



**CITY OF MONROE
MONROE, NORTH CAROLINA**

**SPECIFICATIONS AND BID DOCUMENTS
FOR POWER TRANSFORMER
FOR THE
CITY OF MONROE'S
34.5 TO 4.16 KV SUBSTATION No. 2**

REQUEST FOR BIDS

PIKE

ENGINEERING

**1616 E. Millbrook Road, Suite 210
Raleigh, North Carolina 27609
Phone: (919) 256-5900**

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Raleigh, North Carolina 27609
Phone: (919) 256-5900
North Carolina Firm License # F-1217

I hereby certify this document was prepared by me or under my direct supervision. I also certify I am a duly registered professional engineer under the laws of the State of North Carolina, Registration No. 33731.



July 20, 2020
David K. Taylor, PE

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NOTICE TO PROSPECTIVE BIDDERS

Proposals will be received by the City of Monroe ("Owner") until Friday October 16, 2020 at 2:00 p.m., local time, as specified in the request for proposals, after which time they will be opened, read, and evaluated for the furnishing of the following:

POWER TRANSFORMER FOR THE CITY OF MONROE'S 34.5 TO 4.16 KV SUBSTATION No. 2

Proposals shall be marked "**Formal Bid for Power Transformers for City of Monroe's Substation**". Bidders shall mail or hand deliver their Proposals as follows:

City of Monroe Energy Services Department
2201 Walkup Ave.
P.O. Box 69
Monroe, NC 28111-0069
Attention: Mr. Darwin De Los Santos
ddelossantos@monroenc.org

Hard copies of proposal shall be submitted in duplicate. Specifications and proposal forms may be secured from the City of Monroe Energy Services offices. All hand carried proposals are to be presented at the Engineer's office before the time of the bid closing.

The Bidder's proposal shall specify price, any applicable price terms, approval drawing time, and delivery time. All prices shall be DDP substation site, fully assembled and certified by the manufacturer as ready for operation. The Bidder's proposal shall include an outline drawing indicating approximate overall physical dimensions and weight.

Local sales tax is applicable to this purchase. Each Bidder shall show as a separate item the amounts which will be payable by the Owner for any taxes upon the sale of the proposed materials.

The Owner reserves the right to waive minor irregularities or errors in the Proposal if it appears that such irregularities or errors were made through inadvertence. Any such irregularities or errors so waived must be corrected on the Proposal prior to acceptance by the Owner. The Owner will evaluate all data provided in the proposal and select the proposal that in the sole judgment of the Owner represents the best value to the Owner. The Owner reserves the right to reject any or all proposals. The Owner will not discriminate against any bidder submitting a bid because of race, creed, color, national origin or handicap.

City of Monroe
Owner
Pike Engineering, LLC
Engineer

Date: July 20, 2020

**SPECIFICATION AND BID DOCUMENTS
FOR POWER TRANSFORMER
FOR THE
CITY OF MONROE'S
34.5 TO 4.16 KV SUBSTATION No. 2**

PROPOSAL

<u>Bid Schedule No. 1</u>	<u>Quantity</u>	<u>Unit Price</u>
Outdoor Substation Type Power Transformer, rated 5/7 MVA, per the specifications	1	\$ _____
Applicable Sales Tax		\$ _____
Total Price		\$ _____
Delivery (Weeks)		_____
Warranty Period (Years)		_____

Prices quoted _____ do _____ do not include the cost of a crane and rigging to unload the transformer and set it on the pad.

Prices quoted _____ do _____ do not include the cost of a service engineer to perform final on-site inspection and testing of the transformer.

Prices quoted _____ do _____ do not include the cost of a crew and equipment to dress out the transformer after delivery.

If cost of items listed above are NOT included, specify below:

<u>Service</u>	<u>Unit Price</u>
Cost of crane and rigging to unload onto pad	\$ _____
Cost of service engineer	\$ _____
Cost of crew to dress out transformer	\$ _____

COMPLIANCE AND EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
TRANSFORMER TYPE AND RATINGS				
Frequency	60	Hz		
Phases	3			
HV - LV Phasor Relationship	Leads by 30°			
Impedance, at ONAN	IEEE Std. C57.12.10	%		
Winding material, HV	Copper			
Winding material, LV	Copper			
Coil Construction	Circular			
Construction type	Core			
Oil preservation system	Nitrogen blanket			
Radiator finish	Galvanized			
Paint color	ANSI 70 Gray			
Windings				
High Voltage	34.5	kV		
Low Voltage	4.16/2.4	kV		
HV Connection	Delta			
LV Connection	Wye Gnd			
HV BIL	200	kV		
LV BIL	75	kV		
Loading				
ONAN (55°C/65°C)	5/5.6	MVA		
ONAF1 (55°C/65°C)	6.25/7	MVA		
ONAF2 (55°C/65°C)	N/A	MVA		
Temperature Rise				
By Resistance		°C		
Hottest Spot		°C		
Insulation Liquid				
High Voltage Taps (DETC)				
Tap Position, -5%	32,775	V		
Tap Position, -2.5%	33,638	V		
Tap Position, 0%	34,500	V		
Tap Position, +2.5%	35,363	V		
Tap Position, +5%	36,225	V		

COMPLIANCE & EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1 (Cont.)

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
BUSHINGS				
HV – 34.5 kV (H1, H2, H3)				
Manufacturer				
Catalog No.				
BIL	IEEE C57.19.01	kV		
Current Rating	600	A		
Minimum Creepage Distance	IEEE C57.19.01	in		
Color	ANSI 70 Gray			
Terminals	Threaded Stud			
NEMA 4-Hole pad included?	Yes			
LV – 4.16 kV (X1, X2, X3)				
Manufacturer				
Catalog No.				
BIL	IEEE C57.19.01	kV		
Current Rating	1200	A		
Minimum Creepage Distance	IEEE C57.19.01	in		
Color	ANSI 70 Gray			
Terminals	Threaded Stud			
NEMA 4-Hole pad included?	Yes			
Neutral – 4.16 kV (X0)				
Manufacturer				
Catalog No.				
BIL	IEEE C57.19.01	kV		
Current Rating	1200	A		
Minimum Creepage Distance	IEEE C57.19.01	in		
Color	ANSI 70 Gray			
Terminal	4-Hole Pad			
BUSHING CURRENT TRANSFORMERS				
HV – 34.5 kV (H1, H2, H3)				
Quantity, each bushing	1			
Ampere Ratio	600:5	A		
Accuracy Class	C400			
Thermal Rating	2.0			

COMPLIANCE & EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1 (Cont.)

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
BUSHING CURRENT TRANSFORMERS (Cont.)				
LV – 4.16 kV (X1, X2, X3)				
Quantity, each bushing	1			
Ampere Ratio	1200:5	A		
Accuracy Class	C400			
Thermal Rating	2.0			
Neutral – 4.16 kV (X0)				
Quantity, each bushing	1			
Ampere Ratio	1200:5	A		
Accuracy Class	C400			
Thermal Rating	2.0			
SURGE ARRESTERS				
HV – 34.5 kV (H1, H2, H3)				
Manufacturer				
Catalog No.				
Ur, Duty Cycle	27	kV		
Uc, MCOV	22	kV		
Class, IEC line discharge	IEC 3, Station			
Color	ANSI 70 Gray			
LV – 4.16 kV (X1, X2, X3)				
Manufacturer				
Catalog No.				
Ur, Duty Cycle	3	kV		
Uc, MCOV	2.55	kV		
Class, IEC line discharge	IEC 3, Station			
Color	ANSI 70 Gray			
AUXILIARY SOURCE VOLTAGES				
AC	120/240 1PH	V		
DC	24	V		
COOLING FANS				
First Stage, Qty				
Second Stage, Qty				
Rated Power		HP		
Rated Voltage	240	V		
Phases	1			

COMPLIANCE & EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1 (Cont.)

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
RESISTANCE TEMPERATURE DETECTORS (RTD) & THERMOCOUPLES (TC) (State Manuf. & Model)				
Hottest spot winding temperature				
Main tank top oil temperature				
Ambient temperature				
ACCESSORIES (State Manufacturer and Model)				
Pressure relief device				
Sudden pressure relay				
Winding temperature relay				
Oil level relay				
Pressure-vacuum gauge				
Pressure-vacuum bleeder				
Impact recorder				
Lat-Lon Rail-Rider damage prevention unit, or equal				
ACCESSORIES (State Yes/No)				
Drain and filter valves				
Removable radiators & isolation valves				
Silica gel breather for control cabinet				
Transformer monitor, SEL-2414				
PERFORMANCE & GUARANTEES				
Losses, based on ONAN Rating, 75 °C				
Impedance	IEEE Std. C57.12.10	%		
Excitation	100	%		
No Load @ 20 °C		kW		
Load at 100%		kW		
Total at 100%		kW		
Load at 133.3%		kW		
Total at 133.3%		kW		
Load at 166.7%		kW		
Total at 166.7%		kW		

COMPLIANCE & EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1 (Cont.)

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
PERFORMANCE & GUARANTEES (Cont.)				
Auxiliary (Cooling) Losses				
ONAN Rating		kW		
ONAF1 Rating		kW		
ONAF2 Rating	N/A	kW		
Efficiency Based on ONAN Rating and P.F. = 1				
25% Load		%		
50% Load		%		
75% Load		%		
100% Load		%		
133% Load		%		
166.7% Load		%		
Exciting Current				
95% Voltage		A		
100% Voltage		A		
105% Voltage		A		
110% Voltage		A		
Regulation at ONAN				
100% Power Factor		%		
90% Power Factor		%		
80% Power Factor		%		
NEMA front-of-wave withstand capability		kV		
Switching surge withstand strength, HV winding		kV		
Maximum guaranteed corona level at 100% Induced Test Voltage, RIV		μV		
Corona level considered to be damaging, RIV		μV		
Audible Sound Level				
ONAN	NEMA TR-1	dBA		
ONAF	NEMA TR-1	dBA		
ONAF/ONAF	N/A	dBA		

COMPLIANCE & EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1 (Cont.)

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
ENVIRONMENTAL				
Location (Nearest Town)				
Site Elevation		ft		
Ambient Temperature		°F		
Minimum Temperature		°F		
Maximum Temperature		°F		
IEEE Std 693-2005, Seismic Qualification Level				
Radial Ice Buildup		in		
Wind Speed		mph		
NESC Loading District				
Contamination per IEEE C57.19.100	Medium			
PCB content in oil is less than 1 PPM?	Yes			
PHYSICAL DATA				
Dimensions (Approximate)				
Height		ft-in		
Width		ft-in		
Depth		ft-in		
Height over Cover		ft-in		
Untanking Height (Plus Slings)		ft-in		
Shipping		ft-in		
Attach outline drawing, bulletins, diagrams, etc. to clearly describe transformer and its components				
Weights (Approximate)				
Core and Coils		lbs		
Tank and Fittings		lbs		
Bushings		lbs		
Oil		lbs		
Total Weight		lbs		
Shipping Weight without Oil		lbs		
Shipping Weight with Oil		lbs		
Oil Volume		gal		
COMMERCIAL				
Warranty	5	yr		
Drawings after Order		wks		
Approval		wks		
Shipment After Approval		wks		
Cancellation Policy				

COMPLIANCE & EXCEPTIONS CHECKLIST – BID SCHEDULE NO. 1 (Cont.)

