Training & Certifications for Commissioning

Speakers: Jeff Hammond / *IGSHPA*
Khaled Yousef / *Pyramid Energy Eng., PLLC*

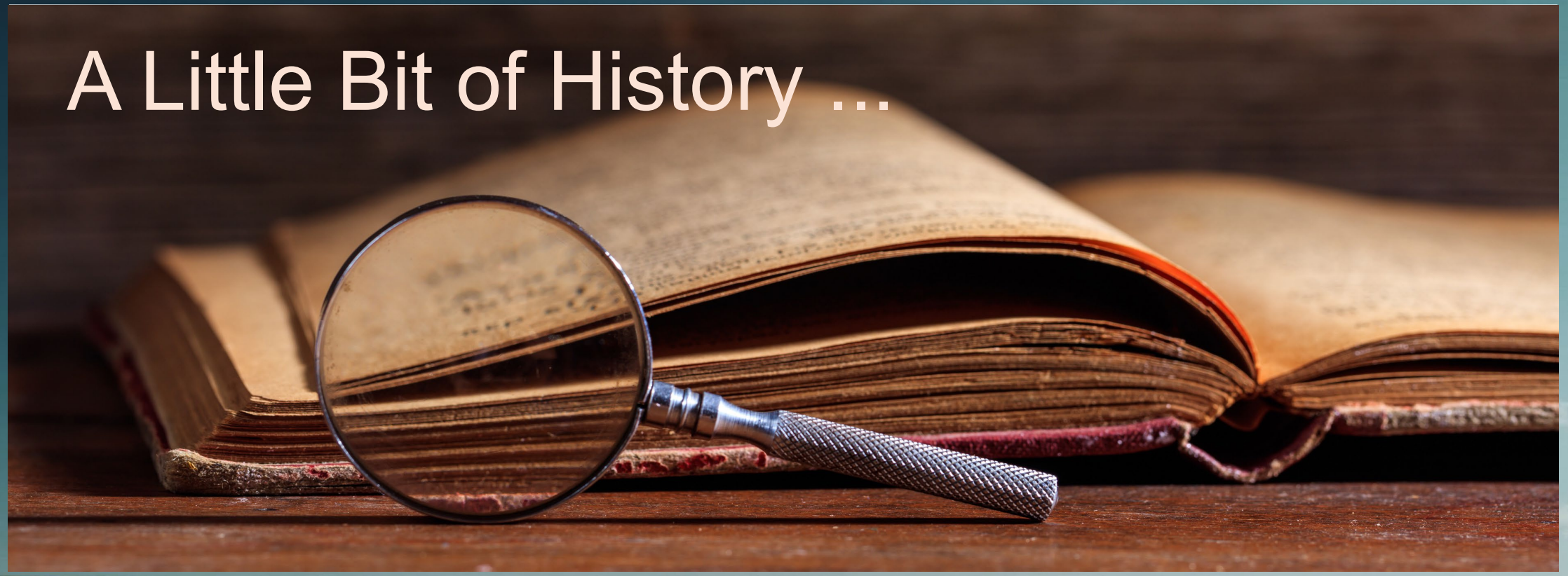
GSHP System Verification & Inspection (GSVI)

Speaker: Jeff Hammond / *IGSHPA*
Executive Director
International Ground Source Heat Pump Association (IGSHPA)

Learning Objectives

- Understand a “little bit of history” about IGSHPA and the new training program
- Review Verification & Inspection Course
- Review Certification Exam Topics
- Q & A

A Little Bit of History ...



Recent Background

- July 2023 to December 2025 training project ...
  - Hired 3 employees to focus on workforce development/training
  - Contracted with CSA Group for new accredited training and certification program (was completed at the end of 2025)
  - Worked on industry “tools” for technology understanding
- Complete curriculum available January 1, 2026
  - Online self-paced courses
  - Instructor-led courses
  - Certification and certificate programs

Why Change?

- Original IGSHPA courses were developed nearly 40 years ago
- Courses were designed for a wide audience
  - e.g., “grouting” and “ductwork” in the same course
  - As the industry grows, we need job-specific training (next slide)
- Courses were typically 3 days
  - Need to be “smaller bites” for better accessibility
  - Need to be less cost for shorter courses
  - Need to be self-paced online options
- Need bi-national certification (Canada & U.S.)
- Need to be based upon C448 Standard

DOE Job Descriptions for GSHP Systems

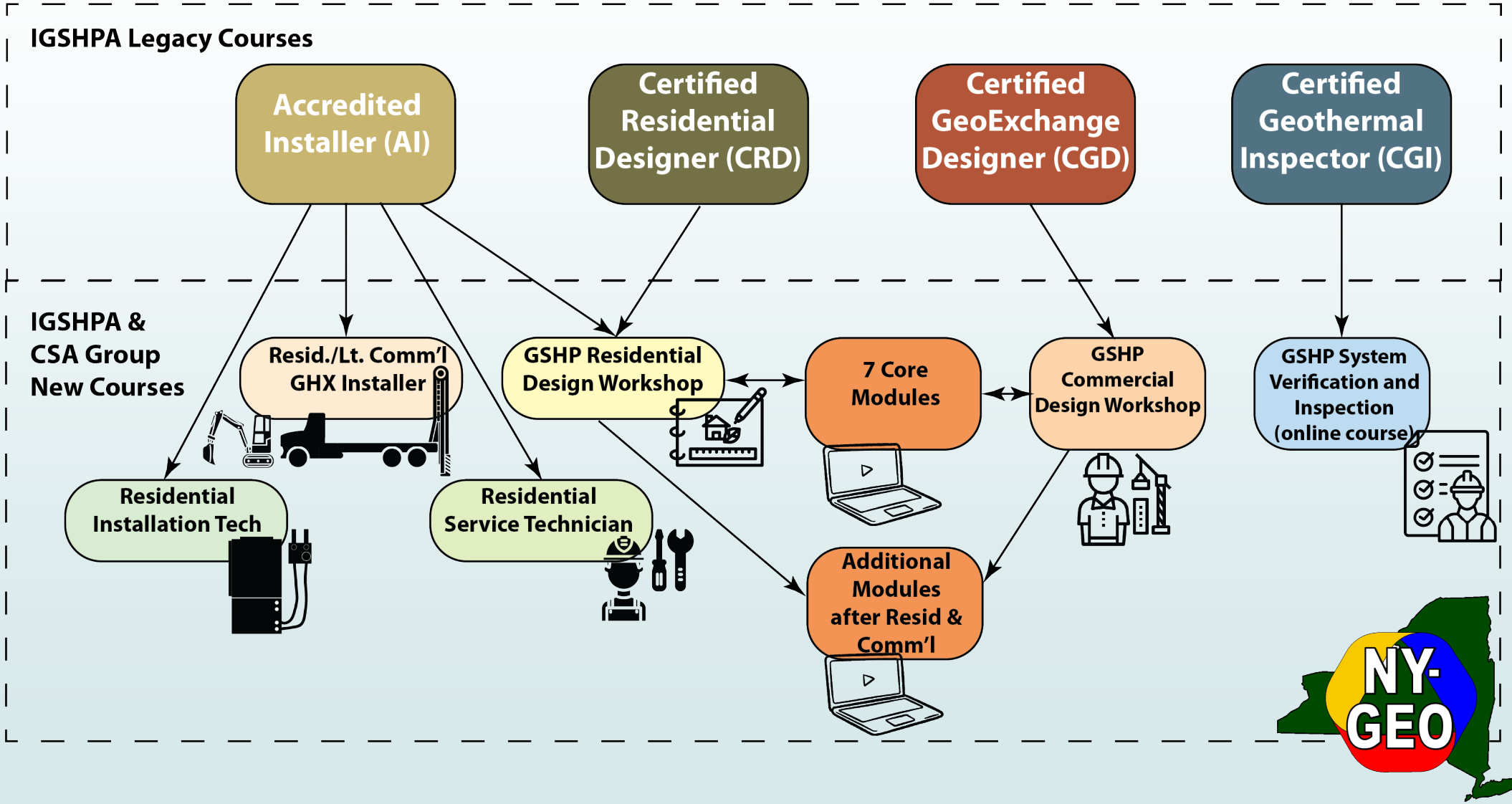
- 5.1 Geothermal Heat Pump System Engineer / Designer
- 5.2 Geological Formation Thermal Properties Tester
- 5.3 Ground Loop Heat Exchanger Grouter
- 5.4 Ground Loop Heat Exchanger Looper
- 5.5 Vertical Loop Driller
- 5.6 Horizontal Directional Driller
- 5.7 Geothermal Heat Pump System Water Well Driller
- 5.8 Geothermal Heat Pump System Water Well Pump Installer
- 5.9 Geothermal Heat Pump System Installer
- 5.10 Geothermal Heat Pump System Operations/Maintenance Technician
- 5.11 Geothermal Heat Pump System Inspector/Regulator
- 5.12 Geothermal Heat Pump System Commissioning Agent
- 5.13 Geothermal Heat Pump System Project Manager
- 5.14 Geothermal Heat Pump System Trainer

Statistics

- 17 new ANSI/CSA accredited courses
  - 14 online self-paced modules
  - 2 instructor-led
  - 1 online course
- 3 new IGSHPA developed courses
- 3 new certification programs
- 3 new certificate programs
- 2 new informational courses
- 2 troubleshooting videos

22 courses / 6 certification & certificate programs completed!

Legacy Course Transition



Review GSVI Course & Certification

GSHP System Verification & Inspection (GSVI)

- One of two types of individuals
  - Inspector working for city/county, experienced with building or piping inspections
  - Project manager, construction manager, or individual familiar with overseeing design and installation on behalf of owner
    - Architect/engineering firm (engineer of record)
    - General contractor
    - Third party consultant

GSHP System Verification & Inspection (GSVI)

- Target Audience
  - Inspectors / Regulators / AHJs
  - Project Managers
  - Construction Professionals, including:
    - Construction Inspectors
    - Construction Managers
    - Commissioning Agents
    - Contractors (General, Mechanical, HVAC)
    - Utilities and Government Employees
    - Professional Engineers (Mechanical, Civil, Geological)

Verification & Inspection Course

- Fully online
- 4 modules
  - 1 to 2.5 hours each
- Interactive interface
- Videos
- Tips
- Quizzes

IGSHPA CSA GROUP

NY-GEO

Interactive Interface

- “Learn more” buttons
- Ability to scroll back to review lesson material

Shipping, storage, and installation of pipe

On-site storage and material cleanliness

CSA/ANSI/IGSHPA C448.0, Clauses 5.5.1 and 5.5.2

Select each "+" to learn more.

