SECTION 26 05 01

COMMON WORK RESULTS - ELECTRICAL

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified within this section apply to all sections in Division 26, Electrical. This section supplements requirements of other Divisions.

1.2 CODES AND STANDARDS

A. Manitoba Building Code (MBC).

B. The Winnipeg Electrical By-law (WEB)

C. CSA C22.1 Canadian Electrical Code - Part 1 (CEC)

D. CSA C22.2 No. 0 General Requirements - Canadian Electrical Code - Part 2

E. CAN3-C235 Preferred Voltage Levels for AC Systems, 0-50,000 V

F. Electrical and Electronic Manufacturers Association of Canada (EEMAC)

G. National Electrical Manufacturers Association (NEMA)

H. Institute of the Electrical and Electronic Engineers (IEEE)

I. Insulated Cable Engineers Association (ICEA)

J. Canadian Standards Association (CSA)

K. Underwriters Laboratories Canada (ULC)

L. American National Standards Institute (ANSI)

M. National Fire Protection Agency (NFPA)

N. Comply with the most current requirements of the Manitoba Energy Code for Buildings (MECB).

O. Comply with the most current locally enforced edition of CSA C22.1 Canadian Electrical Code - Part 1, Winnipeg Electrical By-law, Provincial Safety Electrical Authority Codes and Bulletins.

P. Comply with all laws, ordinances, rules, regulations, codes, and orders of all authorities having jurisdiction relating to this Work. Where these regulations conflict, comply with the most stringent condition.

Q. Comply with latest editions of the CSA Certification Standards and Bulletins.

1.3 DRAWINGS AND SPECIFICATIONS

A. The intent of the Drawings and Specifications is to indicate labor, products, and services necessary for a complete, installed, tested, commissioned and functional installation.

B. Electrical drawings may indicate approximate route to be followed by conduits and cables and general location of electrical equipment. They do not show all structural, architectural and mechanical details. In some cases, conduit or wiring is only shown diagrammatically on the drawings. The details on exact cable or conduit routing, and exact equipment installation location is to be determined on site and coordinated with all other trades.

C. To provide sufficient detail and maximum degree of clarity on the drawings, symbols used for various electrical devices, particularly wall mounted devices, take up more space on the drawings than devices physically do. Locate devices with primary regard for convenience of operation, accessibility and space utilization, rather than locating devices to comply with the exact scaled locations of the electrical symbols.

D. These specifications along with the drawings and specifications of all other divisions shall be considered as an integral part of the drawing package. Any item or subject omitted from the division 26 specifications or the drawings but which is mentioned or reasonably specified in the drawings or specifications of other divisions, shall be considered as properly and sufficiently specified and shall be provided.

E. If discrepancies or omissions in the drawings or specifications are found, or if the intent or meaning is not clear, advise the Contract Administrator for clarification before submitting a bid.

F. Provide all minor items and work not shown or specified but which are reasonably necessary to complete the work.

1.4 CARE, OPERATION AND START-UP

A. Instruct the Contract Administrator’s maintenance and operating personnel in the operation, care and maintenance of systems, system equipment and components.

1.5 PERMITS, FEES AND INSPECTION

A. The Contract Administrator will submit to Electrical Inspection Department and Supply Authority necessary number of drawings and specifications for examination and approval prior to commencement of work.

B. The Contractor shall pay associated fees as required by the Electrical Inspections and Permitting department.

C. Notify the Contract Administrator of changes required by Electrical Inspection Department prior to making changes.

1.6 DEFINITIONS

A. The following are definitions used in Division 26.
1. Inspection Authority means agent of any authority having jurisdiction over construction and safety standards associated with any part of electrical site work.
2. Supply Authority or Supply Utility means electrical power company or commission responsible for delivering electrical power to the project site.
3. Electrical Code or Code means the Electrical Code in force at the project location.
4. CEC means Canadian Electrical Code (latest edition being enforced by law).
5. Contractor means the entity retained to perform the work listed herein.
6. Contract Administrator means the person with the authority to make decisions and administer the contract on behalf of the Owner.
7. Provide means to supply, install, wire, connect, test, commission and leave in complete and working order.
8. The term “Shop Drawing” means drawings, diagrams, illustrations, schedules, performance characteristics, brochures and other data, which are to be provided by the Contractor to illustrate details of a portion of the work.

1.7 DESIGN REQUIREMENTS

A. Design equipment, anchorage, and support systems for vertical and lateral loading in accordance with MBC.

B. Operating voltages to be within those defined in CAN3-C235.

C. Verify before energization that equipment supplied under this contract is compatible with the site electrical power supply system.

D. All equipment, devices and installation methods (even where not specifically expressed on the drawings) shall comply with the Manitoba Energy Code for Buildings (MECB).

1.8 ELECTRICAL COORDINATION

A. Coordinate work with all other trades to ensure that conflicts do not occur.

B. Coordinate requirement of mechanical equipment requiring electrical connection with the Mechanical contractor. Pay specific attention to equipment full load amps, voltage, phase and breaker size.

C. Verify that all equipment ordered is compliant with the Manitoba Energy Code for Buildings.

D. Coordinate work with utilities where appropriate, including but not limited to:
   1. Incoming overhead lines,
   2. Underground buried services,
   3. Transformer(s) supplying main electrical service to the facility,
   4. Installation of Supply Authority meter,
   5. Installation of incoming telephone / data communication service conductors or cables.

1.9 SUBMITTALS

A. Permits, Fees and Inspection:
   1. Furnish copies of all inspection reports and Certificate of Final Acceptance from Electrical Inspection Authority and any authorities having jurisdiction on completion of work to Contract Administrator and include copies in the O & M manuals.

B. Site Documentation
   1. In each electrical room, provide power distribution system single line diagrams in glazed metal frames.
   2. Provide fire alarm riser diagram, plan and building zoning in glazed metal frame at fire alarm control panel and annunciator to meet requirements of Fire Commissioner.
   3. Where work includes modification to existing power distribution or fire alarm systems, provide new single line and riser diagrams showing complete modified system. Reinstall diagram into existing frames where feasible or provide new frame and glazing.

C. Within 15 days of award of the Contract, the Contractor shall submit a completed equipment procurement schedule, which lists the manufacturer and model of equipment, indicating the projected ordering, Shop Drawing submittal date and delivery dates of all products to meet the required construction schedule.

D. Prior to delivery of any products to the job site and sufficiently in advance of requirements to allow ample time for checking, submit Shop Drawings for review as specified in Division 01.

E. Submit Shop Drawings (including product data) for all equipment as required in each section of this specification.

F. Prior to submitting the Shop Drawings to the Contract Administrator, the Contractor shall review, date and sign the Shop Drawings to determine that the equipment complies with the requirements of the specifications and drawings.

G. Shop Drawings shall indicate materials, methods of construction and attachment of support, wiring diagrams, connections, recommended installation details, explanatory notes and other information necessary for completion of the work. Where equipment is connected to other equipment, indicate that such items have been coordinated, regardless of the section under which the adjacent items will be supplied and installed. Indicate cross-references to design drawings and specifications. Adjustments made on Shop

Drawings by the Contract Administrator are not intended to change the contract price. If adjustments affect the value of the work, state so in writing to the Contract Administrator prior to proceeding with the work.

H. Manufacture of products shall conform to the revised Shop Drawings. Failure to supply a product based on the revised, marked up Shop Drawings may require on site product revisions or modifications, which will be at the cost of the Contractor.

I. Keep one (1) complete set of Shop Drawings at job Site during construction.

J. Prior to shipping pre-fabricated control panels, photos of completed panels shall be sent to the Contract Administrator of final review. The resolution of the photos should be such that individual wire tags can be read.

1.10 AS-BUILT DRAWINGS

A. The Contractor shall keep one (1) complete set of white prints at the site during work, including all addenda, change orders, site instructions, clarifications, and revisions for the purpose of As-Built drawings. As the work on-site proceeds, the Contractor shall clearly record in red pencil all as-built conditions, which deviate from the original contract documents. As-Built drawings to include circuiting of all devices, conduit and feeder runs (complete with conductor size and number) and locations of all electrical equipment.

B. On completion of the work, two (2) weeks prior to final inspection, submit As-Built drawings to Contract Administrator for review. The Contractor shall certify, in writing signed and dated, that the As-Built drawings are complete and that they accurately indicate all electrical services, including exposed as well as concealed items

1.11 OPERATIONS AND MAINTENANCE (O & M) MANUALS

A. Provide operation and maintenance manuals as specified herein and in accordance with the general conditions.

B. Include in the operations and maintenance manuals a minimum of:
1. Cover page including project name, year, name of owner and electrical consultant. Cover page shall be enclosed in a clear plastic cover.
2. Index.
3. List of manufacturers and supplier for all items.
4. Names, address and phone number of all local suppliers for items included in maintenance manual.
5. Stamped and signed shop drawings.
6. Details of design elements, construction features, component function and maintenance requirements, to permit effective start-up, operation, maintenance, repair, modification, extension and expansion of portions or features of the installation.
7. Technical data, product data, supplemented by bulletins, component illustrations, exploded views, technical descriptions of items and parts lists. Advertising or sales literature not acceptable.

8. All test results performed. This includes, but is not limited to fire alarm V.I report, grounding system tests, battery bank test results, genset tests, cable tests, MCC tests, load balancing tests, Hi Pot tests, Megger tests, factory tests of all major systems, etc.
9. Panel schedules.
10. As-Built drawings.
11. Signed, dated warrantee certificate.
12. Signed, dated approval by the local Electrical Inspections Department.

C. Deliver to the Contract Administrator prior to the scheduled takeover date, three (3) sets of operation and maintenance manuals. Each operation and maintenance manual shall be contained within one or more 76 mm thick, commercial quality, black, hard cover three "D-ring" binder(s). Each binder shall be labeled directly on the front cover as well as the spine ("ELECTRICAL MAINTENANCE MANUAL – PROJECT NAME – YEAR"). Provide a total of three (3) copies of all manuals.

D. Index tabs shall be provided by specification section. Divider tab pages shall be laminated mylar plastic with reinforced holes. Paper dividers, with plastic tabs and typed insertions will not be accepted.

1.12 ENVIRONMENTAL CONDITIONS

A. Equipment and systems are to be rated to correctly operate in the environment in which they are to be installed.

B. Exterior devices shall be rated to operate in an exterior environment with temperature range of -40°C to +40°C.

1.13 QUALITY ASSURANCE

A. Qualifications
1. For work involving specialties, including, but not limited to, the installation of high voltage switchgear, high voltage cables, overhead pole lines, sound and intercommunication systems, fire alarm systems, lightning protection systems, equipment cathodic protection, grounding systems, instrumentation, controls, electronic access, security systems, fibre optics systems, etc. employ only workers fully trained, qualified and experienced in the aspects of such work.

PART 2 PRODUCTS

2.1 ACCEPTED MATERIALS

A. Materials: approved by and bearing a CSA label. Where equipment or material is not approved or certified as indicated, obtain and pay for special approvals from the Department of Labor.

B. Factory assemble control panels and component assemblies. Control panels to be CSA certified. Include current interrupting rating on the front panel. Shop drawings for custom

built control panels shall be signed and sealed by an engineer, registered in the Province of Manitoba.

C. Minimum enclosure type to be NEMA 12 unless otherwise specified. Refer to the drawings and other specification section for specific requirements.

2.2 EQUIPMENT FINISH

A. Shop finish metal enclosure surfaces by application of rust resistant primer inside and outside, and at least two coats of finish enamel.

B. Paint indoor switchgear and distribution enclosures light grey to ANSI 61 grey enamel, unless otherwise specified.

2.3 EQUIPMENT IDENTIFICATION

A. Identify electrical equipment with nameplates as described below.

B. Nameplates:
1. Lamacoid, 3 mm thick plastic nameplates, mechanically attached with self tapping stainless steel screws, white face with black lettering.
2. Sizes as follows:

NAMEPLATE SIZES

Size 1	10 x 50 mm	1 line	3 mm high letters
Size 2	12 x 70 mm	1 line	5 mm high letters
Size 3	12 x 70 mm	2 lines	3 mm high letters
Size 4	20 x 90 mm	1 line	8 mm high letters
Size 5	40 x 90 mm	2 lines	8 mm high letters
Size 6	25 x 100 mm	1 line	12 mm high letters
Size 7	25 x 100 mm	2 lines	5 mm high letters
Size 8	35 x 100 mm	3 lines	5 mm high letters
Size 9	45 x 100 mm	4 lines	5 mm high letters
Size 10	75 x 160 mm	3 or 4 lines	8 mm high letters

C. Wording on nameplates to be approved by Contract Administrator prior to manufacture.

D. Allow for average of fifty (50) letters per nameplate.

E. Identification to be in English.

F. Provide nameplates for the following, sizes as shown:
1. Power, voice and data receptacles –Size 1
2. Panelboards – Size 9
3. Dry Type Transformer – Size 8
4. Cabinets – Size 8
5. Junction Boxes – Size 1
6. Control panels – Size 8
7. Contactors – Size 8

8. Terminal / splitter cabinets – Size 8
9. MCCs, switchgear, distribution equipment – Size 10
10. Each cell or bucket in an MCC – Size 7
11. Each breaker cell located within switchgear – Size 5
12. Motor starters – Size 8
13. Switches – Size 1
14. Emergency lighting battery banks – Size 7 or Size 8
15. Emergency lights – Size 1
16. Exit signs – Size 3
17. Disconnect switch – Size 8
18. Wall mounted fire alarm devices – Size 2
19. Ceiling mounted fire alarm devices – Size 4

2.4 WIRING IDENTIFICATION

A. Identify wiring with permanent indelible identifying markings, either numbered or coloured plastic tapes, on both ends of phase conductors of feeders and branch circuit wiring.

B. Maintain phase sequence and colour coding throughout.

C. Colour code: to CSA C22.1.

D. Use colour coded wires in communication cables, matched throughout system.

2.5 CONDUIT AND CABLE IDENTIFICATION

A. Colour code conduits, boxes and cables.

B. Code with plastic tape or paint at points where conduit or cable enters wall, ceiling, or floor, and at 5 m intervals.

C. Colours: 38 mm wide prime colour and 19 mm wide auxiliary colours.

System	**Prime Band**	**Aux. Band**
Medium Voltage (>750 V)	Orange	
347/600 V	Yellow	
120/208/240 V Power	Black	
UPS 120/208/240 V Power	Black	Green
Control Wiring (120 V)	Black	Orange
Fire Alarm	Red	
Low Voltage Communication/General	Blue	
Low Voltage Control Wiring (<50 V)	Blue	Orange
Intrinsically Safe	Blue	White
Ground	Green	

D. Cable Identification: Supply and install lamacoid type cable identification tags for all cables. Install identification tag at both ends.

PART 3 EXECUTION

3.1 PREPARATION AND PROTECTION

A. Schedule expediting of materials and execution of work in conjunction with associated work of other trades in order to meet the required work schedule.

B. Post engraved warning signs to meet requirements of local bylaws, Inspection Authority and Contract Administrator.

C. Protect those working on or in vicinity of exposed electrically energized equipment from physical danger. Shield and mark live parts in accordance with local regulations. Indicate the appropriate voltage.

D. Arrange for installation of temporary doors, barriers and similar items for access to rooms and areas containing electrical equipment. Keep these doors locked at all times, except when under direct supervision.

E. Permanently identify with lamacoid nameplate, equipment energized from multiple power sources, noting voltages, power source locations, supply disconnect designations and grounding electrode location.

3.2 WARNING SIGNS

A. As specified and to meet the requirements of Electrical Inspection Department and the Contract Administrator.

B. Lamacoid 3 mm thick plastic engraving sheet, red face, white core, mechanically attached with self tapping screws, 20mm text.

3.3 MOUNTING HEIGHTS

A. Unless otherwise noted, or in contravention of codes and standards, mount equipment replacing existing equipment at the same height.

B. Mounting height of equipment is from finished floor to centerline of equipment unless specified or indicated otherwise.

C. If mounting height of equipment is not indicated, verify with the Contract Administrator before proceeding with the installation.

D. Mount indoor electrical distribution equipment utilizing one of the following:
1. Floor mount on 89mm (3.5”) concrete housekeeping pad
2. Surface wall mount on modular metal support system: Unistrut, Cantruss, or similar.
3. Surface wall mount on 19mm (3/4”) thick fire retardant plywood backboard
4. Recess mount (as indicated on the drawings)

E. Install electrical equipment at the following heights unless indicated or directed otherwise (to bottom of the equipment):
1. Outlets above counters: 150 mm (6”); splashbacks: 100 mm (4”).
2. General receptacles & communications outlets: 400 mm (16”).
3. Receptacles in mechanical and shop areas: 1 m (40”).
4. Switches, dimmers, push buttons: 1.2 m (48”).
5. Thermostats: 1.4 m (56”).
6. Security alarm bells, horns, speakers: 2.2 m (88”).
7. Motor starters: 1675mm (66”) to top.
8. Panelboard: 2.0 m (78”) to top.
9. Control Panels: 1675mm (66”) to top.
10. Clock outlets: 2.15 m (84”).
11. Emergency lighting battery bank unit: 2.1m (82”).
12. Emergency light remote head: 150mm (6”) below ceiling, to a maximum height of 3.0m (118”).
13. Wall mount Exit signs: 2.2m (87”) or higher as required to coordinate with door height.
14. Pushbutton for power door assist: 900mm (35.4”)
15. Intrusion alarm motion detectors: 150mm (6”) below ceiling, to a maximum height of 3.0m (118”).
16. Intrusion alarm keypad: 1500mm (59”)
17. Fire alarm panel: 1650mm (65”) to top
18. End of line resistors: 1.6 m (64”),
19. Fire alarm pull stations: 1320mm (52”),
20. Fire alarm horn / strobe: a minimum of 150mm (6”) below ceiling to the top edge of the device (for low ceiling areas). Where ceilings allow, mount devices at 2400mm (94.5”) (measured to top of device) above finished floor.
21. Coordinate and confirm elevations indicated on the Architectural drawings. Where discrepancies occur, request clarification from the Contract Administrator.
22. Mounting heights to meet all codes and regulations. Fire alarm devices to be in accordance with CAN / ULC-S524.
23. Coordinate and confirm elevations indicated on the Architectural elevations. Where discrepancies occur, request clarification from the Contract Administrator.

