



CERTIFIED
COMMISSIONING AUTHORITY
CXA EXAM

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ACG CxA

Key Terminology Flashcards

Certified Commissioning Authority (CxA) Exam

ACG Guideline Part I · ACG Guideline 2005 · ASHRAE Std 202 / Guideline 0 · EMA

Final Exam Review

- Domain A: Managing Cx Projects (18%) — 68 terms
- Domain B: Preparing Cx Documentation (19%) — 53 terms
- Domain C: Conducting Cx Activities (24%) — 55 terms
- Domain D: Managing Training Activities (4%) — 12 terms
- Domain E: Completing Warranty Phase Activities (5%) — 12 terms
- Domain F: Conducting Existing Building Cx (23%) — 40 terms
- Domain G: Conducting On-Going Cx (7%) — 15 terms

255 terms · Beyond Smart Cities

Domain A - Managing Commissioning Projects: Role, Independence & Ethics**Certified
Commissioning
Authority (CxA)**

ACG credential for the professional who leads and manages the commissioning process and team on the owner's behalf; ACG now calls the project role the Commissioning Provider (CxP) (ACG Part I)

**"Commissioning
authority" vs CxP**

ACG retired "commissioning authority" as a project-role term in favor of Commissioning Provider (CxP); CxA remains the certification title (ACG Part I)

CxA as team leader

Plans, schedules, coordinates and documents Cx activities; facilitates the Cx Team but does not direct contractors' means and methods (ACG Part I)

**Independent,
third-party,
direct-for-owner model**

ACG's preferred delivery: CxP contracted directly by the owner, independent of design and construction firms, so findings reach the owner unfiltered (ACG Part I)

Conflict of interest

Business or personal interest that could bias the CxA's judgment, e.g. also holding the TAB or controls contract; CxA Code of Ethics requires full written disclosure to the affected client

Self-commissioning risk

When the designer or installer commissions its own work, defects may be overlooked; a reason owners and rating systems favor independent CxPs

Domain A - Managing Commissioning Projects: Role, Independence & Ethics**CxA Code of Ethics**

ACG pledge (rev. 01/2024) signed for certification and recertification:
standard of care, integrity, public safety first, disclose conflicts, accurate qualifications, work within competence

Hold paramount public safety

Code of Ethics tenet: the CxA places the health and safety of the public first in performing professional duties, even over client or schedule pressure

Represent qualifications accurately

Code of Ethics tenet: proposals and resumes must show the actual team and credentials; never inflate experience or name staff who will not work on the job

Practice within competence

Code of Ethics tenet: offer services only where competence and expertise satisfy client and public needs; add specialists to the CxP Group otherwise

Standard of care

Level of skill and diligence a reasonably prudent commissioning professional would exercise; the CxA pledges a reasonable industry standard of care

Sanctions (CxA Council)

Possible responses to Code violations: cease and desist, reprimand, censure, suspension or revocation of certification, dismissal from committees (ACG Part I)

Domain A - Managing Commissioning Projects: Role, Independence & Ethics**Objective owner advocate**

The CxA represents the owner's interests by verifying against the OPR/CFR, reporting facts without blame and without taking sides in contractual disputes

CxP authority limits

The CxP observes, tests, reports and recommends; it does not approve submittals, accept work, issue change orders or direct subcontractors (ACG Part I)

Commissioning Provider Group (CxP Group)

The CxA's firm staff and subconsultants (e.g. envelope, electrical, lab specialists) matched to system risk and complexity (ACG Part I)

Red-flag words

Words ACG advises avoiding in Cx documents because they imply unintended duties or guarantees, e.g. ensure, guarantee, inspect, supervise, oversee, shall, must, optimize, final (ACG Part I App. A.4)

Means and methods

Contractor's exclusive responsibility for how work is performed; a CxA who directs means and methods takes on liability it should not hold

Professional liability

Exposure for errors in professional services; managed by careful scope language, avoiding guarantees, professional liability insurance and limits of liability in the PSA

Domain A - Managing Commissioning Projects: Role, Independence & Ethics**Indemnification clause**

Contract term making one party cover another's losses; the CxA should review it with counsel, especially for remote BAS access or design responsibility

Domain A - Managing Commissioning Projects: Cx Team & Delivery Methods**Commissioning Team
(Cx Team)**

Owner, CxP, design team, construction team, O&M staff and end users who carry out the Cx process; the CxA facilitates it (ACG Part I)

Owner (Cx role)

Sets and approves the OPR/CFR, contracts the CxP, approves the Cx Plan and sampling, makes decisions on issues, and accepts the systems

Owner's representative

Person authorized to make day-to-day decisions for the owner; the CxA needs a named contact with decision authority

Design team (A/E)

