SECTION 15950

TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.02 SUMMARY

A. This Section includes TAB to produce design objectives for the following:

1. Air Systems:

a. Constant-volume air systems.
b. Variable-air-volume systems.

2. Hydronic Piping Systems:

a. Constant-flow systems.

3. HVAC equipment quantitative-performance settings.
4. Kitchen hood airflow balancing.
5. Space pressurization testing and adjusting.
6. Vibration measuring.
7. Sound level measuring.
8. Indoor-air quality measuring.
9. Verifying that automatic control devices are functioning properly.
10. Reporting results of activities and procedures specified in this Section.

1.03 DEFINITIONS

A. Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

B. Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to indicated quantities.

C. Barrier or Boundary: Construction, either vertical or horizontal, such as walls, floors, and ceilings that are designed and constructed to restrict the movement of airflow, smoke, odors, and other pollutants.

D. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

E. NC: Noise criteria.

F. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

G. RC: Room criteria.

H. Report Forms: Test data sheets for recording test data in logical order.

I. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

J. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

K. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

L. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

M. TAB: Testing, adjusting, and balancing.

N. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.

O. Test: A procedure to determine quantitative performance of systems or equipment.

P. Testing, Adjusting, and Balancing (TAB) Firm: The entity responsible for performing and reporting TAB procedures.

1.04 SUBMITTALS

A. Qualification Data: Within 30 days from Contractor's Notice to Proceed, submit 2 copies of evidence that TAB firm and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within 30 days from Contractor's Notice to Proceed, submit 2 copies of the Contract Documents review report as specified in Part 3.

C. Certified TAB Reports: Submit two copies of reports prepared, as specified in this Section, on approved forms certified by TAB firm.

D. Sample Report Forms: Submit two sets of sample TAB report forms.

E. Warranties specified in this Section.

1.05 QUALITY ASSURANCE

A. TAB Firm Qualifications: Engage a TAB firm certified by either AABC or NEBB.

B. TAB Conference: Meet with Government's and Contracting Officer's representatives on approval of TAB strategies and procedures plan to develop a mutual understanding of the details. Ensure the participation of TAB team members, equipment manufacturers' authorized service representatives, HVAC controls installers, and other support personnel. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items: Include at least the following:

a. Submittal distribution requirements.
b. The Contract Documents examination report.
c. TAB plan.
d. Work schedule and Project-site access requirements.
e. Coordination and cooperation of trades and subcontractors.
f. Coordination of documentation and communication flow.

C. Certification of TAB Reports: Certify TAB field data reports. This certification includes the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that TAB team complied with approved TAB plan and the procedures specified and referenced in this Specification.

D. TAB Report Forms: Use standard forms from AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems." NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems."

E. Instrumentation Type, Quantity, and Accuracy: As described in AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," Section II, "Required Instrumentation for NEBB Certification."

F. Instrumentation Calibration: Calibrate instruments at least every six months or more frequently if required by instrument manufacturer.

1. Keep an updated record of instrument calibration that indicates date of calibration and the name of party performing instrument calibration.

1.06 PROJECT CONDITIONS

A. Partial Government Occupancy: Government may occupy completed areas of building before Substantial Completion. Cooperate with Government during TAB operations to minimize conflicts with Government's operations.

1.07 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

B. Notice: Provide seven days' advance notice for each test. Include scheduled test dates and times.

C. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.08 WARRANTY

A. National Project Performance Guarantee: Provide a guarantee on AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" forms stating that AABC will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee includes the following provisions:

B. Special Guarantee: Provide a guarantee on NEBB forms stating that NEBB will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee shall include the following provisions:

1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

1. Contract Documents are defined in the General and Supplementary Conditions of Contract.
2. Verify that balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine Project Record Documents described in Division 1 Section "Project Record Documents."

D. Examine design data, including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine equipment performance data including fan and pump curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems--Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.

F. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual Sections have been performed.

G. Examine system and equipment test reports.

H. Examine HVAC system and equipment installations to verify that indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

I. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

J. Examine HVAC equipment to ensure that clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

K. Examine terminal units, such as variable-air-volume boxes, to verify that they are accessible and their controls are connected and functioning.

L. Examine plenum ceilings used for supply air to verify that they are airtight. Verify that pipe penetrations and other holes are sealed.

M. Examine strainers for clean screens and proper perforations.

N. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.

O. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

P. Examine system pumps to ensure absence of entrained air in the suction piping.

Q. Examine equipment for installation and for properly operating safety interlocks and controls.

R. Examine automatic temperature system components to verify the following:

1. Dampers, valves, and other controlled devices are operated by the intended controller.
2. Dampers and valves are in the position indicated by the controller.

3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions. This includes dampers in multizone units, mixing boxes, and variable-air-volume terminals.
4. Automatic modulating and shutoff valves, including two-way valves and three-way mixing and diverting valves, are properly connected.
5. Thermostats are located to avoid adverse effects of sunlight, drafts, and cold walls.
6. Sensors are located to sense only the intended conditions.
7. Sequence of operation for control modes is according to the Contract Documents.
8. Controller set points are set at indicated values.
9. Interlocked systems are operating.
10. Changeover from heating to cooling mode occurs according to indicated values.

S. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.02 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system readiness checks and prepare system readiness reports. Verify the following:

1. Permanent electrical power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance and fire dampers are open.
6. Isolating and balancing valves are open and control valves are operational.
7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.03 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" and NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

C. Mark equipment and balancing device settings with paint or other suitable, permanent identification material, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, to show final settings.

D. Take and report testing and balancing measurements in inch-pound (IP) and metric (SI) units.

3.04 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct airflow measurements.

E. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling unit components.

L. Check for proper sealing of air duct system.

3.05 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure fan static pressures to determine actual static pressure as follows:

a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
b. Measure static pressure directly at the fan outlet or through the flexible connection.
c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

2. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

a. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.

3. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.
4. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
5. Obtain approval from Contracting Officer for adjustment of fan speed higher or lower than indicated speed. Make required adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.
6. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full cooling, full heating, economizer, and any other operating modes to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure terminal outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.06 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a maximum set-point

airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.

B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set outside-air dampers at minimum, and return- and exhaust-air dampers at a position that simulates full-cooling load.
2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within indicated airflow.
4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.

    a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.

6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
8. Record the final fan performance data.

3.07 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check expansion tank liquid level.
3. Check makeup-water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation and set at indicated flow.

5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.08 PROCEDURES FOR HYDRONIC SYSTEMS

A. Measure water flow at pumps. Use the following procedures, except for positive-displacement pumps:

1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
4. Report flow rates that are not within plus or minus 5 percent of design.

B. Set calibrated balancing valves, if installed, at calculated presettings.

C. Measure flow at all stations and adjust, where necessary, to obtain first balance.

1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

D. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than indicated flow.

E. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:

1. Determine the balancing station with the highest percentage over indicated flow.
2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
3. Record settings and mark balancing devices.

F. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.

G. Measure the differential-pressure control valve settings existing at the conclusions of balancing.

3.09 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer, model, and serial numbers.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass for the controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

3.10 PROCEDURES FOR CHILLERS

A. Balance water flow through the evaporator to within specified tolerances of indicated flow with all pumps operating. With the chiller operating, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with the chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
3. Power factor if factory-installed instrumentation is furnished for measuring kilowatt.
4. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatt.
5. Capacity: Calculate in tons of cooling.
6. Air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.11 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record compressor data.

3.12 PROCEDURES FOR BOILERS

A. If hydronic, measure entering- and leaving-water temperatures and water flow.

3.13 PROCEDURES FOR HEAT-TRANSFER COILS

A. Water Coils: Measure the following data for each coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

B. Electric-Heating Coils: Measure the following data for each coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load and at each incremental stage.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Refrigerant Coils: Measure the following data for each coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.14 PROCEDURES FOR TEMPERATURE MEASUREMENTS

A. During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.

B. Measure indoor wet- and dry-bulb temperatures every other hour for a period of two successive eight-hour days, in each separately controlled zone, to prove correctness of final temperature settings. Measure when the building or zone is occupied.

C. Measure outside-air, wet- and dry-bulb temperatures.

3.15 PROCEDURES FOR COMMERCIAL KITCHEN HOODS

A. Measure, adjust, and record the airflow of each kitchen hood. For kitchen hoods designed with integral makeup air, measure and adjust the exhaust and makeup airflow. Measure airflow by duct Pitot-tube traverse. If a duct Pitot-tube traverse is not possible, provide an explanation in the report of the reason(s) why and also the reason why the method used was chosen.

1. Install welded test ports in the sides of the exhaust duct for the duct Pitot-tube traverse. Install each test port with a threaded cap that is liquid tight.

B. After balancing is complete, do the following:

1. Measure and record the static pressure at the hood exhaust-duct connection.

2. Measure and record the hood face velocity. Make measurements at multiple points across the face of the hood. Perform measurements at a maximum of 12 inches (300 mm) between points and between any point and the perimeter. Calculate the average of the measurements recorded. Verify that the hood average face velocity complies with the Contract Documents and governing codes.
3. Check the hood for capture and containment of smoke using a smoke emitting device. Observe the smoke pattern. Make adjustments to room airflow patterns to achieve optimum results.

C. Visually inspect the hood exhaust duct throughout its entire length in compliance with authorities having jurisdiction. Begin at the hood connection and end at the point it discharges outdoors. Report findings.

1. Check duct slopes as required.
2. Verify that duct access is installed as required.
3. Verify that point of termination is as required.
4. Verify that duct air velocity is within the range required.
5. Verify that duct is within a fire-rated enclosure.

D. Report deficiencies.

3.16 PROCEDURES FOR SOUND-LEVEL MEASUREMENTS

A. Perform sound-pressure-level measurements with an octave-band analyzer complying with ANSI S1.4 for Type 1 sound-level meters and ANSI S1.11 for octave-band filters. Comply with requirements in ANSI S1.13, unless otherwise indicated.

B. Calibrate sound meters before each day of testing. Use a calibrator provided with the sound meter complying with ANSI S1.40 and that has NIST certification.

C. Use a microphone that is suitable for the type of sound levels measured. For areas where air velocities exceed 100 fpm (0.51 m/s), use a windscreen on the microphone.

D. Perform sound-level testing after air and water balancing and equipment testing are complete.

E. Close windows and doors to the space.

F. Perform measurements when the space is not occupied and when the occupant noise level from other spaces in the building and outside are at a minimum.

G. Clear the space of temporary sound sources so unrelated disturbances will not be measured. Position testing personnel during measurements to achieve a direct line-of-sight between the sound source and the sound-level meter.

H. Take sound measurements at a height approximately 48 inches (1200 mm) above the floor and at least 36 inches (900 mm) from a wall, column, and other large surface capable of altering the measurements.

I. Take sound measurements in dBA and in each of the 8 unweighted octave bands in the frequency range of 63 to 8000 Hz.

J. Take sound measurements with the HVAC systems off to establish the background sound levels and take sound measurements with the HVAC systems operating.

1. Calculate the difference between measurements. Apply a correction factor depending on the difference and adjust measurements.

K. Perform sound testing for each of the following space types. For each space type tested, select a measurement location that has the greatest sound level. If testing multiple locations for each space type, select at least one location that is near and at least one location that is remote from the predominant sound source.

1. Private office.
2. Open office area.
3. Conference room.
4. Auditorium/large meeting room/lecture hall.
5. Classroom/training room.
6. Each space with a noise criterion of RC or NC 25 or lower.
7. Each space with an indicated noise criterion of RC or NC 35 and lower that is adjacent to a mechanical equipment room or roof mounted equipment.
8. Inside each mechanical equipment room.

3.17 PROCEDURES FOR INDOOR-AIR QUALITY MEASUREMENTS

A. After air balancing is complete and with HVAC systems operating at indicated conditions, perform indoor-air quality testing.

B. Observe and record the following conditions for each HVAC system:

1. The distance between the outside-air intake and the closest exhaust fan discharge, cooling tower, flue termination, or vent termination.
2. Specified filters are installed. Check for leakage around filters.
3. Cooling coil drain pans have a positive slope to drain.
4. Cooling coil condensate drain trap maintains an air seal.
5. Evidence of water damage.
6. Insulation in contact with the supply, return, and outside air is dry and clean.

C. Measure and record indoor conditions served by each HVAC system. Make measurements at multiple locations served by the system if required to satisfy the following:

1. Most remote area.
2. One location per floor.
3. One location for every 5000 sq. ft. (500 sq. m).

D. Measure and record the following indoor conditions for each location two times at two-hour intervals, and in accordance with ASHRAE 113:

1. Temperature.
2. Relative humidity.
3. Air velocity.
4. Concentration of carbon dioxide (ppm).
5. Concentration of carbon monoxide (ppm).
6. Nitrogen oxides (ppm).
7. Formaldehyde (ppm).

3.18 TEMPERATURE-CONTROL VERIFICATION

A. Verify that controllers are calibrated and commissioned.

B. Check transmitter and controller locations and note conditions that would adversely affect control functions.

C. Record controller settings and note variances between set points and actual measurements.

D. Check the operation of limiting controllers (i.e., high- and low-temperature controllers).

E. Check free travel and proper operation of control devices such as damper and valve operators.

F. Check the sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water flow measurements. Note the speed of response to input changes.

G. Check the interaction of electrically operated switch transducers.

H. Check the interaction of interlock and lockout systems.

I. Record voltages of power supply and controller output. Determine whether the system operates on a grounded or nongrounded power supply.

J. Note operation of electric actuators using spring return for proper fail-safe operations.

3.19 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus 5 to plus 10 percent.
2. Air Outlets and Inlets: 0 to minus 10 percent.
3. Heating-Water Flow Rate: 0 to minus 10 percent.
4. Cooling-Water Flow Rate: 0 to minus 5 percent.

3.20 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to

HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: As Work progresses, prepare reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.21 FINAL REPORT

A. General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing engineer.

1. Include a list of instruments used for procedures, along with proof of calibration.

C. Final Report Contents: In addition to certified field report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance, but do not include Shop Drawings and Product Data.

D. General Report Data: In addition to form titles and entries, include the following data in the final report, as applicable:

1. Title page.
2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB firm who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.

13. Data for terminal units, including manufacturer, type size, and fittings.
14. Notes to explain why certain final data in the body of reports varies from indicated values.
15. Test conditions for fans and pump performance forms including the following:

    a. Settings for outside-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Inlet vane settings for variable-air-volume systems.
    g. Settings for supply-air, static-pressure controller.
    h. Other system operating conditions that affect performance.

E. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outside, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

F. Air-Handling Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data: Include the following:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.
    e. Manufacturer's serial number.
    f. Unit arrangement and class.
    g. Discharge arrangement.
    h. Sheave make, size in inches (mm), and bore.
    i. Sheave dimensions, center-to-center, and amount of adjustments in inches (mm).
    j. Number of belts, make, and size.
    k. Number of filters, type, and size.

2. Motor Data:

    a. Make and frame type and size.
    b. Horsepower and rpm.
    c. Volts, phase, and hertz.
    d. Full-load amperage and service factor.
    e. Sheave make, size in inches (mm), and bore.
    f. Sheave dimensions, center-to-center, and amount of adjustments in inches (mm).

3. Test Data (Indicated and Actual Values):

   a. Total airflow rate in cfm (L/s).
   b. Total system static pressure in inches wg (Pa).
   c. Fan rpm.
   d. Discharge static pressure in inches wg (Pa).
   e. Filter static-pressure differential in inches wg (Pa).
   f. Preheat coil static-pressure differential in inches wg (Pa).
   g. Cooling coil static-pressure differential in inches wg (Pa).
   h. Heating coil static-pressure differential in inches wg (Pa).
   i. Outside airflow in cfm (L/s).
   j. Return airflow in cfm (L/s).
   k. Outside-air damper position.
   l. Return-air damper position.
   m. Vortex damper position.

G. Apparatus-Coil Test Reports:

1. Coil Data:

   a. System identification.
   b. Location.
   c. Coil type.
   d. Number of rows.
   e. Fin spacing in fins per inch (mm) o.c.
   f. Make and model number.
   g. Face area in sq. ft. (sq. m).
   h. Tube size in NPS (DN).
   i. Tube and fin materials.
   j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

   a. Airflow rate in cfm (L/s).
   b. Average face velocity in fpm (m/s).
   c. Air pressure drop in inches wg (Pa).
   d. Outside-air, wet- and dry-bulb temperatures in deg F (deg C).
   e. Return-air, wet- and dry-bulb temperatures in deg F (deg C).
   f. Entering-air, wet- and dry-bulb temperatures in deg F (deg C).
   g. Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).
   h. Water flow rate in gpm (L/s).
   i. Water pressure differential in feet of head or psig (kPa).
   j. Entering-water temperature in deg F (deg C).
   k. Leaving-water temperature in deg F (deg C).
   l. Refrigerant expansion valve and refrigerant types.
   m. Refrigerant suction pressure in psig (kPa).
   n. Refrigerant suction temperature in deg F (deg C).
   o. Inlet steam pressure in psig (kPa).

H. Gas-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and unit size.
e. Manufacturer's serial number.
f. Fuel type in input data.
g. Output capacity in Btuh (kW).
h. Ignition type.
i. Burner-control types.
j. Motor horsepower and rpm.
k. Motor volts, phase, and hertz.
l. Motor full-load amperage and service factor.
m. Sheave make, size in inches (mm), and bore.
n. Sheave dimensions, center-to-center, and amount of adjustments in inches (mm).

2. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm (L/s).
b. Entering-air temperature in deg F (deg C).
c. Leaving-air temperature in deg F (deg C).
d. Air temperature differential in deg F (deg C).
e. Entering-air static pressure in inches wg (Pa).
f. Leaving-air static pressure in inches wg (Pa).
g. Air static-pressure differential in inches wg (Pa).
h. Low-fire fuel input in Btuh (kW).
i. High-fire fuel input in Btuh (kW).
j. Manifold pressure in psig (kPa).
k. High-temperature-limit setting in deg F (deg C).
l. Operating set point in Btuh (kW).
m. Motor voltage at each connection.
n. Motor amperage for each phase.
o. Heating value of fuel in Btuh (kW).

I. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Coil identification.
d. Capacity in Btuh (kW).
e. Number of stages.
f. Connected volts, phase, and hertz.

g. Rated amperage.
h. Airflow rate in cfm (L/s).
i. Face area in sq. ft. (sq. m).
j. Minimum face velocity in fpm (m/s).

2. Test Data (Indicated and Actual Values):

a. Heat output in Btuh (kW).
b. Airflow rate in cfm (L/s).
c. Air velocity in fpm (m/s).
d. Entering-air temperature in deg F (deg C).
e. Leaving-air temperature in deg F (deg C).
f. Voltage at each connection.
g. Amperage for each phase.

J. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches (mm), and bore.
h. Sheave dimensions, center-to-center, and amount of adjustments in inches (mm).

2. Motor Data:

a. Make and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches (mm), and bore.
f. Sheave dimensions, center-to-center, and amount of adjustments in inches (mm).
g. Number of belts, make, and size.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm (L/s).
b. Total system static pressure in inches wg (Pa).
c. Fan rpm.
d. Discharge static pressure in inches wg (Pa).
e. Suction static pressure in inches wg (Pa).

K. Round and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

    a. System and air-handling unit number.
    b. Location and zone.
    c. Traverse air temperature in deg F (deg C).
    d. Duct static pressure in inches wg (Pa).
    e. Duct size in inches (mm).
    f. Duct area in sq. ft. (sq. m).
    g. Indicated airflow rate in cfm (L/s).
    h. Indicated velocity in fpm (m/s).
    i. Actual airflow rate in cfm (L/s).
    j. Actual average velocity in fpm (m/s).
    k. Barometric pressure in psig (Pa).

L. Air-Terminal-Device Reports:

1. Unit Data:

    a. System and air-handling unit identification.
    b. Location and zone.
    c. Test apparatus used.
    d. Area served.
    e. Air-terminal-device make.
    f. Air-terminal-device number from system diagram.
    g. Air-terminal-device type and model number.
    h. Air-terminal-device size.
    i. Air-terminal-device effective area in sq. ft. (sq. m).

