        5. An area for the date that the repair was made.
        6. An area for the description of the completed repairs.

9. THERMOGRAPHIC SURVEY

9.4 Test Parameters

1. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1°C at 30°C.

2. Equipment shall detect emitted radiation and convert detected radiation to visual signal.

3. Thermographic surveys should be performed during periods of maximum possible loading. But not less than 40 percent of rated load of the electrical equipment being inspected. Refer to ANSI/NFPA 70B, Section 18-16.

9.5 Test Results

Suggested actions based on temperature rise can be found in Table 10.18.

9.6 Thermographer Qualifications

1. The thermographer must have the following minimum qualifications:

    1. Level 2 Certified Thermographer

    2. Journeyman Electrician

    3. Certified to work with and in the area of exposed 15,000 volt equipment including required safety and operations training.

2. The cover removal and replacement electricians must have the minimum qualifications:

3. Journeyman Electrician

4. Certified to work with and in the area of exposed 15,000 volt equipment including required safety and operations training.

Note:

1. The thermographer and cover removal electricians must have and wear, when applicable, proper safety clothing, high voltage suit and face shields.

2. Exceptions to 9.6.1 and 9.6.2 will not be accepted.

TABLE 10.1

Insulation Resistance Test Values
Electrical Apparatus and Systems

Nominal Rating of Equipment in Volts	Minimum Test Voltage, DC	Recommended Minimum Insulation Resistance in 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
35,000	15,000	100,000
46,000	15,000	100,000
69,000 and above	15,000	100,000

In the absence of consensus standards dealing with insulation-resistance tests, the Standards Review Council suggests the above representative values.

See Table 10.14 for temperature correction factors.

Test results are dependent on the temperature of the insulating material and the humidity of the surrounding environment at the time of the test.

Insulation-resistance test data may be used to establish a trending pattern. Deviations from the baseline information permit evaluation of the insulation.

TABLE 10.2

Switchgear Withstand Test Voltages

Type of Switchgear	Rated Maximum Voltage (kV) (rms)	Maximum Test Voltage kV	
		AC	DC
Low-Voltage Power Circuit Breaker Switchgear	.254/.508/.635	1.6	2.3
Metal-Clad Switchgear	4.76	14	20
	8.25	27	37
	15.0	27	37
	27.0	45	*
	38.0	60	*
Station-Type Cubicle Switchgear	15.5	37	*
	38.0	60	*
	72.5	120	*
Metal Enclosed Interrupter Switchgear	4.76	14	20
	8.25	19	27
	15.0	27	37
	15.5	37	52
	25.8	45	*
	38.0	60	*

Derived from ANSI/IEEE C37.20.1-1993, Paragraph 5.5, *Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear*, C37.20.2-1993, Paragraph 5.5, *Standard for Metal-Clad and Station-Type Cubicle Switchgear* and C37.20.3-1987 (R1992), Paragraph 5.5, *Standard for Metal-Enclosed Interrupter Switchgear*, and includes 0.75 multiplier with fraction rounded down.

The column headed "DC" is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for voltage rating of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment or that a dc withstand test represents an acceptable alternative to the low-frequency withstand tests specified in these specifications, either for design tests, production tests, conformance tests, or field tests. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of one minute.

Because of the variable voltage distribution encountered when making dc withstand tests, the manufacturer should be contacted for recommendations before applying dc withstand tests to the switchgear. Voltage transformers above 34.5 kV should be disconnected when testing with dc. Refer to ANSI/IEEE C57.13-1993 (*IEEE Standard Requirements for Instrument Transformers*) paragraph 8.8.2.

* Consult Manufacturer

TABLE 10.3

Maintenance Test Values
Recommended Dissipation Factor/Power Factor at 20°C
Liquid-Filled Transformers

	Oil Maximum	Silicone Maximum	Tetrachloroethylene Maximum	High Fire Point Hydrocarbon Maximum
Power Transformers	2.0%	0.5%	3.0%	2.0%
Distribution Transformers	3.0%	0.5%	3.0%	3.0%

In the absence of consensus standards dealing with transformer dissipation/power factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 10.4

Suggested Limits for Service-Aged Insulating Fluids

Mineral Oil[a]				
Test	ASTM Method	69 kV and Below	Above 69 kV through 288 kV	345 kV and Above
Dielectric breakdown, kV minimum	D877	26	26	26
Dielectric breakdown, kV minimum @ 0.04 gap	D1816	23	26	26
Dielectric breakdown, kV minimum @ 0.08 gap	D1816	34	45	45
Interfacial tension, mN/m minimum	D971	24	26	30
Neutralization number, mg KOH/g maximum	D974	0.2	0.2	0.1
Water content, ppm maximum	D1533	35	25	20
Power factor at 25°C, %	D924	1.0[d]	1.0[d]	1.0[d]
Power factor at 100°C, %	D924	1.0[d]	1.0[d]	1.0[d]

