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1	03/22/2019	Lessons learned from RLUOB, LLW, and TWF; resolved QPA-IQ: 15-107/IM 2018-128; updated references.	Matt Foster, <i>PID-SU</i>	Larry Goen, <i>ES-DO</i>

## 1.0 PURPOSE, SCOPE AND GRADED APPROACH

### A. Purpose

To establish the minimum requirements and guidance for a systematic approach to commissioning (Cx) for LANL projects within the applicability and scope defined below.<sup>1</sup>

### B. Applicability

1. This chapter applies to:
  - a. new buildings (including prefabricated buildings) and building additions,
  - b. International Existing Building Code (IEBC) Level 3 alterations<sup>2</sup>,
  - c. all other projects performed under SD350, *Project Management for Capital Asset Acquisition and Construction*,
  - d. major modifications<sup>3</sup>, and
  - e. other projects identified by the Facility Design Authority Representative (FDAR)
2. Exclusions from this process are addressed under that heading below.

### C. General

1. This chapter presents the top-level Cx process to be followed. The development and use of numerous detailed sub-processes within and below the top-level process is required to implement this process.
  - a. When the Cx process is to be performed entirely by LANL, Startup procedures AP-350-406 and AP-CMP-401 shall be used with specific test procedures developed for and approved by the project.
  - b. When the LANL Commissioning organization cannot perform commissioning activities with qualified personnel, then the CxA shall be a first tier subcontractor to LANL.<sup>4</sup>
    - 1) The Subcontractor may model their procedure after the LANL procedures or must submit their own system and component test program procedures to the LANL Commissioning Authority (LCA) and LANL Project Manager (LPM) for approval.
2. Projects<sup>5</sup> subject to this chapter shall be evaluated, in the preliminary design phase, for the specific applicability of this chapter by the LCA and the LPM.
3. When this chapter is applicable, the graded approach to be applied, and the responsibilities of the various project entities within the Cx process must be determined in concert with the LCA. The LPM must ensure construction contracts include the necessity to cooperate and coordinate with Cx activities.

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<sup>1</sup> This chapter provides a necessary and sufficient Cx process for LANL; however, LANL has other programs that provide inspections that are pre-requisites to the Cx process (e.g., the ESM Ch 16 IBC Program that ensures the owner reviews design and inspects work for code compliance).

<sup>2</sup> Level 3 Alt: When a major building renovation or reconfiguration work area exceeds 50 percent of the aggregate area of the building (IEBC-2015). See ESM [Ch 16](#) Section IBC-GEN.

<sup>3</sup> Essentially, a change to a nuclear facility that substantially changes the existing safety basis for the facility. See ESM [Ch 1](#) Section Z10 definitions or [DOE-STD-1189](#).

<sup>4</sup> This avoids conflicts of interest and provides independence from other project groups. Reference ANSI/ASHRAE/IES Standard 202-2013, *Commissioning Process for Buildings and Systems*. Independence is a mandate of LEED v4.1 Enhanced Cx. *Ideally, PIO-SU is the STR.*

<sup>5</sup> For the purposes of this chapter, a project is defined as all activities associated with the design, installation, construction, retro-fit, or change in the intent or functionality of structures, systems, or components.

4. Attachment A provides a process flowchart of the major activities within the Cx process and the key entities responsible for those activities. The roles identified are defined in the Responsibilities and Duties section below, and the specific individual or entity fulfilling that role on a project may vary depending on the contractual responsibilities. For example, the CxA may be a LANL Startup Specialist or a Subcontractor's testing manager.
5. General definitions and requirements for variance processing are contained in ESM Chapter 1 General, Section Z10.

#### D. Scope

1. When the project is subject to this chapter, the following Cx and testing activities shall follow the requirements of this chapter (except as specifically excluded; see that heading below).
  - a. Facility
    - 1) Cx testing on newly constructed facilities and engineered modifications.
  - b. Process System
    - 1) Mechanical and Electrical Component Testing
      - Included as a segment of the overall system or facility testing.
    - 2) Control System Functionality
      - Functional testing of individual control loops and instrumentation within that loop including communication with central control systems or digital control systems.
      - Acceptance testing to demonstrate that software/computer program performs its intended functions as specified by design.
    - 3) Overall System Performance to Design
      - Integrated functional testing and tuning of all control loops and individual components which comprise a process system to demonstrate the systems overall performance to design.
  - c. Post-Modification Testing

Testing of systems and components with engineered modifications and that require a new demonstration of performance to design basis.
  - d. Programmatic Testing

Testing of new or modified components or systems of experimental equipment or prototypes which require a demonstration of performance to design basis.
2. Figure 1 below illustrates the typical progression of testing on the LANL site, with
  - component-level tests prescribed by Part 3 of the Specification sections performed first<sup>6</sup>,
  - subsystem (and sometimes system) testing performed next, and

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<sup>6</sup> Part 3 of the Spec sections is intended for onsite (at LANL) work, while factory acceptance tests (FATs) are "Preconstruction Testing" and should be described under that heading under Quality Assurance in Part 2 of spec sections.

