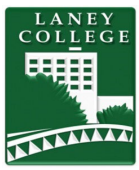
ECT 26 COURSE

LANEY COLLEGE
ENVIRONMENTAL CONTROL TECHNOLOGY

Commercial HVAC Systems Program

ECT 26 Advanced Building Commissioning Course Development

National Science Foundation - National Center for Building Technician Education



5/14/2014

ADVANCED BUILDING COMMISSIONING

Course Documentation

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Catalog description

Advanced processes and applications of building commissioning, re-commissioning and retro-commissioning: conceptual design through the construction process, acceptance testing, writing final commissioning reports, and training of building maintenance and operations personnel.

Syllabus description: Applications of building commissioning, retro-commissioning and re-commissioning, commissioning process from conceptual design through the construction process.

Class hours

Lecture 35 hours Lab 52.5 hours

Units

Lecture 2 semester units Lab 1 semester unit

Entry skills needed

- Reading level: College-level English technical reading. Ability to decode new technical terminology with reference help.
- Writing level: Ability to express complex technical concepts in English.
- Math level: college technical math
    1. Perform mathematical operations using real numbers, fractions, decimals and percentages.
    2. Solve simple linear equations.
    3. Demonstrate knowledge converting fractions to decimals and decimals to fractions.
    4. Solve basic math and geometry problems on area, angles, volume and percentages.
    5. Use algebraic equations to solve heating and cooling load calculation problems.
    6. Solve problems involving ratio and proportions.
    7. Interpret data in graphs in rectangular coordinate systems.
    8. Use and apply Imperial and Metric systems of measurement.
    9. Solve problems involving area and perimeter.

- Introduction to building commissioning skills:
    1. Explain the process of building commissioning, with distinctions between new and existing buildings.

2. Explain the process of commissioning, re-commissioning and retro-commissioning.
3. Describe the building system fundamentals.
4. Describe building equipment such as boilers, chillers, air-handlers, pumps and motors.
5. Explain commissioning terminologies.
6. Utilize controls and energy management systems for commissioning.

Recommended entry skills

- Electricity and instrumentation skills
- Computer information systems skills
- Fundamentals of DDC and advanced DDC skills
- Testing, adjusting and balancing skills
- HVAC system design skills

Suggested co-requisite skills development

- Data analysis for performance monitoring skills:
    1. Determine the data parameters that need to be collected for decision making.
    2. Safely and properly install sensors and data loggers.
    3. Use computer programs to analyze and graph data.
    4. Combine data from multiple sources using time-based or event-based synchronization.
    5. Identify common equipment operating issues through interpretation of trended data.
    6. Compare two datasets for changes, e.g., data taken before and after control changes.
    7. Use data to support systems commissioning.
    8. Use data to identify energy saving measures.
    9. Develop written and oral presentations of data and findings

Syllabus

See Appendix A for sample Syllabus, course schedule, and policies. For Lesson Topics to include in course, see Exit Skills.

Student learning outcomes

The exit skills listed in the next section support these 3 outcomes:

Process & planning

Describe the commissioning, re-commissioning, retro-commissioning processes and document a plan for each.

Protocols

Collect and analyze test data per protocols.

Communication

Communicate findings and train maintenance and facility operations staff.

Exit skills

Course content to achieve 3 outcomes listed above:

Process

1. Identify the key components of the commissioning process.
   Lesson Topics:
   - Introduction to commissioning and types of commissioning
   - Commissioning new and existing buildings

Plans

2. Develop commissioning, re-commissioning and retro-commissioning plans.

Forms

3. Develop commissioning guide specifications and forms.
   Lesson Topics:
   - Pre-functional and functional test forms

Procedures

4. Create appropriate test procedures and data collection protocols.
   Course Content for this objective:
   a. Use of instruments and methods for collecting data
      Lesson Topics:
      - Basic tools, instrumentation, and equipment
      - Commissioning packaged HVAC unit /calibration
      - Commissioning boilers
      - Commissioning pumping systems

- Commissioning air handlers and components: economizer, fans and drives, cooling and heating coils, chillers and CHW piping, humidification.
- Commissioning terminal units
- Commissioning cooling towers and condensers

Data Analysis

5. Demonstrate proper analysis of data collection.

Communication

6. Ensure building operation and maintenance staff is adequately trained.
   Course Content for this objective:
   a. Training procedures for building operation and maintenance staff.

Course materials

Principal text

Building Commissioning, the Key to Quality Assurance. Rebuild America: USDOE. Contents: Two Approaches, Benefits, Investments and Paybacks, Selecting a Commissioning Authority, How to Commission a Building, Operation and Maintenance for Persistence, Appendix: Pre-functional Checklist, Internet Resources.