Test	ASTM Method	Silicone[b]	Less Flammable Hydrocarbon[c]	Tetrachloroethylene[e]
Dielectric Breakdown, kV minimum	D877	25	24	26
Visual	D2129	Colorless, clear, free of particles	--	Clear with purple iridescence
Water Content, ppm maximum	D1533	100	4.5	35
Dissipation/power factor, % maximum @ 25°C	D924	0.2	1.0	12.0
Viscosity, cSt @ 25°C	D445	47.5 - 52.5	--	0
Fire Point, °C, minimum	D92	340	300	--
Neutralization number, mg KOH/g maximum	D974	0.2	--	.25
Neutralization number, mg KOH/g maximum	D664	N/A	0.25	--
Interfacial Tension, mN/m minimum @ 25°C	D971	N/A	22	--

a. IEEE C57.106-1991 *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 5.

b. IEEE C57.111-1989 *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 3.

c. IEEE C57.121-1988 *Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers*, Table 3.

d. IEEE Standard. 637-1985 IEEE *Guide for the Reclamation of Insulating Oil and Criteria for Its Use*.

e. ABB Bulletin: PC-2000 *Instruction Book PC-2000 for Wecosol™ Fluid-Filled Primary and Secondary Unit Substation Transformers*, Westinghouse Electric Corporation, Small Power Transformer Division, South Boston, VA 24592.

TABLE 10.5

Maintenance Testing
Transformer Insulation Resistance

Transformer Coil Rating Type in Volts	Minimum DC Test Voltage	Recommended Minimum Insulation Resistance in Megohms	
		Liquid Filled	Dry
0 - 600	1000	100	500
601 - 5000	2500	1000	5000
Greater than 5000	5000	5000	25000

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

See Table 10.14 for temperature correction factors.

NOTE: Since insulation resistance depends on insulation rating (kV) and winding capacity (kVA), values obtained should be compared to manufacturer's published data.

TABLE 10.6

Medium-Voltage Cables
Maximum Maintenance Test Voltages (kV, DC)

Insulation Type	Rated Cable Voltage (kV)	Insulation Level (Percent)	Test Voltage kV, DC
Elastomeric: Butyl and Oil Base	5	100	19
	5	133	19
	15	100	41
	15	133	49
	25	100	60
Elastomeric: EPR	5	100	19
	5	133	19
	8	100	26
	8	133	26
	15	100	41
	15	133	49
	25	100	60
	25	133	75
	28	100	64
	35	100	75
Polyethylene (see Note 4)	5	100	19
	5	133	19
	8	100	26
	8	133	26
	15	100	41
	15	133	49
	25	100	60
	25	133	75
	35	100	75

Derived from ANSI/IEEE Standard 141-1993 Table 12-9 and by factoring the applicable ICEA/NEMA Standards by 75% as recommended in Section 18-9.2.4 of NFPA 70B, 1998 Edition *Standard for Electrical Equipment Maintenance*.

NOTE 1: Selection of test voltage for in-service cables depends on many factors. The owner should be consulted and/or informed of the intended test voltage prior to performing the test. Caution should be used in selecting the maximum test voltage and performing the test since cable failure during the test will require repair or replacement prior to re-energizing.

NOTE 2: AEIC C55 and C56 list test voltages approximately 20 percent higher than the ICEA values for the first five years of service. These values are based on 65 percent of the factory test voltages. A reduction to 40 percent is recommended for a cable in service longer than five years.

NOTE 3: ANSI/IEEE 400-1991 specifies much higher voltages than either the ICEA or the AEIC. These voltages overstress cables and are intended to find marginal cable during shutdown to avoid in-service failures. These test voltages should not be used without the concurrence of the owner. If the cable is still in warranty, the cable manufacturer should be consulted for their concurrence. (See the Standard for a discussion of the pros and cons of high direct-voltage tests.)

NOTE 4: See Electric Power Research Institute Report, EPRI TR-101245, *Effect of DC Testing on Extruded Cross-Linked Polyethylene Insulated Cables*. DC high potential testing of aged XLPE-insulated cable in wet locations may reduce remaining life.

TABLE 10.7

Molded-Case Circuit Breakers
Inverse Time Trip Test
(At 300% of Rated Continuous Current of Circuit Breaker)

Range of Rated Continuous Current (Amperes)	Maximum Trip Time in Seconds For Each Maximum Frame Rating[a]	
	≤250 V	251 – 600V
0-30	50	70
31-50	80	100
51-100	140	160
101-150	200	250
151-225	230	275
226-400	300	350
401-600	-----	450
601-800	-----	500
801-1000	-----	600
1001 – 1200	-----	700
1201-1600	-----	775
1601-2000	-----	800
2001-2500	-----	850
2501-5000	-----	900
6000	-----	1000

Derived from Table 5-3, NEMA Standard AB 4-1996.

a. Trip times may be substantially longer for integrally-fused circuit breakers if tested with the fuses replaced by solid links (shorting bars).