- Shipping and on-site storage +
- Keeping material clean +
- Design specifications +

Why proper pipe storage matters

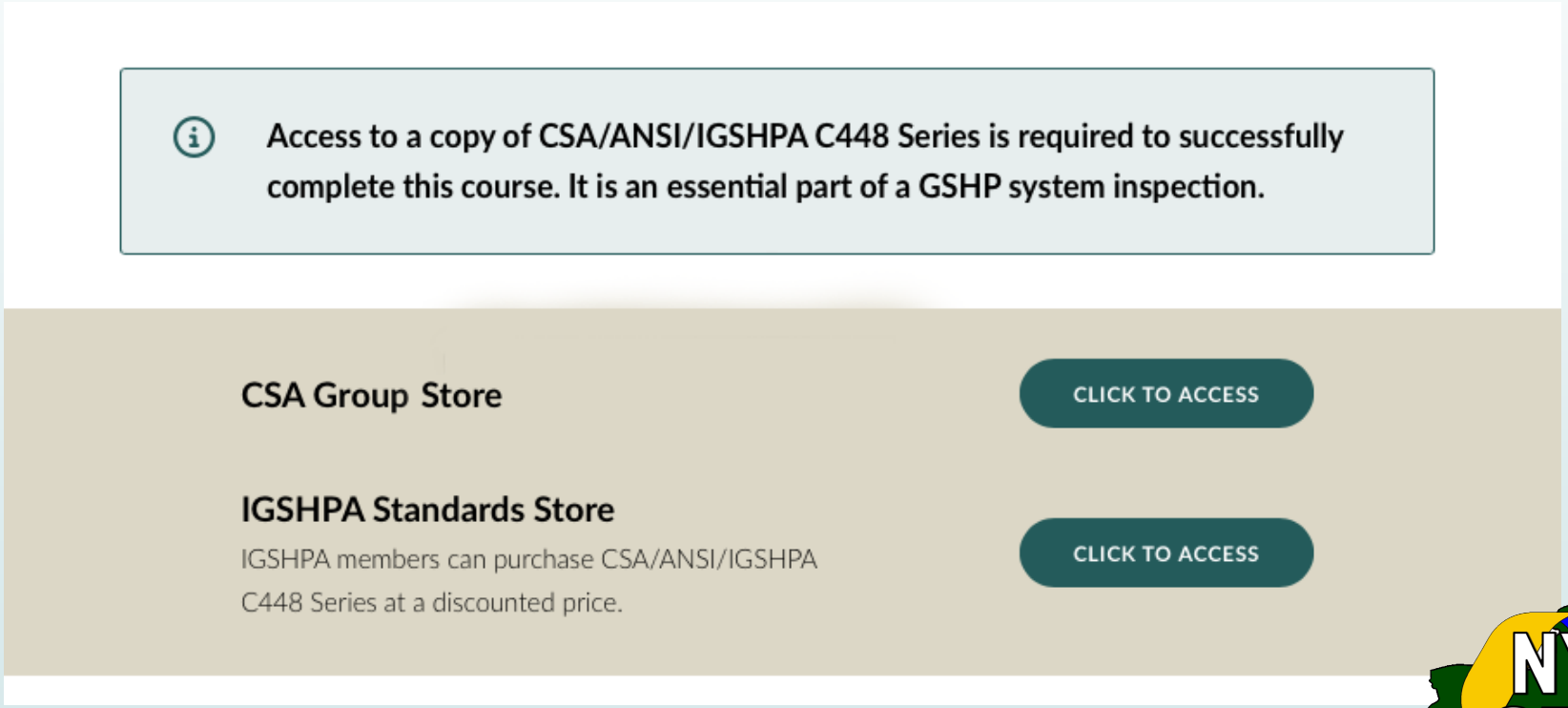
Imagine flushing and purging pipes only to find HDPE shavings, sc
coupons, cell phones, water bottles, or even snack wrappers! These items
have all been found in real situations, causing serious issues and

Videos


GSHP Systems – Installation Fundamentals for Inspection and Verification
QUICKLY INSPECT
MELT THEN FUSE
PIPE & FITTING
0:43 0:48
-0:39
1x

Tips

- Throughout the modules



Quizzes

- Check comprehension of material along the way
- Instant feedback on progress
- Preparation for graded quiz (micro-credential)

- Preparation for certification exam

The following specification is provided on a set of drawings for a small commercial building GHX that is constructed of two circuits of four U-bend assemblies. The U-bend assemblies are 1-1/4-in DR-11 and the field header is 2-in DR-11.

7. GROUND LOOP TESTING
   A. ALL FUSION JOINTS AND LOOP LENGTHS SHALL BE VISUALLY CHECKED TO VERIFY THAT NO LEAKS HAVE OCCURRED DUE TO FUSION JOINING OR SHIPPING DAMAGE.
   B. ALL LOOPS SHALL BE PRESSURE TESTED BEFORE INSTALLATION, AND ALL HORIZONTAL COMPONENTS OF THE GROUND HEAT EXCHANGER SHALL BE PRESSURE TESTED PRIOR TO BACKFILLING.
   C. EACH SUPPLY AND RETURN CIRCUIT SHALL BE FLUSHED AND PURGED IN THE FORWARD AND REVERSE DIRECTIONS WITH WATER AT A MINIMUM VELOCITY OF 2 FT./SEC. (0.6096 M/SEC.) THROUGH EACH PIPING SECTION. FLOW MUST BE MAINTAINED FOR A MINIMUM OF 15 MINUTES IN EACH DIRECTION TO REMOVE ALL DEBRIS AND AIR. TO VERIFY THAT ALL AIR IS REMOVED FROM THE SYSTEM, THE RETURN WATER VALVE TO THE TANK SHALL BE CLOSED. A CHANGE IN THE LEVEL OF FLUID IN THE PURGE PUMP TANK DURING PRESSURIZATION INDICATES AIR STILL TRAPPED IN THE SYSTEM. THE HEAT EXCHANGER SYSTEM PURGING SYSTEM SHALL BE COMPLETED SEPARATELY FROM THE BUILDING SYSTEM. A PUMP CAPABLE OF 50 GPM AT 51 FEET OF HEAD THROUGH ONE CIRCUIT AT A TIME SHALL BE USED TO FLUSH THE SYSTEM (EXCLUDING LOSSES FROM FLUSH/PURGE EQUIPMENT EXTERNAL TO THE PIPING SYSTEM).

What is the required flushing flow rate for a single 1-1/4-in U-bend assembly?

- ○ 5.7 gpm (21.6 L/min)
- ○ 9.0 gpm (34.1 L/min)
- ○ 11.8 gpm (44.7 L/min)
- ○ 18.5 gpm (70.0 L/min)

SUBMIT

GSHP System Verification & Inspection (GSVI)

- Module 1: GSHP Systems - Technology, Terminology, and Standards Required for Inspection -- *Learning Objectives*
  - Define terminology associated with GSHP systems.
  - Identify typical roles involved in a GSHP system construction project, and their key responsibilities.
  - Identify requirements of the CSA/ANSI/IGSHPA C448:25 Series of Standards, *Design and installation of ground source heat pump systems for commercial and residential buildings* applicable to a given scenario.
  - Locate and explain the role of federal, state, provincial, and local codes and standards as they relate to the design and installation of ground heat exchangers (GHXs).
  - Explain federal, state, provincial, and local codes and standards as they relate to the building mechanical system.

GSHP System Verification & Inspection (GSVI)

- Module 2: GSHP Systems - Installation Fundamentals for Inspection and Verification -- *Learning Objectives*
  - Explain the difference between piping materials permitted to construct a ground heat exchanger (GHX) and other piping materials that may be installed on a project site.
  - Identify typical errors made during construction that require correction prior to backfilling or submerging a GHX.
  - Explain the importance of grouting vertically and horizontally drilled boreholes correctly, and the impact of incorrect grouting.
  - Identify proper grouting materials for the ground heat exchanger design and installation.
  - Reference and apply the guidance of CSA/ANSI/IGSHPA C448 related to trenching, backfilling, and compaction to each installation.
  - Locate and comply with local requirements for relevant safety and health authorities and regulatory bodies relative to trenching and drilling.
  - Inspect the installation of pipe location tapes, wires, or devices as required by the ground heat exchanger design.
  - Explain the major steps for integrating outside and interior piping systems at system start-up, including flushing of the interior piping system.
  - Describe the correct steps in the ground heat exchanger pressure testing process and provide guidance when tests do not pass.

GSHP System Verification & Inspection (GSVI)

- Module 3: GSHP Systems - Inspecting Ground, Groundwater, and Surface Water Heat Exchangers -- *Learning Objectives*
  - Identify the type of ground, groundwater, or surface water heat exchanger on a set of construction documents and site observation and determine which sections of the Standard apply.
  - Explain major inspection points, including when they occur in the construction process, relevant to a specific project.
  - Identify installations or materials that are not in compliance with CSA/ANSI/IGSHPA C448 Series.
  - Propose steps to resolve compliance issues for ground, ground water, and surface water heat exchangers.

GSHP System Verification & Inspection (GSVI)

- Module 4: GSHP Systems - Project Delivery and Inspection Skills Application -- *Learning Objectives*
  - Confirm that installations are in conformance with CSA/ANSI/IGSHPA C448 Series:25
  - Explain the importance of current, clear, and concise specifications applicable to each unique project.
  - Examine engineering drawings, reference sections, and project specifications
  - Verify that proper materials and processes are used for the ground heat exchanger (GHX) design and installation.
  - Identify the points of inspection for all pipe, grout, and U-bend assemblies during construction of a GHX.
  - Recognize typical errors made during construction that require correction prior to commissioning a GSHP system.
  - Apply mechanical system construction principles to the installation and commissioning of GSHPs.
  - Review the GSHP start-up sheet or test, adjust, and balance report to confirm that ground loop pump(s), GSHP units and related accessories are operating according to the designer's specification and manufacturer's performance data catalog values.

Construction Documents (discussed in module 4)

- As-built drawings
- Record of system flushing and pressure tests
- In-situ thermal properties test, as applicable
- Operation and maintenance manuals
- Warranty
- Heat transfer fluid specification/SDS as applicable and fluid system design operating pressure specified by the designer
- Commissioning report including TAB report

GSVI Exam*

- Equipment selection
  - Verify that GSHP installed equipment meets specifications
- Ground Heat Exchanger (GHX) installation review
  - Verify piping material(s) and fusion methods for conformance
  - Verify grouting type and material sampling
  - Verify drilling and borehole logs
  - Verify that installation provides component for proper flushing
  - Verify that vertical, horizontal, or surface water closed loop installation complies with CSA/ANSI/IGSHPA C448
  - Verify that groundwater installation complies with CSA/ANSI/IGSHPA C448

(continues)

*Required for certification

GSVI Exam (con'd)

- Above ground and interior piping
  - Verify that type of piping, fittings, required support, valves for proper flushing, and spacing comply with CSA/ANSI/IGSHPA C448
- Flushing, pressure testing, water quality
  - Verify that test report complies with CSA/ANSI/IGSHPA C448
  - Verify that system was commissioned correctly and all valves are in the operational position
  - Verify that heat transfer fluid meetings CSA/ANSI/IGSHPA C448 requirements
  - Verify that flushing apparatus and process comply with CSA/ANSI/IGSHPA C448
  - Verify that system pressures are in range of design specifications and material ratings

(continues)

GSVI Exam (con’d)

- Construction documents / construction support
  - Review ability for follow up with AHJ non-compliance report
  - Verify ability to demonstrate knowledge of required items to be included in inspection and verification report
  - Verify ability to demonstrate delivery documentation, including operation and maintenance manuals per CSA/ANSI/IGSHPA C448

Resources

- Information is online at igshpa.org
  - Click on “Training” menu
    - Course descriptions
    - Training catalog and pricing
    - Links to CSA and IGSHPA pages for registering
- CSA courses are also on the CSA Store at www.csastore.org/store
- Contact IGSHPA at info@igshpa.org or 217-212-2112

Helpful Tip: *Without a copy of the C448 standard, it’s VERY difficult to pass the exams since all new courses are based upon the standard. Take advantage of the IGSHPA member discount on the licensed PDF of C448!*

PDH Questions

1. What design and installation standard is the new GSVI course based upon?
    a. 2017 IGSHPA Design and Installation Standard
    b. AHRI 13256-1 Performance Standard
    c. 2025 CSA/ANSI/IGSHPA C448 Design & Installation Standard
    d. ASTM 8800 GSHP Design Standard

PDH Questions

2. After completing the four online modules for the GSVI course, certification includes ...
    a. Successful completion of the online quizzes (80% or higher) for each of the 4 GSVI modules
    b. Successful completion of a separate online proctored exam once the course has been completed
    c. Submission of field experience and education to the GSVI board for approval as a Certified Inspector
    d. Submission of an application to the AHJ, who provides approval to CSA and IGSHPA for the certification

PDH Questions

3. Who is the target audience for the GSVI course?
    a. Inspectors/regulators/AHJs, project managers, & construction professionals
    b. Commercial designers
    c. Residential designers
    d. Manufacturers' application support personnel, manufacturers' reps, & distributors

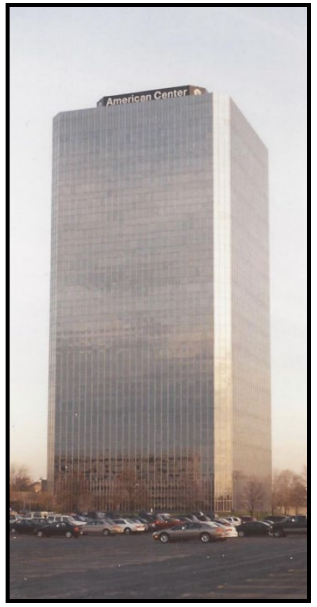
Course Approval **#NY3634**:

This Course has been Evaluated and Approved by The Practicing Institute of Engineering, Inc (PIE) for compliance with the NYS Mandatory Continuing Education requirements for Professional Engineers. Approved for: **1.0 PDH** (Professional Development Hours).

