

Aircraft Hangar Commissioning

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Abstract

In today's world of technologically advanced building, facility and process systems, the need for a comprehensive and dedicated methodology for building commissioning has never been greater. In particular, the Aircraft Hangar dedicated to the sole purpose of decorative paint application and coatings removal or paint stripping is one such facility which demands a rigorous approach to commissioning. Sophisticated building systems and paint or stripping processes can cause the total system to fail if they are not successfully integrated such that the total facility operates continuously as a single piece of finely tuned equipment. This is especially important when new and renovated facilities are designed to be able to accommodate alternate strip and paint technologies and provide for installation of strip and paint technologies not yet developed.

This paper examines the philosophy and management of the commissioning process as related to the large wide bodied aircraft hangar dedicated to the decorative paint process. Current Federal and Commercial/Industry standards are examined in light of contribution towards the successful commissioning process. Examples of recently completed facilities are discussed. An extensive bibliography and reference list will be provided.

INTRODUCTION

Over the years, commissioning has been a neglected element in the design, construction, and operation of buildings and facilities. Commissioning is a process for achieving, verifying, and documenting that the performance of a facility and its various systems meets design intent and the owner's operational needs. Ideally, the commissioning process extends through all phases of a project, from conception to occupancy and operation. As facility projects have become more complex, the need for commissioning has become increasingly necessary. Inspections and start-up tests alone are not comprehensive enough to reveal the design and operational problems occurring in complex buildings. When commissioning becomes an integral part of the design, construction and operation process, facilities and processes will operate more efficiently and function according to original design intent.

Commissioning: In the broadest sense, a process for achieving, verifying and documenting that the performance of a building, facility or process and its various systems meet design intent and the owner and occupants' operational needs. The process ideally extends through all phases of a project, from concept to occupancy and operation. In a narrower sense, the act of statistically and dynamically testing the operation of equipment and building systems to ensure they operate as designed and can satisfactorily meet the needs of the building facility or process throughout the entire range of operating conditions.

Commissioning is therefore a team effort to ensure that all equipment and building systems have been completely and properly installed and put into service. The team is made up of the Commissioning Agent and representatives from the Owner, Architect/Engineer, Contractor and selected equipment suppliers.

THE OBJECTIVE OF COMMISSIONING

Commissioning is a process that extends through all phases of a project from concept to occupancy and operation. The ultimate objective of commissioning is to obtain a building facility or process that operates efficiently, according to the design intent and maintains this intent over the life of the facility. To reach this final goal, it is necessary for the commissioning process to verify and document that performance of the systems meets the owner's requirements. It is important that there is close communication and documentation throughout the process to keep all the parties involved aware of all pertinent data and decisions. Some of the more critical details to be known by all parties include owner's needs, decisions impacting the design, procedures for recording system performance, operational information, final performance verification and building operating staff training needs.

Too often, buildings are delivered to the owner and operating staff with many operational problems remaining. These cause many disruptions during the initial occupancy period which often result in contractor callbacks or long unresolved problems with building systems. All parties can be contributors to the process of creating latent defects and improperly commissioned systems. For example:

- The A/E is provided with less than a complete view of the project intent and capability of owners maintenance forces.
- The contractor is provided skimpy details, confusing design documents, no access to the design team during construction.
- The suppliers withhold equipment and systems O & M Manuals until payments are made to suppliers.

The commissioning effort should emphasize functional performance testing, gathering all available documentation and training the facility staff responsible for the operation of the

building in order to confirm that the building is operating according to design intent. Ideally, testing should be done at peak design loads and at part loads as dictated by seasonal variations in operation. Testing should also verify the interactions of systems and equipment in the building. These tests, along with the other tasks in the commissioning process, help eliminate problems by identifying and correcting of any deficiencies early in the construction process.

