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The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho\overline{U_i}\overline{U_j})=-\frac{\partial \overline{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U_i}}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho\overline{U_i}\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ *biomedical research facilities.*

Mechanical Commissioning - Part 1

Commissioning (Cx) is the systematic process for ensuring systems and equipment perform according to the design intent and the NIH's operational needs. Cx is a multidisciplinary process which integrates a third-party Commissioning Authority (CA) into the Integrated Project Team (IPT), which includes NIH, Architects, Engineers, Contractors, and others. The Cx process begins early in the design phase and continues through acceptance and turnover into the early occupancy phase. This article focuses on the Cx process and sequence requirements of the mechanical Cx. Part 2 will focus on testing requirements for mechanical systems, equipment, and the Building Automation System (BAS).

Design Phase

During the design phase, the CA develops a Cx plan that outlines the Cx process requirements, describes the approach and methods to be used, and defines project team roles and responsibilities, communication protocols, documentation, and the schedule of the activities. This plan is updated several times during the design phase until the start of construction phase, when this document is issued to contractor.

The CA reviews the design documents and other documents, including the Basis of Design (BOD) and the engineer's sequence of operations (SOO), to confirm the design requirements are commissionable. On Aseptic Processing Facility (APF) projects, the CA also reviews the User Requirement Specification (URS). The CA develops Cx specifications which are integrated into the Architect and Engineer's specification manual. These specifications detail the testing and documentation requirements and procedures, which are included in the final bid documents to ensure the Contractor factors coordination and cooperation with the CA into their price and schedule.

Construction Phase

During the construction phase, the CA reviews equipment and controls submittals to make sure they have the information needed to support the Cx process. The CA develops several documents, including detailed pre-functional checklists (PFCs) and Functional Performance Testing (FPT) protocols for mechanical and controls systems, including Integrated System Testing (IST) and failure testing protocols that must be executed during the acceptance phase.

PFCs are structured to capture key installation information regarding equipment installed. It verifies that equipment and materials installed were specified and approved in the submittal and are consistent with design documents. PFT demonstrates that the equipment, components, and accessories associated with the mechanical system and BAS operate in accordance with project contract documentation (e.g., manufacturer design specifications, SOO). The IST is designed to challenge the mechanical system in its entirety, under various operational scenarios including failure modes.

The CA witnesses equipment startup and testing and balancing, which is led by the installing contractor and often with assistance by the equipment vendor. The CA also conducts periodic inspections of the mechanical systems and reviews contractor startup forms and training plan, facility manual, and Operation and Maintenance (O&M) information. When required, the CA will also develop Factory and Site Acceptance Testing (FAT and SAT) protocols for major equipment testing to ensure significant problems are identified before the equipment leaves the manufacturer's facility, then again to ensure it hasn't been damaged during transit.

The prerequisite for execution of FPT is issuance of the Certificate of Readiness (COR) for the system. The COR includes confirmation that the system has been leak tested, point to point check out is complete, BAS graphics are complete, programming is complete, and the contractor has pretested the SOO.

Acceptance Phase

During the acceptance phase, the mechanical system and BAS are tested, verified, and accepted. The CA checks startup and hydronic and airflow balancing reports. Once the contractor establishes BAS trending and monitoring, the CA conducts the PFC and FPT(s), which typically engage the full IPT. The CA notifies the project team of any failed FPT during the testing and creates a punch list of items for the contractor to correct. After the deficiencies discovered during the PFCs and FPTs have been corrected and retested, the CA oversees the execution of the IST, then corrects any deficiencies discovered during the IST. For major projects, the CA then oversees the endurance period or the stability period, where trend reports are generated and reviewed to ensure the facility is stable and free of unexpected alarm conditions.

Final Cx Report

The CA issues a final Cx report that documents all startup, checkout, functional testing, punch list, and action items and their resolutions, along with changes made during the Cx process, training agendas, and evaluations. Any unresolved items that for some reason cannot be completed are noted for future implementation, post-turnover. Offseason testing is scheduled as necessary to verify system performance under peak design weather conditions.

Conclusion

The mechanical Cx process plays a critical quality assurance role in verifying that complex mechanical systems for major laboratory, animal, clinical, or aseptic facilities at NIH are designed, installed, and performing according to the design intent and the NIH's operational needs.

'Design Requirements Manual (DRM) News to Use' is a monthly ORF publication featuring salient technical information that should be applied to the design of NIH biomedical research laboratories and animal facilities. NIH Project Officers, A/Es and other consultants to the NIH, who develop intramural, extramural and American Recovery and Reinvestment Act (ARRA) projects will benefit from 'News to Use'. **Please address questions or comments to:** mario.orellana@nih.gov