

## **TESTING, COMMISSIONING AND TRAINING**

### **DESCRIPTION**

#### **Purpose**

1. Verify operation and functional performance of mechanical, HVAC, process and electrical systems for compliance with design intent.
2. Document mechanical, HVAC, process and electrical system tests and inspections.
3. Verify application of operation and maintenance manuals, as-builts (record) documents, spare parts listing and other items as may be specified herein for support of mechanical, HVAC, process and electrical systems and equipment.
4. Coordinate and direct training to personnel for operation and maintenance of mechanical, HVAC, process and electrical equipment and systems.

#### **General**

1. Furnish all labour, equipment and materials to accomplish complete process systems commissioning as specified herein.
2. The contractor will be responsible for co-ordination of commissioning of all equipment.

#### **Definitions**

1. **Acceptable Performance:** A component or system being able to meet specified design parameters under actual load.
2. **Commissioning Authority:** The qualified person, company, or agency that will plan and carry out the overall commissioning process. The General Contractor shall be the "Commissioning Authority".
3. **Commissioning Plan:** The overall document, prepared by the commissioning authority, which outlines the organization, scheduling, allocation of resources, documentation etc., pertaining to the overall commissioning process.
4. **Design Professional:** The Engineer responsible for the design and preparation of the contract documents for the various systems.
5. **Functional Performance Testing:** That full range of checks and tests carried out

to determine if all components, sub-systems, systems, and interfaces between systems function in accordance with the contract documents. In this context, "function" includes all modes and sequences of control operation, all interlocks and conditional control responses, and all specified responses to abnormal emergency conditions.

## **Documentation**

The Commissioning Authority shall obtain the following:

1. Project plans and specifications (Contract Documents), authorized revisions, equipment shop drawings and submittals (approved), test and inspection reports, equipment start-up and certification reports etc.
2. Records of required code authority inspections, documentation sign-offs, etc.

## **Submittals**

1. Submit documentation to the Engineer.
2. Prior to start of Work, submit name of organization proposed to perform services of Commissioning Authority. Designate who has managerial responsibilities for coordination of entire testing, adjusting and balancing.
3. Process Commissioning Authority will submit to Engineer for approval prior to starting the commissioning process:
  - a. Commissioning plan describing extent and delivery schedule.
  - b. Training plan (describe the extent of plan, expected duration of training, personnel involved, schedule, etc....)
4. Commissioning Authority shall submit other documentation specified throughout at times indicated in the specification.
5. Submit documentation to confirm organization compliance with quality assurance provision.
6. Submit preliminary specimen copies of each of report form proposed for use.
7. Fifteen days prior to Substantial Performance, submit 3 copies of final reports on applicable forms.
8. Submit reports of testing, adjusting and balancing postponed due to seasonal, climatic, occupancy or other reasons beyond Contractor's control, promptly

after execution of those services.

### **Responsibility Of Others**

1. Applicable specification sections may outline trade or manufacturer's responsibilities during the commissioning process.
2. General Contractor shall verify completeness of the building envelope, perimeter and interior items which effect proper operation and control of equipment and systems.
3. The General Contractor will assure participation and cooperation of contractors under his jurisdiction as required for the commissioning process.
4. Mechanical Contractor shall commission Equipment and other mechanical systems specified throughout drawings and specifications
5. HVAC Contractor shall commission HVAC and other systems specified throughout drawings and specifications.
6. Electrical Contractor shall commission electrical systems and equipment specified throughout drawings and specifications.
7. Owner/Operator will schedule personnel to participate in commissioning process. This may include building Engineer, operations and maintenance personnel. Personnel operating and maintaining equipment and systems will attend training sessions, factory schools and educational institutions where indicated.

### **Quality Assurance**

1. Comply with applicable procedures and standards of the certification sponsoring association.
2. Perform services under direction of supervisor qualified under certification requirements of sponsoring association.

### **Final Reports**

1. Organization having managerial responsibility shall make reports.
2. Ensure each form bears signature of recorder, and that of supervisor of reporting organization.
3. Identify each instrument used and latest date of calibration of each.

4. Include all data required throughout the specification sections.

## **Products**

## **Instrumentation**

1. Instrumentation as required shall be provided by Commissioning Authority, or provided by process, mechanical, or electrical Contractors.

## **Execution**

## **General**

1. Commissioning Authority shall actively participate in the construction phase of the project to assure compliance with Commissioning requirements.

## **Procedure**

1. Attend pre-construction meeting and establish requirements for commissioning authority process throughout construction phase.
2. Prepare and submit to Engineer, 6 weeks after the contract award, Commissioning plan which shall outline:
  - a. Responsibility of each trade affected by Commissioning as required by appropriate section of this specification.
  - b. Requirement for documentation as listed elsewhere herein.
  - c. Requirements for documentation of tests and inspections required by code authorities.
  - d. Format for training program for operation and maintenance personnel.
  - e. Periodically attend construction and coordination meetings.