TABLE 10.8

Instantaneous Trip Tolerances for Field Testing of Circuit Breakers

		Tolerances of Manufacturer's Published Trip Range	
Breaker Type	Tolerance of Settings	High Side	Low Side
Adjustable	+40% -30%	-----	-----
Nonadjustable	-----	+25%	-25%

Reproduction of Table 5-4 from NEMA publication AB4-1996.

For circuit breakers with nonadjustable instantaneous trips, tolerances apply to the manufacturer's published trip range, i.e., +40 percent on high side, -30 percent on low side.

TABLE 10.9

Instrument Transformer Dielectric Tests
Field Maintenance

Nominal System (kV)	BIL (kV)	Periodic Dielectric Withstand Test Field Test Voltage (kV)	
		AC	DC*
0.6	10	2.6	4
1.1	30	6.5	10
2.4	45	9.7	15
4.8	60	12.3	19
8.32	75	16.9	26
13.8	95	22.1	34
13.8	110	22.1	34
25	125	26.0	40
25	150	32.5	50
34.5	150	32.5	50
34.5	200	45.5	70
46	250	61.7	+
69	350	91.0	+
115	450	120.0	+
115	550	149.0	+
138	550	149.0	+
138	650	178.0	+
161	650	178.0	+
161	750	211.0	+
230	900	256.0	+
230	1050	299.0	+

Table 10.9 is derived from Paragraph 8.8.2 and Tables 2 and 7 of ANSI/IEEE C57.13, *Standard Requirements for Instrument Transformers*.

+ Periodic dc potential tests are not recommended for transformers rated higher than 34.5 kV.

* Under some conditions transformers may be subjected to periodic insulation test using direct voltage from kenotron sets. In such cases the test direct voltage should not exceed the original factory test rms alternating voltage. Periodic kenotron tests should not be applied to (instrument) transformers of higher than 34.5 kV voltage rating.

TABLE 10.10

Maximum Allowable Vibration Amplitude

RPM @ 60 Hz	Velocity in/s peak	Velocity mm/s	RPM @ 50 Hz	Velocity in/s peak	Velocity mm/s
3600	0.15	3.8	3000	0.15	3.8
1800	0.15	3.8	1500	0.15	3.8
1200	0.15	3.8	1000	0.13	3.3
900	0.12	3.0	750	0.10	2.5
720	0.09	2.3	600	0.08	2.0
600	0.08	2.0	500	0.07	1.7

Derived from NEMA publication MG 1–7.08, Table 7–1. Table is unfiltered vibration limits for resiliently mounted machines. For machines with rigid mounting multiply the limiting values by 0.8.

TABLE 10.11

Periodic Electrical Test Values for Insulating Aerial Devices

Insulating Aerial Devices with a Lower Test Electrode System (Category A and Category B)

Unit Rating	60 Hertz (rms) Test			Direct Current Test		
	Voltage kV (rms)	Maximum Allowable Current Microamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
46 kV & below	40	40	1 minute	56	28	3 minutes
69 kV	60	60	1 minute	84	42	3 minutes
138 kV	120	120	1 minute	168	84	3 minutes
230 kV	200	200	1 minute	240	120	3 minutes
345 kV	300	300	1 minute	360	180	3 minutes
500 kV	430	430	1 minute	602	301	3 minutes
765 kV	660	660	1 minute	924	462	3 minutes

Insulating Aerial Devices without Lower Test Electrode System (Category B)

Unit Rating	60 Hertz (rms) Test			Direct Current Test		
	Voltage kV (rms)	Maximum Allowable Current Microamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
46 kV & below	40	400	1 minute	56	56	3 minutes

Insulating Aerial Ladders and Insulating Vertical Aerial Towers

Unit Rating	60 Hertz (rms) Test			Direct Current Test		
	Voltage kV (rms)	Maximum Allowable Current Microamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
46 kV & below	40	400	1 minute	56	56	3 minutes
20 kV & below	20	200	1 minute	28	28	3 minutes

Chassis Insulating Systems and Lower Insulated Booms

60 Hertz (rms) Test			Direct Current Test		
Voltage kV (rms)	Maximum Allowable Current Milliamperes	Time	Voltage kV	Maximum Allowable Current Microamperes	Time
35	3.0	3 minutes	50	50	3 minutes

Derived from ANSI/SIA A92-2-1990.