3.4 LOCATION OF DEVICES

A. Allow for change of location of devices at no extra cost or credit, provided that the distance does not exceed 3000mm (10’) from that shown on the drawings, when the requirement is made known prior to installation.

3.5 CONDUIT AND CABLE INSTALLATION

A. Sleeves through concrete: schedule 40 galvanized steel pipe, sized for free passage of conduit.

B. For wall, partitions, and ceilings the sleeve ends shall be flush with the finish on both sides but for floors they shall extend 25 mm (1”) above finished floor level.

C. Fire stop opening with ULC approved assembly for the installation conditions.

D. Provide a detailed proposed conduit routing plan to the Contract Administrator prior to proceeding with the installation of conduit.

E. If possible, avoid routing conduits through hazardous area.

F. Separate cables of different voltage levels when cables are installed parallel to each other.

3.6 CUTTING, PATCHING, DRILLING

A. Provide all cutting and patching as required.

B. Return exposed surfaces to an as-found condition.

C. Exercise care where cutting/drilling holes in existing concrete elements so as not to damage existing reinforcing, or any other systems run in the concrete.
1. Locate reinforcing and other existing systems using ground penetrating radar, X-Ray or other suitable means. Mark out on the surface of the concrete the locations of rebar and all other systems.
2. For all holes larger than 50mm passing through reinforced concrete, mark the location of the desired hole and all embedded systems. Obtain approval from the Contract Administrator prior to cutting.

D. Firestop and seal all penetrations.

E. Ensure that water ingress will not occur.

F. Provide expansion joints for penetrations where shifting can occur.

3.7 ANCHOR INSTALLATION

A. The Contractor shall exercise care where installing anchors into existing concrete elements so as not to damage existing reinforcing. All anchors shall be installed utilizing carbide tip drill bits. The existing reinforcing shall be located utilizing a reinforcing bar locator and marked out on the surface of the concrete. The drill holes shall be advanced to the required depth for installation of the anchors. Should reinforcement be encountered while drilling the hole shall be terminated and repositioned to clear the reinforcement. Do not use core bits that can easily intercept and damage/cut the reinforcing during drilling.

3.8 FIELD QUALITY CONTROL

A. All electrical work to be carried out by qualified, licensed electricians or apprentices as per the conditions of the Provincial Act respecting manpower vocational training and qualification. Employees registered in a provincial apprentices program shall be permitted, under the direct supervision of a qualified licensed electrician, to perform specific tasks - the activities permitted shall be determined based on the level of training attained and the demonstration of ability to perform specific duties. A maximum of one apprentice is permitted per qualified electrician.

B. The work of this division to be carried out by a contractor who holds a valid Master Electrical contractor license as issued by the Province of Manitoba.

C. Furnish manufacturer's certificate or letter confirming that entire installation as it pertains to each system has been installed to manufacturer's instructions.

3.9 LOAD BALANCE

A. Drawings and specifications indicate circuiting to electrical loads and distribution equipment.

B. Balance electrical load between phases as closely as possible on switchboards, panelboards, motor control centers, and other equipment where balancing is required.

C. When loads must be reconnected to different circuits to balance phase loads, maintain accurate record of changes made, and provide circuit panel directory that lists final circuit arrangement.

3.10 TESTS

A. Test and check electrical, instrumentation and control systems for correct operation and compliance with statutory and regulatory authority requirements.

B. Perform tests in presence of Contract Administrator. Log, tabulate, sign and include testing and commissioning results in the O & M manuals.

C. Test the following systems:
1. Electrical distribution systems, for correct phasing, voltage, grounding and load balancing.
2. Wire and cable system.
3. Lighting and associated control.
4. Motors, heaters and associated control equipment including sequenced operation of systems where applicable.
5. Communications, control & instrumentation, fire alarm and emergency power systems.
6. All other systems as indicated in the drawings and specifications.

D. Refer to appropriate specification sections for specific system or equipment tests.

E. Supply instruments, meters, consumable parts (such as fuses) and equipment. Arrange for qualified personnel to conduct tests.

F. In cooperation with mechanical trades, take clamp-on ammeter readings with motors operating at full load. Compare values against the equipment nameplate rating. Log, tabulate and include readings in Maintenance Data and Operating Instructions.

G. Correct systems which fail any test, correct and re-do tests to ensure proper operation of the system.

3.11 CHECKOUT AND STARTUP

A. Voltage Field Test:
   1. Refer to section 26 08 05 as applicable.
   2. Check Supply Utility voltage at point of termination of supply conductors when installation is essentially complete and is in operation.
   3. Check voltage amplitude between phases, and phase to neutral for loaded and unloaded conditions.
   4. Check voltage drop on at all distribution panels, and ensure that it is less than 2% in accordance with CEC requirements.
   5. Check voltage drop on equipment loads, and ensure that total voltage drop from the service to the farthest device is less than 5% in accordance with the CEC. Adjust transformer taps, and upsize conductors as required to meet the CEC.
   6. Unbalance Corrections:
      a. Make written request to the Supply Utility to correct conditions if the service voltage unbalance exceeds 3 percent.

B. Current Field Tests:
   1. Make line current check after supply utility has made final adjustments to supply voltage.
   2. Check current balance at the service demarcation point. Adjust loads to ensure that each phase is appropriately balanced.
   3. Check line current in each phase for each piece of equipment.
   4. If the phase current for a piece of equipment is above rated nameplate current, prepare Equipment Line Phase Current Report that identifies cause of problem and corrective action taken.

3.12 TOUCH-UP PAINTING

A. Clean and touch up surfaces of shop painted equipment scratched or marred during shipment or installation, to match original paint.

B. Obtain necessary touch-up paint of original type and quality from equipment manufacturer.

C. Clean surfaces to be painted. Feather out edges of scratch marks. Make patch inconspicuous.

D. Apply one or more coats until damaged surface has been restored to original finish condition.

E. Clean and prime exposed non galvanized hangers, racks and fastenings to prevent rusting.

F. Do not paint nameplates, tags, CSA labels, warning plates and operating instructions. Observe field painting of electrical equipment or raceways. Labels shall be visible and legible after the equipment is installed.

3.13 CLEANING

A. Clean construction debris and materials from enclosures, before final electrical tests. Vacuum the interior and exterior of enclosures to ensure all equipment is free from debris.

3.14 PROVISION FOR FUTURE EXPANSION

A. In each location where space for future equipment is indicated, leave such space clean. Install conduit, wiring and other work in such a manner that necessary connections can be made in future without dismantling existing equipment, raceways or wiring. Consult with Contract Administrator whenever necessary.

END OF SECTION

SECTION 26 05 21

WIRE AND CABLES (0-1000V) - ELECTRICAL

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CAN/CSA-C22.2 No. 38, Thermoset-Insulated Wires and Cables.

B. CAN/CSA-C22.2 No. 49, Flexible Cords and Cables

C. CAN/CSA-C22.2 No. 51, Armoured Cables.

D. CSA C22.2 No. 0.3, Test Methods for Electrical Wires and Cables.

E. CAN/CSA-C22.2 No. 131, Type TECK 90 Cable.

F. CAN/CSA C22.2 No. 174 Cables and Cable Glands for use in Hazardous Locations.

G. CAN/CSA C21.2 300V Control Cable.

H. CAN/CSA-C22.2 No. 239, Control and Instrumentation Cables.

I. CAN/CSA-C22.2 No. 208, Fire Alarm and Signal Cable.

J. American Society for Testing and Materials (ASTM):
   1. B3, Standard Specification for Soft or Annealed Copper Wire.
   2. B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

1.2 SUBMITTALS

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 GENERAL

A. All conductors (including grounds and bonds) to be high conductivity copper.

B. Materials to be manufactured to Canadian CSA standards, approved and suitable for -40°C to +90°C operation. Wires and cables shall meet their applicable CSA standard for construction and for testing.

C. Insulation voltage rating:
1. Conductors carrying 120/208V shall be rated 600V (except as noted otherwise for control cables).
2. Conductors carrying 600V shall be rated 1000V.

D. Increase conductor sizes to account for loading, cable and conductor spacing with the associated de-rating factors, voltage drop, ambient temperature, equipment termination temperature ratings, and all other requirements in accordance with CEC requirements.

2.2 WIRES (POWER)

A. Conductors:
1. Stranded for 10 AWG and larger.
2. Minimum size, 12 AWG.

B. Copper conductors: size as indicated, with insulation of chemically cross-linked thermosetting polyethylene (XLPE) materials, RW90.

C. Wires sized 2 AWG and smaller to be factory colour coded, taping will not be accepted.

2.3 AC 90 ALUMINUM ARMOURED CABLE

A. Cable: to CAN/CSA-C22.2 No. 38 and CAN/CSA-C22.2 No. 51.

B. Insulation: chemically cross-linked thermosetting polyethylene (XLPE) type RW90, FT4 rated.

C. Armour: aluminum interlocked strip.

D. Fastenings for aluminum armoured AC-90 cables:
1. One hole aluminum straps to secure surface cables 25 mm and smaller. Two hole aluminum straps for cables larger than 25 mm.
2. Channel type supports for two or more cables. Space out cables, minimum 1 cable diameter.
3. Minimum 9 mm diameter threaded rods to support suspended channels.

E. Connectors:
1. Locknut, screw type, compression style cable connectors, sized as required.

F. Acceptable cable manufacturer: Nexans, General Cable, Southwire

2.4 TECK 90 CABLE

A. Cable: to CAN/CSA-C22.2 No. 131 and CAN/CSA – C22.2 No. 174

B. Insulation: chemically cross-linked thermosetting polyethylene (XLPE) type RW90.

C. Inner jacket: polyvinyl chloride (PVC), 600V or 1000V, 100% insulation level.

D. Armour: interlocking aluminum (steel armour is not accepted).

E. Outer jacket: FT4, “HL” rated polyvinyl chloride (PVC) material, black colour.

F. Fastenings:
1. One hole aluminum straps to secure surface cables 50 mm and smaller. Two hole aluminum straps for cables larger than 50 mm.
2. Channel type or cable tray supports for two (2) or more cables.

G. Connectors:
1. TECK cable connectors, rated to suit the environment (watertight, or explosion-proof to suit the location).

H. Acceptable manufacturer: Nexans, General Cable, Southwire.

2.5 FIRE ALARM WIRING

A. Cable: to CAN/CSA-C22.2 No. 208

B. Low energy, 300 V, FAS 105 shielded cable: minimum #16AWG, with PVC insulation.

C. Overall aluminum /polyester foil shield, with tinned copper drain wire.

D. All fire alarm cables shall be installed in a separate, dedicated conduit system.

E. Acceptable manufacturer: Belden

2.6 INSTRUMENTATION AND CONTROL WIRING

A. Armoured Control and Instrumentation Cable (ACIC) and Control and Instrumentation Cable (CIC) to: CAN/CSA-C22.2 No. 239 and CAN/CSA C21.2.

B. Conductors: minimum size, #16 AWG, stranded, annealed (7 strand minimum), tinned copper, unless otherwise noted.

C. Insulation: chemically cross-linked thermosetting polyethylene (XLPE), rated type RW90, 300V.

D. Conductor identification: Each grouping (pair, triplet, quad) by consecutive number coding, permanently marked at regular intervals

E. Construction: twisted pair, triplet and quad grouping with staggered lay.

F. Shielding shall be in conformance with:
1. Minimum 100% coverage aluminum foil or mylar tape shield with minimum 25% overlap.
2. Separate drain wire, minimum size 18 AWG, bare, stranded tinned copper. Drain wire to be in direct, continuous contact with the shield.
3. One or more twisted shielded pairs as indicated.

G. Jacket: PVC (-40° C to +90° C), low acid gas, minimum FT4 rated flame spread.

H. Armoured control and instrumentation cable (ACIC), to have aluminum, interlocked armour with overall PVC jacket.

I. Termination fittings: Type, configuration and gender required to connect cable directly to equipment without additional adapters or fittings.

J. Acceptable manufacturer: Belden.

2.7 FLEXIBLE CABLES

A. Cable: to CAN/CSA-C22.2 No. 49.

B. Type SOOW, flexible, extra hard usage conductor, watertight, rubber EPDM insulation, with CPE oil resistant outer covering and incorporated ground conductor, 90°C rated.

C. Instrumentation and control festoon cables, to have braided flexible shield, minimum size 16 AWG.

2.8 VARIABLE FREQUENCY DRIVE CABLES

A. Armoured cable for VFD application:
1. Designed to reduce high frequency noise interference with data and control signals.
2. Three bonding conductors – soft bare copper.
3. Cross-linked polyethylene (XLPE), RW90 insulation on main conductors.
4. Continuously corrugated, corrosion resistant aluminum sheath with matching connectors.
5. Overall PVC outer jacket rated FT4.
6. Acceptable manufacturer, Nexans DriveRx.

B. Fastenings:
1. One hole aluminum straps to secure surface cables 50 mm and smaller. Two hole aluminum straps for cables larger than 50 mm.
2. Channel type or cable tray supports for two (2) or more cables.

C. Connectors:
1. Nexans, Type D or Type W VFD cable connector.

2.9 MINERAL INSULATED CABLE

A. Mineral insulated cables (MI):
1. Conductors: Solid, bare, soft-annealed copper, sizes as indicated.
2. Insulation: Compressed magnesium oxide powder forming compact homogeneous mass throughout cable length.
3. 2 hour rating.
4. Sheath: annealed, seamless copper sheath, type MI, rated 600V or 1000V, 250 degrees C.

5. Acceptable manufacturer: Pyrotenax.

B. Fastenings:
1. One hole aluminum straps to secure surface cables 50 mm and smaller. Two hole aluminum straps for cables larger than 50 mm.
2. Channel type or cable tray supports for two (2) or more cables.

C. Connectors:
1. Pyrotenax MI cable termination / connector kit. Terminate cables using cable manufacturer approved kit, in accordance with the manufacturer's instructions.

2.10 INSULATED GROUND CONDUCTORS

A. Insulated copper ground conductors:
1. Size: as indicated on the drawings, but in no case smaller than CEC required sizes.
2. Type: soft drawn, stranded, flexible, high conductivity
3. Shall meet the requirements of ASTM B8.
4. Insulation: chemically cross-linked thermosetting polyethylene (XLPE) material, rated RW90
5. Flame Test Rating:
   a. CSA FT4 (if exposed)
   b. CSA FT1 (if entirely within conduit)
6. Insulation voltage rating: 600V
7. Colour: green

2.11 BARE GROUND CONDUCTORS

A. Bare copper ground conductors:
1. Size: as indicated on the drawings, but in no case smaller than CEC required sizes.
2. Type: soft drawn, stranded, flexible, high conductivity.
3. Shall meet the requirements of ASTM B8.

2.12 ACCESSORIES FOR CONDUCTORS 1000 VOLTS AND BELOW

A. TECK cable fittings
1. Teck Cable, (Non-Hazardous Locations):
   a. Approved Manufacturers: Thomas & Betts or Cooper Crouse-Hinds
   b. Thomas & Betts Star® Teck ST series, aluminum.
2. Teck Cable, (Hazardous Locations):
   a. Shall meet the requirements of CSA C22.2 No. 174, and be marked Class II or Class II Division 1.
   b. Approved Manufacturers: Thomas & Betts or Cooper Crouse-Hinds
   c. Thomas & Betts, Star® Teck STX series, explosion proof aluminum, CSA certified Class I, Divisions 1 and 2, Groups A, B, C, D, Class II, Divisions 1 and 2, Groups E, F, G.

B. Wiring Accessories
1. Splice connectors for equipment pig-tail, lighting and receptacle circuits: For wire sizes #12 and #10 AWG inclusive, twist-on compression spring type. Wing-Nut by Ideal, Marrette Type II by Marr Electric Ltd.
2. Equipment pig-tail power circuit connections: For wire sizes #8 AWG minimum, split-bolt type, sized to suit number and size of conductors. Servit Type KS by Burndy Inc.
3. Cable grips: To accommodate type and geometry of cable supported, single weave, variable mesh design, by Thomas and Betts Ltd., Crouse Hinds, Woodhead Canada Ltd.

C. Identification Devices:
1. Sleeve: Permanent, PVC, white, with legible machine-printed black markings.
a. Manufacturer and Product: Raychem; Type D-SCE or ZH-SCE.
2. Heat Bond Marker:
a. Transparent thermoplastic heat bonding film with acrylic pressure sensitive adhesive.
b. Self-laminating protective shield over text.
c. Machine printed black text.
d. Manufacturer: 3M Co.; Type SCS-HB.
3. Marker Plate: Nylon, with legible designations permanently hot stamped on plate.
4. Tie-On Cable Marker Tags:
a. Chemical resistant white tag.
b. Size: 13 mm by 51 mm.
c. Manufacturer and Product: Raychem; Type CM-SCE.
5. Grounding conductor: Permanent green heat-shrink sleeve, 51 mm minimum.