- integrated system (or facility) testing last.

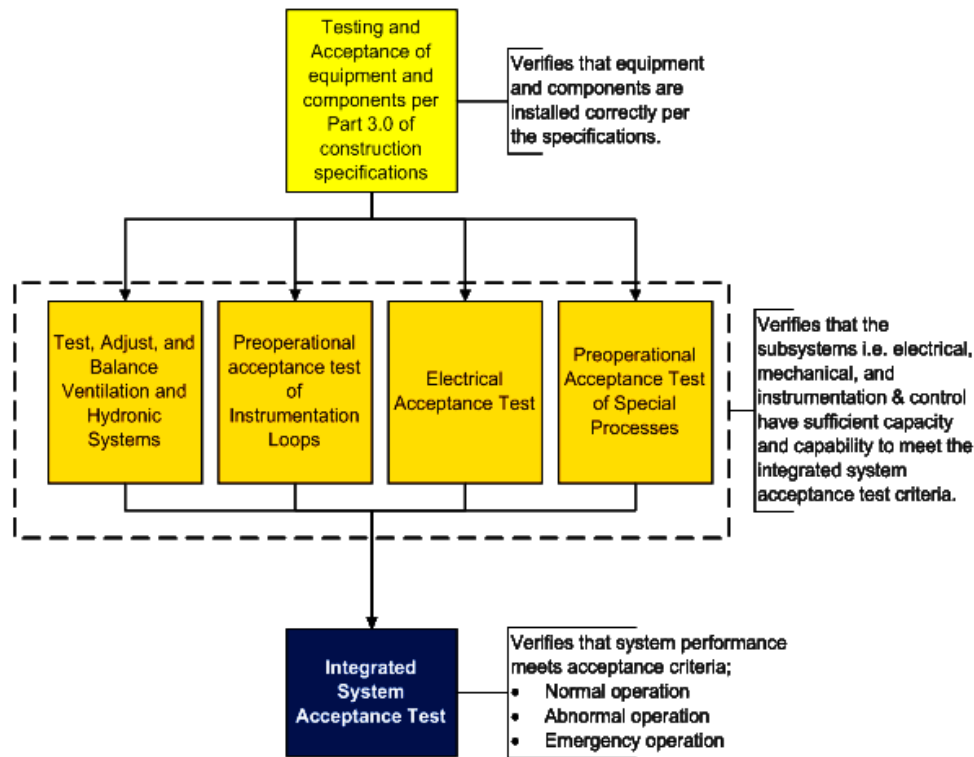


Figure 1. Typical Progression of Testing Performed on LANL Site.

**E. Graded Approach**

*A graded approach is used to determine the appropriate level of Cx rigor to achieve a safe, efficient, and reliable product without performing unnecessary testing, witnessing, and documentation.*

1. The graded approach effort shall consider the Management Levels (ML-1, 2, 3, or 4) as determined by the project team, the complexity of the components and systems to be tested, and the risks their failure or inadequate performance would present to the project.
2. The LCA shall determine, for each project, the appropriate level of rigor and documentation to be applied during the Cx phase. Where necessary the LCA shall utilize system or specialty SMEs to assist in this determination. The final graded approach for Cx must be reviewed, approved and documented by the LPM and LCA in the Cx Plan.
3. For each project, the overall graded approach and the ML levels will have been addressed and documented as they apply to the other functions and phases of the project (e.g., engineering, procurement, and construction). Although the CxA may have been involved in that determination, the rigor and documentation applied during Cx must be addressed separately and specifically (see Table 1 below for minimum requirements). The graded approach shall determine the:
  - specific testing requirements,
  - level of verification signatures,

- need for witness and hold points,
  - need for a Test Review Board (TRB), and
  - documentation requirements.
4. Software: The graded approach application for software quality assurance (and software Risk Level) is defined in ESM Chapter 21, *Software*.
  5. Refer to AP-350-406 (*Section 3.0*) for further guidance on the Cx graded approach, and to LANL SD330 for the overall QA process.

**Table 1 – Minimum Level of Rigor in Cx**  
(R = Required, O = Optional and when appropriate)

See Section 4.0 for document titles

Requirement or Deliverable	Management Level			Reference
	ML-1/2	ML-3	ML-4	
<b>Program-Level Requirements</b>				
ANSI/ASHRAE/EIS Standard 202-2013	R	R	R	ESM Chapter 15
10CFR830, Subpart A Quality Assurance Requirements*	R	R	R	SD330 * Not applicable to non-nuclear facilities
DOE Order 414.1D	R	R	R	SD330
ASME NQA-1-2008/NQA-1a-2009, Part I, Requirements 1, 2, 4–7, 10–12, 15–18, Subpart 2.7 (for testing software see ESM Chapter 21), and Subpart 2.14 (if commercial grade dedication is needed)* * Not applicable to nonnuclear facilities unless otherwise specified	R	Graded**	Graded**	SD330 ** LANL procedures define extent of graded controls for ML-3 and ML-4 items. The extent of graded controls for subcontractors is defined in procurement documents.
ASME NQA-1, Part III, Subpart 3.1, Non-Mandatory Appendix 2A-1 – <i>Guidance on the Qualifications of Inspection and Test Personnel</i> <sup>7</sup>	R	R	R	ESM Chapter 15
Commissioning Plan	R	R	O	AP-350-406
System Acceptance Test Procedures	R	R	O	
Test Review Board	R	O	-	
Test Summary Report	R	O	O	
Test Technician Qualification Program	R <sup>8</sup>	R	R	
<b>Component-Level Requirements (alphabetically)</b>				
Component-level test with results recorded on data sheets	R	R	R	AP-CMP-401
Electrical acceptance test and record on data sheets (NEC; < 1000 V)	R	R	R	AP-CMP-401 <sup>9</sup>
Electrical control scheme verification and recorded on data sheets	R	R	R	AP-350-406

<sup>7</sup> Note: Project (job) specifications may require a subcontractor to comply with additional NQA-1 requirements.

<sup>8</sup> Ibid

<sup>9</sup> Based on ESM Ch 7, D5000, Master spec 26 0813

Requirement or Deliverable	Management Level			Reference
	ML-1/2	ML-3	ML-4	
HVAC test, adjust, and balance (TAB)	R	R	R	AP-CMP-402 <sup>10</sup>
Instrument control loop verification and recorded on datasheets	R	R	R	AP-CMP-401
Rotating equipment mechanical baseline operating data (vibration, rotation, bearing temperatures) and record on data sheets	R	R	R	
Rotating equipment electrical baseline data (starting & running current, voltages, bearing temperatures) and record on data sheets	R	R	R	
Piping system cleanliness verification and recorded in a test procedure	R	R	R	
Process instrument calibration and recorded on data sheets	R	R	R	
Turnover and acceptance of SSCs	R	R	R	AP-350-420
Vendor equipment factory acceptance test (FAT) and record on data sheets	R	R	R	AP-CMP-401
Vendor equipment field test and record on data sheets	R	R	R	AP-CMP-401

**F. Exclusions<sup>11</sup>**

1. Security<sup>12</sup>
2. Weapons components<sup>13</sup>
3. Electrical acceptance testing on >1000 volt systems<sup>14</sup>
4. Post-maintenance testing (and post-mod testing not meeting scope statement on page 1)<sup>15</sup>

**G. Oversight of Special System Cx**

1. For the following systems and/or components, the test technicians and SMEs are generally not in the Cx organization. As such, the LANL SME organizations are responsible for performance of the testing; however, LANL Cx may and normally will witness testing.
2. Approved final acceptance testing documentation shall be submitted to LANL LCA by the LANL testing organization, and LCA will include with final, comprehensive package.<sup>16</sup>

<sup>10</sup> Based on ESM Ch 6 D30HVAC and LANL [Div 23](#) Master Specs 23 0593 and 23 0800

<sup>11</sup> These systems have well-established Cx programs defined elsewhere at LANL; better integration of some of these programs with this chapter may be a future enhancement.

<sup>12</sup> Security system Cx performed by LANL (e.g., SEC-PSS); see ESM Chapter 9 Security and related LANL Master Spec Div 28 sections. LANL Cx to provide support to NIE and obtain completed documentation to evidence of testing completion.

<sup>13</sup> Weapons system components including WR and prototypes are excluded; systems and equipment for the R&D (e.g., design and testing) of such components are not excluded if project is under CM Division management

<sup>14</sup> By LANL's Utilities organization; see ESM Chapter 7 Electrical Section D5000.

<sup>15</sup> Applicable and appropriate testing performed following maintenance to verify that a particular SSC, piece of equipment, or process system performs its intended function based on its design criteria and that the original deficiency has been corrected and no new deficiencies were created (DOE O 433.1B). Post-Maintenance Testing performance is the responsibility of the maintenance organization conducting the maintenance as outlined by the system engineer, and should not be confused with Post-Modification Testing. Small modifications (e.g., engineered equivalent replacements and some IBC Level 1 and 2 mods) not meeting this Chapter's applicability statement follow LANL AP-341-801 *Post Modification/Post Maintenance Testing*.

System	LANL SME Organization	Requirements
Fire suppression and alarm	Fire Protection Group (ES-FP)	ESM Chapter 2, <i>Fire Protection</i> ; Division 21 and 28 Specification sections
Fume Hoods and HEPA filters	OSH-ISH	P101-16, <i>Local Exhaust Ventilation and HEPA Filtration Systems</i> ; Division 23 Specification sections
Telecommunications	Network and Infrastructure Engineering (NIE-TS)	Division 27 telecom Specification sections.

**2.0 ACRONYMS AND DEFINITIONS**

Beneficial Occupancy <sup>17</sup>	Term used to describe the procedure when LANL occupies or makes use of any part of the work prior to Substantial Completion or Final Completion (aka “Mechanical Completion” or “Use and Possession”).
Component Testing (Pre-functional testing)	The individual pieces of equipment are confirmed to be capable of performing in accordance with the specifications, drawings and manufacturer’s requirements. This is documented in a component test data sheet provided by and completed by the Commissioning Agent. The information recorded on the data sheet provides baseline data for future re-evaluation of the components or systems.
Cx	Commissioning
Commissioning Agent (CxA)	A qualified and experienced Cx process person, company, or agency assigned to a specific project, working under the guidance of the LANL Commissioning Authority and the LANL Project Manager. The CxA leads, plans, coordinates and implements the overall project-specific Cx process activities. Qualification is per the judgment of the LCA, but shall be at least a Level II per Appendix A. Must be independent of all non-LANL construction subcontractors.
Commissioning Final Report	The documentation package that records the Cx plan, test procedures and results of the commissioning process, including the recorded performance of the various systems and components. The final report is issued to the facility owner for final acceptance of the facility.
Commissioning Plan (Cx Plan)	The plan which defines the Cx process, including schedules, responsibilities, document requirements and Cx test requirements which are developed in increasing detail as the project progresses through its various phases.
Commissioning Process	The quality-focused methodology for enhancing the project delivery process. The process focuses upon verifying and documenting the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet project requirements.
Commissioning Specification	The specific detailed requirements that defines the subcontractor’s objectives, responsibilities, scope, implementation, documentation and acceptance phases for the Cx process. This is developed in the design phase for inclusion in the construction documents.
Commissioning Team	The team that coordinates, monitors, and documents compliance with the owner’s project requirements and is responsible for working together in carrying out the Cx process.

<sup>16</sup> Results in a single, comprehensive Cx package.

<sup>17</sup> Ref. ESM Chapter 16 – IBC Program (Section IBC-GEN, Form 5) Building / System Final Inspection Checklist and Certificate of Occupancy.

Commissioning Test	Tests by which specific documents, components, equipment, assemblies, systems, and system interfaces are confirmed to comply with the criteria described in the Owner's Project Requirements—including all modes and sequences of control operation, interlocks, conditional control responses and all specified responses in accordance with design basis requirements.
Commissioning Test Procedure	Written, detailed, step-by-step protocol that defines the means and methods, personnel, and expectations for conducting tests on components, equipment, assemblies, systems, and system interfaces. The procedure has provisions for verifying all relevant data, recording the results, and identifying the requirements and responsibility for each test.
Final Acceptance	Final acceptance is the written acceptance issued to the subcontractor by the Project Manager after the subcontractor has achieved final completion.
Functional Testing	Testing of a component or subsystem against prescribed acceptance criteria, based on the owner's project requirements, vendor documentation, or industry standards to ensure that the SSC's functions and follows a prescribed sequence of operations according to the predetermined design requirements.
Final Completion	Final completion occurs when the work is fully and finally completed in accordance with the construction subcontract documents and all deficiencies have been corrected
Graded approach	A process to determine the level or rigor to be used for a particular SSC based on the importance to the work, safety, health, environmental compliance, safeguards and security, programmatic importance, magnitude of potential hazard, and financial impact of the SSC.
Installation verification	The initial portion of the Cx process includes observations and punch-lists recorded and performed by the field engineer to confirm that all equipment is installed in accordance with the specifications and drawings.
LANL Commissioning Authority (LCA)	An independent Cx process person designated by the LANL Projects Integration Division to manage the Cx at LANL and, for facilities, to represent the LANL Building Official's interests in matters related to Cx. Shall meet Level III qualifications of NQA-1 Part III, Subpart 3.1, Non-Mandatory Appendix 2A-1.
Level of Rigor	The level of strictness, detail, validation and judgment to be applied to a specific task or evaluation.
O&M	Operations and Maintenance, the group responsible for the maintenance and operation of facilities and systems after final acceptance.
Performance Testing	Performance tests are conducted to verify performance of entire systems and multiple systems against a defined set of requirements and parameters. Examples of systems which typically require performance tests are HVAC systems, process systems, critical capacity mechanical equipment and integrated operation of systems.
Post-Modification Testing	Validates that the system or component performs as intended and operates within the design requirements after the change is installed and before turnover to operations (DOE-STD-1073).
SME	Subject matter expert
Structure System and Components (SSC)	Structure – an element or a collection of elements to provide support or enclosure such as a building, free standing tank, basin, dikes, or stacks. System – a collection of components assembled to perform a function such as piping, cable trays, conduits, or HVAC. Component – an item of equipment such as a pump, valve, or relay, or an element of a larger array such as a length of pipe, elbow, or reducer.
Substantial Completion	Substantial completion is a legally recognized point in time that allows the owner to take occupancy of the facility even though there is work yet to be completed and documentary, regulatory, and contractual closeout requirements yet to be met.