A method of calculating test voltages for units rated other than those tabulated here is as follows:

The 60 Hz test values are equal to line to ground at the unit rating value time 1.5.

TABLE 10.12

US Standard Fasteners[a]
Bolt Torque Values for Electrical Connections

Part 1 Heat-Treated Steel - Cadmium or Zinc Plated				
Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter in Inches	Torque (Pound-Feet)			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

Part 2 Silicon Bronze Fasteners[b] Torque (Pound-Feet)		
Bolt Diameter in Inches	Nonlubricated	Lubricated
5/16	15	10
3/8	20	14
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 10.12– CONTINUED

US Standard Fasteners[a]
Bolt Torque Values for Electrical Connections

Part 3 Aluminum Alloy Fasteners[c] Torque (Pound-Feet)	
Bolt Diameter in Inches	Lubricated
5/16	8.0
3/8	11.2
1/2	20.0
5/8	32.0
3/4	48.0

Part 4 Stainless Steel Fasteners[d] Torque (Pound-Feet)	
Bolt Diameter in Inches	Uncoated
5/16	14
3/8	25
1/2	45
5/8	60
3/4	90

a. Consult manufacturer for equipment supplied with metric fasteners.

c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

d. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18–8 alloy)
Belleville washers (302 alloy).

TABLE 10.13

SF_6 Gas Tests

Test	Method	Serviceability Limits [a]
Moisture	Hygrometer	Per manufacturer or ≥ 200 ppm[b]
SF_6 decomposition byproducts	ASTM D 2685	≥ 500 ppm
Air	ASTM D 2685	≥ 5000 ppm[c]
Dielectric breakdown Hemispherical contacts	0.10 inch gap at atmospheric pressure	11.5 - 13.5 kV[d]

a. In the absence of consensus standards dealing with SF_6 circuit breaker gas tests, the NETA Standards Review Council suggests the above representative values.

b. According to some manufacturers.

c. Dominelli, N. and Wylie, L., *Analysis of SF_6 Gas as a Diagnostic Technique for GIS*, Electric Power Research Institute, Substation Equipment Diagnostics Conference IV, February 1996.

d. Per Even, F.E., and Mani, G. Sulfur Fluorides, Kirk, *Othmer Encyclopedia of Chemical Technology*, 4th ed., 11,428, 1994.

Reference: IEC 61634 High-Voltage Switchgear and Controlgear - *Use and Handling of Sulfur Hexafluoride (SF_6) in High-Voltage Switchgear and Controlgear*.

TABLE 10.14

Insulation Resistance Conversion Factors
Test Temperature to 20° C

Temperature		Multiplier	
°C	°F	Apparatus Containing Immersed Oil Insulation	Apparatus Containing Solid Insulation
-10	14	0.125	0.25
-5	23	0.180	0.32
0	32	0.25	0.40
5	41	0.36	0.50
10	50	0.50	0.63
15	59	0.75	0.81
20	68	1.00	1.00
25	77	1.40	1.25
30	86	1.98	1.58
35	95	2.80	2.00
40	104	3.95	2.50
45	113	5.60	3.15
50	122	7.85	3.98
55	131	11.20	5.00
60	140	15.85	6.30
65	149	22.40	7.9
70	158	31.75	10.00
75	167	44.70	12.60
80	176	63.50	15.80
85	185	89.789	20.00
90	194	127.00	25.20
95	203	180.00	31.60
100	212	254.00	40.00
105	221	359.15	50.40
110	230	509.00	63.20

Derived from *Stitch in Time...The Complete Guide to Electrical Insulation Testing*, AVO/Biddle Instruments.
Formula:

$R_c = R_a \times K$

Where: R_c is resistance corrected to 20°C
R_a is measured resistance at test temperature
K is applicable multiplier

Example: Resistance test on oil-immersion insulation at 104°F
$R_a = 2$ megohms @ 104°F
$K = 3.95$
$R_c = R_a \times K$
$R_c = 2.0 \times 3.95$
$R_c = 7.90$ megohms @ 20°C

TABLE 10.15

High-Potential Test Voltage for Automatic Circuit Reclosers

Nominal Voltage Class, kV	Maximum Voltage, kV	Rated Impulse Withstand Voltage, kV	Maximum Field Test Voltage, kV, AC
14.4 (1ø and 3 ø)	15.0	95	26.2
14.4 (1 ø and 3 ø)	15.5	110	37.5
24.9 (1 ø and 3 ø)	27.0	150	45.0
34.5 (1 ø and 3 ø)	38.0	150	52.5
46.0 (3 ø)	48.3	250	78.7
69.0 (3 ø)	72.5	350	120.0

Derived from ANSI/IEEE C37.61-1973(R1993) (*Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers*), C37.60-1981(R1993) (*Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for AC Systems*).