## **COMMISSIONING**

### **PHASE 1 – PRE CONSTRUCTION**

#### **Introduction**

1. The objective of this phase is to outline the scope of design requirements for the process and electrical systems being constructed with a comprehensive commissioning process. The commissioning authority shall meet and review with the design Engineer the design intent and work with the design Engineer to develop the design criteria.

## **Scope of Phase 1**

Phase 1 documents should include detailed requirements for commissioning as follows:

1. Design criteria and assumptions
2. Description of the mechanical, HVAC, process and electrical systems, intended operation and performance.
3. Commissioning plan
4. Documentation required
5. Verification procedures
6. Commissioning documentation
7. Operation and performance
8. Design Criteria: Design criteria and assumptions should include design conditions for each system.

## **Description of mechanical, HVAC, process and electrical systems**

1. The description of the mechanical, HVAC, process and electrical systems and its intended operation and performance shall include design intent, assumptions, design criteria and system loadings.
2. The description of the process, and electrical systems shall include basic system type, major components, capacity and sizing criteria, automatic controls and sequence of operation.
3. The operation and performance data shall include equipment selection and redundancy criteria, intended operation under all operating loads, changeover procedures, part-load operational strategies, modes of operation, design set-points of control systems with permissible adjustments and any other engineered operational mode of the system.

## **Commissioning Plan**

1. The commissioning plan shall detail the implementation of the commissioning process. It shall include the requirements that each party involved in the commissioning process will have to accomplish, including:  
Sequence, scheduling, documentation requirements, verification procedures,

staffing requirements, etc.

2. The parties involved will include the Owners, design professional, contractors, vendors, project managers, commissioning authority, manufacturers and other parties as required.
3. The needed staffing skills and qualifications shall be specified for the following:  
Commissioning team  
  
Operation and maintenance teams

### **Documentation Requirements**

1. The requirements for each party involved in the process commissioning process shall detail the documentation that each must prepare to satisfy the commissioning plan requirements of the specification and submit for review.
2. The documents shall include the following:
  - a. Detailed procedures for the test to be performed by each party in the commissioning process.
  - b. Detailed checklists for performance testing.
  - c. Report forms that will be used to submit test data and results
  - d. Calibration data for test equipment.
  - e. Sequence and schedule of procedures.
  - f. Verification Procedures: The procedures for performance tests and verification include, but are not limited to, the following:
    - i. Testing, adjusting and balancing performance.
    - ii. Verification of all equipment performance.
    - iii. Verification of the performance of subsystems consisting of combinations of equipment
    - iv. Verification of the performance of the automatic controls in all operating modes.
    - v. Verification of the performance of the systems as a whole

3. Commissioning Documentation: Commissioning documentation shall be prepared and submitted by the commissioning authority at the completion of the commissioning process. This documentation shall include readiness, start-up and performance checklists of the commissioning plan with actual results achieved.
4. Testing, adjusting and balancing.
5. Performance of all equipment.
6. Control schematics, performance reports, and checklists for verification of the total process systems and process subsystems.
7. Operating data to include all necessary instructions to the Owners maintenance and operating staff in order to operate the system to specified standards.
8. Maintenance data to include all necessary information required to maintain all equipment in continuous operation.
9. As-built documents for the each systems to include all systems, equipment, automatic controls and piping systems.
10. Operation and performance: The schedules for the participation of the operations and maintenance personnel during the construction phase and the subsequent phases of the commissioning process.

## **PHASE 2 – CONSTRUCTION**

### **Introduction**

1. This section describes the commissioning process during the construction phase of the project. In this phase, the systems are installed, tested and put into operation. When construction is completed, the systems are ready for functional performance testing.
2. Commissioning is an ongoing process. It continues through the installation of the systems. In this phase, the commissioning authority shall witness all pressure tests of piping and duct systems and shall also coordinate and participate in all start-up testing, adjusting and balancing and calibration activities.
3. An important part of the commissioning process is the training of the operations and maintenance personnel. The commissioning authority shall direct this training.

## **Procedure**

1. This section describes the events and procedures that should occur during the construction phase in order to facilitate proper commissioning.
2. The system operation description should be updated to incorporate design changes that occur prior to or during the construction phase. This information then should be combined with the equipment maintenance data and equipment submittals, including performance data, to form one complete operations and maintenance manual for training and subsequent use of the operations and maintenance staff.

## **Operation**

1. During the construction phase, the building operations and maintenance staff should be available at the site for the purpose of observing construction, especially equipment installations.