Test Review Board (TRB) <sup>18</sup>	The group of representatives from the Design Authority, Quality Assurance, LANL Engineering, LANL Startup and Testing Services Group, and Facility Operations responsible for reviewing and approving Cx test results.
Testing Contractor	The person, company, or agent responsible to the prime subcontractor for: <ul style="list-style-type: none"> <li>• Making inspections required for Cx.</li> <li>• Coordinating, scheduling, and managing Cx activities of the Subcontractor, sub-tier subcontractors, and suppliers.</li> <li>• Obtaining documentation required for Cx from the Subcontractor, sub-tier subcontractors, and vendors.</li> </ul>

**3.0 RESPONSIBILITIES AND DUTIES**

**A. General Guidance**

1. Typical project participants are depicted in Figure 2.



**Figure 2.** Typical project participants.

**B. LANL Project Manager (LPM)**

1. Approves the scope of Cx services required and arranges for such services (in-house and/or subcontract).
2. Ensures funding is available to support programs and personnel necessary to accomplish the Cx testing scope of work.
3. Ensures funding and resources are available for the Test Review Board (TRB) representatives and facilitates their efforts in reviewing and approving project Cx test results.
4. Reviews and approves the Cx plans and procedures.
5. Reviews and approves the Final Test Summary Report.
6. Ensures construction subcontracts direct the cooperation of the constructor (e.g., through exhibits or specification sections)

**C. Responsible Subject Matter Expert (SME)**

1. Participate as a member of the Cx team and provides technical input as required.

<sup>18</sup> AP-350-406, Startup and Commissioning, provides instruction on how to organize a Test Review Board

2. Support and witness field Cx tests as necessary.
3. Review and approve Cx plans and other documents as submitted by the CxA.

**D. LANL Commissioning Authority (LCA, aka Startup Manager)**

1. Point-of-contact (POC) and support for all Cx issues including providing clarification, making recommendations on variance requests, maintaining the chapter and master specifications, and chairing the Chapter 15 Technical Committee.
2. Review CxA status reports.
3. Establish, review, and accept the CxA's qualifications for a project assignment.
4. Review and approve the qualifications of subcontractor CxA team members.
5. Review and approve all Cx activities conducted by the Project CxA.
6. Participate in project reviews as required.
7. Review and approve the Final Commissioning Report.

**E. Commissioning Agent (CxA) (LANL or Independent Third Party)**

1. Test personnel hold current NQA-1 Level II qualification as a minimum.
2. Establish the Cx Plan and coordinate the Cx Team.
3. Provide support to the owner to evaluate and verify that the owner's project requirements for the facility are satisfactorily achieved and documented during all phases of the project.
4. The CxA's roles and responsibilities must be in agreement with the contractual requirements established for the project. The specific requirements may significantly change based on design and construction approach (e.g. design-bid-build, design-build, etc.) selected by the Project Manager.
5. The CxA's responsibilities include the following tasks:
  - a. Develop the Cx process, plan, documentation and requirements throughout the life of the project.
  - b. In conjunction with the LCA, establish a Project Commissioning Team and define roles and responsibilities.
  - c. Develop a formal Cx Plan, budget and schedule.
  - d. Coordinate the Cx activities in a safe, logical, sequential, and efficient manner utilizing standardized protocols defined in ~~CMP-400~~ AP-350-406<sup>19</sup>.
  - e. Define the Cx requirements and activities to the construction manager, Subcontractors, architect/engineer of record, and the owner's project leader to ensure that Cx activities are included in the master design and construction schedules.
  - f. Plan and conduct Cx planning meetings.
  - g. Review design and construction documentation with respect to Cx requirements.
  - h. Review design and construction installation verification reports and Cx test data.

