

HVAC Service Technicians Training Center

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Operation & Essential Elements of Control Systems (CS-1)

This course covers the control of pressure and temperature; energy sources for control systems; operation principles of automatic control systems; the types of control action & control circuits; starters, contractors & relays; & fundamental controls for valves & dampers.

DAY 1

SUBJECT: Servicing Controls & Control Circuits

GOAL: Identify what controls & control circuits are & how they control

OBJECTIVES: At the completion of this lesson, the student will be able to:

- A. Describe the construction of a transformer & the way that current is induced in a secondary circuit.
- B. Identify some typical problems on an electrical circuit.
- C. Follow the sequence of electrical circuit.
- D. Identify the project board for lab, hands-on, projects.
- E. Describe & discuss electrical grounding.

SUBJECT CONTENTS:

- A. Transformers identification
- B. Thermostats identification

RESOURCES:

- A. W/J/T Refrigeration & Air Conditioning Technology
- B. Instructor's Handouts

EVALUATION: Smith: Electricity for Refrigeration
Read: pg 58-71, par (4-1 to 4-4)
Plus pg. 52 par 3-4

DAY 2

SUBJECT: Symbols & Rules for Diagrams.

GOAL: Recognize a sequence in a diagram by understanding symbols & rules for diagrams.

OBJECTIVES: At the completion of this lesson the student will be able to:

- A. Recognize & name a symbol.
- B. Describe the symbol as cycling or safety
- C. Describe what the term "pole" means & how they operate.
- D. Describe what the term "throw" means & to use the "throw".
- E. Draw symbol for:
 - 1. SPST 2. SPDT 3. DPST 4. DPDT.
- F. Define a "switch loop" circuit.

SUBJECT CONTENTS:

- A. Class exercise sheet.
- B. Discussion of symbols on overhead.
- C. Demonstrate a cycling control.
- D. Demonstrate a safety control.
- E. Demonstrate what the term "pole" means.
(In relays, contactors & starters)

1. Single pole
2. Double pole
3. Three pole

(Usually the voltage passed through the contacts poles & feeds the load)

- F. Demonstrate what the term "throw" means.
- G. Demonstrate devices that are "poles" devices.
- H. Demonstrate why the N.Y.C.E.C. permits a switch loop wiring circuit.

**METHODS/
TECHNIQUES:**

- A. Class Discussion
- B. Handouts & overheads
- C. Class exercises
- D. Lab exercises

RESOURCES:

- A. Hand-out
- B. Overheads
- C. WJT: read pg. 201 (par. 12.20)-23
Pg. 228 (par. 14.3)

EVALUATION:

- A. Lab experiment
- B. Homework: smith: read pg. 268 – par 10-2 thru 4
(anticipators)
- C. Class discussion

DAY 3

SUBJECT:

Relays & contactors (new & old)

GOAL:

Identify & distinguish between circuits with relays & contactors with coil voltages of 24, 120, & 208.

OBJECTIVES:

- A. At the completion of this lesson, the student will be able to:
- B. Introduction of circuits utilizing relays & contactors.
 - Recognize advanced applications of the following controls & applications
 - Single pole relay
 - Multiple pole relay
 - Multiple pole & multiple throw relay
 - High amperage rating relay
- C. How to troubleshoot the above relays.
- D. Perform relay interchange when called for.

SUBJECT CONTENTS:

- A. Defining the relay
 - A control which operates one or more sets of contacts (switches) by magnetic induction.
 - Relays are designed (or ordered) by the number of contacts, the normal position of the contacts, number or poles, & coil voltage.
 - The amperage the contact can carry.
- B. When to change a relay.
- C. When not to change a relay.
- D. Different components that do the same thing.
- E. Perform relay interchange when called for.

**METHODS/
TECHNIQUES:**

- A. Class discussion
- B. Handouts & overheads
- C. Class exercises

- D. Lab exercises
- E. Hands-on of various types of relays in class.
- F. Diagramming, using relays as the major device.