2. Test Data (Indicated and Actual Values):

    a. Airflow rate in cfm (L/s).
    b. Air velocity in fpm (m/s).
    c. Preliminary airflow rate as needed in cfm (L/s).
    d. Preliminary velocity as needed in fpm (m/s).
    e. Final airflow rate in cfm (L/s).
    f. Final velocity in fpm (m/s).
    g. Space temperature in deg F (deg C).

M. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

    a. System and air-handling unit identification.
    b. Location and zone.
    c. Room or riser served.
    d. Coil make and size.
    e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm (L/s).
b. Entering-water temperature in deg F (deg C).
c. Leaving-water temperature in deg F (deg C).
d. Water pressure drop in feet of head or psig (kPa).
e. Entering-air temperature in deg F (deg C).
f. Leaving-air temperature in deg F (deg C).

N. Packaged Chiller Reports:

1. Unit Data:

a. Unit identification.
b. Make and model number.
c. Manufacturer's serial number.
d. Refrigerant type and capacity in gal. (L).
e. Starter type and size.
f. Starter thermal protection size.
g. Compressor make and model number.
h. Compressor manufacturer's serial number.

2. Air-Cooled Condenser Test Data (Indicated and Actual Values):

a. Refrigerant pressure in psig (kPa).
b. Refrigerant temperature in deg F (deg C).
c. Entering- and leaving-air temperature in deg F (deg C).

3. Evaporator Test Reports (Indicated and Actual Values):

a. Refrigerant pressure in psig (kPa).
b. Refrigerant temperature in deg F (deg C).
c. Entering-water temperature in deg F (deg C).
d. Leaving-water temperature in deg F (deg C).
e. Entering-water pressure in feet of head or psig (kPa).
f. Water pressure differential in feet of head or psig (kPa).

4. Compressor Test Data (Indicated and Actual Values):

a. Suction pressure in psig (kPa).
b. Suction temperature in deg F (deg C).
c. Discharge pressure in psig (kPa).
d. Discharge temperature in deg F (deg C).
e. Oil pressure in psig (kPa).
f. Oil temperature in deg F (deg C).
g. Voltage at each connection.
h. Amperage for each phase.
i. Kilowatt input.
j. Crankcase heater kilowatt.
k. Chilled-water control set point in deg F (deg C).
l. Condenser-water control set point in deg F (deg C).

m. Refrigerant low-pressure-cutoff set point in psig (kPa).
n. Refrigerant high-pressure-cutoff set point in psig (kPa).

5. Refrigerant Test Data (Indicated and Actual Values):

a. Oil level.
b. Refrigerant level.
c. Relief valve setting in psig (kPa).
d. Unloader set points in psig (kPa).
e. Percentage of cylinders unloaded.
f. Bearing temperatures in deg F (deg C).
g. Vane position.
h. Low-temperature-cutoff set point in deg F (deg C).

O. Compressor and Condenser Reports: For refrigerant side of unitary systems, stand-alone refrigerant compressors, air-cooled condensing units, or water-cooled condensing units, include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Unit make and model number.
d. Compressor make.
e. Compressor model and serial numbers.
f. Refrigerant weight in lb (kg).
g. Low ambient temperature cutoff in deg F (deg C).

2. Test Data (Indicated and Actual Values):

a. Inlet-duct static pressure in inches wg (Pa).
b. Outlet-duct static pressure in inches wg (Pa).
c. Entering-air, dry-bulb temperature in deg F (deg C).
d. Leaving-air, dry-bulb temperature in deg F (deg C).
e. Condenser entering-water temperature in deg F (deg C).
f. Condenser leaving-water temperature in deg F (deg C).
g. Condenser-water temperature differential in deg F (deg C).
h. Condenser entering-water pressure in feet of head or psig (kPa).
i. Condenser leaving-water pressure in feet of head or psig (kPa).
j. Condenser-water pressure differential in feet of head or psig (kPa).
k. Control settings.
l. Unloader set points.
m. Low-pressure-cutout set point in psig (kPa).
n. High-pressure-cutout set point in psig (kPa).
o. Suction pressure in psig (kPa).
p. Suction temperature in deg F (deg C).
q. Condenser refrigerant pressure in psig (kPa).
r. Condenser refrigerant temperature in deg F (deg C).
s. Oil pressure in psig (kPa).

t. Oil temperature in deg F (deg C).
u. Voltage at each connection.
v. Amperage for each phase.
w. Kilowatt input.
x. Crankcase heater kilowatt.
y. Number of fans.
z. Condenser fan rpm.
aa. Condenser fan airflow rate in cfm (L/s).
bb. Condenser fan motor make, frame size, rpm, and horsepower.
cc. Condenser fan motor voltage at each connection.
dd. Condenser fan motor amperage for each phase.

P. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Service.
d. Make and size.
e. Model and serial numbers.
f. Water flow rate in gpm (L/s).
g. Water pressure differential in feet of head or psig (kPa).
h. Required net positive suction head in feet of head or psig (kPa).
i. Pump rpm.
j. Impeller diameter in inches (mm).
k. Motor make and frame size.
l. Motor horsepower and rpm.
m. Voltage at each connection.
n. Amperage for each phase.
o. Full-load amperage and service factor.
p. Seal type.

2. Test Data (Indicated and Actual Values):

a. Static head in feet of head or psig (kPa).
b. Pump shutoff pressure in feet of head or psig (kPa).
c. Actual impeller size in inches (mm).
d. Full-open flow rate in gpm (L/s).
e. Full-open pressure in feet of head or psig (kPa).
f. Final discharge pressure in feet of head or psig (kPa).
g. Final suction pressure in feet of head or psig (kPa).
h. Final total pressure in feet of head or psig (kPa).
i. Final water flow rate in gpm (L/s).
j. Voltage at each connection.
k. Amperage for each phase.

Q. Boiler Test Reports:

1. Unit Data:

   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and type.
   e. Model and serial numbers.
   f. Fuel type and input in Btuh (kW).
   g. Number of passes.
   h. Ignition type.
   i. Burner-control types.
   j. Voltage at each connection.
   k. Amperage for each phase.

2. Test Data (Indicated and Actual Values):

   a. Operating pressure in psig (kPa).
   b. Operating temperature in deg F (deg C).
   c. Entering-water temperature in deg F (deg C).
   d. Leaving-water temperature in deg F (deg C).
   e. Number of safety valves and sizes in NPS (DN).
   f. Safety valve settings in psig (kPa).
   g. High-limit setting in psig (kPa).
   h. Operating-control setting.
   i. High-fire set point.
   j. Low-fire set point.
   k. Voltage at each connection.
   l. Amperage for each phase.
   m. Draft fan voltage at each connection.
   n. Draft fan amperage for each phase.
   o. Manifold pressure in psig (kPa).

R. Sound Measurement Reports: Record sound measurements on octave band and dBA test forms and on an NC or RC chart indicating the decibel level measured in each frequency band for both "background" and "HVAC system operating" readings. Record each tested location on a separate NC or RC chart. Record the following on the forms:

1. Date and time of test. Record each tested location on its own NC curve.
2. Sound meter manufacturer, model number, and serial number.
3. Space location within the building including floor level and room number.
4. Diagram or color photograph of the space showing the measurement location.
5. Time weighting of measurements, either fast or slow.
6. Description of the measured sound: steady, transient, or tonal.
7. Description of predominant sound source.

S. Indoor-Air Quality Measurement Reports for Each HVAC System:

1. HVAC system designation.
2. Date and time of test.
3. Outdoor temperature, relative humidity, wind speed, and wind direction at start of test.
4. Room number or similar description for each location.
5. Measurements at each location.
6. Observed deficiencies.

T. Instrument Calibration Reports:

1. Report Data:

a. Instrument type and make.
b. Serial number.
c. Application.
d. Dates of use.
e. Dates of calibration.

3.22 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional testing, inspecting, and adjusting during near-peak summer and winter conditions.

END OF SECTION 15950

SECTION 16010

BASIC ELECTRICAL REQUIREMENTS

PART 1 - GENERAL

1.01 GENERAL REQUIREMENTS

A. The General Conditions, General requirements and Division 1 issued for this project shall be considered part of the Electrical Specification, and the Contractor shall be bound by their requirements.

B. It is the intent of this specification and accompanying drawings to describe and indicate the manufacture, erection and installation of the equipment and connections to the work specified herein and shown on the drawings for this project. It is not intended that the specifications and drawings describe and indicate each piece of equipment required for installation, for where items are required for satisfactory installation and are considered to be the accepted practice of the trade, they shall be considered to be both specified and indicated.

C. It shall be understood that the Contractor as hereinafter mentioned shall be the Electrical Contractor, unless specifically noted otherwise.

D. The Contractor shall furnish all labor and material necessary for the complete and satisfactory installation and operation of all electrical work for this contract.

E. The Contractor shall assume the entire responsibility for the materials, workmanship, and satisfactory operation of the various electrical systems, and other work as specified herein and/or as shown on the drawings.

F. The Electrical Contractor shall schedule and coordinate all work in close cooperation with all contractors working on this project in accordance with Project Phasing.

1.02 WORK INCLUDED

A. The Contractor shall provide materials, labor, equipment and appliances required to furnish and install a completely operational, coordinated and tested electrical system and related work, including but not limited to:

1. Primary power ductbanks and conduits.
2. Secondary power ducts, conduits, cables, fittings and grounding.
3. Main distribution switchboards and panelboard systems.
4. Telephone and communication system ducts, raceways.
5. Building and site power distribution system conduits and cables.
6. Power, lighting and receptacle panelboards.
7. Disconnect switches for specified equipment including HVAC.
8. Wiring devices, switches, receptacles and multi-outlet assemblies.
9. Branch circuit conduit and wiring.

10. Equipment power wiring and connections.
11. Lighting fixtures and lamps systems.
12. Exterior site lighting, controls, poles, grounding, wiring and ducts.
13. Fire alarm system.
14. Security system.
15. Grounding systems.
16. Dry-type transformers and accessories.
17. Data system raceways, outlets and rack terminations.
18. Miscellaneous electrical equipment, devices, fittings, etc.
19. System tests with certified reports.
20. Operation and maintenance manuals (10 copies).
21. As-built drawing preparation (4 sets).
22. Work described under paragraph 1.03 and 1.04.
23. Padmount transformer foundations, grounding and conduit systems.
24. Electrical demolition requirements.
25. 400 hertz power supply set.
26. Lightning protection systems.

1.03 RELATED WORK

A. Division 11 – Equipment.

B. Division 15 - Mechanical.

1.04 WORK FURNISHED AND INSTALLED UNDER OTHER SECTIONS BUT WIRED UNDER THIS CONTRACT AS DEFINED ON CONTRACT DRAWINGS

A. Electric motor loads, as shown on the Drawings.

B. Unit heaters, cabinet heaters, water heaters, radiant heaters and electric heaters.

C. Mechanical equipment package units such as chillers, air conditioning and other HVAC units.

D. Kitchen equipment.

E. Overhead doors.

F. Paint spray booth.

G. Fuel dispensing equipment.

1.05 QUALITY ASSURANCE

A. The requirements of the national, state and local codes establish the minimum acceptable quality of workmanship and materials, and work shall conform thereto, unless more stringent requirements are indicated or specified by the Contract Documents.

B. Electrical equipment, installation, and workmanship shall comply with the latest edition of national, state and local codes, safety laws, and fire laws as applicable and establish minimum requirements. Special requirements which shall exceed these minimum requirements are indicated or specified by the Contract Documents.

1.06 PERMITS AND FEES

A. This Contractor shall obtain all permits required for construction and/or building occupancy in compliance with Federal, State and local requirements for this work. The costs of these permits will be paid by the Contractor. This shall include any Utility backcharges.

1.07 REGULATORY REQUIREMENTS

A. The installation, including any temporary services for construction, shall comply with state and local laws and regulations applying to electrical installations in the applicable City or Town, with applicable requirements of the National Electrical Code and its latest revisions and with the requirements of the Telephone Government and Power Companies where such requirements do not conflict with the laws and regulations in effect.

1.08 DEFINITIONS

A. The following definitions of terms and expressions used in this section are in addition to the listing given in Special Provisions.

1. "Provide" shall mean "furnish and install," unless otherwise indicated.

2. "Herein" shall mean the content of a particular section where this term appears.

3. "Indicated" shall mean "indicated on contract drawings."

4. "Concealed," where used in conjunction with conduit, junction boxes, outlet boxes and accessories, shall mean that they are hidden from sight as in trenches, chases, furred spaces, shafts or hung ceilings.

5. "Exposed," where used in conjunction with conduit, junction boxes, outlet boxes and accessories, shall mean that they are not "concealed" as defined herein above.

1.09 MATERIALS AND WORKMANSHIP

A. Materials shall be new and shall conform with the standard of the Underwriters' Laboratories, Inc. in every case where such a standard, listing or label has been established for the particular type of material in question.

B. Names of manufacturers, catalog numbers, models or types, when used in this section and the included drawings, are intended to indicate the standards of type and quality of material.

C. Where two or more units of the same class of equipment are required, these units shall be the product of a single manufacturer having a minimum of five years successful manufacturing of this equipment.

D. Substitutions: Shall be requested through submittal procedure provided with General Requirements. All substitutions shall be of equal quality and operation and shall require the approval of the Government and/or the Contracting Officer.

1.10 DRAWINGS

A. The drawings show the layout of the electrical system and indicate the approximate locations of outlets, apparatus and equipment. The runs of feeders and branches as indicated are schematic only. The exact routing of conduit shall be determined by the structural conditions and other obstructions. Field routing shall not be construed by the Contractor to mean that the design of the systems may be changed but refers only to physical runs of conduit between given points.

B. Consult contract and reference drawings available at time of installation which may affect the location of any outlets, apparatus and equipment to avoid possible interference and permit full coordination of work. The right to make any reasonable change in location of outlets, apparatus and equipment up to the time of roughing-in is reserved by the Government and/or the Contracting Officer.

C. It shall be the responsibility of this Contractor to see that electrical equipment such as junction and pull boxes, panelboards, switches, controls and such other apparatus as may require maintenance and operation from time to time is made easily accessible. Although the equipment may be shown on the Drawings in certain locations, the construction may disclose the fact that such locations do not make its position readily accessible. In such cases, this Contractor shall call the attention of the Government and/or the Contracting Officer to the condition before advancing the construction to a state where a change will reflect additional expenses.

D. Contractor is particularly cautioned in the running of conduit on process equipment to avoid blocking removal of such equipment requiring future maintenance.

1.11 RECORD DRAWINGS

A. Maintain at the job site a complete set of blueline prints of the electrical work on which shall be marked, clearly, neatly, accurately and promptly a record of the work done as the work progresses.

B. Record drawings shall conform to General Requirements.

1.12 SUBMITTALS

A. Submit shop drawings as required by these specifications and Section 01300.

B. Submit shop drawings giving dimensions and details of electrical design requirements.

C. Submit samples of plugs, receptacles, disconnect switches and other small parts as requested by the Government and/or the Contracting Officer.

D. General bulletins or catalogs will not be accepted as shop drawings unless the equipment on which approval is to be obtained is specifically marked and information pertaining to the item, including dimensions where required for installation, is included. These types of documents shall be certified as planned for construction by the Contractor.

E. Submit manufacturers notarized certificates of compliance for cable and other electric equipment.

F. Submit copies of electrical test reports.

1.13 GUARANTEE

A. The Contractor shall guarantee the electrical systems, including fixtures, to be free from short circuits, open circuits, loose connections, over-heating and such other defects.

1.14 EQUIPMENT AND SCAFFOLDING

A. The Contractor performing work under this section shall be responsible for furnishing tools and equipment, scaffolding and other temporary construction facilities required for the execution of the work in a safe and legal manner.

1.15 TEMPORARY POWER AND LIGHT

A. Temporary service for construction will be provided by the Contractor. An existing service may be utilized under agreement with the Government.

B. Each Contractor shall provide and maintain, at its own expense, extension cords, lighting, appurtenances and accessories for lights or power tools required in addition to and beyond the temporary service provided.

C. The cost of electrical energy used for temporary power and lighting for the work of Contractor shall be borne by the Contractor, as indicated in the General Requirements.

D. Upon completion of the work and before final acceptance of the entire project, each Contractor shall remove, at his own expense, wiring appurtenances and accessories used in the performance of its respective work to the satisfaction of the Government and/or Contracting Officer. The temporary service area shall be cleaned and restored to acceptable condition by the Contractor.

E. Construction phasing will require existing service relocations. These will be the responsibility of the Contractor.

1.16 INSPECTION AND TESTS

A. Provide tests as directed under the individual Sections of Division 16.

B. Connections at cabinets, switches, circuit breakers and splices must be made prior to the time of final inspection and testing. Circuits shall be continuous from service switches to each outlet. Each system shall test free from short circuits and ground and shall have an insulation resistance between conductors and ground based on maximum load not less than requirements of the latest edition of the National Electrical Code.

C. Voltages shall be tested at the line side of the main breaker with switches or circuit breakers in the open position.

D. This Contractor shall be responsible for correct voltages, tap settings and correct phase designations on the electrical equipment.

E. Circuit breakers shall be tested for instantaneous and time delay trip. Breakers shall be tested at 300 percent overload. Certification by the manufacturer that the equipment furnished will conform to these requirements will be acceptable.

F. The grounding installation shall be tested and the resistance between ground and absolute earth shall not exceed 10 ohms and shall be measured by the Contractor before the equipment is placed in operation.

G. Testing equipment necessary to satisfactorily conduct the tests shall be provided. The tests shall be made in the presence of the Contracting Officer at no additional expense to the Government.

H. Lighting fixtures and systems shall be tested with specified lamps in place, for a period not less than twenty hours.

I. Failure or defects in workmanship or materials revealed by tests or inspection shall be corrected promptly and tests shall be reconducted by the Contractor. Defective material shall be replaced promptly with new and unused material at no additional expense. Insofar as practical, a normal full load test shall be made on the power and lighting systems.

J. The Contractor shall measure and record minimum and maximum voltages, measure and record voltage between phase wires and neutral.

K. Copies of all test reports shall be submitted to the Contracting Officer per the procedure described in General Requirements for acceptance and approval.

1.17 CUTTING AND PATCHING

A. The Contractor shall arrange to have the conduit, panelboards, boxes and such other pertinent parts set in place ahead of the construction work wherever possible to eliminate the need for cutting and patching. Cutting and patching shall be done as specified herein.

1.18 ELECTRICAL CHARACTERISTICS

A. Building power distribution design will be 120/208 volts, 3-phase, 4-wire, 60 hertz; 277/480 volts will be utilized to feed mobile units.

B. Power system for convenience outlets, appliances, and incandescent lighting -120/208 volts, 3-phase, 4-wire, 60 hertz, as required.

C. Motors 1/2 horsepower and larger - 208 volts, 3-phase, 3-wire.

D. Motors less than 1/2 horsepower – 120 volts, single-phase, 2-wire, unless otherwise indicated on Drawings.

E. Fluorescent, and metal halide lighting - 120 volts, single-phase, 2-wire, unless otherwise indicated on the Drawings.

F. Incandescent Lighting – 120-volts, single-phase, 2-wire, unless otherwise indicated on the Drawings.

G. Provision shall be made for harmonic effects in all electrical systems, i.e., equipment with lowest THD shall be provided.

1.19 COORDINATION

A. The Electrical Contractor shall be responsible for fully coordinating the various parts of the work included under this Contract, and such other disciplines work as it may affect the completion of this Contract, throughout the various phases of construction and before the ordering or fabrication of the various parts of the work, so as to insure compliance with the drawings and specifications, and as necessary to provide the installations complete and in satisfactory operating condition.

B. Mechanical and Electrical Coordination

The interconnecting power wiring and conduit, control wiring rated 120 volts (nominal) and conduit, the motor control equipment of switchgear assemblies, and the electrical power circuits are included under this Contract. The electrical components of mechanical equipment, such as motors, control or pushbutton stations, float or pressure switches, solenoid valves, and other devices functioning to control mechanical equipment, and control wiring and conduit are provided under other Contracts.