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<sup>19</sup> Reference AP-350-406, Conduct of Testing (Section 6.0)

- i. Identify, document, and report Cx test deficiencies. Coordinate re-testing as necessary, until satisfactory performance is achieved.
- j. Maintain a test deficiency report log.
- k. Provide to the owner/project manager written progress reports and test results with recommended actions.
- l. Review non-conformance and corrective action documentation that has a Cx impact.
- m. Review the Cx documentation utilized to establish Cx acceptance.
- n. Support the review of O&M submittals from a life-cycle O&M perspective, as required.
- o. Review and approve subcontractor installation verification checklists prior to the commencement of Cx activities.
- p. Provide coordination with the project STR for vendor training of owner personnel<sup>20</sup>.
- q. Observe components and systems installations. Attend planning and job-site meetings to obtain information on construction progress.
- r. Witness Cx tests when performed by subcontractors, vendors or independent agencies to assure that proper procedures are being followed and to validate acceptable results.
- s. Conduct retests of systems or components which failed the initial testing requirements.
- t. Develop System Integrated Test Procedures when required.
- u. Work with the installing subcontractors and include data from vendor tests.
- v. Analyze all test data collected to verify actual performance results for inclusion into the final Cx report and when required submit for TRB approval.

**F. Startup Specialist (aka Test Tech or Startup Test Specialist)**

- 1. Conduct tests as assigned by the CxA in accordance with approved test procedures and in support of the Cx Plan and Schedule.

**G. Facility Design Authority Representative (FDAR)**

- 1. Approve test and inspection requirements and acceptance criteria.

#### 4.0 APPLICABLE CODES, STANDARDS, AND OTHER REFERENCES

**A. LANL (ADPM APs in [EDRMS](#); P- and SD- docs [here](#))**

- 1. AP-350-406, *Startup and Commissioning Procedure*
- 2. AP-350-420, *Project Turnover and Acceptance*
- 3. AP-CMP-401, *System/Process Component Testing Procedure*
- 4. AP-CMP-402, *HVAC Air Flow Balance Testing*
- 5. P330-8, *Inspection and Test*

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<sup>20</sup> Reference AP-350-420, Section 4.0, Systems & Structures Training

6. PLAN-350-183, *Transition to Operations*
7. SD 330, *Los Alamos National Laboratory Quality Assurance Program*
8. SD 350, *Project Management for Capital Asset Acquisition and Construction*
9. Other chapters of the Engineering Standards Manual and related specification sections.

**B. Department of Energy (DOE) (Directives [here](#))**

1. DOE O 425.1D, Chg. 1, *Verification of Readiness, Startup or Restart of Nuclear Facilities*
2. DOE O 414.1D, Chg. 1, *Quality Assurance*
3. [10 CFR 830.122](#), *Quality Assurance Criteria* (nuclear facilities)

**C. National Standards (national standards subscription [here](#))**

1. ASHRAE – American Society of Heating, Refrigeration, and Air Conditioning Engineers
  - a. ANSI/ASHRAE/EIS Standard 202-2013, *Commissioning Process for Buildings and Systems*
2. ASME NQA-1-2008/NQA-1a-2009, *Quality Assurance Requirements for Nuclear Facility Application* (Non-Mandatory Appendix 2A-1 – *Guidance on the Qualifications of Inspection and Test Personnel*), Requirement 2, *Quality Assurance Program*; Requirement 11, *Test Control*.
3. InterNational Electrical Testing Association, Inc. (NETA)
4. National Electrical Contractors Association (NECA)
5. US Green Building Council's *Leadership in Energy and Environmental Design* ([LEED](#)) Rating System (e.g., v4.1)

## 5.0 Cx PROCESS REQUIREMENTS AND PHASES

**A. Requirements**

1. Conduct of Tests<sup>21</sup>

The CxA, and or the Startup Specialist shall test all structures, systems, and components within the scope of the project in accordance with the rigor of testing determined during the Graded Approach review and any specific or special tests as called out in the project contract documents. The conduct of test procedures shall ensure the safety of personnel and plant equipment. Notification tags and lock outs, as appropriate, shall be verified prior to performance of each test procedure or discrete test section.

2. Cx Plan

The CxA shall prepare a Cx Plan to clearly layout the scope, and responsibilities for successfully executing the Cx for his/her project. The Cx Plan shall be reviewed and approved by the LCA, the responsible Subject Matter Experts (SME), and the LPM.

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<sup>21</sup> NQA-1 2008/NQA-1a-2009, Requirement 11, provides direction for test control. See AP-350-406, Section 6.0, for specific instructions on Conduct of Testing.

3. Test Procedures<sup>22</sup>

The CxA shall prepare detailed component and system test procedures in accordance with the level of rigor for each system, or subsystem as determined in the Graded Approach Review for the project.

The procedures shall have appropriate levels of verification signatures, witness and hold points, and test results documentation to fully comply with all code requirements invoked by the quality level and rigor of testing assigned in the Graded Approach Review.

4. Procedure Review and Approval

System acceptance test procedures shall be reviewed the responsible SMEs, the Project Team, and LCA—and approved by the LCA.

5. Test Personnel Qualification

Test personnel qualification and competency to perform testing assigned to them by the CxA must be documented. The Subcontractor CxA may use AP-350-406<sup>23</sup> or they may submit their own test personnel qualification procedure to the LCA for approval.

Levels of qualification and experience shall use a graduated competency scale based on the individuals' education and experience level. Task assignments shall be based upon the test personnel's level of competency. The complexity and risk of the assigned test must be taken into consideration when ensuring that test personnel are competent and fully qualified to perform the test. See Appendix A, *Startup Specialists and Cx Agent Qualification Guidelines*.

B. Phases of a Project

1. Design Phase

a. Project Definition

*Guidance: For major capital acquisitions, it is helpful to the project to consult with the LCA when the project is being defined so Cx needs are understood.*<sup>24</sup>

b. Conceptual Design

*Guidance: The PE should involve the LCA with the Facility Design Authority Representative (FDAR) and Design Agency to evaluate design input documentation, prepare recommendation for method of turnover (zone, system, etc.), and develop preliminary schedule for Cx activities.*

c. Preliminary Design

- 1) When the engineering design is approximately 60% complete, the LCA will review the preliminary design, determine the applicability of the LANL Cx Process and this chapter, and collaborate with the LPM and the Project Team to gain concurrence and to select a CxA and set preliminary Division of Responsibilities (DOR).
- 2) Once the CxA is on board, they will, in collaboration with the LCA, identify and document the owner's project requirements for

<sup>22</sup> AP-350-406, Section 5.0, provides specific instruction in the development and approval process for test procedures.

<sup>23</sup> AP-350-406, Section 4.0, follows ASME NQA-1-2008/NQA-1a-2009, Non-mandatory Appendix 2A-1, Guidance on the Qualification of Inspection and Test Personnel

<sup>24</sup> This may be required by other LANL documents (AP-350-420, Section 3.0, states that Cx will be involved starting at the project definition stage).

- Cx and develop an initial approach to Cx, conduct the graded approach review and determination, and prepare a preliminary Cx Plan and DOR.
- 3) The Cx Plan will be reviewed for preliminary concurrence by the LCA, appropriate SMEs, and the LPM.
  - 4) Throughout the design phase the CxA and its Cx team will review and comment on design operability, maintainability, and testing readiness.
- d. Final Design
- As the engineering design approaches completion (90%), the CxA reviews and updates the preliminary Cx documents and issues the final Cx Plan for approval. The CxA shall incorporate project specific Cx requirements into the project specifications before they are issued for purchasing and construction.
2. Construction Phase
- a. At the beginning of the construction phase, the CxA shall issue the final Cx Plan once concurrence is reached and all approvals are obtained.
  - b. The CxA, working with the project scheduler, shall develop the Cx schedules for incorporation into the Master Construction Schedule. These schedules shall include milestones for turnover from construction to the Cx team, system test sequencing and test completion dates.
  - c. The CxA shall develop component test and system acceptance test procedures for each system. The system acceptance test procedures are then reviewed and approved by the LCA and SMEs prior to implementation.
  - d. As construction nears completion the construction focus shall shift to completing entire systems in accordance with the turnover milestones documented in the Master Construction Schedule. Installation verification walkdowns shall be conducted by construction with the CxA and the Cx Team taking custody and control of the system after acceptance.<sup>25</sup>
  - e. Ensure Pressure Safety Officer reviews are performed as required by ESM [Chapter 17](#), *Pressure Safety*.
3. Testing Phase
- NOTE: This testing should not be confused with testing and inspections (T&I) as required by the International Building Code and as described in ESM [Chapter 16](#), *IBC Program*. Those tests are the responsibility of the Subcontractor or LANL Building Official (LBO) as noted in that chapter.
- a. Testing by the Cx Team shall be in accordance with AP-350-406 or the Subcontracted CxA's procedure for same. The Cx Team shall execute the approved component and system test procedures, document test results, and submit them for post-test approval as required by the Cx Plan. Test Acceptance Criteria shall be documented in each test (as required by ESM [Chapter 20](#), *Systems Engineering*, when applicable).

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<sup>25</sup> AP-350-420, *Turnover and Acceptance* provides instruction on the conduct of walkdowns and the turnover of systems for commissioning.

