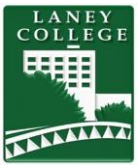
ECT 22 COURSE

LANEY COLLEGE
ENVIRONMENTAL CONTROL TECHNOLOGY

Commercial HVAC Systems Program

ECT 22 Commercial HVAC Systems Course Development

National Science Foundation - National Center for Building Technician Education



5/14/2014

COMMERCIAL HVAC SYSTEMS

Course Documentation

This material is based upon work supported by the National Science Foundation under Grant Number (DUE 1204930).

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Catalog description

Introduction to commercial HVAC Systems, with emphasis on how building components such as chillers, boilers, fans, pumps, variable frequency drives, and associated ventilation and zone equipment work together to form complex systems. This course will also cover the psychrometric processes of air, review of thermodynamics of heating, ventilation and air conditioning (HVAC), system commissioning, energy conservation, proper and safe use of tools and instrumentation, and good maintenance practices.

Class hours

Lecture 26.25 Hours Lab 26.25 Hours

Units

Lecture 1.5 semester units Lab 0.5 semester units

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.

- Fundamentals of heating and air conditioning skills:
    1. Describe the theory and operation of an air conditioning system.
    2. Identify and describe electrical and mechanical components of a refrigeration system.

3. Describe various applications of mechanical and electrical components in refrigeration systems.
4. Describe the operation of various mechanical and electrical components in refrigeration systems.
5. Demonstrate good safety practices when working with electricity, refrigerants and combustible gases.
6. Demonstrate proper use of instrumentation.
7. Describe the difference between primary and secondary controls.
8. Explain the operation of ECM motors.
9. Describe the theory of operation for 70%, 80%, and 92% efficient residential and light commercial furnaces.
10. Explain the different types of ignition systems and burners.
11. Explain the sequence of operation of a direct spark ignition system with induced vent blower.
12. Describe the operation of furnace blowers and controls.
13. Explain the refrigeration systems used in ice machines and water coolers.
14. Explain how defrost systems work.
15. Describe the different type of defrost systems and their use.
16. Explain the difference between single-stage and two-stage compressors and their uses.

- Energy analysis and conservation skills:
  1. Demonstrate the necessary knowledge for selecting the most efficient appliances and equipment.
  2. Define heat energy, and calculate conduction and infiltration heat loss and gain.
  3. Describe common locations of conduction and infiltration energy loss.
  4. Evaluate proper sizing of HVAC equipment and its effect on energy use and first cost.
  5. Perform a home or building energy usage analysis using blueprints and on-site information.
  6. Describe construction methods and materials and their affects on heat flow.
  7. Describe various types of solar and water heating systems.
  8. Perform computer modeling of commercial and residential energy-efficiency options.
  9. Analyze utility bills and sub-metered energy –use data.
  10. Conduct cost-benefit analysis of energy-efficiency improvements.

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 4 outcomes:

HVAC system

Explain the purposes and functions of the main components that make up a commercial building mechanical system.

HVAC principles

Explain the principles of thermodynamics as they apply to HVAC systems.

HVAC service

Describe proper and safe practices when working on mechanical equipment, electricity and other energy sources.

HVAC maintenance & operation

Describe proper maintenance requirements and procedures for building mechanical systems to achieve better human comfort and energy conservation.

Exit skills

Course content to achieve 4 outcomes listed above:

HVAC systems & components

1. Describe and explain the functions of all the HVAC system components.
   Course Content for this objective:
   a. Review of building HVAC systems. Identify and explain the functions of all system components.
      Lesson Topics:
      - Refresh: using the P-T chart as a service tool
      - Why we need air conditioning
      - Human comfort standards
      - Components of air conditioning systems
      - Furnaces and boilers, function, safety, controls
      - Chillers
      - Cooling towers
      - Fans
      - Package unit HVAC

Principles of thermodynamics

2. Explain the principles of thermodynamics as they apply to HVAC systems.

Lesson Topics:

- Measurement
- Density, pressure, energy
- Phase change
- Ideal gas law
- First & second laws of thermodynamics

Introduction to HVAC load calculations

3. List and explain the sources of heating and cooling loads in commercial buildings.

Lesson Topics:

- Heat flow conversions for air and water
- Design conditions
- Conduction and infiltration heat loss
- Room and solar heat gain
- System losses & heat gains
- Energy conservation

Introduction to psychrometrics

4. Use the psychrometric chart to evaluate thermal comfort conditions.

Course Content for this objective:

a. Understanding what affects human comfort conditions.