Ways in which commissioning adds value to a project and benefits all parties involved, from the owner to the user organizations:

- Provides owner with a facility that operates in accordance with original design intent and is tuned to user needs.
- Reduces energy and operating costs by having systems functioning at maximum efficiency.
- Reduces the number of contractor callbacks, allowing contractors to focus efforts on other projects and obtain payments on schedule.
- Generates dollar savings by reducing occupant complaints due to discomfort, thus minimizing service calls to building operators and service contractors.
- Provides documentation, training and education for operators and facility managers, thus ensuring persistence of savings and longer equipment life.
- Provides a healthy working environment for occupants.
- Advances energy-efficient and new process technologies through successful application.

What Commissioning Is Not

Commissioning goes beyond testing and balancing. While it may include spot checks of balancing reports or even extensive airflow measurements on a job where balancing has been particularly troublesome, commissioning is aimed at assessing system performance from a functional standpoint.

Commissioning is not a substitute for a punch list inspection and is quite distinct from "punching out" a job. Commissioning will uncover and correct deficiencies such as misconnected ductwork, improperly installed controls which were missed by the contractor/engineer in the course of punch out. Punch lists deal with details of construction, such as missing plugs on blowdown valves, the type of duct sealant used and whether the job has been assembled using quality materials and good workmanship.

What Commissioning Is

Commissioning, on the other hand, deals with system performance and involves checking the coordinated product of multiple trades. Paralleled to the punch list examples just given, commissioning might involve checking the location of the blowdown valve to see if it services the proper equipment and opening the valve to see if the liquid runs clear, measuring duct leakage or imposing a false load on the system to see if the controls and controlled equipment produce the desired response.

Commissioning also differs from other forms of testing and inspection in that it deals with the system as an integrated whole as opposed to individual pieces of equipment.

Commissioning is a process of system delivery that begins when the project is conceived and ends when the useful life of the resulting structure is complete. ASHRAE *Guidelines 1* defines commissioning as "the process of achieving, verifying and documenting a concept through design, construction and a minimum of one year of operation."

The ASHRAE guideline establishes procedures for the commissioning process in each of the five phases of a project: programming, design, construction, acceptance and post-acceptance. The phases are shown in *Figure 1*. A fully functioning, fine-tuned system with complete documentation is the end-result of the successfully applied commissioning process.

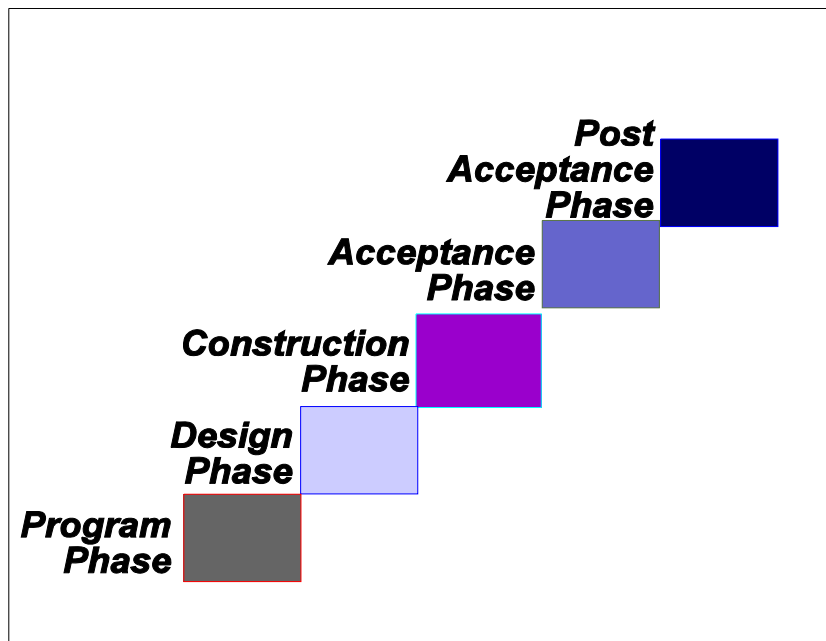


Figure 1 - Commissioning Process/Five Phases

APPROACH/PROCESS

Building Commissioning is a process involving many discreet actions. The process ideally would begin during the initial conceptualization of the building by a consultant or a team of consultants and continue throughout the design, construction and occupancy of the building.