1.20 OPERATIONS AND MAINTENANCE MANUAL

A. The Contractor shall furnish an operation and maintenance manual for each electrical system and for each piece of equipment furnished under his contract. Ten copies of the complete manual bound in hardback binders or an approved equivalent shall be provided to the Government.

B. The manual shall include the names, addresses, and telephone numbers of each subcontractor installing equipment and system, and of the local representatives for each item of equipment and each system.

C. The manual shall include, but not be limited to, the following: a system layout showing circuits, devices and controls; wiring and control diagrams with data to explain detailed operation and control of each component; a control sequence describing start-up, operation and shut-down; a detailed description of the function of each principal component of the system; the procedure for starting; the procedure for operating; shut-down instructions; lubrication schedule including type, grade, temperature range, and frequency; safety precautions, diagrams, and illustrations; test procedures; performance data; and parts list with identifying drawings. The parts list for equipment shall indicate the source of supply, recommended spare parts, and the service organization which is reasonably convenient to the building site within a fifty-mile radius.

D. The manual shall include complete instructions for equipment, controls, and accessories as provided.

1.21 DELIVERY, STORAGE AND HANDLING

A. Deliver material in manufacturers' original unopened protective packaging.

B. Store materials in original packaging in a manner to prevent soiling, physical damage, wetting or corrosion prior to installation.

C. Handle in a careful manner to prevent damage to finished surfaces.

D. Where possible, maintain protective coverings until installation is complete and remove such covers as part of final clean-up.

E. Touch up any damage to finishes to match adjacent surfaces to the satisfaction of the Contracting Officer.

F. The Contractor shall be responsible for replacing, in kind, all material and equipment that is damaged due to handling or storage, at no cost to the Government.

1.22 WARNING SIGNS

A. Warning signs for the enclosures of electrical transformers and switchgear having a nominal rating exceeding 600 volts shall be baked enamel on metal for indoor or outdoor use with legend "DANGER HIGH VOLTAGE" in nominal 3-inch high letters conforming to ANSI Z35.1.

1.23 ELECTRICAL DEMOLITION

A. The Contractor shall be responsible for the safe and legal removal of all electrical materials and devices indicated for demolition on the Drawings. Government designated salvage items

shall be stored per Government instructions. Non-salvage items shall become the Contractor's responsibility and ownership.

PART 2 - PRODUCTS

2.01 MATERIAL AND EQUIPMENT TO BE FURNISHED

A. Equipment and materials furnished shall be new and unused, prior to this installation, first grade commercial quality and shall be essentially the standard cataloged products of a manufacturer regularly engaged in the manufacture of the products for a successful minimum of five years. Rebuilt or remanufactured equipment will not be permitted.

2.02 IDENTIFICATION

A. All parts of equipment, such as, but not limited to, switchboards, panelboards, safety switches, motor starters, circuit breakers, time clocks, contactors and similar items shall be identified by name, function or control with laminated plastic nameplates consisting of two black sheets with one white sheet bonded to and between the two outer sheets and having letters machine engraved in the face sheet to the depth of the white plastic. Nameplates shall not be smaller than 1 inch x 3 inches with characters not less than one-quarter inch. Where letter sizes are not specified, use one-inch high letters for panelboards and switchboards and one-quarter inch high elsewhere. Nomenclature shall be according to a schedule approved by the Contracting Officer. Nameplates shall be mounted with two stainless steel screws.

B. All device plates other than lighting switch plates, telephone and 120 volt, single-phase, 15 or 20 ampere receptacles, shall have black or white (as directed) silk-screened lettering Helvetica Medium typeface (or other typeface as directed by the Contracting Officer) designating:

1. System

2. Voltage (where applicable)

3. Number of phases (where applicable)

4. Current rating (where applicable)

5. Frequency (where applicable)

C. Before placing orders for nameplates or silk-screened device plates, submit a typewritten list to the Contracting Officer for review.

D. The outside of the covers of all junction or pull boxes located above hung ceilings and the inside of the covers of all junction or pull boxes exposed shall be labeled with an indelible marker indicating the operating voltage and the system contained therein.

PART 3 - EXECUTION

3.01 MEASUREMENTS

A. Before ordering material or performing work, the Contractor shall verify such measurements as may be required for the proper fitting of his work to other adjoining work. Contractor shall be responsible for the correctness of the dimensions and shall satisfactorily correct, without extra charge to the Government, work which does not fit, by furnishing new work if required for the purpose. No extra charge will be allowed for minor differences between actual dimensions and the measurements indicated on the drawings.

3.02 LOCATION OF ELECTRICAL EQUIPMENT

A. The locations and dimensions of electrical equipment shown on plans shall be considered as approximate and diagrammatic only. The Contractor shall determine the exact locations, subject to the approval of the Contracting Officer to meet field conditions, avoid interference with other equipment and service or for other sufficient reasons. The right to make any reasonable change in location of equipment before installation is reserved by the Contracting Officer and such changes shall be made without additional expense to the Government.

B. When the construction discloses the fact that certain equipment locations are not feasible, the Contractor shall notify the Contracting Officer before advancing with the installation and construction to a stage where change will reflect additional expense to the Government.

3.03 PROTECTION OF ELECTRICAL EQUIPMENT

A. The Contractor shall protect at his expense, materials and equipment that are subject to injury during the course of construction. Such protection shall include and is not limited to the capping or plugging of conduit and outlet boxes and the sealing of cables. The Contractor shall also accept responsibility for damage done to his work until his work has been accepted by the Government. The Contractor shall repair damage which may occur to his operation during construction at no extra cost to the Government, except where such damages are caused by the Government to equipment and installations which were properly protected against damage during construction by the Contractor.

3.04 NAMEPLATE MOUNTING

A. Nameplates shall be mounted on electrical equipment installed under these specifications, including distribution panels, starters, transformers, switches, pushbuttons, selector switches, and remote controls. They shall be securely fastened using two or more stainless steel screws and centered directly over or on the instruments and devices, or as shown on the drawings.

3.05 WARNING SIGN MOUNTING

A. Provide warning signs per NEC with the legend "DANGER HIGH VOLTAGE" for the enclosures of electrical transformers and switchgear having a nominal rating exceeding 600 Volts. When such equipment is guarded by a fence, mount signs on the fence. Provide the

number of signs required to be readable from each accessible side, but space the signs a maximum of 30 feet apart.

3.06 FITTING, CUTTING AND PATCHING

A. The Contractor shall do cutting and fitting of his work, and of work that may be required to make the several parts come together properly, and fit his work to receive or be received by the work of other contractors as shown upon, or reasonably implied by, the drawings and specifications. Cost of cutting and fitting caused by defective or ill-timed work shall be borne by the party responsible therefor.

B. The Contractor shall properly complete, patch and finish up his work after cutting and fitting. Unless otherwise specified, the Contractor shall perform and pay for cutting and patching required throughout the project for completion of the work in accordance with the plans and specifications.

C. Surface damaged by notching, drilling, welding or other process during the installation of the electrical work shall be repaired and painted without cost to the Government, and to the satisfaction of the Government.

3.07 LOCATION OF EQUIPMENT

A. Unless otherwise shown on the Contract Drawings, the location of outlets or devices, from finished floor to center of plate or device, shall be as follows:

1. Lighting switches: 48 inches

2. Receptacles: 18 inches

B. Unless otherwise shown on the Contract Drawings, the location of equipment, from finished floor to top of enclosures shall not exceed 6 feet, 6 inches. Equipment installations shall meet all National Electric and Safety Codes.

3.08 DISSIMILAR METALS

A. Dissimilar metals shall mean those metal which are incompatible with one another in the presence of moisture, (i.e., copper and aluminum), as determined from their relative positions in the Electrochemical Series, or from test data. Where dissimilar metals come in contact, coat the joint both inside and out with approved material so as to exclude moisture from the joint, or provide a suitable insulating barrier separating the metals.

B. Transitions in raceways, from one metal to a dissimilar metal (i.e., copper to aluminum) shall only be made at boxes or other enclosures, except where shown on the Contract Drawings. Transition between metals shall be made using a bi-metallic plated connection.

3.09 FINAL FIELD TESTS

A. The entire electrical installation shall be inspected prior to final acceptance testing, thoroughly cleaned, and damaged finishes touched up after final completion and prior to final acceptance testing being performed. Not less than 30 days prior to the testing, furnish a test plan, to the Contracting Officer for review, outlining all aspects of the testing, including tests to be performed and the expected results.

B. Perform the following field test in the presence of the Contracting Officer to demonstrate the reliability of the electrical installation. Give the Contracting Officer a minimum of one-week advance notice of such tests.

Operate all electrical systems and equipment for a period of 24 hours, unless in the opinion of the Contracting Officer, a different test period is required, to prove the operation and performance of a system and its equipment.

Should the foregoing test reveal any defects, promptly correct such defects and re-run the tests until the entire installation conforms to the requirements of these Specifications and the Contract Drawings.

C. Tests requiring certified reports and those requiring factory or field inspection shall be conducted and reported to the Contracting Officer in conformance with standards herein specified.

3.10 SAFETY MEASURES TO BE TAKEN

A. The Contractor will be solely and completely responsible for conditions of the job site, including safety of all persons and property during performance of the work. This requirement will apply continuously and not be limited to normal working hours. The duty of the Contracting Officer and Contracting Officer to conduct construction observations of the Contractor's performance is not intended to include review of the adequacy of the Contractor's safety measures, in, on or near the construction site. It shall be the Contractor's responsibility to comply with "Safety and Health Regulations for Construction," Volume 36, No. 75, Part 11 of the Federal Register by the U.S. Department of Labor and the National Electric Safety Code. Contractor shall be responsible for providing such safety measures and shall consult with the state or federal safety inspector for interpretation whenever in doubt as to whether safe conditions do or do not exist of whether he is or is not in compliance with state or federal regulations.

3.11 WORK RESPONSIBILITIES

A. Drawings indicate diagrammatically desired locations or arrangement of conduit runs and outlets equipment. Proper judgment shall be exercised in executing Work so as to secure best possible installation in available space and to overcome local difficulties due to space limitations or interference with structural conditions. Contractor shall be responsible for correct placing of Work and proper location and connection of Work in relation to Work of other trades. Advise appropriate trade as to locations of access panels.

3.12 WARRANTY

A. The Contractor shall be responsible for all work installed under this specification. He shall make good, repair or replace, at his own expense as may be necessary, any defective work, materials or parts which may show themselves within one year after final acceptance, two years for ballasts with installation, if in the opinion of the Contracting Officer said defect is due to imperfection in material, design or workmanship. Incandescent lamps are not warranted, but all shall be operating at time of final acceptance.

3.13 RUBBER MATTING

A. Provide continuous insulated rubber matting not less than 36 inches wide and not less than one-quarter inch thick in one piece in front of

1. Main Distribution Switchboard.

2. Motor Control Center.

B. Matting shall conform to ASTM D178, Type 2.

END OF SECTION 16010

SECTION 16012

TESTING AND QUALITY CONTROL

PART 1 - GENERAL

1.01 WORK INCLUDED

A. This section outlines the requirements and procedures for Sections of Division 16 as hereinafter specified.

B. Field Inspection:

1. The Contractor shall be responsible for a complete inspection of all equipment, prior to testing and energization to ascertain that it is free from any damage, scratches, or missing components and that all power connections are correct, and that they are right in conformance with recommended standard practice. The inspection shall also include a check of control wiring, terminal connections and all bolts and nuts.

2. Field inspection shall be performed by the Contractor during a time when the Contracting Officer and/or Government is present to witness each inspection and its performance.

3. Any deficiencies found during the inspection shall be corrected by the Contractor prior to the energization and testing of the equipment.

C. The following requirements are supplementary to tests specified for individual equipment or systems.

1. Written notice of test dates shall be given at least two weeks in advance in order for the Contracting Officer and the Government to make arrangements to be present during the tests.

2. Concealed or insulated work shall remain uncovered until required tests have been completed. However, if construction schedule requires, arrange for prior test on parts of the system.

3. As soon as conditions permit, conduct preliminary test of equipment to ascertain compliance with specified requirements. Make needed changes, adjustments or replacements as preliminary tests may indicate, prior to acceptance test.

4. Conduct performance and operating tests as specified or required for each system or equipment unit in presence of the Contracting Officer as well as representatives or agencies having jurisdiction.

5. The Contractor shall furnish labor, material and instrument and shall bear all others costs in connection with tests, unless otherwise indicated.

6. Obtain any certificates of approval and/or acceptance as required in compliance with regulations of agencies having jurisdiction. Work shall not be deemed complete until such certificates have been delivered to and reviewed by the Contracting Officer.

7. Testing shall prove conclusively that all electrical systems operate properly, efficiently, and quietly in accordance with the letter and the intent of the Drawings and specifications.

1.02 REFERENCES

A. Applicable Sections of Division 16 specified hereinafter.

B. American National Standards Institute

1. ANSI C1 National Electrical Code.
2. ANSI C2 National Electrical Code.
3. C2-93 National Electrical Safety Code, 2766-0879.

C. National Electrical Manufacturer's Association (NEMA).

D. (NFPA) Publications: 70-1993 National Electrical Code (NEC).

E. American Society for Testing and Materials (ASTM).

F. Institute of Electrical and Electronics Engineers (EEE).

G. International Electrical Testing Association (NETA).

H. Insulated Cable Engineer's Association (ICEA).

I. Association of Edison Illuminating Companies (AEIC).

J. State and Local Codes and Ordinances.

K. Local Utility Codes and Ordinances.

L. Occupational Safety and Health Administration (OSHA).

M. American National Standards Institute (ANSI).

1.03 SUBMITTALS

A. Submit documentation as required by this Section of the Contract to the Contracting Officer.

B. Submission to include the following:

1. Field inspection report as required for each item of material and/or equipment outlined herein.
2. Field-testing report as required for each item of material and equipment outlined herein.

C. Test Reports:

1. Each test report prepared by the respective testing firm(s) shall comply, where applicable, to all stipulations specified for the operation, maintenance and installation manual with reference to preparation, paper requirements, indexing and binders. Each test report shall include the following:

   a. Summary of project.
   b. Description of equipment or system tested.
   c. Description of test.
   d. Test results.
   e. Conclusions and recommendations
   f. Appendix, including appropriate test forms.
   g. Identification of test equipment used.
   h. Signature of responsible test organization authority.
   i. Furnish five copies of each completed report to the Contracting Officer no later than 30 days after completion of each test. The testing firm shall assemble and certify each final test report which shall be submitted to the Contracting Officer for review, comments and subsequent approval.

1.04 QUALITY ASSURANCE

A. The services of a qualified technician shall be provided by the Contractor to supervise the installation, adjustments and testing of project equipment. The technician shall instruct designated Government personnel in the operation, adjustment and maintenance of the system.

B. The manufacturer and/or his authorized agent shall maintain a fully equipped factory parts and service capable of furnishing adequate inspection and service at a location no further than 50 miles from the job site.

C. The manufacturer and/or his agent shall be prepared to offer the Government a service contract for the maintenance of the installed systems after the guarantee period expires. "On Call" or "Contract" service shops are not acceptable.

D. Equipment manufacturer shall furnish the Government a one-year contract for maintenance and inspection service, effective from the date of acceptance of the installation. Service contract shall provide for a minimum of two inspections during the contract year.

E. System and its components shall be the product of a manufacturer who has designed and produced similar systems and components for a period of at least 10 years.

F. Vendors shall be prepared to furnish a list of 10 similar installations in the project area for possible inspection by the Contracting Officer and/or the Government.

G. Distributors shall be authorized agents of the equipment furnished.

1.05 INSTRUCTION MANUALS

A. Six bound copies of complete instructions for the operation and maintenance of the system shall be furnished to the Government including circuit drawings and wiring diagrams.

1.06 INSPECTION AND TESTING

A. General:

1. The Contractor shall engage the services of a recognized independent testing firm to perform such tests that are stipulated and are required by these Contract Documents.

2. The testing firm used shall be approved by the Contracting Officer.

3. The cost of such tests shall be included in the Contractor's Bid Price for the applicable bid item.

B. Testing Firm's Responsibility:

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

2. It is the intent of these tests to assure that all electrical equipment, including both contractor and Government-supplied, is operational and within industry and manufacturer's tolerances and is installed in accordance with specifications.

3. The tests and inspections shall determine suitability for energization.

4. The testing firm shall be a member of NETA and a corporately independent testing organization which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installer of equipment or systems evaluated by the testing firm.

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

6. The testing firm shall have been engaged in such practices for a minimum of five years.

7. The testing firm shall meet Federal OSHA criteria for accreditation of testing laboratories, Title 29, Parts 1907, 1910 and 1936. Full membership in the International Electrical Testing Association constitutes proof of such criteria.

8. The lead, on site, technical person shall be currently certified by the International Electrical Testing Association (NETA) in Electrical Power Distribution System Testing.

9. The testing firm shall utilize only full-time technicians who are regularly employed by the firm for testing services. Electrically unskilled employees are not permitted to perform testing or assistance of any kind. Electricians may assist, but may not perform testing and/or inspection services.

10. The testing firm shall submit proof of the above qualifications with bid documents when requested.

11. The testing firm shall be an independent organization as defined by OSHA Title 29, Part 1936 and the International Electrical Testing Association.

12. All instruments used by the testing firm to evaluate electrical performances shall meet NETA's Specifications for Test Instruments.

13. The terms used, here within such as Test Agency, Test Contractor, Testing Laboratory, or Contractor Test Company, shall be construed to mean testing firm.

C. Division of Responsibility:

1. The Contractor shall perform routine insulation resistance, continuity and rotation tests for all distribution and utilization equipment prior to and in addition to tests performed by the testing firm specified herein.

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

3. The Contractor shall notify the testing firm when equipment becomes available for acceptance tests. Work shall be coordinated to expedite project scheduling.

4. The Contractor is responsible to obtain, as required, an approved short circuit analysis and coordination study prepared by an independent testing firm or consulting engineer.

5. The Contractor shall supply, as required, a short circuit analysis and coordination study, a protective device setting sheet, a complete set of electrical plans, specifications and any pertinent change orders to the testing firm prior to commencement of testing.

6. The Contractor shall notify the Contracting Officer prior to commencement of any testing by the testing firm.

7. Any system, material or workmanship which is found defective on the basis of acceptance tests shall be reported to the Contracting Officer.

8. The testing firm shall maintain a written record of all tests and no later than thirty days after completion of the tests the testing firm shall assemble and certify the final test report which shall be submitted to the Contracting Officer for review, comments and subsequent approval.

D. Test Instrument Calibration:

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

2. The accuracy shall be directly traceable to the National Bureau of Standards.

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

a. Field Instruments:

Analog - 6 months
Digital - 12 months

b. Laboratory Instruments: 12 months

c. Leased specialty equipment: 12 months
(Where accuracy is guaranteed by lessor)

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

5. Records must be kept up-to-date which show date and results of instruments calibrated or tested.

6. An up-to-date instrument calibration instruction and procedure will be maintained for each test instrument.

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

E. Safety and Precautions:

1. Safety practices shall include, but are not limited to, the following requirements:

a. Occupational Safety and Health Act of 1970-OSHA.

b. Accident Prevention Manual for Industrial Operations, National Safety Council, Chapter 4.

c. Applicable State and Local safety operating procedures.

d. NETA Safety/Accident Prevention Program.

e. Department safety practices.

f. National Fire Protection Association - NFPA 70E.

g. ANSI 244.1 American National Standards for Personnel Protection.

2. All tests shall be performed with apparatus de-energized except where otherwise specifically required.

3. The testing firm shall have a designated safety representative on the project to supervise operations with respect to safety.

1.07 ELECTRICAL EQUIPMENT TESTING SCHEDULE

A. When an item of electrical equipment furnished as work for these Specifications, which is designated for testing in the Contract Documents, has been completely erected, including controls and/or instrumentation, the Contractor shall notify the Contracting Officer who will designate the time to make the required tests. All testing shall be done in the presence of the Contracting Officer and/or the Government and the item of equipment operated to the satisfaction of the Contracting Officer or Government.