Architect and engineers of record who write the BoD and design; they respond to design review comments and approve submittals

**Engineer of Record
(EOR)**

Licensed engineer responsible for a discipline's design; interprets design intent when test disputes arise

**General contractor /
Construction manager**

Leads the construction team, maintains the construction schedule and directs subcontractors to perform Cx duties

Domain A - Managing Commissioning Projects: Cx Team & Delivery Methods**Installing contractors**

Trades who complete checklists, start-up and testing support and correct deficiencies under their contracts

TAB agency

Independent firm measuring and adjusting air and water flows; its report is spot-checked by the CxA before FPT

Controls (ATC) contractor

Installs and programs the BAS; provides point-to-point, sequences, trends and graphics and supports FPT

Integrator of Record (IOR)

Party responsible for integrating multiple control and building systems into a coordinated whole (ACG Part I term)

O&M staff on the Cx Team

Operators who give maintainability input, witness tests and receive training; involve them from design onward

Authority having jurisdiction (AHJ)

Code official or agency approving life safety and code compliance; Cx does not replace AHJ inspections

Domain A - Managing Commissioning Projects: Cx Team & Delivery Methods**Design-bid-build (Cx impact)**

Separate design and construction contracts; Cx requirements must be in bid documents so contractors price them

Design-build (Cx impact)

One entity designs and builds; the owner-contracted CxA protects independence and OPR compliance when design and construction share incentives

Construction manager at risk (CMAR)

CM guarantees a maximum price and manages trades; engage early so Cx is in GMP scope and preconstruction reviews

Domain A - Managing Commissioning Projects: Scope, Fees & Procurement**Scope of commissioning services**

Systems, phases, deliverables, sampling rates and level of effort the CxA will provide; reconcile the RFP scope with the OPR goals before pricing

Commissioned systems list

Systems included in scope (HVAC, controls, plumbing, electrical, life safety, envelope, specialty); ACG Part I Appendix A.6 lists typical candidates

Request for Qualifications (RFQ)

First stage of two-stage procurement: owner screens CxP firms on experience, staff and certification before inviting proposals

Request for Proposal (RFP)

Owner's request for technical approach and fee; should state scope, sampling rates, schedule, selection criteria and fee negotiation process

Qualifications-based selection

Selecting the CxP primarily on qualifications, then negotiating fee; ACG favors it over lowest-bid selection

Selection default provisions

RFP clause: if fee talks with the first-ranked CxP fail, the owner negotiates with the second, then the third; protects the owner's schedule (ACG Part I)

Domain A - Managing Commissioning Projects: Scope, Fees & Procurement**Scoring rubric**

Weighted criteria used to rank proposals; weighted score = Σ (criterion score $\times$ weight)

Professional services agreement (PSA)

Contract between owner and CxP defining scope, fee, schedule, deliverables, insurance, liability and termination

Fee development

Estimating CxA effort from systems, sampling rates, meetings, site visits, reports and travel; sampling rates strongly drive cost (ACG Part I)

Fixed (lump-sum) fee

Set price for defined scope; CxA bears effort risk, so scope growth requires an additional services request

Time and materials (T&M)

Fee from hourly rates and expenses actually incurred; suits uncertain scope but needs owner budget control

Not-to-exceed (NTE)

T&M with a ceiling; track hours left against the NTE and alert the owner before it is reached

Domain A - Managing Commissioning Projects: Scope, Fees & Procurement**Cost-plus
(cost-reimbursable) fee**

Reimbursement of costs plus a fee (fixed, percentage or incentive tied to objective criteria)

Additional services

Work beyond the agreed scope (extra retests, added systems, schedule extension); document and authorize before performing

Commissioning budget management

Tracking effort and cost vs plan, forecasting cost at completion and reporting variances to the owner (CxA task A3)

Backcharge for retests

Cost of repeated failed tests charged to the responsible contractor when the contract documents allow; define in the Cx Specification

Value engineering (VE)

Review of alternatives to cut cost while maintaining function; the CxA assesses VE proposals against the OPR, maintainability and life-cycle cost

Total cost of ownership (TCO)

First cost plus energy, maintenance, replacement and other life-cycle costs; the CxA uses it to show VE trade-offs to the owner

Domain A - Managing Commissioning Projects: Meetings, Risk & Issues**Commissioning kick-off meeting**

First Cx meeting of a phase: introduces team, Cx Plan, roles, communications, schedule and expectations; agenda sample in ACG Part I

Commissioning meeting

CxA-led meeting to review Cx progress, issues log, upcoming tests and responsibilities; give advance notice and distribute minutes

OAC meeting

Owner-Architect-Contractor project meeting; the CxA attends to raise Cx issues and integration risks affecting schedule and quality