RESOURCES:

- A. Smith: Electricity For Refrigeration, Heating, & Air Conditioning.
- B. W/J: Refrigeration & Air Conditioning Technology
- C. Overheads & handouts
- D. Diagrams

EVALUATION:

- A. Lab exercises
- B. Diagrams
- C. In class exercises
- D. Homework: Unit 17 handout: read & answer questions

DAY 4

SUBJECT: Disconnects, circuit breakers & fuses

GOAL: Identify & troubleshoot disconnect switches fuses & circuit breakers.

OBJECTIVES:

- A. At the completion of this lesson, the student will be able to:
- B. Identify & troubleshoot indoor/outdoor disconnect switches.
- C. Identify & troubleshoot fused; on-fused disconnect switches.
- D. Discuss how to properly place an order for a new disconnect switch.
- E. Demonstrate troubleshooting of a single & multiple pole circuit breakers.
- F. Demonstrate troubleshooting of a fuse.
- G. Discuss advantages & disadvantages between fuses & circuit breakers.
- H. Explain "phasing in" of a six-pole circuit breaker.

SUBJECT CONTENTS:

- A. Identify indoor disconnect switches & their characteristics
 - 1. Power in at the top of the panel.
- B. Identify outdoor disconnect switches & the different form indoor switches.
- C. Disconnect switches
 - 1. Fused
 - 2. Non-fused
- D. Circuit breakers
 - 1. Single pole
 - 2. Multiple pole
- E. Fuse identification
 - 1. Edison based
 - 2. Cartridge

METHODS/
TECHNIQUES:

- A. Homework assignment
- B. Class participation
- C. Performance in lab exercises
- D. Diagrams exercises
- E. Quizzes

RESOURCES:

Refrigeration & Air Conditioning Technology-W/J.
Electricity for Refrigeration, Heating, & Air Conditioning-Smith
Instructor Handouts.
Overheads.
"O.E.M." Wiring Diagrams

Hands-On Disconnect Switches (System Room)
Hands-On Fuses & Circuit Breakers.

DAY 5

SUBJECT: Time Clocks

GOAL: Identify & troubleshoot time clocks

OBJECTIVES: At the completion of this lesson the student will be able to:
A. Identify the time clock electrical connections & mechanical arts
B. Identify some typical problems in a time clock circuits
C. Introductions of circuits utilizing time clock

SUBJECT CONTENTS: A. One day time clocks
B. Seven day time clock
C. Time clock termination

RESOURCES: Smith: Electricity for Refrigeration
W/J Refrigeration & Air Conditioning Technology

EVALUATION: Read Smith pg 296 - timeclocks
Read WJT pg. 431 (par. 25-21 to 27)
Pg. 867 (par. 43-29)

DAY 6

SUBJECT: Pressure Controls

GOAL: Define the various application of pressure controls & the difference function of the control

OBJECTIVES: A. Define range
1. Components range
2. Operation range
B. Define action
C. Reset
1. Manual
2. Automatic
D. Medium
1. Air
2. Water
3. Refrigeration
4. Glycol

SUBJECT CONTENTS: A. Define pressure control: A control that will open or close a set of switches based on the amount of pressure applied to it.
B. Define range: Is the operating pressure the control will start (close) or stop (open) a set of switches to operate a device.
C. Define action: The movement of the contacts in the control – to change from normally open to close or normally close to open. SPST or SPDT.
D. Define manual or auto reset: After an unsafe condition the device will be designed to restart itself or someone will have to restart it after the unsafe condition has been corrected.
E. Define the medium: The “what” to be measured
1. Air
2. Water

3. Refrigerant
4. Glycol

DAY 7

SUBJECT: From a job description, make a wiring diagram

GOAL: When the temperature rises, the compressor turns on through one starter turning off crankcase heater. When the water pressure drops, the pressure stat closes, solenoid water valve opens. At all times a relay is energized turning on a chilled water pump, through a "HOA" single pole control switch. One lamp is on with compressor, one lamp in on with chilled water pump.