D. Cable ties:
1. Nylon, adjustable, self-locking.
2. Use nylon cable ties only in horizontal cable tray runs, to secure cables to the tray. Nylon cable ties are not to be used for cable support.
3. Manufacturer and Product: Thomas & Betts Ty-Rap.

E. Heat shrinkable insulation:
1. Thermally stabilized, crosslinked polyolefin.
2. Manufacturer and Product: Thomas & Betts Shrink-Kon.

PART 3 EXECUTION

3.1 INSTALLATION OF WIRES AND CABLES

A. Field Quality Control
1. Perform tests in accordance with 26 05 01 – Common Work Results.
2. Perform tests on all power cables 10 AWG and larger prior to energizing electrical systems.

B. Re-use of Existing Wiring
1. Except where specifically identified or approved, reuse of existing wiring is not permitted.
2. Ensure all existing wiring is tagged prior to disconnection of equipment.
3. Tag spare wires as “Spare” and indicate the location of the other end of the wire.

C. General Requirements
1. Wiring inside walls to drop vertically from above or come up from below. Horizontal cable runs within a wall are not permitted.
2. Branch circuit wiring for surge suppression receptacles and permanently wired computers and electronic equipment to have a dedicated neutral conductor. Do not share neutrals.
3. Conductor length for parallel feeders to be identical.
4. Install wires and cables in a continuous length between termination points. Splices are not permitted, except within junction boxes or where specifically approved by the Contract Administrator. Where splices are necessary and approved utilize the cable manufacturer approved and recommended kit.
5. For outdoor or exposed installations, make all entries of cables or wires to equipment or panel from the bottom or side to minimize water entry points. Make no entries of cables or wires from the top unless specifically approved by the Contract Administrator.
6. For exterior wall penetrations:
    a. Utilize Roxtec weatherproof sealing system.
    b. Install to manufacturer’s recommendations.
    c. Install flush with exterior of the wall.
    d. Prior to installation of seals, contractor to submit proof of training to the Contract Administrator. Do not install the cable seal system without equipment manufacturer training, as work will have to be re-done. Contact Roxtec for training.
    e. Prior to covering up wall penetration work, arrange for a site inspection of the work with the Contract Administrator. Proof of proper installation is required.
7. Do not pull conductors into conduit or cable tray until rough building construction operations have been completed.
8. Steel armor, steel conduit, and steel cable supports are not permitted. Utilize aluminum materials in order to prevent corrosion.
9. Heat shrink insulation shall be used where additional insulation or dressing of connected cables is required. Electrical tape shall not be used for additional insulation or dressing of connected cables. The use of heat shrink tubing and electric heat gun to heat the shrink tubing is the required method.
10. Do not embed cables or conduits in masonry or concrete without written approval from the Contract Administrator. Wiring through conduit sleeves for short, direct wall or floor penetration is accepted.
11. Design wire and cable anchorage and support system for vertical and lateral loading in accordance with the Manitoba Building Code (MBC).
12. Provide non-ferrous GPO (glastic) or aluminum plates for single conductor cable entry into an enclosure. Aluminum entry plate shall be used where conductor

armour is required to be bonded to the enclosure. GPO (glastic) materials shall be used where cable armour is not bonded to the enclosure.

D. Installation of AC-90 Cables:
1. To be used in dry, non-hazardous commercial office type of occupancy.
2. Do not use AC-90 in industrial, wet well, pumping stations, or similar type of facilities.
3. Where AC-90 is permitted to be used, its use is limited as indicated:
   a. AC-90 is limited to 15A receptacle or lighting circuits only.
   b. All AC-90 cable runs must be concealed within a wall, or within a drop ceiling. Surface mounted AC-90 runs are prohibited.
   c. AC-90 drops to recessed light fixtures are permitted but shall not be run horizontally more than 6.5’ (2m) from conduit system boxes in ceiling space.
   d. AC-90 drops from conduit system in the ceiling space to feed outlets in wall stud partitions shall not run more than 6.5' (2 m) horizontally from the ceiling outlet box to the point where the AC-90 drops vertically into the partition.
   e. Where the total length of AC-90 would be greater than 2 m horizontally in the ceiling, provide conduit to a junction box closer to the drop location.
   f. Cable runs to receptacles in walls shall be made from an accessible junction box. Do not use receptacles as feed through devices.
   g. Do not run AC-90 horizontally within enclosed walls.

E. Installation of Teck 90 Armored Cables:
1. Shall be installed in industrial, hazardous, underground or wet areas as applicable.
2. Where surface mounted, cables shall be securely supported using aluminum cable clamps and cantruss supports. Space supports a maximum of 1 m apart.
3. Where multiple cables are run into an area, install cables on cable tray or on cantruss hangers.
   a. Where applicable, de-rate and upsize cables in accordance with the CEC.
4. Minimum bend radius is 12 times, or larger as required by the cable manufacturer.

F. Installation of single RW90 Conductors:
1. Install in conduit as per Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.
2. Use pulling lubricant when pulling conductors in conduit to reduce the strain on the wires. Lubricants must be polymer based, and must not adversely affect or degrade cable insulation.
3. Do not combine conductors in a common duct or conduit without regard for de-rating. De-rating is as per the CEC.

G. Installation of Control Cables:
1. Install control cables in conduit.

2. Ground shields at one end only. Where possible, ground shields at the end where power is supplied to the cable. Utilize shield grounding bar in panels, where present.
3. Shield drain wires, at the ungrounded end, are to be taped back to the cable. Do not cut the shield drain wire off.
4. CIC cable may not be installed in cable tray. Protection in conduit is required over the entire length.
5. ACIC cable may be installed in cable tray, provided that:
    a. The cable tray does not contain power cables, unless specifically authorized by the Contract Administrator in writing.
    b. The ACIC cable voltage rating is equal to or greater than the highest voltage contained in the cable tray.

H. Installation of Fire Alarm Cabling:
1. Install in conduit as per Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.
2. Install conductors to be entirely independent of all other wiring. Do not enter raceway, boxes or enclosures occupied by other wiring except where necessary to connect to power supply, communication circuit, or ancillary devices.
3. Shields to be grounded at one end only (source end).
4. For data communication link A (DCLA) fire alarm circuits, install primary wiring circuit and alternate wiring circuit in separate conduit having a minimum separation of
    a. 300mm when installed vertically
    b. 1200mm when installed horizontally
5. For data communication link A (DCLA) fire alarm circuits, the primary wiring circuit and alternate wiring circuit may share the same conduit:
    a. For a distance of less than 3000mm where the primary and return conductors enter or exit field devices, control unit or transponder enclosures.
    b. For single conduit drops to individual field devices
    c. For single conduit drops to multiple field devices installed in a single room not exceeding 100m².

I. Installation of Flexible Cables:
1. Flexible, non-armored cables to be installed where plug / cord assemblies are specified and required.
2. Flexible festoon cables to be installed where specifically required for mobile equipment. Terminate both ends of festoon cables, providing cable strain relief.

J. Installation of Mineral Insulated Cables:
1. Install cable securely supported by straps and hangers.
2. Support 2 hour fire rated cable a minimum of every 1 meter intervals (or less).
3. Make cable terminations by using cable manufacturer approved termination kits. Termination must be performed by personnel specifically trained by the equipment manufacturer.

K. VFD cable to be installed as follows:
1. VFD cable to be installed between a variable frequency drive (VFD) and the load which it serves.
2. Secure using aluminum cable clamps. Route cabling surface mounted, on cantruss supports, and on cable tray as required.
3. Space VFD cable as per the following minimum distances:
   a. From 120/208V wiring: 300 mm
   b. From 24 VDC instrumentation and control wiring: 300 mm

3.2 COLOUR CODING AND TAGGING

A. Colour code all power distribution and control conductors at both ends throughout facility.

B. Same colour for same phase throughout, by insulation colour or permanently applied colour banding at all distribution centres, panels and outlet boxes.

C. Colour tape shall be vinyl, 19mm wide, red, blue, white.

D. Colour coding to be in accordance with CEC and as follows:

Equipment Grounding Conductor	- green
Neutral conductor	- white
1 Phase, 3 wire	- red, black and white
3 Phase	- red (A), black (B), blue (C)
DC (positive)	- blue with white stripes
DC (negative)	- white with green stripes

E. All control conductors shall have wire numbers at both ends of each wire using Brady heat shrink sleeves with typewritten wire numbers. Wire markers shall have a white background and black lettering. Hand written tags on adhesive tape is not acceptable. The contractor shall adhere to the tagging scheme shown on the control drawings.

F. Use wire markers in terminating all wiring, including but not limited to power, control, signal, communication and lighting wiring.

G. Identify all multi-conductor cables at all termination points with wire markers. In addition to identifying the cable, indentify each of the individual conductors at all termination points, unless it is a color coded power conductor. All cable markers must be readily visible when the device cover is open.

END OF SECTION

SECTION 26 05 22

CONNECTORS AND TERMINATIONS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA C22.1, Canadian Electrical Code, Part 1, Safety Standard for Electrical Installations.

B. CSA C22.2 No.41, Grounding and Bonding Equipment (Tri-National Standard, with NMX-J-590ANCE and UL 467).

C. CSA C22.2 No.65, Wire connectors (Tri-National Standard, with UL 486A-486B NMX-J-543-ANCE).

PART 2 PRODUCTS

2.1 CONNECTORS AND TERMINATIONS

A. Splices:
1. Utilize cable manufacturer approved splice kits.
2. Acceptable manufacturer: 3M or approved equal in accordance with B7.

B. Lugs and connectors:
1. To CSA C22.2 No.65.
2. Provide lugs / connectors for power and ground connections where required including:
   a. Where internal lugs are not included with a piece of equipment.
   b. Ground connections.
3. Lugs for power conductors shall be copper, long barrel compression type.
4. Rated 600 / 1000 volts of same material as conductor metal.
5. Shall be suitable for 75°C cable termination.
6. Provide 1 hole compression lugs for conductors 1/0 AWG and smaller, 2 hole lugs for 2/0 AWG and larger conductors.
7. Lugs for ground conductors 14 AWG and smaller, shall be ring type.
8. Lugs for control wiring shall be spade or ring type.
9. Hardware for bolting to cable lugs and ground lugs to ground bus shall be chrome plated Grade 5 bolts, nuts, split and flat washers.
10. Lugs shall be compatible with the conductor size, the cable voltage rating, and the equipment connection.
11. Acceptable manufacturer: Burndy, Thomas & Betts.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install terminations, lugs, connectors, and splices in accordance with manufacturer's instructions.

B. Wiring and connections should be made within junction boxes, termination cabinets, panels and devices. Use splice kits, only where absolutely necessary, and with specific approval from the Contract Administrator.

C. Splices shall only be used with specific written approval from the Contact Administrator. Otherwise, connection shall be made using suitable lugs and connectors in approved junction boxes or pull boxes.

END OF SECTION

SECTION 26 05 28

GROUNDING AND BONDING

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 05 01, Common Work Results - Electrical.

1.2 CODES AND STANDARDS

A. American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)
   1. ANSI/IEEE 837, Qualifying Permanent Connections Used in Substation Grounding.

B. Canadian Standards Association, (CSA International)

1.3 SUBMITTALS

A. Submit shop drawings indicating all components and equipment to be used:
   1. Manufacturer's product data sheets:
      a. Part number.
      b. Materials.
      c. Installation instructions.
      d. Certifications.

1.4 O&M MANUAL

A. Include all shop drawings and product submittals.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. Exterior exposed grounding conductors:
   1. TWU green insulated, soft drawn, stranded copper wires shall be used for exposed, above grade grounding conductors.

B. Exterior buried or imbedded grounding conductors :
   1. Bare, soft drawn, stranded copper shall be used below grade.

C. Insulating Paint
   1. Insulating paint shall be gray Gyptal.

D. Interior equipment grounding and bonding conductors:

1. Run in conduit: RW90, green insulated, soft drawn, stranded copper shall be used inside conduits.

2. Run in cable tray or channel: soft drawn, stranded copper shall be used for cable tray bonds.

E. Rod electrodes: copper clad steel, 19 mm diameter, minimum length of 3 m. Provide longer ground rods as indicated on the drawings. Where multiple rods are connected, utilize a threadless compression coupling.
1. Acceptable manufacturers:
    a. Burndy 38-7408-02
    b. Slacan 9340
    c. Joslyn J5349
    d. Hydel 3410G
    e. T & B GR7510

F. Non-corroding accessories necessary for grounding system, type, size, material as indicated, including but not necessarily limited to:
1. Grounding and bonding bushings.
2. Protective type clamps.
3. Bolted type conductor connectors.
4. Thermit welded type conductor connectors.
5. Bonding jumpers, straps.
6. Pressure wire connectors.
7. Acceptable manufacturers:
    a. Erico
    b. Burndy
    c. or approved equal in accordance with B7

G. Ground Pipe Clamp
1. Requirements:
    a. Tinned copper or high copper alloy bronze
    b. Separate bolts for mounting on pipe and connecting wire
    c. 2/0 AWG conductor connection
    d. CSA or cUL approved.

H. Ground Wells
1. Requirements:
    a. Diameter: minimum 254mm (10”)
    b. Depth: minimum 254mm (10”)
    c. Material: high density polyethylene
    d. Cover: bolted in place
2. Acceptable manufacturer and model:
    a. Erico T416B
    b. or approved equal in accordance with B7

I. Compression Connection – “C” Tap
   1. Requirements:
      a. Material: solid copper
      b. Type: “C” Tap
   2. Acceptable manufacturer and model:
      a. Burndy YGHC
      b. or approved equal in accordance with B7

J. Compression Connection – Butt Splice
   1. Requirements:
      a. Material: solid copper
      b. Type: heavy duty splice
   2. Acceptable manufacturer and model:
      a. Burndy YGHS
      b. or approved equal in accordance with B7

K. Exothermic Connection
   1. Requirements:
      a. Material: copper
   2. Acceptable manufacturer and model:
      a. Burndy ThermOweld or BurndyWeld product lines
      b. or approved equal in accordance with B7

PART 3 EXECUTION

3.1 GENERAL

A. Provide a complete permanent, continuous grounding system, including electrodes, conductors, connectors and accessories.

B. Provide a complete bonding system, connected to the facility ground. Structural steel, cladding, and all metal equipment are to be bonded to ground.

C. Install connectors in accordance with manufacturer's instructions.

D. Protect exposed grounding conductors from mechanical injury.

E. Make buried connections and connections to electrodes, using copper welding by thermit process to ANSI/IEEE 837.

F. Obtain approval from the Contract Administrator before any conductor connections are buried.

G. Soldered joints not permitted.

3.2 INSTALLATION

A. Conduit runs and cable trays shall be mechanically joined together and bonded to the building steel and main ground grid to ensure electrical continuity.

B. The ground conductor in Teck 90 cable shall be bonded to ground at both ends (unless noted otherwise for single conductor runs) using compression type connectors or manufacturer supplied grounding screws.

C. Supply and install all Teck 90 connectors complete with grounding rings to ensure adequate bonding of Teck cable armour.

D. Where cables enter a termination or junction box, all grounding conductors shall be bonded and connected to a common grounding point and to metallic box enclosures.

E. All metallic devices mounted in non-metallic enclosures shall be bonded and grounded. Manufacturer's bonding rings shall be used where available.

F. For both metallic, and non-metalic conduit system, an insulated bonding conductor shall be run inside the conduit and bonded at termination points. Using the conduit as a bonding means is not acceptable. Bonding conductors are not specifically shown on the drawings. Provide conductors sized in accordance with Table 16 of the CEC.

G. All above grade bonding or grounding connections shall be cleaned to bare metal, treated with cleaning paste, connected to the structure or equipment, then sprayed with Gyptal.

H. All above grade ground conductors shall be continuously run and without splices where possible.

I. Ground conductors installed along beams or columns shall be run on the inside of the flange adjacent to the web, where practical. The conductor shall be supported at maximum intervals of 3 feet with one-hole conduit clamps.

J. Exposed grounding conductors shall be protected where subject to mechanical injury.

K. Exterior run grounding conductors shall be run in rigid PVC conduit where required for support or mechanical protection.

L. Use mechanical compression connectors for grounding/bonding connections to equipment provided with lugs.

M. All connections to building steel and to ground rods shall be by exothermic (cadweld) connections.

N. Compression type connectors and exothermic connections shall be installed in accordance with the Manufacturer's instructions.

O. Install conductors with a minimum of bends and without kinking. Where bends are unavoidable, make bends as smoothly as possible.

P. Minimum bending radius for grounding conductors shall be 2 inches.

Q. Install bonding conductor in cable trays installed in this Contract.

R. Grounding and bonding connection to panels shall be made on the interior of the panel.

3.3 INSPECTION

A. Do not allow or cause any work performed or installed to be covered up or enclosed by work of this Section prior to the required inspections, tests and approvals.

B. Ensure grounding lugs are torqued to the required values. Required values shall be established by the equipment manufacturer or by CSA standards.

3.4 ELECTRODES

A. Install rod electrodes and make grounding connections as shown on the drawings.

B. Connect multiple rod electrodes together as shown on the drawings.

C. Use size 4/0 AWG copper conductors for connections to ground electrodes unless indicated otherwise.

D. Install a ground well at each ground rod location.

E. Locate all existing underground services in the area prior to installation of ground electrodes. Ensure no existing underground pipes or cables are damaged during the installation of the electrodes.

F. Determine location of existing electrodes and modify drawings to show the exact location.

G. Connect new electrodes to existing electrodes at locations shown on the drawings.

3.5 INSULATED CONDUCTOR JOINTS

A. For joints made on insulated ground conductors, use exothermic or compression connectors. Wrap all exposed bare copper with self annealing splice tape and cover with green electrical tape.

