

The formulae $\frac{\partial p_i}{\partial x_j} + \frac{\partial}{\partial x_j}(\rho U_i) = -\frac{\partial}{\partial x_j} \left(\mu \frac{\partial U_i}{\partial x_j} \right) + g_i(\rho - \rho_0)$ for building $\frac{\partial}{\partial x_j}(\rho U_i) = -\frac{\partial}{\partial x_j} \left(\mu \frac{\partial U_i}{\partial x_j} - \rho u_i u_j \right) + g_i(\rho - \rho_0)$ state of the art $\frac{\partial}{\partial x_j}(\rho U_i) = -\frac{\partial}{\partial x_j} \left(\lambda \frac{\partial T}{\partial x_j} - \rho u_i u_j \right)$ biomedical research facilities.

Architectural Commissioning: An Overview

The purposes of architectural commissioning are manifold, including reducing the likelihood, extent, and cost of failures by ensuring the Owner's intent has been met, regulatory requirements are satisfied, the architect and engineer's design and specifications have been faithfully executed, and the manufacturer's installation and warranty requirements and any other applicable criteria have been adhered to in the work as constructed. Successful commissioning results in lower costs and effort to operate and maintain a facility and assurance that the Owner receives a building that meets their expectations for aesthetics, durability, and occupant comfort. Architectural commissioning, like the more traditional engineering systems commissioning, can be applied to any architectural system, most frequently including the exterior envelope systems (e.g., roofing, curtain walls, exterior doors/windows, etc.) and critical interior systems (e.g., stairwells, interior doors/hardware, high performance coating systems, etc.). Architectural commissioning is most frequently utilized for new construction, but it may come in various overall forms to encompass large or complex renovations or refurbishment of in-service architectural systems.

Architectural Commissioning (Cx): Cx should be initiated during the project planning phase and extend through turnover and occupancy. The specific Cx workflow may vary, but generally consists of the following:

- **Planning Phase:** The project management team initiates the process for engaging third party architectural Cx Agent (CxA) services. The CxA supports the inclusion of design qualification (a specialized design phase review to ensure all the Owner's Project Requirements are consistent with applicable regulations and reasonably achieved by the proposed design).
- **Design Phase:** The CxA develops Cx specifications, functional performance tests, an architectural systems manual, and training requirements; executes the design qualification review in parallel with typical design review processes; tracks to resolution all design review comments; and reviews all design/Basis Of Design submissions and variance requests.
- **Construction Phase:** The CxA holds a Cx kickoff meeting with the project's Integrated Project Team, including subcontractors and key manufacturers; reviews all

construction phase submittals, shop drawings, and coordination drawings; inspects all mockups; executes, oversees, and documents all work described in the Cx specification; executes all functional performance tests and other tests; assists in troubleshooting and accommodation of varying site conditions and latent defects discovered during the course of demolition and construction activities; assists in adjusting/optimizing active architectural systems; executes verification checks; oversees factory/manufacturer's acceptance tests and site acceptance tests; oversees the execution of all training; and tracks all open punch list items to closure.

- **Turnover Phase:** The CxA collates and organizes all Cx and training documentation into a Cx report and architectural systems manual; reviews the contractor's Operations and Maintenance (O&M) binders to assure all documents are complete, in order, and legible, with all signatures and dates affixed; confirms all warranty and guarantee information is complete and filed; and holds the Cx closeout meeting.
- **Operations & Maintenance Phase:** The CxA returns as required to perform/oversee the execution of seasonal and deferred testing; performs near warranty-end review of architectural materials and systems; reviews all maintenance orders, change directives, and similar documents generated since turnover; and provides recommended changes to the system manual, as appropriate.

Several specialized types of architectural Cx exist that are appropriate for certain applications, including:

Retro-Commissioning (RCx): The model of Cx generally used for existing buildings that have not been previously commissioned, or for which considerable time has passed or changes have occurred, making prior Cx documentation unreliable. RCx involves detailed investigation and documentation of existing conditions to improve the performance of the system(s) being commissioned through changes to O&M procedures, especially execution of deferred maintenance and mitigations to correct identified deficiencies or repair degradation. RCx follows a similar workflow to Cx with an investigation phase between planning and design, which is used by the project team to inform decisions on scope,

sequence, schedule, and budget that are necessary to establish the owner's intent heading into the design phase.

Re-Commissioning (ReCx): The model for Cx of existing, previously commissioned buildings. ReCx occurs periodically during O&M to improve and update maintenance schedules and adjust maintenance procedures, equipment, and systems to optimize performance and maximize the service life of architectural finishes and other systems.

Ongoing Commissioning (CCx): Often referred to as Continuous Commissioning, this process generally relies on regularly scheduled preventative and/or predictive maintenance to make improvements. Periodic Cx confirms that a facility's quality and consistency continue to meet the Owner's requirements. CCx provides an opportunity to document and integrate any changes to the Owner's requirements that have occurred over time into the facility O&M activities. CCx also includes the development of CCx specifications in the design phase, which are executed during the construction phase and incorporated into the O&M manuals during the turnover phase.

Monitoring-Based Commissioning (MBCx): MBCx utilizes sensors to monitor conditions that trigger O&M activities as needed. It is generally coupled with a preventative and/or predictive maintenance O&M program to ensure the required level of performance of architectural materials and systems. Periodic ReCx is also utilized to confirm that the quality and consistency of the O&M program continue to meet the Owner's requirements.

Conclusion:

Successful commissioning results in lower costs and effort to operate and maintain a facility and assures that the Owner receives a building that meets their requirements. It also maximizes the likelihood that a manufacturer will be required to honor claims against their warranties and guarantees. The Cx process will be explored in subsequent articles in this series, including an overview of exterior envelope commissioning, with deeper dives into the commissioning of roofs and exterior fenestrations. Later in the year, we will provide a series of articles exploring interior architectural commissioning featuring ceilings, walls, floors, doors, and hardware.

Further Reading

1. California Nonresidential Building Commissioning Guide
https://www.energy.ca.gov/sites/default/files/2020-05/12_BuildingCommissioningGuide.pdf
2. Whole Building Design Guide (WBDG) Building Commissioning
<https://wbdg.org/building-commissioning>
3. U.S Department of Energy, Energy Efficiency and Renewable Energy Program, Commissioning for Federal Facilities Guide
https://www.energy.gov/sites/default/files/2014/07/f17/commissioning_fed_facilities.pdf
4. International Code Council (ICC) Codes, ICC G4 Guideline for Commissioning
<https://codes.iccsafe.org/content/ICCG42018>