IMPROVING TRANSITION FROM CONSTRUCTION TO OPERATIONS WITH CONDITION MONITORING BASED COMMISSIONING

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History of Commissioning

- 1950's DoD uses Cx for Military Construction (Mil-Con) in shipbuilding and shore construction, includes quality verification
- 1960's Cx replaces Zero-Defect 100% Inspection Programs
- 1970's Public Works increases prescriptive Cx process in facility and capital projects using appropriated funds
- 1984 University of Wisconsin provides ASHRAE Commissioning Authority Professional (CAP) development training & Cx requirements

History of Commissioning

- **1989** - ASHRAE prepares and publishes initial HVAC Cx testing guidelines
- **1990** - San Diego County issues General Policy-15, Smart Building Initiative for source energy and water use metering, measurement, and controls. Additional sustainability initiatives are launched.
- **1990's** - ENERGY Star and USGBC issues LEED certification criteria v1.1, 2.1
- **1991** – Public and private utilities companies begin commissioning with Energy Efficiency Measure (EEM) grant programs
- **1992** - US Energy Policy Act requires Cx Plans for Federal funded programs
- **1998** - Building Commissioning Association (BCA) & PECI National Strategies

History of Commissioning

- **2003** - California Commissioning Collaborative establishes programs with the utilities and industry in commissioning best management practice
- **2004** - State of California issues a Green Building Executive Order in CBC to include Title-24 energy efficiency for buildings to achieve LEED Silver level
- **2008** – California Green Building Standards Code, Part II, Title 24, establishing agencies to require specific green building standards
- **2010** - State of California CAL-Green initiatives include mandatory commissioning at fundamental commissioning level requirements
- **2013** - San Diego County Woman's Detention Facility (SDCWDF) is initiated with County DGS Operations and Facilities Maintenance Cx Team implementing LEED Enhanced Cx process and tools.

Mission of Commissioning

- Quality process verifies performance meets design
- Documents performance by testing and reports
- Demonstrates operational performance and energy savings as predicted by the design
- Existing buildings –
  - Re-commissioning maintains energy efficiency, design reliability, reduce life cycle O&M costs
  - Retro-commissioning restores controls, measures, and sequences to original design intent, reduce O&M costs

Case Studies

- Sponsors included:
  - Lawrence Berkeley National Laboratory
  - U.S. Department of Energy
  - Building Commissioning Association
  - Pacific Energy Center, Pacific Gas & Electric Company
  - ASHRAE (American Society of Refrigeration and Air-conditioning Engineers)
  - California Commissioning Collaborative
  - California Energy Commission (CEC)

Case Studies

- Case Quantities, Types and Timeframes
  - More than 650 buildings
    - Over 300 Energy Efficiency Measure (EEM) projects
    - Both Existing & New buildings
    - LEED types NC, EB, C&S, TI, CI, including CALGreen projects
  - Over 100 Million square-feet of conditioned floor space
    - Includes commissioning, re commissioning, and retro-commissioning
    - Over 10,000 energy- related problems revealed
    - $ 2.5 billion in total construction costs
  - Over 20 different commissioning companies
    - $ 45 million in commissioning expenditures (1.8% of construction costs)

Case Studies

- Four (4) Key Components of Case Studies
  1. Cx Scope
  2. Payback Formula
  3. Cx Building Types
  4. Cost Components
     a. Included costs
     b. Excluded costs
     c. Non energy benefits

Case Studies

- Component #1 – Commissioning Agent's Scope
  - 1. Design Criteria, DD | CD Documents for Commissioning
    - Performance specification including sequence of operations
    - Contractor use of PFTs, FPTs, start up, and functional testing
    - Contractor's quality control process and report requirements
  - 2. Contractor Submittals
    - Product submittals, quality characteristics, and checklists
    - Installation, startup, and testing using PFTs, and FPTs
    - Functional testing & reports

Case Studies

- Component #1 – Commissioning Agent Scope
  - 3. Cx Issues Log, tracking, and resolution
    - Cx spot checks of PFTs, FPTs,
    - Identify and track Cx exceptions
    - Track and back check resolutions
  - 4. Verify Training - agenda, attendees, and records
  - 5. Verify Systems Testing, Systems, O&M Manual
    - Systems trend analysis and performance verification
    - Verify basis of design,
    - Owner's Project Requirements

