

## SECTION 01655 –EQUIPMENT TESTING AND START-UP

### PART 1 – GENERAL

#### 1.1 DESCRIPTION

- A. Equipment testing including pump/lift station startup are requisite to satisfactory completion of the project and, therefore, shall be completed within the required time. Thorough and rigorous testing of all equipment and facilities is required. The CONTRACTOR shall prepare and submit a complete Facilities Startup and Testing Plan for review and approval by the AGENCY. The CONTRACTOR shall initially start-up, test, and place all equipment into successful operation according to manufacturers' written instructions. Upon completion of individual equipment startup and testing, the CONTRACTOR shall startup, test, and place into successful operation all equipment and pump station systems according to the requirements of the project. The CONTRACTOR shall provide all material, labor, tools, equipment, and expendables required to complete the work.
- B. The pump station, SCADA and Pump Control panels, including all other systems and equipment, shall be loop tested and approved by the AGENCY prior to final acceptance.

#### 1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Contract Documents are a single integrated document, and as such all Divisions and Sections apply. It is the responsibility of the CONTRACTOR and its Sub-Contractors to review all sections to insure a complete and coordinated project.
- B. Section 01300 – Record Drawings and Submittals

#### 1.3 REQUIREMENTS

- A. All electrical work shall be performed by a Class C-10 licensed contractor.
- B. The Control System Supplier (CSS) shall fully commission and test the entire Instrumentation and Control system complete.
- C. Factory, functional and operational testing shall be a collaborative effort between the CSS and the System Programmer to verify all system operations.
- D. The CSS shall assign a project manager to the commissioning process for the coordination of and scheduling of the equipment testing phases. The CSS project manager shall be the single point of contact for all start-up and commissioning efforts related to the instrumentation and control systems.

#### 1.4 COORDINATION

- A. The CSS shall coordinate all testing with the packaged system suppliers, AGENCY's system programmer, construction manager and electrical contractor to verify operation between all systems.

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### 1.5 CONTRACTOR SUBMITTALS

- A. The following items shall be submitted in accordance with the standard specifications.
1. All Shop Drawings, materials lists, catalog cut sheets, and other information required in individual equipment Specification Sections.
  2. CSS shall develop and submit an overall testing plan for SCADA and new Pump Control Panel to show that the systems hardware and software is fully operational and in compliance with the requirements specified in the Contract Drawings. The plan shall describe each system to be tested, test methods, test materials, test instruments and recorders, and results to be recorded. The overall test plan must be submitted for review and approval by the Engineer 22 working days before detailed test plan, procedures, and forms will be reviewed.
    - a. Describe the test phases as they apply specifically to this Project and each process system.
    - b. Provide preliminary schedule to show sequence of tests and commissioning as they apply to each process system and each PLC.
    - c. Provide description of factory tests. Describe what equipment will be included, what testing equipment will be used, and the simulator that will be used.
  3. CSS shall prepare testing and quality control submittals and shall provide forms and checklists to be used for each of the following:
    - a. Instrument Calibration Forms
    - b. Loop Commissioning Forms
    - c. Loop validation tests
    - d. PLC point testing forms
    - e. Testing Procedures
    - f. Test Reports
    - g. Instrumentation and Controls Performance test
    - h. At the conclusion of each test, submit a complete test report, including all test results and certifications
  4. Testing plan shall be broken out per the various test sequences to address:
    - a. Digital Point Testing
    - b. Analog Loop Testing
    - c. Instrument Loop Tests
    - f. Functional Equipment Testing
    - g. Communications System Testing
    - h. Operational Readiness Testing

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5. The CSS shall submit comprehensive-testing procedures, forms and reports complete. Testing submittals shall address all the factory testing requirements.
6. Identify each person or organization that will have a functional part in the startup, and identify their duties and responsibilities.
- 7.