## **Submittals**

1. Submittals shall be reviewed prior to construction. In addition to shop drawings, equipment submittals, testing and balancing procedures and forms, submittals shall also include the commissioning plan and commissioning format.
2. Equipment submittals shall include complete performance data for each piece of equipment – capacity, flow rates, velocity, pressure losses, horsepower, rpm, electrical data, etc. After review of equipment submittals, the equipment operations and maintenance information (including parts lists, installation instructions and special tools needs) shall be submitted in accordance with specifications requirements.
3. Because of the importance of the control systems to the proper operation of the mechanical, HVAC, process and electrical systems, control submittals shall be carefully reviewed to ensure it includes all information needed by the operations and maintenance staff to keep the control systems adjusted and calibrated. Information shall include:
  - a. A fully labeled control piping or wiring schematic, which shows point-to-point piping and wiring and includes all performance parameters such as set points, throttling ranges, actions, spans, proportional bands, and other control component adjustment or setting data. Locations of pneumatic test ports and electronic terminal strips should be indicated on the schematic drawings.
  - b. Fully labeled elementary electrical ladder diagrams.
  - c. Sequence of operation (narrative description of control system



functions) cross- referenced to the control schematics and elementary electrical ladder diagrams.

- d. Specification sheets for each control component.
4. The commissioning plan shall detail how the commissioning process will be organized, scheduled and documented to include:
    - a. The organization of the commissioning team (commissioning authority; testing, balancing, and adjustment specialists; contractors, vendors, manufacturers; Owners operations and maintenance staff, etc...)
    - b. A list of activities required to commission the subsystems and systems and the functions of each member of the commissioning team.
    - c. A logical sequence schedule for each commissioning activity coordinated with all members of the commissioning team.
    - d. Commissioning plan documentation forms for all components and systems submitted.
  5. The procedures for testing, balancing and adjusting shall be performed in accordance with recognized standards and as specified on the Contract drawings.
  6. Construction phase activities:
    - a. Each Section Contractor, contractor shall perform testing, adjusting and balancing work prior to start of commissioning. Operational tests shall also be conducted on equipment, pipe and control systems to verify that pressures and flow rates meet design requirements.
    - b. Controls testing and calibration shall begin concurrent with and be completed subsequent to the testing, adjusting and balancing work.
    - c. The commissioning authority shall observe and verify all start-up, testing and balancing, and calibration activities as part of the ongoing commissioning process.
    - d. Controls testing shall be accomplished on each control device. Actuators shall be checked and adjusted for beginning and extent of travel. All relays and adapters shall be checked for proper action. All system interlocks, interconnections and safety devices shall be checked for proper function.
    - e. All control devices shall be adjusted and calibrated. All control settings

shall be verified by comparing actual input and output values to calculated values.

- f. Testing, adjusting and balancing work shall be substantially complete with reports submitted prior to the verification and acceptance phase.
- g. Training, warranty, special tools and spare parts shall be taken into account under the construction phase.
- h. Contractor and equipment warranties shall be verified.
- i. Special tools and spare parts list shall be verified.

### **PHASE 3 - ACCEPTANCE PROCEDURES**

#### **Introduction**

- 1. This section describes acceptance procedures for the commissioning process.
- 2. Pre-requisites to Functional Performance Tests:
  - 1. Prior to functional performance testing of each system, the commissioning authority shall observe and verify that the physical installation of components and systems being tested is substantially installed in accordance with the contract documents.
  - 2. This shall include: hydrostatic testing, flushing, cleaning, start-up or activation of equipment and systems, completion of testing, adjusting and balancing, calibration and testing of automatic controls.

#### **General**

- 1. The functional performance test checklists contained in the approved commissioning plan shall be used to document the results of the functional performance testing process.
- 2. The functional performance testing process shall be accomplished for all equipment, subsystems, systems and system interfaces. There may be several similar pieces of equipment, systems, etc., on a project. All must be tested for acceptances, and there shall be a separate checklist for each to ensure documentation specific to each is complete.
- 3. Functional performance testing shall progress from equipment or components through subsystems to complete systems. Functional performance testing will have to consider sequences of testing, starting with components and progressing towards complete systems. As a result, the causes of any functional problem should be easier to locate and correct.

4. The specific tests and the most efficient order of testing will vary widely depending on the type of system, the number of systems, the sequence of construction, the relationship between building systems, the degree of interaction between systems, the complexity of the controls sequence, the impact of system failures on health or safety and other factors.
5. At the end of the process, every mode of systems operation, all system equipment, components and zones and every component in the control sequence description shall have been proved operational under all normal operational modes, including part and full load and under abnormal or emergency conditions.

### **Equipment and Subsystem Functional Performance Tests**

1. Operate the equipment and subsystems through all specified modes of control and sequences of operation. Include full and part load and emergency conditions.