Meeting minutes

Record of attendees, decisions, assigned actions and due dates; owner decisions that change the OPR must be recorded and the OPR updated

Issues and Resolution Log

Single master record of each issue: description, location, date, responsible party, status, resolution and verification; replaces ACG's former RTF (ACG Part I)

Issue closure

An issue is closed only after the CxA verifies the correction in the field or by retest, not when a contractor reports it fixed

Domain A - Managing Commissioning Projects: Meetings, Risk & Issues**Writing an issue entry**

State observed condition, location, requirement (OPR/BoD/spec) violated and consequence; factual, no blame, one issue per entry

Risk assessment

Identifying commissioning risks (complex integration, schedule compression, occupied areas, owner vendors), rating likelihood and impact, and planning responses

Risk register

Log of identified risks with likelihood, impact, owner, response and status; update as risks change and record new risks raised in meetings

Expected monetary value (EMV)

$EMV = \text{probability} \times \text{cost impact}$; sum of EMVs helps size a risk contingency

Commissioning as risk mitigation

Cx reduces the owner's risk of failed systems, delays, comfort complaints and high operating cost by finding issues early (ACG Part I)

Pass/fail criteria (acceptance criteria)

Measurable, pre-agreed conditions (values, tolerances, response times) that define a passing test; set before testing, derived from OPR/BoD/specs

Domain A - Managing Commissioning Projects: Meetings, Risk & Issues**Tolerance band**

Allowable deviation around a setpoint or design value; a reading inside the band passes, e.g. airflow $\pm 10\%$ of design

Commissioning schedule

Cx activities integrated with the construction schedule; the construction team leader maintains the project schedule, and the CxA monitors Cx milestones

Process tracking metrics

Measures of Cx progress: checklists complete, tests passed, open issues by age and priority; used in progress reports to the owner

Substantial completion

Stage when the owner can occupy or use the work for its purpose; Cx tasks such as deferred tests and training may continue past it

Domain B - Preparing Commissioning Documentation: Owner & Design Documents**Owner's Project Requirements (OPR)**

Owner-owned document of goals, criteria and expectations; Std 202 calls it the primary tool for benchmarking success and quality at all phases

CxA role in the OPR

Facilitates workshops and interviews, turns vague goals into measurable criteria, but the owner decides and approves the requirements

OPR workshop

Facilitated session with owner, users, O&M and designers to gather and prioritize requirements; probe generalities for measurable values

Measurable OPR criterion

Requirement stated with a value and method, e.g. "space 21–24°C, 30–60% RH, NC 35"; enables pass/fail testing later

OPR version control

Each approved change is recorded in the version history with date and reason; the owner formally approves changes after initial acceptance

Current Facility Requirements (CFR)

Existing-building equivalent of the OPR stating present owner and occupant requirements; drafted early in EBCx (ACG Part I)

Domain B - Preparing Commissioning Documentation: Owner & Design Documents**Basis of Design (BoD)**

Design team's document of assumptions, criteria, calculations and system choices showing how the design meets the OPR; archive each version

BoD-OPR conflict

BoD value inconsistent with the OPR (e.g. humidity band); the CxA logs it and asks the owner and designer to resolve before construction

Design review (Cx design review)

CxA review of drawings and specifications at defined stages for OPR compliance, coordination, commissionability, maintainability and access

Back-check

Follow-up review confirming design review comments were incorporated or responded to in the next submission

Commissionability

Design features that allow testing and verification: test ports, sensors, trend points, access, isolation valves and documented sequences

Maintainability review

Checking access, service clearances, filter and coil access, labeling and spare-part strategy, with O&M staff input

Domain B – Preparing Commissioning Documentation: Owner & Design Documents**Design Phase
Commissioning Report**

Report at end of design summarizing Cx activities, review findings, OPR/BoD status and readiness for construction (ACG Part I)

Equipment List

Matrix of systems and equipment to be commissioned with tags, locations and data; basis for checklists, tests and sampling (ACG Part I)

Project Manual

Specifications and contract conditions issued with the drawings; Cx requirements must be integrated here to bind contractors

Domain B – Preparing Commissioning Documentation: Standards & Rating Systems**ANSI/ASHRAE/IES
Standard 202**

Consensus standard defining the minimum commissioning process for buildings and systems; it does not mandate specific phases (ACG Part I)

ASHRAE Guideline 0

The Commissioning Process guideline; its phased approach is the basis for ACG's four phases (ACG Part I)

ASHRAE Guideline 0.2

Commissioning Process for Existing Systems and Assemblies; guidance for EBCx

ASHRAE Guideline 1.1

HVAC&R Technical Requirements for the Commissioning Process; technical detail for HVAC&R Cx

ACG four phases

Project Initiation, Design, Construction, Occupancy and Operations (ACG Part I, following Guideline 0)