- Show one diagram with control circuit of 120 volts.
- Show one diagram with control circuit 24 volts.

OBJECTIVES: Make a diagram & turn diagram into lab exercise that will operate in system room on project board.

SUBJECT CONTENTS:

- Proper use of symbols
- Sequence operation
- Avoiding short circuits
- Making diagram readable for others
- Able to test/troubleshoot project from diagram.

**METHODS/
TECHNIQUES:**

- Student troubleshooting
- Instructor troubleshooting/diagram
- Installing project on lab-board in system room.
- Instructor troubleshooting/lab board.

RESOURCES:

- A. W/J Refrigeration & Air Conditioning Technology.
- B. Smith: Electricity for Refrigeration, Heating & Air Conditioning
- C. Handouts & notes from class.

EVALUATION:

Lab exercises
Diagram exercises
Quiz
Homework: Read pg. 288, par 17-7
pg. 823, par 41-9 thru 11
pg. 923, par 45-11 thru 17
Service calls 3, 5, 6 pg. 948

DAY 8

SUBJECT: From a job description, make a wiring diagram, tuning it into a lab project.

GOAL: Define the function of a gas-fired, force air furnace.

OBJECTIVES: Make a pictorial & a schematic diagram that will become lab exercise that will operate in system room on project board.

- A. A gas-fire forced air furnace, operating on line voltage, with automatic, low-voltage controls. Provision is made for uniform delivery temperatures & a safety control prevents furnace over heating.
- B. The function of the equipment list
 1. Standard home electrical source: 120 volts, 60 cycle (Hz), single phase (1 pH), alternating current (AC)
 2. A fuse is requested by the safety code.

3. A step-down transformer is required for 24 volt control.
4. A thermostat with terminals "R" & "W" is required.
5. A gas valve is required for heat generation.
6. A normally-closed thermal limit switch is needed to prevent overheating.
7. A normally-open thermal plenum-switch is needed for air temperature control.

SUBJECT CONTENTS:

- A. Proper use of symbols
- B. Sequence operation
- C. Avoiding short circuits
- D. Making diagram readable for others
- E. Able to test/troubleshoot project form diagram

**METHODS/
TECHNIQUES:**

- A. Student troubleshooting
- B. Instructor troubleshooting/diagram
- C. Student installing project on lab-board in system room.
- D. Instructor troubleshooting lab-board.

RESOURCES:

- A. W/J: Refrigeration & Air Conditioning Technology
- B. Smith: Electricity for Refrigeration, Heating & Air Conditioning
- C. Handouts & Notes from class

EVALUATION:

- A. Wiring Diagrams
 - B. Lab projects
 - C. Quiz
 - D. Homework
- W/J: read par. 30-13 thru 25, 26
 Questions: pg. 612 9 thru 15, 19, 20, 21
 Read: preventive maintenance pg. 607-608

DAY 9

SUBJECT:

From a job description, make a schematic & pictorial diagram, turning it into a lab project.

GOAL:

Define the function of an oil-fired, forced air furnace heating system

OBJECTIVES:

- A. Make a pictorial & schematic diagram that will become a lab exercise that will operate in systems room on project board.
- B. List of Electrical Components:
 1. The standard home electrical source is 120 volts, 60 cycle (60 Hz), singlephase (1 pH), alternating current (AC).
 2. A fuse is required by the safety code.
 3. An internally-protected, permanent split capacitor fan motor is needed to drive the forced air fan.
 4. A normally open plenum switch is needed for air temperature control.
 5. A normally closed thermal limit switch is needed to prevent overheating.
 6. A burner motor relay coil is needed to control the burned motor that both pumps the oil & supplies combustion air.
 7. A cad cell flame detector is needed to ensure shutdown on flameout.
 8. An oil burner primary control is needed to supply 24 volts & for ignition controls.