3.6 PIPE GROUNDING

A. For pipe grounding, connect ground conductor to pipes using a pipe clamp or exothermic weld directly to the pipe. Remove enough paint from the pipe to provide a sufficient area of bare metal for the grounding connection to the pipe. After ground connection is installed, replace insulation and paint the affected pipe sections and any bare copper to match the existing pipe colour.

END OF SECTION

SECTION 26 05 34

CONDUITS, CONDUIT FASTENERS, AND CONDUIT FITTINGS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified within this section apply to all sections in Division 26, Electrical. This section supplements requirements of other Divisions.

1.2 CODES AND STANDARDS

A. CAN/CSA C22.2 No. 18, Outlet Boxes, Conduit Boxes, and Fittings and Associated Hardware.

B. CSA C22.2 No. 45, Rigid Metal Conduit.

C. CSA C22.2 No. 56, Flexible Metal Conduit and Liquid-Tight Flexible Metal Conduit.

D. CSA C22.2 No. 83, Electrical Metalic Tubing.

E. CSA C22.2 No. 211.2, Rigid PVC (Unplasticized) Conduit.

F. CSA C22.2 No. 211.1, Rigid Types EB1 and DB2 / ES2 PVC Conduit

G. CAN/CSA C22.2 No. 227.3, Flexible, Non-metallic Tubing.

1.3 GENERAL CONDUIT REQUIREMENTS

A. The drawings do not show every specific conduit run. Supply and install conduit, and support systems as required for a complete installation.

B. The materials for each conduit must meet the requirements of the area. Some areas are wet, highly corrosive, and care must be taken in making the proper conduit selection.

C. Design equipment anchorage and support system for vertical and lateral loading in accordance with the MBC.

1.4 SUBMITTALS

A. Submit written certification from a professional engineer licensed in the Province of Manitoba stating that support systems, anchorage, and equipment are structurally sound, and have been designed according to requirements of the MBC.

B. Submit Shop Drawings indicating the component and equipment to be used:
   1. Electric metallic tubing.
   2. Rigid aluminum conduit.
   3. Rigid PVC conduit.
   4. Flexible metal, liquid tight conduit.
   5. Flexible non-metallic, liquid tight conduit
   6. Conduit fittings, conduit couplings.
   7. Hazardous area sealing fittings, coupling and sealing compound
   8. Conduit clamps and support systems.
   9. Submit details of the ULC approved fire stop assembly for approval prior to installation.

PART 2 PRODUCTS

2.1 CONDUITS

A. Rigid aluminum conduit
   1. Meet requirements of CSA C22.2 No. 45.
   2. Materials: type 6063, copper-free aluminum alloy.

B. Rigid PVC conduit
   1. Meet requirements of C22.2 No. 211.2.
   2. Materials: Polyvinyl Chloride (PVC).

C. Rigid DB2 PVC conduit
   1. Meet requirements of C22.2 No. 211.1.
   2. Materials: Polyvinyl Chloride (PVC).

D. HDPE conduit
   1. Meet the requirements of C22.2 No. 211.2
   2. Materials: High Density Polyethylene

E. EMT conduit
   1. Meet requirements of C22.2 No. 83.
   2. Materials: steel, electroplated outside finish, aluminum painted inside walls.

F. Flexible liquid tight, metal conduit
   1. Meet requirements of CSA C22.2 No. 56.
   2. Materials: heavy duty, liquid tight, PVC with stainless steel core.

G. Flexible non-metalic liquid tight conduit
   1. Meet requirements of CSA C22.2 No. 227.3.
   2. Materials: heavy duty, liquid tight, PVC.

H. Conduits shall be sized in accordance with CEC requirements for wire counts installed. Conductors shall be de-rated according to code requirements. Upsize conductors as required to meet CEC and voltage drop requirements. Minimum conduit size: 21 mm, unless specifically indicated otherwise on the drawings or specifically approved by the Contract Administrator.

I. Conduits shall be EMT, rigid aluminum, liquid tight, and rigid PVC, as required to meet the requirements of the installation. Do not use steel conduit for areas where H2S gas or other corrosive gasses or liquids are present

2.2 CONDUIT FASTENINGS

A. One hole straps to secure surface conduits 50 mm and smaller. Two hole straps for conduits larger than 50 mm.

B. Beam clamps to secure conduits to exposed steel work.

C. Channel type supports for two or more conduits.

D. Strap material to match conduit material.

E. Threaded rods, minimum 10 mm diameter, to support suspended channels.

2.3 CONDUIT SPACERS

A. PVC coated malleable metal spacers, CSA approved for the purpose.

B. Aluminum channel may be utilized where conduits are grouped, however a non-metallic spacer must be provided between the aluminum channel and concrete.

2.4 CONDUIT FITTINGS

A. General:
1. Utilize factory made elbows for 27mm and larger conduits.
2. All components to be CSA certified for the intended area of use.
3. Meet all requirements of the CEC with respect to hazardous area sealing fittings.
4. Utilize insulated grounding bushings at all enclosure entries for metallic conduit.

B. Electric metallic tubing (EMT):
1. Meet requirements of CSA C22.2 No. 45.
2. Type: steel body and locknuts with steel or malleable iron compression nuts. Set screw and drive-on fittings not permitted.
3. Electro zinc-plated inside and out.
4. Raintight.
5. Coupling manufacturers and products:
   a. Appleton type 95T.
   b. Crouse-Hinds.
   c. Thomas & Betts.

6. Connector manufacturers and products:
    a. Appleton type 86T.
    b. Crouse-Hinds.
    c. Thomas & Betts.

C. Rigid aluminum conduit:
1. Meet requirements of CSA C22.2 No. 45.
2. Type: threaded, copper-free aluminum. Set screw fittings not permitted.
3. Insulated bushing:
    a. Material: Cast aluminum, with integral insulated throat, rated for 150 degrees C.
    b. Manufacturer and Product: O-Z/Gedney Type AB.
4. Grounding bushing:
    a. Material: Cast aluminum with integral insulated throat, rated for 150 degrees, with solderless lugs.
    b. Manufacturer and Product: O-Z/Gedney Type ABLG.
5. Conduit hub:
    a. Material: cast aluminum, with insulated throat.
    b. ULC listed for use in wet locations.
    c. Manufacturers and Products:
        1) O-Z/Gedney Type CHA.
        2) Thomas & Betts Series 370AL.
        3) Meyers Series SA.
6. Refer to 26 05 32 for outlet boxes, conduit boxes and fittings.
7. Expansion Fitting Manufacturers and Products:
    a. Deflection/Expansion Movement:
        1) Appleton type DF.
        2) Crouse-Hinds type XD.
    b. Expansion Movement Only:
        1) Appleton type XJ.
        2) Crouse-Hinds type XJ.

D. Flexible metal, liquid-tight conduit:
1. Meet requirements of CSA C22.2 No. 56.
2. Metal insulated throat connectors with integral nylon or plastic bushing rated for 105 degrees C.
3. Insulated throat and sealing O-rings.
4. Manufacturers and Products:
    a. Thomas & Betts; Series 5331.
    b. O-Z/Gedney; Series 4Q.

E. Flexible, nonmetallic, liquid-tight conduit:
1. Type: High strength plastic body, complete with lock nut, O-ring, threaded ferrule, sealing ring, and compression nut.
2. Body/compression nut (gland) design to assure high mechanical pullout strength and watertight seal.
3. Manufacturers and Products:

a. O-Z/Gedney; Type 4Q-P.
b. Thomas & Betts; Series 6300 or Carlon; Type LT.

F. PVC Conduit and Tubing:
1. Meet requirements of NEMA TC-3.
2. Type: PVC, slip-on.

G. HDPE Conduit and Tubing:
1. Meet requirements of CSA C22.2 No. 211.2 and UL 651 for electrical cable raceway.
2. Type: Manufacturer approved

2.5 EXPANSION FITTINGS FOR RIGID CONDUIT

A. All conduits entering outlet boxes and devices that are located in walls subject to movement shall be terminated by means of liquid-tight flexible conduit, approximately 450 mm in length between the conduit and the outlet box or device which is being supplied. All conduits, bus duct, wireways, etc., passing through or across expansion joints of the building shall be installed with the use of approved expansion fittings.

B. There are structural expansion joints in the facility. Provide expansion couplings and fittings for all conduit crossing the joints. Do not locate rigid devices (for example panels) across or on top of the expansion joints. Add expansion fittings as required to accommodate expansion joints due to temperature variations.

2.6 FISH CORD

A. Polypropylene.

2.7 CONDUIT BONDING

A. All conduits shall have a bare or insulated copper bonding conductor run within. The bonding conductor shall be sized as per the CEC, table 16. The conduit itself cannot be used as the only means of bonding.

PART 3 EXECUTION

3.1 ROUTING

A. Locate conduits containing communication and low voltage conductors away from conduits containing power wiring.

B. Run parallel or perpendicular to building lines.

C. Route conduits on suspended channels where possible.

D. Avoid routes that would interfere with any potential maintenance activities.

E. Where not specifically shown in detail on the drawings, review proposed conduit routing with Contract Administrator prior to installation. Comply with all routing changes requested by the Contract Administrator.

F. Install conduits to conserve headroom in exposed locations and cause minimum interference in spaces through which they pass.

3.2 INSTALLATION

A. General

1. All conduits shall be cut square and reamed smooth.
2. Metal, threaded conduit to be cut with a cutting tools that provide a 19mm taper per foot.
3. Remove burrs, ream and clean metal conduit before installation of conductors, wires, or cables.
4. Threaded conduit connections shall have a minimum of 5 full threads of engagement or greater.
5. For metallic conduits, install within a PVC sleeve for holes / penetrations through concrete walls and slabs.
6. Provide drain seal in vertical raceways where condensate may collect above sealing fitting.
7. Follow structural surface contours when installing exposed raceways. Avoid obstruction of passageways.
8. Unless otherwise indicated, install conduits surface-mounted on walls and ceilings. Conceal or embed conduits only where indicated.
9. Do not pass conduits through structural members except as specified on the drawings, or as permitted by the Contract Administrator.
10. Install concealed, embedded, and buried raceways so that they emerge at right angles to surface and have no curved portion exposed.
11. Remove and replace blocked conduit sections. Do not use liquids to clean out conduits.
12. Install pullcords in empty conduit systems.
13. Dry conduits out before installing wire.
14. All conduits exposed in finished areas are to be free of unnecessary labels and trade marks.
15. Seal conduits with duct seal where conduits are run between heated and unheated areas.
16. Where conduits pass through walls, group and install through openings. After all required conduits are installed; close wall openings with material compatible with the wall construction. Perform fire stopping & sealing to ensure integrity of wall.
17. Do not locate conduits less than 75 mm parallel to steam or hot water lines with minimum of 25 mm space at crossovers.
18. Provide a minimum of 1 conduit diameter of space between adjacent conduit runs.
19. PVC conduit sections and fittings shall be connected using watertight PVC conduit cement.

B. Fire Stop Assemblies
   1. Seal and firestop penetration around conduit with ULC approved fire stop assembly for the installation conditions.

3.3 CONDUIT APPLICATION

A. Interior, exposed:
   1. Rigid threaded aluminum.
   2. Rigid PVC, FT4.
   3. EMT (for office type of areas only).

B. Interior, concealed (office type of areas):
   1. EMT.

C. Connections to vibrating equipment:
   1. Liquid tight, flexible conduit.

D. Aboveground embedded in concrete walls, ceilings, or floors:
   1. Rigid PVC, FT4.

E. Direct earth burial:
   1. Rigid PVC.
   2. HDPE horizontal directional drilling conduit – Used where specifically approved by the Contract Administrator.

F. Concrete Encasement
   1. Rigid PVC, type DB2

G. Under slabs on grade:
   1. Rigid PVC.

H. Wet or Corrosive areas:
   1. Rigid threaded aluminum.
   2. Rigid PVC, FT4 rated conduit where acceptable by code and where approved on the drawings.

I. Hazardous locations:
   1. Rigid threaded aluminum.
   2. All fittings, couplings and devices shall be rated for Hazardous Class I, Div. 1 & 2 (or Zone 0, 1 and 2), Groups C, D Locations.

3.4 SPACING AND SUPPORTS

A. Wall Spacing
   1. Group conduits wherever possible on suspended or surface mounted channels.

2. Install spacers as required to provide a space between the conduits and the supporting surface, with a minimum space as follows:
   a. Above grade spaces not classified as CEC Category 1 or 2:
      1) Drywall / wood surfaces: no space required
      2) Masonry / concrete surfaces: 6 mm
      3) Below grade spaces: 12 mm
   b. Wet locations: 12 mm

B. Supports for Metalic Conduit
1. Maximum spacing between supports for metallic conduit:

a.	16mm conduit:	1.0 m
b.	21mm conduit:	1.5 m
c.	27mm conduit	1.5 m
d.	35mm conduit	2.0 m
e.	41mm conduit and larger	2.5 m

C. Supports for PVC Conduit
1. Maximum spacing between supports for rigid PVC conduit:

a.	21mm conduit	0.75 m
b.	27mm conduit	0.75 m
c.	35mm conduit	0.75 m
d.	41mm conduit	1.2 m
e.	53mm conduit	1.5 m
f.	63mm conduit	1.5 m
g.	78mm conduit	1.5 m
h.	91mm conduit and larger	2.0 m

3.5 CONNECTIONS

A. For motors, wall or ceiling mounted fans and unit heaters, dry type transformers, electrically operated valves, instrumentation, and other equipment where flexible connection is required to minimize vibration:
1. Wet or corrosive areas: flexible, non-metallic liquid tight conduit.
2. Dry and non-corrosive areas: flexible, metallic liquid tight conduit.
3. Hazardous areas: flexible liquid tight conduit, with couplings and fittings suitable for Class I, Division 1 and 2 areas.
4. Length: 450 mm minimum, 1500 mm maximum, sufficient to allow movement and adjustment of equipment.

B. Luminaires in dry areas: flexible, metallic liquid-tight conduit or approved cabling.

C. Transition from underground or concrete embedded to exposed: rigid PVC to rigid aluminum conduit.

D. Exterior light pole foundations: rigid PVC conduit.

3.6 BENDS

A. Conduit runs shall not exceed four 90 °bends (for a total of 360°) between pullboxes.

B. Bend conduit cold. Replace conduit if kinked or flattened more than 1/10th of its original diameter. Bends are to be symmetrical.

C. Avoid field-made bends and offsets, but where necessary, make with an acceptable bending machine. Do not heat metal raceways to facilitate bending.

D. Make bends in parallel or banked runs from same center or centerline with same radius so that bends are parallel.

E. Factory elbows may be installed in parallel or banked raceways if there is change in plane of run, and raceways are same size.

F. Use factory made elbows for conduits over 27 mm in diameter.

G. Install concealed raceways with a minimum of bends in the shortest practical distance.

H. PVC Conduit:
1. Bends 30°and larger: provide factory made elbows.
2. Use manufacturer’s recommended method for forming bends.

I. Do not make bends that exceed allowable conductor or cable bending radius; or that significantly restrict cable pulls.

3.7 PENETRATIONS

A. Make at right angles, unless otherwise shown.

B. Notching or penetration of structural members, including footings and beams, is not permitted unless specifically approved by the Contract Administrator.

C. Firestop openings around penetrations to maintain fire-resistance rating.

D. Apply single layer of wraparound duct band to all metallic conduit protruding through concrete floor slabs to a point 50 mm above and 50 mm below concrete surface.

E. Concrete walls, floors, or ceilings (above ground): provide non-shrink grout dry-pack, or use watertight seal device.

F. Entering Structures:
1. General: seal raceway at the first box or outlet with oakum or expandable plastic compound to prevent the entrance of gases or liquids from one area to another.
2. Exterior wall penetration:
   a. Utilize Roxtec weatherproof sealing system.
   b. Install to manufacturer’s recommendations.

c. Install flush with exterior of the wall.
d. Prior to installation of seals, contractor to submit proof of training to the Contract Administrator. Do not install the cable seal system without equipment manufacturer training, as work will have to be re-done. Contact Roxtec for training.
e. Prior to covering up wall penetration work, arrange for a site inspection of the work with the Contract Administrator. Proof of proper installation is required.

3. Concrete roof or membrane waterproofed floor:
   a. Provide a watertight seal.
   b. Without concrete encasement: Install watertight entrance seal device on each side.
   c. With concrete encasement: install watertight entrance seal device on the accessible side.
   d. Securely anchor watertight entrance seal device into construction with one or more integral flanges.
   e. Secure membrane waterproofing to watertight entrance seal device in a permanent, watertight manner.
4. Heating, ventilating, and air conditioning equipment:
   a. Penetrate equipment in area established by manufacturer.
   b. Connect equipment using liquid tight flexible conduit.
5. Corrosive sensitive Areas:
   a. Seal all conduit passing through corrosive room walls.
   b. Seal conduit entering equipment panel boards and field panels containing electrical equipment.
6. Existing or precast wall (underground): core drill wall and install a watertight entrance seal device.
7. Nonwaterproofed floor (underground, without concrete encasement):
   a. Provide watertight entrance seal device.
   b. Fill space between raceway and sleeve with expandable watertight compound or oakum and lead joint, on each side.
8. For exterior installations, conduit entry shall be from the bottom, unless approved otherwise by the Contract Administrator.

3.8 UNDERGROUND CONDUIT INSTALLATIONS

A. Minimum burial depths shall be as detailed on the drawings, but in no case less than the requirements indicated in the CEC.

B. Conduits shall have a red plastic warning tape placed above, buried at a depth of 305mm below grade. The plastic tape is to completely cover all conduits, and overlap the width of all conduits by at least 150mm on either side. Provide mechanical protection, planking in accordance with the U.G trenching specifications.