ACG 2005 five phases

Pre-Design, Design, Construction, Acceptance, Post-Acceptance; Part I folds Acceptance and Post-Acceptance into Occupancy and Operations

Domain B - Preparing Commissioning Documentation: Standards & Rating Systems**Comprehensive commissioning**

Cx starting at the earliest (pre-design/project initiation) phase and continuing through occupancy; ACG's recommended approach

Construction-phase-only Cx

Cx started during construction; loses design review benefits, so the CxA must quickly review OPR/BoD and documents

LEED Fundamental Commissioning

LEED prerequisite: qualified CxA, OPR and BoD, Cx Plan, Cx requirements in construction documents, verification and testing, Cx report

LEED Enhanced Commissioning

LEED credit adding CxA submittal review, systems manual and training verification, and a post-occupancy (about 10-month) review; options for MBCx and envelope Cx

Building enclosure commissioning (BECx)

Cx of the exterior enclosure; increasingly common in severe climates and for buildings with strict IEQ needs such as hospitals and labs (ACG Part I)

Envelope testing

Tests such as water penetration, air leakage (blower door), mockups and thermography, specified in the enclosure sections

Domain B - Preparing Commissioning Documentation: Cx Plan & Specifications**Commissioning Plan (Cx Plan)**

Document of Cx organization, schedule, resource allocation and documentation requirements; framed early, updated each phase (Std 202; ACG)

Cx Plan contents

Scope, systems, team roles, communications, schedule, submittals reviewed, checklists, test procedures, sampling, issues process, training, deliverables

Cx Plan update

Revise when scope, systems, schedule or team change (e.g. new storage type); the final version goes in the Final Commissioning Report

Commissioning Specification

Contract language (usually Division 01, plus trade sections) setting contractors' Cx duties, submittals, checklists, testing support and training

Division 01 general requirements

Specification division where general Cx requirements usually sit so they apply to all trades; trade sections add system-specific duties

Communications plan

Defines who sends what to whom, channels, distribution lists, response times and document control; essential under design-build and multi-tenant projects

Domain B - Preparing Commissioning Documentation: Cx Plan & Specifications**Site visit protocol**

Logistics for visits: notice, access, escort, PPE, security clearances, sign-in, photography rules and daily report distribution

Daily (field) report

CxA record of each site visit: purpose, attendees, observations, issues found and follow-up; supports the issues log

Commissioning Progress Report

Periodic report to the owner on Cx status, metrics, open issues, risks and next steps; tailor detail to executives vs field staff

Owner-furnished equipment

Items bought by the owner (often through separate vendors); include their Cx requirements in purchase orders and the Cx Plan

Tenant fit-out commissioning

Cx of tenant work tied to base-building systems; set requirements in the tenant work letter and coordinate communication paths

Design-build Cx requirements

Place Cx duties in the criteria package and contract, define communication lines and integrate the builder's QA program

Domain B – Preparing Commissioning Documentation: Checklists, Tests & Reports**Construction checklist**

Installation verification form completed by contractors (verified by the CxA) before start-up; ACG now calls the former SVC simply a "checklist"

Pre-functional checklist (PFC)

Common name for construction checklists; confirms equipment is installed, connected and ready for start-up and testing

CxP checklist

Checklist the CxA completes while observing installation or verifying contractor work (ACG Part I)

Project-specific checklist items

Items added beyond generic forms to reflect the system's risks, e.g. clearance around detention areas or panel cooling

Functional performance test (FPT) procedure

Step-by-step test script: prerequisites, setup, actions, expected response, acceptance criteria, and recorded results and signatures

Test prerequisites

Conditions required before testing: checklists complete, start-up done, TAB complete, point-to-point verified, open issues resolved

Domain B – Preparing Commissioning Documentation: Checklists, Tests & Reports**Integrated systems test (IST) script**

Test of interactions among systems (power, HVAC, fire alarm, BAS) under scenarios such as utility loss; defines sequence, observers and recording

Sampling plan in the Cx Plan

States population, sample size or rate, selection method and what happens on failure; owner approves it

Construction Phase Commissioning Report

Summary of construction-phase Cx: checklists, tests, issues and status; precedes the final report (ACG Part I)

Final Commissioning Report

Complete record: executive summary, Cx Plan, OPR/BoD, checklists, test results, issues log and resolutions, training, deferred items (ACG Part I)

Systems Manual

Living reference for operating staff: OPR, BoD, sequences, setpoints and why, schematics, test records, training, recommissioning guidance; start it in design

Systems Manual vs O&M Manual

Systems Manual explains how and why systems operate together; O&M Manual compiles manufacturer data for maintaining individual equipment