Introduction to Trainings and Certifications for Commissioning & Retro Commissioning

NY-GEO 2026 Conference - March 24-25, 2026

New York Marriott at the Brooklyn Bridge - Brooklyn, NY



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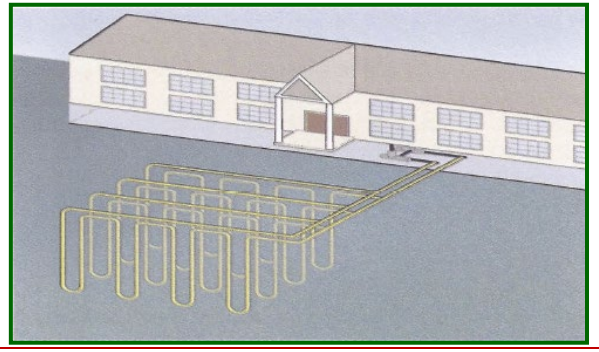

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Disclaimers

- All illustrations, diagrams, examples and explanations shown in this training are conceptual and are not intended as fully detailed installation drawings or project specifications.
- They are included for educational and illustrative purposes only and can be subject to changes or updates without notice.
- No warranty is made as to the suitability of any drawings and/or data for a particular application - each application must be handled separately and based on its own site specific conditions.
- The success of implementing the Commissioning procedures, achieving projected/desired energy and costs savings, and desired project performance, etc. all depend on the quality and completeness of the engineering design, construction, TAB Procedures (Testing, Adjusting and Balancing), proper application of the system commissioning during all project stages, system controls/integration, proper PM, weather, many behavioral/operational factors, and many other factors outside the control of Pyramid EES.
- As such, Pyramid EES does not guarantee project performance and shall in no event be liable should the actual performance (and energy and cost savings) vary from the desired project performance.

Course/Workshop Intended Diverse Audience

- This course primarily caters to Design Engineers, Technicians, Facilities Managers, Construction Contractors, Consultants, Construction Managers, Project Managers, Architects, Specialty MEP Equipment Vendors;
- In addition to other professionals like Scientists, R&D researchers supporting testing and demonstration projects, and energy and climate policy makers.
- All interested in seriously enhancing their knowledge and exposure to a broad spectrum of commissioning procedures supporting a wide range of residential, commercial, industrial, and institutional facilities and master energy and environmental plans in need of a wide range of commissioning types to achieve desired goals.

Training and Certifications for Commissioning/Retro Commissioning
Course Description

This **Joint** session will outline the newly developed certification course by **IGSHPA** for the **GSHP** System Verification & Inspection (**GSVI**). This certification course is for professionals interested in the skills necessary to evaluate, interpret, and verify compliance with the ANSI/CSA/IGSHPA C448:25 Series standard.

Additionally, training and certification courses in **commissioning** and **retro-commissioning** of any type of building, encompassing any combination of energy systems will also be identified and resources to access such training will be included.

Topics Covered / Learning Objectives - (1 of 4)

- The most known and Key organizations issuing Commissioning (Cx) Certifications
- Included in such certifications: Varying Building, Systems & Equipment Types.
- Courses elaborate and emphasizes the importance of Cx.
- Courses Illustrate the devastating impacts of lack of Cx by sharing details of numerous ***lessons learned*** from varying HVAC/MEP system commercial installations and some may pertaining to several GTHP (as a technology specific example) as well as other technologies.

Topics Covered / Learning Objectives - (2 of 4)

Detailed Cx Course and Certifications Introduce Important & Key Cx Components and Stages:

- [1] **PFCs** (Prefunctional Checklists).
- [2] **FPTs** (Functional Performance Tests).
- [3] Relevant **Cx Procedure Details**.
- [4] Numerous **Lessons Learned Details** (caused by lack of Cx in several example projects) - www.HeatSpring.com/Cx
- Note - [5] **Site Visits** of commissioned systems when available near some course venues.

www.HeatSpring.com/Cx

Topics Covered / Learning Objectives - (3 of 4)

- Presents how following the core 4-Phase **Total Cx process** would have prevented numerous problems identified during system troubleshooting:
  - [1] Cx During **Pre-Design** Phase.
  - [2] Cx During **Design** Phase.
  - [3] Cx During **Construction**.
  - [4] Cx During **Occupancy & Operations**.
- All presentations coupled by valuable and in-depth Cx **PFC** & **FPT** **technology specific examples** and shares other relevant Cx procedures and details.

Topics Covered / Learning Objectives - (4 of 4)

- **Detailed Cx Certification Courses** cover varying types of Commissioning include, but are not limited to:

1. Total Building Cx Process (TBCxP) [Inclusive of all 4 Phases].
2. Continuous Cx Process.
3. Ongoing Cx Process (OCx).
4. Re-Cx.
5. **Retro-Cx**.
6. Cx Light (or Custom Cx).

PDH Questions / Answers - (Q/A 1)

Q1 - What are most knows organizations issuing Cx Certifications?

A1 - ASHRAE, AABC/ACG, AEE, BCA/BCxA/BCCB, Univ. of Wisconsin-Madison, NEBB.

- **[1] ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers**
  - BCxP - Building Commissioning Professional Certification
  - CPMP - Commissioning Process Management Professional
- **[2] AABC = Associated Air Balance Council**
- **ACG = AABC Commissioning Group**
  - CxA - Certified Commissioning Authority (Certification issues by ACG)
  - CxTs - Certified Commissioning Technicians (Certification issues by AABC or ACG)
  - EMP - Energy Management Professional (Certification issues by ACG)
- **[3] AEE = Association of Energy Engineers**
  - CBCP - Certified Building Commissioning Professional
- **[4] BCxA = Building Commissioning Association**
- **BCCB = Building Commissioning Certification Board**
  - CCP - Certified Commissioning Professional
  - ACP - Associate Commissioning Professional
  - BEMP - Building Energy Modeling Professional Certification (Certification issues by ASHRAE & is a prerequisite for the CCP certification)

PDH Questions / Answers - (Q/A 1 Cont.)

Q1 - What are most knows organizations issuing Cx Certifications?

A1 - ASHRAE, AABC/ACG, AEE, BCxA/BCCB, Univ. of Wisconsin-Madison, NEBB.

- **[5] University of Wisconsin-Madison.**

  Descriptions of Certifications for Educational Achievement:

  - QCxP - Qualified Commissioning Process Provider.
  - BECxP - Building Enclosure Commissioning Process Provider.
  - CxA+BE - Commissioning Authority + Building Enclosure.

  Descriptions of Certifications for Educational Achievement Plus Project Experience:

  - CxAP - Commissioning Process Authority Professional
  - CxM - Commissioning Process Manager
  - CxTS - Commissioning Process Technical Service Provider
  - GCxP - Green Commissioning Process Provider

- **[6] NEBB - National Environnemental Balance Bureau.**
  - BSC CP - Building System Commissioning Certified Professional
  - BSC CxCT - Building System Commissioning Certified Technician
  - CxPP - Commissioning Process Professional Certified Professional
  - RCx-EB CP - Retro-Commissioning of Existing Buildings Certified Professional.

PDH Questions / Answers - (Q/A 1 Cont.)

Q1 - What are most knows organizations issuing Cx Certifications?

A1 - ASHRAE, AABC/ACG, AEE, BCxA/BCCB, Univ. of Wisconsin-Madison, NEBB.

- **[7] NIBS - National Institute of Building Sciences (Defines the Total Building Cx Process).**
  - NCBC - National Conference on Building Commissioning.

- **[8] SMACNA - Sheet Metal & Air Conditioning Contractors' National Association.**
  - SMACNA HVAC System Commissioning Manual.

The Comprehensive Total Building Commissioning Process (TBCxP) takes place in Four (4) Phases of the project.

Per the ASHRAE **Cx Guidelines**, **Total** Commissioning can take place in **4 Phases**:

1. Cx During Pre-Design Phase.
2. Cx During Design Phase.
3. **Cx During Construction**.
4. Cx During Occupancy & Operations.

ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process) defines the **Cx Process** as "*A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements*".

Types of Buildings in need of Commissioning:

1. Cx of ***Existing*** Buildings.
2. Cx of ***New*** Buildings.
3. Cx of *Existing* Buildings that are undergoing ***Substantial Renovations***.

Make a differentiation between the 3 building types and determine additional sensors to incorporate during the design and construction phases to support the Total Building Cx Process (TBCxP) for new and substantially renovated buildings and to facilitate Ongoing Cx moving forward in both bldg types using those new built-in sensors for both monitoring based Cx (MBCx) (& M&V if needed).

Per the ASHRAE **Cx Guidelines**, the "**Other**" varying types of Commissioning include, but are not limited to:

1. **Total Building Cx Process (TBCxP) [Inclusive of all 4 Phases]**.
2. Continuous Cx Process.
3. Ongoing Cx Process (OCx).
4. Re-Cx.
5. **Retro-Cx**.
6. Cx Light (or Custom Cx).

The Core of the Construction Phase Cx Process:

Prefunctional Checklists (PFCs) & Functional Performance Testing (FPTs)

[1] Prefunctional Checklists (PFCs)

Prefunctional Checklists (PFCs) - (1 of 4)

- Document that equipment and systems are properly installed and operational so that functional performance testing may proceed without unnecessary delays.
- Each piece of equipment receives full prefunctional checkout by the installing contractor.
- **No sampling strategies are allowed**.
- Pre-Functional Performance Testing ***must be successfully completed prior*** to formal functional performance testing of equipment or subsystems.

Very Important Point

Prefunctional Checklists (PFCs) - (2 of 4)

- Prefunctional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., proper fan belt tension, valve installed in proper direction, proper oil level provided, labels affixed, gauges in place, sensors calibrated, etc.).

- However, some PFC items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a 3-phase pump motor, verifying that a fan rotates in the proper direction, etc.).

- ***The word prefunctional refers to "before" functional testing***.