Lesson Topics:

- Human comfort standards
- Properties of air
- Psychrometric chart analysis
- Sensible & latent heat change
- Applying the psychrometric chart to air conditioning processes

HVAC electrical & mechanical systems operation

5. Demonstrate proficiency in the electrical and mechanical aspects of HVAC systems.

Course Content for this objective:

a. Identification of electrical & mechanical components and their system relationships
b. Overview of proper building equipment operation and maintenance procedures
c. Safe practices working with electrical and mechanical equipment

Instrumentation

6. Demonstrate proper use of instrumentation.
   Course Content for this objective:
   a. Evaluation of system performance as compared to the design intent of the building
   b. Safe practices working with electrical and mechanical equipment
   c. Proper procedures for calibrating system components and controls
   d. Use of software and instrumentation for collecting data and analyzing HVAC systems

HVAC controls

7. Demonstrate a good understanding of HVAC mechanical, electrical, pneumatic and electronic controls.
   Course Content for this objective:
   a. Review types of building HVAC control systems
   b. Identification of mechanical, electrical, pneumatic and electronic HVAC controls, components and their functions
   c. Review of electrical theory and instrumentation

Hydronic systems

8. Demonstrate proficiency in hydronics systems.
   Course Content for this objective:
   a. Identify hydronic system components.
      Lesson Topics:
      - Hydronic piping systems, terminal units and piping arrangements
      - Fluid flow in piping, pressure loss, pipe sizing
      - Piping, valves, and insulation

Energy conservation

9. Identify and explain best practices for energy conservation through proper operation of building systems.
   Course Content for this objective:
   a. Proper procedures for calibrating system components and controls
   b. Evaluation of system performance as compared to the design intent of the building
   c. Energy savings using economizer, temperature reset and equipment schedules
   d. Overview of proper building equipment operation and maintenance procedures

Software tools for energy conservation

10. Use different software tools to measure and analyze HVAC systems.
    Course Content for this objective:
    a. Software tools to measure and analyze HVAC systems
    b. Use of software and instrumentation for collecting data and analyzing HVAC systems

Course materials

Principal text

Edward G. Pita Air Conditioning Principles and Systems, 4th.edition. Prentice Hall, (2002). Chapters 1 through 9, see Lesson Topics for correlation to chapter titles.

Lecture materials and handouts

- Review for testing refrigeration charge (Sporlan): "Using The P-T Card As A Service Tool" includes test exercise (Sporlan Div.,Parker Hannifin Corp., 2011)
- Presentation on HVAC Systems: 24 slides in PowerPoint covering comfort, psychrometrics, central plant system component images. Chuck Frost, UC Berkeley Energy Manager and Laney College instructor.
- *Danfoss VFD-101 for the HVAC Market*: proprietary curriculum on variable frequency drives including 5 lesson outlines and 5 pre-post test sets. (Danfoss Corporation, online current).
- HVAC Economizers 101: ten PowerPoint presentations covering Economizers (Greg Jourdan, Wenatchee Valley College, Srinivas Katipamula, Ph.D. and Michael Brambley, Ph.D., Battelle Pacific Northwest Division)
- Pressure-Enthalpy Chart
- Thermal Expansion Valve (TXV) reading (Sporlan Div., Parker Hannifin Corp., 2005)
- Sample pump cut sheet
- *A Retro-commissioning Guide for Building Owners* (Portland Energy Conservation, Inc./USEPA, 2007)
- Sample fan coil cut sheet
- Sample boiler cut sheet

Other reference materials

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) offers education packages, publications, and resource materials.

RSES (Refrigeration Service Engineers Society) offers training, resources, certification testing.

NATE (North American Technician Excellence) offers industry certification.

Lab materials

- No software required for this course.
- Variable valves for HVAC hydronic system w/lab directions
- Variable air volume terminals w/lab directions

Lab equipment & instruments required

FIGURE 1 - Economizer on built-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

Selected exercises are assigned from the chapters related to the corresponding Lesson Topics section. The source of exercises is the principal text.

Ch1: Overview of Air Conditioning systems

> **Question 2.** List the four conditions that an air conditioning system may be required to control.
> **Problem 1.2** As the operating engineer of an HVAC system in a large office building, you have been instructed to raise the summer thermostat setting from 76 F to 80 F to conserve energy. Prepare a list of suggestions you might give to the building's occupants on how to minimize their decrease in comfort.