1. "Completely erected" shall mean that the installation is erected, all necessary adjustments have been made, all required utility connections have been made, and that the following requirements have been met: O&M Manuals submitted and approved, electrical system tests completed, spare parts lists and manufacturer's installation certificate submittals received. The Contractor shall furnish labor, and all other materials, equipment and instruments necessary for all system tests.

2. The Contractor shall provide competent and experienced engineers or superintendents, who shall represent the manufacturer of equipment furnished and installed under this Contract, to assist the Contractor, in the installation, adjustment, and testing of equipment in conformity with the Contract Documents.

B. After an item of equipment has satisfied all of the above conditions, the Contractor shall notify the Contracting Officer and shall, at such time, as directed, conduct operational tests to demonstrate to the Contracting Officer's and/or the Government's satisfaction that the equipment is ready for operation. Specific operational testing requirements shall e as specified hereinafter and as contained in the individual sections of these Contract Documents.

1.08 SHOP DRAWINGS

A. Submit under the provisions of this Section as described under "Submittals."

PART 2 - PRODUCTS

Not Used

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. General:

1. Unless waived in writing by the Contracting Officer, the Contractor shall be present during the tests.

3.02 INSPECTIONS AND TESTS

A. This section of the specifications sets forth the testing procedures required for the acceptance of certain items of electrical equipment and/or systems described herein. The purpose of the specified tests and inspection is to determine that each piece of equipment is in satisfactory condition to successfully perform its intended function. It is the intent of these procedures to insure that all workmanship, material and the manner and method of erection and installation conform to manufacturer's instructions, and, except as modified herein, IEEE and ANSI standards and the National Electrical Code. Test requirements for other systems including, but not limited to, lighting, alarm, communication, etc., are described within their individual specifications.

B. The Contractor shall perform and supervise the electrical system tests on equipment and/or systems provided under this Contract unless specifically noted otherwise herein. The Contractor shall furnish all test equipment required for tests performed by him or his assignees and shall be responsible for providing such safety measures as required for each test.

1. The Contractor shall schedule all testing with the Contracting Officer and/or the Government and no testing of any kind shall be performed without the Contracting Officer's and/or the Government's approval.

2. The Contractor shall give manufacturers sufficient notice to allow the necessary arrangements to be made and to have their engineer or representative present at tests where their presence is required. Where the manufacturer's responsibility includes both electrical and mechanical performance, the Contractor shall coordinate the tests with others involved.

3. The Contracting Officer shall examine the Contractor's test equipment and calibration log prior to use.

4. The Contractor shall notify the Contracting Officer and/or the Government at least 48 hours prior to test, advising him of the test, to be performed and to schedule the date and time of test. The Contracting Officer shall be responsible for having his representative present at the designated time.

5. The Contracting Officer shall ascertain that all tests specified are performed.

C. The Contractor shall prepare all procedures and forms used in the test reports and shall submit them to the Contracting Officer for approval prior to commencement of testing. The test reports shall contain as a minimum, the following information.

1. Job title.

2. Date of test.

3. Equipment, system or cable identification.

4. Specific type of test.

5. Description of test instrument and date of latest calibration.

6. Section of specification defining test along with description of test and evaluations as reported by the testing company.

7. Test results (correct all "Megger" readings at 20 degrees C).

8. Signature of person supervising test.

9. Signature for the firm performing the electrical work.

10. Space for Contracting Officer's signature.

11. Refer to individual tests and inspections hereinafter specified for any additional or specified requirements.

D. Power Distribution System:

1. Main Switchboard

a. Inspect for physical, electrical and mechanical condition.

3.03 600 V ELECTRICAL SYSTEMS TEST MEASUREMENTS

A. Thermographic Inspection:

1. Perform thermographic inspection of the electrical equipment and installations listed herein in the presence of a duly authorized representative of the Contracting Officer.

2. The purpose of thermographic inspection is to locate, by comparisons of temperature levels, high resistive points in installations of electrical materials and equipment. Comparisons are made by referencing a known ambient temperature of the object being scanned to the hot spot detected.

3. Detection Equipment: Equipment shall consist of an infrared camera that provides input to a display screen over a range of at least -200C to 9000C with the infrared emissions of the object being displayed having an accuracy of 0.10C.

   a. The camera shall have three lenses, one 70 telephoto lens, one 200 wide-angle lens, and one 400 extra-wide lens.

   b. The camera shall detect infrared wavelengths, converting them into video signals which are then projected onto a monitor screen in the form of a line thermal image which is then to be photographed to provide a record of the temperature variations. Two photographs required for the report.

   c. In addition to above stated capabilities needed for the infrared scan, the scanner shall have capability to produce an image in both a gray step mode and color monitor. These capabilities allow distinct temperature levels to be shown in black and white and color on the thermogram.

4. The Contractor shall submit prospective bidders with their bidder's Qualification statement, indicating experience in performing thermographic inspection and familiarity with equipment similar to that stated herein.

5. Equipment Operator: Engage the service of a specialist who has at least one-year actual experience operating thermographic inspection equipment of the type stated herein, and who is familiar with the various electrical equipment and installations being scanned which are as follows:

   a. Distribution Panelboards.

   b. Dry Type Transformers.

   c. Disconnect Switches.

   d. Circuit Breakers.

   e. Instrumentation Systems

6. Inspection Field Report: Prepare inspection field report in duplicate indicating in actual photographs and thermographs the defective equipment and installations. Also include in such report the probable cause, severity of defect, and corrective measure recommendations. Submit both copies of the report to the Contracting Officer who will make the determination of corrective measures. Based on the Contracting Officer's decisions make such actual corrections and retest at no added increase in Contract Price.

B. Continuity Test: Make test for continuity and correctness of wiring and identification on all conductors installed.

C. 600 Volt Rated Wires and Cables:

1. Inspections:

a. Inspect cables for physical damage and proper connection in accordance with approved shop drawings.

b. Test cable connections for proper torque in accordance with manufacturer's recommended values.

2. Tests:

a. After wiring is completed and connected ready for operation, but prior to placing in service and before any branch circuit breakers are closed, perform the following:

1) Continuity tests to insure proper cable connections.

2) Insulation resistance tests between conductors and between each conductor and ground.

b. Use an instrument capable of making measurements at an applied potential of 1000 volts DC. Take readings after the voltage has been applied for a minimum of one minute.

c. Each coil, reel or length of wire or cable shall have an insulation resistance in megohms - 1000 feet at temperature of 60 degrees F. (15.6 degrees C.) of not less than the value of R. R. is calculated by using the following formula:

$R = K \text{ Log}_{10} D$ (as per ICEA)

3. The following cables shall be tested:

a. Service cables.

b. All feeders and circuits originating from the main switchboard and distribution panel.

D. Power Distribution System:

1. Main Switchboard

a. Inspect for physical, electrical and mechanical condition.

b. Compare equipment nameplate information with latest. single line diagram and report discrepancies in writing to Contracting Officer within 24 hours.

c. Check for proper anchorage, required area clearance, physical damage, and proper alignment.

d. Inspect all doors, panels and sections for paint, dents, scratches, fit and missing hardware.

e. Verify that fuse and/or circuit breaker sizes and types correspond to Drawings. Report deviations to Contracting Officer in writing within 24 hours.

f. Inspect all bus connections for high resistance. Use low resistance ohmmeter, or check tightness of bolted bus joints by calibrated torque wrench method. Refer to manufacturer's instructions for proper torque levels.

g. Clean entire switchgear using manufacturer's approved methods and materials.

h. Inspect insulators for evidence of physical damage or contaminated surfaces.

i. Verify proper barrier and shutter installation and operation.

j. Verify appropriate contact lubricant on moving current carrying p arts.

k. Exercise all active components.

l. Inspect all indicating devices for proper operation.

m. Perform ground resistance tests.

n. Perform insulation resistance tests on each bus section, phase-to-phase and. phase-to-ground for one minute. Test voltage shall be 1000 volts minimum, and insulation resistance shall be 100 megohms minimum.

o. Perform an over potential test on each bus section, each phase-to-ground, for five minutes at manufacturer's recommended potential. Test results are evaluated on a go, no-go basis by slowly raising the test voltage to the required value. The final test voltage shall be applied for five minutes for dc test potentials, and one minute for ac test potentials.

2. Small Transformers - Dry Type, Air Cooled

a. Inspect for physical damage, broken insulation, tightness of connections, defective wiring and general condition.

b. Thoroughly clean unit.

c. Perform ratio test.

3. Circuit Breakers - Molded Case

a. Circuit breaker shall be checked for proper mounting, conductor size and feeder designation.

b. Operate circuit breaker to ensure smooth operation.

c. Inspect case for cracks or other physical defects.

d. Check tightness of connections with calibrated torque wrench. Refer to manufacturer's instruction for proper torque levels.

e. Perform a contact resistance test or measure millivolt drop at rated current.

f. Perform an insulation resistance test at 1000 volts dc for one minute from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase - 500V D.C. if circuit breaker is solid state.

g. Adjustable trip breakers shall have minimum pickup current determined by primary current injection where applicable.

h. Perform long time delay time-current characteristic tests by passing the hundred percent (300 percent) rated current through each pole separately. Determine trip time.

i. Determine ground fault pickup and time delay by primary current injection if applicable to the particular breaker.

k. Determine instantaneous pickup current by primary injection using run-up or pulse method. Clearing times shall be within four cycles.

l. Verify trip unit reset characteristics.

m. Perform adjustments for final settings in accordance with breaker setting sheet if applicable to the particular breaker.

n. Compare contact resistance or millivolt drop values to adjacent poles and similar breakers. Investigate deviations of more than fifty percent. Investigate any value exceeding manufacturer's recommendations.

o. Insulation resistance shall not be less than 100 megohms.

p. Trip characteristic of adjustable trip breakers shall fall within manufacturer's published time-current characteristic tolerance band.

q. All circuit breakers mounted in switchboards and distribution boards shall be time-current tested by primary current injection where possible, and also any remotely mounted breakers of frame size 400 ampere and larger.

r. Adjust settings and calibrate all circuit breakers as recommended in the short circuit analysis and coordination study.

4. Motor Control Centers

a. Inspect for physical damage, proper anchorage and grounding.

b. Compare equipment nameplate data with design plans or starter schedule.

c. Motor Running Protection

Compare overload heater rating with motor full load current rating to verify proper sizing.

If motor running protection is provided by fuses, verify proper rating considering other characteristics.

Check tightness of bolted connections.

d. Measure insulation resistance of each bus section phase-to-phase and phase-to-ground for one minute.

e. Measure insulation resistance of each starter section phase-to-phase and phase-to-ground with the starter contacts closed and the protective device open.

f. Measure insulation resistance of each control circuit with respect to ground.

g. Test motor overload units by injecting primary current through overload unit and monitoring trip time at three hundred percent of motor full load current.

h. Perform operational tests by initiating control devices and instrumentation to affect proper operation.

i. Bolt torque levels shall be in accordance with manufacturer's recommendations.

j. Perform insulation resistance test, 1000 VDC minimum test voltage and 100 megohms minimum insulation resistance.

k. Control wiring insulation test voltage shall be 1000V dc. Manufacturer shall be consulted for test voltage where solid-state control devices are utilized.

l. Perform overload tests at three hundred percent of motor full load current. Trip times shall be in accordance with manufacturer's tolerances. Investigate values in excess of one hundred twenty seconds.

5. Panelboards

a. Inspect for physical damage and proper grounding.

b. Compare nameplate information with schedules and report any discrepancies.

c. Inspect all panelboards for cleanliness, workmanship, etc.

3.4 GROUNDING SYSTEM MEASUREMENTS

A. Ground-resistance measurements of each ground rod shall be taken, before any wire is connected, and test results recorded. Perform all measurements in normally dry weather, not less than 48 hours after rainfall.

B. Ground-resistance measurements shall be made from all grounded non-current carrying metallic parts of electrical equipment (enclosures) to the ground electrode, and measured results recorded. Values obtained shall not exceed a maximum resistance to solid "earth" (ground) of two ohms.

C. Recorded results shall be tabulated to form a test report. The test report shall include, but not be limited to, the following:

1. Identification of each component tested.

2. Location of each component tested.

3. Time of each test.

4. Resistance values.

5. Soil condition and resistivity at the time the test (for ground rod measurements) was performed.

D. Test Methods:

1. Perform "fall-of-potential" type test per IEEE Standard No. 81 on the main grounding electrode or system.

2. Perform the "two-point" type test per IEEE No. 981, to determine the ground resistance between the main grounding system and non-current carrying metallic parts of electrical equipment (enclosures), system neutral and/or derived neutral points.

E. Inspection: Inspect ground system for compliance with plans and specifications.

END OF SECTION

SECTION 16050

BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 - GENERAL

1.01 WORK INCLUDED

A. Interior and/or exterior electrical work as provided on electrical drawings and specifications herein.

1. Raceway systems.
2. Boxes and fittings.
3. Hangers and supports.
4. Wire and cable.
5. Connectors and terminals.
6. Motor starters.
7. Disconnect devices.
8. Fuses.
9. Dry type transformers.
10. Panelboards.
11. Wiring devices.
12. Outlet plates and covers.
13. Motor and control wiring.
14. Nameplate and indexing.
15. Relays.
16. Underground conduit.
17. Surface non-metallic raceway.
18. Lighting fixtures.
19. 400 Hz power supply.

1.02 RELATED WORK

A. Section 16010 - Basic Electrical Requirements.

B. Division 15 - Mechanical.

1.03 APPLICABLE PUBLICATIONS

The following publications (latest issue or revision) listed below form a part of this specification to the extent they apply to the equipment, materials, installation and workmanship specified herein.

A. American National Standards Institute (ANSI) Publications

C80.1 Specification for Rigid Steel Conduit, Zinc-Coated

C80.3 Electric Metallic Tubing - Zinc-Coated

B. American Society for Testing and Materials (ASTM) Publications

B 1-81	Hard-Drawn Copper Wire
B 8-81	Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

C. National Electrical Manufacturers Association (NEMA) Publications

ABI	Molded Case Circuit Breakers
ICS 1	General Standards for Industrial Controls and Systems
ICS 2	Standards for Industrial Control Devices, Controllers and Assemblies
ICS 2-447	AC Automatic Transfer Switches
ICS 6	Enclosures for Industrial Controls and Systems

D. Insulated Cable Engineers Association (ICEA)

WC 3-80 7 2-85)	Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-19-81)
WC 5-73 7 10-83)	Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-61-402)
WC 7-82 7 1984)	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-66-524)
WC 8-76 7 7-84)	Ethylene-Propylene-Rubber-Insulated Wire and Cable for Transmission and Distribution of Electrical Energy (ICEA S-65-516)

E. National Fire Protection Association (NFPA) Publication

NFPA 70	National Electrical Code (NEC)

F. Underwriters Laboratories, Inc. (UL) Publications

1-85 6-85	Flexible Metal Conduit Rigid Metal Conduit
50-80 7 2-85)	Cabinets and Boxes
67	Panelboards
98-81 7 8-84)	Enclosed Switches

467-84 7 4-85)	Grounding and Bonding Equipment
489-80 7 10-84)	Molded Case Circuit Breakers and Circuit Breaker Enclosures
510-82	Insulating Tape
514B-82 7 6-85)	Fittings and Conduit and Outlet Boxes
651-81 7 6-85)	Schedule 40 Rigid PVC Conduit
797	Electrical Metallic Tubing
1008	Automatic Transfer Switches

G. National Electrical Code - Latest edition.

H. Institute of Electrical and Electronic Engineers, Inc. (IEEE)

C-2 National Electric Safety Code - Latest Edition

241 (Gray Book) Recommended Practice for Electric Power Systems in Commercial Buildings

446 (Orange Book) Recommended Practice for Emergency and Standby Power System

1.04 SUBMITTALS

A. Manufacturer's data shall be submitted in accordance with Basic Electrical Requirements, but not limited to, the following requirements:

1. Wire and cable, conduit, ducts and fittings
2. Splice materials
3. Boxes and fittings
4. Disconnect switches and circuit breakers
5. Fuses
6. Dry-type transformers
7. Panelboards

8. Wiring devices, including receptacles, multi-outlet assemblies, and light switches.

9. Lighting Fixtures

10. Motor Starters

11. Main Distribution Switchboard

12. Handholes

13. Device plates

14. Transfer switches

15. Conduit hangers and supports

16. Wireway and cable trays

17. 400 Hz power

B. Submittals shall include the manufacturers name, product descriptive data, performance data, catalog cuts identified, certification compliance, etc.

C. Shop Drawings submittal circuit details:

1. Panelboards.

2. Wire ways.

3. Cable trays.

1.05 REGULATORY REQUIREMENTS

A. Install electrical work in accordance with National Electrical Code, State, and local Authority in Charge (AIC) codes.

1.06 QUALITY ASSURANCE

A. Manufacturer of submitted products shall have a minimum of five (5) years in the successful installation and operation of their materials and equipment.

1.07 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Ship all items securely packaged for handling, or weather to avoid damage.

B. Identify each item with applicable standard.

C. Store all materials per manufacturer's recommendations including original packaging against weather, dirt, and other damage.

D. All damaged items shall be replaced with new by the Contractor at no cost to the Government.

PART 2 - PRODUCTS

2.01 MATERIAL AND EQUIPMENT - GENERAL

A. Material, equipment and devices shall meet UL and NEC.

B. Enclosures shall meet NEMA requirements per Contract Drawing installation.

2.02 RACEWAY SYSTEMS

A. Conductors for feeders, branch circuits and controls, shall be installed in raceways as specified in NEC and as indicated on Drawings and specifications. Raceways shall be of the sizes indicated and shall bear the label of the Underwriters' Laboratories, Incorporated. Raceways shall include electrical metallic conduit and tubing, intermediate metal conduit, rigid metal conduit, rigid PVC conduit, and flexible metallic conduit. Tray type systems shall be installed where indicated.

B. Raceways shall be installed as follows:

1. Raceways installed underground and in concrete slabs shall be heavy wall galvanized rigid steel threaded conduit. Rigid steel conduit shall be hot dip galvanized. Rigid steel conduits shall conform to Federal Specification WW-C-581d. Minimum size shall be 3/4-inch. Conduit threads shall be hot dipped galvanized in the factory. Where conduits are cut in the field, they shall be coated with galvanized hot stick. Fittings shall conform to UL6.

2. All raceways installed above hung- ceilings, in masonry walls and exposed in unfinished areas shall be electrical metallic tubing, and shall conform to Federal Specification WW-C-563. Minimum size shall be 3/4-inch. Tray systems shall be hot-dipped galvanized or aluminum as indicated on the Drawings.

3. Contractor may, at his option, use Schedule 40 PVC for raceways installed underground in concrete envelope. Schedule 40 conduit shall be solvent joint type, shall be manufactured to NEMA TC-2, Federal Specifications WC1094, UL standard 651. Conduit shall be rated for use with 90E C. conductors and be sunlight-resistant. Conduit fittings, adapters and cement shall be of the same manufacturer. Risers shall be rigid galvanized steel. Fiberglass reinforced epoxy (FRE) shall not be less than 2 inches and conform to NEMA TC-14 and shall be UL listed.

4. Raceways indicated as exposed in dry finished areas shall be wiremold surface raceways furnished complete with all necessary fittings, boxes, accessories and

connectors. Raceways shall bear the label of the Underwriters' Laboratories, Incorporated.

C. Couplings and connectors for the Electrical metallic tubing shall be of the steel set screw type and shall use the insulated-bushings. Connectors and couplings for the Electrical metallic tubing in masonry walls shall be of the compression, rain tight/ concrete tight type. Bonding and grounding bushing shall be provided where required.

D. Flexible metallic conduit shall be furnished and installed where indicated per UL-1 for final connections to motors, transformers and equipment. Flexible steel connectors shall be Type "LT" as required. Liquidtight flexible conduit per UL 360 to motors, transformers and devices shall not exceed 18 inches. Grounding shall be metallically continuous. All work shall meet the requirements of the National Electric Code.

