

ABSTRACT

Commissioning is a neglected but contractually significant activity that is frequently contentious. Many of the points of contention can be diffused in advance by being clear on the requirements, and harmonizing the requests for proposal, contract documents and obligations of the designer accordingly. Proper planning is beneficial and will streamline the process. Attention to contractual requirements is crucial. Careful data gathering is also key. With the construction team's support, the commissioner will contribute to the success of all project stakeholders

Introduction

There are volumes of information on commissioning, and if you are new to it, where do you start? Why is it important?

Commissioning is important because:

- It takes you from construction to production through a systematic process of testing and verification
- It is usually linked to a contractual milestone, such as substantial completion
- It identifies and resolves problems that the operators would otherwise need to address, resulting in production delays, off-spec product, lost revenue to the client, etc.

While most people agree on the value of commissioning, not everybody agrees on what it is. Further, different organizations and publications use different terminology, or the same terms differently. If there is no guidance specific to your business sector (for example, the International Society for Pharmaceutical Engineering's *Commissioning and Qualification* guide) where do you start?

Commissioning answers the basic questions:

- Is the client getting what the client paid for?
- Does the equipment, process, or facility work the way it's supposed to work?
- Is it ready?

It is absolutely necessary to have clarity on what commissioning means in a given project, and how it fits with respect to satisfying contractual requirements and closeout, for the owner, the General Contractor (GC) and the subcontractors.

What is commissioning?

If a more formal definition is needed, an internet search readily yields definitions from ASHRAE, the Building Commissioning Association, the Department of Energy, NEBB, AABC, and others. ASHRAE Publication Guideline 0-2005 *The Commissioning Process* defines the commissioning process as: “A quality-focused process for enhancing the delivery of the project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner’s Project Requirements.” As definitions go, it is sweeping, but not a bad place to start. Note that “operated and maintained”, in this context, would refer to operation and maintenance of equipment in partially commissioned systems until turnover.

Note that commissioning of industrial facilities has different emphases than commissioning commercial/institutional facilities. Much of the published literature is only peripherally relevant to industrial facilities. There are also established practices that are complimentary to commissioning but may not traditionally be part of commissioning for a given site, such as the PID walk-down of a system, alignment and vibration testing of rotary equipment, environmental reviews, lock out/tag out, and HAZOPing activities.

Commissioning Strategy

The commissioning strategy needs to be developed during design, and should be tailored to reflect:

- The type of project – high voltage systems have different considerations than low voltage systems, a wastewater treatment plant with effluent limitations would be commissioned differently than a gypsum mill
- The level of expertise expected from the project team - a skilled operations team with time to be involved or a highly knowledgeable GC intimately familiar with the system will ease the staff loading required for commissioning
- The type of contract - design-bid-build will be commissioned differently and with different people, than design-build, or design-build-own-operate

Start with an idea of the number of work packages and how the project will roll out. Complex projects or projects with phased completion, start-up, and training, require coordination with subcontractors and suppliers and owner’s personnel. That coordination role can be performed by others, but is best performed by a commissioner, who can offer a reality check on the commissioning progress and the readiness claimed by subcontractors.

If the owner is using the engineer as a construction manager, commissioning is a natural fit in that set of services. If the project is design-build, then commissioning needs to be part of the general contractor's scope, but the owner needs to provide a commissioning counterpart to monitor progress. If the project is design/build/operate, with performance requirements in the contract, then all responsibility is on the contractor. Often projects are a hybrid, with a technology supplier providing a system that will be installed by others, but inspected and commissioned by the supplier. In this case, there is a significant coordination role.

All subcontractor's and major equipment suppliers should be expected to support commissioning, but it may be unrealistic to expect them to do commissioning. It is best to recognize up front that certain contractors will not be up to commissioning, and plan accordingly.

If a facility is being refurbished, there are further implications. A strong resident knowledge base will point to greater owner involvement.

Sharpening the Focus

After establishing an overarching strategy or approach to commissioning, sharpen the focus by considering the following:

Systems:

What systems need to be commissioned? Prioritize mission-critical processes, processes with programming and numerous adjustments, processes with serious consequences for failure, and life safety systems. Also remember the systems and facilities that are subject to regulatory scrutiny, like elevators, fire protection, emissions control, and others.