C. All underground direct buried conduits shall be rigid PVC.

D. Provide rigid PVC conduit, type DB2 for encasement in concrete for duct banks. HDPE conduit can be used only where specifically approved by the Contract Administrator.

E. Maintain a minimum of 1200mm horizontal clearance distance from underground structures such as buildings and equipment foundations.

F. Maintain a minimum of 600mm horizontal clearance distance from underground equipment such as piping and other underground conduit runs.

G. All clearances in strict accordance with the MBC, CEC, and all other bylaws.

H. Provide Universal GPS coordinates of all underground conduit runs at every bend, and at every 6000mm intervals. Include coordinates on the As-Built drawings.

I. Provide man-holes and hand-holes as required to accommodate the conductor pull.

J. Slope conduits away from building and enclosures entry points, to provide drainage.

3.9 INSTALLATIONS IN CATEGORY 1 LOCATIONS

A. Arrange to provide drainage at frequent intervals to suitable locations.

B. Equip with approved fittings to permit the moisture to drain out of the system.

C. Install the conduit with a minimum of 12 mm space from the supporting surface.

D. Every joint, coupling and fitting to be water-tight.

E. Where conduit leaves a warm room and enters a cooler atmosphere, seal the conduit and arrange the conduit in a manner to avoid condensation accumulation at the seal.

3.10 INSTALLATIONS IN CATEGORY 2 LOCATIONS

A. Comply with all requirements of Category 1 locations.

3.11 INSTALLATIONS IN CATEGORY 2 WET LOCATIONS

A. Comply with all requirements of Category 1 locations.

3.12 INSTALLATIONS IN HAZARDOUS LOCATIONS

A. Install conduit system, complete with explosion proof conduit sealing fittings:
   1. Provide sealing fittings to suit the area classification, and to meet the CEC requirements.
   2. Install sealing compound following manufacturer’s instructions.

END OF SECTION

SECTION 26 08 05

ACCEPTANCE TESTING

PART 1 GENERAL

1.1 REFERENCES

A. NETA Acceptance Testing Specifications, 2009 (ATS-2009)

B. CSA C282, Emergency Electrical Power Supply for Buildings.

C. City of Winnipeg inspection / test forms.

1.2 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures.

B. Submit:
1. Test equipment to be utilized with last calibration date.
2. Qualifications of lead electrical inspections technician.
3. Test forms that will be utilized.

1.3 QUALIFICATION

A. Provide competent lead electrical inspection technician thoroughly familiar with all aspects of electrical testing. It is expected that the technician will have a CET, Journeyman Electrician's certificate, or other equivalent designation. The designated technician is to be on-site and lead all electrical testing.
1. The Contract Administrator reserves right to approve the lead electrical inspection technician, and request an alternate technician if deemed to be unqualified.
2. The Contract Administrator reserves the right to request documentation and proof from the Contractor that their lead electrical inspections technician is qualified to perform the work. The documentation and proof can include the following:
   a. A request for references from past previous projects.
   b. A request for a list of past previous projects.
   c. A request for an interview and seminar to be given by the lead electrical inspection technician demonstrating in-depth knowledge of the subject matter.
3. In the circumstance where the Contract Administrator rejects the lead inspection technician, the Contractor will be responsible for providing a suitably qualified individual to perform the work, at no additional cost to the City of Winnipeg. Qualifications will be specifically analyzed by the Contract Administrator, based on the following:
   a. The qualified lead electrical inspection technician will have performed similar work at other similar installations.

b. The qualified lead electrical inspection technician will be trained in using the instruments and measuring devices; and adjusting the settings or programming the devices.
c. The qualified lead electrical inspection technician will have experience in analyzing the results obtain from the instruments or measuring devices.
d. The qualified lead electrical inspection technician will have sufficient experience to immediately recognize erroneous measurements based on past work experience and expected results.
e. The qualified lead electrical inspection technician will be familiar with the settings and methodologies required to perform the work.

4. In the circumstance where the Contractor cannot provide a competent lead electrical inspection technician, the Contract Administrator reserves the right to hire a qualified individual separate from this Contract and to back charge the Contractor for services and costs performed in order to complete the work.

1.4 TESTING EQUIPMENT

A. All test equipment shall be in good mechanical and electrical condition.

B. Accuracy of metering in test equipment shall be appropriate for the test being performed.

C. Wave shape and frequency of test equipment output waveforms shall be appropriate for the test and the tested equipment.

D. The test equipment shall be calibrated as specified below:
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 testing organization will have calibration certifications for test equipment, and a copy will be made available to the Contract Administrator.
3. The firm providing calibration service shall maintain up-to-date instrument calibration instructions and procedures for each test instrument calibrated.
4. Instruments shall be calibrated in accordance with the following frequency schedule:
a. Field instruments: Analog, 6 months maximum. Digital, 12 months maximum.
b. Laboratory instruments: 12 months maximum.
c. Leased specialty equipment: 12 months maximum.
d. Dated calibration labels shall be visible on all test equipment.
e. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date.
f. Calibrating standard shall be of higher accuracy than that of the instrument tested.

E. Specific requirements of insulation resistance meters.
   1. Must be digital units. Crank-type analog insulation resistance meters will not be acceptable.

F. Ensure suitable power supply is available for test equipment, be this 120Vac or battery powered devices. Record make, model, and calibration date of test instrument.

G. Test to be conducted with full safety requirements in force, including "barrier" of conductor ends, proper bonding, "flag-person" as necessary.

H. All test equipment to have valid calibration stickers displayed on the equipment.

I. DC High Pot (dielectric strength) Units:
   1. Test instrument to have minimum output of 60 kV dc capacity.
   2. 120Vac powered.

J. AC High Voltage (dielectric strength) Units:
   1. Use AC High voltage units for insulation tests and other tests as indicated, at voltage levels indicated, or required by manufacturers recommendations.

K. Low Resistance Test Units (Ductor):
   1. Low resistance test units to have 10A output.
   2. Digital display and accuracy to 1 micro-ohm, with a range from 1 μΩ to 1000 Ω. Standard electrician multimeters will not be accepted.

L. Insulation Resistance Tests (Megohmmeter/Megger):
   1. Use a megger with 20,000 M-ohm resolution for megger tests.
   2. Output voltages on DC megger units to be 250V, 500V, 1000V, 2500V or other as required.
   3. Record ambient temperature and adjust the measured M-ohms to 20(C ambient.
   4. Use 2.5kV megger for 5 kV and15 kV equipment and 1000 V megger range for power equipment of 600 V and below.
   5. For 10-minute megger tests, record M-ohm values in M-ohm at 30 seconds, 60 seconds, 5 minutes and 10 minutes. Plot M-ohm against time for each connection, calculate and record the ratio of measured M-ohm as follows:
      a. 60 sec M-ohm/30 sec M-ohm = dielectric absorption.
      b. 10 min M-ohm/1 min M-ohm = polarization index.
      c. Report the 1 minute M-ohm as the insulation resistance value.
   6. Submit tabulated measure M-ohm figures for 10-minute insulation tests, submit a graph.
   7. Apply megohmmeter dc voltage in accordance with the equipment manufacturer's recommendations or NETA ATS-2009 Table 100.1.

M. VLF Test:
   1. Use a VLF tester capable of 40 kV peak that is capable of testing 1.1uF of cable load at 0.1 Hz up to 5.5 uF at 0.2 Hz.

N. Relay Test Equipment:
1. Relay test equipment to be designed for relay testing, secondary current injection.
2. Current output to a minimum of 60Amps for testing of instantaneous features.
3. Indicators to detect open signals, pick-up signals and other required signals.
4. Timers to 1 millisecond.
5. MultiAmp or equivalent relay test units. Specifically designed relay testers for specific relays should be used if available.
6. For equipment required on three phase systems, have a three phase voltage and relay output test unit.
7. For equipment required on three phase differential tests, have a six phase voltage and relay output test unit.

O. Ground Resistivity Tester:
1. Ground resistivity tester to measure earth impedance in variable distances from the source.
2. Unit to be capable of plotting ground resistivity from 0.1 ohms and up.

P. Other test equipment as required in order to satisfy the requirements of this section as detailed herein.

1.5 TESTING REPORT

A. Prepare an overall inspection and test report that details all investigations and tests.

B. The Contractor shall furnish five paper copies and two electronic copies on CD of each final report.
1. The electronic copies of the report, including the test forms, shall be provided in PDF format.
2. The Microsoft Word version of the all completed test forms provided to the Contractor shall also be included on the CDs.

C. The report shall be neat and organized. Any omissions, inconsistencies, or incomplete work identified by the Contract Administrator shall be corrected and incorporated into the report in the appropriate section, and completely resubmitted.

D. A draft of each report shall be completed and sent to the Contract Administrator for review a maximum of one month after the completion of the inspections at the Site.

E. The final report shall be submitted a maximum of two weeks after the Contractor receives the mark-up of the draft report from the Contract Administrator.

F. The report shall include the following:
1. Summary of project.
2. Testing Equipment.
3. Detail the type, manufacturer, model, last calibration date and test certificate for all testing equipment used.
4. Description of equipment tested.
5. Description and methodology of all tests performed.

6. Typed inspection forms including:
   a. Identification of the testing organization.
   b. Equipment identification.
   c. Humidity, temperature, and other conditions that may affect the results of the tests/calibrations.
   d. Date of inspections, tests, maintenance, and/or calibrations.
   e. Identification and signed initials of the testing technician.
   f. Indication of inspections, tests, maintenance, and/or calibrations performed and recorded, along with charts, and graphs as applicable. All measurements and readings taken shall be noted for inclusion in the report. Where repairs are made, measurements and readings before and after the repair shall be included.
   g. Indication of expected results, when calibrations are to be performed.
   h. Indication of "as-found" and "as-left" results, as applicable.
7. Itemized list of all repaired deficiencies which shall include:
   a. Detailed description of the deficiency.
   b. Detailed description of the deficiency repair.
8. Itemized list of all un-repaired deficiencies encountered which shall include:
   a. Detailed description of the deficiency.
   b. Recommended action to be taken to repair the deficiency.
   c. Reason for not performing the recommended repair (such as equipment or component not available).
   d. Schedule and subsequent follow up and documentation of the repair of the deficiency.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. Provide all tests results with typed test reports and signed field test sheets.

B. All test sheets to include equipment nameplate data, customer identification, time and date of tests, environmental conditions during tests, and test results.

C. Provide testing equipment, lifts, man-baskets, temporary connections, cabling, lugs, leads, clips, and all other devices and equipment as required to perform the required tests and complete the required documentation.

PART 3 EXECUTION

3.1 TEST PLAN

A. Prior to performing testing, the lead electrical inspection technician shall submit written test procedures indicating details of the work to be performed to the Contract Administrator for review and approval prior to proceeding.

B. As a minimum, the test plan shall include the following:
   1. Type of tests.
   2. Equipment being used to perform the test.
   3. Equipment settings for each test.
   4. Test sheets.
   5. Safety checks and safety plan.
   6. An indication of expected results.

C. The cost of any damage to equipment due to improper test methods or procedures will be borne by the contractor performing the tests.

3.2 SCOPE OF TESTING

A. Perform testing and commissioning of electrical devices, in accordance with the drawings and specifications to suit the actual project. Scope of work for testing includes the following devices:
   1. Motor Control Centers (MCCs), including:
      a. Surge Protector
      b. Power Meter
      c. Voltage Monitor
      d. CTs
      e. PTs (if present)
      f. Branch Circuit Breakers
      g. Motor Starters
      h. Interlocks
      i. Kirk keys
   2. Panelboards and distribution panels, greater than 225A, including:
      a. Surge Protector
      b. Power Meter
      c. Voltage Monitor
      d. CTs
      e. PTs
      f. Branch Circuit Breakers
   3. Air circuit breakers.
   4. Static Uninterruptible Power Supply (UPS)
   5. Molded case circuit breakers, greater than or equal to 250A frame.
   6. Contactors, greater than or equal to 100A.
   7. Protective relays
   8. Medium voltage switchgear, including:
      a. Surge Protector
      b. Power Meter
      c. Voltage Monitor
      d. CTs
      e. PTs
      f. Relays
      g. Switches, pushbuttons
      h. Lock-out relays
      i. Interlocks

j. Kirk keys

9. Power factor correction, including:
   a. Metering
   b. Capacitors
   c. Branch Circuit Breakers
   d. Contactors
10. Dry type transformers, greater than 75 kVA.
11. Oil filled transformers.
12. Motors, 50 HP and greater.
13. Gensets.
14. Transfer switches.
15. Safety switches, greater than 200A.
16. Battery systems.
17. Surge arrestors.
18. Soft starters.
19. VFDs.
20. Cables:
    a. Test all 208 V / 240 V / 600 V power cables and wires No. 4/0 AWG or larger
    b. Test all 5 kV cables
    c. Test all 15 kV cables
21. Grounding system.
22. Perform harmonics measurements and analysis at all main distribution panels at all available voltage levels at the facility. Harmonics measurements are to be taken with all loads in operation.

B. All equipment which fails the tests shall be replaced, repaired and corrected at no additional charge. These items are deemed to be under warrantee, and the warrantee shall not be affected or voided as a result of the testing performed.

3.3 INPECTION, TESTING AND MAINTENANCE PROCEDURES

A. General
1. All tests are based on NETA (InterNational Electrical Testing Association) standard ATS-2009. Where manufacturer's specifications, tolerances, and/or published data are not available, refer to the appropriate tables in ATS-2009. Confirm with the equipment manufacturer that the test will not damage the equipment or void the warrantee prior to proceeding with tests.
2. Torque all accessible bolted electrical connections. Additional requirements apply as specified.
3. Utilize the drawings for reference while performing the specified electrical inspection work. Where the existing installation deviates from that shown on the drawings, mark-up the drawings with red pen as required to reflect the installation. Include the marked-up drawings in the report.
4. The scope of required drawing checks is limited to the equipment and components that are part of the electrical inspection work.
5. Any repairs made that affect the accuracy of the drawings shall be marked up on the drawings.

6. All inspection values, readings, corrections, and assessments shall be clearly recorded for inclusion within the report.
7. Where corrections or repairs are made, record both as found/as left test readings on the inspection sheet. If space is not provided on the inspection form, record the readings in the Note fields or on a separate sheet.

B. Inspection Forms
1. The inspection forms are to be provided, and completed by the Contractor. These shall be typewritten (in Microsoft Word or Excel format) and submitted the Contract Administrator for format approval.
2. Make appropriate print-outs of the inspection forms and utilize for entry of data and test results on site.
3. Utilizing the Microsoft Word form templates, enter the data recorded manually into the forms electronically.
4. Complete the inspection forms in their entirety and include them in the report.
5. Submit electronic PDF copies of the inspection forms.
6. The scope of work required in the specifications is in no way limited by the inspection forms, or spaces provided. Provide additional pages, documents, and forms as required to provide a complete report.
7. The inspection forms may be updated during the by the Contract Administrator. Utilize the latest forms.
8. Perform insulation resistance temperature correction calculations utilizing the following:
   a. To correct to 20°C, utilize Table 260805-1.
   b. To correct to 40°C, utilize Table 260805-2.

Table 260805-1

Insulation Resistance Correction Factors (20 °C)

Measured Temperature (°C)	Oil Immersed Insulation	Solid Insulation
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00

Table 260805-1 Insulation Resistance Correction Factors (20 °C)		
Measured Temperature (°C)	**Oil Immersed Insulation**	**Solid Insulation**
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

Table 260805-2 Insulation Resistance Correction Factors (40 °C)		
Measured Temperature (°C)	**Oil Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40

Table 260805-2 Insulation Resistance Correction Factors (40 °C)		
Measured Temperature (°C)	**Oil Immersed Insulation**	**Solid Insulation**
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

C. Perform winding resistance temperature correction calculations utilizing the following:

1. $$R_C = R_M \frac{T_C + T_K}{T_M + T_K}$$

2. Where, RC = Resistance at corrected temperature.
RM = Resistance at measured temperature.
TC = Temperature to correct to in °C.
TM = Measured temperature in °C.
TK = Temperature Resistance Constant
(234.5 °C for copper, 226.0 °C for aluminum)

3.4 CABLES (ALSO FEEDERS IN CONDUIT), UP TO 600 V

A. Perform inspection and tests on cables prior to installing sealing compound in the conduit system. This applies to hazardous areas and to weatherproof penetration sealant.

B. Inspection and testing shall be comprised of the following:
1. For cables/wires 4/0 AWG or larger, inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate and correct values

which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2. Torque all accessible bolted electrical connections.
3. Inspect compression applied connectors for correct cable match and indentation.
4. Inspect grounding and cable/conduit support.
5. Verify that visible cable bends meet or exceed the minimum allowable bending radius.
6. Measure length of cable/conduit and record in meters.
7. If cables/wires are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.
8. Perform an insulation-resistance test on each conductor. Individually test each conductor with all other conductors and shields grounded. The test duration shall be one minute. Investigate resistances less than 1 Gigohms for power cabling. The voltage applied shall be 1000 Vdc for 600 V or 1000 V rated cables.