Ch4: Furnaces and boilers

> **Question 6**. List the major components of a hot water boiler and a steam boiler. List and explain the purpose of common boiler accessories.
> **Problem 4.5** A boiler is using 1.3 GPM of No. 2 fuel oil. It has a steady-state efficiency of 72% and the piping and pickup loss is 22%. What is gross output and net output of the boiler?
> **Computer Solution Problem: 4.11** Prepare a directive for proper heating boiler blowdown procedures. Try the Website www.cleaver-brooks.com.

Ch5: Hydronic systems

Question 2. Sketch the arrangements for the four types of hydronic piping system arrangements.
Problem 5.4 The flow rate through a convector is 4.5 GPM. Water enters the unit at 220 F and leaves at 208 F. What is the heat output of the convector?
Computer Solution Problem 5.16 A room has a heating load of 8300 BTU/hr. Select the required 3/4 in. baseboard radiation from the website www.sterlinghvac.com. The water supply temperature is 200 F and flow rate is 2 GPM. Produce the appropriate detail and dimension drawing and a brief specification.

Ch6: Cooling and heating loads

Problem 6.2 A southeast facing wall of a building located in Las Vegas, Nevada, is 90 ft by 24 ft. The wall is constructed of 8 in. concrete, R-5 insulation and 1/2 in. gypsum wallboard. The inside design condition is 77 F. Determine the cooling load through the wall at:

A. June 15 at 11 AM
B. Time of peak wall heat gain

Ch7: Psychrometrics

Problem 7.2 Air at 40 F DB and 60% RH is heated by an electric heater to 80 F. Find the DP, WB, and RH of the air leaving the heater. Draw the process line on the psychrometric chart.

Ch10: Fans

Question 2. What is the difference between a vane axial and a tube axial fan?
Problem 10.4 Select a ceiling diffuser to deliver 2000 CFM in a 30 ft by 30 ft classroom.

Ch13: Chillers, package units, heat pumps

Question 5. What are the three types of condensers and their features?
Problem 13.3 Find the capacity, KW required, and COP of the unit selected in Problem 13.2 if the condenser fouling factor is 0.001.

Ch15: Energy conservation

Problem1 5.2 A heat recovery exchanger is used to recover 30% of the wasted heat from the gas turbine in Problem 15.1 to heat hot water from 50 F to 120 F. How many GPM of water can be heated if all the recovered waste heat is used?

Project

Problem-based learning (PBL) project under development for 2013: students will research and create pneumatic control trainers using existing equipment in the lab. PBL should be planned to avoid student cohorts in concurrent courses having to complete multiple PBL projects simultaneously. PBL method should enable students to add to their course learning content; however, students indicate the process might take time away from learning content.

Assessment

Methods

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

See Appendix B – Sample project rubric for project assessment.

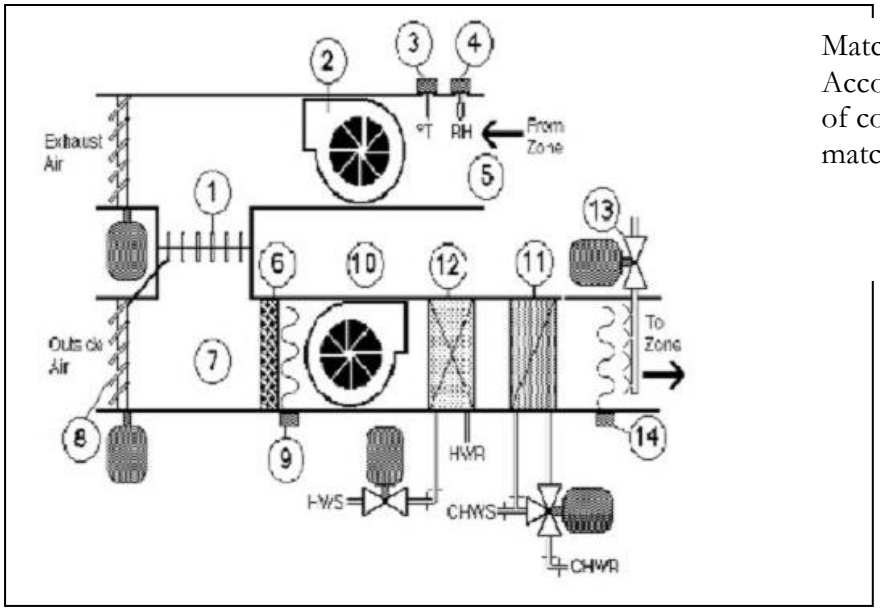
Sample test questions

- Midterm: 50 questions, matching, true/false, multiple choice, completion, essay.
- Final: 55 questions, true/false, multiple choice, matching

Homework essay question example: Research causes and corrections of a comfort-related fault in an HVAC system.