Description	Specified Rating	Units	Meets or Exceeds?	If no, state exception (alternatively, Manufacturer or Catalog No.)
SHIPPING				
Method of Shipment				
Transformer will be shipped oil-filled or dry air-filled	Oil Filled			
MANUFACTURER				
Manufacturer				
Place of Manufacture				
Years of operating at this manufacturing facility				
Years of experience manufacturing this size and voltage transformer				
Nearest Shop Repair Facility				
Nearest Installation & Service Engineering Facility				
Other Utilities Purchasing Units of Similar Design				
Attach additional sheets if necessary				

REQUESTED ADDITIONAL INFORMATION

Manufacturer _____

Place of Manufacture _____

Method of Shipment _____

Nearest Shop Repair Facility _____

Nearest Installation & Service Engineering Facility _____

Years of experience manufacturing this size and voltage transformer _____

Years of operating at this manufacturing facility _____

Transformer will be shipped oil-filled _____ or dry air-filled _____

Other Utilities Purchasing Units of Similar Design _____

(Attach additional sheets if necessary.)

1. The Owner may accept or reject any Schedule or portion thereof, adder, or deduct quoted above or purchase additional quantities of any quoted materials. The Owner may also choose to evaluate any alternate proposal that in the sole judgment of the Owner is deemed advantageous.
2. The prices of equipment set forth herein do not include any sums which are or may be payable by the Materialman for taxes imposed by any taxing authority upon the sale, purchase, or use of equipment. If any such tax is applicable to the sale, purchase, or use of the equipment hereunder, the amount thereof shall be added to the purchase price and paid by the Owner.
3. The materials quoted conform to the Specifications, or any exceptions or clarifications are clearly noted under paragraph 13 of this proposal. (Exceptions or clarifications included elsewhere in the Bidder's Proposal will not be accepted unless they are clearly noted in Paragraph 13. Exceptions and clarifications may be listed in a separate proposal, but will not be considered valid unless so noted in paragraph 13 and clearly marked as "Exceptions to Specifications" in the separate proposal.)
4. The prices quoted shall include delivery of the materials and equipment by truck or rail DDP substation site, with unloading and placement of the transformer on the pad. Delivery will not be deemed complete until transformer is fully assembled and tested.
5. Prices shall include the services of a Field Service Engineer. Refer to the "MANUFACTURER'S FIELD REPRESENTATIVE" paragraph of the Specifications for details of Field Service Engineering responsibilities and required field-testing.
6. Price Policy: The prices quoted herein are firm.

Note: If the manufacturer is proposing partial payments be made prior to the delivery of the transformer, the manufacturer will be required to furnish a performance bond in the full amount of the contract at no cost to the Owner if this method of payment is accepted.

7. Proposals shall include the following:
 - a. Catalog numbers, manufacturer, ratings, characteristics, types, sizes, etc., of all materials and equipment included. A simple statement that all necessary materials and equipment will be provided is not satisfactory.
 - b. Performance data for the items set forth in the detailed Specifications.

8. The time of delivery shall be as follows:

- a. Approval Drawings _____ (Weeks)*
- b. Final Drawings** _____ (Weeks)*
- c. Delivery** _____ (Weeks)*

*Number of consecutive calendar weeks after receipt of a written purchase order.

**Allow two (2) weeks for receipt and return of Approval Drawings.

The time for delivery shall be extended for the period of any reasonable delay due exclusively to causes beyond the control and without the fault of the Materialman, including acts of God, fires, floods, strikes, and delays in transportation.

- 9. Receipt of Approval Drawings by the Materialman constitutes authorization for manufacture predicated upon the approved Drawings and corrections found thereon. After the return of Approval Drawings, release for shipment is to be granted by the Owner based upon the manufacturer's compliance with the following:
 - a. Notification of at least fourteen (14) days prior to tests, so the Owner may have a representative present to witness the tests.
 - b. Furnishing of the requested number of copies of the Final Drawings as called for in the Specifications.
 - c. Thirty (30) days' notification of tentative shipping schedule and forty-eight (48) hours' notification prior to all deliveries.
- 10. Title to the equipment shall pass to the Owner upon delivery to the point specified herein, completion of final assembly as directed by the Materialman's certified representative, and declaration by Materialman's certified representative that transformer is ready to be energized.
- 11. This Proposal is made pursuant to the provisions of the Notice and Instructions to Bidders, the Specifications, and the Materialman agrees to the terms and conditions thereof.
- 12. The Materialman warrants that the Equipment will conform to the performance data and guarantees, which are attached hereto.

Delivery of all items of equipment to the Owner's designated delivery point shall be made to permit unloading between the hours of 8:00 a.m. and 3:00 p.m., local time Monday through Thursday, holidays excluded.

13. The following Exceptions / Clarifications to the Specifications are applicable to the materials proposed:

Proposal / Specification Reference	Exception

14. Non-Collusive Bid Certification: By the submission of this bid, the Materialman certifies that:

- a. This bid has been arrived at by the Materialman independently and has been submitted without collusion with any other manufacturer of materials, supplies, or equipment of the type described in the Notice to Prospective Bidders or the Specifications.
- b. The contents of the bid have not been communicated by the Materialman or, to his best knowledge and belief, by any of his employees or agents to any person not an employee or agent of the Materialman, and will not be communicated to any person prior to the official opening of the bid.

15. If, in submitting this Proposal, the Materialman has made any change(s) from the Specifications to offer an alternate proposal(s), the Materialman understands that the Owner may evaluate the effect of such change as it sees fit, or may exclude the Proposal from consideration in determining the award of the Purchase Order.

Submitted this the _____ day of _____, 2020.

Name of Firm _____

Signature _____

Printed or Typed Name _____

Title _____

Address of Materialman: _____

Telephone _____

E-mail _____

**SPECIFICATION AND BID DOCUMENTS
FOR POWER TRANSFORMER
FOR THE
CITY OF MONROE'S
34.5 TO 4.16 KV SUBSTATION No. 2**

TECHNICAL SPECIFICATIONS – BID SCHEDULE NO. 1

1. SCOPE

The work shall include furnishing all equipment and materials, as set forth in the Bid Schedule(s) and as specified herein.

2. GENERAL CONDITIONS

All materials and equipment shall be new. These Specifications describe the type, size, and characteristics of the various materials and equipment required to be furnished. Strict adherence to these general Specifications is required to facilitate review and consideration of the Proposal. Alternate proposals will be evaluated if deemed appropriate.

It is the intent of these Specifications that the transformer shall be complete and fully operable. Any details or materials not mentioned in the Specifications, but required for satisfactory operation, shall be furnished and installed by the Materialman.

Station power available at the Owner's substation will be 120/240 volts, 60 Hz, single-phase. Control DC voltage at the substation will be 24 volts. The equipment on the transformers shall coordinate with these voltages, as appropriate.

3. SPECIAL CONDITIONS

3.1 Defective Materials, Equipment, and Workmanship

All materials and equipment furnished hereunder shall be subject to the inspection, tests, and approval of the Engineer and the Materialman shall furnish all information required concerning the nature or source of all materials and equipment, as well as provide adequate facilities for testing and inspecting the materials and equipment at the plant of the Materialman.

The materials and equipment furnished hereunder shall become the property of the Owner when the transformer is sitting on the pad fully assembled and certified ready for energization by a certified representative of the manufacturer, provided, however, that the

Owner may reject any such materials and equipment which do not comply with the Specifications for materials and equipment and/or warranties of the Materialman and manufacturers. Recognition and subsequent rejection of any defective materials and equipment may occur either before or after incorporation of such materials and equipment into the facilities, provided such rejection is made within one year of date of delivery of the materials and equipment. Upon any such rejection, the Materialman shall replace the rejected materials and equipment with materials and equipment complying with the Specifications for materials and equipment and warranties, DDP substation. The Owner shall return the rejected materials DDP truck at the substation. In the event of the failure of the Materialman to so replace rejected materials and equipment, the Owner may make such replacement and the cost and expense thereof shall be paid by and recoverable from the Materialman.

3.2 Miscellaneous

The Materialman shall hold harmless and indemnify the Owner, its agents and employees, from any and all claims, suits and proceedings for infringement of any patent or patents covering materials and equipment purchased hereunder. The Materialman shall defend any suit or proceeding brought against the Owner, its agents or employees, based upon a claim that the materials and equipment or any part thereof constitute an infringement of any patent, or if the Materialman shall fail to defend such suit or proceeding, the Owner may do so and the Materialman shall make reimbursement for the expense of such litigation. If the materials and equipment, or any part thereof, are held to constitute infringement and the use thereof is enjoined, the Materialman shall, at its own expense, either procure for the Owner the right to continue to use the materials and equipment, or such part thereof, or shall replace the materials and equipment, with non-infringing materials and equipment.

3.3 Standards

All equipment and materials covered by these Specifications and all tests applied thereto shall, unless otherwise stated herein, be in accordance with the applicable provisions of the latest editions of the Standards of the ASTM, ANSI, AEIC, AWS, NEMA, IEEE, and NESC. Where the term "Standards" is used in the specifications, it shall be understood to refer to the above standards.

3.4 Drawings

3.4.1 Preliminary

Before proceeding with fabrication, the manufacturer shall submit for approval to the Owner sufficient Drawings to demonstrate that all parts conform to the requirements and intent of these Specifications. The Drawings shall include outline, control cabinet front view and layout, nameplate, applicable equipment nameplates, material list with manufacturer part numbers, control schematics and wiring diagrams, and proof of design to withstand short circuit forces as specified herein. Drawings shall be submitted electronically as AutoCAD ".dwg" drawings and in PDF format. Each drawing shall contain identifying information such as, but not limited to, customer and project name. Catalog cut sheets and details of instrument transformers, bushings, bushing terminal connectors, surge arresters, relays, and all accessories shall also be submitted for approval.

The Outline Drawing shall show dimensions of equipment, including bushings, bushing designations, radiators and cooling equipment, base, control cabinet, and all other important external features. Outline Drawings shall be to scale and include plan view and elevations from all four (4) sides. These Drawings shall show shipping weight, total weight, center of gravity, bushings, bushing catalog numbers and ampere ratings, description of top bushing terminals, and arrangement of all external accessory devices. Control schematic drawings shall clearly indicate power requirements for DC circuits and AC auxiliary power (amps/volts/watts).