Modern Refrigeration and Air Conditioning 18th Ed., Althouse, Turnquist and Bracciano, Goodheart and Wilcox Co. Inc, (2004).

Lecture materials and handouts

- Data sheet: "**Design Intent and Basis of Design of Energy- and Comfort-Related Systems**" - A format to record the primary areas related to energy use and comfort for which the design intent and basis of design should be defined. The design intent provides the explanation of the ideas, concepts and criteria that are considered to be very important to the owner, coming out of the programming and conceptual design phases.

- Data sheet: "**Terminal Unit Standard Commissioning Procedure**" 8/1997 - A format to document testing and certification of common terminal units.

- Data sheet: "**Functional Test- Small Package Rooftop Unit DX/Gaspack**"

- Reference: **Commissioning Plan --Construction Phase-- A Healthcare Facility,** Portland Energy Conservation, Inc. (PECI) 2005. Summary: During the construction phase, the plan provides direction for the commissioning tasks during construction. The plan focuses on providing support for the specifications and provides forms for the application of the commissioning process.

- Data sheet: "**HVAC System Verification and Start Up**", ACG Commissioning Guideline. Checklists for all HVAC system components.

- Presentation: "**Testing Ventilation Systems**" - Air flow measurement tools, techniques, and formulas. 24 Slides. (2 versions included)

- Reference: " **Using Utility Bills and Average Daily Energy Consumption to Target Cx Efforts and Track Building Performance**", David Sellers, Portland Energy Conservation, Inc. (PECI) 2001.

- Reference: "**AABC Commissioning Guideline",** James Magee, TBE**,** Associated Air Balance Council - provides overview of Cx goals, process, and workforce issues.

- Reference: "**Building Commissioning Guideline ver 2.2**" US DOE. Contents: Overview of Cx, Team & Responsibilities, Management Approach, Program Phase, Design Phase, Construction Phase, Acceptance Phase, Post-acceptance Phase.

- Reference: "**A Specifications Guide for Performance Monitoring Systems"**, developed by CEC, PIER-DOE to assist commercial and institutional building owners in specifying what is required to obtain building operating data to initiate and sustain an ongoing commissioning activity.

- Reference: "**Request for Proposal (RFP) Checklist for Retrocommissioning Services**" - what to include in an RFP.

- Reference: "**Guidelines for Verifying Existing Building Commissioning Project Savings**" - designed to help commissioning service providers, building owners and managers, and energy efficiency program managers to understand how to manage, design, and complete robust M&V procedures within individual EBCx projects.

- **AHU testing guides folder**: contains Functional Testing Field Tips (key Cx requirements, cautions, time requirements), Calibration and Leak-by Test Procedures (sensor calibration and valve leakage testing), Functional Test for AHU with cooling (data sheet), Verification Checklist (process accountability form).

- **Boiler testing guides folder**: contains Schematics & Sequence of Operations (points for 1 and 2 boiler systems), Functional Test Forms and Tips for boilers and associated pumps, mixing valves, and DHW recirculation pumps.

- **Chiller testing guides folder**: contains Cx Procedure, Example Sequence of Operations, Verification Test Procedure, Pre-functional Test of chiller and CHW piping (data sheets), Functional Test (data sheet) and tips.

- **Economizer testing guides folder**: contains How to Measure Economizer Airflow document, Economizer Theory, Economizer Cx Tips, Verification Checklist, Pre-functional Test guide, and Functional Test guide.

- **Exhaust fan testing guides folder**: contains Motor Nameplate Decoding instructions, Fan Theory, Pre-functional and Functional Testing (start up) templates.

- **Filter testing guides folder**: contains Functional testing tips and theory.

- **Packaged Roof Top Unit (RTU) testing guides folder**: Contains: Cx Process for RTUs, Cut sheet sample, Small HVAC design guidelines (CEC), RTU Sequence of Operations, RTU Economizer Details, Prefunctional and Functional Test data sheets and tips, Split DX AC Functional Test data sheet.

- Reference: Samples of commissioning proposal and scope documents

Other reference materials

California Commissioning Guide: Existing Buildings. Contents: Benefits of Cx, RetroCx Team, RetroCx Process, Strategies for Ensuring Persistence of Benefits.

California Commissioning Guide: New Buildings. Contents: Benefits of Cx, Cx Team, Cx Process, Strategies for Ensuring Persistence of Benefits.