Certification:

Is third party certification of systems required? If so, what is to be certified? Consider conformance to the contract requirements, versus conformance to codes, versus conformance to the designer-of-records intentions.

Qualifications:

Consider the qualifications to be required of the commissioner or the commissioning team in light of the systems to be commissioned, and certification needs. (see Section 6.0)

Witnessing:

How much witnessing by the client or the client's agents is intended? Consider demonstrations after commissioning, versus shadowing during commissioning.

Training:

How much training is needed, contractually, and what level of prior understanding of the new systems do the operators offer?

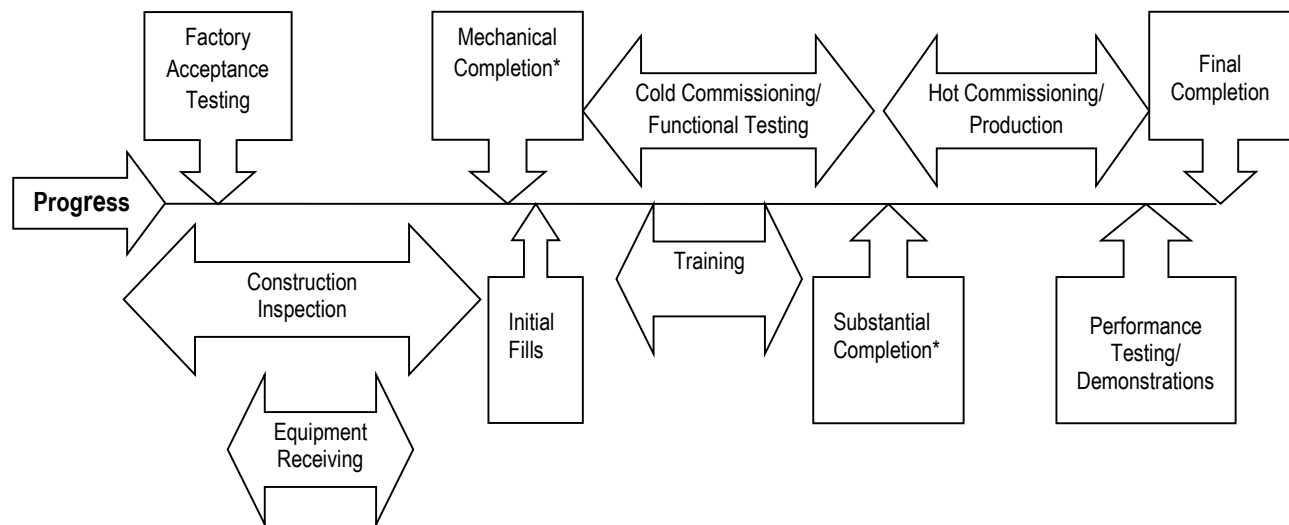
Who coordinates training by vendors, and how much is on-site? On-site is generally preferred.

Relationship to Completion:

Is completion by system likely to occur in phases, with beneficial use achieved with some systems before others? Consider how commissioning fits with the completion definitions used in the contract (i.e., mechanical, substantial and final), and if there are links to milestone payments. This information will be beneficial with respect to motivating the contractors and suppliers. See Figure 1.

System Operations Manual

Is a systems operation manual required? Generally, the answer is yes. It is preferable for the systems operation manual to be prepared by the engineer or the commissioner can prepare this document. Both approaches have merit.

Figure 1: Commissioning Related Activities vs Progress

Note: The locations of these points with respect to progress will vary with definitions in the contract and the specifications. The relative positions shown are typical.

* Mechanical and substantial completion are not typically used on the same project.

Defining Commissioning Scope

“If you don’t know where you’re going, you’ll end up somewhere else.”