Approval of Drawings shall not relieve the manufacturer of obligations to meet all requirements to the Specifications or of responsibility for correctness of the Drawings, or of responsibility to meet original shipping promise on the basis of customer being allowed two (2) weeks for approval.

The Engineer may require additional submittals of Shop Drawings if, in the opinion of the Engineer, such is required due to the extent of changes required on the previous submittal(s). If an extension of time is required due to a protracted drawing approval process, the price will remain as quoted for the quoted delivery.

Receipt of Approval Drawings by the Materialman constitutes authorization for manufacture based upon the corrections

found thereon.

No changes shall be made in the final Drawings from the approved Approval Drawings. Any proposed changes from the approved drawings must go through the approval drawing process again **with the changes clearly denoted.**

Following approval of drawings the Materialman shall submit a complete set of "For Construction" drawings to the Engineer.

3.4.2 Final Drawings and Instruction Manuals

Materialman shall furnish five (5) hard copies of instruction manuals **prior to the shipment of the equipment.** One (1) copy shall be sent to the Engineer and the other four (4) copies shall be sent to the Owner. Each instruction manual shall include a digital medium (such as a USB drive) that contains entire contents of instruction manual in PDF format. Final drawings are to be certified as "As-Built" and shall be provided in AutoCAD format in addition to PDF format.

Instruction manuals are to include, as a minimum, each of the following:

- 3.4.2.1 Materialman's installation and maintenance instructions for transformer
- 3.4.2.2 Manufacturer manuals for components, fittings, valves, controls, and accessories
- 3.4.2.3 Outline and assembly drawings
- 3.4.2.4 Control cabinet front view and layout drawing(s)
- 3.4.2.5 Nameplate drawing(s)
- 3.4.2.6 Material list drawing
- 3.4.2.7 Schematic and wiring diagram drawings for all control and accessory items
- 3.4.2.8 Details of bushing and bushing terminal connectors
- 3.4.2.9 Diagram of bushing current transformers indicating connection, number of turns, polarity marking, ratio, accuracy class, and thermal rating factor
- 3.4.2.10 Catalog cut sheets for instrument transformers,

surge arresters, relays, and all control accessories

3.4.2.11 Renewal parts catalog

3.4.2.12 Certified test report

4. SHIPPING OF POWER TRANSFORMER

The transformer shall be shipped to the substation site and installed on a concrete pad. **NOTE: Materialman shall be responsible for providing crane and rigging to off-load transformer from delivery truck onto pad.** Before shipment, power transformer shall be completely assembled to determine if all parts fit properly. Parts removed for shipment shall be marked so as to permit easy identification when reassembling.

Method of packing and loading shall be such as to protect all parts from dampness, corrosion, breakage, or vibration injury that might reasonably be encountered in transportation, storage, and handling. Release for shipment is to be granted based upon the manufacturer's compliance with the following:

- a. Fourteen (14) days notification of tests shall be given so the Engineer may have a representative present for witness of the tests.
- b. Furnishing of the required number of copies of the Final Drawings and Instruction Books as called for in the Specifications.
- c. Thirty (30) days notification of tentative shipping schedule shall be given, and forty-eight (48) hours notification prior to delivery.
- d. An impact recorder shall be installed to travel with the transformer during shipment, and shall remain with the unit until it is unloaded, unless the Materialman is relieved of this requirement by the Engineer. The impact recorder shall be read prior to loading and after arrival at the site.
- e. It is preferred that transformer be shipped oil-filled with the low-voltage bushings installed, unless otherwise approved by the Engineer.
- f. If the transformer is not shipped oil-filled, it shall be shipped dry air-filled and equipped with proper pipe connections for checking and filling under vacuum. The oil shall be shipped by tanker with the unloading pump furnished. The unloading pump shall have been flushed free of undesirable contaminants by flushing with the same type oil provided for the transformer. The Materialman shall furnish all equipment, labor, and supervision required for filling, and the Materialman shall coordinate timing and arrangements. Materialman

shall be responsible for proper cleanup of any oil spilt during the filling operation.

- g. Method of shipment (oil-filled or dry air-filled) shall be specified in the Proposal and this shall be evaluated when awarding the Purchase Order.
- h. Delivery shall be made to the substation site, located at:

City of Monroe's Substation
3850 Aeropointe Parkway
Monroe, NC 28110

5. MANUFACTURER'S FIELD REPRESENTATIVE(S)

The manufacturer shall provide, and include as a part of his Proposal, all the costs associated with furnishing the services of a Field Service Engineer as required for final assembly and acceptance testing. The duties of the Field Service Engineer shall include supervising installation of Materialman provided component parts removed for shipment, including but not limited to bushings, radiators, and surge arresters. If oil is to be shipped separately and transformer filled on site, Materialman shall also be responsible for supplying all labor and equipment needed to vacuum fill the transformer. He shall supervise installation of all control and auxiliary wiring. He shall perform field acceptance tests after assembly as called for in the "Tests" section of this specification. It is preferred that the Materialman also furnish all the labor and equipment needed to perform the field assembly and testing work, but the owner can supply this if needed. The cost for Owner supplied labor and equipment will be considered in evaluation of the bids received. Field Service Engineer shall clean and repair any surfaces that were soiled, discolored, or otherwise damaged by abrasion since leaving the factory. Field Service Engineer shall certify when the transformer is ready to be energized.

6. TRANSFORMER

6.1 Type and Rating

The transformer shall be three-phase, 60 Hertz, suitable for outdoor service at an altitude less than one kilometer (3300 feet) above sea level. The windings shall be insulated and connected as follows:

Winding	Voltage (kV)	Connection	BIL (kV)
High Voltage	34.5	Delta	200
Low Voltage	4.16/2.4	Wye	75

The high voltage shall lead the low voltage by 30° phase angle. The

transformer will be operated with the neutral tied solidly to ground. All windings shall be copper.

Transformer shall be oil-immersed for continuous self-cooled/forced air-cooled operation ONAN/ONAF with one (1) stage of fan cooling and shall be furnished complete with oil. Fans shall be included with the transformer; operating voltage for fans shall be 240 volts, single-phase. Transformer ratings, when loaded in accordance with ANSI C57.92 (latest edition) "Guide for Loading Oil-Immersed Distribution and Power Transformers," shall be as follows:

Class	Rise (°C)	Rating (kVA)
ONAN	55/65	5,000/5,600
ONAF1	55/65	6,250/7,000

The transformers shall be capable of carrying rated current continuously at 5% above rated secondary voltage without exceeding an average winding temperature rise of 65°C above a 40°C maximum ambient and 30°C average ambient over 24 hours.

The transformer shall be 55/65°C construction where the winding temperature rise by resistance will not exceed 55°C; hottest-spot winding temperature rise will not exceed 80°C; suitable for loading in accordance with ANSI C57.92 (latest edition) "Guide for Loading Oil-Immersed Distribution and Power Transformers."

The transformer shall have five (5) full capacity, high voltage taps at rated kVA and shall be provided as follows:

HV Taps Rating (volts)
32,775
33,638
34,500
35,363
36,225

A weatherproof hand-operated tap changing mechanism shall be provided, suitable for de-energized operation, with one external handle that may be operated from the transformer base level and have provision for locking in any position. An external indicator shall clearly display the tap position.

Core shall be of cruciform, or circular, shape. Obround, oval, and elliptically shaped cores are not acceptable.

High voltage, low voltage, and tertiary windings (as applicable) shall use a continuous-disc or helical winding design exclusively. Pancake and layer (or "barrel") type windings are not acceptable.

The windings shall be properly braced and blocked so the coils will withstand short circuits forces caused by short circuits on the secondary terminals.

Windings and bracing shall be designed to withstand short circuit magnitudes of a minimum of 10,000A. Evidence of design conformance to this requirement shall be submitted with approval submittals.

All windings shall be wound with copper conductors. On coils requiring multiple conductors per turn, continuously transposed copper cable shall be used to minimize losses and hot-spot temperatures and to produce a more compact winding with improved short-circuit performance.

Any variation on winding design shall be preapproved.

Photographs of high voltage and low voltage sides of core and coil assembly indicating blocking, bracing, and dressing out of leads shall be submitted for approval prior to tanking.

6.2 Case and Cover

Tank shall be designed and braced for full vacuum and suitable for filling with oil under a vacuum of 28 inches of mercury, in the field.

Containing case shall not leak oil. Welded joints and seams shall be employed whenever practicable. No welds will be made on vertical corners of tank. Welds will not be greater than 2' from vertical edge of transformer.

Main transformer cover shall be welded. Gasketed joints for manhole covers, bushings, and other bolted attachments shall be sealed with a durable and reusable gasket material (ordinary cork or corkprene not approved) and shall be designed so as to permit their being made oil tight in reassembly. Mechanical stops shall be provided to prevent crushing (controlled compression).

Transformer base design shall be suitable for skidding the transformer in a direction parallel to either centerline of the tank, and shall be capable of supporting the transformer on two pier foundations. The bottom of the transformer tank shall not bear on the concrete pad in the finished installation. The bottom shall be primed and painted as described above. Flat bottom transformers

shall be furnished with supporting spacer beams. The dimensions and locations of these beams shall be shown in the manufacturer's drawings.

All conduits provided on the exterior of the transformer case shall be rigid steel. PVC or EMT is not acceptable.

All surfaces of case and covers, both exterior and interior, shall be thoroughly cleaned by means of shot-blasting or by any other equally effective method. Primer coats of exterior paint and exterior paint top coat shall comply with applicable standards for painting of substation transformers and meet the stipulations of the EEI finishing requirements.

The exterior surface of all bolts, nuts, and washers shall be primed and painted as above, or such parts shall be galvanized. No exposed cadmium-plated or zinc chromate-plated parts will be allowed.

The transformer tank shall be furnished with supported 4" x 1/4" copper bus bars from the top of the tank to a location 12" above the base of the tank on both diagonal corners to connect high-and low-voltage surge arresters and the X0 neutral bushing. Support points shall be at four feet maximum spacing from the tank base to the top surface. Arrester leads shall be 4/0 AWG copper or 1/4" x 2" copper bar minimum and the neutral bushing lead shall be 1000 MCM copper or equivalent minimum. All leads shall be connected to the main 1/4" x 4" bars with NEMA 4-hole drilling. One (1) spare NEMA 4-hole drilling shall be provided on each copper bar for connection to station ground system.

6.3 Impedance

The percent impedance voltage at the self-cooled rating as measured on the rated voltage connection shall be in accordance with the latest revision of IEEE Std. C57.12.10 and tolerance shall be as specified in the latest revision of IEEE Std. C57.12.00.

6.4 Sound Level

The transformer shall be so designed that the average sound level will not exceed the values given in the latest revision of NEMA TR-1 when measured at the factory in accordance with the conditions outlined in the latest revision of IEEE Std. C57.12.90.

6.5 Bushings and Terminals

The transformer shall be provided with cover-type bushings constructed of high strength wet-process porcelain and be clearly

labeled externally. All bushings shall be light gray, ANSI No. 70, condenser type, and have provisions for power factor testing. High voltage bushings shall be oil-filled and dimensionally interchangeable between circuit breakers and transformers, according to latest revisions of ANSI Standard C76. The high voltage bushings shall be draw lead type and the low voltage bushings shall be bottom connected.

Type of contaminated environment: Medium

Minimum creepage distance shall be based on type of contaminated environment stated above and as described in latest revision of IEEE Std C57.19.100.

Bushings shall be rated to meet or exceed electrical insulation characteristics given in the latest revision of Table 1 of IEEE Std C57.19.01.

Bushings shall be provided as follows:

Location	Voltage (kV)	Amperes	Connection
H1, H2, H3	34.5	600	Draw Lead
X1, X2, X3	4.16	1200	Bottom
X0	4.16	1200	Bottom

The neutral bushing shall be furnished with a NEMA 4-hole spade-type terminal for connection with 1000 MCM copper to the 1/4" x 4" copper neutral bus extending from the terminal to a tank ground pad for direct connection to the station ground system.

All primary and secondary bushings shall be provided with copper-threaded studs sized in accordance with their respective current ratings. Each bushing stud shall be provided with a NEMA 4-hole flat spade terminal connector. High and low voltage terminal studs and flat spade terminal connectors shall have silver-plated contact surfaces.

The bushings shall be spaced to comply with, or exceed, minimum phase-to-phase and phase-to-ground external clearances between live parts in accordance with NEMA Standard TR-1.

6.6 Auxiliary Cooling

Cooling equipment shall be furnished in accordance with ANSI standards for transformer self-cooled and forced-cooled ratings of

ONAN/ONAF.

Galvanized cooling radiators shall be mounted independently of one another on the transformer and individually removable from the transformer tank. Radiators shall be designed and braced to withstand all vibration and operating forces.

Radiator mounting flanges on the transformer tank shall each be equipped with valves to permit the removal or replacement of an individual cooling radiator without loss of either oil or gas above oil in the transformer tank.

Each cooling radiator shall be equipped with a fill valve at the top and a drain valve at the bottom of the unit. All cooling fans shall be equipped with automatic control to provide the operation of all cooling stages, based on the sensing of transformer winding temperature. Each fan shall be driven by an enclosed waterproof induction motor-rated 240 volts AC, single-phase, 60-Hertz. Each motor shall be equipped with thermal overload protection. Each fan shall be dynamically balanced for vibration-free operation.

Automatic control of all electrically powered cooling systems shall be accomplished by the closure of contacts within the transformer monitor. Recommendations for set points for turning cooling fans on and off, alarming, and tripping shall be supplied by the manufacturer.

The cooling systems shall provide a control switch for the transfer of cooling operation from automatic to manual control. All cooling system controls shall be enclosed in the transformer control cabinet, complete with all conduit and inner wiring to the fan. This function may be provided by the transformer monitoring system in lieu of a separate relay if so equipped.

6.7 Current Transformers

The power transformers shall be equipped with bushing type current transformers mounted inside the main case on terminals H1, H2, H3, X1, X2, X3, and X0 with leads brought to identified terminal blocks in a control cabinet.

Bushing type current transformers shall have standard taps and be furnished in accordance with the latest revision of Table 5 of IEEE Std C57.12.10 as follows:

Location	Ampere Ratio	Quantity EA/ Bushing	Total	Revenue Metering Class	Accuracy Class	Thermal Rating
H1, H2, H3	600:5	1	6	0.3B-1.8	C400	2.0
X1, X2, X3	1200:5	1	6	0.3B-1.8	C400	2.0
X0	1200:5	1	1	0.3B-1.8	C400	2.0

If the current transformers are mounted in a removable current transformer adapter, the current transformer shall be shipped in the main transformer mounted in the adapters. The current transformer secondary leads shall be wired directly to the shorting terminal blocks in the control cabinet. No splicing of secondary current transformer leads shall be required after delivery to the Owner. A CT metal diagram instruction plate shall be provided. Turns progression, accuracy class, and thermal rating factor of bushing current transformers shall be shown on the nameplate.

6.8 Surge Arresters

Surge arresters shall be transformer-mounted for the high and low voltage side on each phase. These shall be rated:

System Voltage, L-L (kV)	Ur, Duty Cycle (kV)	Uc, MCOV (kV)
34.5	27	22
4.16	3	2.55

Surge arresters shall be polymer housed, IEC line discharge class 3 (station class), light gray, ANSI No. 70. The surge arresters shall comply with the latest revision of ANSI Standard C62.11. Only metal oxide arresters are acceptable.

The surge arresters shall be located with relation to one another and the bushings to comply with, or exceed, minimum phase-to-phase and phase-to-ground clearances between live parts in accordance with ANSI Std C57-12.00-2010 Table 11.

The surge arresters shall be provided with 4-hole NEMA pad connectors to the bushing terminals. Ground conductors equivalent at minimum to 4/0 copper or 1/4" x 2" copper bus shall also be furnished and carried from the arrester bases to the transformer ground buses (looped configuration).

6.9 Control Cabinet

A weatherproof, painted, and galvanized steel control cabinet shall be

furnished enclosing control circuits, signal circuits, protective relays, individual transformer alarm indicators, and a suitable 240-volt, 60 Hertz thermostatically controlled heater with double-pole terminal circuit breaker.

The weatherproof control panel shall be centrally located near the bottom of the tank at a location to be approved by the Engineer. The cabinet door shall be completely weatherproof and shall have a handle with a triple latching mechanism, hinged on the left side. Handle/latch mechanism shall be furnished with padlocking provisions. Bolted door covers will not be acceptable. Doors shall have provisions for locking in the opened position. Breathers for the control cabinet shall be silica-gel type. Window shall be UV protected safety glass.

A dead-front control panel in the control cabinet shall contain the necessary switches, circuit breakers, relays, indicating lamps, etc. Target relays or indicating lamps shall be visible through a glass window in the front door of the cabinet.

The control cabinet heater shall be equipped with guards and thermostatically controlled so that the guard temperature cannot exceed 120°F. The 240-volt electric terminals of the heater shall also be covered.

All cabinets attached to the transformer shall be solidly grounded to the transformer case.

6.10 Transformer Monitoring System

A microprocessor-based transformer monitoring system shall be installed and programmed on the transformer. Self-checking functions shall be included. Specific requirements are as follows:

Front-panel visualization. The transformer monitoring system shall be capable of displaying measured values, calculated values, I/O statuses, device status, and configuration parameters on a front-panel LCD display. The display shall have a rotating capability to display custom messages and data. Thirty-two display messages shall be provided. The front panel shall also have a minimum of six user-programmable LEDs and four user-programmable pushbutton controls.

Functions provided. The transformer monitoring system shall monitor and report the following functions: top oil temperature, hot spot temperature on LV windings, load, transformer insulation aging, overload capability, transformer gas pressure, main tank liquid level,

warnings and alarms with dry contact output, through fault current measuring, monitoring of fans, exercise and rotation of fans, event recording, and remote access of data.

Programming capability. The transformer monitoring system shall be capable of implementing a wide variety of logic and control functions using the tools available in the Programming Language. Logic shall have the ability to use math functions, comparison functions, and Boolean logic functions.

IRIG-B synchronized, time stamped events. The transformer monitoring system shall store up to 512 event records with IRIG-B synchronized timestamps. An internal real time clock shall be used for time stamping if an IRIG-B signal is not available.

Sequential Event Recorder. A chronological report shall be provided by the transformer monitoring system to help determine the order and cause of events and assist in troubleshooting. The last 512 input, output, and element events shall be recorded.

Metering. The transformer monitoring system shall include metering capabilities for real time current, voltage, power, and energy quantities, as well as phase demand and peak demand current values for all ac current and voltage inputs.

Transformer Thermal Monitor. The system shall incorporate a transformer thermal monitor based on IEEE C57.91-1995. The model shall include capability for entering known transformer thermal constants as well as default constants. Three (3) loss-of-insulation-life alarms shall be provided, including loss-of-life per day, total loss-of-life, and insulation aging factor.

Through-Fault Event Monitor. The system shall provide for the capability of reporting fault current level, duration, and date/time for overcurrent events through the differential protection zone. Through-fault monitoring shall provide accumulated through-fault levels, number of through-faults and the total consumed through-fault capacity of the transformer (based on the *IEEE Guide for Liquid-Immersed Transformer Through-Fault-Current Duration, C57.109-1993*).

Event Record. The transformer monitoring system shall store up to 15 cycles of raw data with 16-sample/cycle resolution.

Voltage Inputs. Voltage inputs shall accept 0–300 Vac.

Current Inputs. Current inputs shall accept 0–5 A

Fiber-optic serial communications port to communicate with the

substation RTU via DNP3.

DNP3. The transformer monitoring system shall be capable of operating as a DNP3 Slave Level 2 either serial or LAN/WAN. All control points within the transformer monitor shall be available as DNP3 control points using latch on/latch off, pulse on/pulse off, or trip/close control functions.

PC Software. The transformer monitor shall include compatibility with a PC software program for use in programming control settings and logic functions and retrieving event data. The PC software shall be supplied as part of the transformer monitor.

Operating Temperature. The transformer monitor shall have an operating temperature range of -40° to $+85^{\circ}\text{C}$ (-40° to $+185^{\circ}\text{F}$) and a power supply input of applicable DC control voltage.

Specification Compliance. The transformer monitoring system front panel shall meet NEMA 12/IP54. The programmable automation controller shall be type tested to sections of C37.90, IEC 60255, IEC 60068, and IEC 61000 standards.

Warranty. The transformer monitoring system shall have a minimum 10-year warranty.

Transformer monitoring system device shall be a SEL 2414 part number 241422B1B913B851430, Key 0163 or approved equal. One (1) SEL-2886 EIA-232 to EIA-485 Interface Converter shall be provided for connection to rear port.

The transformer monitor shall be wired in accordance with the Input/Output Schedule included in the Appendix.

6.11 Pressure Relief

A pressure relief valve with visual indication shall be provided on the transformer for the detection of excessive positive increase in transformer tank pressure. The pressure relief alarm point contact shall be wired to the transformer monitor.

Transformer pressure relief device shall be provided to release at no more than 10 psi. Stainless steel or galvanized piping shall be provided to direct oil released through the pressure relief device to the base of the tank.

The pressure relief device shall be Qualitrol XPRD or approved equal.