### **1.6 QUALITY ASSURANCE**

#### **A. Test Personnel:**

1. Furnish qualified technical personnel to perform all calibration, testing, and verification. The test personnel are required to be familiar with this Project and the equipment, software, and systems before being assigned to the test program.

## **PART 2 – PRODUCTS**

### **2.1 GENERAL**

- A. The CONTRACTOR shall furnish all materials and equipment required to perform startup and testing.
- B. Test equipment shall be provided to allow the operators to fully diagnose and test required functions on all equipment including instrumentation, PLC's, electrical systems and communication devices.

### **2.2 DIAGNOSTIC EQUIPMENT**

- A. Diagnostic Laptop – Provide a diagnostic laptop for system testing and control. The diagnostic laptop shall be provided with all test software and software modules loaded. The software modules shall be those products supplied by the various instrument manufactures for testing and calibration of their products.
- B. The diagnostic laptop shall be provided with appropriate communication software for connection to and communication with the MCC's for set-up, configuration and tuning of the MCC starters, VFD and power meters.
- C. The CSS shall create a user interactive directory on the laptop which shall include all testing software modules, instrumentation operations manuals in PDF format and associated configuration software modules supplied with the equipment.
- D.

## **PART 3 – EXECUTION**

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### 3.1 GENERAL

- A. It shall be the responsibility of the CSS to furnish all facilities, necessary testing devices and sufficient manpower to perform the tests required by the Engineer to determine conformance to the requirements of the Contract documents.
- B. Factory Inspection:
  - 1. Instrumentation and control panels shall be inspected for compliance with specified requirements at the factory prior to comprehensive system factory testing and before shipment to the CSS and from the CSS facility to the job site. The Contractor shall notify the Engineer six weeks in advance of the testing date. A representative of the AGENCY and Project Manager will visit the factory to make the inspection.
  - 2. A preliminary factory test shall be provided by the CSS. The CSS shall perform the following inspection and tests prior to arrival of the Engineer:
    - a. All air lines adequately tested for leaks.
    - b. All alarm and interlock circuits rung out to determine their operability.
    - c. Electrical circuits checked for continuity and where applicable, operability.
    - d. Basic panel operation.
    - e. Packaged system panels are wired and assembled per the contract requirements and approved submittals.
    - f. Nameplates checked for correct spelling and correct size of letters.
    - g. Other tests deemed necessary by the Engineer that are required to place the panel in an operating condition.
  - 3. If the above tests have not been performed prior to the arrival of the Engineer, the Contractor shall reimburse the AGENCY for the cost of the extra time required for the inspector's services and travel expenses.
- C. Factory Testing:
  - 1. The CSS shall set-up, configure and interconnect all PLC panels and computer equipment in an environmentally controlled area with sufficient space and access for PLC and SCADA system testing by the AGENCY's representative. The system shall remain set-up until the factory testing is completed.
  - 2. The CSS shall coordinate the delivery of, set-up and configuration of the control panels to be included as a part of the overall test. The CSS shall allow for space, interconnection and power of equipment supplied by others.

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3. The CSS shall coordinate all panel configuration and interconnection with the AGENCY's representative.
4. The CSS shall furnish and install all temporary interconnection cables and terminations for loop testing, PLC and SCADA communications and analog signal tests.
5. The CSS shall provide the services of a qualified PLC technician to assist the AGENCY's representative during the factory test. The PLC technician shall setup, configure and test each PLC system to verify equipment operation prior to the factory test. The technician shall be experienced in the programming, configuration and testing of PLC systems employing the communication protocols utilized. The CSS shall make technical personnel available for a total of 80 hours to assist in additional testing.
6. The CSS shall coordinate all shipping of packaged system equipment, set-up, configuration and testing tasks related to the factory test.
7. Tests shall be conducted to exercise all process variables and confirm set point trip points, process permissives, process interlocks, alarming and control functions. The CSS shall provide the necessary personnel to operate, simulate, test and confirm all SCADA and PLC associated functions pertaining to graphical displays, set point interaction, PLC control strategies, alarm monitoring and manual control of the equipment with the AGENCY's system programmer.
8. The CSS shall prepare a factory test procedure in the form of I/O checklists, calibration sheets for analog I/O tests that exercise all normal, emergency and alternative control modes. I/O checklist shall reference each I/O by type, tag and description with a checkbox to verify PLC operation, Communication, SCADA Display, Alarm Function and Command function with a comment field for testing notes.
9. The CSS shall prepare process control test forms for each control strategy subdivided into individual process loops and modes of operation contained within the process control strategy. The test procedure shall be provided on a step-by-step basis addressing each process on a loop-by-loop and function-by-function basis.