Traditionally, while the contractor is turning over the building to its owner, the last-minute clean-up and removal of construction materials is taking place, the owner is attending to the many details involved in moving in and the design team is involved with punching out and getting contractual matters in place. The various aspects of building management are often set aside (such as training the building personnel, preparing as-built documents, preparing operation and maintenance management programs). Today's complex buildings, building systems and contracts require an organized transfer of ownership. Building Commissioning is designed to ensure the success of this critical period.

For example, building mechanical systems commissioning can involve consideration of the following plus other possible considerations:

- Air Distribution Products
- Filters
- Lubrication
- Instrumentation
- Hydronic Systems
- Refrigeration Systems
- Coil Condition
- Factory Technicians
- Pump and Valves
- Cooling Towers
 - A. Levels
 - B. Winterization
- Power Connections
- Automatic Control Systems
- Safety & Operation
- Testing & Balancing
- Documentation
- O&M Manuals
- Clean-up & Inspection
- Operator Training
- Observe & Log Operation
- Verify Software Operations
- Maintenance Program
- Proper Utility Rate
- Final Report
- Assist in Conflict Resolution

Depending on the facility and its systems, the Commissioning Agent selects the above-mentioned areas of involvement to suit the particular requirements of the building. These areas may be covered in more or less detail to suit the desires of the owners and operations objectives.

The Building Commissioning process requires persons very experienced in design, construction and facilities management as well as having the ability to establish and facilitate communications among a diverse team.

Commissioning Phases

- A. Program or Predesign Phase
 - 1. Evaluate Client Program
 - 2. Define Technical Requirement
 - 3. Review Design Concepts
 - 4. Document Phase Activity

- B. Design Phase
 - 1. Define Detailed Requirements
 - 2. Evaluate Design Criteria
 - 3. Description of Systems
 - 4. Prepare Commissioning Plan
 - 5. Documentation - Test Procedure
 - 6. Prepare Verification Procedures
 - 7. Commissioning Documentation - Readiness, Start-up and Performance Checklists

 - 8. Operation and Performance Scheduling
- C. Construction Phase
 - 1. Procedures
 - 2. Inspections
 - 3. Submittals
 - 4. Testing & Balancing (T & B)
 - 5. Documentation

- D. Acceptance Phase
 - 1. Prefunctional Test Observations
 - 2. Functional Tests - Equipment
 - 3. Systems Functional Tests
 - 4. Documentation
 - 5. Deferred Functional Performance Tests
 - 6. Corrective Measures
 - 7. Intersystem Functional Tests
 - 8. Acceptance Documentation
 - 9. Operator Training

- E. Post Acceptance Phase
 - 1. Record Drawings
 - 2. Alternatives
 - 3. Maintenance Programs

The Process

As noted above, Commissioning should start at project initiation and be a continuous process through Start-Up and Post Acceptance. The critical phase in this process is Acceptance where final tests are performed, corrective measures are taken, personnel are trained and the operating facility is turned over to the owner. The activity in advance of this phase is designed to assure success of Acceptance and the activity after this phase documents this success.

Given the criticality of the Acceptance Phase, it is appropriate to examine the tasks that are involved with facility acceptance in more detail.

Acceptance

A. System Start-Up

One of the greatest obstacles to a smooth commissioning process is the necessity (usually caused by job conditions) to start the system in segments. This creates the problem of starting only a portion of the system now and another later. Out of this arises problems with equipment warranty and loss of continuity for the start-up team. If records are kept, the start-up team can take up where they left off when they return for the final start-up. Assuming that the partial start-up is accomplished, the team will tackle the actual complete start-up. There are several steps and they will be taken in an order that usually works for all concerned.