Very Important Point

Prefunctional Checklists (PFCs) - (3 of 4)

- Prefunctional checklists augment and are combined with the manufacturer's start-up checklist and plan.
- Contractors typically already perform some, if not many, of the prefunctional checklist items the commissioning authority will prescribe.
- However, unfortunately, not all contractors document in writing the execution of these checklist items.
- Put all Prefunctional checklists developed for the project in **Appendix C** of the Cx Plan.

Prefunctional Checklists (PFCs) - (4 of 4)

- Procedures must be documented in writing by the installing technician using the standard checklists developed and/or co-developed by the CxA as well as the manufacturer's start-up checklist and/or a satisfactory/comprehensive combination of both following whatever is more stringent and best for the project.

- The CxA does not witness much of the prefunctional checklist execution, except for testing of larger or more critical pieces of equip and some spot-checking of minor equipment.

[2] Functional Performance Testing (**FPTs**)

Functional Performance Testing (FPTs) - (1 of 3)

- Functional performance testing (FPT) is the *dynamic* testing of systems (rather than just components) under full operation.
- Ex. - The variable speed district loop glycol pumps are tested interactively with the individual building's heat exchangers, and with the modulating terminal control valves. That is to verify that pump speed ramps up and down to maintain the differential pressure at target setpoint, and/or maintain desired flow rates following other system control requirements/targets.
- More complex dynamic testing for example will also involve the heat pump sequencing and integration with the operation of the other MEP systems at the individual buildings/MERs, and the ground loop, or loop(s).

Functional Performance Testing (FPTs) - (2 of 3)

- Generally, systems are tested under various modes, such as during low and intermediate heating (or cooling) loads, shoulder seasons, high loads, component failures, unoccupied (or setback) mode, varying outside air temperatures, power failure, etc.
- The systems are run through all of the control system's sequences of operation and components are verified to be responding as the sequences state.

Functional Performance Testing (FPTs) - (3 of 3)

- The commissioning authority develops (and/or co-develops) the functional test procedures in a sequential written form, and then coordinates, oversees and documents selected actual testing;
- All testing is performed by the installing contractor or vendor under the guidance (and/or the direction) of the CxA.
- Put the project specific functional test forms available to date in **Appendix D**, while make a note that some others may still be forthcoming if not ready yet.

Suggested
Issues & Resolution Log
(or Deficiencies Log)
Detailed Layout/Table & Minimum Content Requirements

Issues & Resolution Log (Deficiencies Log) - (1 of 3)

Issues and Resolution Log

Pyramid EES
Energy Engineering Services, PLLC

Facility or Project Name: [Updated as of MM/DD/YEAR]
Building or Location:
Commissioning Authority (CA or CxA): Pyramid Energy Engineering Services, PLLC (Pyramid EES)

Issue or Item #	System or Equipment & Location	Equipment Type[1]	Project Phase[2]	Date Identified	Initiated by	Issue Description or Deficiency	Issue Class[3]	Responsible Contractors	Recommended Actions	Status (Open or Closed)	Date Resolved[4]	Response by (Name)	Explanation of Correction and Other Notes or Comments	Note #

Notes:

1. **Equipment Type**: Mech, Elec, Ltg, Plumbing, MEP, BOP, Piping, TES Tank, Pellet Storage and Conveyance, BMS, M&V, Boiler Venting/Chimney (Flue Products), Boiler Room Ventilation, General, Building Envelope (Container or MER), Enclosure, Structural, Site, Safety, etc.
2. **Project Phase**: Construction, TAB (0 - 99) then Cx Phases: PFC = prefunctional (100 - 199), S = spot-check of prefunctional testing, FPT = functional testing (200 - 299), TD = trend data (300 - 399), M&V (400 - 499), etc.
3. **Issue Classes**: Energy, IEQ, Operations and Maintenance (O&M), Measurement and Verification = M&V, TAB, Safety, Procedural, Proper Storage of Materials & Equip, Scheduling and Construction Management (CM), PM, QA/QC, Change Orders, Access, Aesthetics, etc.
4. **Date Resolved**: Indicate the date that the issue was resolved or its correction was verified.

Disclaimer - CA (or CxA) assumes no responsibility for how the material in these Cx Issues and Resolution Logs may be utilized by users. The users assume full responsibility for any and all liability that may arise from any reference to, or use of, this material. This log is not intended to capture all issues during construction and Cx as it captures only what CxA and Owner had observed during site visits/inspections. It is the contractors, CM, GC and Design Engineer's full responsibility to ensure that any other unobserved issues are addressed and the project is built and controlled in compliance with the construction documents and following all best practices.

- END OF LOG -

Use the space below if additional space is needed for NOTES and reference the systems and page numbers from previous in this Issues and Resolution Logs:

Issues & Resolution Log (Deficiencies Log) - (2 of 3)

1. Issue or Item #
2. System or Equipment & Location
3. Equipment Type[1]
4. Project Phase[2]
5. Date Identified
6. Initiated by
7. Issue Description or Deficiency
8. Issue Class[3]
9. Responsible Contractors
10. Recommended Actions
11. Status(Open or Closed)
12. Date Resolved[4]
13. Response by (Name)
14. Explanation of Correction and Other Notes or Comments
15. Note#

1. **Equipment Type**: Mech, Elec, Ltg, Plumbing, MEP, BOP, Piping, TES Tank, Pellet Storage and Conveyance, BMS, M&V, Boiler Venting/Chimney (Flue Products), Boiler Room Ventilation, General, Building Envelope/Enclosure, Structural, Site, Safety, etc.

2. **Project Phase**: Construction & TAB (0 - 99); then Cx Phases: PFC = prefunctional (100 - 199), S = Spot-Check of prefunctional testing, FPT = functional testing (200 - 299), TD = Trend Data (300 - 399), M&V (400 - 499), etc.

3. **Issue Classes**: Energy, IEQ, O&M, M&V, TAB, Safety, Procedural, Proper Storage of Materials & Equip, Scheduling CM, PM, QA/QC, Change Orders, Access, Aesthetics, etc.

4. **Date Resolved**: Indicate the date issue was resolved or its correction was verified.

Issues & Resolution Log (Deficiencies Log) - (3 of 3)

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- -- END OF LOG –
- Use the space below if additional space is needed for NOTES and reference the systems and page numbers from previous in these Issues and Resolution Logs:

Commissioning Schedule & Typical/General Scheduling Issues & Warnings

Cx Scheduling & Issues & Warnings

The following **sequential** priorities shall be followed:

1. Equipment is not "temporarily" started (for heating or cooling) until pre-start checklist items and all manufacturers' pre-start procedures are completed and moisture, dust and other environmental and building integrity issues have been addressed.

2. **Functional testing is not begun until prefunctional checklists, start-up and TAB are completed** for a given system (this does not preclude a phased approach).

3. The controls system and equipment it controls are not functionally tested until all points have been calibrated and pre-functional testing completed.

4. TAB is not performed until the control system has been sufficiently functionally tested by the CC and approved by the GC (or CM), A/E and CxA for TAB work.

Very Important Slide

Overview of the Construction Phase Commissioning Process

Overview of Commissioning Process - (1 of 4)

1. Cx during construction ***begins*** with a "commissioning scoping meeting", conducted by the CxA preferably within 60 to 90 days of the beginning of construction, where the Cx process is reviewed with Cx team members.
2. Additional meetings will be required throughout construction to plan, coordinate, schedule future activities, and resolve problems. The additional meetings will be scheduled as needed by the GC (or CM).
3. Equipment documentation shall be submitted to the CxA during normal submittals, including detailed start-up procedures.
4. The CxA develops (and/or oversees the development of) prefunctional checklists (PFC) and submits blank forms to the GC (or CM) for assignment and distribution to the subcontractors. Subcontractors shall *properly and thoroughly* complete **FPCs** during the start-up process.

Overview of Commissioning Process - (2 of 4)

5. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels. Prefunctional checklists must be completed and returned to the CxA ***before*** functional testing begins.

6. Contractors, under their own direction and/or preferably via schedule coordination with the GC (or CM), execute and document the prefunctional checklists (PFC) and perform start-up and initial checkout. The GC or CM (and at times the CxA for selected equipment) document the completion of the PFCs and startup procedures according to the approved plans and using the PFC forms provided by the CxA and whatever other sources of documentation and forms they desire to use for best documentation. This may require the presence of the CxA as a witness upon start-up of selected equipment.

Overview of Commissioning Process - (3 of 4)

7. CxA develops (and/or oversees the development of) specific equipment and system functional performance test (**FPT**) procedures and forms.
8. FPTs are executed by the contractors and the appropriate forms are properly completed under the guidance (and/or the direction) of the CxA. The Contractors (and/or CM/GC) properly and thoroughly document the functional performance test results using the appropriate forms provided by the CxA for the CxA's review. Any deficiencies are recorded by the CxA (and/or the Contractors or CM) on the **Commissioning Issues Log**.
9. Items of non-compliance in material, installation, or setup are corrected at the contractor's expense, and the deficient system will be *retested*.
10. CxA (and CM) review O&M documentation for completeness.

Overview of Commissioning Process - (4 of 4)

11. Contractors submit to the CxA through the GC (or CM) *training plans*, and the CxA reviews and pre-approves training plans before training by the contractors can proceed. The GC (or CM) coordinates any training provided by the contractors. The CxA verifies that training was completed as required.

12. Seasonal or other deferred testing is conducted, as specified or required.

13. CxA prepares a final report to document the results of the commissioning process.

14. CxA returns to the site approximately 8 to 10 months into the 12-month warranty period to review current building and system operation with facility staff and address the any conditions or outstanding issues related to the owner's project requirements.