### 3.2 SYSTEM PRE-COMMISSIONING

#### A. General

1. Pre-commissioning testing shall be conducted prior to any system commissioning efforts to verify general equipment installation, instrument calibration and equipment configurations are per the specified requirements.
2. The CSS shall provide all necessary labor, tools, and equipment to field test, inspect and adjust each instrument to its indicated performance requirement in accordance with manufacturer's specifications and instructions. Any instrument which fails to meet any Contract requirement, or any published manufacturer performance specification for functional and operational parameters, whether or not indicated in the Contract Documents, shall be recalibrated, repaired or replaced, at the discretion of the Engineer at no additional cost to the AGENCY.

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3. Prior to System Commissioning all cable testing shall be complete as follows:
  - a. Continuity Tests
  - b. Megger Testing
  - c. Communications Cable Testing
  - d. Conductors terminated and labeled
- B. Equipment Installation Verification
  1. The CSS shall confirm all equipment is installed and terminated in conformance with the contract drawings, approved interconnection drawings and manufacturer's recommended procedures.
  2. The CSS shall verify:
    - a. Operational Voltages
    - b. Fuse Sizes
    - c. Equipment Terminations
    - d. Ventilation
- C. Basic Operational Testing
  1. All equipment shall undergo a basic individual equipment operational test to confirm the following:
    - a. Equipment Rotation
    - b. Operator Switches are functional
    - c. Indicators are operating correctly
    - d. Equipment displays do not indicate failure
- D. Communications Cabling Test
  1. The CSS shall test all plant communication links utilizing communications test equipment and diagnostic software to verify that a viable communication link is established.
- E. Instrument Calibration
  1. All analog and discrete instrumentation and all control system equipment shall be field calibrated and tested after installation to verify that requirements are satisfied.

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2. The CSS shall provide all necessary labor, tools, and equipment to calibrate and test each instrument in accordance with the manufacturer's instructions. Each instrument shall be calibrated at a minimum of three points (0%, 50% and 100% scale) using test equipment to simulate inputs and read outputs.
3. All test equipment and all instruments used to simulate inputs and read outputs shall be suitable for the purpose intended and shall have accuracy better than the required accuracy of the instrument being calibrated. Test equipment shall have accuracies traceable to the NIST as applicable. All analog instruments shall be calibrated and tested in place without removal.
4. The AGENCY's field representative shall witness all instrument calibrations.
5. A calibration report shall be delivered to the Engineer for each instrument, certifying that the instrument has been calibrated in the presence of the AGENCY's designated representative and meets contract and system requirements.

### F. Point Testing

1. **Digital Loop Test:** The CSS shall be responsible for loop checking and testing all digital instrument, device and equipment status loops including digital loops associated with the packaged system supplier's equipment. The CSS shall coordinate all loop check functions with the PLC and SCADA system, final element, PLC logic and intermediate equipment to ensure that a single total loop check is conducted. The intent of the loop checks is to confirm and document each loop's component specification conformance up to and including all field-situated devices.
2. **Analog Loop Tests:** The CSS shall be responsible for loop checking and testing all instrumentation loops including instrument loops associated with any packaged system supplier's equipment. The CSS shall coordinate all loop check functions with the PLC and SCADA system, final element, PLC logic and intermediate equipment to ensure that a single total loop check is conducted. The intent of the loop checks is to confirm and document each loop's component specification conformance up to and including all field-situated devices.
3. Programmable Controllers, Operator Interface Units, and electronic function modules, shall be tested and exercised by the CSS with the AGENCY's System Programmer to demonstrate the correct operation, first individually and then collectively as functional analog networks.