Domain B - Preparing Commissioning Documentation: Checklists, Tests & Reports**O&M Manual review**

CxA checks manuals are complete, model-specific, organized and include maintenance schedules and warranties

End-of-warranty review process

Documented plan for the near end-of-warranty review: inputs collected through the year, attendees, issues and actions (CxA task B15)

Domain C - Conducting Commissioning Activities: Construction & Controls**Construction Phase
kick-off**

First construction-phase Cx meeting reviewing Cx Specification duties, checklists, submittals and schedule with contractors

**Construction submittal
review**

CxA reviews selected submittals for OPR/BoD compliance and commissionability; comments go to the design team, which holds approval authority

**Sequence of operation
(SOO) submittal**

Controls contractor's written sequences; check all modes and transitions, alarms, setpoints, failure responses

**Construction
observation**

Site visits to observe installation quality and compliance before work is concealed (e.g. before ceiling closure)

Installation verification

Confirming equipment is installed per documents, accessible and labeled; mismatches are logged at once

Delivery inspection

Checking equipment and materials on arrival for model, rating, material and damage against approved submittals

Domain C - Conducting Commissioning Activities: Construction & Controls**Coordinated planning**

Pre-installation coordination among trades and CxA to prevent conflicts, access blockage and rework

Start-up

Manufacturer or contractor first operation of equipment per procedures; documented start-up report precedes FPT

Factory witness test (FWT)

CxA or owner observes testing of equipment at the factory before shipment, e.g. generators, switchgear, large AHUs

Point-to-point verification

Checking each BAS point from field device to controller to graphics: correct wiring, scaling, range and command response

Duct leakage test

Pressurizing a duct section and measuring leakage vs allowance; allowable leakage = rate per area × tested duct surface area

Hydrostatic pressure test

Pressure test of piping for leaks before insulation and concealment

Domain C - Conducting Commissioning Activities: Construction & Controls**Pipe flushing and cleaning**

Removing debris and treating water before connecting sensitive equipment (heat pumps, coolant distribution units); document results

Pre-testing (trial testing)

Contractor runs tests before formal witnessed FPT, reducing failed tests and retest cost

Ready for testing

State defined by the CxA (not the installer) when prerequisites are met; ACG notes the phrase is subjective so criteria must be stated (ACG Part I)

TAB report verification

CxA spot-checks a sample of reported airflows/water flows; discrepancies beyond tolerance trigger further checks or rebalancing

Control loop tuning (PID)

Adjusting proportional, integral and derivative gains so loops are stable; trends showing hunting point to poor tuning or sticking actuators

Graphics verification

Confirming BAS graphics show correct live values, status and setpoints; GUI status that contradicts the field device is an issue

Domain C - Conducting Commissioning Activities: Construction & Controls**Alarm management**

Defining alarm priorities, limits and delays to avoid nuisance alarms and alarm floods during IST and operation

Operator override

Manual command holding a point; overrides left in place defeat sequences, so trend and report them

Sensor calibration check

Comparing sensors with a calibrated reference; drifted or flat-lined sensors drive wrong control actions

Static pressure reset

Lowering duct static setpoint as VAV dampers open less; a reset pinned at maximum suggests a rogue zone

Domain C - Conducting Commissioning Activities: Testing & Acceptance**Acceptance phase**

Period when FPTs, IST, training and documentation confirm systems meet the OPR before owner acceptance (ACG 2005 phase; combined into Occupancy and Operations in Part I)

Functional performance testing

Verifying systems perform in all modes (occupied, unoccupied, failure, emergency, seasonal) against acceptance criteria

Hierarchical testing order

Test components, then equipment, then systems, then integrated systems; failures at a lower level stop higher-level testing

Random sampling

Testing a random fraction of identical units (e.g. 5–10% of AHUs); if results pass, the rest may not need testing (ACG Part I)

Investigative (stratified) sampling

Sampling chosen to probe likely problem groups (by installer, floor or type)

Prototypical sampling

Thoroughly testing a first or typical unit to prove the procedure before testing the rest

Domain C - Conducting Commissioning Activities: Testing & Acceptance**Failure threshold and expanded sampling**

If failures exceed the allowed rate, test a larger sample or all units at the contractor's cost, per the Cx Specification

Pausing testing

When failure rates exceed tolerances, the CxA may stop testing, report the high failure rate and resume when contractors have corrected work (ACG Part I)

Sampling vs scope limitation

Sampling tests part of a population to infer the whole; scope limitation simply excludes items from commissioning (ACG Part I)

Trend logging

BAS data collected over time to verify control stability, sequences and schedules; specify points, intervals and duration

Failure mode testing

Simulating failures (fan, pump, sensor, power) to verify alarms and safe responses

Integrated systems testing (IST)