15. CxA develops a re-commissioning management manual for the owner, as needed.

Key Cx Phase Process Flow Charts

Very Important Flow Charts

Figure 5-1: Typical Construction Phase Commissioning Activity Flow Chart

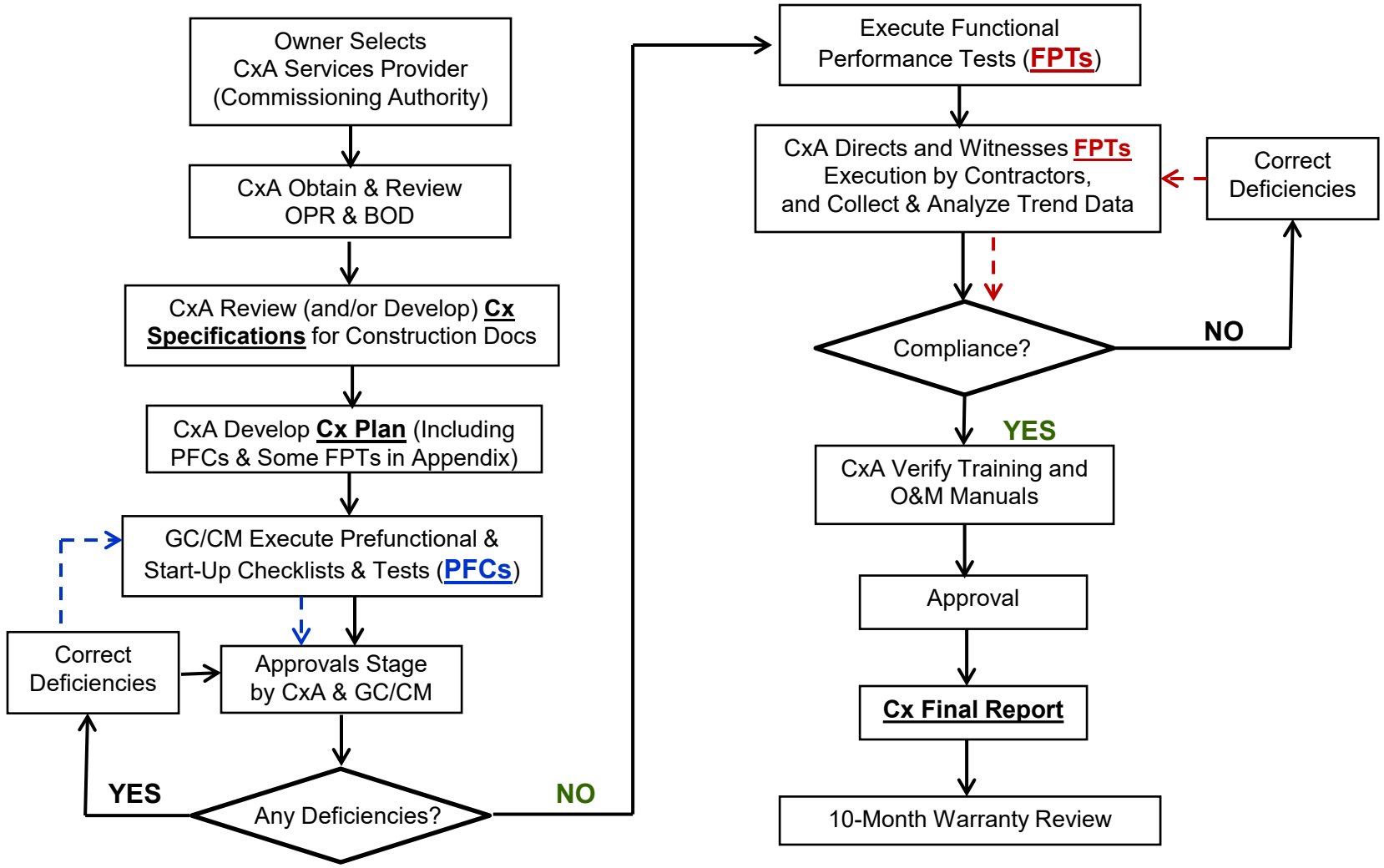


Figure 5-2: Start-up, Prefunctional Checklists (PFCs) & Initial Checkout Forms Development

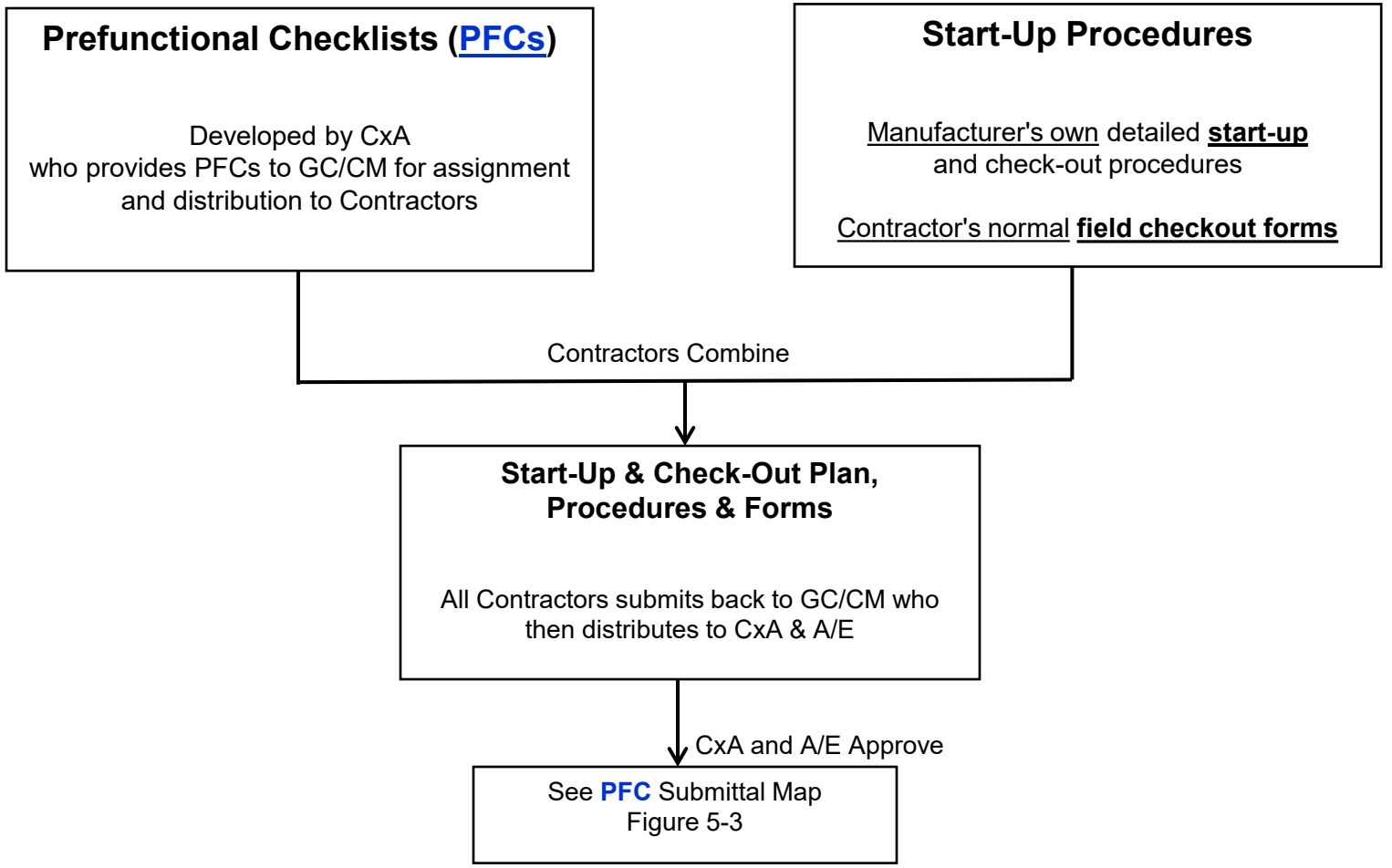


Figure 5-3: Prefunctional Checklist (PFC) & Start-up Report Submittal Map

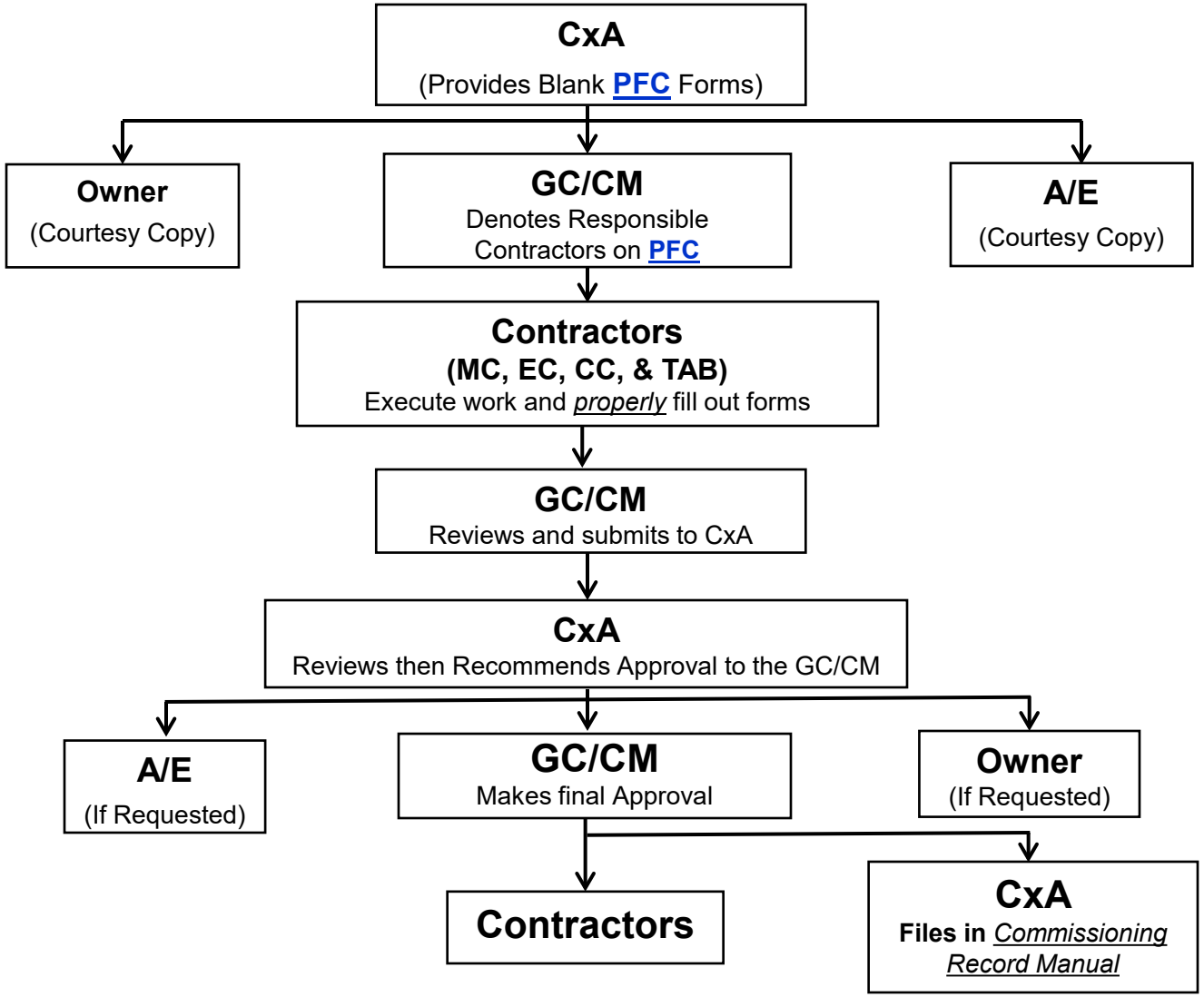


Figure 5-4: Functional Performance Test (FPTs) Forms Development

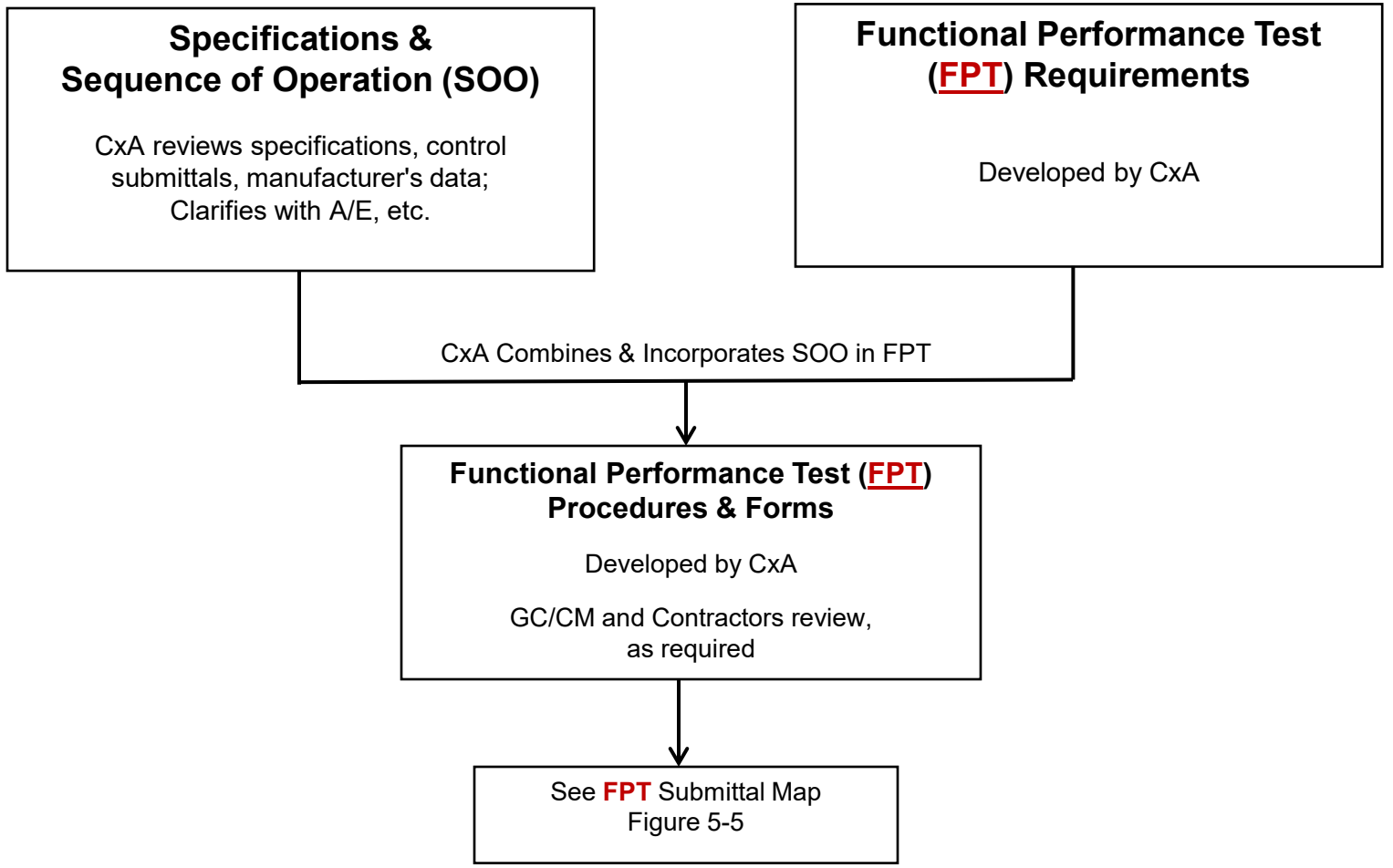


Figure 5-5: Functional Performance Test (FPT) Submittal Map

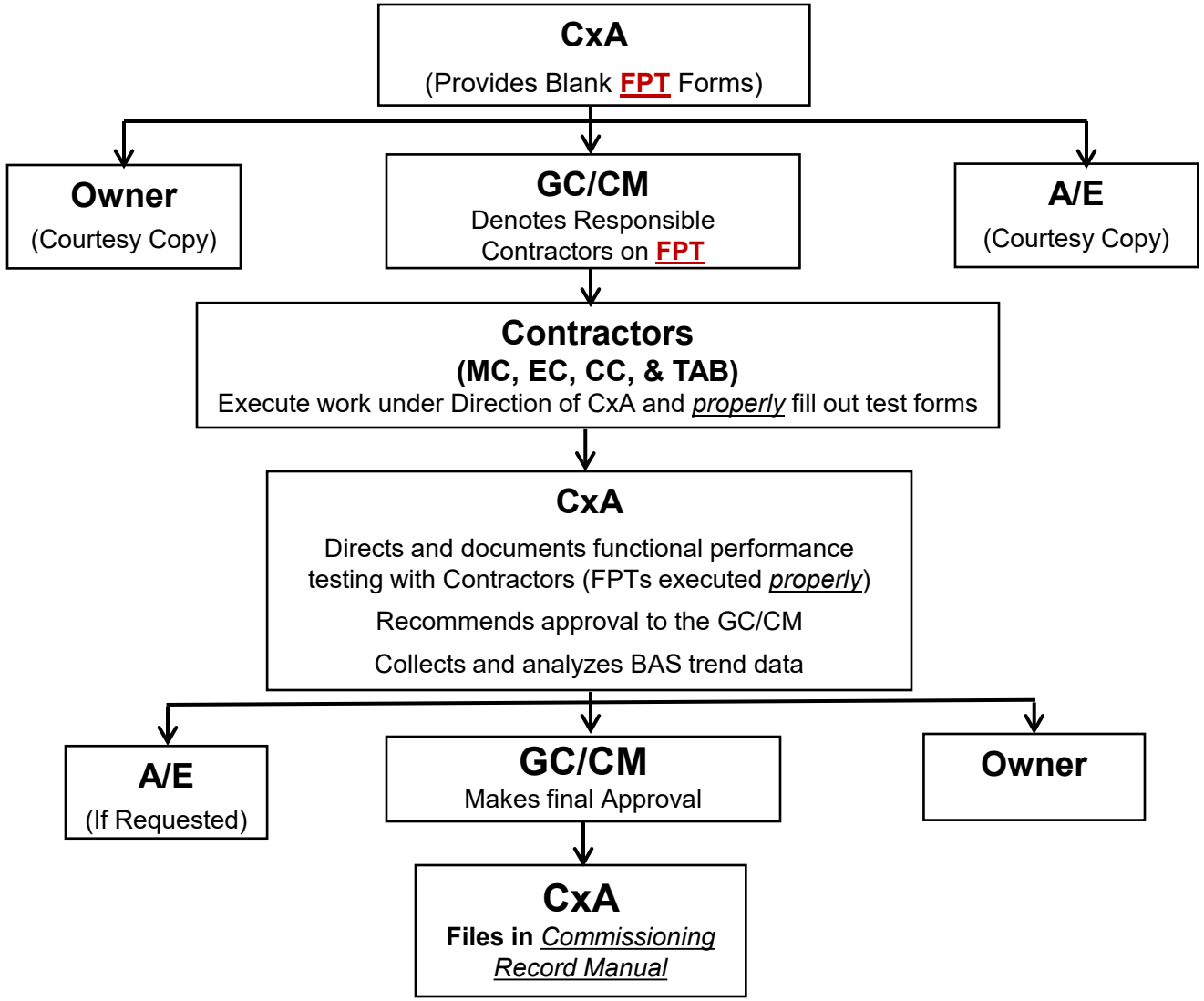


Figure 5-6: Prefunctional Checklist (PFC) & Functional Performance Testing (FPT) Approval Process

This chart begins with the Prefunctional Checklist or the Functional Performance Test that was already completed.

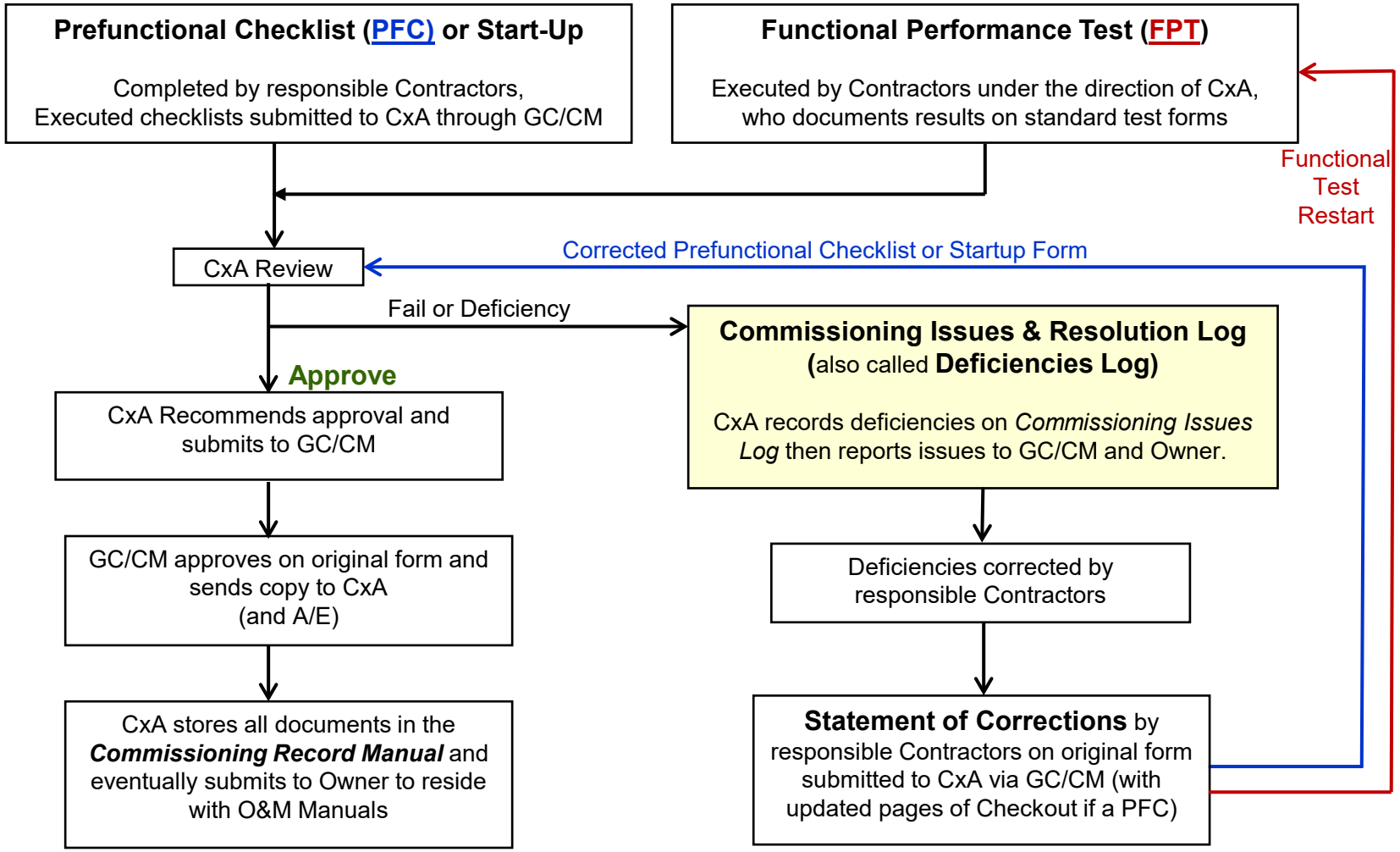
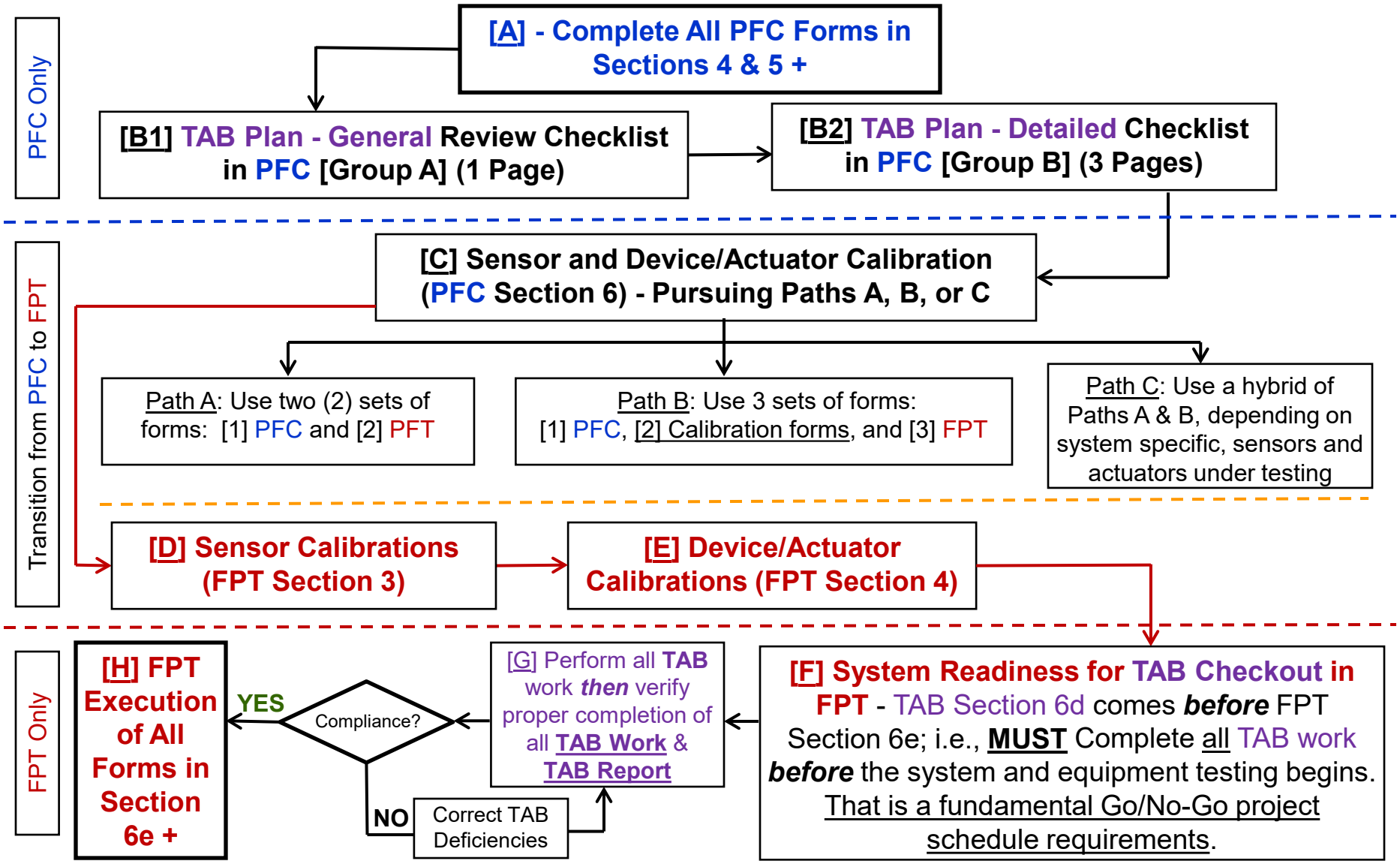


Figure 5-7: TAB & Sensor & Device/Actuator Calibration Key Reminders/Sequences



Suggested Commissioning Plan Detailed Outline

Cx **Plan** Detailed Outline - (1 of 9)

- Glossary of Terms and Abbreviations
- Objectivity and Related Affiliations
- Notice
- Acknowledgments
- Table of Content

- **Section 1.0 - Project Overview**:
- 1.1 Background & Project History.
- Recap on OPR (& BOD).

Cx **Plan** Detailed Outline - (2 of 9)

- 1.2 - Description of Building Energy Systems & Features:
  - All Buildings (Age, Envelope, Lighting, HVAC Systems, Schedules, etc.).
  - The Boiler Room.
- 1.3 - Key Abbreviations and key Definitions:
  - Commissioning (or the Commissioning Process)
  - Cx Plan
  - Cx Authority (or Cx Agent)
  - Testing, Adjusting, and Balancing (TAB)
  - [See Definitions presented earlier in the slides]
- 1.4 - Purpose of the Commissioning Plan.
- 1.5 - Cx Scope (& 1.6 - List of Commissioned Systems).
- 1.7 - Spec Sections (Referenced for supporting Cx).
- 1.8 - Spec Relevant Notes.

Cx **Plan** Detailed Outline - (3 of 9)

- **Section 2 - General Building Information**
  - Includes but not limited to Bldg & Proj Description, Location, Building Type, Floor Area, Number of Stories, Owner, Construction Period, Construction Schedule [See Appendix B-1], and Cx Schedule [See Appendix B-2].
- **Section 3 - Commissioning Team Members**
  - Table 3-1 includes all Commissioning Team Members complete contact Info, Agency Name, Member Name, Title, Address, email, Phones (landline and mobile), and web page).
- **Section 4 - Roles and Responsibilities**
  - 4.1 - Cx Team Members
  - 4.2 - General CxA Management Plan
  - 4.3 - General Description of Team Member Roles

Cx **Plan** Detailed Outline - (4 of 9)

- **Section 5 - Commissioning Process**
  - 5.1 Overview….
  - 5.2 Commissioning Scoping Meeting
  - 5.3 Final Commissioning Plan - Construction Phase
  - 5.4 Site Observation (& Site visits schedule)
  - 5.5 Misc. Meetings (to be scheduled as needed)
  - 5.6 Misc. Management Protocols & flow of Docs.)
  - 5.7 Progress Reporting (& Cx Issues & resolution log)
  - 5.8 Initial Submittals and Documentation
    - 5.8.1 Standard Submittals
    - 5.8.2 Special Submittals, Notifications and Clarifications

Cx **Plan** Detailed Outline - (5 of 9)

- **Section 5 - Commissioning Process (Cont.)**
- **5.9 Prefunctional Checklist (PFC), Tests & Start-Up**:
  - 5.9.1 Overview
  - 5.9.2 Start-up Plan
  - 5.9.3 Execution of Checklists and Start-up
  - 5.9.4 Deficiencies and Non-Conformance
  - 5.9.5 Testing and Balancing
  - 5.9.6 Controls Checkout Plan
- **5.10 Functional Performance Test (FPT) Development and Verification Procedures:**
  - 5.10.1 Overview
  - 5.10.2 Scope of Testing
  - 5.10.3 Development Process
  - 5.10.4 Testing Plan Overview and Schedule

Cx **Plan** Detailed Outline - (6 of 9)

- **Section 5 - Commissioning Process (Cont.)**
- **5.11 Execution of Functional Testing Procedures**
  - 5.11.1 Coordination and Scheduling
  - 5.11.2 Deficiencies and Retesting
  - 5.11.3 Facility Staff Participation
  - 5.11.4 Sampling
  - 5.12 O&M Manuals and Warranties
    - 5.12.1 Standard O&M Manuals
    - 5.12.2 Commissioning Record
    - 5.12.2a O&M Manuals General Format
  - 5.13 Training and Orientation of Owner Personnel
  - 5.14 Warranty Period

Cx **Plan** Detailed Outline - (7 of 9)

- **Section 6 - Written Work Products**
  - 6.1 Overview of Work Products [Described later in PP Slides]
  - 6.2 Commissioning **Final Report** [Suggested Detailed Outline shown later]

- **Section 7 - Commissioning Schedule**
  - 7.1 General Scheduling Issues
  - 7.2 Commissioning Schedule [See Appendix B]

Cx **Plan** Detailed Outline - (8 of 9)

- **Section 8.0 - Appendices**
  - Appendix A - Owner's Project Requirements (OPR) Docs
  - Appendix B - Construction Schedule
  - Appendix C - **Prefunctional Checklists (PFC)** (Can be Editable & Executable).
  - Appendix D - **Functional Performance Testing (FPT)** Requirements and Test Forms (Can be Editable and Executable)
  - Appendix E - Selected Spec Sections calling for Cx, TAB, and Varying Test Requirements (based on the Contract Documents)

Cx **Plan** Detailed Outline - (9 of 9)

- **Section 8.0 - Appendices (Cont.)**
  - Appendix F - Selected Construction Phase Application/Implementation forms in support of both the Prefunctional and the Functional Performance Testing.
  - Appendix G - Other Appendices TBD as needed.
- **End**
  - Keep space for Review Notes and Other Comments by Cx Plan Users.

Suggested Commissioning Report Outline

Commissioning **Report Outline** - (1 of 5)

Cx report to be prepared by CxA and shall include, but is not limited to:

- **Executive Summary**, project overview, & relevant project background, concise list of Exec level findings, conclusions & recommendations. All to fit within a few pages.
- Generally, the use of photographs and other graphic illustrations is encouraged.
- List of project participants and their roles and responsibilities.
- Building and energy system descriptions.
- Overview of commissioning and testing scope.
- A general description of the testing and verification methods used.

The above is to be followed by a detailed description of the testing and verification methods used coupled with necessary illustrations.

Commissioning **Report Outline** - (2 of 5)

For each piece of commissioned equipment, the report shall contain the disposition of the commissioning authority regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:

- Equipment meeting spec.
- Equipment installation.
- Functional performance and efficiency.
- Equipment documentation and design intent.
- Operator training.

Commissioning **Report Detailed Findings** - (3 of 5)

- Present results of the Cx project in more detail; keeping in mind that the main focus of Cx effort was ensuring systems & equipment operate efficiently and reliably so predicted savings and/or fuel displacements are achieved.
- Confirm (as applicable and as practicable) that the CxA has also reviewed submittals and inspected systems and equipment to determine if they meet minimum requirements set forth by the project initial Technical Feasibility Study [Dated], the design documents [Dated] and the OPR and BOD [Dated] and any other relevant resources.
- All Deficiencies and/or outstanding items shall be reported as detailed below:

Commissioning **Report Details** - (4 of 5)

Cx report shall also address the following items:

- All outstanding non-compliance items shall be specifically listed.
- Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be provided.
- Each non-compliance issue shall be referenced to a specific functional test, inspection, trend log, etc., where the deficiency is documented.
- The functional performance and efficiency section for each piece of equipment shall include a brief description of the verification method used (i.e., manual testing or BAS trend data analysis) and include observations and conclusions from the testing.
- CxA to produce graphs from logged data to make trends more apparent so that system operational issues can be more easily identified. Graphical data displays are key to successfully illustrate the completion of the testing and operation of the tested equipment and systems.

Commissioning **Report Details & Appendix** - (5 of 5)

During reporting on the above items, include any Appendix type or lengthy material into well organized and tabbed Appendices. This can include, but is not limited to:

- Selected parts of the additional trend data plots beyond what was necessary in the body of the report.
- Detailed Cx Issues & Resolution Logs.
- Also include the complete project contact list for the record.
- Additional equipment submittals that were provided during the Cx process, but were not necessarily part of the bid Docs.
- Any project awards or certificates that are worth sharing.
- Final Cx Plan & PFCs do not have to be part of the final report, but will be stored in the Cx Record Manual, that will be referenced as part of the Cx report. That is because by now should have already been submitted to Owner, GC (or CM).

PDH Questions / Answers for Assessment of Learning

PDH Questions / Answers - (Q/A 1)

- **Q1** - Is the **Cx Plan**, **PFCs**, **FPTs**, **proper execution of all forms**, **Issues Logs** then **Cx Report** enough for conducting Cx? True or False?
- **A1a** - Yes and No!
- **A1b - Yes**; If you are only doing Construction Phase Cx.
- **A1c - NO**; If the intention is a comprehensive and **Total Cx process** during **all** project phases starting from:
  - [1] Cx During Pre-Design Phase,
  - [2] Cx During Design Phase,
  - **[3] Cx During Construction**,
  - and [4] Cx During Occupancy & Operations.
  - Therefore, Phase 3 only does not suffice for a **comprehensive** or **Total** Cx process; & Phases 1, 2 & 4 must be done.