### **Systems Functional Performance Test**

1. Each system shall be operated through all modes of system operation, such as seasonal and part loading, including every individual interlock and conditional control logic, all control sequences, both full and part load conditions, and simulation of all abnormal conditions for which there is a specified system or controls response.
2. Temporary upsets of systems, such as distribution fault, control loss, set point change, equilibrium upset and component failure shall be imposed at different operating loads to determine system stability and recovery time.

### **Verification and Documentation**

1. As each individual check or test is accomplished, the commissioning authority shall observe the physical responses of the system and compare them to the specified requirements to verify the test results. The actual physical responses of the system components must be observed. Reliance on control signals or other indirect indicators is not adequate. The input and output signals for each control component also need to be observed to confirm they are correct for each physical condition.
2. Verification of the testing, adjusting and balancing report shall be an integral part of functional performance testing.
3. The commissioning authority shall record the result of each individual check or test on the pre-approved test and report form from the commissioning plan.

### **Deferred Functional Performance Tests**

1. If any check or test cannot be accomplished for seasonal reasons, lack of loading or for other reasons, this fact shall be noted along with an indication of when the test will be scheduled.
2. If any check or test cannot be accomplished due to building structure or other building system deficiencies, these deficiencies shall be resolved and corrected by the appropriate parties before completion of the commissioning process.
3. Every check or test for which acceptable performance was not achieved shall be repeated after the necessary corrective measures have been completed. This re-testing process shall be repeated until acceptable performance is achieved.

### **Corrective Measures**

1. If acceptable performance cannot be achieved, then the necessary corrective measures shall be carried out. The General Contractor shall determine corrective measures in conjunction with the design Engineer.

### **Intersystem Functional Performance Tests**

1. When all individual systems' functional performance has been proved, the interface or coordinated responses between systems shall be checked. The systems involved may be within the overall process, electrical work, or they may involve other systems, such as emergency systems for life safety.
2. The approach to intersystem performance testing shall follow that previously described for systems.

### **Acceptance Documentation:**

1. A copy of the commissioning plan and functional performance test results shall be included with each copy of the Operations and Maintenance Manuals. These manuals, along with testing and balancing reports, controls schematics and any other documents required, shall be submitted to the design professional for review.

### **Operator Training:**

1. Operator training shall provide a complete overview of all equipment, components and systems with an emphasis on:
  - Documentation in the final Operations and Maintenance Manuals.
  - How to use the Operation and Maintenance Manuals.

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- System operational procedures for all modes of operation and all loading conditions.
- Acceptable tolerances for system adjustments in all operating modes.
- Procedures for dealing with abnormal conditions and emergency situations for which there is a specified system response.

### **Final Acceptance:**

1. When requirements of the commissioning plan have been completed and satisfactorily documented and required documentation has been completed, submitted to the Engineer, and accepted, the commissioning will be considered complete.

## **DEMONSTRATION AND TRAINING REQUIREMENTS**

1. Procedures for demonstration and instruction of equipment and systems to Owner's personnel.

### **Description**

1. Demonstrate scheduled operation and maintenance of equipment and systems to Owner's personnel
2. Owner will provide list of personnel to receive instructions and will coordinate their attendance at agreed upon times.

### **Quality Control**

1. When specified in individual specifications, require manufacturer to provide authorized representative to demonstrate operation of equipment and systems, instruct Owner's personnel and provide written report that demonstration and instructions have been given.

### **Submittals:**

1. Submit schedule of time and date for demonstration of each item of equipment and each system two weeks prior to designated dates, for Engineer's approval.
2. Submit reports within one week after completion of demonstration, that demonstration and instructions have been satisfactorily completed.
3. Give time and date of each demonstration, with list of persons present.

### **Conditions for Demonstrations**

1. For training during installation, confirm dates for installation have not changed.
2. For training after completion of construction ensure:
  - a. Equipment has been inspected and put into operation in accordance with specifications.
  - b. Testing, adjusting and balancing has been performed.

- c. Commissioning and equipment and systems are fully operational.
- d. Copies of completed Operation and Maintenance Manuals for use in demonstrations and instructions are provided.

**Preparation:**

1. Verify that conditions for demonstration and instructions comply with requirements.
2. Verify that designated personnel are present.

**Demonstration and Instructions**

1. Demonstrate start-up, operation, control, adjustment, troubleshooting, installation servicing and maintenance of each item of equipment at agreed upon times, at the designated location.
2. Instruct personnel in all phases of operation and maintenance using Operation and Maintenance Manuals as the basis of instruction.
3. Review contents of manual in detail to explain all aspects of operation and maintenance.
4. Prepare and insert additional data in Operations and Maintenance Manuals when the need for additional data becomes apparent during instructions.