Existing Building Commissioning Toolkit, CA Cx Collaborative (CACx) Source for several workbooks included in the files for this course. Templates and sample documents provided for Cx reporting.

Commissioning for Federal Facilities: A practical guide to building commissioning, recommissioning, retrocommissioning and continuous commissioning, US DOE, EERE, 2008. Contents: Types of Cx, Why Cx?, Cx Management, Cx Process, RetroCx Process, ReCx Process, Continuous Cx Process, Sustainable Cx.

Commissioning of Mechanical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities, 2002, US Army. Contents: Need for Cx, Cx Process, HVAC Equipment and Controls, Generators and Ancillary Equipment, Air Compressors and Pneumatic Control Systems, Fire Fighting and Suppression Systems, Lifting and Moving Devices: Cranes & Elevators, Water and Sewage Treatment Systems.

Portland Energy Conservation, Inc. (PECI): Designs and manages energy efficiency programs for utility providers, government organizations and other clients. Programs aim to promote the understanding and adoption of energy-efficient technology, and demonstrate the value of efficient homes, retail spaces, offices and warehouses.

Software needed

Excel-related use:

- Workbook: **"Retrocommissioning Findings Workbook, ver. 1.0",** CA Commissioning Collaborative, Jan 2008. The Findings Workbook helps organize, track, and report retrocommissioning (RCx) investigation and implementation activities. It includes the following features: • defines key fields used to track the progress and results of an RCx project, • automates the creation of tables for reporting at each stage of an RCx project, • allows measures not selected for implementation to be automatically filtered from reports, • facilitates the estimation of cost savings from user-input energy savings by including the typical structure of several rate tariffs from California, • aids research by including standard drop-down categories to group RCx findings, and • facilitates decision-making through clear presentation of prioritized measures for implementation..

- Workbook: "**Monthly Utility Consumption Analysis, ver 1.0**" CA Commissioning Collaborative, Jan 2008. Calculates the Average Daily Use for each calendar month. See " Using Utility Bills and Average Daily Energy Consumption to Target Cx Efforts and Track Building Performance".

- **Energy Savings Calculation Tools (EnergyCalc 2)** 2009:

  Energy Savings Calculation Tools package contains 6 files
  - FanSystemCalc_v2.0.xls
  - PumpSystemCalc_v2.0.xls
  - EnergyCalc-training_v2.0.pdf
  - FanSystemCalc-reference_v1.0.pdf
  - PumpSystemCalc-reference_v1.0.pdf
  - ReadMe information file

  "FanSystemCalc_v2.0.xls" and **"PumpSystemCalc_v2.0.xls"** are the Excel workbooks for estimating the energy savings for variable flow fan and pump systems respectively. The PowerPoint file "**EnergyCalc-training_v2.0.pdf**" provides the main training for the Excel workbooks. **"FanSystemCalc-reference_v1.0.pdf"** and **"PumpSystemCalc-reference_v1.0.pdf"** provide information on how to obtain some of the information needed in the field for input to the workbooks.

Energy Charting and Metrics Tool (ECAM): This tool for energy charting and metrics is intended to facilitate the examination of energy information from buildings, reducing the time spent analyzing trend and utility meter data. See PNNL website.

Lab materials

Pencils, colored felt tip pens, graph paper with 1/8" squares, circle template, line paper, safety glasses, gloves, medium flat blade and Philips screwdrivers, two adjustable wrenches one 8" and one 12", combination wire cutter, stripper and crimper, one roll of electrical tape, wire connectors, fuse puller, multi-meter, pocket thermometer and tool box or pouch.

See "Instruments and Tools" list for comprehensive list of Cx tools required by the professional. This is included in the Labs Folder.

Lab equipment & instruments required

FIGURE 1 - Economizer on build-up AHU in lab. Controls fully accessible for adjustment, setting up faults, or commissioning activities.

FIGURE 2 - Variable Frequency Drive, 3 are connected to water circulation pumps in lab. Can be programmed by students, faults can be set up by instructor.

Generally, hands-on implementation of concepts is key to successful learning of equipment function and relationships. Laney ECT department's lab has a fully functional commercial building central plant system for demonstration purposes. All components of the system are accessible to students for operation, measurement, diagnosis, servicing, and commissioning. See Laney College - Commercial HVAC Systems program documentation for lab layout and more detailed information on equipment and instruments.

A connected and functional commercial HVAC system should include a boiler, chiller, water pumps, air handling units, terminal units, cooling towers, control systems(pneumatic and/or DDC), sensors, and actuators. Monitoring access point computers accompanied by one or more control system trainer boards (with equivalent connected controls and actuators) will allow students maximum access.