- b. Test types:
  - 1) Component Testing

As systems are turned over from Construction to the Cx Team component testing will begin with basic tests to determine that each component operates as intended and that it is ready to be integrated into system testing.
  - 2) Factory Acceptance Testing (FAT)

Many vendor systems major components and software design are best tested at the vendor's facility prior to shipping to avoid possible delays and added costs should a problem be found requiring additional vendor technician time. These factory acceptance tests (FAT) shall be witnessed by members of the Cx Team and/or the responsible SME. The project representatives attending the FAT shall ensure that the vendor follows submitted and approved test procedures, documents all results, and that the results meet pre-determined acceptance criteria. FATs may not be substituted for system acceptance tests performed in the field.
  - 3) System Acceptance Testing (SAT)

System Acceptance Testing (SAT) is the testing performed in-place and in accordance with the CxA's approved test procedures to demonstrate the overall functionality and performance of the system to design.
  - 4) Software Verification and Validation

As required by the project software plan and SAT, include a minimum of one comprehensive, end of development acceptance test. The acceptance test must be performed and accepted prior to approval of the computer program for use. See also ESM [Chapter 21](#), *Software (SOFT-V&V)*.
  - 5) Acceptance Test Review

Review and approval of the acceptance test results by the Test Review Board provides assurance that the system(s) perform per design and confirms satisfactory completion of software validation.
- 4. Turnover to the Owner

As entire systems are satisfactorily functional tested the CxA shall assemble completion packages and a Final Commissioning Report for turnover to the owner. The Completion Packages and the Final Commissioning Report shall be turned over to the owner in accordance with PM Procedure AP-350-420, *Project Turnover and Acceptance*.
- 5. Project Closeout and Warranty
  - a. The CxA and LCA shall provide support to the owner during transition to full operations.
  - b. Lessons learned throughout the execution of the project shall be captured at closeout by the CxA and LCA for the benefit of future projects and to identify best practices.

- c. The LCA shall provide warranty support and analysis assistance to the owner as requested.
- d. The LCA shall provide support for seasonal testing and verification testing to meet LEED requirements or other commitments that could not be verified prior to turnover or require repeated testing during various seasonal conditions.

## 6.0 DOCUMENTATION REQUIREMENTS

- A. The following documents shall be prepared, approved and retained for each project executed under this standard. Additional documentation requirements may be applied in the Project Execution Plan.
  - 1. Commissioning Plan
  - 2. Commissioning/Test Procedures
  - 3. Final Test Summary Report.

## 7.0 APPENDICES

- A. Test Technician and Cx Agent Qualification Guidance

## 8.0 ATTACHMENTS

- A. Commissioning Process Flow Chart



**Appendix A**  
**Test Technician and Cx Agent Qualification Guidance**

Level	Desired Capabilities	Desired Education and Experience
I	Capable of performing and documenting the results of inspections and tests that are required to be performed in accordance with documented procedures, acceptance standards, and/or industry practices as defined in user's written procedures.	2 years of related experience in equivalent inspection or testing activities; or
		High school graduation and 6 months of related experience in equivalent inspection or testing activities; or
		Completion of college level work leading to an associate degree in related discipline plus 3 months of related experience in equivalent inspection or testing activities
II	All the capabilities of a Level I person for the inspection or test category or class in question.  Additionally, have demonstrated capabilities in planning inspections and tests, in setting up tests, including preparation and setup of related equipment, as appropriate; in supervising or maintaining surveillance over inspections and tests; in supervising and certifying lower level personnel; and in evaluating the validity and acceptability of inspection and test requirements.	1 year satisfactory performance as a Level I in the corresponding inspection or test category or class; or
		High school graduation plus 3 years of related experience in equivalent inspection or testing activities; or
		Completion of college level work leading to an associate degree in related discipline plus 1 year of related experience in equivalent inspection or testing activities; or
		Graduation from a 4-year college plus 6 months of related experience in equivalent inspection or testing activities
III	All the capabilities of a Level II person for the inspection or test category or class in question.  Additionally, be capable of evaluating the adequacy of specific programs used to train and certify inspection and test personnel whose qualifications are covered by this appendix.	6 years of satisfactory performance as a Level II in the corresponding inspection or test category or class or
		High school graduation plus 10 years of related experience in equivalent inspection or testing activities; or high school graduation plus 8 years of experience in equivalent inspection or testing activities (and, for nuclear work, with at least 2 years as a Level II and with a least 2 years associated with nuclear facilities, of sufficient training to be acquainted with the relevant quality assurance aspects of a nuclear facility); or
		Completion of college level work leading to an associate degree plus 7 years of related experience in equivalent inspection or testing activities (and for nuclear work, with at least 2 years of this experience associated with nuclear facilities or at least sufficient training to be acquainted with the relevant quality assurance aspects of a nuclear facility); or
		Graduation from a 4-year college plus 5 years of related experience in equivalent inspection or testing activities (and, for nuclear work, with at least 2 years of this experience associated with nuclear facilities or at least sufficient training to be acquainted with the relevant quality assurance aspects of a nuclear facility)