Testing interactions across systems under real scenarios after individual systems pass; critical for hospitals and data centers (ACG Part I)

Domain C - Conducting Commissioning Activities: Testing & Acceptance**Emergency power transfer test**

Utility loss to verify generator start, transfer and restart of HVAC, drives and controls in correct sequence

Deferred testing

Tests postponed because conditions (load, occupancy, weather) are not available; record in the issues log and Final Report

Off-season (seasonal) testing

Testing heating or cooling modes in the season when design conditions occur, often during the warranty period

Retest

Repeat of a failed test after correction; record result and close the issue only on passing

Demonstration vs test

In a demonstration the contractor shows operation; in a test the CxA verifies against acceptance criteria with recorded results

Commissioning test dispute

When parties disagree on sequence intent, the CxA refers to OPR, BoD and specs and asks the design team for interpretation

Domain C - Conducting Commissioning Activities: Systems & Calculations**Sensible load (air)**

$$Q = \rho c_p V \Delta T; \text{SI} \approx 1.2 \times 1.006 \times \text{m}^3/\text{s} \times \text{K} \text{ (kW)}; \text{IP} \approx 1.08 \times \text{cfm} \times \Delta T \text{ (Btu/h)}$$

Latent load (air)

$$\text{SI} \approx 3.0 \times \text{L/s} \times \Delta w \text{ (g/kg) (W)}; \text{IP} \approx 0.68 \times \text{cfm} \times \Delta \text{grains (Btu/h)}$$

Total coil load

$$Q = \rho \times V \times (h_{\text{entering}} - h_{\text{leaving}}); \text{IP} \approx 4.5 \times \text{cfm} \times \Delta h \text{ (Btu/h)}$$

Water-side load

$$Q = m c_p \Delta T; \text{IP: Btu/h} \approx 500 \times \text{gpm} \times \Delta T; \text{SI: kW} \approx 4.19 \times \text{L/s} \times \Delta T$$

Fan brake power

$$\text{IP: bhp} = \text{cfm} \times \text{TSP (in. w.g.)} \div (6,356 \times \eta); \text{SI: kW} = \text{m}^3/\text{s} \times \text{Pa} \div (1,000 \times \eta)$$

Affinity laws

Flow $\propto$ speed; pressure $\propto$ speed²;
power $\propto$ speed³; used to predict fan
and pump performance at new speeds

Domain C - Conducting Commissioning Activities: Systems & Calculations**Valve flow coefficient
(Cv)**

$\text{gpm} = \text{Cv} \times \sqrt{(\Delta P \text{ psi} \div \text{SG})}$; used to check reheat coil flow from valve size and measured pressure drop

**VAV flow from velocity
pressure**

$\text{cfm} = K \text{ (flow factor)} \times \sqrt{(\text{VP})}$; verify box calibration against TAB readings

**Energy recovery
effectiveness**

Sensible effectiveness = $(T_{\text{supply leaving}} - T_{\text{OA}}) \div (T_{\text{exhaust entering}} - T_{\text{OA}})$ for the supply stream

Room pressurization

Pressure difference created by airflow offset between supply and exhaust; isolation rooms negative, ORs and protective rooms positive

**Leakage-area pressure
relation**

Offset flow $\propto$ leakage area $\times \sqrt{\Delta P}$; doubling the offset raises pressure about fourfold for the same leakage area

**Chilled-water low delta
T**

Return water too cold for the design ΔT ; raises flow and pump energy and limits chiller loading; causes include three-way valves and coil fouling

Domain C - Conducting Commissioning Activities: Systems & Calculations**Cooling tower approach**

Leaving water temperature minus
entering wet-bulb; range = entering –
leaving water temperature

Ice storage capacity

Ton-hours = tons × hours; recharge
hours = ton-hours ÷ charging capacity
(tons)

Motor load factor

Load = measured input kW × motor
efficiency ÷ (rated hp × 0.746)

Domain D - Managing Training Activities**O&M Training Plan**

CxA-developed or reviewed plan of training topics, audiences, trainers, durations, formats and records, tied to systems and OPR requirements

Training coordination meeting

Meeting to agree training content, schedule, attendees and logistics with contractors, manufacturers and the owner before sessions start

Role-based training

Content tailored to each audience: operators, technicians, managers, occupants or event crews

Competency verification

Checking trainees can perform tasks (quiz, demonstration) before independent operation; especially for critical systems

Training records

Attendance sheets, agendas, materials and recordings retained in the Systems Manual or owner's quality system

Training follow-up

Reviewing whether training changed practice, delivering supplemental or seasonal training and adjusting plans after observation

Domain D - Managing Training Activities**Deferred training**

Training for seasonal modes or systems not ready at turnover, scheduled for when they operate