### G. Functional Loop Testing

1. Each hardwired analog control network shall be tested to verify proper performance within indicated accuracy tolerances. Accuracy tolerances for each analog network are defined as the root-mean-square summation of individual component accuracy tolerances. Individual component accuracy tolerances shall be as indicated by contract requirements, or by published manufacturer accuracy specifications, whenever contract accuracy tolerances are not indicated.

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2. Each analog network shall be tested by applying simulated inputs to the first element(s). Simulated sensor inputs corresponding to 10 percent, 50 percent, and 90 percent of span shall be applied, and the resulting outputs read to verify compliance to network accuracy tolerance requirements. Temporary settings shall be made on controllers, alarms, etc., during analog loop tests. All analog loop test data shall be recorded on test forms.
3. When installation and loop tests have been successfully completed for all individual instruments and all separate analog control networks, a certified copy of all test forms signed by the AGENCY’s representative as a witness, with test data entered, shall be submitted together with a clear and unequivocal statement that all instrumentation has been successfully calibrated, fully inspected, and fully tested.
4. Functional loop test will be tested end to end with the SCADA/PLC system utilizing a diagnostic test screen to verify range, scale and I/O channel from the instrument to the PLC. The CSS shall coordinate PLC testing of the analog loops with the AGENCY.

H. Pre-commissioning Responsibility Chart

Pre-commissioning Tests	C	O	PSS	CSS	SP
Equipment Installation Verification	X	X	X	X	
Basic Operational Equipment Test	X	X	X	X	
Instrument Calibration	X	X	X	X	
Point Testing	X	X	X	X	X
Functional Loop Testing	X	X	X	X	X
Communications Link Test	X	X	X	X	X

1. C – Contractor: Contractor Responsible for all Activities
2. O - AGENCY: AGENCYs representative to witness and inspect all testing
3. PSS – Packaged System Suppliers: As required for equipment testing
4. CSS – Control System Supplier
5. SP – System Programmer

3.3 SYSTEM COMMISSIONING

A. General

1. System commissioning shall be a joint effort between the CONTRACTOR and AGENCY to facilitate the plant start-up.
2. The CONTRACTOR and CSS shall provide qualified start-up and testing representatives on-site, assisting and participating in the testing, for the duration of System Commissioning.



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3. Provide additional staff as needed to operate equipment, provide safety, verify field signals, verify equipment operation, etc.
- B. Functional Testing
1. All equipment and packaged systems shall be functionally tested as a part of the operational readiness test and prior to process testing.
  2. The CSS shall coordinate the functional testing effort with the packaged system suppliers and verify that the individual equipment is ready for functional testing by the PSS.
  3. General equipment items shall be functionally tested and verified operational by the CSS and Contractor.
  4. Small packaged systems such as chemical feed, compressor and lift station systems shall undergo a basic operational system test.
- C. Packaged Systems Functional System Test (FST)
1. Packaged system suppliers (PSS) equipment functional system testing shall be coordinated by the Contractor and tested by the CSS in conjunction with the PSS and SP. Functional testing for packaged systems shall not be started until the following is complete:
    - a. Interconnection drawings are complete
    - b. Operations Manual On-Site
    - c. All packaged system software is complete and communications registers have been supplied to the SP for SCADA access and are ready for testing.
    - d. Packaged system supplier technician/technical representative is available for testing.
  2. The following packaged systems shall undergo functional testing:
    1. Bubbler Control System
    2. Odor Control System
    3. Engine Generator System
- D. Operational Readiness Testing (ORT)
1. The CSS shall be responsible for demonstrating the operability of all electrical controlled and monitored equipment provided under this and other related specifications. The ORT shall commence after acceptance of all wire, all calibrating and loop tests, and all inspections have been conducted. The ORT shall demonstrate proper operation of all sub-systems with process equipment operating over full operating ranges under actual operating conditions whenever possible.
  2. Operational readiness testing activities shall include the use of water to establish service conditions that simulate, to the greatest extent possible,