E. Conduit expansion fittings shall be provided where required and shall be hot dipped galvanized, with seal packing and copper braid bonding jumper.

2.03 BOXES AND FITTINGS

A. Unless otherwise indicated or specified, conduit boxes shall be steel construction, spot, or seam welded at the joints, and hot-dip galvanized after fabrication and meet requirements for NEMA 051/250; UL 50/514A/514B; NFPA 70.

B. Boxes shall be sufficiently rigid to withstand moderate twisting strains. Steel boxes of 100 cubic inches or less shall be No. 14 USS gage; between 101 and 8500 cubic inches shall be No. 12 USS gage; larger boxes shall be No. 10 USS gage.

C. Boxes shall be of adequate size to accommodate the installation of conductors without excessive bending of the conductor which would damage the insulation. Maximum number of conductors in a box shall comply with NEC 370-6.

D. Steel boxes other than wiring device outlet boxes, unless otherwise specified herein or shown on the drawings, shall have a shop-applied finish of enamel.

E. Gang type boxes shall be of unit construction of the size required for the number of switches, or other devices and outlets shown. Sectional switch boxes shall not be permitted.

F. Lighting fixture outlet boxes for exposed indoor circuit runs shall be threaded hub cast metal with mounting lugs. Pendant mounted fixtures shall be connected to the box with a cast metal hub cover or cast metal swivel flexible fixture hanger cover.

G. Lighting fixture outlet boxes embedded in ceilings shall be octagonal, provided with plates and fixture studs where required, of a size suitable for the weight of the fixture to be supported. The stud shall be integral construction with the box or back plate. In no case shall the weight of the fixture be dependent upon screws holding fixture strap or cover plate to the box.

H. Lighting fixture outlet boxes for outdoor installation shall be cast metal with threaded hubs and mounting lugs. Appropriate covers and gaskets shall be provided for weatherproof rating.

I. Switch and receptacle outlet boxes concealed indoors in masonry walls shall be pressed steel, zinc coated and provided with proper sized knockouts.

J. Switch and receptacle outlet boxes for exposed interior unfinished locations and exterior locations shall be cast-metal with threaded hubs.

K. Outdoor conduit junction boxes and pullboxes shall be gasketed with screw covers and furnished with mounting lugs. Conduit connections shall be made either to threaded hubs or by using liquid-tight sealing fittings.

L. Fittings shall be malleable iron with gasketed covers.

M. Boxes shall be furnished with a grounding terminal having a slotted Hexagonal head washer face ground screw with green die finish for ground termination.

N. Floor boxes shall be cast-steel, waterproof, adjustable with threaded entrance hubs, gasketed, brass floor plates and flush screw on covers. Unused hubs shall be plugged. Screws shall be stainless steel or brass.

2.04 HANGERS AND SUPPORTS

A. General

1. Unless otherwise shown on the Contract Drawings, provide hangers and supports as specified below.

2. Hangers and supports, for which there are established Underwriters Laboratories Inc. (UL) standards, shall bear the UL label.

B. Raceway Support

1. Clevis Hangers - For supporting horizontal conduit; galvanized steel; with hole for threaded steel rod and sized for their bearing load.

2. Riser Clamps - For supporting vertical conduit; galvanized steel; size as required.

3. Reducing Couplings - Rigid galvanized steel reducing coupling; size as required.

4. C-Clamps - Black malleable iron or galvanized steel; with hole for threaded steel rod size as required.

5. I-Beam Clamps - Galvanized steel, size as required.

6. Right Angle or Parallel Beam Clamps - Galvanized steel clamps for supporting or fastening conduit, up to 2-inch trade size.

7. One-Hole Conduit Straps - For supporting up to 1-inch conduit or electrical metallic tubing (EMT); galvanized steel.

8. Two-Hole Conduit Straps - For supporting conduit or EMT larger than 1-inch; galvanized steel shall have 3/4-inch strap width.

9. Hexagon Nuts: Galvanized steel as required.

10. Round Steel Rod: Galvanized steel; threaded size as required.

11. Trapeze Hangers: Same as specified in 2.03 C below, but not smaller than 3/8-inch diameter and threaded to permit 1-1/2 inch of adjustment. Horizontal members shall be a minimum of 12 gauge hot-dip galvanized after fabricated.

12. The following types of hangers and supports shall not be used:

    a. Perforated metal strapping;

    b. Slotted, perforated angles;

    c. Spring pressure or torsion clips, hangers, or supports.

C. Supporting Steel Sections and Channels

1. Supporting steel sections and channels shall be fabricated of ASTM A 36 steel in accordance with the appropriate requirements of the AISC, AISI and AWS publications and shall be hot-dipped galvanized after fabrication, sized as required.

2. Channel concrete inserts shall be continuous slot type, 12 gauge minimum, foam-filled or protected against installation concrete fill seepage and galvanize protected finish after fabrication. Load rating shall be 1500-pound minimum per foot with a safety factor of 3.

3. Spot concrete inserts shall be galvanized after fabrication, concrete seepage protected and shall have 1000-pound minimum load rating with a safety factor of 3.

D. Cable Supports

1. Provide cable supports with insulating wedging plug for non-armored type electrical cables in risers. Assembly shall include body of galvanized malleable iron with insulating wedging plug.

2. Provide cable supports for armored type electrical cables in risers. Assembly shall include body and pressure plates of galvanized steel.

E. Fasteners

1. General

a. Unless otherwise shown on the Contract Drawings, provide fasteners as specified below.

b. Where more than one type of fastener is suitable for the intended use, selection is at the Contractor's option, subject to approval by the construction coordinator/specialist.

2. Toggle Bolts

Toggle bolts shall be springhead, galvanized steel, 1/4-inch to 2-inch, length as required.

3. Expansion Anchors

Expansion anchors shall be metallic galvanized steel expansion anchors or shields, including drop-in anchors, wedge and sleeve anchors, and two-piece and three-piece shields for lag screws or machine screw or bolts.

4. Powder Activated Fasteners

Powder activated fasteners shall be steel, pin or stud type, selected for proper length and penetration for the equipment, clamp or strap to be installed, and the base material.

5. Bolts, Nuts, Lockwashers, and Washers

a. All hardware shall be galvanized steel, unless otherwise shown on the Contract Drawings.

b. Bolts and nuts, 1/4-inch trade size and larger, shall be hex head or hex socket type, standard American sizes.

c. Lockwashers shall match the finish of the furnished bolts and nuts, and generally be installed one-per-bolt, at the nut end of the assembly.

d. Washers shall be standard or fender type, as required, and sized to match the installed bolts or screws.

6. The following types of fasteners shall not be used:

a. Lead anchors or studs;

b. Wooden plugs or anchors;

c. Plastic anchors;

d. "Nail-in" anchors, either of the plastic or metal type;

2.05 WIRE AND CABLE

A. Wire and cable shall conform to the specifications and sizes indicated on the drawings, and shall be in accordance with the latest requirements and specifications of the NEC.

B. Unless otherwise noted, wire shall be single conductor, stranded copper, not smaller than No. 12 AWG, except for control wiring where No. 14 AWG may be used. Wire shall be concentric strand, IPCEA Class B, except for control wiring where they shall be Class C (19 strand) and where otherwise noted.

C. Wire for building services control wiring shall be 19-strand copper conductors rated for 600 Volt service and conductor temperature of 75C in general wet or dry locations, NEC Type THWN.

D. Multiple conductor control cable, used for building services, shall be of the number and size of conductors as indicated, 19-strand copper conductors, insulated for 600 Volt service. Provide cables with necessary fillers and binder tape. Color-code individual conductors in accordance with ICEA, Method 1.

1. Cable for control circuits shall have NEC Type THWN insulated conductors with an overall flame-resistant jacket.

E. Bonding and grounding conductors shall conform to ASTM B 1, solid bare copper wire for sizes No. 8 AWG and smaller and ASTM B 8, Class B, stranded bare copper wire for sizes No. 6 AWG and larger.

F. Wire for lighting branch circuits and miscellaneous building services branch circuits shall be rated for 600 Volts service and conductor temperature of 75C in general wet or dry locations, NEC type THWN - THHN.

G. Wire in continuous fluorescent lighting fixtures for supplying power from one fixture to another fixture of the same assembly shall be rated for 600 Volt service and conductor temperature of 90C, NEC type XHHW or THHN or THW.

H. Wire for grounding of raceways and equipment shall be rated for 600 Volt service with green insulation for sizes No. 8 and smaller, NEC type THWN -THHN.

I. Wire for underground circuits, shall be rated for 600 Volt service and conductor temperature of 75C in general wet or dry location, NEC type XHHW.

J. Wire for ground electrode networks shall be bare, uncoated soft drawn electrical grade copper suitable for use as a ground conductor. Size as required per NEC.

K. Flexible cord shall be rated for 600 Volt service and conductor temperature of 75C in general wet and dry locations, No. 14 AWG minimum size, NEC type SO.

L. Metal-clad sheathed cable, Type "MC," shall **not** be allowed.

M. All wire and cable shall be color coded as follows:

Conductor	System Voltage	
	208Y/120V	480Y/277V
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Gray
Ground	Green	Green

2.06 CONNECTORS AND TERMINALS

A. Wire and cable connectors, including miscellaneous nuts, bolts and washers for copper conductors shall be high copper alloy, everdur, durium, duronze or silicon bronze. Ferrous materials shall not be used. Bimetallic connections shall be provided with non-corrosive contact point between dissimilar metals.

B. Wire and cable connectors shall be of the bolted clamp pressure type or the tool applied compression-deformation type except where other constructions are permitted. Compression-deformation connectors shall be indent type for No. 10 AWG and smaller size wires and circumferential type for No. 8 AWG and larger size wires.

C. Connectors for motor terminations shall be ring tongue indent compression-deformation type for No. 10 AWG and smaller size wires and one hole circumferential compression-deformation type for No. 8 AWG and larger size wires.

D. Ring tongue connections shall be made with a lock washer under the nut.

E. Connectors for building services control wiring shall be ring tongue type with insulated barrel, or forked-spade locking type with insulated barrel terminations. Crimping tools shall be of the type that "proves" a full indent has been made after each operation.

F. Connectors for lighting fixture and receptacle circuits shall be of the screwed-on pressure type with non-restricted zinc coated spring, insulated with vinyl jacket having a flexible skirt.

G. Terminal blocks shall have sufficient space for wire connection, and have marker strips. Current transformer connections shall be provided with short circuiting straps.

2.07 AC MOTOR STARTERS (CONTROLLERS)

A. Starter, where required, shall be provided with mechanical equipment and shall be specified under the mechanical design, except as otherwise indicated, size 1 minimum, rated at 600

Volts, with 120 Volt control voltage and shall be furnished with three universal type auxiliary contacts, over-current protection in all three phases. Control transformers rated 480-120 Volts and fused on primary and secondary with one secondary leg grounded, shall be provided. Motor starter systems and accessories shall be heavy-duty or tight design meeting NEMA ICS1/ICS2.

B. The following motor starters shall be considered:

1. Across-the-line magnetic including protection system and hands-off-automatic (HOD) features as required for 480-volt or 208 volt B 3φ operation.

2. Manual starters using toggle system and thermal overload relay features for 120 volt, 60-hertz operation.

3. Multi-speed starters for two-speed motors using across-the-line start-up design.

4. Reduced voltage starters for 3φ motors over 75 horsepower.

5. Fire pump starters as provided under Section 997.140 "Pumps."

6. Three-phase motors minimum starter size shall meet NEMA size 0 unless specified elsewhere.

2.08 DISCONNECTING DEVICES

A. Disconnecting devices, when not included with electrically operated equipment furnished under other paragraphs, shall be provided and installed under this paragraph. Disconnects shall be NEMA Type HD and UL listed. When required, disconnect shall be suitable for use as service equipment.

B. Electrical characteristics of disconnects including voltage class, Ampere rating, number of poles and NEMA enclosure type shall be as shown on the drawings or specified herein. Disconnects shall be 3-pole in general purpose NEMA 1 enclosure unless otherwise indicated. NEMA 4X switches shall be code gauge (UL 98) stainless steel enclosures where specified.

C. The external operating handle shall be mechanically interlocked with the enclosure cover. The interlock shall make it necessary for the disconnect to be in the "OFF" position for normal access to the inside of the enclosure. A means for bypassing the mechanically interlocked cover and handle shall be provided.

D. Enclosure shall have provisions for locking the operating handle in the "OPEN" position. Position of disconnect shall be clearly indicated on the enclosure.

E. Disconnect Switches

1. Disconnect switches shall be fused or non-fused as shown, single throw safety switch in a separate enclosure.

2. Switch shall be quick-make, quick-break, and manually operated by a lever action handle which shall make or break all poles simultaneously.

3. Switch shall be heavy-duty industrial type suitable for use with the fuse type and sizes indicated on the drawings.

F. Disconnect Circuit Breakers

1. Disconnect circuit breakers shall be molded case, thermal-magnetic circuit breaker in a separate enclosure meeting UL 489; NEMA AB-1; FS W-C375B. Interrupting capacity shall be as shown on the Contract Drawing.

2. Circuit breakers shall provide positive trip-free operation on abnormal overloads with quick-make and quick-break contact under both manual and automatic operation. Stationary and movable contacts shall be non-welding silver alloy and shall be protected with effective and rapid arc interruption. Each pole of the circuit breaker shall be equipped with an inverse time delay thermal overcurrent trip element and magnetic instantaneous overcurrent trip elements for common tripping of all poles. Circuit breakers of 225-ampere frame size and larger shall have interchangeable trip units and adjustable instantaneous trips, unless otherwise shown.

G. Motor Circuit Protector

Motor circuit protector shall be molded-case, 3-pole, quick-make, quick-break, magnetic only circuit breaker with adjustable instantaneous trip settings. Adjustable trip range shall be between 4 and 12 times the continuous rate.

2.09 FUSES

A. Fuse type and size shall be as indicated on the drawings. Coordination curve shall be submitted to the Contracting Officer for review of short circuit levels. Fuse voltage rating shall meet circuit voltage rating.

B. Furnish 100% spare fuses in design size according to the Drawings and Specifications.

2.10 DRY TYPE TRANSFORMERS

A. Dry type transformers rated 25 kVA or less, single phase, 480-120/240V, shall be wall mounted general purpose, for indoor and outdoor use with encapsulated core and coil. Transformers 3 kVA to 25 kVA shall have four (4) 2-1/2 percent taps, two (2) above and two (2) below rated primary Volts (115' rise).

B. Dry type transformers rated 15 kVA or less, three phase, 480-120/208V shall be wall-mounted general purpose, for indoor and outdoor use. Transformers 3 kVA to 15 kVA shall have four (4) 2-1/2 percent taps, two (2) above and two (2) below rated primary volts.

C. Dry type transformers rated 15 kVA and larger, 3-phase, 480-120/ 208V shall be indoor type with four (4) 2-1/2 percent taps, two (2) above and two (2) below rated primary Volts. Where wall mounting is noted on Drawings, provide support bracket, platform or hanger as required.

2.11 PANELBOARDS

A. Panelboards shall be dead front general purpose type for flush or surface wall mounting as shown or indicated on the drawings. Panelboards shall be UL listed and carry a UL label and shall conform with the latest NEMA standards for panelboards. Interior shall be factory assembled with bolt-on devices designed to allow replacement of devices without removing main bus connection.

B. Box shall be fabricated from hot galvanized code gauge sheet steel. Wiring gutters shall be at least four inches wide, or wider, if necessary. A full neutral insulated bus shall be provided.

C. Trim or panelboard front door shall be made of code gauge cold rolled sheet steel using 12 gauge minimum thickness.

D. Trim shall be installed plumb and square prior to finish painting. Finish shall be dark gray enamel over an industrial grade rust inhibitor.

E. Panelboard interiors consisting of branches mounted on buses and a back pan shall be assembled as a complete unit to fit its cabinet.

F. Buses shall be copper, rigidly supported and insulated, and designed so branch circuits can be removed without disturbing adjacent units, or changed without additional machining, drilling or tapping. Temperature rise shall be 50EC maximum at 40EC ambient continuous rating.

G. Bus work, drilling and blank plates shall be provided for installation of future circuit breakers where shown.

H. Screws and bolts used for making copper connections shall be equipped with lockwashers. Riveted bus connections shall not be acceptable.

I. Panels shall be provided with double lugs at the top or bottom of panel bus where sub-feed to another panel is indicated. Sub-feed through the panel bus shall not be permitted.

J. Panelboard mains shall be phased A-B-C left to right when facing the front of the panel. Branch circuit phasing shall be A-B-C top to bottom.

K. Provide ground bus and weld ground connector to cabinet including compatible lugs for incoming and outgoing feeder ground connections to ground bus.

L. Panelboard front shall consist of a one piece sheet steel trim covering terminals and gutter space, and a door for access to circuit breakers. Door shall be flush with trim and attached with completely concealed hinges. Door shall have flush type combination lock and catch. For doors over 45 inches high, provide two catches. Each lock shall be provided with two

mill type keys. Panelboards shall be keyed alike. Panels shall have door in door construction. Steel shall be code gauge.

M. Panels shall be provided with typed directories having circuit numbers and ample space for labeling branch circuits.

N. Branch circuit breakers shall be bolted-on one, two or three pole, quick-make, quick-break, thermal-magnetic automatic molded case circuit breakers per UL 489; AB-1; FSW-C-375B. Frame size and trip rating shall be as shown on Panelboard Schedule. Short circuit rating shall be as indicated on the Panelboard Schedule.

O. Panelboard circuit breakers shall be fully rated. Cascading or series rating of circuit breakers is not acceptable. Where panelboard design requires corrosion/water resistant, enclosure shall be high impact strength fiberglass reinforced polyester. Access door shall have padlock provisions.

P. Multiple breakers shall have common trip from a single operating handle causing all poles to open. Gauged single pole breakers are not acceptable.

Q. Ground fault circuit interrupters meeting UL 1053 and NFPA 70 shall have a "push-to-test" button.

R. Panelboards shall be as manufactured by Square D, Cutler Hammer or Allen Bradley.

2.12 WIRING DEVICES

A. Toggle switches shall be single or double-pole, 3 or 4-way as required, color, per Government, to match wall finish or outlet box (brown for cast boxes), rated 20 Amperes, 120-277 Volts, specification grade of heavy duty thermoset plastic with steel mounting strap conforming to NEMA WD-1; UL 20; and FS-W-S-896. Switches shall be Arrow Hart, Hubbel or Levition.

B. Duplex receptacles shall be specification grade, color per Government to match wall finish or outlet boxes (brown for cast boxes), rated 20 Amperes, 125 Volts heavy-duty thermoset plastic conforming to NEMA WD-1; UL 498; FS-W-W-596. Receptacles shall be Arrow Hart, Hubbell or Levition.

C. Weatherproof receptacles for single and duplex units shall be installed in cast metal box, with gasketed weatherproof cast metal cover using hinged flap and include UL and NEC approval.

D. Ground Fault Circuit Interruptor (GFCI) shall have earth leakage current sensitivity of 5 milliampere and trip time of 1/40 second with test/retest buttons. Receptacle shall be rated UL 943, Class A duplex, 125 volt, 20 ampere, NEMA 5-20R.

E. Special receptacles are provided as indicated on the Contact Drawings and the Specifications.

F. Cord assemblies and plugs shall be specified according to Project requirements and shall include a grounding contact provision.

2.13 OUTLET PLATES AND COVERS

A. Plates for interior flush construction shall be Type 302 stainless steel, stain finish, with suitable hole(s) for device or as indicated on the drawings.

B. Plates for cast-metal wiring device boxes shall be cast-metal. Plates for exterior locations shall be gasketed and provided with a weatherproof cap over each opening permanently attached to the plate by a spring-loaded hinge per NEC.

2.14 MOTOR AND CONTROL WIRING

A. Unless otherwise noted, the work under this Section shall include providing conductors, raceways and connections necessary to operate motors and their control equipment. This shall include power and control wiring indicated on the electrical drawings for ventilators, fans, pumps, motor starters and such other related items as may be furnished under other Sections. Under this Section, provide a suitable disconnect switch for each motor and its controller. Electric-pneumatic switches, motors and other types of control will be furnished under their respective Sections, but wired under this Section. Phasing and grounding requirements will be provided according to motor characteristics.