1. Preparation

- a. Since most of the mechanical equipment has electrical connections, ensure that all equipment has been wired properly in accordance with the manufacturer's recommendations and to verify that all controls, safeties, and interlocks are complete.
- b. Verify that all duct connections are made and all dampers are installed and complete in time to start all air systems.
- c. Verify that all piping connections are made and control valves installed and the system is filled and properly flushed and refilled. Establish a time to start up pump systems.
- d. Verify that all systems are complete and ready to operate and to check equipment. Any system that is incomplete is given a completion time and a priority so that the main system start-up will not be delayed. A target is also set for final check of the system in all operating sequences.

- e. Chillers, multi-speed pumping systems, cooling towers, air compressors, chemical treatment, and boiler systems are to be started and given an operational run by their manufacturers, with written reports submitted to verify same.
 - f. The testing and balancing contractor is to be notified of the schedule for the fans, pumps, and chillers to be running and the approximate time for full system performance test. The testing and balancing contractor should have inspected the system prior to this to ensure that all necessities, such as balancing dampers, valves, test, plugs, and gauges, are properly installed so that a proper test and balance can be made.
 - g. The facility automation system has caused more problems at this time than any other phase of the mechanical system start-up. For this reason, the mechanical start-up must coordinate with this contractor to determine what steps must be taken to bypass segments of the automation to start the system.
 - h. Listing cost system and important components should be prepared.
 - i. Listing all items of equipment should be prepared.
2. Actual Start-Up Process
- a. Verify that the following has been accomplished. Align all direct coupled equipment, such as fans and pumps. This is an important step and caution must be taken to meet all factory tolerances.
 - b. Check all blower and motor belts to ensure that belts are properly aligned and that there is proper belt tension. Make sure the belt guards are not "lost", since they must be installed after final adjustments.
 - c. Lubricate all moving parts and check off list of all equipment that is to be lubricated. Too often a bearing fails within 90 days because it has never been lubricated properly. Remove all tie-downs on fans and compressors. Check rotation of all electrically driven equipment, to insure direction of rotation is correct.
 - d. Sequence all controls and interlocks. This is a dry run without load connections made. Ensure that all sequences are according to the specified sequence.
 - e. Ensure that all dampers are in the proper position for air handling units prior to start-up and that they will travel freely. Inspect overloads on all starters for proper setting.
 - f. Start all units, including fans, air-handling units, and pumps.

- g. Start the chiller and all heating components. Use ammeter and check all components listed to ensure that they are within their rated amperages.
- h. Verify that testing and balancing has been started and check to see that estimated completion date will be met.
- i. Make corrections required for proper system operation.
- j. If system bake out is required, run the systems per specifications.

B. System Testing

With the equipment started, each item involved in the total process can be tested as an integrated system.

1. Temperature Control System

- a. Check sequence of each individualized zone and each individual air unit to be sure that they are performing as specified.
- b. Place the main air systems in operation under full automatic control and make a performance inspection of the system sequence.
- c. These units and systems are inspected.
- d. All final temperature setpoints for the different points of control should be documented.
- e. Documentation should be kept so that discrepancies as well as satisfactory completion of the test can be noted.

2. Facility Automation System

- a. It is necessary to test the performance of this system separately, and the same sequence should be performed as with the temperature control system.
- b. Each point at which the systems starts, stops, or controls must be inspected and the performance verified in the same manner as for the temperature control system.
- c. Document test results.

- d. Monitoring, report capability, and other requirements for this system that do not affect the actual operation of the mechanical system should be inspected and documented point by point.
 - e. All discrepancies are to be noted and corrected in the same manner as for the temperature control system.
3. Testing and Balancing
- a. All testing and balancing reports should be turned in to the Project Manager.
 - b. These reports should be reviewed carefully at a meeting of the commissioning authority, project engineer, start-up technician, and testing and balancing supervisor.
 - c. Any problem areas should be reported at this meeting. Final reports are turned over to the Project Manager after all corrections and final adjustments are made.
4. Equipment Documentation

The start-up technician has the task of documenting each piece of equipment furnished by the mechanical contractor on the equipment data sheets. This list is then turned over to the Project Manager and is incorporated in the operation and maintenance manual that is to be turned to the owner.

C. Final Acceptance

1. Commissioning Meeting

After final start-up, a commissioning meeting should be held with the representatives of the contractor, commissioning agent, consulting engineer, and owner's representative and maintenance people. All final documents to be submitted to the owner are reviewed at this meeting. These include:

- As-Built Drawings
- As-Built Temperature Control Drawings
- As-Built Automation Drawings And Documentation
- Instruction Manuals
- Testing And Balancing Reports
- Maintenance And Repair Manuals
- Building Inspector's Approval
- State Certificates
- Equipment Manufacture Start-Up Documentation

Warranties/Guarantees
System Data Sheets
Equipment Data Sheets

In addition, a general discussion of the system should cover all questions about sequences, setpoints, and operation. After this meeting, all documents mentioned above should be turned over to the general contractor or construction manager for transmittal to the proper authorities. At this point, the date for owner training should be set. The number of hours, if not specified, should be determined along with the number of sessions required to meet this goal.

2. Personnel Training

The final step of the commissioning process involves personnel training. All the documentation should have been forwarded to the owner, and the general contractor should have set dates with the owner. Training sessions should be outlined with dates and time allotments for each session. These dates and times must be set up to the satisfaction of all concerned. Agenda items for these sessions may include:

- a. A complete discussions of system design, why its effective, and the reasons why the operating personnel should not make changes without consulting the designer.
- b. Operating personnel not previously involved should be shown the location of all equipment and oriented on using the as-built mechanical drawings, control prints, and automation point schedule. This is a very important step and one that can save the operating engineer many hours.
- c. A generous amount of time should be allotted the review the system sequence, since today's systems are very sophisticated and require a thorough familiarity if they are to be operated effectively.
- d. All maintenance schedules for each piece of equipment should be reviewed. One point that is often misunderstood is that the warranty obligations of a contractor and manufacturer's warranties do not include preventive maintenance unless specified in the original contract document.
- e. The training session should also cover symptoms, causes, and correction. It should give the operating personnel enough knowledge to be able to adequately describe any problems that are encountered and to take emergency steps to keep afloat until help arrives.
- f. Familiarize operating building personnel with major points of automation system. At least one person should be trained in depth.

- g. Establish comprehensive preventative maintenance.

COMMISSIONING THE PROJECT

Following the detailed commissioning plan, each of these subsystems, equipment and services must be individually and then collectively tested and driven through complete performance and functional tests. Complex control systems are now common place in today's hangar environment , be they DDC systems for environmental or PLC for the myriad process systems. This is one area in which to be particularly thorough during the commissioning process. For example, in reviewing DDC control software on a recent commissioning project, we have seen where the software house "improved" the engineers routines or sequences of operation. We only want what we asked for on the design documents. It could be very detrimental to operations when outside parties dabble with systems without benefit of knowledge of the design intent.

SUMMARY

To review, the suggested of methods and philosophy to a successful commissioning process must be based on:

- Active and willing participation by all primary parties involved with the project
- A planned approach by the contractor for start-up of the facility and systems
- Trained, competent, conscientious personnel to supervise the start-up process
- Involvement by the designer in the commissioning process
- A complete system start-up
- Detailed and complete documentation
- Properly planned owner training
- Owner participation in training
- Good clear communication between all parties

If those methods are employed the simple yet absolute benefits of commissioning will be:

- Systems that operate as designed
- Proper documentation of system operation
- Operating personnel who understand the system and know how to operate them.