9. A thermostat with terminals "R" & "W" is required for automatic control.

SUBJECT CONTENTS:

- A. Proper use of symbols
- B. Sequence operation
- C. Avoiding short circuits
- D. Making diagram readable for others
- E. Able to test/troubleshoot project from diagram

**METHODS/
TECHNIQUES:**

- A. Student troubleshooting
- B. Instructor troubleshooting/diagram
- C. Student installing project
- D. Instructor troubleshooting/lab-board

RESOURCES:

- A. W/J: Refrigeration & Air Conditioning Technology
- B. Smith: Electricity for Refrigeration, Heating & Air Conditioning
- C. Handouts & Notes from class

EVALUATION:

- A. Wiring Diagrams
 - B. Lab projects
 - C. Quiz
 - D. Homework
- W/J: read pg 614 par. 31-1 thru 31-8
Questions: pg. 644: 2, 6, 8, 12, thru 17
Read: preventive maintenance pg 641

DAY 10

SUBJECT:

From a job description, make a schematic & pictorial diagram, tuning it into a lab project.

GOAL:

Define the function of a typical plug in air conditioning unit. Completely wired by the manufacturer, with a two speed fan.

OBJECTIVES:

Make a pictorial & schematic diagram that will become a lab exercise that will operate in the systems room on the project board.

- A. Define the function of an automatically operated air conditioner with two speed fan motor that can be operated when cooling is not required.
 - Show diagram in both 120 volts & 240 volts
 - Show working diagram of two speed fan motor.
- B. List the electrical components:
 - 1. The standard home electrical source is 120/240 volts, 60 Hz, single phase (1pH), alternating current (AC).
 - 2. Fuse or circuit breakers is required by the safety code.
 - 3. A selector switch for operation control. This multi –position switch selects the following operating modes:

Switch position	Contact made
Off	None
Hi-fan	L1-Hi
Lo-fan	L1-Lo
High-cool	L1 High-cool
Lo-cool	L1 Lo-Cool

- A. A two-speed fan motor is required for lo & hi-fan & cool operation.
- B. A thermostat is required for automatic control of compressor.
- C. A permanent split capacitor (PSC) motor, with internal protector is

used to drive the compressor.

- SUBJECT CONTENTS:
- A. Proper use of symbols
 - B. Sequence operation
 - C. Avoiding short circuits
 - D. Making diagrams readable for others
 - E. Able to test/troubleshoot project from diagrams.
- METHODS/
TECHNIQUES:
- A. Student troubleshooting
 - B. Instructor troubleshoot/diagram
 - C. Student installing project on lab-board in system
 - D. Instructor troubleshooting lab board
- RESOURCES:
- A. W/J: Refrigeration & Air Conditioning Technology
 - B. Smith: Electricity for Refrigeration, Heating & Air Conditioning
 - C. Handouts & Notes from class

- EVALUATION:
- A. Wiring Diagrams
 - B. Lab projects
 - C. Quiz
 - D. Homework
- W/J: read par. 47.6 thru 47-8
Questions: pg. 1009 4, 5, 15, thru 20
Smith: pg. 446 pump down system
- Make a diagram with an on hard start kit, for areas that experience persistent low voltage.

DAY 11

SUBJECT: From a job description, make a schematic & pictorial diagram, tuning it into a lab project.

GOAL: Define the function of a package unit: a complete factory-wired single "package" air cooled air conditioner system. With a low voltage (24V) remote thermostat. The primary voltage is 208/230., 1pH 60 Hz.