Training session hours

Total hours = Σ (sessions $\times$ duration); compare with the hours specified per system in the Cx Specification

Recorded training

Video of sessions kept for new staff and refreshers; useful with rotating shifts and turnover

Language and literacy needs

Training adapted for staff with limited English or varied experience, using visuals, demonstrations and translated materials

Alarm response training

Instruction on what each critical alarm means and the required response; often overlooked in generic equipment training

Occupant orientation

Brief training for occupants on thermostats, lighting controls, windows and how to report problems

Domain E - Completing Warranty Phase Activities**Warranty period**

Typically 12 months from substantial completion or acceptance; contractors correct defects at no cost; verify each system's actual start date

Warranty phase activities

Seasonal testing, issue tracking, troubleshooting, trend review and coordination of warranty repairs by the CxA (ACG Part I)

Near end-of-warranty review

Meeting before warranty expiry to revisit open items, confirm performance meets the OPR/CFR and let O&M staff document issues (ACG Part I)

Near end-of-warranty timing

For a 12-month warranty, hold the review after about 9–10 months (75–85% through), leaving 8–12 weeks to resolve issues (ACG Part I)

Warranty issue troubleshooting

CxA helps identify root cause (design, installation, operation) using trends and tests so the right party makes corrections

O&M work under warranty

Owner staff performing repairs on warranty equipment may void coverage; coordinate with the contractor first

Domain E - Completing Warranty Phase Activities**Recurring failure pattern**

Repeated failures of the same component (bearings, canisters, compressors) suggest a systemic cause to resolve before warranty ends

Measure energy performance

Compare metered energy with design or model expectations during warranty, weather-normalized, to catch underperformance early

Lessons learned

Workshop or record of what worked and what did not, used to improve future projects and the owner's standards

Final Commissioning Report update

Add deferred and seasonal test results and warranty-period findings to the final documentation

Warranty start date verification

Confirming when each warranty began, since equipment started early may expire before the building warranty

Post-occupancy feedback

Occupant and O&M feedback collected during warranty to find comfort or operability issues

Domain F - Existing Building Commissioning: Concepts & Scope**Existing building
commissioning (EBCx)**

Commissioning process applied to existing buildings to verify and improve operation against the CFR; includes retro-, re- and ongoing commissioning (ACG; Std 202)

**Retrocommissioning
(RCx)**

Commissioning an existing building never commissioned before, to find and correct operational problems and improve performance

Recommissioning

Repeating commissioning on a previously commissioned building to restore performance after time, use changes or problems

EBCx planning phase

Set goals, review documents and utility data, conduct site survey and interviews, finalize scope and prepare the EBCx plan (ACG 2005 recommissioning)

**EBCx implementation
phase**

TAB, functional tests, analysis of results, O&M practice review, corrections and the final report (ACG 2005 recommissioning)

Pre-proposal site visit

Visit before pricing EBCx to see systems, controls, documentation and staff capability; reduces scope surprises

Domain F - Existing Building Commissioning: Concepts & Scope**Right-sizing EBCx scope**

Matching scope to building size, systems, budget and goals; prioritize systems with largest energy and comfort impact

Portfolio prioritization

Choosing which buildings to commission first using EUI, complaints, age, controls and potential savings

EBCx team

Owner representative, O&M staff, CxP, controls and TAB contractors, plus design team or specialists as needed

CFR development in EBCx

Interview owner, managers, O&M and occupants on current needs; translate legacy OPRs into the CFR when they exist

Missing documentation

When drawings and manuals are absent or wrong, the CxA documents existing systems through survey, BAS review and testing

Building performance assessment

Benchmarking energy (EUI, Energy Star), comfort complaints and maintenance history to find where performance falls short (CxA task F2)

Domain F - Existing Building Commissioning: Concepts & Scope**Systems assessment**

Review of each system's condition, controls, sequences and operation vs CFR (CxA task F4)

Site investigation

Field measurements, trend review, functional tests and staff interviews to identify deficiencies and opportunities (CxA task F5)

Domain F - Existing Building Commissioning: Analysis & Measures**Utility data analysis**

Monthly and interval data review: EUI, seasonal patterns, base load, after-hours use, demand peaks and weather correlation

Site energy use intensity (EUI)

Annual site energy ÷ floor area; convert fuels to common units (e.g. 1 kWh = 3.412 kBtu, 1 therm = 100 kBtu)

Energy balance

Allocation of metered energy to end uses; a large "miscellaneous" share means loads remain unidentified

Regression baseline

Energy modeled vs degree days or other drivers; weak correlation suggests schedule or process loads dominate

Blended rate

Total bill cost ÷ total kWh; use marginal rates instead when savings occur in specific TOU periods or demand