B. Unless otherwise noted, the work under this Contract shall include conductors, raceways and connections necessary to operate motors and their control for collateral equipment installed under other Sections.

C. Plumbing, heating, ventilating and air conditioning controls are not generally shown on the electrical drawings. Determine their exact locations from the heating and ventilating drawings, specifications and shop drawings.

2.15 NAMEPLATE AND INDEXING

A. Equipment not normally supplied with directory frames shall be provided with dark engraved bakelite nameplates with engraving through to white core. Nameplate markings shall be approved by the Contracting Officer. Only a part of the required nameplates are indicated.

B. Engraved bakelite nameplates shall be provided on, but not limited to, the following equipment; including equipment provided under other divisions. Minimum tag size shall be (2) 2 inch x 2 inch with 1/4-inch character stamped therein.

1. Panelboards indicating voltage, designation and source.

2. Pull boxes, indicating function.

3. Disconnect switches/circuit breakers, indicating function and source.

4. Pushbuttons and selector switches.

5. Lighting system equipment.

6. Terminal boxes

7. Switchboard.

8. Automatic transfer switches.

9. Starters and contactors.

Nameplates shall be secured with two stainless steel screws.

C. Nameplates for equipment 120 Volts and above shall indicate voltage and service type.

2.16 RELAYS

A. Auxiliary relays shall be provided as required and shall be as indicated on the Drawings.

B. Auxiliary relays shall have convertible contacts where available.

2.17 UNDERGROUND CONDUIT

A. Plastic conduits shall be polyvinyl chloride Schedule 40 or 80 PVC pipe for concrete encasement and shall be laid in trench at ductbank as indicated. PVC conduit, fittings and duct spacers shall be manufactured by Carlon or approved equal.

B. Rigid steel heavy wall steel conduits shall be used to a minimum point 5'-0" outside buildings, under parking areas, roadways, concrete pads and where jacked under concrete sidewalks.

C. All PVC conduit shall carry one base conductor for grounding, size as required by National Electric Code.

D. Split duct shall be PVC and self-locking to minimize need for plastic straps and tapes. Duct shall meet ASTM D-635 specifications and shall be listed for concrete encasement.

E. PVC embedded ductline shall change to rigid galvanized steel type at riser location for poles, transformer and switchgear foundation pads, etc.

F. The Contractor shall stake out the conduit route subject to Government and/or Contracting Officer approval. Conduit shall be installed according to the Drawings, and restrained to the spacing to allow concrete pour. Lay ducts with joints staggered.

G. The conduit installation shall be mandrel swabbed and plugged to assure clean runs.

H. All conduit not concrete encased shall receive two coats of asphalt varnish on its exterior.

2.18 SURFACE NON-METALLIC RACEWAY

A. The surface nonmetallic raceway system specified herein for branch circuit wiring and/or data network, voice, video and other low-voltage wiring shall meet all the performance standards specified herein.

B. The raceway and all system components must be UL listed and exhibit nonflammable self-extinguishing characteristics, tested to comparable specifications of UL 94V-0. The raceway base, cover and divider shall be available in 8' lengths.

C. The raceway shall be a two-piece design with a base and a snap-on cover. Total width shall be 6.68" by 1.75" deep with an approximate thickness of .10". The raceway shall be available with and without multiple wiring channels formed by integral barriers in the base.

The base shall have one wiring channel with integral ribs in the bottom to accept divider sections. Divider walls, which snap onto the base to form separate channels, must be available. The base shall be manufactured of rigid PVC compound. The base shall have a smooth texture, ivory in color.

The alternate base shall have three wiring channels separated by two integral barriers. The channels must be large enough to accept standard power and communication devices in each channel. The barriers shall be removable to form one or two channels. Divider walls must be available to replace the removed barriers. The base shall be manufactured of a rigid PVC compound. The base shall have a smooth texture, ivory in color.

D. The cover shall have flanges for snapping onto the base. The cover shall be manufactured of a rigid PVC compound. The cover shall have a matte texture, ivory in color to match the base.

E. The divider shall have integral slots which snap onto the base or alternate base after the integral barrier has been removed. The divider shall be manufactured of a rigid PVC compound. The divider shall have a smooth texture, natural in color.

F. A full compliment of fittings must be available, including but not limited to flat, internal and external elbows, tees, entrance fittings, cover slips and end caps. They shall be manufactured of a rigid PVC compound. The fittings shall have a matte texture, in ivory color to match the base and cover. They shall overlap the cover and base to hide uneven cuts. All fittings shall be supplied with a base where applicable to eliminate mitering. A transition fitting shall be available to adapt to raceways, as shown on the Drawings.

G. Device brackets shall be available for mounting standard devices in-line or offset from the raceway. A device bracket shall be available for mounting up to four devices at one location. Faceplates shall match and fit flush in the device plate. They shall be manufactured of rigid PVC compound. they shall be ivory color to match the raceway base and cover.

2.19 LIGHTING FIXTURES

A. All lighting fixtures and equipment shall be furnished complete, including canopies, suspension of proper lengths, hickeys, casings, sockets, holders, reflectors and such other incidental items, all wired and assembled.

1. All fixtures shall be lamped as indicated on the drawings.

2. All incandescent lamps shall be suitable for operation on 120-volt circuits.

3. All fluorescent lamps shall be as shown in the fixture schedule, and shall be suitable for operation, on 120 or 277-volt circuits as indicated. All fluorescent fixtures shall have high power factor CBM-ETL approved ballasts.

4. Ballasts shall be energy-saving as manufactured by Advance "Mark V", Universal, "Watt Reducer" or approved equal to meet Section 410-73(e) of the NEC and Specification JLP 715.

5. Fixture manufacturer shall submit with shop drawings NEMA LE. 1-105-1969 Temperature Test on each lighting fixture. Lamps shall be energy saving type as manufactured by Phillips or General Electric.

B. Ballasts shall have the following sound ratings for two lamp units:

1. Rapid start and 8' slimline - Class A.

2. 800 Milliamp and 4' slimline - Class B.

3. 1500 Milliamp - Class C.

C. Lamp life shall be not less than the following, with a minimum of 3 hours per start.

1. Incandescent - 2,500 hours.

2. Metal Halide - 15,000 hours.

3. Fluorescent - 20,000 hours.

4. Mercury - 24,000 hours.

5. High pressure sodium - 24,000 hours.

D. Metal halide shall have self-extinguishing mechanisms to automatically extinguish themselves upon a breakage in their glass envelope.

E. High pressure sodium ballasts shall be rated 90% power factor, minimum, for the life of the lamp. Exterior ballasts shall be rated at minus 20 degrees F. Ballasts shall be regulating type and shall be suitable for operation at + or - 10% of rated voltage.

1. Provide one ballast tester for coil and core, starter board and capacitor equal to Holophane Catalog #CA 1000.

F. Lighting fixtures and equipment of the exact type and quality specified and indicated on the drawings shall be provided in order to achieve the quality and levels of illumination incorporated in the lighting design. Substitutions: Under provisions of Section 01600.

G. All lighting fixtures mounted on/or in suspended ceilings shall be independently supported from the building structure and not from the suspended ceiling.

2.20 400 HERTZ POWER SUPPLY

A. Provide 400 hertz power supply Pwr Kart Series as manufactured by Unitron or approved equal.

B. General Specification:

Input:

Voltage	208 volts, ±10%, 3Ø, 3-wire plus ground
Frequency	60 Hz ±10%, (see options)
Phase Rotation	Any
Protection	Over/Undervoltage, loss of phase, overcurrent, short circuit
Starting Current	No greater than 100% of full load current

Output:

Power Rating	15 kVA through 150 kVA, See Table 1
Overload	See Table 1
Voltage	115/200 volts, 3Ø, 4-wire plus grounded neutral
Voltage Regulation	±1.0% under all conditions of line, balanced loads and temperature
Voltage Transients	IAW MIL-STD-740E, Figure 4
Frequency Regulation	400 Hz ±0.01% under all conditions of line, load and temperature
Frequency Transients	None
Phase Angle Regulation	±2 degrees for balanced loads

Harmonic Distortion	2.0% max.
Protection	Overvoltage, short circuit, over/undervoltage, and safety disconnect

Energy Factors:

Efficiency	95% max. at full load. Will vary depending on power level.
Energy Efficiency Ratio	20.0 typical

Environmental:

Acoustical Noise	65 dBA maximum at 5 feet
Temperature Range	-40°C to +55°C
EMI/RFI	Compatible with aircraft systems

Monitoring/Controls:

Meters	Output voltage and current, internal elapsed time indicator, optional output frequency meter.
Controls	Input contactor "ON", input contactor "OFF", output contactor "ON"/OFF" output "Locate/Remote" control, "Reset/Lamp Test" switch, alarm silence, output meter "phase" select, and optional output voltage an frequency adjust, internal automatic line drop compensation.
Indicators	Input "ready", unit "ON", output contactor control "ON", maintenance (bypass) mode, external line fault, internal unit fault, external load fault, summary alarm, and audible alarm indicator.

Mechanical:

Size	See Table 1
Weight	See Table 1
Construction	Indoor/Outdoor
Cooling	Forced Convection

Standard Features:

- MIL-STD-704E compliant
- Automatic input line monitoring
- Emergency Mushroom "OFF" switch

- Indoor/Outdoor (hangar/ramp) use
- Automatic line drop compensation (LDC) up to 7%
- Padlockable "ON" control and entry
- Coordinate protection, plug-in printed circuit boards, ribbon cable wiring throughout
- 18-inch hazard area clearance (See Note 6)
- Built-in safety disconnect from aircraft
- Pneumatic tires
- Local/Remote Output Control

Options:

- Output cable with MS 90328 connector
- 100 foot input cable
- Built-in diagnostic system
- Output voltage adjust
- Output frequency adjust
- Output frequency meter
- Dual output with individual automatic safety disconnect from aircraft
- 300% overload for 6 seconds
- 12% input current distortion
- Input transient protection – IEEE E62.41, CatB

PART 3 - EXECUTION

3.1 GROUNDING

A. Unless otherwise shown on the drawings, the grounding system shall be installed to comply with this paragraph.

B. The grounding system shall be mechanically and electrically connected to provide an independent return to the grounding source and have a maximum resistance of 25 ohms per NEC, or as specified by the Contracting Officer.

C. Buried, permanent or inaccessible grounding connections shall be made by an exothermic welding process unless otherwise indicated. In general, connections shall be permanent, except that substantial mechanical compression connectors shall be used where disconnection is required for test and where called for on the drawings.

D. Ground cables, where subject to mechanical damage, shall be protected by rigid steel conduit.

E. Bonding jumpers shall be copper and of a cross sectional area at least equal to the corresponding grounding conductors. Solderless lugs, compression connectors or clamps shall be used where bonding jumpers are attached to equipment, conduit and cabinets. No soldered connectors shall be used.

F. A separate insulated conductor shall be provided for the grounding of raceways and equipment. A bare conductor may be used where safe from mechanical injury. Equipment grounding conductors shall be of the type specified elsewhere under Wire and Cable and shall conform to the copper wire size indicated in NEC Tables 250-94 or 250-95, unless otherwise shown on the drawings.

G. Insulated grounding conductors shall have green colored insulation, except that sizes larger than No. 8 AWG may be bare where exposed, painted green, or marked with green colored tape.

H. Equipment grounding conductors shall be run in the same raceways enclosing the power leads supplying the equipment, and shall be connected to the ground established at the source of supply. The conduits or raceways shall not be used as grounding conductors, unless indicated on the drawings.

I. The grounding conductor shall in no case be a neutral current carrying conductor of any system. The neutral shall be carried via its own full capacity fully insulated conductor to the insulated neutral terminal strips in the panelboards. Neutral conductors will be sized to meet any system harmonic input.

J. The frames of electrical equipment, including motors, panels, and lighting fixtures, and the extra pole provided on receptacles shall be grounded to the equipment grounding conductor.

K. Branch circuit equipment grounding conductors shall be carried to the equipment ground stud or bus in the panelboard.

L. Panelboards shall be grounded by connecting the equipment ground stud or bus directly to ground via a grounding conductor. The point of grounding shall be at the point of supply which may be a distribution load center or the secondary of a lighting transformer.

M. Motors shall be grounded by connecting the grounding conductor from a ground connection at the starter to the motor frame. The grounding conductor shall be terminated in the motor connection box providing the terminal is mechanically connected to the frame. If this is not feasible, the grounding conductor shall be extended through an insulated bushed opening in the connection box and connected to the motor base.

N. The secondary neutral of polyphase or center-tapped lighting and power transformers shall be connected directly to the ground, via the grounding conductor run in the same raceway as the supply leads.

3.2 CONDUITS AND RACEWAY

A. Requirements of this specification applying to installation of rigid galvanized steel and EMT per NEC.

B. The exact locations and routing of raceways, when not shown in detail on the drawings, shall be determined by the Contractor subject to the approval of the Contracting Officer. Conduit size shall be as shown on the drawings. No conduit shall be smaller than 3/4 inch.

C. Conduit embedded in floors, walls or beams of reinforced concrete structures, other than those merely passing through, shall be sized according to the drawings and shall not be installed where the outside diameter of the conduit would be greater than one-third the thickness of the structure, nor impair the strength of the construction. The Contractor shall provide expansion joints and wall seals wherever required on the installation.

D. Conduits shall be concealed within finished walls, ceilings and floors, where possible.

E. Conduits shall be adequately supported and secured at intervals of not more than eight feet, except under special conditions by permission of the Contracting Officer, but in no case exceeding the intervals in NEC Table 346-12. They shall be run with a slight pitch in a manner that condensate traps will be avoided. Exposed conduits shall be as nearly as possible parallel to walls, structural members and ceilings. Supports shall be furnished and installed where required whether or not shown on the drawings. Supports shall be painted with at least one coat of zinc chromate primer with one finish coat of pearl grey enamel.

F. Care shall be taken to prevent the lodgment of plaster, dirt or trash in conduits, boxes, fittings and equipment during the course of construction. Conduit ends shall be reamed, and raceways shall be finished and swabbed free of obstructions prior to installation of the conductors. End caps or plugs shall be applied after swabbing to prevent entrance of debris before pulling of cable.

G. Conduits shall be supported by straps, hangers, or clamps. Conduit supports and directly-fastened boxes, panels, etc., shall be fastened with wood screws on wood, with cinch anchors, precast inserts or bolts and expansion shields on concrete or masonry, with toggle bolts on hollow masonry units, and with machine screws, welded thread studs, beam clamps or welded clips on steel work. Wooden plugs inserted in concrete are not acceptable for raceway fastenings. Raceways or pipe straps shall not be welded to steel structures. The Contractor shall meet seismic requirements for the installation.

H. Conduits shall be installed with the straightest maximum runs of approximately 100 feet and with not more than the equivalent of three 90 bends between pull points. A bend within 3 feet of the end of the conduit opposite the pulling end shall not count as a bend. Suitable pull boxes shall be installed to fulfill this requirement whether or not shown on the drawings. Conduit fittings shall not be substituted for boxes. Pulling distances greater than 100 feet between pull points will be allowed if pulling calculations indicate that the pulling tensions will not damage cable.

I. Feeders and branch circuits shall be run in separate conduit and raceways unless specifically indicated differently on the drawings.

J. Long thread known as "running threads" shall not be used.

K. Conduit bends shall not have kinks or flats, and shall not be less than standard radii.

L. Conduits to motors, transformers, and rotating and vibrating equipment shall be terminated in liquid-tight flexible conduit per NEC.

M. Spare conduits shall be sealed at both ends by terminating in a coupling and a screwed plug.

N. Rigid steel conduit shall be terminated with two locknuts and one steel bushing except when threaded into hub. Slip-fit, set-screw, jam-lock and similar fasteners are not acceptable to couplings and connections to boxes and cabinets. Insulated metallic bushings shall be used on conduits entering panel cabinets, pullboxes and wiring gutters, except on branch lighting circuits. After assembly, conduit locknuts, coupling fittings, and bond wire screws shall be set up tight before installation of wiring.

O. Set screw fittings shall be allowed on EMT installations.

3.3 INSTALLATION OF HANGERS AND SUPPORTS

A. General

1. All conduits and equipment mounting and supports shall comply with the requirements of Seismic Restraints and NEC.

2. Install hangers and supports, sleeves and fasteners in accordance with approved printed manufacturers' installation procedures, and as specified and/or shown on the Drawings.

3. Coordinate all aspects of the electrical work, including installation of the electrical system as necessary to interface with other project work.

4. Install hangers and attachments to properly support raceways, equipment and accessories from building structure. Arrange for parallel runs of horizontal conduits to be supported together on trapeze hangers where possible. Install hanger and supports with maximum spacings not to exceed that permitted by NFPA 70 and NECA 5055, unless otherwise shown on the Contract Drawings.

5. Secure threaded rod couplings, trapeze hangers or supports or similar horizontal elements, using lockwashers and jam nuts to prevent loosening.

B. Conduit and Raceway Supports

1. Do not support raceways from hung ceiling supports, mechanical ductwork, ductwork supports, piping, piping supports or the metal roof deck.

2. Threaded rod, for the support of conduits, raceways or trapeze hangers of the given size, shall be not less than shown on the Drawings or listed below:

Conduit, Raceway, Hanger Size (inches)	Threaded Rod Size (inches)
2 or less	3/8
2 1/2 - 3 1/2	1/2
4 - 6	5/8
6	3/4

3. Where trapeze hangers are used, bolt or clamp the raceways in place to at least every third hangers and to the first hanger on each side of a bend, fitting, junction or pull box or change in direction.

C. Sleeves

1. Unless otherwise shown on the Contract Drawings, extend sleeves for raceways and risers on the one inch beyond top of finished floor, curb or building element being penetrated.

2. Install sleeves level and plumb, accurately located and positioned to conform to the requirements of the equipment and in accordance with the approved layout drawings.

3. Install interlocking modular seals in tandem, one at the interior and one at the exterior face of the pipe sleeve.

4. Tighten sleeve seal nuts until sealing grommets have expanded to form watertight seal.

D. Fasteners

1. Corrosion-resistant wood screws, lag screws, carriage bolts or machine screws shall be utilized for wood or materials of similar fibrous nature.

2. Welded or brazed threaded corrosion-resistant studs, bolts or machine screws or clamps shall be utilized for structural and miscellaneous steel, iron or other metals.

3. Corrosion-resistant metallic expansion shields, wedge anchors, drop-in anchors, lag screws, bolts or machine screws shall be utilized for solid masonry or concrete.

4. Corrosion-resistant sleeve anchors, drop-in anchors or toggle bolts shall be utilized for concrete masonry units (CMU). Do not use powder activated fasteners in CMU.

3.04 CABLING

A. Cables shall be adequately supported and tied. No cable shall be supported at less than 48-inch intervals unless otherwise shown or authorized by the Contracting Officer.

B. Wires shall be routed and clamped, using nylon clamp to avoid damage. No wire or wire harness shall be routed across sharp metal surfaces or edges without adequate protection. Grommets shall be used when wires or wire bundles are routed through equipment holes.

C. Cables and wire bundles shall have bend radii not less than 6 times the diameter of the cable or wire bundle.

D. When crimping lugs on wires, retain insulation so no bare conductor shall be left exposed beyond the lug. No strands shall be cut out of conductors to fit lugs or terminals.

E. The hot side of plug-receptacle connection shall include socket-type pins.

F. Cables should have loops provision for future extension and/or repair.

3.05 WIRING

A. The outside covering of wire No. 8 AWG size and smaller shall be color coded. Wire sizes No. 6 and larger shall be identified with color-coated tape at terminations. Unless otherwise noted, color coding shall be as follows:

1. 277/480 Volts, 3-phase, 4-wire: phase A - black-white, phase B - red-white, phase C - blue-white, neutral - gray.

2. 120/208 Volts, 3-phase, 4-wire: phase A - black, phase B - red, phase C - blue, neutral - white.

3. Equipment ground: green.

B. No wire shall be pulled until the conduit system is completely installed from pull point to pull point.

C. Care shall be exercised when installing wire in conduits so as not to damage the conductor insulation. Lubricating compounds used for pulling conductors through the raceways shall not have a deleterious effect on jacket or insulation. Compounds used shall be only those recommended by the cable manufacturer.

D. Bending radius of any insulated wire or cable shall not be less than minimum recommended by the cable manufacturer.

E. Maximum pull tension for wire or cable shall not exceed cable manufacturer's recommendations. The Contractor shall use a dynamometer to monitor cable pulling tension.

F. Wiring inside equipment, panels, and boxes shall be installed in a neat, workmanlike manner. The wiring shall be neatly harnessed and laced with cord or cable ties.

G. Terminations of insulated power cables shall be protected from accidental contact, deterioration of coverings and moisture by the use of terminating devices and materials.

Terminations shall be made using materials and methods as specified herein and/or as designated by the written instruction of the cable and termination kit manufacturers.

H. Splices

1. Splices are not permitted except in junction boxes, outlet boxes or other permanently accessible locations. Splices, where permitted, shall be made in a neat, workmanlike manner using approved mechanical connectors. Wire nuts or spring tension connectors shall not be used.

2. Insulation for splices in 600 Volt wire and cables shall be made by applying two half-lapped layers of varnished cambric tape before applying insulating putty to fill voids and irregularities and finished with two half-lapped layers of vinyl plastic tape. After connecting conductors, insulation equal to one and one-half times that on the spliced wires. All spliced cable shall be given electrical insulation tests.

I. Branch lighting and appliance circuits shall be two-wire circuits with individual neutral conductors, except where three or four wire circuits are shown. Where three or four wire circuits are indicated, the circuits shall consist of two or three phase conductors, respectively, with a jacket of distinguishing color and a common neutral. Branch circuit shall be checked for excessive neutral harmonic loads, in sizing the neutral conductor.

J. Polarity of electrical connections shall be identified in order to preserve phase relationship in feeders and equipment.

K. Wire shall be marked at terminations, junction boxes, ducts or raceway entrances as soon as they are connected to apparatus. Unless otherwise indicated on the drawings, the numbering shall identify the system, terminal block and terminal point using "opposite call-out."

1. Circuit phases shall be color coded at terminations, splices and pull boxes with UL listed electrical plastic vinyl tape.

2. Wire markers shall be black-on-white printed numbers on a pressure sensitive adhesive tape. Markers shall be attached to cables as close to terminal points as possible, and shall be applied on a clean, dry section of the cable. Extra care shall be taken to insure proper adhesion of markers in and around areas where oil, vapors, grease, etc. may be encountered.

3.06 UNDERGROUND DUCT

A. The underground duct installation, unless otherwise indicated on the drawings, shall be PVC schedule 40 or 80 designed for concrete encasement or direct burial.

B. The Contractor shall stake out the routing of the underground ducts as soon as field conditions permit subject to the approval of the Contracting Officer. (Utility for primary) Finished grades shall be indicated at stakes. The Contracting Officer reserves the right to make any reasonable change in location without additional expense to the Government.

C. Trenches shall be excavated and ducts laid at least 18 inches below finished grade and shall slope at least 3 inches per 100 feet of run as established by a surveyor's level. Drainage shall be toward the manhole/handhole. Except at conduit risers, accomplish changes in direction of runs exceeding a total of 10 degrees, either vertical or horizontal, by long sweep bends having a minimum radius of curvature of 25 feet. Sweep bends may be made up of, one- or more curved or straight sections or combinations thereof. Manufactured bends shall have a minimum radius of 18 inches for use with conduits of less than 3 inches in diameter and a minimum radius of 36 inches for ducts of 3 inches in diameter and larger.

D. Entire trenches between ends of duct shall be opened and accurately graded. Installed ducts by the "built-up" method using approved spacers or separators under and between the ducts. Lay ducts with staggered joints.

1. The duct structure shall be tied with heavy cord at or near the separators so as to secure hold the ducts in position during the pouring of the concrete encasements.

2. Joints in ducts shall be of the tapered sleeve coupling type. The duct ends and couplings shall be kept clean and the couplings carefully driven without the use of jointing compound.

3. Joints which must be cut in the field shall be made with an approved hand type machine made for the purpose by the duct manufacturer.

E. The concrete encasement shall be poured around the ducts as soon as possible after they have been placed to protect them from mechanical injury. Top of concrete encasement shall not be less than 18 inches below grade.

F. A mandrel swab shall be drawn through new and existing underground ducts immediately after they have been laid to remove any dirt or debris. The ducts then shall be plugged until such time when cables are to be pulled. The ducts shall be swabbed again just prior to the cable installation.

G. Underground conduits shall be rigid steel from a point five feet beyond the building and at the equipment. Where underground conduits enter equipment, they shall be sealed with compound bushings. Compound bushings shall be malleable cast iron, zinc plated. Sealing compound for compound bushings shall be in accordance with above specification. All underground conduits not encased in a concrete envelope shall be painted with two coats of asphalt varnish.

3.07 MANHOLES, HANDHOLES AND VAULTS

A. Precast units shall be set on 6 inches compact granular fill of 3/4-inch aggregate.

B. Cable racks shall be corrosion-resistant spaced under three feet apart with a minimum of 6 racks per manhole, handhole or vault.

C. Frame and cover shall be traffic rated where required and be set flush with paved surfaces.

D. All installation shall include ground rod provision according to Drawings.

E. Bituminous waterproof coating shall be applied to all manhole, handhole and vault interior.

F. Install pulling irons on each side.

G. Covers shall be embossed with "Electric" label.

H. The Contractor shall compact soil after backfill and restore the surface to its surrounding status.

3.08 SWITCHBOARDS AND PANELBOARDS

A. Switchboard and panelboard installations shall meet requirements of NEC, the project drawings, and be per manufacturer's requirements

B. All installations shall meet professional workmanship standards for location, appearance, clearances to satisfy approvals of the Contracting Officer and/or the Government.

3.09 MOTORS AND TRANSFORMERS

A. Motors and transformers shall be installed according to project drawings, NEC requirements and manufacturer's requirements.

B. All installations shall meet professional workmanship standards for location, appearance, clearances to satisfy approvals of the Contracting Officer and/or the Government.

C. Seismic requirements for motors and transformer installations shall be included.

D. A safety factor of 3 shall be provided for all hanger-type installations.

3.10 LIGHTING SYSTEMS

A. Lighting fixtures, controls and protection shall be installed according to project drawings and NEC requirements. Verify ceiling types with Architectural drawings for compatibility.

B. Hung fixtures shall be suspended from the building structure and shall not be suspended from any dropped ceiling installation.

C. Seismic requirements for special fixture installations shall be included where needed.

D. All lighting installation shall meet professional workmanship standards for location, appearance, clearances to satisfy approvals of the Contracting Officer and/or the Government.

3.11 RELAYS AND FUSES

A. The protection installation of relay and fusing shall comply with project drawings and NEC requirements.

B. Relay and/or fusing shall meet UL, the manufacturer=s and project design capacities.

C. The installation shall include a minimum of one spare fuse sized for each installed fuse used. Fuses to be provided in a lockable, corrosion-resistant steel, wall-mounted cabinet.

D. The Contractor shall be responsible for installation and testing of the systems to the approval and satisfaction of the Contracting Officer and/or the Government.

3.12 TELEPHONE SYSTEM

A. The Contractor shall provide telephone backboard and terminations of telephone conduit runs in the telephone closet.

B. Conduit runs to designated areas shall be provided according to the project drawings and NEC standards.

C. The installation of the telephone communication system shall be provided by others.

D. The raceway, conduit and boxes shall meet UL and professional workmanship standards to satisfy approvals of the Contracting Officer and/or the Government.

3.13 SPECIAL INSTALLATIONS

A. Special installations, including but not limited to, fire alarm, security, public address, data, CCTV, etc., shall be completed according to their project drawings, design specifications and authorizing agencies.

B. All special installations shall meet professional workmanship standards to satisfy approvals of the Contracting Officer and/or the Government.

END OF SECTION

SECTION 16060

GROUNDING AND BONDING

PART 1 - GENERAL

1.01 GENERAL

A. Work specified in this Section consists of furnishing installing, and testing of all required materials and components for a complete grounding and bonding system.

B. The system shall provide:

1. System(s) Grounding.

2. Equipment Grounding.

3. Bonding of Metallic Objects for Personnel Safety.

1.02 REFERENCES

A. The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by basic designation only. In case of conflict between provisions of codes, laws, ordinances, and these specifications, including the Contract Drawings, the more stringent requirements will apply.

1. American National Standards Institute (ANSI) Publication:

C2 National Electrical Safety Code

2. National Fire Protection Association (NFPA) Publication:

70 National Electrical Code (NEC)

3. Underwriter's Laboratories Inc. (UL) Publication:

467 Grounding and Bonding Equipment

4. Institute of Electrical and Electronic Engineers (IEEE) Publication:

80 Guide for Safety in AC Substation Grounding

81 Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potential of a Ground System.

1.03 RELATED WORK

A. General requirements include those specified in Section 16010, Electrical "General Provisions" and as specified herein. Materials not normally furnished by the manufacturer with this equipment are specified in:

1. Section 16012, "TESTING AND QUALITY CONTROL"

2. Section 16050, "BASIC MATERIALS AND METHODS"

3. Section 16402, "UNDERGROUND DISTRIBUTION RACEWAY SYSTEMS"

1.04 SUBMITTALS

A. Manufacturer's Data: Shall be submitted for the following:

1. Ground Rods

2. Ground Connectors

3. Exothermic Welds

4. Grounding Resistors

5. High Resistance Grounding Equipment

6. Grounding Conductor

B. Shop Drawings: Shall be submitted for the following:

1. Grounding system(s) complete and fully detailed.

C. Certification:

1. Certified test reports verifying that ground resistance of each ground grid when installed and ground bus when connected to the ground grid does not exceed specified values.

D. Test Procedures: Shall be submitted for acceptance prior to testing. This submittal shall clearly identify the procedures, methods, equipment and expected results.

E. Test Reports: Shall be submitted for the following:

1. Ground-resistance measurements

1.05 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Ship each unit or component securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

B. Mark each item, unit or component in accordance with applicable reference standard.

C. Store materials in secure and dry facility and in original packaging in a manner to prevent soiling, physical damage, wetting or corrosion prior to installation.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT, GENERAL

A. All materials, equipment, and devices shall, as a minimum, meet the requirements of UL where UL standards are established for those items, and the requirements of NFPA 70. All equipment and materials provided shall be new, unless specified otherwise or indicated.

B. Grounding and Bonding Equipment: Shall conform to UL 467.

2.02 GROUND RODS

A. Material: Copperweld.

B. Type: Sectional

C. Size: Having diameter adequate to permit driving to full length of the rod, but not less than 5/8-inch, by 8 feet long.

D. Provide driving couplings wherever threaded rods are used.

2.03 GROUNDING CONDUCTORS

A. Grounding Electrode Conductors:

1. Type: Insulated or bare as shown

2. Materials:

Insulated: No. 6 AWG and smaller shall be solid copper per ASTM B3, those No. 4 AWG and larger shall be copper Class B stranded per ASTM B8. Insulation shall be NEC Type RHW ethylene propylene rubber (EPR). Color to be green.

3. Size: In accordance with NEC Table 250-94

B. Equipment Grounding Conductors:

1. Type: Insulated or bare as shown.

2. Material: As specified in Section 16110, "Wires and Cables@.

3. Size: In accordance with NEC Table 250-95.

C. Bonding Conductors:

1. Type: Insulated or bare as shown.

2. Material:

a. Main and equipment grounding: Insulated or bare copper similar to equipment grounding conductor.

3. Size: In accordance with NEC Table 250-94.

2.04 GROUND BUS

A. Material: Copper

B. Size: 1/4-inch by 2-inch, length as shown

C. Mounting: As shown on the drawings.

D. Connections: Drilled to receive bolted ground cable connections to equipment and for attachment of an external grounding conductor(s).

E. Frame Assembly: Shall be constructed from corrosion resistant hot dipped galvanized angle. All members shall be assembled using outdoor hardware and be of sufficient strength to withstand severe mechanical stress.

F. Enclosure: A grounded safety-screen enclosure shall be provided for personnel safety. The enclosure shall provide adequate electrical clearance from the resistor frame based on system voltage.

2.05 TERMINAL LUGS

A. Type:

1. NEMA 2-hole, copper compression type for all conductors #4/0 AWG and smaller.

2. NEMA 2-hole, long barrel, copper, double compression type for all conductors 250 Kcmil and larger.

B. Construction:

1. Lugs shall be tin plated to minimize corrosion or bimetallic contact.

2.06 EXOTHERMIC WELDING

A. General: All materials required for the exothermic welding process must be the product of one manufacturer regularly engaged in the production of these materials for the intended application specified herein. All connections made with these materials must have verifiable proof of meeting or exceeding the requirements of IEEE Standard 80.

B. Application: The product shall be suitable, but not be limited to, the following welding applications:

1. Cable to cable connections.

2. Cable to ground rod connections.

3. Cable to steel structure connections.

4. Cable to rebar connections.

C. Product: Weld metal shall contain tin oxide. Starting material shall contain no phosphorous or other dangerous materials. Low emission type exothermic welding connections with battery start shall be used in all locations such as vaults, manholes, tunnels or other confined spaces.

D. Coal Tar Epoxy: Polyamide cured coal tar epoxy, applied to a dry film thickness of 8 mils per coat.

E. Epoxy resin encapsulation: Two-component epoxy resin type with plastic snap mold.

2.07 FLEXIBLE GROUNDING JUMPERS

A. Braided copper, 1/8-inch by 1-inch, length as required, having suitable treatment for connection to zinc-coated steel.

PART 3 - EXECUTION

3.01 GROUNDING INSTALLATION

A. General: Neutral conductors, cable shields, metallic cable sheaths and armor, metallic conduits cable terminations, junction boxes, poles, surge arresters, fencing enclosing electrical equipment, and other non-current carrying metallic parts of electrical equipment shall be grounded. The installation shall conform to the requirements of ANSI C2, NFPA 70, local Electrical Code, and to the requirements specified herein.

B. Resistance Values: Non-current carrying metallic parts of electrical equipment shall have a maximum resistance to solid "earth" (ground) not exceeding 25 ohms.

C. Grounding Connections:

1. Below Grade or encased in concrete: Weld buried or encased in concrete ground connections exothermically in strict accordance with manufacturer's recommendations as described in the instructions accompanying the product. Clean and coat with coal tar epoxy applied with a 32 mils dry film thickness using multiple coats. Allow drying between coats. Encapsulate with epoxy resin, all buried ground, concrete-encased and dissimilar metal ground connections such as the over-cut on the insulated copper grounding electrode conductor.

2. Above Grade: Use terminal lug(s) to connect grounding conductor to equipment enclosure. Use approved ground connector(s) to connect grounding conductor to piping, fencing and conduit systems.

3. Manholes, Handholes and Vaults: Each manhole, handhole and vault shall have one or more driven ground rod(s) or ground mat beneath its base, or as detailed on the Drawings. Cable racks, cable shielding, metallic sheath and armor at each cable joint or splice shall be properly connected, by means of #4 AWG conductor or equivalent braided tinned copper wire, to the ground rod or mat. Connections to metallic cable sheaths shall be by means of tinned terminals soldered to ground wires and cable sheaths. Care should be taken during soldering as not to damage metallic cable sheaths or shields.

4. Splices: Grounding conductors shall not be spliced.

5. Junction Boxes: Provide all boxes with a grounding stud or a means for the connection of equipment grounding conductors and bonding of all metal conduits. Use bonding jumpers or bonding type locknuts and bushings for bonding conduits to the boxes. Connect and bond the equipment grounding conductor of the cable running thru each non-metallic conduit to the boxes.

6. Pullboxes: Provide a grounding bus in each pullbox for bonding pulling irons, cable rack supports, frames, metal covers, conduits, and #4/0 AWG insulated copper metal (RW) ground cable. In pullboxes, bond the grounding rod or mat to the grounding bus.

7. Boxout Pull and Junction Boxes: Provide two 3/8 inch x 2 inch grounding studs as a means for bonding metal covers, metal conduit and equipment grounds.

8. Manholes: Provide a grounding bus in each manhole for bonding pulling irons, cable rack supports, frame and metal covers, metal conduits and #4/0 AWG ground conductor. Connect and bond the station or building grounding conductor to the bus. Bond the grounding rod or mat to the grounding bus.

9. Electrical Rooms: Install copper ground bus minimum 3/8' x 3' x 24' mounted on insulators with provision for minimum 8 terminal lugs. Bonded insulated #4/0 AWG ground leads to ground bus. Embed all grounding conductors in finish slab where possible. Support the surface grounds in a manner and location accepted by the Contracting Officer.

10. Conduit and Cable Trays: Bonding bushings and ground connectors shall be used on all ends of conduit and cable trays regardless of length.

D. Grounding Electrodes:

1. Install a grounding electrode system consisting of number of individual copperweld ground rods effectively bonded together by copper conductors and buried in earth or encased in concrete in a pattern and location shown on the Contract Drawings.

2. Install the grounding electrode grid system not less than 30 inches below the finished grade.

3. Ensure 24-inches minimum separation between grounding electrode grid system installations.

4. Ground rods shall be driven into the ground until the top of the rod is approximately 6-inches below grade.

5. The grounding electrode system shall be effectively bonded to metallic underground water pipe in accordance with NEC using insulated #4/0 AWG copper grounding conductor.

6. The grounding electrode system shall be effectively bonded to all the metal structural columns in accordance with NEC using insulated #4/0 AWG copper grounding conductor.

7. Provide interconnecting conductors to enclosures of electrical equipment, metal fences, structures, ground buses, metallic piping, metallic finishes, elevator components, and all other items as required by the NEC. Conductors shall be copper cable. The fire protection piping shall be grounded to prevent personnel shock hazards. As a minimum the hose valves, Siamese valves, and handles shall be grounded.

E. Separately Derived AC Systems:

1. Ground as shown on the Contract Drawings and in accordance with the NEC.

F. Service Equipment:

1. Ground as shown on the Contract Drawings and in accordance with the NEC.

2. Provide a code rated bonding jumper or disconnecting link between the neutral and the ground bus.

G. Equipment Grounding:

1. Shall be provided for personnel safety and continuous operation of equipment at ground potential.

2. Equipment grounding shall be provided by means of a green-colored insulated conductor, separate from the electrical system neutral conductor, and installed within or as part of the feeder and branch circuit raceway system. Equipment grounding conductor shall be provided with:

a. All feeder circuits

b. Branch circuits

3. Equipment grounding conductors shall be sized as shown on the Contract Drawings (in accordance with NEC, Table 250-95).

3.02 BONDING

A. General: For personnel safety, non-electrical metallic objects and equipment in the vicinity of electrical equipment, such as substation, switchgear, transformer(s) and motor control center(s), shall be bonded to a ground bus or grounding conductor using #6 AWG insulated conductor minimum. The bonding shall be provided to eliminate any possibility of difference in 'potential' that could develop between the metallic object(s) and the ground potential.

B. Metallic objects to be bonded to a ground bus or grounding conductor are:

1. Ductwork.

2. Metallic piping.

3. Metallic ladders or stairs.

4. Other enclosures as required by the NEC and as shown on the Contract Drawings.

3.03 FIELD TESTS AND INSPECTIONS

A. Ground-Resistance Measurements:

1. Ground-resistance measurements of each ground rod shall be taken, before any wire is connected, and test results recorded. Perform all measurements in normally dry weather, not less than 48 hours after rainfall. Ground resistance shall be 25 ohms or less.

2. Each Contractor shall provide measurement of resistance to earth from all grounded noncurrent carrying metallic parts of electrical equipment and pull boxes (enclosures) to a reference ground, auxiliary (mode) electrode, or ground electrode. It is the responsibility of the Contractor to construct an auxiliary electrode or reference ground where ground electrode is not practical. Each Contractor shall also provide measurement of resistance to earth of each ground electrode and ground bus located in pullboxes,. manholes, electrical rooms, utility rooms and in locations installed by the Contractor. All measured results shall be recorded and tabulated.