Case Studies

- Component #1 – Commissioning Agent's Scope
  - 6. Facilitate updated Sequence of Operation
    - Cx Report, M&V Plan, Energy-Use Intensity (EUI)
    - Verify sub-metering during design and startup
    - Commission sub-metering and energy reporting
    - Verify EUI Energy Efficiency Measures (EEMs)
  - 7. Verify /prepare Cal-Green /LEED submittals
    - LEED Fundamental commissioning EAp1
    - LEED Enhanced commissioning EAc3
    - Title-24 Energy LEED Measure and Verification (M&V) EAc5

Case Studies

- Component #2 – Formula for Simple Payback Time (Years)

  - **Payback in years** =

    [$ Cx Costs] +/- [$ Non-energy Cx impact costs]
    [$ Annual Energy Savings] +/- [$ Non-energy Cx benefits]

    = _____ **years payback**

Case Studies

- Component #3 – Building Systems Types
  - Whole Building (All systems)
    - Holistic - Envelope, MEP and Low Voltage systems
    - CalGreen/LEED Fundamental Cx - MEP & Irrigation
    - LEED Enhanced Cx - Design through Warranty Phase
  - Energy Isolation (One system only)
    - One system - Such as a boiler, or chiller, or lighting system
    - Energy boundary - Isolate system only, excludes all others
    - Parameter - Measure energy input / output crossing boundary

Case Studies

- Component #4 Cost Items consisting of three (3) Cost Types (4.1, 4.2, 4.3)
  - Type 4.1(Cost excluded, not included) in Cx Cost Items
    1. Non-billable in-house operations staff fixed costs
    2. Contractor cost - Contract compliance
    3. Test and Balance (TAB)
    4. Correcting design deficiencies and errors
    5. Resolving system installation deficiencies/conflicts with scope
    6. Major capital improvements to resolve deficiencies
    7. Analysis, troubleshooting, and/or research resolution
    8. Costs to correct deficiencies found & re-testing to verify resolution

Case Studies

- Component #4 Cost Items consisting of three (3) Cost Types (4.1, 4.2, 4.3)
  - Type 4.2 - Cost Items included in Case Study Cx Cost Items

1. Cx providers fixed costs
2. Contractor's Cx related costs, coordination with Cx provider
3. Improving design or operations directly from Cx findings
4. Functional testing for Cx sampling (not contractor's QC program testing)
5. Resolution costs for resolving Cx Issues (could be considered ZD effort)
6. Costs related to multiple trades / coordination with Cx provider
7. Costs associated with resolution of O&M issues from Cx findings
8. Minor capital improvement costs to resolve deficiencies (out of scope)
9. Cx costs associated with training on-site O&M staff, Cx FPT backchecks
10. Non-energy impacts associated with Cx process

Case Studies

- Component #4 Cost Items consisting of three (3) Cost Types (4.1, 4.2, 4.3)
  - Type 4.3 - Non-Energy costs **related Cx benefits**
    1. Construction benefits
       1. **Contract change orders reduced by up to 87%**
       2. **Contractor callbacks reduced by up to 90%**
       3. **Construction costs reduced by 4 to 9%**
    2. Extended equipment life cycle
       1. **Improved system reliability performance**
       2. **Restore (E) systems to original design sequences**
       3. **Improve (N) systems controllability / functionality**
    3. Longer system run times without issues
       1. **Materials savings**
       2. **Less man-hours troubleshooting**
       3. **Fewer redundant repairs**

Case Studies

- Findings – Items A thru E as shown below:
  A. Deficiencies found
  B. Improved performance outcomes
  C. Cx costs per square-foot
  D. Return on Cx Investment - Payback in _____months
  E. Summary of Cx Parameters & Metrics

Case Studies

- Findings
  - **A. Deficiencies found (typical)**
    - Loose fan belts, leaking valves
    - Balancing out of calibration, shaft misalignment
    - T-stats and sensors out of calibration
    - VAV terminal boxes malfunctions
    - Economizer sequences not working
    - Controls out of sequence or set points inadequate
    - Chronic temperature complaints
    - Energy costs excessively high
    - Equipment running more than required
    - Sequence of Operations & set points (messed up)

Case Studies

- Findings
  - **B. Improved performance outcomes**
    - More precise & stable building controls performance
    - Better occupant comfort (less complaints)
    - Improved Indoor Air Quality (IAQ), fresh air, and temperature
    - Improved efficiency of equipment (kW input / BTU output)
    - Lower O & M costs over system life cycle, reduce energy use
    - Less trouble calls, fewer call-backs
    - Extend equipment life / restore design reliability
    - Updated Preventative Maintenance (PM) procedures
    - Refreshed and improved O&M staff training

Case Studies

- Findings
  - **C. Investment in commissioning per square foot**
    - Cx of *whole building* MEP systems
      - **0.5% to 1.8% of total building construction costs**
    - Cx of *energy isolation* systems
      - HVAC/BAS Controls
    - **1.5 % of total mechanical systems costs**
      - Electrical & Lighting Controls
    - **1% to 1.5% of total E-systems costs**
      - Energy Efficiency Measures (EEM) Re-commissioning
      - **$0.25 to $0.45 / square foot of EEM impacted area**

Case Studies

- Findings
  - **D. Return on investment _____ years payback**
    - **New (N) buildings**
      - Cx Costs in range of $1.00 to $3.00 /square foot
      - Twenty-eight (28) significant deficiencies per building
      - Average Simple Payback time in range of 4.8 to 48 months
    - **Existing (E) buildings**
      - Cx Costs in range of $0.18 to $0.30 /square foot
      - Eleven (11) significant deficiencies per building
      - Energy savings in range of 12 % to 18 %
      - Average Simple Payback time in range of 8 to 13 months
    - **Overall**
      - Most successful results with more energy intensive buildings
      - Not commissioned building will cost 8% to 20% more to operate
      - Energy savings rise with more thorough Cx applied

Case Studies

- Findings
  - **E. Key Cx Parameters and Benefits**
    - **Parameter with commissioning**
    - **Energy Savings (Reduced Energy Use)**
    - **Cost Savings (Reduced Cost/SF -Yr)**
    - **Increased Productivity and/or other benefits regarding return on investment (Improve IAQ & Work Environment)**

Case Studies

- **Sample #1 – Lighting Retrofits in range of $0.90 to $1.20 per square foot**
  - **Energy Savings**
    - **20% to 30% reduction**
  - **Cost Savings**
    - **6% to 9% less annual costs**
  - **Increased productivity and/or other benefits regarding return on investments**
    - Energy efficiency measures may increase asset value. More PMs may be needed.

Case Studies

- **SAMPLE #2** – High-efficiency packaged or split system A/C equipment in range of $150 - $180 /ton more than conventional units
  - **ENERGY SAVINGS**
    - **30%** TO **45%** REDUCTION AS PER CONTROLS SEQUENCE
  - **COST SAVINGS**
    - **$0.10 -$0.20** PER SQ-FT, OR **10% - 20%** OF ANNUAL HVAC ENERGY COSTS
  - **INCREASED PRODUCTIVITY AND/OR OTHER BENEFITS REGARDING RETURN ON INVESTMENTS**
    - IMPROVED RUN TIMES, INCREASED RELIABILITY, LESS MAINTENANCE. OPTIMIZATION OF CONTROLS AND SEQUENCE OF OPERATION BETTER MEETS PROJECT SPECIFIC REQUIREMENTS.

Case Studies

- **Sample #3.** Premium efficiency motors by incremental verses whole building replacement in range of $16/HP for 1HP - 10HP; $8/HP over 10HP
  - VFD control motors **will cut energy use by about half.**
  - Cost savings of **30% - 40%** for VFD control motors
  - Energy costs **will be lower due to both less demand (KW) due to soft startup conditions and lower energy consumption (KWH). Motor and shaft reliability improves due to reduced rotational vibration and stress.**

Case Studies

- **SAMPLE #4 –** Retro-Cx (E) whole building in range of $0.25 to $0.45 /square foot (SF) to address mechanical, plumbing, electrical, and EMS controls.
  - **15% to 20% energy use reduction, off-peak rates.**
  - **Annual energy savings $0.27 to $0.35/sq-ft** with **payback in range of 1-year**
  - **Improved** indoor air quality, **optimized** building controls sequence, **restores** original design intent. **Depending** on **existing design** and **condition, level of ROI improvements may be constrained.**

Case Studies

- **SAMPLE #5 –** Cx costs new building in range of $0.50 to $3.00 / SF for Fundamental - Enhanced Cx
  - **5% to 10% improved performance**
  - **Saving in range of $0.05 /SF**
  - **BAS Controls optimization, improved system performance, controllability, IAQ stability. Less call backs during warranty phase.**

Case Studies

- **SAMPLE #6 –** Energy efficient MEP equipment to replace conventional products
  - **3% to 12% less energy consumption**
  - **Annual savings in equipment loads 3 - 12%**
  - **Lower emissions and less KWH energy use**
  - **Lower downtime and reduced maintenance hours**

Case Studies

- **Sample #7–** Solar Photo-Voltaic electricity, Solar Collector - hot water heating systems
  - **10% to 100% depending on system rating**
  - **ZNE or better performance**
  - **Energy depends on location, climate, panels, cost in range of $3.50 /watt; with inverter and installed cost in range of $6 - $9 /watt.**

Commissioning Talking Points

Key questions to ask

#1 Who is best qualified as a Cx Authority (CxA)?

- CxA with CAP and/or CCP certification, CEM, and/or P.E.
- CxA experience in new, existing, and historic buildings
  - Holistic & Envelope Whole building commissioning
  - LEED and CALGreen qualifications a high priority
  - Energy Efficiency Measures (EEMs) process & tools
- CxA experience in benchmarking
  - Ability to apply International Performance Measurement & Verification (IPM&VP)
  - Applies energy performance analysis using sub-metering, and M&V methods
  - Understands Condition Monitoring Based Continuous Commissioning

Commissioning Talking Points

Key questions to ask

- **#2 How does Owner's commissioning differ from contractor's?**
  - Owner = > Quality Assurance (QA)
    - QA process uses selected sampling techniques
    - Owner's QA to verify Contractor's QC process & tools
    - CALGreen & LEED requires 3rd Party CxA
  - Contractor = > Quality Control (QC)
    - Responsible to conduct 100% testing using PFTs & FPTs
    - PFTs and FPT checklists (Manufacturer's recommended installation, startup, testing, and calibration procedures)

Commissioning Talking Points

Key questions to ask

- **#3 What are Benefits to Owner from Commissioning?**
  - Benefits at Opening Day… "Ribbon Cutting" with Less Issues at Closeout
  - On-going Life Cycle Benefits… O&M Cost Savings & Lower Energy use
  - Warranty Call Backs less… (with effective Commissioning)
    - **Please Note:**
    1. Commissioning is a best management practice & the **Right Thing To Do!**
    2. Commissioning should not be about just **"Checking A Box"!**
    3. Commissioning should be for the life cycle of the building, & *not just about* **"Ribbon Cutting".**

Commissioning Talking Points

Key questions to ask

- **#4 When is best time to begin Cx process?**
  - Pre-planning and project concept phase
    - Not so effective if later, during construction…
  - Owner's Project Requirements (OPR),
    - Basis of Design (BOD) and through DD CD Phase
    - Prepare & Implement a Cx Plan, Cx Issues Log,
  - CALGreen & California Energy Commission (CEC)
    - Mandatory Compliance Forms (Title-24 Measures & Metrics)
    - Project Closeout to include Preliminary Cx Report

Commissioning Talking Points

Key questions to ask

- **#5 What are the <u>most important</u> components of commissioning ?**
  - Commissioning (Cx) Team ….
  - Cx in Planning Phase – Prepare Cx Plan
    - Owner's Project Requirements (OPR)
    - Basis of Design (BOD) | CALGreen & California Energy Commission (CEC)
    - Cx Requirements in DD | CD | Cx in Contractor's Scope of Work thru Close Out
  - Cx in Construction Phase – Implement Cx Plan
    - QA/QC Process | PFTs | FPTs | Integrated Performance Testing | O&M Training
    - Cx Issues Log
    - Submittals | Test Procedures | Tester Qualifications | Test Reports | Benchmarking
  - Cx in Operations Phase
    - Condition Monitoring Based Continuous Commissioning

Commissioning Talking Points

- **#6 "So What" is planned for your projects ?**
  - Commissioning Improves Transition from Construction to Operations
    - Vetting of new systems by functional performance testing
    - Review Results, Lessons Learned, achieve Return on Investment
    - Apply Benchmarking, compare as-built performance versus design
  - Condition Monitoring Based (CMB) Commissioning
    - Re-commissioning/Retro-commissioning improves building performance
    - Incorporate benchmarking into O&M planned maintenance program
    - Apply CMB Continuous Commissioning to achieve building "Sweet Spot"

Commissioning Talking Points

- Commissioning & Return on Investment