Demand ratchet

Billing demand set to a percentage of the highest recent peak; one peak can raise charges for months

Domain F - Existing Building Commissioning: Analysis & Measures**Simultaneous heating and cooling**

Heating and cooling active together in the same zone or air stream; trend-based share of hours flags waste

After-hours energy use

Load outside occupied hours from schedules, overrides or failed controls; found in interval data and BAS trends

Energy conservation measure (ECM)

Change reducing energy use or cost; documented with savings, cost and payback for owner decision

Facility improvement measure (FIM)

Measure improving operation, comfort, reliability or maintenance, with or without energy savings

Interacting measures

Combined savings of measures that affect the same load are less than the sum; calculate sequentially

Simple payback

Net cost (after incentives) ÷ annual savings; payback = (cost – incentive) ÷ annual savings

Domain F - Existing Building Commissioning: Analysis & Measures**Net present value
(NPV)**

Σ discounted savings – investment;
NPV > 0 justifies the measure at the
owner's discount rate

**Corrective action
recommendation**

Recommend corrections (repairs,
sequence changes, tuning) or capital
improvements with evidence, priority
and cost

Change control

Owner-approved procedure for making
EBCx changes in critical facilities
(hospitals, labs) with risk review and
rollback

Finding outside scope

Issue discovered beyond the approved
EBCx scope; report it to the owner
rather than ignoring or fixing without
authorization

Domain F - Existing Building Commissioning: Implementation & Verification**Oversee corrective measures**

CxA tracks implementation by staff or contractors, verifies installation and functional results (CxA task F7)

Installation check (EBCx)

Confirm measures were installed as recommended, e.g. drives not left in bypass and schedules actually loaded

Performance verification

Retesting and trend review to confirm corrected systems meet the CFR and expected savings (CxA task F8)

Measurement and verification (M&V)

Determining actual savings by measurement and baseline comparison (IPMVP framework); state confidence and uncertainty

IPMVP options

A: key parameter measurement; B: all parameter measurement; C: whole facility; D: calibrated simulation

Baseline adjustment

Non-routine adjustment when conditions change (e.g. added gym, new loads) so savings are fairly compared

Domain F - Existing Building Commissioning: Implementation & Verification**Final EBCx report**

Documents findings, measures implemented, verification results, savings, recommendations, updated documentation and training (ACG; EMA)

Updated Systems Manual (EBCx)

Revise or create the Systems Manual with current sequences, setpoints and CFR after EBCx

Customized retraining

Training on changed sequences and new practices after EBCx so O&M staff sustain results

Persistence of savings

Savings maintained over time through OCx, trending, training and clear responsibilities

Domain G - Conducting On-Going Commissioning**Ongoing commissioning (OCx)**

"A continuation of the [commissioning process] well into occupancy and operations to continually improve" performance to meet current and evolving CFR or OPR (Std 202)

Monitoring-based commissioning (MBCx)

Technology-driven subset of OCx using permanent meters, trending and analytics to detect and prioritize issues (ACG Part I)

Ongoing Commissioning Plan (OCx Plan)

Defines OCx goals, team, metrics, monitoring points, review frequency, responsibilities and reporting; start it before turnover with O&M input

OCx Team

Owner, O&M staff, CxP, controls integrator and others responsible for continuing performance

Fault detection and diagnostics (FDD)

Software rules or models flagging faults (stuck dampers, leaking valves, simultaneous heating/cooling) from BAS and meter data

Fault prioritization

Ranking analytics faults by energy cost, comfort, risk and frequency so staff address the most important first

Domain G - Conducting On-Going Commissioning**IEQ performance measurement**

Monitoring temperature, humidity, CO₂, particulates and acoustics against the OPR/CFR (CxA task G1)

Outdoor air fraction from CO₂

OA fraction = $(C_{\text{return}} - C_{\text{mixed}}) \div (C_{\text{return}} - C_{\text{outdoor}})$; delivered OA = fraction × supply airflow

Building operating plan review

Review of schedules, setpoints and operating strategies vs current use; update after space or function changes (CxA task G3)

Maintenance activity review

Linking OCx findings to work orders and PM tasks in the CMMS so issues are fixed and tracked

Space/function change

Changes in use or occupancy require updating CFR, sequences, airflow and the Systems Manual (CxA task G5)

Cumulative savings tracking (CUSUM)

Running sum of (expected – actual) energy; a flattening or falling curve signals lost savings

Domain G - Conducting On-Going Commissioning**Rotating sample testing**

Testing a different subset of terminal units each period so all are checked over a cycle

Publishing OCx results

Reporting metrics and savings to stakeholders in terms each values (cost, comfort, carbon) (CxA task G7)

Defending the OCx budget

Showing new management avoided costs, savings persistence and risk reduction delivered by OCx

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