Yogi Berra

It is beneficial to determine in your own mind the answers to these questions:

1. When does commissioning start?

In view of the decisions that need to be made early in the project, getting commissioning input during the design phase is best. In addition to the impact on contract and work-breakdown structure, there is a benefit to design. Commissioners will see deficiencies of a certain type that are less evident to other reviewers, such as: missing sampling points; missing injection points for passivating, disinfecting, or other agents; inadequate clearance for filter changes; poor lines of sight for reading gauges, etc. The easier the commissioner’s job is, the faster a facility gets to full production. In fact, it is always good to get the commissioner(s) involved earlier than later.

Further, if there is a performance requirement to be demonstrated (and what contract does not have such a requirement?), involving the commissioner early in the project gives the commissioner an opportunity to evaluate the system while it is still on paper. The commissioner will be thinking about what needs to be accomplished versus what is to be provided.

Giving the commissioner an opportunity to review draft bid specs allows the commissioner to harmonize the commissioning requirements of Div 1 of the construction specifications with the scattershot, sometimes conflicting requirements of the other divisions of the specifications. It avoids “gotcha” games later.

A good time for the commissioner to be on-site is when equipment is arriving. Inspecting the equipment and checking nameplate data is easier on the ground than on the roof or in the sump, and mis-shipments can be caught early. Using the commissioner in this way gives the site superintendent some relief and begins collaboration between superintendent(s) and commissioner(s). Further, the commissioner can check what is received against the design. If the design did not consider a purge line, vent, or other function, it is easy to fix. The commissioner’s calibrated eye lends itself to this type of discovery.

As the project progresses, the commissioner can prepare commissioning checklists, expedite vendor submittals and manuals, catalogue the same, as well as

support inspection, help area managers assess progress, contribute to the schedule updates and tasking, and build relationships with the subcontractors.

It is not beneficial to bring the commissioner on board only as construction is approaching completion. The commissioner will have to rely heavily on other people and will lose an element of independence. The planning will be haphazard, coordination will suffer accordingly, and there will be delays and frustration all around.

2. What tools are needed for commissioning?

The most important tool for commissioning is a clear and complete sequence-of-operations. This can go by other names: functional description, functional specification, process description and others. The intentions of the designer of record, with the owners understanding and approval, have to be provided to the commissioner. Otherwise valuable time is wasted by the commissioner building consensus among the project stakeholders.

Operation & Maintenance Manuals need to be on-site for formal field commissioning to begin; preferably several weeks in advance in support of the commissioning planning. If the owner uses a Maintenance Management Software, information sharing and coordination will be required between the commissioning team and the owner's maintenance group.

The June 2008 issue of Consulting-Specifying Engineer (www.csemag.com) features an article: "Commissioning Documents: necessary evil" that speaks to the importance of three documents prepared prior to commissioning – owner's project requirements, basis of design, and a systems manual. The latter is important to understanding how the entire assemblage is intended to work and performance expectations.

To execute commissioning, checklists are useful. They should be tailored to the project. Generic checklists result in corner cutting. Options are possible – for example; running a highlighter over each demonstrated function in a written sequence of operations is not as tidy but serves the same function as a checklist. Vendor checklists are frequently beneficial, but care must be taken not to over-rely on them.

Consider the preparation of an overall project plan that defines information needs by system, and then system-by-system commissioning plans, checklists, testing, and punchlists.

3. What is the relationship between inspection and commissioning?

Hydro-testing and air testing of lines is usually witnessed and documented by inspectors. Inspectors usually punch out areas, and commissioning punches out systems. Contractor's resent multiple punch lists and evolving punch lists. However, integrating the punch lists requires a level of collaboration between all parties involved that is not always achieved. Decide in advance if you wish to live with two or more lists, or who will administer a consolidated master list.

4. What is the relationship between design and commissioning?

Usually the commissioner will be pulled into gathering field measurements for the designer to make modifications, and the designer will respond to the commissioner's Requests for Information (RFIs) and will participate in the commissioning plan approval. While it should be self-evident, the commissioner cannot be responsible for code-compliant design, and should not be counted on to find code violations, although this is often the case.

5. What is the relationship between training and commissioning?

Typically, the commissioner will coordinate the training activities of the equipment or system suppliers when they come in to check out their equipment, verify readiness, and start or demonstrate it.