TABLE 10.16

High-Potential Test Voltage for Periodic Test of Line Sectionalizers

Nominal Voltage Class kV	Maximum Voltage kV	Rated Impulse Withstand Voltage kV	Maximum Field Test Voltage kV, AC	DC 15 Minute Withstand (kV)
14.4 (1 ø)	15.0	95	26.2	39
14.4 (1 ø)	15.0	125	31.5	39
14.4 (3 ø)	15.5	110	37.5	39
24.9 (1 ø)	27.0	125	45.0	58
34.5 (3 ø)	38.0	150	52.5	77

Derived from ANSI/IEEE C37.63-1984(R1990) Table 2 (*Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Line Sectionalizers of ac Systems*).

The table includes a 0.75 multiplier with fractions rounded down.

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

NOTE: Values of ac voltage given are dry test one minute factory test values.

TABLE 10.17

Metal-Enclosed Bus Dielectric Withstand Test Voltages

Type of Bus	Rated kV	Maximum Test Voltage, kV	
		AC	DC
Isolated Phase for Generator Leads	24.5	37.0	52.0
	29.5	45.0	--
	34.5	60.0	--
Isolated Phase for Other than Generator Leads	15.5	37.0	52.0
	25.8	45.0	--
	38.0	60.0	--
Nonsegregated Phase	0.635	1.6	2.3
	4.76	14.2	20.0
	15.0	27.0	37.0
	25.8	45.0	63.0
	38.0	60.0	--
Segregated Phase	15.5	37.0	52.0
	25.8	45.0	63.0
	38.0	60.0	--
DC Bus Duct	0.3	1.6	2.3
	0.8	2.7	3.9
	1.2	3.4	4.8
	1.6	4.0	5.7
	3.2	6.6	9.3

Derived from ANSI-IEEE C37.23-1987, Tables 3A, 3B, 3C, 3D and paragraph 6.4.2. The table includes a 0.75 multiplier with fractions rounded down.

Note:

The presence of the column headed "DC" does not imply any requirement for a dc withstand test on ac equipment. This column is given as a reference only for those using dc tests and represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for each class of bus.

Direct current withstand tests are recommended for flexible bus to avoid the loss of insulation life that may result from the dielectric heating that occurs with rated frequency withstand testing.

Because of the variable voltage distribution encountered when making dc withstand tests and variances in leakage currents associated with various insulation systems, the manufacturer should be consulted for recommendations before applying dc withstand tests to this equipment.

TABLE 10.18

Thermographic Survey
Suggested Actions Based on Temperature Rise

Temperature difference (ΔT) based on comparisons between similar components under similar loading.	Temperature difference (ΔT) based upon comparisons between component and ambient air temperatures.	Recommended Action
1°C - 3°C	1°C - 10°C	Possible deficiency; warrants investigation
4°C - 15°C	11°C - 20°C	Indicates probable deficiency; repair as time permits
- - - - - -	21°C - 40°C	Monitor until corrective measures can be accomplished
>15°C	>40°C	Major discrepancy; repair immediately

Temperature specifications vary depending on the exact type of equipment. Even in the same class of equipment (i.e., cables) there are various temperature ratings. Heating is generally related to the square of the current; therefore, the load current will have a major impact on ΔT. In the absence of consensus standards for ΔT, the values in this table will provide reasonable guidelines.

An alternative method of evaluation is the standards-based temperature rating system as discussed in Section 8.9.2, Conducting an IR Thermographic Inspection, *Electrical Power Systems Maintenance and Testing*, by Paul Gill, PE.

It is a necessary and valid requirement that the person performing the electrical inspection be thoroughly trained and experienced concerning the apparatus and systems being evaluated as well as knowledgeable of thermographic methodology.

TABLE 10.19

Overpotential Test Voltages for Electrical Apparatus Other than Inductive Equipment

Nominal System (Line) Voltage[a] (kV)	Insulation Class	AC Factory Test (kV)	Maximum Field Applied AC Test (kV)	Maximum Field Applied DC Test (kV)
1.2	1.2	10	6.0	8.5
2.4	2.5	15	9.0	12.7
4.8	5.0	19	11.4	16.1
8.3	8.7	26	15.6	22.1
14.4	15.0	34	20.4	28.8
18.0	18.0	40	24.0	33.9
25.0	25.0	50	30.0	42.4
34.5	35.0	70	42.0	59.4
46.0	46.0	95	57.0	80.6
69.0	69.0	140	84.0	118.8

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

a. Intermediate voltage ratings are placed in the next higher insulation class.

TABLE 10.20

Rated Control Voltages and Their Ranges for Circuit Breakers

When measured at the control power terminals of the operating mechanisms with the maximum operating current flowing, nominal voltages and their permissible ranges for the control power supply of circuit breakers shall be as shown below.

Direct Current Voltage Ranges (1) (2) (3) (5) (8) (9)				Alternating Current Voltage Ranges (1) (2) (3) (4) (8)	
Closing and Auxiliary Functions				Nominal Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
Nominal Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Tripping Functions All Types	Single Phase 120 240	Single Phase 104-127 (7) 208-254 (7)
24 (6)	---	---	14-28	Polyphase 208Y/120 240	Polyphase 108Y/104 - 220Y/127 208 - 254
48 (6)	38-56	36-56	28-56		
125	100 - 140	90 - 140	70 - 140		
250	200 - 280	180 - 280	140 - 280		

Notes:

(1) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(2) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(3) Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance. For those solenoid operated devices, the following applies:

Rated Voltage	Closing Voltage Ranges for Power Supply
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary , and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

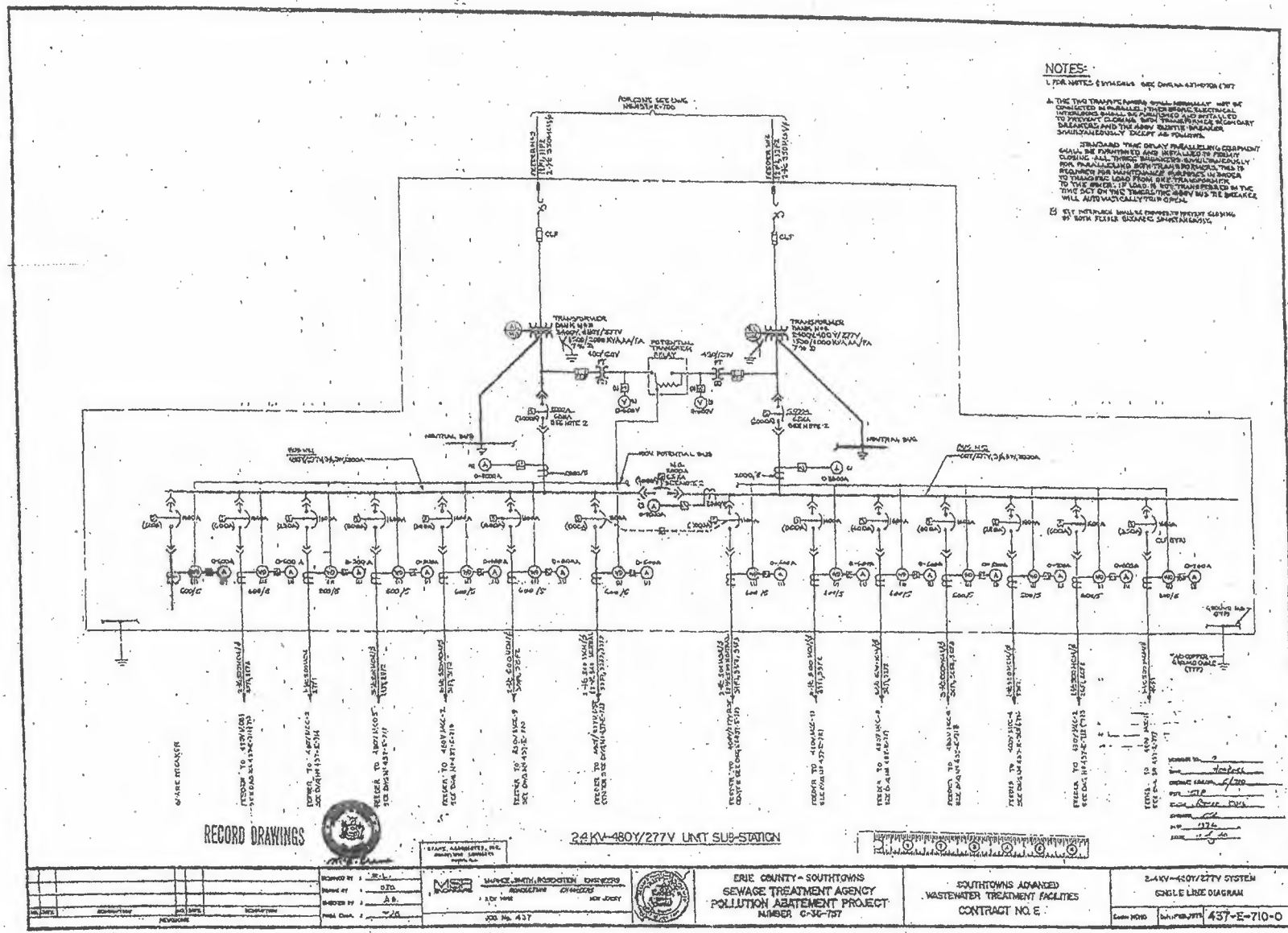
(7) Includes heater circuits

(8) Extended voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges.

(10) This table also applies for circuit breakers in gas insulated substation installations.

Derived from Table 9, ANSI C37.06.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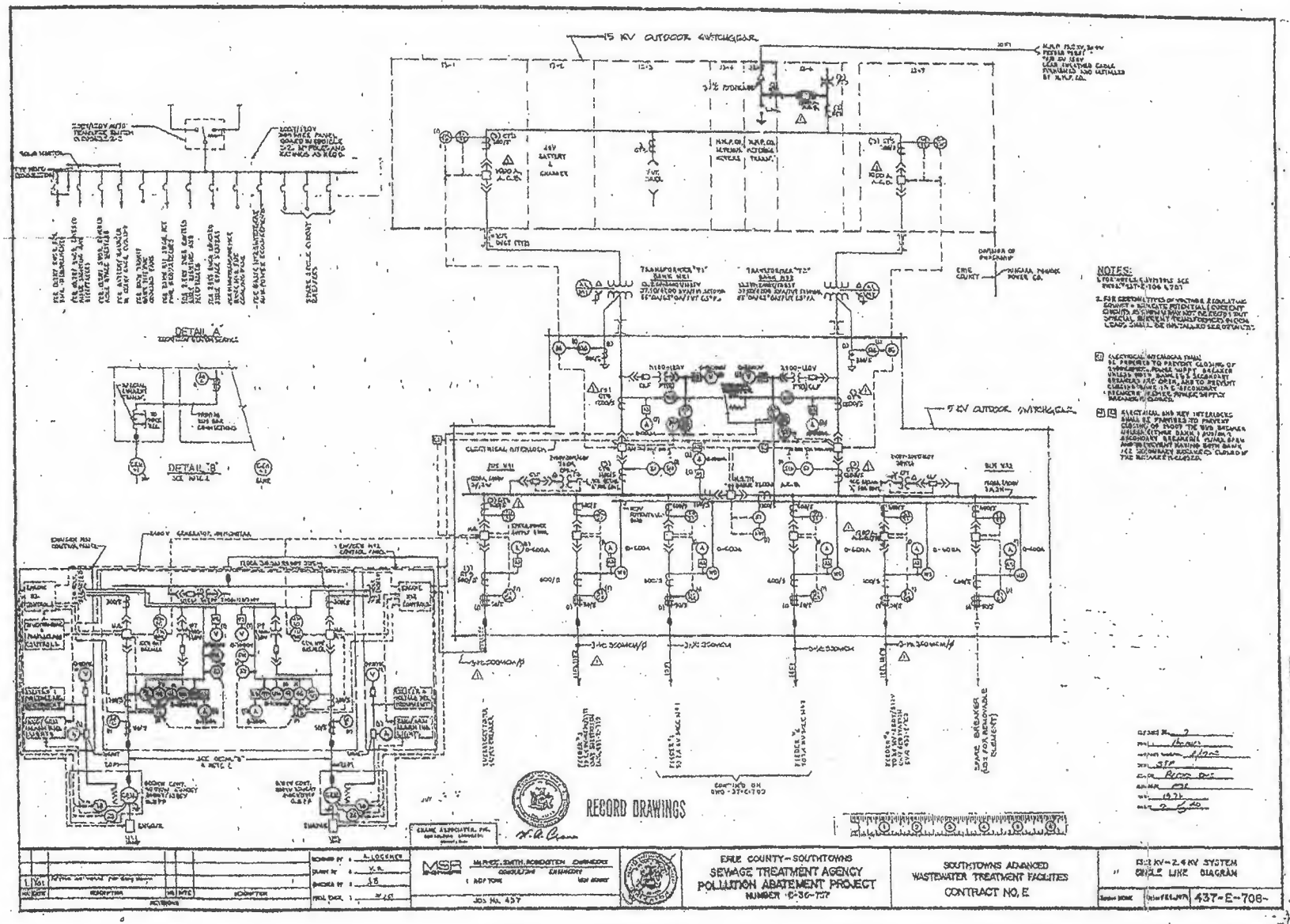
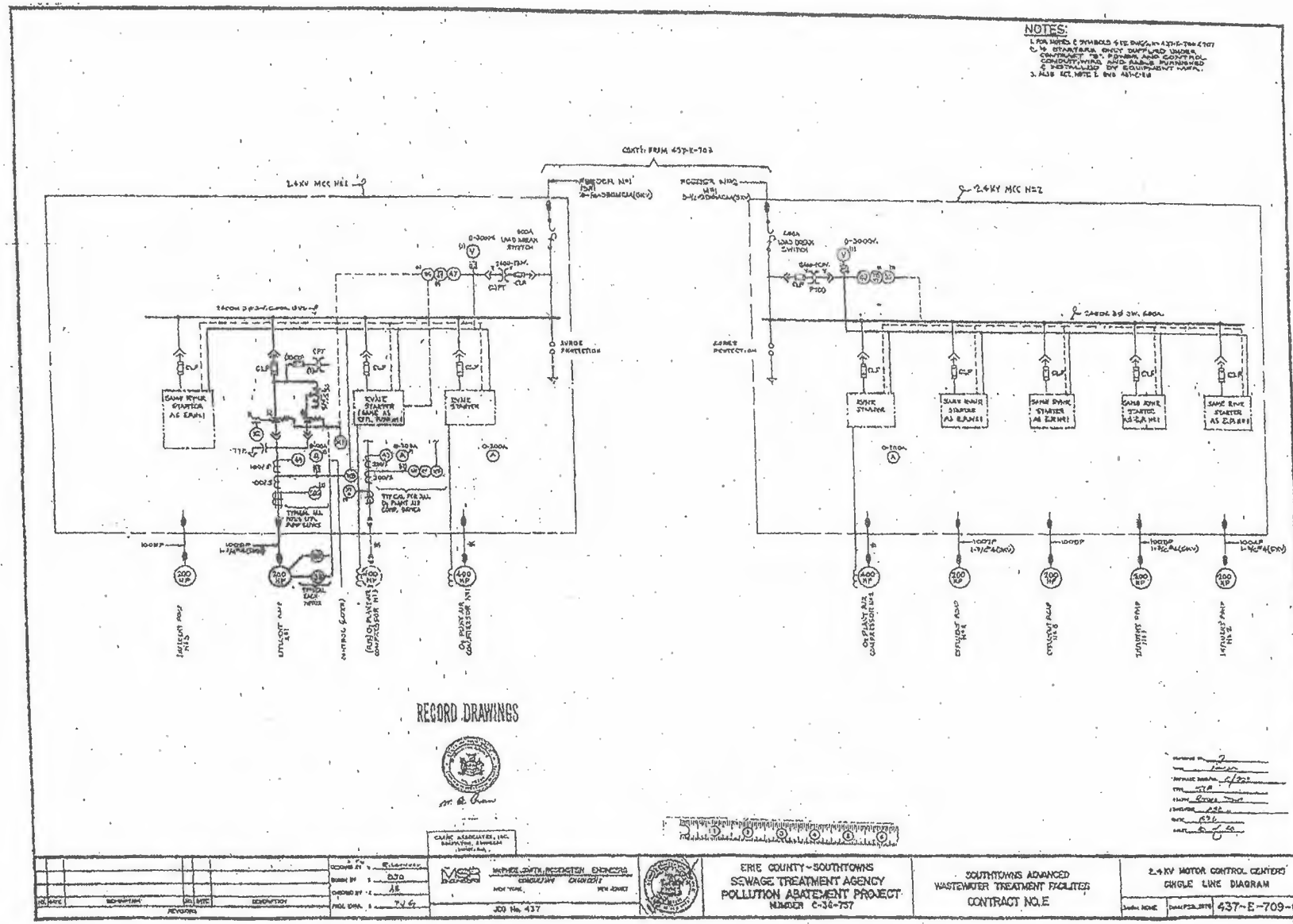
RECORD DRAWINGS
24 KV-480Y/277V UNIT SUB-STATION
ERIE COUNTY - SOUTHTOWNS
SEWAGE TREATMENT AGENCY
POLLUTION ABATEMENT PROJECT
NUMBER C-36-1757
SOUTHTOWNS ADVANCED
WASTEWATER TREATMENT FACILITIES
CONTRACT NO. E
24 KV-480Y/277V SYSTEM
SINGLE LINE DIAGRAM
437-E-710-0


15 KV OUTDOOR SWITCHGEAR
5 KV OUTDOOR SWITCHGEAR
NOTES:
RECORD DRAWINGS
ERIE COUNTY - SOUTHTOWNS
SEWAGE TREATMENT AGENCY
POLLUTION ABATEMENT PROJECT
NUMBER C-36-727
SOUTHTOWNS ADVANCED
WASTEWATER TREATMENT FACILITIES
CONTRACT NO. E
13.8 KV - 2.4 KV SYSTEM
SINGLE LINE DIAGRAM
437-E-708-
JOB NO. 437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2.4KV MCC NO2
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RECORD DRAWINGS
ERIE COUNTY - SOUTHTOWNS
SEWAGE TREATMENT AGENCY
POLLUTION ABATEMENT PROJECT
NUMBER C-36-757
SOUTHTOWNS ADVANCED
WASTEWATER TREATMENT FACILITIES
CONTRACT NO.E
2.4 KV MOTOR CONTROL CENTERS
SINGLE LINE DIAGRAM
JOB No. 437
437-E-709-0