3.5 CABLES, MEDIUM VOLTAGE (5 kV AND 15 kV)

A. Inspection and testing shall be comprised of the following:
   1. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
   2. Proper connections in accordance with single-line diagram.
   3. Proper circuit and phase identification.
   4. Inspect terminations and splices for physical damage and evidence of overheating and corona.
   5. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. 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.
   6. Inspect compression applied connectors for correct cable match and indentation.
   7. Check for proper lug installation.
   8. Confirm bolt torque levels are in accordance with manufacturer's recommendation.
   9. Inspect shield grounding and cable support.
   10. Verify that visible cable bends meet or exceed the minimum allowable bending radius.
   11. Measure and record the length of cable.
   12. If cables are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.
   13. Perform a shield-continuity test on each power cable by ohmmeter method. The shielding must exhibit continuity. Investigate resistance values in excess of 10 ohms per 1000 feet of cable.
   14. Perform an insulation-resistance test on each conductor utilizing a megohm-meter :
      a. Utilize 2,500-volt megohmmeter for 5 kV, 8 kV, 15 kV conductors in accordance with NETA standards.

b. Individually test each conductor with all other conductors and shields grounded. The test duration shall be one minute. Investigate resistances less than 5 Gig-ohms for 5 kV cable, and 15 Gig-ohms for 15 kV.

15. Perform a Very Low Frequency (VLF) ac high-potential test on cables. Adhere to all precautions and limits as specified in the applicable NEMA / ICEA Standard for the specific cable. Perform tests in accordance with IEEE Standard 400.2. Test procedure shall be as follows, and the results for each cable test shall be recorded as specified herein. The test voltage shall be sinusoidal with a frequency of 0.1 Hz, and shall not exceed cable manufacturer's test values or IEEE 400.2 values as indicated:

Cable rating phase to phase (RMS)	Acceptance test phase to ground	Maintenance test phase to ground
5 kV RMS	10 kV RMS (14 peak)	7 kV RMS (10 peak)
15 kV RMS	20 kV RMS (28 peak)	16 kV RMS (22 peak)

a. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the over-potential test, the test specimen is considered to have passed the test.
b. Ensure that the input voltage to the test set is regulated.
c. Current-sensing circuits in test equipment shall measure only the leakage current associated with the cable under test and shall not include internal leakage of the test equipment.
d. Record wet and dry-bulb temperatures or relative humidity and temperature.
e. Test each section of cable individually.
f. Individually test each conductor with all other conductors grounded. Ground all shields.
g. Terminations shall be adequately corona-suppressed by guard ring, field reduction sphere, or other suitable methods as necessary.
h. Ensure that the maximum test voltage does not exceed the limits for terminators specified in IEEE Standard 48 or manufacturer's specifications.
i. Raise the conductor test voltage to the specified maximum test voltage and hold for five minutes. Record leakage current.
j. Apply grounds for a time period adequate to drain all insulation-stored charge.

16. Perform a Dissipation Factor (Tangent Delta) test on all cables.
a. Perform tests in accordance with IEEE Standard 400.2.
b. The test voltage applied shall be a 0.1 Hz sinusoidal waveform.
c. The dissipation factor shall be calculated for an applied voltage of 1 Uo RMS.
1) Test 5 kV cable to 1 Uo (1 Uo is defined as 1 x line to ground operating voltage; which is 2400V RMS for 5 kV cable, and 4.16 kV phase to phase distributions).
2) Test 15 kV cable to 1 Uo or 7,200V RMS for 15 kV cable, and 12.47 kV phase to phase distributions.

d. Provided that the dissipation factor does not rise significantly while raising the voltage, the dissipation factor shall also be calculated for an applied voltage 2 Uo RMS.
   1) Test 5 kV cable to 2 Uo or 4800V RMS for 5 kV cable, and 4.16 kV phase to phase distributions.
   2) Test 15 kV cable to 2 Uo or 14,400V RMS for 15 kV cable, and 12.47 kV phase to phase distributions.

17. In the event of a cable failure discovered during testing, replace the cable.

3.6 CIRCUIT BREAKERS, INSULATED-CASE/MOLDED CASE, UP TO 600 V

A. Inspection and testing shall include the following:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Record all adjustable settings.
   3. Inspect physical and mechanical condition.
   4. Inspect anchorage and alignment.
   5. Clean the unit.
   6. Torque all accessible bolted power connections.
   7. Operate the circuit breaker to insure smooth operation.
   8. Test all breakers utilizing the “Push-To-Trip” button, if equipped.
   9. Move operating handle to the off and on position.
   10. Restore breaker position to original position.

B. For cables 4/0 AWG and larger, inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. 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.

C. For breakers with a frame size greater or equal to 250A, or as specified elsewhere in the specification:
   1. Perform an insulation resistance test.
   2. Breakers rated less than 600V, test voltage is to be 500 VDC.
   3. Breakers rated at 600V, test voltage is to be 1000 VDC.

D. Perform a contact/pole-resistance test.

3.7 AIR CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:
   1. Proper cell fit and element alignment.
   2. Proper operation of cubicle shutters and racking mechanism.
   3. Bolt torque level in accordance with manufacturer’s recommendations and NETA ATS-2009, Table 100.12. Where conical washers (Belleville or other) are used, consult with the Contract Administrator prior to tightening or applying pressure to connections.
   4. Proper contact condition.
   5. Perform mechanical operator and contact alignment tests on breaker and it’s operating mechanism in accordance with manufacturer’s instructions.

6. Verify primary and secondary contact wipe, gap setting, and other dimensions vital to breaker operations are correct.
7. Ensure that maintenance devices are available for servicing and operating breaker.
8. Check for adequate lubrication on contact, moving, and sliding parts.
9. Check condition of brushes and limit switches on charging and lifting motors.
10. With Breaker in TEST Position:
    a. Trip and close breaker with control switch.
    b. Trip breaker by manually operating each protective relay.
11. Perform breaker travel and velocity analysis in accordance with manufacturer's instructions; values shall be in accordance with manufacturer's acceptable limits.

B. Electrical Tests:
1. Insulation Resistance Tests:
    a. Utilize:
        1) 1,000 volt megohmmeter for 600V circuit breakers
        2) 2,500-volt megohmmeter for 5 kV and 15 kV circuit breakers
    b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute
    c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
    d. Test values to comply with NETA ATS-2009 Table 100.1.
2. Contact Resistance Tests:
    a. Contact resistance in microhms across each pole.
    b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
3. Dieletric Withstand Tests:
    a. Maximum applied voltage for equipment in accordance with NETA ATS-2009, Table 100.2 and Table 100.19
    b. Each pole-to-ground with other poles grounded and contacts closed.
    c. Test results evaluated on pass/fail basis.
4. Minimum pickup voltage tests on trip and close coils.

3.8 VACUUM CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:
1. Check for proper element alignment.
2. Check for proper operation of cubicle shutters and racking mechanism.
3. Bolt torque level in accordance with manufacturer's recommendations and NETA ATS-2009, Table 100.12. Where conical washers (Belleville or other) are used, consult with the Contract Administrator prior to tightening or applying pressure to connections.
4. Perform mechanical operational tests on breaker and it's operating mechanism in accordance with manufacturer's instructions, plus check:
    a. Pull rod adjustment.
    b. Trip latch clearance.
    c. Overtravel stops.
    d. Wipe and gap setting.

5. Perform breaker travel and velocity analysis in accordance with manufacturer's instructions; values shall be in accordance with manufacturer's acceptable limits.
6. Check contact erosion indicators in accordance with manufacturer's instructions.
7. With Breaker in TEST Position:
    a. Trip and close breaker with control switch.
    b. Trip breaker by manually operating each protective relay.

B. Electrical Tests:
1. Insulation Resistance Tests:
    a. Utilize 2,500-volt dc megohmmeter for 5 kV and 15 kV circuit breakers.
    b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute
    c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
    d. Test values to comply with NETA ATS-2009, Table 100.1
2. Contact Resistance Tests:
    a. Between the line and load stab of closed contact resistance in microhms across each pole.
    b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
3. Dielectric Withstand Tests:
    a. Maximum applied voltage in accordance with NETA ATS-2009, Table 100.19.
    b. Each pole-to-ground with other poles grounded and contacts closed.
    c. Test results evaluated on pass/fail basis.
4. Minimum pickup voltage tests on trip and close coils.

3.9 CONTACTOR PANELS, UP TO 600V

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Torque all accessible bolted power connections.
6. Inspect unit for evidence of overheating or stress.
7. Visually inspect and exercise transfer switch.

B. If power and/or control fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

C. Perform an insulation resistance tests.
1. Units rated less than 600V, test voltage is to be 500 VDC.
2. Units rated at 600V, test voltage is to be 1000 VDC.

D. Perform a contact/pole-resistance tests.

E. Perform functional testing to verify operation of unit.

3.10 CONTROL POWER TRANSFORMERS, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
   1. Record the equipment nameplate data for inclusion in the report.
   2. Inspect physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
   3. Verify that primary and secondary fuse ratings or circuit breakers match available drawings. Where drawings are not available, note fuses that appear to be sized incorrectly, based upon application of the Canadian Electrical Code. Mark fuse sizes and type on the drawings, where not shown.
   4. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be:
      a. windings less than 250 V: 500 Vdc
      b. windings greater than 250 V: 1000 Vdc

3.11 CURRENT INSTRUMENT TRANSFORMERS

A. Inspection and testing shall be comprised of the following:
   1. Inspect physical and mechanical condition.
   2. Record the equipment nameplate data for inclusion in the report.
   3. Ensure that CT shorting bars are removed or installed as required.
   4. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.
   5. Perform an insulation resistance test of the current transformer primary and secondary windings, and wiring to ground at 1000 Vdc. Do not perform this test on solid-state devices. Investigate any resistance values less than 25 megohms.
   6. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
   7. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. Note any ratio accuracies not within 0.5% of nameplate or manufacturer's published data.
   8. Perform an excitation test on transformers used for protection or relaying applications in accordance with ANSI C57.13.1.

3.12 GROUNDING SYSTEM

A. Inspection and testing shall be comprised of the following:
   1. Perform resistance tests between the main grounding electrode and grounded points in the electrical distribution system located in the switchgear, transformers, and MCCs. Investigate connections with a resistance greater than 0.5 milliohms.

3.13 HARMONICS MEASUREMENTS

A. Testing shall be comprised of the following:
   1. Connect to existing CTs and PTs, if provided. If not provided, supply appropriate CTs and PTs as required.
   2. Test duration at each location is to be one hour.

3. Coordinate with operations personnel to ensure the loads run during the test are representative of normal and maximum plant operation.
4. Monitor the following for all three phases:
   a. Voltage, current, and power factor
   b. Harmonic voltage level for 1st (base) through 15th harmonics.
   c. Harmonic current level for 1st (base) through 15th harmonics, expressed in % of current.
   d. Total harmonic distortion (THD)
5. Record samples as one (1) minute intervals.
6. Provide Microsoft Excel files of the test results.
7. Provide a summary page in the report indicating the THD, and maximum, average, and minimum for each voltage and current harmonic.

3.14 PROTECTIVE RELAYS

A. Visual and Mechanical Inspection:
   1. Visually Check Each Relay For:
      a. Tight cover gasket and proper seal.
      b. Unbroken cover glass.
      c. Condition of case shorting contacts if present.
      d. Circuit wiring and connections
   2. Mechanically Check Each Relay For:
      a. Freedom of movement.
      b. Proper travel and alignment.
      c. Trip plunger mechanism.
   3. Verify That Each Relay:
      a. Complies with Contract Documents and application.
      b. Is set in accordance with recommended settings.

B. Electrical Tests:
   1. Tests on Nominal Recommended Setting For:
      a. Perform tests to suit the type of relay and the type of protection in accordance with NETA ATS-2009.
      b. Pickup parameters on each operating element.
      c. Timing at three points on time-current curve.
      d. Pickup target and seal-in units.
      e. Special tests as required to check operation of restraint, directional, and other elements in accordance with manufacturer’s instruction manual and NETA standards.
   2. Phase angle and magnitude contribution tests on differential and directional relays after energization to vectorially verify proper polarity and connections.
   3. Current Injection Tests:
      a. For entire current circuit in each section.
      b. Secondary injection for current flow.
      c. Test current at each device.
   4. For Motor protection Relays and similar relays, use 3-phase current injection for unbalanced protection testing, unless recommended otherwise by the manufacturer.

5. Use 6 phase current injection and voltage relay (3 phase line, 3 phase load) test units for differential protection relays.

3.15 METERING DEVICES, DIGITAL

A. Inspection and testing shall be comprised of the following:
1. Inspect physical and mechanical condition.
2. Torque all bolted connections.
3. Record the equipment nameplate data for inclusion in the report.
4. Verify accuracy of voltage and current at a minimum of two points each.
5. If required, calibrate meters in accordance with manufacturer's published data.

3.16 PANELBOARDS, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Clean the unit.
5. Inspect breakers and verify mechanical operation by exercising all circuit breakers.
a. Record breaker data on the inspection form.
b. Test all breakers utilizing the "Push-To-Trip" button, if equipped.
c. Move operating handle to the off and on position.
d. Restore breaker position to original position.
6. Test with current injection, main and feeder/load breakers with a frame size greater than or equal to 250A, or with long, short, or ground fault settings and complete a separate inspection form for each.
7. Torque all accessible bolted power connections including incoming, load neutral and ground connections.
8. Perform insulation-resistance tests on each bus phase with all other phases grounded.
a. The main breaker, if present, is to be open for the test. If no main breaker is present, disconnect the supply conductors.
b. Open all load breakers.
c. Test voltage for all 600/347 V panelboards to be 1000 Vdc.
d. Test voltage for all 120/208 V panelboards to be 500 Vdc.

3.17 MOTOR CONTROL, UP TO 600 V

A. Visual and Mechanical Inspection:
1. Proper barrier and shutter installation and operation.
2. Proper operation of indicating and monitoring devices.
3. Proper overload protection for each motor.
4. Improper blockage of air cooling passages.
5. Proper operation of drawout elements.
6. Integrity and contamination of bus insulation system.

7. Check Door and Device Interlocking System By:
   a. Closure attempt of device when door is in OPEN position.
   b. Opening attempt of door when device is in CLOSED position.
8. Check Key Interlocking Systems For:
   a. Key captivity when device is in CLOSED position.
   b. Key removal when device is in OPEN position.
   c. Closure attempt of device when key has been removed.
   d. Correct number of keys in relationship to number of lock cylinders.
   e. Existence of other keys capable of operating lock cylinders; destroy duplicate sets of keys.
9. Check Nameplates for Proper Identification Of:
   a. Equipment title and tag number with latest one-line diagram.
   b. Pushbuttons.
   c. Control switches.
   d. Pilot lights.
   e. Control relays.
   f. Circuit breakers.
   g. Indicating meters.
10. Verify that fuse and circuit breaker sizes and types conform to the drawings.
11. Verify that current and potential transformer ratios conform to the drawings.
12. Check Bus Connections for High Resistance by Low Resistance Ohmmeter, Calibrated Torque Wrench Applied to Bolted Joints and Thermographic Survey:
   a. Ohmic value to be zero.
   b. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
   c. Thermographic survey temperature gradient of 2 degrees C, or less.
13. Check Operation and Sequencing of Electrical and Mechanical Interlock Systems By:
   a. Closure attempt for locked open devices.
   b. Opening attempt for locked closed devices.
   c. Key exchange to operate devices in OFF-NORMAL positions.
14. Verify performance of each control device and feature furnished as part of the motor control center.
15. Control Wiring:
   a. Compare wiring to local and remote control, and protective devices with elementary diagrams.
   b. Check for proper conductor lacing and bundling.
   c. Check for proper conductor identification.
   d. Check for proper conductor lugs and connections.
16. Exercise active components.
17. Inspect Contactors For:
   a. Correct mechanical operations.
   b. Correct contact gap, wipe, alignment, and pressure.
   c. Correct torque of all connections.
18. Compare overload heater rating with full-load current for proper size.
19. Compare, fuse, motor protector, and circuit breaker with motor characteristics for proper size.

20. Perform phasing check on double-ended motor control centers to ensure proper bus phasing from each source.

B. Electrical Tests:
1. For units with solid state components, follow manufacturer's recommendations prior to performing any tests.
2. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage.
   b. Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
   c. Contactor phase-to-ground and across open contacts for 1 minute on each phase.
   d. Starter section phase-to-phase and phase-to-ground on each phase with starter contacts closed and protective devices open.
   e. Test values to comply with NETA ATS-2009, Table 100.1.
3. Current Injection Through Overload Unit at 300 Percent of Motor Full-Load Current and Monitor Trip Time:
   a. Trip time in accordance with manufacturer's published data.
   b. Investigate values in excess of 120 seconds.
4. Control Wiring Tests:
   a. Apply secondary voltage to control power and potential circuits.
   b. Check voltage levels at each point on terminal boards and each device terminal.
5. Operational test by initiating control devices to affect proper operation.
6. Verify the correct operation of the network cabling, network switch, and associated components within Smart MCCs.
   a. Verify I/O and metering data from each Intelligent Overload.

3.18 DISTRIBUTION SWITCHBOARDS / SWITCHGEAR, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
1. Inspect the switchboard physical, electrical, and mechanical condition.
2. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
3. Inspect all doors, panels, and sections for dents, holes, fit, and missing hardware.
4. Verify that fuse and / or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
5. Verify that current and potential transformer ratios correspond to drawings.
6. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. 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. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
8. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
9. Make key exchange with all devices included in the interlock scheme as applicable.