3. Recorded results shall be tabulated to form a test report. The test report not be limited to, the following:

   a) identification of each component tested

   b) Location of each component tested

   c) Time of each test

   d) Resistance values

   e) Soil condition and resistivity at the time the test (for ground rod measurements) was performed.

4. Test Methods:

   a) Perform "fall-of-potential' type test per IEEE Standard No. 81 on the grounding electrode system.

   b) Perform the 'two-point' type test per IEEE No. 81, to determine the ground resistance between the grounding electrode system and non-current carrying metallic parts of electrical equipment (enclosures), system neutral and/or derived neutral points.

   c) Perform the ratio method type test on the grounding electrode system.

B. Inspections: Inspect ground system for compliance with plans and specifications.

END OF SECTION

SECTION 16071

SEISMIC INSTALLATION FOR ELECTRICAL WORK

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, shall apply to this Section.

B. This Section includes seismic restraints and other earthquake-damage-reduction measures for electrical components. It complements optional seismic construction requirements in the various electrical component Sections.

1.2 RELATED WORK

A. Section 16050 "Basic Materials and Methods."

B. Section 16060 "Grounding and Bonding."

C. Section 16110 "Wire and Cable."

1.3 REFERENCES

A. BOCA: BOCA National Building Code.

B. SBC: Standard Building Code.

C. UBC: Uniform Building Code.

D. Seismic Restraint: A fixed device (a seismic brace, an anchor bolt or stud, or a fastening assembly) used to prevent vertical or horizontal movement, or both vertical and horizontal movement, of an electrical system component during an earthquake.

E. Mobile Structural Element: A part of the building structure such as a slab, floor structure, roof structure, or wall that may move independent of other mobile structural elements during an earthquake.

1.4 SUBMITTALS

A. Product Data: Illustrate and indicate types, styles, materials, strength, fastening provisions, and finish for each type and size of seismic restraint component used.

1. Anchor Bolts and Studs: Provide types and sizes, complete with rated strength in tension and shear.

B. Shop Drawings: For anchorage and bracing not defined by details on Drawings, indicate materials, and show designs and calculations signed and sealed by a professional engineer.

1. Design Analysis: To support selection and arrangement of seismic restraints. Include calculations of combined tensile and shear loads.
2. Details: Detail fabrication and arrangement. Detail attachment of restraints to both structural and restrained items. Show attachment locations, methods, and spacings, identifying components and listing their strengths. Indicate direction and value of forces transmitted to the structure during seismic events.
3. Preapproval and Evaluation Documentation as required by Local AHJ: By **ICBO Evaluation Service**] (**an agency approved by authorities having jurisdiction**), showing maximum ratings of restraints and the basis for approval (tests or calculations).

C. Coordination Drawings: Plans and sections drawn to scale and coordinating seismic bracing for electrical components with other systems and equipment, including other seismic restraints, in the vicinity.

D. Product Certificates: Signed by manufacturers of seismic restraints certifying that products furnished comply with requirements.

E. Qualification Data: For firms and persons specified in "Quality Assurance" Article.

F. Material Test Reports: From a qualified testing agency indicating and interpreting test results of seismic control devices for compliance with requirements indicated.

1.5 QUALITY ASSURANCE

A. Comply with seismic restraint requirements in [**BOCA**], unless requirements in this Section are more stringent.

B. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing seismic engineering services, including the design of seismic restraints, that are similar to those indicated for this Project.

C. Testing Agency Qualifications: An independent testing agency, acceptable to authorities having jurisdiction, with the experience and capability to conduct the testing indicated.

1.6 PROJECT CONDITIONS

A. Project Seismic Zone and Zone Factor as defined for the project site, i.e., [**Zone 1, Zone Factor 0.075**] [**Zone 2A, Zone Factor 0.15**] [**Zone 2B, Zone Factor 0.20**] [**Zone 3, Zone Factor 0.30**] [**Zone 4, Zone Factor 0.40**].

B. Identify occupancy category.

C. Indicate acceleration factor used in seismic restraint.

1.7 PROJECT CONDITIONS

A. Provide acceleration factor.

B. Provide Project Seismic Hazard Exposure Group as defined in BOCA or SBC: **[I]** [**II**] [**III**].

1.8 COORDINATION

A. Coordinate layout and installation of seismic bracing for electrical equipment with building structural system and architectural features, and with mechanical, fire-protection, electrical, and other building features in the vicinity.

B. Coordinate electrical equipment concrete bases for seismic bracing with building structural system.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work shall certify their successful product installations for a minimum of 5 years documented successful experience.

2.2 MATERIALS

A. Use the following materials for restraints:

1. Indoor Dry Locations: Steel, zinc plated.
2. Outdoors and Damp Locations: Galvanized steel.
3. Corrosive Locations: Stainless steel.

2.3 ANCHORAGE AND STRUCTURAL ATTACHMENT COMPONENTS

A. Strength: Defined in reports by ICBO Evaluation Service or another agency acceptable to authorities having jurisdiction.

1. Structural Safety Factor: Strength in tension and shear of components used shall be at least three times the maximum seismic forces to which they will be subjected.

B. Concrete and masonry anchor bolts and studs shall be steel-expansion wedge type.

C. Concrete inserts shall be steel-channel type.

D. Through bolts shall be structural type, hex head, high strength and shall comply with ASTM A 325.

E. Welding lugs shall comply with MSS SP-69, Type 57.

F. Beam clamps for steel beams and joists shall be double sided. (Single-sided type is not acceptable.)

G. Bushings for floor-mounted equipment anchors shall be neoprene units designed for seismically rated rigid equipment mountings, and matched to the type and size of anchor bolts and studs used.

H. Bushing assemblies for wall-mounted equipment anchorage shall be assemblies of neoprene elements and steel sleeves designed for seismically rated rigid equipment mountings, and matched to the type and size of attachment devices used.

2.4 SEISMIC BRACING COMPONENTS

A. Slotted steel channel shall be 1-5/8-by-1-5/8-inch (41-by-41-mm) cross section, formed from 0.1046-inch- (2.7-mm-) thick steel, with 9/16-by-7/8-inch (14-by-22-mm) slots at a maximum of 2 inches (50 mm) o.c. in webs, and flange edges turned toward web.

1. Materials for channel shall meet ASTM A 570, GR 33.
2. Materials for fittings and accessories shall meet ASTM A 575, ASTM A 576, or ASTM A 36.
3. Fittings and accessories shall be products of the same manufacturer as channels and designed for use with that product.
4. Finish shall be baked, rust-inhibiting, acrylic-enamel paint applied after cleaning and phosphate treatment, unless otherwise indicated.

B. Channel-type bracing assemblies shall be slotted steel channel, with adjustable hinged steel brackets and bolts.

C. Cable-type bracing assemblies shall be zinc-coated, high-strength steel wire rope cable attached to steel thimbles, brackets, and bolts designed for cable service.

1. Arrange units for attachment to the braced component at one end and to the structure at the other end.
2. Wire Rope Cable: Comply with ASTM 603. Use 49- or 133-strand cable with a minimum strength of 2 times the calculated maximum seismic force to be resisted.

D. Hanger rod stiffeners shall be slotted steel channels with internally bolted connections to hanger rod.

PART 3 - EXECUTION

3.1 APPLICATION

A. Generator Sets: Comply with Division 15 Section "Mechanical Vibration Controls and Seismic Restraints."

3.2 INSTALLATION

A. Install seismic restraints according to applicable codes and regulations and as approved by authorities having jurisdiction, unless more stringent requirements are indicated.

3.3 STRUCTURAL ATTACHMENTS

A. Use bolted connections with steel brackets, slotted channel, and slotted-channel fittings to spread structural loads and reduce stresses.

B. Attachments to New Concrete: Bolt to channel-type concrete inserts or use expansion anchors.

C. Attachments to Existing Concrete: Use expansion anchors.

D. Holes for Expansion Anchors in Concrete: Drill at locations and to depths that avoid reinforcing bars.

E. Attachments to Solid Concrete Masonry Unit Walls: Use expansion anchors.

F. Attachments to Hollow Walls: Bolt to slotted steel channels fastened to wall with expansion anchors.

G. Attachments to Wood Structural Members: Install bolts through members.

H. Attachments to Steel: Bolt to clamps on flanges of beams or on upper truss chords of bar joists.

3.4 ELECTRICAL EQUIPMENT ANCHORAGE

A. Anchor rigidly to a single mobile structural element or to a concrete base that is structurally tied to a single mobile structural element.

B. Anchor panelboards, motor-control centers, motor controls, switchboards, switchgear, transformers, unit substations, fused power-circuit devices, transfer switches, busways, battery racks, static uninterruptible power units, power conditioners, capacitor units, communication system components, and electronic signal processing, control, and distribution units as follows:

1. Size concrete bases so expansion anchors will be a minimum of 10 bolt diameters from the edge of the concrete base.
2. Concrete Bases for Floor-Mounted Equipment: Use female expansion anchors and install studs and nuts after equipment is positioned.
3. Bushings for Floor-Mounted Equipment Anchors: Install to allow for resilient media between anchor bolt or stud and mounting hole in concrete.
4. Anchor Bolt Bushing Assemblies for Wall-Mounted Equipment: Install to allow for resilient media where equipment or equipment-mounting channels are attached to wall.
5. Torque bolts and nuts on studs to values recommended by equipment manufacturer.

3.5 SEISMIC BRACING INSTALLATION

A. Install bracing according to spacings and strengths indicated by approved analysis.

B. Expansion and Contraction: Install to allow for thermal movement of braced components.

C. Cable Braces: Install with maximum cable slack recommended by manufacturer.

D. Attachment to Structure: If specific attachment is not indicated, anchor bracing to the structure at flanges of beams, upper truss chords of bar joists, or at concrete members.

3.6 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Make flexible connections in raceways, cables, wireways, cable trays, and busways where they cross expansion and seismic control joints, where adjacent sections or branches are supported by different structural elements, and where they terminate at electrical equipment anchored to a different mobile structural element from the one supporting them.

3.7 FIELD QUALITY CONTROL

A. Testing Agency: The Contractor will engage a qualified seismic control testing agency certified to perform the following field quality-control testing:

B. Testing: Test pull-out resistance of seismic anchorage devices.

1. Provide necessary test equipment required for reliable testing.
2. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
3. Schedule test with Government, through Contracting Officer, before connecting anchorage device to restrained component (unless post-connection testing has been approved), and with at least seven days' advance notice.
4. Obtain Government's approval before transmitting test loads to the structure. Provide temporary load-spreading members.
5. Test at least four of each type and size of installed anchors and fasteners accepted by the Contracting Officer.
6. Test to 90 percent of rated proof load of device.
7. If a device fails the test, modify all installations of same type and retest until satisfactory results are achieved.
8. Record test results and submit test results to the Government and/or the Contracting Officer.

END OF SECTION

SECTION 16145

LIGHTING CONTROL DEVICES

PART 1 - GENERAL

1.1 WORK INCLUDED

A. Drawings and general provisions of the Contract, and Specification Sections shall apply to this Section.

B. Lighting control devices for interior and/or exterior systems shall be provided and installed by the Contractor.

C. This Section shall include, but not be limited to time switches, photoelectric relays, occupancy sensors, dimmers and multipole lighting relays and contactors.

1.2 RELATED WORK

A. Section 16050 "Basic Materials and Methods" lighting system equipment.

B. Section 16140 "Wiring Devices" for electrical systems.

C. Section 16500 "Lighting" for low-voltage, manual and programmable lighting systems.

1.3 SUBMITTALS

A. Product Data: Include dimensions and data on features, components, and ratings for the project lighting control devices.

B. Samples: Occupancy sensors for color selection and evaluation of technical features.

C. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

D. Maintenance Data: For lighting control devices to include in maintenance manuals specified in Division 1.

1.4 QUALITY ASSURANCE

A. Limitations: The Contractor shall obtain lighting control devices from a single manufacturer with a 5-year experience in successful lighting control system components specified in this Section.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100 and UL, for their indicated use and installation conditions by a testing agency acceptable to authorities having jurisdiction.

C. Comply with NFPA 70.

1.5 COORDINATION

A. Coordinate the installation of devices specified in this Section with systems and components specified in other Sections to form an integrated system of compatible components. Match components and interconnections for optimum performance of specified functions. Include coordination with the following:

1. Section 16050 "Basic Materials and Methods."
2. Section 16423 "Panelboards."

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Subject to compliance with drawing and specification requirements, manufacturers offering products that may be incorporated into the Work shall show successful product manufacturing for a minimum of 5 years.

B. Subject to compliance with requirements, the manufacturer shall provide products that meet and exceed the design standards.

C. Products shall carry the UL label and meet NEMA standards.

2.2 GENERAL LIGHTING CONTROL DEVICE REQUIREMENTS

A. Provide line-voltage surge protection to include in all 120- and 277-V control solid-state equipment. Comply with UL 1449 and with ANSI C62.41 for Category A locations.

2.3 TIME SWITCHES

A. Description: Solid-state programmable units with alphanumeric display complying with UL 917.

B. Description: Electromechanical-dial type complying with UL 917.

1. Astronomic dial.
2. Two contacts, rated 30 A at 277-V ac, unless otherwise indicated.
3. Two pilot-duty contacts, rated 2 A at 240-V ac, unless otherwise indicated.
4. Eight-day program uniquely programmable for each weekday and holidays.
5. Skip-day mode.

2.4 PHOTOELECTRIC RELAYS

A. Description: Solid state, with single-pole, double-throw dry contacts rated to operate connected relay or contactor coils or microprocessor input, and complying with UL 773A.

B. Light-Level Monitoring Range: 0 to 3500 fc (0 to 37 673 lx), with an adjustment for turn-on/turn-off levels.

C. Time Delay: Prevents false operation.

D. Indoor Ceiling- or Wall-Mounting Units: Adjustable for turn-on/turn-off levels, semi-flush, calibrated to detect adequacy of daylighting in perimeter locations, and arranged to turn artificial illumination on and off to suit varying intensities of available daylighting.

E. Indoor Skylight Units: Housed in a threaded plastic fitting for mounting under skylight.

F. Outdoor Sealed Units: Weathertight housing, resistant to high temperatures and equipped with sun-glare shield and ice preventer.

2.5 OCCUPANCY SENSORS

A. Ceiling-Mounting Units: Unit receives control power from a separately mounted auxiliary power and control unit, and operates power switching contacts in that unit.

B. Ceiling-Mounting Units: Unit receives 24-V dc power from a remote source and, on sensing occupancy, closes contacts that provide signal input to a remote microprocessor-based lighting control system.

C. Switch-Box-Mounting Units: Unit receives power directly from switch leg of the 120- or 277-V ac circuit it controls and operates integral power switching contacts rated 800 W at 120-V ac, and 1000 W at 277-V ac, minimum.

D. Operation: Turns lights on when room or covered area is occupied and off when unoccupied, unless otherwise indicated.

1. Time Delay for Turning Lights Off: Adjustable over a range from 1 to 15 minutes, minimum.
2. Manual Override Switch: Turns lights off manually regardless of elapsed time delay.
3. Ambient-Light-Level Control: Adjustable for setting a level of ambient illumination above which sensor will not turn lights on when occupancy is sensed.
4. Isolated Relay Contact: Operates on detection of occupancy or vacancy, as indicated, to activate an independent function.

E. Auxiliary Power and Control Units: As follows:

1. Relays rated for a minimum of 20-A normal ballast load or 13-A tungsten filament or high-inrush ballast load.
2. Sensor Power Supply: Rated to supply the number of connected sensors.

F. Passive-Infrared Type: Detects occupancy by a combination of heat and movement in zone of coverage. Each sensor detects occupancy anywhere in an area of 1000 sq. ft. (93 sq. m) by detecting occurrence of 6-inch (150-mm) minimum movement of any portion of a human body that presents a minimum target of 36 sq. in. (232 sq. cm) to the sensor.

G. Ultrasonic Type: Emits a beam of ultrasonic energy and detects occupancy through use of Doppler's principle in discerning movement in zone of coverage by sensing a change in pattern of reflected ultrasonic energy.

H. Dual-Technology Type: Uses a combination of passive-infrared and ultrasonic detection methods to distinguish between occupied and unoccupied conditions for area covered. Particular technology or combination of technologies that controls each function (on or off) is selectable in the field by operating controls on unit.

2.6 MULTIPOLE CONTACTORS AND RELAYS

A. Description: Electrically operated and mechanically held, and complying with UL 508 and NEMA ICS 2.

1. Current Rating for Switching: UL listing or rating consistent with type of load served, including tungsten filament, inductive, and high-inrush ballast (ballasts with 15 percent or less total harmonic distortion of normal load current).
2. Control Coil Voltage: Match control power source.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install equipment level and plumb and according to manufacturer's written instructions.

B. Mount lighting control devices according to manufacturer's written instructions and requirements in Division 16 Section "Basic Electrical Materials and Methods."

C. Mounting heights indicated on Drawings are to bottom of unit for suspended devices and to center of unit for wall-mounting devices.

3.2 CONTROL WIRING INSTALLATION

A. Install wiring between sensing and control devices according to manufacturer's written instructions and as specified in Division 16 Section "Wire and Cables" for low-voltage connections and Division 16 Section "Communication Systems" for digital circuits.

B. Wiring Method: Install all wiring in raceway as specified in Division 16 Section "Raceways and Boxes," unless run in accessible ceiling space and gypsum board partitions.

C. Bundle, train, and support wiring in enclosures and raceways.

D. Ground equipment according to Section 16060 "Grounding and Bonding".

E. Connections: Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.

3.3 IDENTIFICATION

A. Identify components and power and control wiring according to Division 16 Section 16050" Basic Electrical Materials and Methods."

B. Identify components and power and control wiring according to Division 16 Section 16500, "Lighting."

3.4 FIELD QUALITY CONTROL

A. Schedule visual and mechanical inspections and electrical tests with at least seven days' advance notice to the Contracting Officer and/or the Government.

B. Inspect control components for defects and physical damage, testing laboratory labeling, and nameplate compliance with the Contract Documents.

C. Check tightness of electrical connections with torque wrench calibrated within previous six months. Use manufacturer's recommended torque values.

D. Verify settings of photoelectric devices with photometer calibrated within previous six months.

E. Electrical Tests: Use particular caution when testing devices containing solid-state components. Perform the following according to manufacturer's written instructions:

1. Continuity tests of circuits.
2. Operational Tests: Set and operate devices to demonstrate their functions and capabilities in a methodical sequence that cues and reproduces actual operating functions.

    a. Include testing of devices under actual operational conditions. Record control settings, operations, cues, and functional observations, as required.

F. Correct deficiencies, make necessary adjustments, and retest. Verify that specified requirements are met.

G. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency representative signature.

H. Reports: Provide reports of tests and observations to the Contracting Officer and the Government. Correct all defective materials, workmanship and unsatisfactory test results at no cost to the Government. Record repairs and adjustments.

3.5 CLEANING

A. Cleaning: Clean all equipment and devices internally and externally using methods and materials recommended by manufacturers, and repair any damaged finishes.

3.6 DEMONSTRATION

A. Coordinate with Government personnel training for low-voltage, programmable lighting control system specified in Division 13 Section "Lighting Controls." Provide a minimum of 4 hours training by a lighting control specialist.

B. Engage the factory-authorized service representative to train Government's maintenance personnel as specified below:

1. Train Government's maintenance personnel on troubleshooting, servicing, adjusting, and preventive maintenance. Provide a minimum of four hours' training.
2. Training Aid: Use the approved final version of maintenance manuals as a training aid in combination with "hands on" experience.
3. Schedule training with Government and/or the Contracting Officer with at least seven days' advance notice.

3.7 ON-SITE ASSISTANCE

A. Occupancy Adjustments: The control system installer shall, within one year of date of Substantial Work Completion, provide up to three Project site visits, when requested, to adjust light levels, make program changes, and adjust sensors and controls to suit actual conditions.

END OF SECTION