Companion test essay question example: Describe causes and corrections of a comfort related fault in an HVAC system.

Other Test Questions:



Matching Question: Accompany with list of components to match.

True/False
Indicate whether the sentence or statement is true or false.

____ 1. The Sensible Heat Equation is. Q = CFM x 1.08 x Δ T

____ 2. Combustion is the rapid chemical combination of the combustible substances in a fuel with oxygen

Multiple Choices
Identify the letter of the choice that best completes the statement or answers the question.

____ 28. Name the main component of a building mechanical system that moves chilled water?
a. HW Pump
b. CT pump
c. CH Pump
d. Chiller

____ 29. In California most of the Boilers run on
a. natural gas
b. electricity
c. oil
d. propane

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: Commercial HVAC Systems **Course Number/code:** ECT 022
Time: [3 classroom hours/week]
Instructor: **Office:** **Office Hours:** _____
Phone: **Units:** 2 units.

Course Description: Introduction to commercial HVAC Systems, with emphasis on how building components such as chillers, boilers, fans, pumps, variable frequency drives, and associated ventilation and zone equipment work together to form complex systems. This course will also cover the Psychrometric processes of air, review of thermodynamics of (HVAC) Heating Ventilation and Air Conditioning, system commissioning, energy conservation, proper and safe use of tools and instrumentation and good maintenance practices.

Student Outcomes:

1. Explain the purpose and their function of the main components that make up a commercial building mechanical system.
2. Explain the principles of thermodynamics as they apply to HVAC systems.
3. Describe proper and safe practices when working on mechanical equipment, electricity and other energy sources
4. Describe proper maintenance requirements and procedures for building mechanical systems for better human comfort and energy conservation.

Recommended preparation: basic skill levels in reading, writing, and math,

Text Book: Air conditioning Principles and Systems by Edward G. Pita

Supplies Needed: Pencils, colored highlighters, graph paper, line paper, safety glasses, gloves, medium flat blade, flathead and phillips screwdrivers, two adjustable wrenches one 8" and one 12", combination wire cutter, stripper and crimper, one roll of electrical tape, wire connectors, fuse puller, digital multi-meter and tool box.

Lecture: The class will concentrate on the following areas:

1. Review of building HVAC systems.
2. Overview of the Psychometric processes of air
3. Review of electrical theory and instrumentation
4. Energy savings using economizer, temperature reset and equipment schedules
5. Overview of proper building equipment operation and maintenance procedures
6. Evaluation of system performance as compared to the design intent of the building.

Grading Policy:	Attendance and class participation	50%
	Midterm Exam	25%
	Final Exam	25%
	Total: 100 points	

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.

Appendix B – Sample project rubric

Pneumatic Control Trainer Construction Project
Student Name: _____

CATEGORY	4	3	2	1
Information Gathering	Accurate information taken from several sources in a systematic manner.	Accurate information taken from a couple of sources in a systematic manner.	Accurate information taken from a couple of sources but not systematically.	Information taken from only one source and/or information not accurate.
HVAC Pneumatic Control Knowledge	Explanations by all group members indicate a clear and accurate understanding of Pneumatic Control component functions.	Explanations by all group members indicate a relatively accurate understanding of Pneumatic Control component functions.	Explanations by most group members indicate relatively accurate understanding of Pneumatic Control component functions.	Explanations by several members of the group do not illustrate much understanding of Pneumatic Control component functions.
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Construction - Care Taken	Great care taken in construction process so that the trainer is neat, attractive and follows plans accurately.	Construction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive product.	Construction accurately followed the plans, but 3-4 details could have been refined for a more attractive product.	Construction appears careless or haphazard. Many details need refinement for a useful & attractive trainer
Function at first try	Trainer functions extraordinarily well, at all operating conditions.	Trainer functions well, at most operating conditions.	Trainer functions pretty well, but fails under several operating conditions.	Trainer does not function.
Modification/ Testing	Clear evidence of troubleshooting, testing, and refinements based on data and control	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.

Total score of all 6 rows: _____.
Scoring: Assign earned value (1 to 4) for each row. Multiply by 4.167. = Group Project Score_____

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

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