PDH Questions / Answers - (Q/A 2)

- **Q2** - Can the GC start **FPT** before **PFC** (and why yes or no)?

- **A2** - The word prefunctional refers to ***before*** functional testing.
  - Prefunctional Performance Checklists/Testing must be successfully completed ***prior to*** formal functional performance testing of equipment or subsystems.
  - PFCs basically document that equipment and systems are properly installed and operational so that functional performance testing ***may proceed without unnecessary delays***.

PDH Questions / Answers - (Q/A 3)

- **Q3** - List a few of the known ***barriers*** impeding the implementation of the proper Cx process in numerous projects and how to avoid them?

- **A3a** - Lack of knowledge of the multiple benefits of Cx.
- Lack of Cx budgets.
- Bad value engineering, where Cx can be removed from proj!
- Lack of requiring Cx by law (i.e., Cx may not be part of building code) in some areas.
- Lack of customer and project team education.
- Lack of qualified Cx contractors.
- Lack of good project leadership in the first place.
- **A3b** - Educate, Educate, Educate all team members (starting with owner) & budget for Cx like any other important project item.

PDH Questions / Answers - (Q/A 4)

- **Q4** - Per the ASHRAE Cx Guidelines, what are the varying types of Commissioning and why are there that many?

- **A4a** - [1] Total Building Cx Process (TBCxP) [4 Phases].
- [2] Continuous Cx Process.
- [3] Ongoing Cx Process (OCx).
- [4] Re-Cx.
- [5] Retro-Cx.
- [6] Cx Light (or Custom Cx).

- **A4b** - Cx Type variations depend on whether the building is **existing** or **new**, or if it has been commissioned in past, and if that past Cx was adequate, etc.

PDH Questions / Answers - (Q/A 5)

Q5 - Besides GSHP systems, provide multiple examples of other building types, technologies, systems, equipment, master energy plans and programs that could benefit from the Cx process (diverse audience involvement needed)?

A5 - This is a long list, includes but is not limited to:

1. Carbon reduction, decarbonization, and electrification goals using numerous technologies in residential, commercial, industrial, and institutional facilities as well as state-wide and national targets.
2. Smart grid controls and dispatch of varying power generation assets.
3. Heat pump operation (air-source, water source, air-to-water, ground heat exchanger temperature management) and proper integration with other systems.
4. Free cooling applications (air side & water side) to bypass mechanical cooling when ambient conditions permit.
5. CHP and CCHP.
6. Climate goals and Carbon footprint reduction goals.

PDH Questions / Answers - (Q/A 5 Cont.)

Q5 - Besides GSHP systems, provide examples of other buildings, technologies, systems and equipment that could benefit from the Cx process?

A5 - This is a long list, includes but is not limited to:

7. Optimization of electricity storage systems to best support smart grid (batteries, fly wheels, pumped water, compressed air storage, and software).
8. Optimization of cold storage systems to best serve large commercial and industrial cooling applications.
9. All types of building management systems (BMS) and industrial SCADA systems.
10. Large electric cooling applications & large non-electric cooling applications and the integration and dispatch of both.
11. Optimized dispatch of wind and solar electricity generating assets, varying types of elec/thermal storage, and integration with the grid.
12. Integrating multiple technologies encompassing all of the above.
13. Large heating applications and with varying fuel types.

PDH Questions / Answers - (Q/A 5 Cont.)

Q5 - Besides GSHP systems, provide examples of other buildings, technologies, systems and equipment that could benefit from the Cx process?

A5 - This is a long list, includes but is not limited to:

14. District Heating and Cooling Systems.
15. Laboratory testing to produce accurate and reliable results in support of numerous commercial applications, R&D, policy making, regulation, safety, public health, etc.
16. Variable speed pumping, primary, secondary, tertiary, decoupling and hydraulic separation techniques.
17. Entire BOP components (balance of plant)
18. Industrial cooling, aggressive dehumidification needs, optimization or air pressurization controls and requirements in labs and mission critical facilities.
19. Lighting applications with advanced controls, DL harvesting, automatic dimming, responding to smart grid signals, etc.

PDH Questions / Answers - (Q/A 5 Cont.)

Q5 - Besides GSHP systems, provide examples of other buildings, technologies, systems and equipment that could benefit from the Cx process?

A5 - This is a long list, includes but is not limited to:

20. A very wide range of energy recovery technologies (residential, commercial, industrial and institutional) both air and water/Glycol sides, Steam Generating Energy Recovery Heat Pumps, Electricity Generating OCRs (Organic Rankine Cycles), and all applications involving sensible and latent energy recovery..
21. Use your Imagination.

Q/A

Thank you all for Attendance and Participation

Khaled A. Yousef, PE, CEM, CDSM, LEED AP, GBE

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Credits to NEW YORK STATE OF OPPORTUNITY. NYSERDA *for remarkable support*

Credits to NEW YORK STATE OF OPPORTUNITY Department of Environmental Conservation *for facilitating host sites*

Optional/Suggested Commissioning Reference Material & Handouts

Suggested Commissioning Management Protocols

Commissioning Management Protocols - (1 of 2)

	Issue	Protocol
1	For requests for information (RFI) or formal documentation requests:	The CxA goes first through the GC (or CM) *then* through the contractors.
2	For minor or verbal information and clarifications:	The CxA goes directly to the informed party.
3	For notifying contractors of deficiencies:	The CxA documents deficiencies through the GC (or CM), but may discuss deficiency issues with contractors prior to notifying the GC (or CM). The A/E is also informed of deficiencies identified by the CxA.
4	For scheduling **functional tests**:	The CxA schedules functional tests through the GC (or CM).
5	For scheduling commissioning meetings:	The GC (or CM) selects the date, in coordination with the CxA, and makes necessary arrangements for the meeting.
6	For making a request for significant changes:	**The CxA has no authority to issue change orders.**

Commissioning Management Protocols - (2 of 2)

	Issue	Protocol
7	For making small changes in specified sequences of operations:	**Generally, the CxA may *not* make changes to specified sequences without approval from the A/E.** In limited situations, however, the CxA may recommend making small sequences of operations changes to improve efficiency or control or to correct deficiencies, through the responsible contractor, but shall document the change and provide all changes of specified sequences to the CM, GC and A/E. Responsible suggestions shall be made preferably in consultation and coordination with the GC (or CM), the CC and the major equipment maker impacting and/or impacted by the sequence of operation changes as applicable).
8	Contractors disagreeing with requests or interpretations by the CxA shall:	Attempt to resolve with the CxA first. Then work through the GC (or CM), who will work with CxA directly to resolve the situation.
9	For scheduling training:	The CxA may provide input for and do some coordination of training, but does not do the scheduling; Scheduling done through the GC (or CM).

Suggested Commissioning Written Work Products

Cx Written Work Products (1 of 3)

	Product	Developed By
1	Final commissioning plan	CxA
2	Meeting minutes	CxA, GC (or CM)
3	Commissioning schedules	GC (or CM) with Contractors and CxA
4	Equipment documentation submittals	GC (or CM) and Contractors
5	Sequence clarifications	CC, Boiler manufacturer, Hydronics Consultant, A/E, or a combination of the above, as needed.
[6]	Prefunctional checklists (PFC)	CxA (& with support from GC (or CM), CC, Subcontractors and the Boiler Manufacture, as needed).
[7]	Start-up and initial checkout plan	GC and Contractors (compilation of existing documents)
[8]	Start-up and initial checkout forms filled out	GC (or CM) and Contractors

Cx Written Work Products (2 of 3)

	Product	Developed By
9	Final TAB report	TAB Subcontractor
10	Commissioning Issues Log (deficiencies)	CxA
11	Commissioning Progress Record	CxA
12	Deficiency reports	CxA (& also based on executed functional test forms completed by contractors).
[13]	Functional performance tests (FPC) and forms	CxA (& with support from GC (or CM), CC, Subcontractors and the Boiler Manufacture, as needed).
[14]	Executed functional test forms	GC (or CM) and Contractors

Cx Written Work Products (3 of 3)

	Product	Developed By
15	O&M manuals	GC (or CM) and Contractors
16	Commissioning record manual	CxA
17	Overall training plan	GC (or CM) with Contractors; and reviewed by CxA
18	Specific training agendas	GC (or CM) with Contractors; and reviewed by CxA
19	Final commissioning report	CxA
20	Recommissioning Management Manual	CxA
21	Miscellaneous Cx-related approvals	GC (or CM), A/E and CxA

Suggested Project Close-out Documents

Project Completion & Closeout Docs (1 of 3)

1. Provide all **Equipment Warranty** documentation.
2. Provide all equipment **Installation**, and **O&M Manuals**.
3. Provide all as-installed and complete **Equipment Submittals** as part of the O&M Manuals.
4. Define all related **O&M Roles and Responsibilities** moving forward between the Service Contractor, Boiler Maker, and the Site Owner in terms of scopes and schedules.
5. Secure **Service Agreements** to support the site in the future at a minimum with the **Mechanical Service Contractor** and preferably with the **Controls Contractor**. Ensure all agreements have enough detail in terms of scope details and frequency of services.
6. Provide **As-Built Mechanical Drawings** & as-built/updated equipment & pump & HX schedules.
7. Provide **As-Built Wiring (& Control) Diagrams**.
8. Provide **As-Built Architectural & Structural Drawings** & all project related drawings not include above.

Project Completion & Closeout Docs (2 of 3)

9. Provide **As-Built Control Sequences of Operation (SOO)** especially after many control changes were done during system Cx. Ex. Clearly spell out how the pellet boilers are controlled using external commend as opposed to the tank upper and lower Temperature sensors for on/off signals to the pellet boilers.
10. Provide updated & final as-built **Controls Submittals** including all sensors covering all hardware, all software, all updated drawings & all details.
11. Provide written Standard Operating Procedures (**SOPs**) and access credentials for all information needed to successfully run the plant BMS, acquire data from the BMS and from all Monitoring based Cx equipment for Ongoing Cx and verification of as intended operation of all systems.
12. Provide the updated and **As-Built Test and Balance (TAB) Report**.
13. Secure a reliable and quality **Supply Source of Pellets**.

Project Completion & Closeout Docs (3 of 3)

14. Completion of adequate customer **Controls Training**.
15. Completion of adequate customer **Boiler Training**.
16. Completion of adequate customer other **BOP Training** and system components (water softener, glycol system, chemicals, etc.).
17. **Training Manuals** for all training(s) for entire system and all BOP.
18. Attach clear **Equipment & Pipe Labels** that indicate flow direction everywhere for your flag ship projects.
19. Verify **full sets of soft & hard copies** of the items listed above are provided & easily accessible to those needing them for proper system operation, maintenance, trend logging, ongoing Cx, and project demonstration for success stories.
20. Include **Other Documentation** as need such as all proj permits, inspection records, financial and legal project paperwork, or items of project relevance not included above, etc.

Project Completion & Closeout **Cx** Docs (1 of 1)

1. **Cx Plan** (Updated as necessary).
2. **OPR** & **BOD** (Updated as necessary).
3. **Training Manual** for entire system and all BOP.
4. **System O&M Manual** for entire system & all BOP.
5. **Issues and Resolution Log** (Closeout & completed).
6. Final **Cx Report**.
7. Convene **Lessons Learned Workshop** (Optional, but strongly recommended).
8. **Other TBD** as needed on case by case basis.

Suggested List Courtesy of ASHRAE Cx Resources

Q/A

Thank you all for Attendance and Participation

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Speakers: Jeff Hammond / *IGSHPA*
Khaled Yousef / *Pyramid Energy Eng., PLLC*