6. Where does commissioning stop?

The commissioner verifies readiness by: compiling and checking bench calibration reports for instruments; field checking calibration to the extent possible; verifying rotation; and verifying safeties and interlocks through manually tripping limit switches, modifying set points at the HMI, throwing disconnects and breakers (with care not to do anything that causes damage), or otherwise triggering boundary conditions. Typically, when product starts to flow (hot commissioning), the owner will take over and the commissioner will step back. Since the commissioner has not had the benefit of the owner's experience with running materials with the same characteristics as the raw materials, intermediates and products, final tuning by the owner is expected.

7. How "hands on" should the commissioner be?

The extent to which the commissioner is "hands on" will vary depending on the implications for assuming ownership, whether jurisdiction issues have the potential to be created, and whether safety issues have the potential to be created. It is safer for the commissioner to request the General Contractor to energize

equipment until commissioning of a system is completed, the client has assumed ownership, and the laborers are out of an area. If the commissioner is to energize equipment, the contractor must be notified as well as all personnel in the area of concern. Consider scheduling commissioning activities after normal working hours if this is the case.

8. What authority does the commissioner have, and what is the relationship between commissioning and closeout?

This drives directly back to the commissioning strategy. When the engineer is the construction manager, the commissioner will often be a direct report to the project manager. Otherwise the commissioner usually reports to the construction manager or GC.

Regarding closeout, many closeout documents will bear on commissioning, but it is usually beneficial to have dedicated closeout personnel address these needs, in coordination with the commissioner.

Once these questions have been addressed, consider an overarching commissioning requirement for Division 1 of the specifications. Otherwise the owner relies on the balance of the specifications and contract documents for commissioning requirements, and they may not harmonize, or be consistent with the owner's goals. Specifications generated by different departments or organizations on a project tend to conflict with respect to commissioning.

Planning

"A fool with a plan can outsmart a genius with no plan."

T. Boone Pickens

When the above issues have been addressed, it is a relatively simple to roll into planning. The steps for planning should include the following:

- A complete, line-by-line review of the specifications, for commissioning references and requirements. The plan should index the references and roll-up the requirements. Read the specifications line-by-line, and summarize the requirements for commissioning, testing, verification, demonstrations, etc. These will be tasks in the schedule.
- Summarize the system; the design, the PIDs, and the submittals. Put on paper how the system is expected to work if this has not already been done.
- Identify the level of effort required for commissioning. Here are some potential criteria:
 - Passed inspection

Technical Brief

- Checked out by Equipment Supplier and Witnessed by Client
- Verified against sequence of operations and PIDs
- System specific checklist required
- System specific checklist required, with approval by the designer-of-record
- Readiness checkout and punch-listing (prior to commissioning)
- Commissioning punch-list
- Coordination of commissioning related lists with the master punch list
- Identify relationships with construction inspectors, code inspectors,

If a commissioner is new to a project, planning can be time-consuming. Allow sufficient time for the commissioner to get familiar with the drawings and specifications, to ask questions, prepare documents, and to get acquainted with the subcontractors and their product.

Review each system. Verify that that the design addresses the commissioning needs based on process understanding; the design documents; conversations with reps; examination of the specifications; and ideally, commissioning involvement during the design phase. Commonly omitted items include injection points for line passivation or sterilization, adequate pressure and temperature indicators to follow how the system responds to changing operating parameters, intermediate sampling points, tees for diverting intermediate product away from downstream systems, and features for proper flow balancing.

The commissioner(s) should then:

- Prepare plans and checklists customized to each system, to compliment but not overlap what others do.
- Outline the steps required prior to commissioning. Refractory or castable may need to be dried and cured in a phased sequence that requires co-commissioning of a hot gas generator. Tie-ins to existing potable or fire water supplies may be needed.
- Prepare a plan and schedule showing key interdependencies between pre-requisite non-commissioning activities and commissioning activities.