6.12 Sudden Pressure Relay

A sudden pressure relay shall be provided on the transformer for the detection of rapid rates of positive increase in transformer tank pressure. The sudden pressure alarm point contact from the seal-in panel shall be wired to the transformer monitor and the trip point contact from the seal-in panel shall be wired to a terminal block for customer use as indicated on drawing in the Appendix.

Contacts supplied for alarms and initiation of lockout shall be dry, normally-open, latching operation with manual hand reset. Contacts shall be suitable for use at the station DC control voltage, 20 amperes resistive. Sudden pressure trip and alarm circuitry shall be powered by the Owner's station DC control voltage service.

The sudden pressure detection relay shall be Qualitrol Series 900/910 with seal-in panel, or approved equal.

6.13 Winding Temperature Relay

A winding temperature relay shall be provided on the transformer for the detection of over-temperature. The relay shall have four (4) sets of contacts and be wired to the transformer monitor for remote alarm and remote initiation of a transformer lockout relay. Contacts supplied for alarms and initiation of lockout shall be dry and normally-open.

The four-element winding temperature relay shall incorporate an indicating dial to display the winding temperature of the transformer.

The winding temperature device shall be Qualitrol or approved equal.

6.14 Top Oil Temperature Relay

A top oil temperature relay shall be provided on the transformer for the detection of over-temperature. The relay shall have four (4) sets of contacts and be wired to the transformer monitor for remote alarm and remote initiation of a transformer lockout relay. Contacts supplied for alarms and initiation of lockout shall be dry and normally-open.

The four-element winding temperature relay shall incorporate an indicating dial to display the top oil temperature of the transformer.

The top oil temperature device shall be Qualitrol or approved equal.

6.15 Oil Level Relay

An oil level relay shall be provided on the transformer for the detection of low oil. The relay shall have two (2) sets of contacts and be wired to the transformer monitor for remote alarm and remote initiation of a transformer lockout relay. Contacts supplied for alarms and initiation of lockout shall be dry and normally-open.

The two-element liquid level relay shall incorporate an indicating dial to display the liquid level of the transformer.

The winding temperature device shall be Qualitrol or approved equal.

6.16 Windings, Oil, and Ambient Temperatures

Resistance temperature detectors (RTD) and thermocouples (TC) shall be provided for detection of hottest spot winding temperature, transformer main tank top oil temperature, and ambient temperature.

RTDs shall be four (4) wire style. The outputs shall be wired to the transformer monitor RTD/TC inputs for remote alarm, remote initiation of a transformer lockout relay, and control of fans.

6.17 Undervoltage Relays

Undervoltage relays shall be provided to monitor AC and DC circuits. Each stage of fans shall be individually monitored as well as DC trip circuit(s) on the load side of the breakers. Alarm contacts shall be supplied and wired out to inputs of transformer monitor.

6.18 Positive Pressure System

The transformer shall be equipped with a positive pressurizing system utilizing nitrogen gas to protect the transformer oil in the main tank from oxidation and moisture absorption. The system shall consist of a nitrogen gas supply (cylinder) complete with supply pressure gauge, multi-stage pressure reduction assembly, thermostatically controlled heater, and associated piping and valves to control the flow of gas to and from the tank. The system shall provide alarms for low gas supply, high tank pressure, and low tank pressure conditions.

All tanks, gauges, regulators, valves and wiring shall be contained in a weatherproof cabinet. The cabinet door shall have a handle with a triple latching mechanism complete with padlocking provisions.

The system shall maintain transformer pressures at 1.0 psi minimum and 5.0 psi maximum, with appropriate fill and bleed-off regulation. Gas system alarms shall actuate whenever pressure falls below 0.5 psi, or rises above 5.5 psi, or whenever supply pressure falls below 200 psi. The system shall incorporate an indicating dial to display the gas system pressure of the transformer.

6.19 Wiring

The primary insulation jacket of all wiring shall be 600-volt, 90° C, water, oil, and flame resistant. All power wiring shall be made with #12 AWG or larger stranded tinned copper wire. All current transformer leads are to be #12 AWG stranded tinned copper or larger in size. All voltage transformer wiring shall be made with #14 AWG or larger stranded tinned copper wire. All control wiring shall be flexible SIS type, minimum 41 stranded, and not smaller in size than 14 AWG tinned copper wire, with the exception that wiring to alarm auxiliary relays and indicating lights may be smaller in size.

All wire into the control cabinet shall be enclosed in conduit. All conductors into the control cabinet shall terminate on a clearly marked and properly identified terminal blocks.

- a. Power wiring shall be sized in accordance with the National Electrical Code.
- b. All connections for wiring shall use silicon bronze, split-type lock washers.
- c. All wires shall be identified at each end with legible permanent labels.
- d. Wiring connections between fixed and hinged sections shall be SIS flexible type minimum 41-stranded wire.
- e. All terminal connections for conductor sizes #10 AWG in size and smaller shall be made with non-insulated full-ring tongue, crimp-type lugs. Lugs shall be AMP, Inc. "Solistrand Diamond-Grip" or approved equivalent. Spade-type terminals or slip-on connectors are not acceptable.
- f. All terminal connection for conductors sizes #2 AWG through #8 AWG shall be made with Burndy HYLUG Type YAV-L, or approved equivalent.
- g. All terminal connections for conductor sizes larger than #2 AWG shall be made with two-hole, long barrel, double-indent, crimp-type lugs: Burndy Hylug Type YA or approved

equivalent. (Single-hole lugs may be used only where necessary.)

- h. Grommets shall be provided for all openings in metal barriers used for wiring.
- i. Uninsulated exposed conductor or terminal lug shall not extend beyond the sides of the terminal block or its insulating barriers.
- j. All leads for multi-ratio current transformers shall be wired to terminal blocks in the control cabinet. If junction boxes are required in wiring between current transformer and control cabinet, terminal blocks shall be used for wiring connections. In-line type disconnecting terminals such as American Petroleum Institute (API) No. 32488 or Burndy No. YZ10 will not be acceptable.
- k. Bushing current transformer grounds: jumpers must be from the sixth pole of the shorting terminal block on the manufacturer's side directly to the ground bar. Jumpers between shorting terminal blocks are not acceptable unless jumpers are strictly between terminal blocks grouped together. An example of a grouping would be H1-H2-H3.
- l. If accidental short-circuiting of certain wires can result in malfunction of equipment, these wires shall not be terminated on adjacent terminal block points.
- m. No more than two wires per terminal point are permissible.
- n. All conduits mounted on the transformer shall be rigid steel unless otherwise specified.

6.20 Terminal Blocks and Molded Case Circuit Breakers

All terminal points shall be furnished with screws and lock washers.

Marathon 1500 STD series or equivalent terminal blocks shall be provided furnished with white marking strips for identification of terminal wires for all connections except current transformers and control power.

A minimum of 15-percent spare (but no less than 12 points) terminal points shall be provided in the control cabinet.

Marathon 1500 SC series terminal blocks shall be provided for

current transformer leads with at least three shorting screws per terminal block. A separate short-circuit type terminal block shall be provided for each set of current transformer leads.

Marathon Catalog No. 1423123 power terminal blocks shall be provided for landing of Owner's ac control power leads.

Marathon Catalog No. 1422123 power terminal block shall be provided for landing of Owner's dc voltage control power leads.

Molded case circuit breakers shall be used for interruption and protection of low voltage circuits.

6.21 Test Switch

One (1) test switch shall be furnished for bringing currents through the SEL-2414 transformer monitor as indicated on drawing in the Appendix. Test switch shall be ABB type FT-1, 10-pole, 2 potentials, 8 currents (W C-C R-R 7-7 9-9W) with clear cover and screw terminals (similar to style No. C129A518G01 except with colored handles).

7. TESTS

Transformer shall receive standard commercial tests in accordance with ANSI Standards. The Materialman shall furnish evidence of short circuit testing on similar units having the same basic ratings and designs. Short circuit tests shall comply with appropriate ANSI regulations.

Transformer shall receive standard ANSI impulse tests, including full wave and chopped wave on each high-voltage line terminal and on each low-voltage line terminal. Copies of oscillograms and a formal report will be submitted as a record of the tests.

In addition to the Standard ANSI tests, the transformer shall be corona tested at the full induced-test voltage level. Equipment and general method used will be in accordance with IEEE Transformer Committee Report. IEEE Transactions PAS 86 No. 12, December 1967, "Tests for Damaging Corona on Oil-Insulated Power Transformers".

No transformer will be accepted for shipment until approved by the Engineer. All impedances between windings shall be shown on the test reports.

The Materialman may offer in his quotation deductions for substitution of manufacturers' standard tests in lieu of those specified. However, the basic quotation must include all tests specified.

The Engineer reserves the option of having a representative present to inspect the core and coils prior to tanking and to witness any or all tests.

Without limiting in any way any obligation of the Materialman under this agreement, the Materialman shall demonstrate to the satisfaction of the Engineer that the transformer proposed to be furnished under this Specification shall have sufficient mechanical strength to withstand without failure all fault currents. The Materialman shall demonstrate that the transformers meet this requirement by one of the following methods:

- a. Certified test data showing that a transformer with a core and coil identical in design and construction and identical or similar with respect to kVA capacity, kV ratings, BIL, impedance, and voltage taps has been tested without failure for short-circuit strength. A description of the test code under which the transformer was tested for short-circuit strength will be provided by the Materialman to the Engineer.
- b. A history of successful experience with transformers of identical or similar ratings, design, and construction. The Materialman shall list all transformers in service with core and coils which are essentially identical in design, construction, and manufacture to the transformer covered by this specification, and provide information on the date of installation, location, and failures if any. Where such transformers have not been built or the cumulative service record is less than 20 transformer years, a list of transformers in service which represent the closest approximation to the transformer covered by this Specification shall be submitted. The information submitted shall be representative of the total experience of the manufacturer with the design of the transformer it proposes to furnish and include the dates of installation or shipping, the ratings of the transformers and the failures and causes of failure if any have been experienced.
- c. The Materialman shall submit with his Proposal a complete listing of all full-size transformers of his manufacture of similar ratings which have been short-circuit tested. The list shall include all full-size units tested, whether they were developed tests or tests of customer units. Complete ratings shall be given of each unit and each shall be noted as to whether copper or aluminum windings were used for comparison with that winding material offered on this bid. In the case of units tested for or by the ultimate customer, indication shall be given on each unit as to whether the test was successful or unsuccessful and, if tested more than once, each subsequent test shall be so listed and appropriate comments given as to

design changes made - if any.

- d. If the Materialman has no such test data available, he shall so state on the Proposal.

The transformer shall be tested for the following:

Factory Tests

Performance Tests

- Winding resistance measurements
- Ratio on all taps
- Polarity and Phase relation tests
- No-load losses and excitation current at 100% and 110% rated voltage
- Impedance voltage and load loss
- Operation tests of all devices
- Control (auxiliary) and cooling consumption losses
- Zero-phase sequence impedance voltage and load loss
- Temperature rise
- Dissolved gas in oil analysis (before start of all tests and after the completion of all tests)
- Audible sound level

Dielectric Tests

- Winding insulation resistance
- Core insulation resistance
- Insulation power factor and capacitance
- Low-frequency test on auxiliary devices and control and current transformer circuits
- Lightning impulse
- Low-frequency
- Partial discharge tests

Mechanical Tests

- Pressure
- Leak

Field Tests/Checks

All tests as called for by the latest revision of ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems shall be performed. For reference, applicable portions of ANSI/NETA ATS-2009 have been included in the Appendices. In addition, a

Sweep Frequency Response Analysis shall be performed.

Any tests listed that are not included in the bidder's proposal shall be so noted in the list of exceptions to the specifications.

In addition, the manufacturer shall provide certification for all design and other tests listed in Table 18 of ANSI C57.12.00 including verification that the design has passed Short Circuit Criteria per ANSI C57.12.00 and C57.12.90.

8. TRANSFORMER BID EVALUATION

Transformer bids shall be evaluated for "Equivalent First Cost of Ownership" utilizing initial cost and transformer losses. The formula is as follows:

$$\text{"Cost of Ownership"} = (\text{Unit Cost}^*) + (\text{Factor A} \times \text{No-Load Losses}) + (\text{Factor B} \times \text{Winding Losses})$$

*Including escalation if any.

The Cost of Losses will be evaluated using the following kW charge:

	<u>Factor</u>	
No-Load Loss	A	\$5,400 per kW
Winding Loss	B	\$1,450 per kW

The No-Load and Winding Losses quoted by the Materialman are of the essence of the Contract. Should the Materialman fail to meet the quoted losses, the Owner shall have the right to deduct from and retain out of such monies which may be then due or which may become due and payable to the Materialman the sum equal to the difference in quoted loss values and the actual loss values as verified by the certified test reports provided after manufacture computed in dollars utilizing the No-Load Loss and Winding Loss values listed above as liquidated damages and not as a penalty. In no event shall the adjustment factor under this provision result in a net price increase to the Owner. If the amount due and to become due from the Owner to the Materialman is insufficient to pay in full any such liquidated damages, the Materialman shall pay to the Owner the amount necessary to effect such payment in full, provided however, that the Owner shall promptly notify the Materialman in writing of the manner in which the amount retained, deducted, or claimed as liquidated damages was computed.

9. WARRANTY

The Materialman shall guarantee his materials and workmanship against defect due to faulty materials or faulty workmanship or negligence for a period as outlined below following final acceptance of the work. He shall make good such defective materials or workmanship and any damage resulting therefrom during the warranty period without any cost to Owner.

Each class of equipment shall carry a full five (5) year warranty against defects.

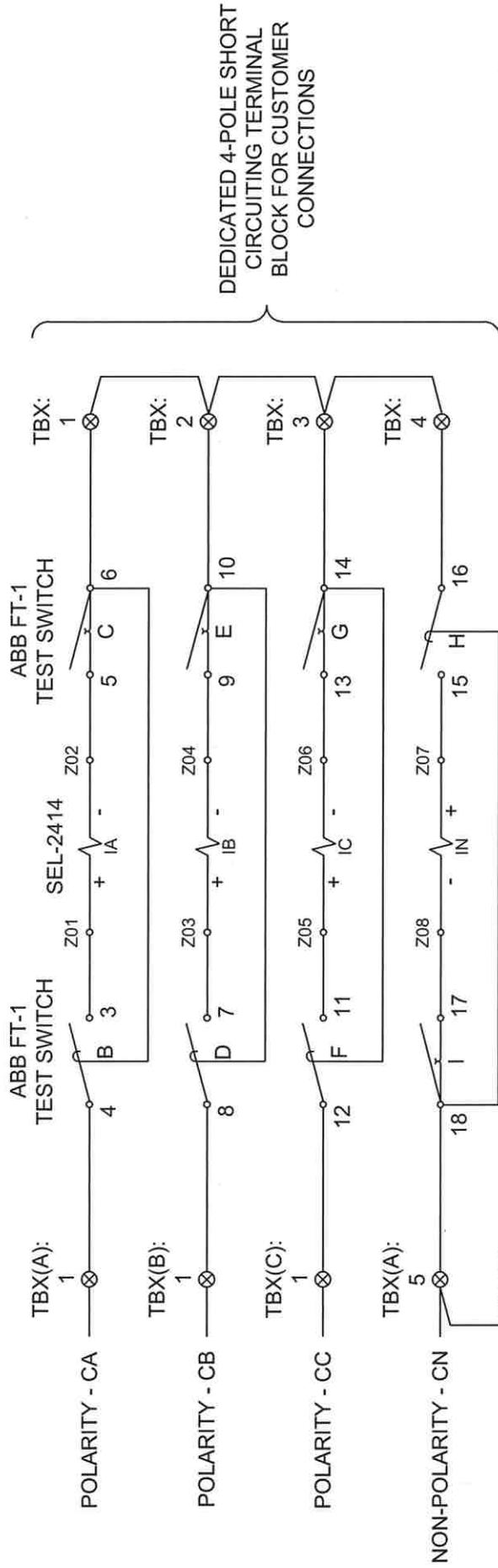
APPENDIX

SEL-2414 Transformer Monitor
Input/Output Schedule
For Transformer without LTC

Digital Inputs	
IN101	71Q Alarm (SW1 - Low Oil Level Main Tank)
IN102	71Q Trip (SW2 - Critical Low Oil Level Main Tank)
IN301	49T Stage 1 (SW#1 Winding Temperature)
IN302	49T Stage 2 (SW#2 Winding Temperature)
IN303	49T Alarm (SW#3 Winding Temperature)
IN304	49T Trip (SW#4 Winding Temperature)
IN501	63SPX Alarm (Sudden Pressure from Qualitrol Seal-In Panel)
IN502	27AC Alarm (Undervoltage AC Circuit - Stage 1 Fans)
IN503	27AC Alarm (Undervoltage AC Circuit - Stage 2 Fans)
IN504	27DC Alarm (Undervoltage DC Circuit - Trip)
IN505	63PR (Pressure Relief Main Tank)
IN506	63PS Alarm (Nitrogen Pressure Low)
IN507	63PS Alarm (Nitrogen Pressure High)
IN508	63L Alarm (Nitrogen Bottle Low)
RTD/TC Inputs	
RTD/TC 1	Winding Temp (49T)
RTD/TC 2	Top Oil Temp - Main Tank (26Q)
RTD/TC 3	Ambient Temp
RTD/TC 4	Spare
RTD/TC 5	Spare
RTD/TC 6	Spare
RTD/TC 7	Spare
RTD/TC 8	Spare
RTD/TC 9	Spare
RTD/TC 10	Spare
Current Inputs	
601-608	LV CT's, Inner Set (via test switch)
Outputs	
Out101	Trip (Primary Relay - 49T, 26Q, 71Q) - Wire to Terminal Blocks
Out102	Trip (Backup Relay - 49T, 26Q, 71Q) - Wire to Terminal Blocks
Out103	Relay Health Alarm - Wire out to Terminal Blocks
Out301	Fans - Stage 1
Out302	Fans - Stage 2
Out303	Communication Alarm - Wire out to Terminal Blocks
Out304	Spare - Wire out to Terminal Blocks
Communication	
Port 1A	Fiber Optic Ethernet
Port 2	Fiber Optic (serial)
Port 3	EIA-232 (with SEL-2886 EIA-232 to EIA-485 converter)
Power Supply	
DC (Station Batteries)	

Direct Trip Points (wire out to terminal blocks for customer use):

63SP1 Sudden Pressure Rise from Qualitrol Seal-In Panel

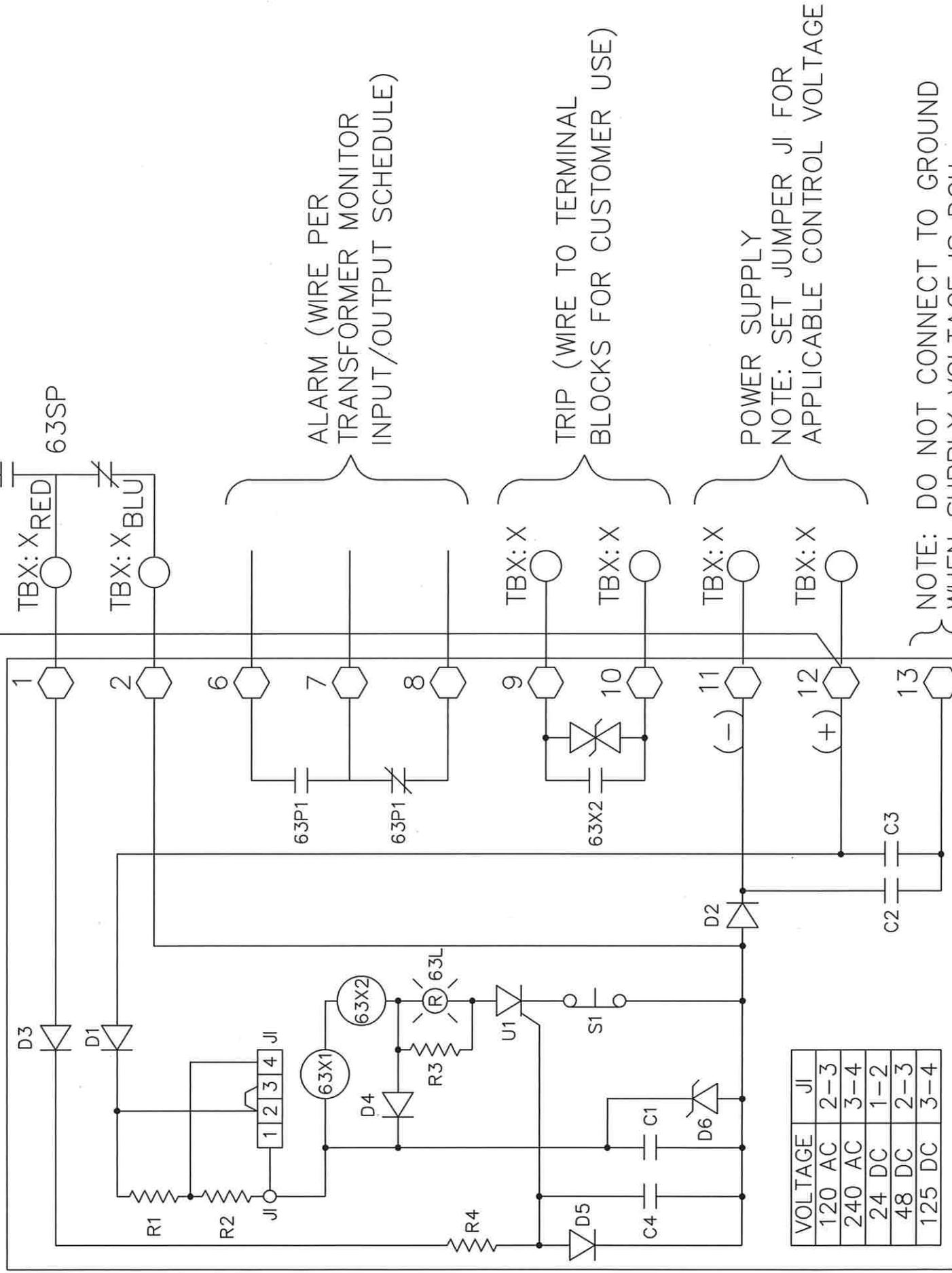


LEGEND:

- ⊗ SHORT CIRCUITING TERMINAL BLOCK
- DEVICE TERMINAL

SEL-2414 CURRENT INPUTS SCHEMATIC

63XP SUDDEN PRESSURE SEAL-IN PANEL



ANSI/NETA ATS-2013

AMERICAN NATIONAL STANDARD

STANDARD FOR
ACCEPTANCE TESTING SPECIFICATIONS for
Electrical Power Equipment
and Systems

Secretariat
InterNational Electrical Testing Association

Approved by
American National Standards Institute





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The following sections of the *ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems* must be incorporated by reference as part of any subsection:

3. Qualifications of Testing Organization and Personnel
 - 3.1 Testing Organization
 - 3.2 Testing Personnel
4. Division of Responsibility
 - 4.1 The Owner's Representative
 - 4.2 The Testing Organization
5. General
 - 5.1 Safety and Precautions
 - 5.2 Suitability of Test Equipment
 - 5.3 Test Instrument Calibration
 - 5.4 Test Report

The purchaser is required to include the above sections with any section(s) of 7.

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InterNational Electrical Testing Association
3050 Old Centre Avenue, Suite 102
Portage, MI 49024
E-mail: neta@netaworld.org • Web: www.netaworld.org



ANSI/NETA ATS-2013

3. QUALIFICATIONS OF TESTING ORGANIZATION AND PERSONNEL

3.1 Testing Organization

1. The testing organization shall be an independent, third party entity which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems being evaluated.
2. The testing organization shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.
3. The testing organization shall use technicians who are regularly employed for testing services.
4. An organization having a designation of *NETA Accredited Company* issued by the InterNational Electrical Testing Association meets the above criteria.
5. The testing organization shall submit appropriate documentation to demonstrate that it satisfactorily complies with these requirements.

3.2. Testing Personnel

1. Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must evaluate the test data and make a judgment on the serviceability of the specific equipment.
2. Technicians shall be certified in accordance with ANSI/NETA ETT-2010, *Standard for Certification of Electrical Testing Technicians*. Each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing.



4. DIVISION OF RESPONSIBILITY

4.1 The Owner's Representative

The owner's representative shall provide the testing organization with the following:

1. A short-circuit analysis, a coordination study, and a protective device setting sheet as described in Section 6.
2. A complete set of electrical plans and specifications, including all change orders.
3. Drawings and instruction manuals applicable to the scope of work.
4. An itemized description of equipment to be inspected and tested.
5. A determination of who shall provide a suitable and stable source of electrical power to each test site.
6. A determination of who shall perform certain preliminary low-voltage insulation-resistance, continuity, and low-voltage motor rotation tests prior to and in addition to tests specified herein.
7. Notification of when equipment becomes available for acceptance tests. Work shall be coordinated to expedite project scheduling.
8. Site-specific hazard notification and safety training.

4.2 The Testing Organization

The testing organization shall provide the following:

1. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform such tests and inspections.
2. Specific power requirements for test equipment.
3. Notification to the owner's representative prior to commencement of any testing.
4. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests.
5. A written record of all tests and a final report.



5. GENERAL

5.1 Safety and Precautions

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

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 29 CFR Part 1910 and 29 CFR Part 1926.
 2. ANSI/NFPA 70E, *Standard for Electrical Safety in the Workplace*.
 3. Applicable state and local safety operating procedures.
 4. Owner's safety practices.
2. The testing organization shall have a designated safety lead person on site to supervise operations with respect to safety.
3. A job hazard analysis and 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.

5.2 Suitability of Test Equipment

1. All test equipment shall meet the requirements in Section 5.3 and be in good mechanical and electrical condition.
2. Field test metering used to check power system meter calibration must be more accurate than the instrument being tested.
3. Accuracy of metering in test equipment shall be appropriate for the test being performed.
4. Waveshape and frequency of test equipment output waveforms shall be appropriate for the test to be performed and the equipment to be tested.



5. GENERAL

5.3 Test Instrument Calibration

1. The testing organization shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy for each test instrument calibrated.
2. The firm providing calibration service shall maintain up-to-date instrument calibration instructions and procedures for each test instrument calibrated.
3. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST).
4. Instruments shall be calibrated in accordance with the following frequency schedule:
 1. Field instruments: Analog and Digital, 12 months maximum.
 2. Laboratory instruments: 12 months maximum.
 3. Leased specialty equipment: 12 months maximum.
5. Dated calibration labels shall be visible on all test equipment.
6. Records which show date and results of instruments calibrated or tested must be kept up to date.
7. Calibrating standard shall be of better accuracy than that of the instrument tested.



5. GENERAL

5.4 Test Report

1. 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.
2. 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 and/or 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. Identification of all test results outside of specified tolerances.
 10. Sufficient spaces to allow all results and comments to be indicated.
3. The testing organization shall furnish a copy or copies of the complete report as specified in the acceptance testing contract.



5. GENERAL

5.5 Test Decal

1. The testing organization shall affix a test decal on the exterior of equipment or equipment enclosure of protective devices after performing electrical tests.
2. The test decal shall be color-coded to communicate the condition of maintenance for the protective device. Color scheme for condition of maintenance of overcurrent protective device shall be:
 1. White: electrically and mechanically acceptable.
 2. Yellow: minor deficiency not affecting fault detection and operation, but minor electrical or mechanical condition exists.
 3. Red: deficiency exists affecting performance, not suitable for service.
3. The decal shall include:
 1. Testing organization
 2. Project number
 3. Test date
 4. Technician name



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect impact recorder prior to unloading.
- *4. Test dew point of tank gases
5. Inspect anchorage, alignment, and grounding.
6. Verify the presence of PCB content labeling.
7. Verify removal of any shipping bracing after placement.
8. Verify the bushings are clean.
9. Verify that alarm, control, and trip settings on temperature and level indicators are as specified.
10. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay, if applicable.
11. Verify that cooling fans and pumps operate correctly and have appropriate overcurrent protection.
12. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a 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 100.12.
 3. Perform thermographic survey in accordance with Section 9.
13. Verify correct liquid level in tanks and bushings.
14. Verify that positive pressure is maintained on gas-blanketed transformers.
15. Perform inspections and mechanical tests as recommended by the manufacturer.
16. Test load tap-changer in accordance with Section 7.12.3.
17. Verify presence of transformer surge arresters.
18. Verify de-energized tap-changer position is left as specified.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

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. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform turns-ratio tests at all tap positions.
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 on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the 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 high-voltage winding in each de-energized tap-changer position. Measure the resistance of each low-voltage winding in each de-energized tap-changer position, if applicable.
- *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.
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

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

- *7. Water in insulating liquids: ASTM D 1533. (Required on 25 kV or higher voltages and on all silicone-filled units.)
- *8. 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, if present.
- 14. Test transformer neutral grounding impedance device, if present.
- 15. Verify operation of cubicle or air terminal compartment space heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

- 1. Alarm, control, and trip circuits from temperature and level indicators as well as pressure relief device and fault pressure relay shall operate within manufacturer's recommendations for their specified settings. (7.2.2.1.10)
- 2. Cooling fans and pumps shall operate. (7.2.2.1.11)
- 3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.2.1.12.1)
- 4. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.2.1.12.2)
- 5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.2.1.12.3)
- 6. Liquid levels in the transformer tanks and bushings shall be within indicated tolerances. (7.2.2.1.13)
- 7. Positive pressure shall be indicated on pressure gauge for gas-blanketed transformers. (7.2.2.1.14)

3.2 Test Values – Electrical

- 1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall not be less than 1.0.
3. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.
4. Maximum winding insulation power-factor/dissipation-factor values of liquid-filled transformers shall be in accordance with the manufacturer's published data. In the absence of manufacturer's published data use Table 100.3.
5. Investigate bushing power-factor and capacitance values that vary from nameplate values by more than ten percent. Hot-collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.
6. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
7. Temperature corrected winding-resistance values shall compare within one percent of previously obtained results.
8. Core insulation values shall be compared to the factory test value but not less than one megohm at 500 volts dc.
9. Investigate the presence of oxygen in the nitrogen gas blanket.
10. Insulating liquid values shall be in accordance with Table 100.4.
11. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.
12. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.
13. Results of surge arrester tests shall be in accordance with Section 7.19.
14. Compare grounding impedance device values to manufacturer's published data.
15. Heaters shall be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Verify correct connection of transformers with system requirements.
4. Verify that adequate clearances exist between primary and secondary circuit wiring.
5. Verify the unit is clean.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.10.2.1 and 7.10.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
7. Verify that all required grounding and shorting connections provide contact.
8. Verify correct operation of transformer withdrawal mechanism and grounding operation.
9. Verify correct primary and secondary fuse sizes for voltage transformers.
10. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

2.1 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 its secondary wiring with respect to ground at 1000 volts dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
3. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
4. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1.
5. Perform an excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

6. Measure current circuit burdens at transformer terminals in accordance with ANSI/IEEE C57.13.1.
7. When applicable, perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.5.
- *8. Perform dielectric withstand tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.9.
9. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data.
10. Verify that current transformer secondary circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. That grounding point should be located as specified by the engineer in the project drawings.

2.2 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 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
3. Perform a polarity test on each transformer to verify the polarity marks or H_1 - X_1 relationship as applicable.
4. Perform a turns-ratio test on all tap positions.
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 100.9. The test voltage shall be applied for one minute.
7. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data.
8. Verify that voltage transformer secondary circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. The grounding point should be located as specified by the engineer in the project drawings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

2.3 Electrical Tests - Coupling-Capacitor 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 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
3. Perform a polarity test on each transformer to verify the polarity marking. See ANSI/IEEE C93.1 for standard polarity marking.
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 100.9. The test voltage shall be applied for one minute.
7. Measure capacitance of capacitor sections.
8. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data.
9. Verify that the coupling-capacitor voltage transformer circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. That grounding point should be located as specified by the engineer in the project drawings.

2.4 Electrical Tests – High-Accuracy Instrument Transformers (Reserved)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.10.1.6.1)
2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.10.1.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.1.6.3)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

3.2.1 Test Values – Current Transformers – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of instrument transformers shall not be less than values shown in Table 100.5.
3. Polarity results shall agree with transformer markings.
4. Ratio errors shall be in accordance with C57.13.
5. Excitation results shall match the curve supplied by the manufacturer or be in accordance with ANSI C57.13.1.
6. Measured burdens shall be compared to instrument transformer ratings.
7. Insulation-resistance values of instrument transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5.
8. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the primary winding is considered to have passed the test.
9. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
10. Test results shall indicate that the circuits have only one grounding point.

3.2.2 Test Values – Voltage Transformers – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of instrument transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5.
3. Polarity results shall agree with transformer markings.
4. Ratio errors shall be in accordance with C57.13.
5. Measured burdens shall be compared to instrument transformer ratings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

6. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the primary windings are considered to have passed the test.
7. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
8. Test results shall indicate that the circuits are grounded at only one point.

3.2.3 Test Values – Coupling Capacitor Voltage Transformers

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of instrument transformers shall not be less than values shown in Table 100.5.
3. Polarity results shall agree with transformer markings.
4. Ratio errors shall be in accordance with C57.13.
5. Measured burdens shall be compared to instrument transformer ratings.
6. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.
7. Capacitance of capacitor sections of coupling-capacitor voltage transformers shall be in accordance with manufacturer's published data.
8. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
9. Test results shall indicate that the circuits are grounded at only one point.

3.2.4 Test Values – High-Accuracy Instrument Transformers (Reserved)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect impact recorder, if applicable.
5. Verify removal of any shipping bracing and vent plugs.
6. Verify the unit is clean.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.12.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
8. Verify correct auxiliary device operation.
9. Verify correct operation of motor and drive train and automatic motor cutoff at maximum lower and maximum raise positions.
10. Verify appropriate liquid level in all tanks.
11. Perform specific inspections and mechanical tests as recommended by the manufacturer.
12. Verify appropriate lubrication on motor components.
13. Record as-found and as-left operation counter readings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.12.3.1.
2. Perform insulation-resistance tests in any off-neutral position in accordance with Section 7.2.2.
3. Perform insulation power-factor or dissipation-factor tests in accordance with Section 7.2.2.
- *4. Perform winding-resistance test at each tap position.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers (*continued*)

5. Perform special tests and adjustments as recommended by the manufacturer.
6. Perform turns-ratio test at all tap positions.
7. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested for the following in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877
 2. Color: ANSI/ASTM D 1500
 3. Visual condition: ASTM D 1524
8. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved gas analysis in accordance with ANSI/IEEE C57.104 or ASTM D 3612.
- *9. Perform vacuum bottle integrity tests (dielectric withstand voltage) across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer's published data.
10. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.3.1.7.1)
2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.3.1.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.12.3.1.7.3)
4. Auxiliary device operation shall be in accordance with design intent. (7.12.3.1.8)
5. Motor, drive train, and automatic cutoff shall operate in accordance with manufacturer's design intent and automatic motor cutoff shall operate at maximum lower and maximum raise positions. (7.12.3.1.9)
6. Liquid level in tanks shall be within indicated tolerances. (7.12.3.1.10)
7. Operation counter shall have had an incremental change in accordance with tap-changer operation. (7.12.3.1.13)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations shall be investigated.
3. Maximum winding insulation power-factor/dissipation-factor values of liquid-filled transformers shall be in accordance with the transformer manufacturer's published data. In the absence of manufacturer's published data, use Table 100.3.
4. Consult the manufacturer if winding-resistance values vary by more than one percent from measurements of adjacent windings.
5. Special tests and adjustments shall be in accordance with manufacturer's published data.
6. Turns-ratio test results shall maintain a normal deviation between each voltage step and shall not deviate more than one-half percent from the calculated voltage ratio.
7. Results of insulating liquid tests shall be in accordance with Table 100.4.
8. Results of dissolved-gas analysis shall be evaluated in accordance with ANSI/IEEE C57.104.
9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.
10. Heaters shall be operational.

* Optional



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ANSI/NETA ATS-2013

7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems

1. Visual and Mechanical Inspection

1. Verify ground system is in compliance with drawings, specifications, and NFPA 70 *National Electrical Code Article 250*.
2. Inspect physical and mechanical condition.
3. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.13.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
4. Inspect anchorage.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with section 7.13.1.
2. Perform fall-of-potential or alternative test in accordance with ANSI/IEEE 81 on the main grounding electrode or system.
3. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and derived neutral points.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Grounding system electrical and mechanical connections shall be free of corrosion. (7.13.1.2)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.13.1.3.1)
3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.13.1.3.2)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems

1. Visual and Mechanical Inspection

1. Verify ground system is in compliance with drawings, specifications, and NFPA 70 *National Electrical Code Article 250*.
2. Inspect physical and mechanical condition.
3. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.13.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
4. Inspect anchorage.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with section 7.13.1.
2. Perform fall-of-potential or alternative test in accordance with ANSI/IEEE 81 on the main grounding electrode or system.
3. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and derived neutral points.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Grounding system electrical and mechanical connections shall be free of corrosion. (7.13.1.2)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.13.1.3.1)
3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.13.1.3.2)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. The resistance between the main grounding electrode and ground shall be no greater than five ohms for large commercial or industrial systems and one ohm or less for generating or transmission station grounds unless otherwise specified by the owner. (Reference ANSI/IEEE Standard 142)
3. Investigate point-to-point resistance values that exceed 0.5 ohm.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.1 Surge Arresters, Low-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and clearances.
4. Verify the arresters are clean.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.19.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.1.1.
2. Perform an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer's published data.
3. Test grounding connection in accordance with Section 7.13.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.19.1.1.5.1)
2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.19.1.1.5.2)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.1 Surge Arresters, Low-Voltage (*continued*)

2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm and in accordance with Section 7.13.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and clearances.
4. Verify the arresters are clean.
5. Inspect bolted electrical connections for high resistance using one or more 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 100.12.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Verify that the stroke counter is correctly mounted and electrically connected, if present.
8. Record the stroke counter reading.

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 on each arrester, phase terminal-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Test grounding connection in accordance with Section 7.13.
- *4. Perform a watts-loss test.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.19.2.1.5.1)
2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.19.2.1.5.2)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated
3. Resistance between the arrester ground terminal and the ground system shall be less than 0.5 ohm and in accordance with Section 7.13.
4. Watts-loss values are evaluated on a comparison basis with similar units and test equipment manufacturer's published data.

* Optional



9. THERMOGRAPHIC SURVEY

1. Visual and Mechanical Inspection

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
- *3. Perform a follow-up thermographic survey within 12 months of final acceptance by the owner.

2. Report

Provide a report which includes the following:

1. Description of equipment to be tested.
2. Discrepancies.
3. Temperature difference between the area of concern and the reference area.
4. Probable cause of temperature difference.
5. Areas inspected. Identify inaccessible and unobservable areas and equipment.
6. Identify load conditions at time of inspection.
7. Provide photographs and/or thermograms of the deficient area.
8. Recommended action.

3. 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. Refer to ANSI/NFPA 70B, 2010 Edition, Section 11.17.

4. Test Results

Suggested actions based on temperature rise can be found in Table 100.18.



TABLE 100.3
Recommended Dissipation Factor/Power Factor at 20° C
Liquid-Filled Transformers, Regulators, and Reactors
Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

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



TABLE 100.4
Insulating Fluid Limits

Table 100.4.1					
Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

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

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

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



TABLE 100.4 (continued)
Insulating Fluid Limits

Table 100.4.3 Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment				
ASTM Method	Test	Results		
		Minimum	Maximum	
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----	0.03	
D877	Dielectric breakdown voltage kV	30	-----	
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	-----	0.1	
		-----	1	
D1533B	Water content, ppm	-----	25	
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275	-----	
D92	Fire point (° C)	300 ^a	-----	
D971	Interfacial tension, mN/m, 25° C	38	-----	
D445	Kinematic viscosity, mm ² /s, (cSt), 40° C	1.0 X 10 ² (100)	1.3 X 10 ² (130)	
D1500	Color	-----	L2.5	

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

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

- a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.



TABLE 100.5
Transformer Insulation Resistance
Acceptance Testing

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 100.14 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 100.9
Instrument Transformer Dielectric Tests
Field Acceptance

Nominal System Voltage (kV)	BIL (kV)	Periodic Dielectric Withstand Test Field Test Voltage (kV)	
		AC	DC*
0.60	10	3.0	4
1.20	30	7.5	10
2.40	45	11.25	15
5.00	60	14.25	19
8.70	75	19.5	26
15.00	95	25.5	34
15.00	110	25.5	34
25.00	125	30.0	40
25.00	150	37.5	50
34.50	200	52.5	70
46.00	250	71.2	+
69.00	350	105	+
115.00	450	138	+
115.00	550	172	+
138.00	650	206	+
161.00	750	243	+
230.00	900	296	+
230.00	1050	345	+
345.00	1300	431	+
500.00	1675	562	+
500.00	1800	600	+
765.00	2050	690	+

Table 100.9 is derived from Paragraph 8.8.2 and Tables 2 of ANSI/IEEE C57.13-1993, *Standard Requirements for Instrument Transformers*.

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

* DC potential tests are not recommended for transformers rated higher than 200 kV BIL. DC tests may prove beneficial as a reference for future testing. In such cases the test direct voltage shall not exceed the original factory test rms alternating voltages.



TABLE 100.12.1
Bolt-Torque Values for Electrical Connections
US Standard Fasteners ^a
Heat-Treated Steel – Cadmium or Zinc Plated ^b

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in ²)	64K	105K	133K	150K
Bolt Diameter (Inches)	Torque (Pound-Feet)			
	1/4	5/16	3/8	7/16
1/2	9/16	5/8	3/4	7/8
1.0				

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.



TABLE 100.12.2
US Standard Fasteners^a
Silicon Bronze Fasteners^{b c}
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.
- c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 100.12.3
US Standard Fasteners^a
Aluminum Alloy Fasteners^{b c}
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.
- c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.



TABLE 100.12.4
US Standard Fasteners^a
Stainless Steel Fasteners^{b c}
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.
- c. 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).

Tables in 100.12 are compiled from Penn-Union Catalogue and Square D Company, Anderson Products Division, *General Catalog: Class 3910 Distribution Technical Data, Class 3930 Reference Data Substation Connector Products*.



TABLE 100.18
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 Chapter 8.9.2, Conducting an IR Thermographic Inspection, *Electrical Power Systems Maintenance and Testing*, by Paul Gill, PE, 1998.

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.