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normal final control element operating conditions in terms of applied process loads, operating ranges and environmental conditions. Final control elements, control panels, and ancillary equipment shall be tested under start-up and steady-state operating conditions to verify that proper and stable control is achieved using motor control center and local field mounted control circuits. All hardwired and software control circuit interlocks and alarms shall be operational.

3. The control of final control elements and ancillary equipment shall be tested using both manual and automatic (where provided) control circuits. The stable steady-state operation of final control elements running under the control of field mounted automatic analog controllers or software based controllers shall be assured by adjusting the controllers, as required, to eliminate oscillatory final control element operation. The transient stability of final control elements operating under the control of field mounted, and software based automatic analog controllers shall be verified by applying control signal disturbances, monitoring the amplitude and decay rate of control parameter oscillations (if any) and making necessary controller adjustments, as required, to eliminate excessive oscillatory amplitudes and decay rates.
4. All electronic control stations incorporating proportional, integral or differential control circuits shall be optimally tuned, experimentally, by applying control signal disturbances and adjusting the gain, reset or rate setting(s) as required to achieve a proper response. Tuning shall be based on the ¼ amplitude response method.
5. Equipment functional testing:
  - a. All individual equipment items shall be functionally tested in hand, local auto and auto to verify proper equipment configuration and operating status.
  - b. Functional tests shall include verification of hardwired interlocks with other equipment.
6. Measured final control element variable position/speed set point settings shall be compared to measured final control element position/speed values at 10 percent, 50 percent and 90 percent of span and the results checked against indicated accuracy tolerances. Accuracy tolerances are defined as the root-mean-square summation of individual component accuracy tolerances.
7. Individual component accuracy tolerances shall be as indicated in the Contract Documents or as specified by published manufacturer accuracy specifications whenever not indicated.

### E. Process Control Testing (PCT)

1. Process Control Testing shall proceed after all equipment has been functionally tested and commissioned per the operational readiness testing requirements including those systems provided by the Packaged System Suppliers and the Control System Supplier.

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2. Process Testing: The CSS and Contractor shall furnish his own personnel, electrical personnel, and any instrument manufacturer's representatives as required during the testing period to produce and maintain a fully operational system.
3. Process testing shall be conducted by the CSS and Contractor in conjunction with the SP to operate the system under various load and operational conditions. The operational testing shall include all normal modes of operation, alternate models of operations, demonstrate all back-up control systems, demonstrate all emergency power systems and operate the system under various control scenarios. The CSS and contractor shall provide field personal to exercise all modes of operation and demonstrate the system to the AGENCY.

### **3.4 FINAL ACCEPTANCE AND OPERATINAL TESTING**

- A. Upon completion of Operational Readiness Testing, the entire system shall undergo an Operational Test. The CONTRACTOR shall notify the AGENCY prior to any operational test so the AGENCY can witness exercising of all systems. For the AGENCY to consider the Operational Test successful the entire system shall run uninterrupted for 20 calendar days without experiencing any major defects. A major defect is one that causes a complete system shutdown or shutdown of any major system component thus reducing overall system capacity or redundancy.
- B. Prior to acceptance of the system, the CONTRACTOR shall furnish to the AGENCY all Operations and Maintenance Manuals, As-Built Drawings and Field Interconnection Drawings.

**\*\*END OF SECTION\*\***