10. Vacuum debris from interior of switchboard. Clean off all dust and adhesive residue from switchboard.
11. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
12. Inspect insulators for evidence of physical damage or contaminated surfaces.
13. Verify correct barrier and shutter installation and operation.
14. Exercise all active components.
15. Inspect all mechanical indicating devices for correct operation.
16. Verify that filters are in place and / or vents are clear.
17. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects, current-carrying and grounding contacts.
18. Perform point to point ground-resistance tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and / or derived neutral points. Investigate point-to-point resistance values which exceed 0.5 ohm.
19. Perform insulation-resistance tests each bus section, phase-to-phase and phase-to-ground.
    a. Test voltage for 600/347 V equipment to be 1000 Vdc.
    b. Test voltage for 120/208 V equipment to be 500 Vdc.
20. Inspect all surge arrestors if available.
21. Inspect control power transformers.
22. Inspect all current instrument transformers.
23. Inspect potential transformers.
24. Inspect all metering devices.
25. Inspect and test air circuit breakers.
26. Inspect and test protective relays.
27. Inspect and test all associated motor starters.
28. Inspect and test all moulded case feeder breakers. Feeder breakers with a frame size less than 250A, and without long, short, or ground fault settings, may be recorded on the Switchboard inspection form. Record test results on other breakers on the appropriate inspection form.
    a. Inspect and test all capacitors.
    b. Perform a system function test to prove the correct interaction of all sensing, processing, and action devices. Perform system function tests upon completion of the maintenance tests defined, as system conditions allow.
29. Perform tests for the purpose of evaluating performance of all integral components and their functioning as a complete unit within each cell.
30. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.
31. Verify the correct operation of all sensing devices, alarms, and indicating devices.
32. Verify the correct operation of the network cabling, network switch, and associated components.

3.19 MEDIUM VOLTAGE SWITCHGEAR AND MOTOR CONTROL CENTERS (5 kV AND 15 kV)

A. Visual and Mechanical Inspection:
1. Insulator damage and contaminated surfaces.
2. Proper barrier and shutter installation and operation.
3. Bolt torque level in accordance with manufacturer's recommendations and NETA ATS-2009, Table 100.12. Where conical washers (Belleville or other) are used, consult with the Contract Administrator prior to tightening or applying pressure to connections.
4. Proper operation of indicating devices.
5. Proper overload protection.
6. Blockage of air cooling passages.
7. Proper operation of drawout elements.
8. Integrity and contamination of bus insulation system.
9. Check Door and Device Interlocking System By:
   a. Closure attempt of device when door is in OPEN position.
   b. Opening attempt of door when device is in CLOSED position.
10. Check Key Interlocking Systems For:
   a. Key captivity when device is in CLOSED position.
   b. Key removal when device is in OPEN position.
   c. Closure attempt of device when key has been removed.
   d. Correct number of keys in relationship to number of lock cylinders.
   e. Existence of other keys capable at operating lock cylinders; destroy duplicate sets of keys.
11. Check Nameplates for Proper Identification of Each:
   a. Equipment title and tag number with latest one-line diagram.
   b. Pushbutton.
   c. Control switch.
   d. Pilot light.
   e. Control relay.
   f. Circuit breaker.
   g. Indicating meter.
12. Verify that fuse sizes and types conform to the drawings.
13. Check Bus Connections for High Resistance by Low Resistance Ohmmeter, Calibrated Torque Wrench Applied to Bolted Joints and Thermographic Survey:
   a. Ohmic value to be zero.
   b. Bolt torque level in accordance with manufacturer's recommendation.
   c. Thermographic survey temperature gradient of 2 degrees C, or less.
14. Check Operation and Sequencing of Electrical and Mechanical Interlock Systems By:
   a. Closure attempt for locked open devices.
   b. Opening attempt for locked closed devices.
   c. Key exchange to operate devices in OFF-NORMAL positions.
15. Verify performance of each control device and feature furnished as part of the motor control center.

16. Control Wiring:
    a. Compare wiring to local and remote control, and protective devices with elementary diagrams.
    b. Check for proper conductor lacing and bundling.
    c. Check for proper conductor identification.
    d. Check for proper conductor lugs and connections.
17. Exercise active components.
18. Verify performance of charging mechanisms.
19. For motor starters:
    a. Inspect magnetic contactors for:
        1) Correct mechanical operations.
        2) Correct contact gap, wipe, alignment, and pressure.
        3) Correct torque of connections.
    b. Perform phasing check on motor control centers to ensure proper bus phasing from each source.

B. Electrical Tests:
1. For units with solid state devices follow manufacturer's recommendations prior to performing any tests.
2. Insulation Resistance Tests:
    a. Applied megohmmeter dc voltage.
    b. Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
    c. Contactor phase-to-ground and across open contacts for 1 minute on each phase.
    d. Starter section phase-to-phase and phase-to-ground on each phase with starter contacts closed and protective devices open.
    e. Test values to comply with NETA ATS-2009, Table 100.1
3. Overpotential Dielectric Tests:
    a. Maximum applied voltage in accordance with NETA ATS, Table 100.19.
    b. Phase-to-phase and phase-to-ground for 1 minute for each phase of each bus section.
    c. Test results evaluated on pass/fail basis.
4. Bottle integrity test for vacuum contactors in accordance with manufacturer's procedure.
5. Test by Primary Current Injection:
    a. Overload units at sensors using 300 percent of motor full-load current.
        1) Overload trip times to be in accordance with manufacturer's published data.
    b. Check voltage levels at each point on terminal boards and each device terminal.
6. Control Wiring Tests:
    a. Apply secondary voltage on control power and potential circuits.
    b. Check voltage levels at each point on terminal boards and at each device terminal.
7. Test indicating and monitoring devices for proper operation.

8. Perform setup and testing of solid state relays and multifunction protective devices in accordance with manufacturer's instructions. Relays and electronic components to be tested by means of secondary current injection test.
9. Measure Contact and Power Fuse Resistances:
    a. Contact resistance shall not exceed manufacturer's recommended values.
    b. Resistance of power fuses not to deviate more than 15 percent between identical fuses.
10. Verify the correct operation of the network cabling, network switch, and associated components.
    a. Verify I/O, communications, metering data from relays or other solid state devices.

3.20 MOTORS, INDUCTION, AC, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging. Air baffles and filter media should be clean. Cooling fans should operate. Slip ring wear and brushes should be within manufacturer's tolerances for continued use. Brush rigging should be intact.
5. Inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. 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.
6. Verify the application of appropriate lubrication and lubrication systems.
7. Verify the absence of unusual mechanical or electrical noise or signs of overheating.
8. Perform a rotation test to insure correct shaft direction.
9. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43. Test voltage shall be in accordance with manufacturer's published data or 500 Vdc.
    a. Where possible, test each winding separately. Ground all windings not under test.
    b. Ensure all cables and accessories are disconnected during the test.
    c. For motors less than or equal to 150kW (200 HP), the test duration is to be one (1) minute. Calculate the dielectric absorption ratio.
    d. For motors greater than 150kW (200 HP), the test duration is to be ten (10) minutes. Calculate the dielectric absorption ratio and polarization index.
    e. Correct test results to 40 °C.
    f. Investigate readings below 100 megohms. Investigate dielectric absorption ratios less than 1.4 and polarization index ratios less than 2.0 for Class B insulation and Class F insulation.
10. Where it is not possible to perform an insulation resistance test separately on each winding, perform a winding resistance test on each winding using a low-resistance ohmmeter.

11. Measure running voltage and current and evaluate relative to load conditions and nameplate full-load amperes. Utilize a true RMS meter.
    a. Where powered by a VFD with bypass, perform test with the motor powered by the VFD and by the bypass starter.
12. Perform insulation-resistance test on insulated bearings in accordance with manufacturer's published data, if applicable.
13. Perform resistance tests on resistance temperature detector (RTD) circuits. RTD circuits should conform to design intent and/or machine protection device manufacturer's specifications.

3.21 SAFETY SWITCHES, UP TO 600 V

A. Visual and Mechanical Inspection:
   1. Proper blade pressure and alignment.
   2. Proper operation of switch operating handle.
   3. Adequate mechanical support for each fuse.
   4. Proper contact-to-contact tightness between fuse clip and fuse.
   5. Cable connection bolt torque level in accordance with NETA ATS-2009, Table 100.12.
   6. Proper phase barrier material and installation.
   7. Verify that fuse sizes and types correspond to one-line diagram.
   8. Perform mechanical operational test and verify electrical and mechanical interlocking system operation and sequencing where installed.

B. Electrical Tests:
   1. Insulation Resistance Tests:
      a. Applied megohmmeter dc voltage.
      b. Phase-to-phase and phase-to-ground for 1 minute on each pole.
      c. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
   2. Contact Resistance Tests:
      a. Contact resistance in microhms across each switch blade and fuse holder.
      b. Investigate deviation of 50 percent or more from adjacent poles or similar switches.

3.22 MOTOR STARTERS, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Record all adjustable settings, size of overload, etc.
   3. Inspect physical and mechanical condition.
   4. Inspect anchorage, alignment, and grounding.
   5. Verify the unit is clean.
   6. Torque all accessible bolted power connections.
   7. Inspect contactors for evidence of overheating or stress.
   8. Visually inspect and exercise circuit breaker.
   9. If power fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

3.23 MOTOR STARTERS, SOFT STARTER, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Confirm soft starter parameters.
   3. Record size and setting of overload.
   4. Inspect physical and mechanical condition.
   5. Inspect anchorage, alignment, and grounding.
   6. Verify the unit is clean.
   7. Torque all accessible bolted power connections.
   8. Inspect contactors for evidence of overheating or stress.
   9. Perform resistance measurements with a low-resistance ohmmeter for each pole of the following:
      a. Bypass contactor.
      b. Capacitor contactor, if applicable.
      c. Main disconnect/circuit breaker.
      d. Main fuses.
   10. Perform power cable insulation resistance measurements. Test voltage for 208V or 240V to be 500V, 600V rated equipment is to be 1000V. Disconnect the power cables from the soft starter module and control power fuses prior to test. Test to include:
      a. Bypass contactor line and load to GND.
      b. Bypass contactor line to load with contactor open.
   11. Perform an operational inspection while starting, running, and stopping the motor at normal load. Include:
      a. Measurement of ramp up time.
      b. Measurement of motor current.
      c. Recording of soft starter, ammeter, and remote displayed current readings.
      d. Measurement of ramp down time.

3.24 VARIABLE FREQUENCY DRIVE, LOW VOLTAGE (LESS THAN 37.5 kW)

A. Inspection and testing shall be comprised of the following:
   1. Inspect physical and mechanical condition.
   2. Inspect anchorage, alignment, and grounding.
   3. Clean the unit.
   4. Check the air filters.
   5. Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt.
   6. Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
   7. Visually inspect VFD grounding to ensure continuity.
   8. Inspect condition and connections of line reactors, and load reactors / load filter if present.
   9. Inspect DC bus capacitors for bulging and leakage.
   10. Cooling fans and heat sinks:
      a. Visually inspect and listen for any abnormal noises or vibration.

b. Verify that fans rotate freely.
c. Verify correct direction of airflow.
d. Clean and verify integrity of heat sinks.
e. Verify the operation of the grounding switch, if present.

11. Perform all other work in accordance with the manufacturer's instructions.

B. Record the following VFD Parameters:
1. Motor voltage, current, frequency, nominal speed, nominal power.
2. Control mode / method.
3. Minimum and maximum control frequency.
4. Acceleration and deceleration time.
5. Compare drive overcurrent set points with motor full-load current rating to verify correct settings.

C. Power Fuses:
1. Record fuse data. Confirm that the fuses are of the correct type and rating. Utilize manufacturer's published data where available.
2. Measure fuse resistance.

D. Bolted Connections:
1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. 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. Torque all bolted connections.

E. Inverter / Supply Module Power Connections:
1. Remove each power module and visually inspect the contacts.
2. Torque all cable connections.
3. Clean all contact surfaces and apply suitable joint compound as recommended by manufacturer.

F. Operator Interface:
1. Check the display and keypad for proper operation and communication.
2. Retrieve fault history log and note any faults.

G. Grounding/Bonding measurements:
1. Measure the resistance of the ground bonding connection between the VFD and the main grounding bus in the corresponding electrical room.

H. Control Wiring:
1. Check for tightness of all accessible control wiring and torque any loose connections.

I. Perform Operational Tests by Initiating Control Devices.
1. Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
2. Verify operation of drive from local start/stop and speed control signals.
3. Verify operation of all local pilot lights.

4. Verify the operation of any emergency stop switches.
5. Perform all other tests in accordance with the manufacturer's instructions.
6. Perform all tests in accordance with the manufacturer's recommendations and instructions.

J. Voltage and Current Testing:
1. With the VFD under load, measure and record the following:
a. Incoming AC voltage and currents.

K. With the VFD output in START/RUN mode, and at zero speed:
1. Measure and record the AC output voltage. Voltages above 40 VAC should be investigated.

3.25 VARIABLE FREQUENCY DRIVE, LOW VOLTAGE (GREATER THAN 37.5 kW AND LESS THAN 150 kW)

A. Inspection and testing shall be comprised of the following:
1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Clean the unit.
4. Check the air filters.
5. Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt.
6. Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
7. Visually inspect VFD grounding to ensure continuity.
8. Inspect condition and connections of line reactors, if present.
9. Inspect condition and connections of DC Link Reactors, if present.
10. Inspect condition and connections of load reactors or load filter, if present.
11. Inspect condition of isolation transformers, if present.
12. Inspect DC bus capacitors for bulging and leakage.
13. Cooling fans and heat sinks:
a. Visually inspect and listen for any abnormal noises or vibration.
b. Verify that fans rotate freely.
c. Verify correct direction of airflow.
d. Clean and verify integrity of heat sinks.
e. Verify the operation of the grounding switch, if present.

B. Record the following VFD Parameters:
1. Motor voltage, current, frequency, nominal speed, nominal power.
2. Control mode / method.
3. Minimum and maximum control frequency.
4. Acceleration and deceleration time.
5. Compare drive overcurrent set points with motor full-load current rating to verify correct settings.

C. Power Fuses:
1. Record fuse data. Confirm that the fuses are of the correct type and rating. Utilize manufacturer's published data where available.
2. Measure fuse resistance.

D. Bolted Connections:
1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. 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. Torque all bolted connections.

E. Inverter / Supply Module Power Connections:
1. Remove each power module and visually inspect the contacts.
2. Torque all cable connections.
3. Clean all contact surfaces and apply suitable joint compound as recommended by manufacturer.

F. Operator Interface:
1. Check the display and keypad for proper operation and communication.
2. Retrieve fault history log and note any faults.

G. Grounding/Bonding measurements:
1. Measure the resistance of the ground bonding connection between the VFD and the main grounding bus in the corresponding electrical room.

H. Control Wiring:
1. Check for tightness of all accessible control wiring and torque any loose connections.

I. Perform operational tests by initiating control devices.
1. Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
2. Verify operation of drive from local start/stop and speed control signals.
3. Verify operation of all local pilot lights.
4. Verify the operation of any emergency stop switches.

J. Voltage and Current Testing:
1. With the VFD under load, measure and record the following:
   a. Measure and record incoming AC voltage and currents.
   b. Measure and record DC and AC bus voltages.
2. Utilize a recording oscilloscope to capture the input voltage waveform and verify correct operation.
3. Utilize a recording oscilloscope to capture the output voltage waveform and verify correct operation.
4. Include input and output waveforms with the report.

K. With the VFD output in START/RUN mode, and at zero speed:
1. Measure and record the AC output voltage. Voltages above 40 VAC should be investigated.

3.26 SURGE ARRESTORS, UP TO 600V

A. Inspection and testing shall be comprised of the following:
1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Clean the unit.
4. Verify that arrestors are electrically connected in their specified configuration.
5. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. 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.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Verify that stroke counter, if present, is correctly mounted and electrically connected.
8. Perform insulation-resistance tests for one minute from each phase terminal to the case.
9. Equipment rated greater than or equal to 600V, utilize a test voltage of 1000 VDC.
10. Equipment rated less than 600V, utilize a test voltage of 500 VDC.
11. Test the grounding connection. Resistance between the arrester ground terminal and the ground system should be less than 0.5 ohm.

3.27 TRANSFORMERS, DRY-TYPE, UP TO 600V

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Clean the unit.
5. Torque all accessible bolted power connections.
6. Record the tap setting.
7. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Duration of the test is to be one minute. Calculate the dielectric absorption ratio.
a. 600 V windings shall be tested at 1000 Vdc.
b. 120/208 V windings shall be tested at 500 Vdc.

3.28 TRANSFORMERS, DRY-TYPE, MEDIUM VOLTAGE

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.

4. Clean the unit.
5. Verify that alarm settings on temperature indicators are as specified and operate within manufacturer's recommendations for specified settings.
6. Inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. 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. Record tap setting. Confirm the tap setting appears reasonable by measuring the voltage during normal facility operation.
8. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Calculate polarization index. Minimum insulation-resistance values of transformer insulation should be 1000 megohms for the 4160 V windings and 100 megohms for the 600 V windings. Values of insulation resistance less than the values stated should be investigated. The polarization index should not be less than 1.0.
   a. The test duration shall be 10 minutes for each winding.
   b. 4160 V windings shall be tested at 2500 Vdc.
   c. 600 V windings shall be tested at 1000 Vdc.
9. Perform turns-ratio tests at the designated tap position. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
10. Measure the resistance of each winding at the designated tap position.
11. Measure core insulation resistance at 500 Vdc if the core is insulated and if the core ground strap is removable.
12. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading. Phase-to-phase and phase-to-neutral secondary voltages should be in agreement with nameplate data.

3.29 LIQUID FILLED TRANSFORMERS

A. Inspection and testing shall be comprised of the following:
   1. Physical and insulator damage.
   2. Conduct external inspections in accordance with layout shop drawings. Check nameplates and vector diagrams against test results.
   3. Inspect silica gel breathers, oil gauge, temperature gauge and similar devices where fitted. For devices with settings, record the settings in use. Record actual reading of all gauges and ambient temperature.
   4. Proper winding connections.
   5. Bolt torque level in accordance manufacturer's recommendations.
   6. Defective wiring.
   7. Proper operation of fans, indicators, and auxiliary devices.
   8. Effective core and equipment grounding. Review neutral grounding device wiring and connections (if present).
   9. Removal of shipping brackets, fixtures, or bracing.
   10. Inspect for oil leaks, correct oil level, and sign of rusting.
   11. Integrity and contamination of bus insulation system.
   12. Verify that tap-changer is set at correct ratio for rated voltage under normal operating conditions.

13. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.
14. Exercise the manual tap changer to check its functions and ease of access.
15. Operate and simulate alarm and trip conditions of each protective device.

B. Electrical Tests:
1. As a minimum, perform the following transformer tests:
   a. Perform high voltage AC insulation tests on high voltage windings to ground, low voltage windings to ground, high voltage windings to low voltage windings. Perform dobble test on transformer, or equivalent Capacitance and Dissipation Factor tests.
   b. Inspect bushings, and measure insulation resistance with use of high voltage AC insulation test.
   c. Winding resistance measurement on all windings (standard test protocol).
   d. Oil analysis and gas analysis.
   e. H.V. test on oil samples from transformer tank for each transformer.
   f. Voltage ratio three phase, for each tap (Transformer Tap ratio).
   g. Relay and protective devices operation.
2. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage for each:
      1) Winding-to-winding.
      2) Winding-to-ground.
   b. 10-minute test duration with resistances tabulated at 30 seconds, 1 minute, and 10 minutes. Results temperature corrected in accordance with NETA ATS-2009, Table 100.14 or Tables 260805-1 and 260805-1.
   c. Temperature corrected insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
   d. Insulation resistance test results to compare within 1 percent of adjacent windings.
3. Perform tests and adjustments for fans, controls, and alarm functions as suggested by manufacturer.

3.30 GROUNDING SYSTEMS

A. Visual and Mechanical Inspection:
1. Equipment and circuit grounds in motor control center, panelboard, switchboard, and switchgear assemblies for proper connection and tightness.
2. Ground bus connections in motor control center, panelboard, switchboard, and switchgear assemblies for proper termination and tightness.
3. Effective transformer core and equipment grounding and bonding.
4. Accessible connections to grounding electrodes for proper fit and tightness.
5. Accessible exothermic-weld grounding connections to verify that moulds were fully filled and proper bonding was obtained.

B. Electrical Tests:
1. Fall-Of-Potential Test:
   a. In accordance with IEEE 81, Section 8.2.1.5 for measurement of main ground system’s resistance.

b. Main ground electrode system resistance to ground to be a maximum of 1 ohm for substation grounds, and 5 ohms for industrial facilities.

2. Two-Point Direct Method Test:
   a. In accordance with IEEE 81, Section 8.2.1.1 for measurement of ground resistance between main ground system, equipment frames, and system neutral and derived neutral points.
   b. Equipment ground resistance shall not exceed main ground system resistance by 0.5 ohm. Investigate higher values.

3.31 GROUND FAULT SYSTEMS

A. Inspection and Testing Limited To:
   1. Zero sequence grounding systems.
   2. Residual ground fault systems.

B. Visual and Manual Inspection:
   1. Neutral Main Bonding Connection to Assure:
      a. Zero sequence sensing system is grounded ahead of neutral disconnect link.
      b. Ground strap sensing system is grounded through sensing device.
      c. Neutral ground conductor is solidly grounded.
   2. Verify that control power has adequate capacity for system.
   3. Manually Operate Monitor Panels For:
      a. Trip test.
      b. No trip test.
      c. Nonautomatic rest.
   4. Zero sequence system for symmetrical alignment of core balance transformers about current carrying conductors.
   5. Relay check for pickup and time under simulated ground fault conditions.
   6. Verify nameplate identification by device operation.

3.32 AUTOMATIC TRANSFER SWITCHES

A. Visual and Mechanical Inspection:
   1. Check doors and panels for proper interlocking.
   2. Note the equipment nameplate data for inclusion in the report.
   3. Record all adjustable settings, setpoints, delays, etc.
   4. Inspect physical and mechanical condition.
   5. Inspect anchorage, alignment, and grounding.
   6. Verify the unit is clean.
   7. Torque all accessible bolted power connections.
   8. Visually inspect and exercise transfer switch.
   9. Check connections for high resistance by low resistance ohmmeter and calibrated torque wrench applied to bolted joints.
   10. Check positive mechanical and electrical interlock between normal and alternate sources.
   11. Check for Proper Operation:
      a. Manual transfer function switch.

b. Generator under load and nonload conditions.
c. Auto-exerciser of generator under load and no-load conditions.

12. Verify settings and operation of control devices.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage for each phase with switch CLOSED in both source positions.
   b. Phase-to-phase and phase-to-ground for 1 minute.
   c. Test values in accordance with manufacturer's published data.
2. Contact Resistance Test:
   a. Contact resistance in microhms across each contact for both source positions.
   b. Investigate values exceeding 100 microhms.
   c. Investigate values deviating from adjacent pole by more than 50 percent.
3. Set and Calibrate in Accordance with Specifications:
   a. Voltage and frequency sensing relays.
   b. Time delay relays.
   c. Engine start and shutdown relays.
4. Perform Automatic Transfer Tests By:
   a. Simulating loss of normal power.
   b. Return to normal power.
   c. Simulating loss of alternate power.
   d. Simulating single-phase conditions for normal and alternate sources.
5. Monitor and Verify Operation and Timing Of:
   a. Normal and alternate voltage sensing relays.
   b. Engine start sequence.
   c. Timing delay upon transfer and retransfer.
   d. Engine cool down and shutdown.
   e. Interlocks and limit switch functions.
   f. Engine cool down and shutdown feature.
6. If power and/or control fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

3.33 BATTERY SYSTEM

A. Visual and Mechanical Inspection:

1. Physical damage and electrolyte leakage.
2. Evidence of corrosion.
3. Intercell bus link integrity.
4. Battery cable insulation damage and contaminated surfaces.
5. Operating conditions of ventilating equipment.
6. Visual check of electrolyte level.

B. Electrical Tests:

1. Measure:
   a. Bank charging voltage.
   b. Individual cell voltage.

c. Electrolyte specific gravity in each cell.
d. Measured test values to be in accordance with manufacturer's published data.

2. Verify During Recharge Mode:
   a. Charging rates from charger.
   b. Individual cell acceptance of charge.
3. Load tests for integrity and capacity; test values in accordance with ANSI 450.

3.34 STANDBY AND EMERGENCY GENERATOR SYSTEMS

A. Perform tests and commissioning in accordance with CSA C282 (latest) Section 10 – Initial Installation Performance Test. Tests include, but are not limited to the requirements below.

B. Visual and Mechanical Inspection:
1. Proper grounding.
2. Blockage of ventilating passageways.
3. Proper operation of jack water heaters.
4. Integrity of engine cooling and fuel supply systems.
5. Excessive mechanical and electrical noise.
6. Overheating of engine or generator.
7. Proper installation of vibration isolators.
8. Proper cooling liquid type and level.
9. Operate Engine-Generator and Check For:
   a. Excessive mechanical and electrical noise.
   b. Overheating.
   c. Correct rotation.
   d. Check resistance temperature detectors or generator inherent thermal protectors for functionability and proper operation.
   e. Excessive vibration.
10. Verify that voltage regulator and governor operation will cause unit speed and output voltage to stabilize at proper values within reasonable length of time.
11. Proper operation of meters and instruments.
12. Compare generator nameplate rating and connection with one-line diagram.
13. All other tests in accordance with the manufacturer's recommended testing and commissioning requirements.

C. Electrical and Mechanical Tests:
1. Alternator insulation shall be tested ("megger") in compliance with IEEE standard 43-2000 (200kW and above).
2. Ensure the engine starts (both hot and cold) within 15 seconds.
3. Cold start test by interrupting normal power source with test load consisting of connected system load to verify:
   a. Transfer switch operation.
   b. Automatic starting operation.
   c. Operating ability of engine-generator.
   d. Overcurrent devices capability to withstand inrush currents.
   e. Verify no load frequency and voltage to be as specified

4. Phase rotation tests.
5. Test Engine Protective Shutdown Features For:
   a. Low oil pressure.
   b. Overtemperature.
   c. Overspeed.
6. Vibration levels in accordance with manufacturer's recommendations.
7. Load bank test or system load tests as required by the Contract Administrator:
   a. 25 percent applied load for 30 minutes.
   b. 50 percent applied load for 30 minutes.
   c. 75 percent applied load for 30 minutes.
   d. 100 percent applied load for 4 hours.
   e. Load test results to demonstrate ability of unit to deliver rated load for test period.
8. One-Step Rated kW Load Pickup Test:
   a. Perform test immediately after performing load bank test.
   b. Apply rated load, minus largest rated hp motor, to generator.
   c. Start largest rated hp motor and record voltage drop for 20 cycles minimum with high-speed chart recorder or digital storage oscilloscope.
   d. Compare voltage drop with maximum allowable voltage dip for specified starting situation.
9. Record the following items at first load acceptance, and at 15 minute intervals:
   a. Time delay on start.
   b. The cranking time until the engine starts and runs.
   c. The time required to come up to operating speed.
   d. The time required for each life safety equipment transfer switch to be transferred to the emergency position.
   e. The time required to achieve steady-state condition, with all switches transferred to the emergency position.
   f. The time delay(s) for the connection of any loads arranged to be connected to the emergency supply later than the life safety equipment.
   g. The voltage, frequency and amperes at start-up, at any observed change in load, and at full load.
   h. The engine oil pressure, water temperature, and the battery charge rate 1 minute after start, at 5 minute intervals for the first 15 minutes, and at 15 minute intervals thereafter.
   i. The time delay on retransfer for each transfer switch.
   j. The time delay on engine cool-down and shutdown.
10. Cycle crank test shall be demonstrated by preventing the engine from running (any method recommended by the manufacturer may be used). The mode selector shall then be placed in the "Manual" position to cause the engine to crank.
11. All safety shutdowns and alarms as specified in CSA C282 Table 1 shall be verified and tested.
12. Factory authorized manufacturer's representative shall deliver operator training to ensure that appropriately qualified personnel are trained to operate the emergency power systems.
13. The test results shall be saved for comparison with future routine scheduled analyses.

14. All other tests in accordance with the manufacturer's testing and commissioning requirements.

3.35 STATIC UNINTERRUPTIBLE POWER SUPPLY (UPS)

A. Testing configuration shall not interfere with the supply of power to the load ultimately supplied by the UPS.

B. Provide a complete UPS testing report in accordance with the manufacturer's recommendations and these documents.

C. Test equipment:
1. Instruments used during testing are to have been calibrated within one year prior to the test date. Include a copy of the calibration certificate
2. Load bank for testing, adjustable to 110 % of system rated output power.
   a. Load bank to be CSA, ULC approved or equivalent.

D. Provide competent field personnel to perform test, adjustments and instruction on UPS equipment.

E. Perform a visual inspection and identify deficiencies. Inspection to include:
1. Materials, workmanship, and assembly conform with design requirements.
2. Parts are new and free of defects.
3. Accessories are present.
4. Inspect equipment for signs of damage.
5. Verify installation per drawings.
6. Inspect cabinets for foreign objects.
7. Verify neutral and ground conductors are properly sized and configured.
8. Battery and components are not damaged.
9. Battery cells are of identical construction.
10. Inspect battery for proper polarity.
11. Confirm polarity of connections to inverter are correct.
12. Verify all printed circuit boards are configured properly.

F. Mechanical Inspection
1. Check all control wiring connections for tightness.
2. Check all power wiring.
3. Check all terminals screws, nuts, and/or spade lugs for tightness.

G. Electrical Inspection
1. Confirm input voltage and phase rotation is correct.
2. Verify control transformer connections are correct for voltages being used.
3. Verify UPS control wiring and terminations.
4. Assure connection and voltage of the battery string(s).
5. Verify neutral and ground conductors are properly landed.
6. Inspect external maintenance bypass switch for proper terminations and phasing.

H. Demonstrate System Operation:
1. System start-up and shut down.

2. Verify proper firmware control functions.
3. Verify proper firmware bypass operations.
4. System switchover to and from internal and external bypass.
5. Simulate utility power failure.
6. Verify proper charger operations.
7. Adjustable settings.

I. UPS Measurement Test:
1. Test and record all UPS internal measurements against calibrated test instruments for 50% and 100% output load. The tests shall include:
   a. Output voltage, current, frequency, and power.
   b. Battery voltage and current.
   c. Input voltage, current, and power.
   d. Bypass voltage and frequency.

J. Steady Load Test:
1. Switch system onto AC mains, start UPS and connect load bank at UPS rated load.
2. Operate system at full rated load for one (1) hour.
3. Record data, utilizing UPS display, at start of test and every 10 minutes thereafter. including:
   a. Output voltage phase to phase, phase to neutral.
   b. Output current each phase.
   c. Output frequency.
   d. Output kW.
   e. Battery voltage and current

K. Battery Testing:
1. Charge battery to ensure cells are fully charged. When voltage reaches steady value at end of charge, record:
   a. Ambient Temperature.
   b. Temperature of each cell.
   c. Voltage of each cell.
   d. Voltage of overall battery string.
   e. Charger output voltage and current
   f. AC ripple current and voltage imposed on the battery.
   g. Internal ohmic values of each cell and battery.
   h. Measure intercell connection resistances for all cells.

L. Battery Load Test
1. Charge battery to ensure cells are fully charged.
2. Connect the load bank to the UPS output, configured for the UPS rated output power.
3. Record data, utilizing UPS display, at start of test and every 5 minutes thereafter. Including:
   a. Output voltage phase to phase, phase to neutral
   b. Output current each phase.
   c. Output frequency.

d. Output kW.
e. Battery voltage and current.

4. Upon the Battery Low Alarm, record:
   a. The test time expired.
   b. Battery voltage and current.
5. Allow the UPS to automatically shutdown on low battery. Record the time of automatic shutdown

M. PLC Alarms
1. With the assistance of City of Winnipeg personnel, test the UPS alarms transmitted to the PLC system.

N. Document, sign, and date test results. Include all documentation in the O & M manuals.

3.36 POWER FACTOR CORRECTION / HARMONICS FILTERS

A. Visual and Mechanical Inspection:
1. Note the equipment nameplate data for inclusion in the report.
2. Record all adjustable settings.
3. Inspect physical and mechanical condition.
4. Inspect anchorage, alignment, and grounding.
5. Torque all accessible bolted power connections.
6. Verify capacitors are connected in proper configuration.
7. For units switched with motors, verify that capacitor rating does not exceed maximum allowable design value.

B. Electrical Tests:
1. Insulation resistance, each pole-to-case and pole-to-ground; values in accordance with manufacturer's recommendation.
   a. Units rated less than 600V, test voltage is to be 500 VDC.
   b. Units rated greater than or equal to 600V (but less than 1000V), test voltage is to be 1000 VDC.
2. Capacitance for pole-to-pole combinations; ratings differing more than plus 15, minus 0 percent from manufacturer's values shall be replaced by contractor.
3. Resistance of internal discharge arrestors with analog volt-ohmmeter; resistance to be in excess of 2 megohms.
4. Perform a contact/pole-resistance test.
5. Verify voltage discharge time.

C. If power and/or control fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

D. Measure and record capacitance of each capacitor.

E. Measure and record resistance of discharge resistors, if present.

F. Perform functional testing to verify operation of unit.

3.37 THERMOGRAPHIC INSPECTION

A. Camera
   1. Minimum IR resolution:320 x 240 pixels.
   2. Minimum visible resolution: 640 x 480 pixels.

B. Thermographic insepections and photographs shall be completed in accordance with the recommendations of the Standard for Infrared Inspection of Electrical Systems and Rotating Equipment published by the Infraspection Institute.

C. Provide a thermographic survey of connections associated with incoming service conductors, bus work, and branch feeder conductors and larger at each:
   1. Medium voltage switchgear.
   2. Low voltage switchgear, greater than 225A
   3. Panelboards greater than 225A.
   4. Motor control centers
   5. Transfer switches
   6. All other equipment specified herein which requires a thermographic survey.

D. Provide a thermographic survey of feeder conductors terminating at:
   1. Motors rated 50 HP and larger
   2. Transfer switches.
   3. Engine-generators.

E. Inspection and testing shall be comprised of the following:
   1. Remove all necessary covers prior to thermographic inspection.
   2. Equipment to be inspected shall include all current-carrying devices.
   3. Test Parameters:
      a. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1 °C at 30 °C.
      b. Equipment shall detect emitted radiation and convert detected radiation to a visual signal.
      c. Thermographic surveys should be performed during periods of maximum possible loading but not less than 40% of rated load of the electrical equipment being inspected. Coordinate with City as required.
      d. Note all temperature differences larger than 1°C. Investigate all temperature differences larger than 4 °C.
      e. Re-inspect deficient areas with the thermographic camera following repairs and corrections, for deficient areas identified.

F. Provide a report which shall include the following:
   1. Description of the equipment tested.
   2. Discrepancies found.
   3. Temperature difference between the area of concern and the reference area.
   4. Probable cause of temperature difference.
   5. Identify any repairs made during the thermographic inspection. If no repairs were made, provide recommended action for repair.

6. Areas inspected. Identify inaccessible and / or unobservable areas and / or equipment.
7. Identify load conditions at time of inspection.
8. Provide photographs and thermograms of all areas investigated, with deficient areas identified. Visible light photographs and thermograms shall align in a manner to allow for easy identification of the components shown on the thermograms.
9. Provide thermograms of all deficient areas corrected, and identify the load conditions at the time of re-inspection.

END OF SECTION