- OBJECTIVES:** Make a pictorial & schematic diagram that will become a lab exercise that will operate in the system room on the project board.
- A. Define the function of the equipment: this is an automatically-controlled air conditioner with a single phase compressor
 - B. List of electrical components
 1. The electrical source is 208/230 volts, 1pH, 60Hz
 2. Fuses are required by the safety code.
 3. One single phase compressor-motor with thermal overloads is required for cooling
 4. A starter with overloads for starting the compressor
 5. A high pressure switch to protect the compressor
 6. A single phase, psc motor is used at the condenser. It is operated in tandem with the compressor.
 7. An indoor fan motor is needed to circulate the cooled air fan relay controls this motor.
 8. A 208/230 volt step-down transformer is needed to supply 24 volts current to the low voltage circuit. The transformer is fuse protected.

- SUBJECT CONTENTS:**
- A. Proper use of symbols
 - B. Sequence of operation
 - C. Avoiding short circuits
 - D. Making diagram readable for others
 - E. Able to test/troubleshooting project from diagrams
- METHODS/
TECHNIQUES:**
- A. Student troubleshooting
 - B. Instructor troubleshooting/diagram
 - C. Student installing project on lab-board in system room
 - D. Instructor troubleshooting lab board
- RESOURCES:**
- A. W/J: Refrigeration & Air Conditioning Technology
 - B. Smith: Electricity for Refrigeration, Heating & Air Conditioning
 - C. Handouts & Notes from class
- EVALUATION:**
- A. Wiring Diagrams
 - B. Lab projects
 - C. Quiz
 - D. Homework
- W/J: read Chapter 39 – pg 788
 Par. 39.1 thru 39.9
 Questions: pg. 797 – 1, 2, 5, 6, 8, 9
- Add a low pressure switch to circuit, & change compressor to a three phase motor

DAY 12

SUBJECT: **From a job description, make the schematic & pictorial diagram, turning it into a lab project.**

GOAL: Define the function of an automatically operated, 240 volt, electric resistance, hot-air furnace, designed to energize the heating elements in three steps. For added safety, each heating stage is equipped with a thermal limit switch that opens if the fan fails or any malfunction lead to overheating. All high-voltage circuits are doubly fused & all heating elements are isolated by additional fuses.

OBJECTIVES: Make a pictorial & schematic diagram that will become a lab exercise that will operate in the system room on the project board.

- A. Define the function of the equipment: this is an automatically operated, resistance hot air furnace, steps. Each heating elements equipped with a thermal limit switch that opens if the fan fails or any malfunction leads to overheating.
- B. List of electrical components:
 1. A 240 volt, 60 Hz, single-phase, AC power source is required.
 2. A fuse is required by the safety code.
 3. A thermostat, with terminals of common, heat & fan is needed for automatic control.
 4. A permanent split capacitor motor is required for hot air distribution.
 5. A fan relay is needed for each fan. Three pairs of resistance heating elements, each separated by a fusible link, are required for heat output.
 6. Each heating stage is protected by a thermal limit switch.
 7. A step-down transformer is used to supply 24 volt power to the control circuit.

8. Each stage is sequenced by a time-delay relay composed of a heater & two sets of normally open contacts: one set in the low voltage circuit, the other in the high voltage circuit.

SUBJECT CONTENTS:

- A. Proper use of symbols
- B. Sequence of operation
- C. Avoiding short circuits
- D. Making diagram readable for others
- E. Able to test/troubleshooting project from diagrams

METHODS/
TECHNIQUES:

- A. Student troubleshooting
- B. Instructor troubleshooting/diagram
- C. Student installing project on lab-board in system room
- D. Instructor troubleshooting lab board

RESOURCES:

- A. W/J: Refrigeration & Air Conditioning Technology
- B. Smith: Electricity for Refrigeration, Heating & Air Conditioning
- C. Handouts & Notes from class

EVALUATION:

- A. Wiring project
 - B. Lab projects
 - C. Quiz
 - D. Homework
- W/J/T: Read chapter 29 par. 1 thru 14
Preventive maintenance
Questions: pg. 568 1 thru 15