Some important points to remember regarding planning, include:

- Logic based on relays is almost a thing of the past. Typically, every system and every skid have a PLC and many have an HMI. Each system and each skid have operating parameters and control parameters. VFDs or soft starts also have operating and control parameters that can be adjusted. Factory default settings are just a starting point to a achieving a tuned, balanced system. Balancing of

- operating and control parameters takes time, a number of starts and stops, and a range of operating conditions.
- One a related note, if a representative used the term “plug-and-play” for any system or skid, disregard it. Allow time for commissioning. Allow time for commissioning planning.
 - If there is consensus as to how a system is to operate, and it’s not written down, it means that there is no consensus. The designer-of-record, with the owner/operator should write down how the system is to operate. In the absence of that fundamental for project success, the commissioner should write down how the system is to operate based on the commissioner’s interpretation of the design documents and seek verification from the designer-of-record and the owner/operator.
 - Provide budget for the designers-of-record to support commissioning. The commissioners have to understand the designer’s intentions, not just the owner’s expectations. The commissioners need the designers input especially if performance targets are not achieved

Staffing

“I’m not looking for the best guys, I’m looking for the right guys!”
Herb Brooks, coach of the 1980 US Olympic “Miracle on Ice” Hockey Team

Minimally, the commissioning team needs two skill sets:

- Someone needs to understand the process and be comfortable working with equipment.
- Someone needs to understand controls and have basic electrical competency.

For larger projects, additional expertise may be added based on project needs.

In addition, commissioning personnel need:

- To be not intimidated by complicated unfamiliar systems. (Somebody else was able to figure it out and they can too.)
- To have follow-through. This is key for documentation, for troubleshooting, and many other aspects of commissioning
- To be flexible with respect to working hours and location, as commissioning can extend far into the night and can mean weekends away from home.

With those elements in place, there is a fair degree of flexibility in staffing.

Factory Representatives

Factory representatives can be a vital extension of the commissioning team, or serious liabilities, or something in-between. Within the constraints of the representative's contractual obligations, the commissioner needs to find the fits for these people.

The commissioner should talk to the equipment suppliers about what they intend to do and ask for their forms and checklists in advance of them coming on-site. This will allow coordination with the other trades, who may need to work in other areas, or who may need to complete, say, a water line before the reps can start, and with operations, who may want to witness some, but not all of the activities. It also helps identify equipment that may need to be scheduled – such as a scissor-lift, and materials that need to be ordered, such as lubricants and other “first-fills”.

While there are still pros out there who need no supervision and come prepared with their own tools, it is increasingly common to encounter reps who have not been given basic information about the equipment they are to checkout, do not bring tools, and have no idea that their activities will affect other people's work. For each rep that comes on site, it is good to have the relevant equipment manuals assembled, and some basic tools on hand.

The commissioner needs to cultivate good relationships with the subcontractors and the storeroom, so that when a rep needs tools, or a safety harness, they can be borrowed.

Schedules

The schedules prepared by the project controls group may not reflect commissioning relationships well, if at all. The scheduler may have more experience with the scheduling tool than field experience, probably gets minimal input from those who do have field experience and is probably obliged to work around milestones set by someone with less field and scheduling experience. Therefore, time spent with these people is often appreciated. It is important for the commissioner to have a good relationship with this group so that they seek input before the schedules are etched in stone, and so the commissioner gets an “early warning system” when tasks significant to commissioning are changed.

As areas or systems approach completion, it is important for the commissioner to walk each system and provide independent feedback to the scheduler on readiness for commissioning. An inspector's opinion of readiness, or a project superintendent's, may differ from the commissioners. This is a contentious area, as it inevitably leads to contributions to the punch list and contractor resentment. Cultivating good relationships is key here.

Liquidated damages introduce an element of unreality to the planning process. Each subcontractor's schedule will be an exercise in radical optimism. Therefore, the commissioning schedule, including start-date, may be a totally different looking creature from the project schedule. This violates scheduling orthodoxy, but it is better to realize that the end date is five months out and schedule the reps accordingly, than schedule them according to a sliding end-date that is always 6 weeks out.

In the Field

Walk the systems down, with each contractor, and with the equipment suppliers if possible. Ask about their outstanding RFI's and then expedite them. The contractor will view the commissioner as just another hurdle to their making money but expediting RFI's is one way the commissioner can change this opinion. One exception – it is hard to help the contractor who knows everything. When you meet one of these – don't bother. Prepare as best you can, document everything you can, and get ready for tough slogging.

Walk the systems after hours and make sketches of key areas before ceilings are closed in or other piping gets in the way. Consider how commissioning tasks will be done. Get nameplate data. Start sending RFIs. Contact the designers directly to build a relationship and to understand their intentions with respect to how their design is supposed to operate.

A good functional description and a good system manual are invaluable. Start your own if they are not available.

Find the operation and maintenance manuals. If you were not on site from day 1 to corral them, they will be scattered. Get them catalogued, and on a shelf. Identify what is missing and begin the process of expediting them. If resistance is encountered, bring in the contract manager, and help him do his job by pointing out where the manuals are required in the specifications, so that he can relate them to closeout and payment.

Prepare a comprehensive index of what is required from each contractor, and equipment supplier as part of commissioning. This includes:

- Equipment manuals
- Test reports such as backflow preventer certifications, hydrotesting and air testing reports, weld reports, etc

Get the construction team's buy-in. Fighting with an uncooperative or disgruntled contractor wastes time. With support, the commissioner can be a problem-solver and an aid to the contractor achieving completion quickly. Without support, the commissioner will be seen as a punchlist tinkering nuisance.

If the contractor says a system is ready and the commissioner says it isn't, pay attention to the commissioner.

As Formal Commissioning Approaches...

As formal commissioning approaches, the commissioner should:

- Get approvals on commissioning plans, from the designer-of-record and the owner/operator
- Be familiar with the site's lockout/tagout procedures. Know which starters on which MCC will need to be energized in advance of a test, know whose locks are on the starters, and notify them at least two days in advance that their locks will need to be removed, and notify them daily thereafter.
- Spot check lubricant levels in gearboxes and other critical pieces of equipment, regardless of the verification sheets from the contractor.
- Update the factory representatives regularly about the schedule. Show respect for their time; they will appreciate the consideration.
- Consider tagging equipment as it is commissioned, as well as preparing system-by-system reports system-specific lists of functional deficiencies.
- Get operations involved in commissioning. There is no better training.

During Formal Commissioning

During commissioning, the commissioner should remember:

- Use an attendance sheet, especially if training is being done at the same time.
- PLCs and HMIs are great, inexpensive tools. Use trending. Use the internet for remote monitoring. It will save time and help in diagnostics.
- Stay focused on commissioning of the system of interest. Client's have a tendency to offer observations on everything they see and expect the commissioner to note them. These are rabbit trails to be avoided.
- Prepare a punch list that addresses functionality issues only. A leak or a limit switch that needs to be re-positioned belongs on the commissioning punch list. Concrete spatters on a door do not belong on the commissioning punch list.
- Take photographs. Sometimes seeing is believing.
- Enter the data in a spreadsheet as it is generated. It is an opportunity to catch transposed digits, and other errors. This is a good job for an intern if one is available.
- Note settings, for all equipment
- Get as many signoffs as you can at the time.

After Commissioning

As the end of a system commissioning approaches, or immediately after, the commissioner should:

- Print the relevant trends and make hand notes as to their significance. For example, note the where trips occurred, or conditions were changed.
- Prepare a timeline, in some form.
- Prepare a preliminary report, however rough, with impressions noted. The supporting data can be attached later.

After addressing the above needs, and preferably after a well-earned rest:

- Review the data carefully, and compare it to the electronic version, and to the printed trends
- Watch for scaling issues on SCADA, data appearing in the wrong field, and basic errors such as flow arrows in the wrong direction, incorrect units and other screen errors.
- Watch for discrepancies between instruments that should be reading comparably.
- Have all calculations checked.
- Consider carefully what the data means, and what the data does not mean. This bears on the degree to which contractual compliance can be verified, and the degree to which a commissioner is qualified to offer a legal interpretation.

As the reports for each system are prepared, consider how the commissioning product bears on closeout and the release of the responsible suppliers and sub-contractors. Release and final payment to a supplier or subcontractor should not be unreasonably withheld, but pre-mature release invariably leads to short-term memory loss and unresponsiveness from the obligated party.

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