Economizers need to be set up to demonstrate response to any outdoor conditions regardless of the time of day or year the lab class is meeting. A furnace/AC unit has been installed to supply "outside air" to the economizers at a selected temperature between 55°F and 120°F.

Samples of weekly assignments

See future update.

Project

See future update.

Problem-based learning (PBL) methods should enhance student learning in this inherently problem-oriented course.

Assessment

Methods

- Tests
- Peer-evaluated presentations
- Instructor verified hands-on lab work

See Appendix B – Sample project rubric for project assessment.

Sample test questions

See future update.

Adaptability to on-line format

The lecture portion can be delivered and assessed on line with traditional methods. The laboratory portion requires hands-on experience with equipment, so on line delivery needs to be supported by real world access. Adaptation of laboratory equipment for video presentation might support on-line demonstrations. Refer to "PNNL Retuning Commercial Buildings" for examples of web-based interactive problem scenarios.

Appendix A – Sample syllabus

(See Exit Skills section for lesson topics.)

LANEY COLLEGE
Environmental Control Technology

Course code: ECT 26- **Course Term:**
Time: Monday and Wednesday 5:30pm to 7:45pm **Units:** Lec 2 units - Lab 1 units
Instructor: **Phone:**
Office Hours: Wednesday 7:45 pm to 8:15 pm **Email:**

Course Description: Applications of building commissioning, retro-commissioning and re-commissioning, commissioning process from conceptual design through the construction process.

Learning Outcomes: Describe the commissioning, re-commissioning, retro-commissioning process and planning methods; Demonstrate ability to analyze and test data protocols; Demonstrate ability to train maintenance and facility operation staff; Quantifying energy savings

Text:
1. California Commissioning Guide – New Buildings
2. California Commissioning Guide – Existing Buildings
3. Power Point Presentations

Supplies Needed: Calculator, note book, pen or pencil,

Resources:
http://www.peci.org/resources/commercial-retail.html
http://www.commissioning.org/commissioningguideline/
http://www.cacx.org/resources/rcxtools/spreadsheet_tools.html

Evaluation: Classroom work and projects will be evaluated and graded accordingly.

1.	Homework	10%
2.	Attendance	10%
3.	Participation in class	10%
4.	Midterm and quizzes	20%
5.	Lab work	35%
6.	Final Exam	15%

Attendance: Students may be dropped from the course if the number of absences exceeds two days worth of class meetings. However, extenuating circumstances may warrant consideration. The department head will decide what are extenuating circumstances. Tardiness (more than 30 minutes) will count as a missed day unless previous arrangements are made with the instructor. Missing more than one day will effect a student's grade.

Conduct: **No cell phone or electronics use is allowed in class**. Returning calls/texting must wait until break or the end of class. Any other phone use must be cleared with the instructor before each session starts. **Cell phone calculators are not acceptable; you must have a real calculator.** Laney is a tobacco free environment, including smokeless tobacco.

NOTE: CHEATING = FAILING GRADE

***Disclaimer:* The syllabus is subject to modification. The instructor will communicate to students any changes or revisions.**

Wk 1 – Introduction to Commissioning and types of Commissioning
Wk 2 – Commissioning New and Existing Buildings - Review
Wk 3 – Pre-Functional and Functional Test Forms
Wk 4 – Basic Tools, Instrumentation, and Equipment
Wk 5 – Commissioning Packaged HVAC Unit /Calibration
Wk 6 – Commissioning Boilers
Wk 7 – Commissioning Pumping Systems
Wk 8 – Commissioning Air Handlers and its Components
Wk 9 – ----------MIDTERM REVIEW - MIDTERM ----------
Wk 10 – Economizer

Wk 11 – Fans and Drives
Wk 12 – Cooling and Heating Coils
Wk 13 – Chillers and CHW piping
Wk 14 – Humidification
Wk 15 – Terminal Units (TU)
Wk 16 – Cooling Towers and Condensers
Wk 17 – ----------FINAL REVIEW - FINAL----------

Academic honesty: Plagiarism occurs when a student misrepresents the work of another as his or her own. Plagiarism may consist of using the ideas, sentences, paragraphs, or the whole text of another without appropriate acknowledgment, but it also includes employing or allowing another person to write or substantially alter work that a student submit as his or her own.

Appendix B – Sample project rubric

See future update.

BEST Center Curricula, Resources & Recordings

Academic Programs
Georgia Piedmont Technical College - Building Automation Systems
Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
Reports & Case Studies
Marketing Resources

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation