Section 6

Air Conditioning (Heating and Humidification)

UNIT 30—Electric Heat

30.1 Introduction

a. Produced by using nichrome wire in an electrical circuit
   1. Nickel Chromium
   2. Nichrome wire does not conduct electricity well
   3. Resistance produces heat

b. Efficient but relatively expensive—Very little loss of electrical energy

c. Structures heated with electric heat are usually well insulated to keep energy costs down

30.2 Portable Electric Heating Devices

a. Transfer heat by radiation

b. Radiant heat dissipates quickly

c. Heat concentration decreases by the square of the distance

d. Forced convection heaters—Utilize fans to move air over the element

30.3 Radiant Heating Panels

a. Installed in ceilings and controlled with individual thermostats

b. Used in residential and light commercial buildings

c. The back of the panels must be well insulated from behind

30.4 Electric Baseboard Heating

a. Convection heaters used for individual areas or whole-house applications

b. Controlled by individual thermostats

c. Usually installed on outside walls

d. Natural draft

e. Easy to control, safe, and evenly distributed

30.5 Unit Heaters

a. Usually suspended from the ceiling

b. Use fans to circulate air

30.6 Electric Hydronic Boilers

a. Similar in operation to a domestic water heater

b. Uses a pump to move the hot water through the boiler and terminal units

c. Electric boilers are very efficient

d. Relatively easy to troubleshoot and repair

30.7 Central Forced-Air Electric Furnaces

a. Used with ductwork to distribute the heated air

b. Heaters usually controlled by a single thermostat

c. Individual duct heaters can be installed for individual areas
   1. Can only be energized when the blower is operating—Interlocked
   2. Each area can be set to maintain a different temperature

d. Nichrome elements are mounted on ceramic insulation

e. Electric heaters have many exposed wires and connections

30.8 Automatic Controls for Forced-Air Electric Furnaces

a. Maintain space temperatures and protect equipment

b. Thermostats, sequencers, and contactors

30.9 The Low-Voltage Thermostat

a. Used because they are safe, compact, and easy to install and troubleshoot

b. Isolated subbase—Provides for two power supply connections
   1. Can have a heating transformer and a cooling transformer
   2. If only one power supply is used, a jumper can be installed

c. Heat anticipator
   1. Must be set at time of installation
   2. Setting corresponds to the control circuit amperage
   3. Use an ammeter with a ten-wrap to determine the amperage

30.10 Controlling Multiple Stages

a. Package sequencers
   1. Energizes electric strip heaters at different times
   2. Prevents energizing a high power load all at once

3. Utilizes a bimetal strip with a low-voltage coil around it
4. The bimetal strip heats up and warps, closing the contacts one at a time
5. Can control three heaters, a fan, and another sequencer

b. Individual sequencers
   1. Only control one heating element
   2. Can have two other circuits
      a. One circuit to control another sequencer
      b. One circuit to control a fan motor
   3. One sequencer would be needed for each heating strip

30.11 Wiring Diagrams

a. Pictorial diagrams show the location of the components
b. Schematic diagrams show the current path to the components
   1. Used by technicians to help understand the sequence of operations
   2. Also called line or ladder diagrams

30.12 Control Circuits for Forced-Air Electric Furnaces

a. Low-voltage control circuits control the heating elements
b. Safety devices and switches are integral parts of these circuits
   1. Limit switch—De-energizes a circuit in case of high temperature
   2. Thermostats—Open and close contacts in order to maintain space temperature
c. Power-passing devices—Wired in series with power consuming devices
d. Power-consuming devices—Wired in parallel with each other
e. When thermostat contacts close, a low-voltage circuit is completed
f. This circuit then activates other circuits (usually line voltage)

30.13 Fan Motor Circuits

a. Fan motor must turn on before furnace becomes too hot
b. At the end of the cycle, the fan motor must run long enough to cool down the furnace
c. Forced-air furnace with individual sequencers
   1. Common terminal feeds all power-consuming devices
   2. R from the transformer feeds power to the thermostat
   3. On a cooling call, contact is made between R and Y, and R and G
   4. On a heating call, contact is made between R and W
      a. The contacts on sequencer 1 close
      b. Power is passed on to heater 1
      c. Fan is also started (low speed)
      d. Low-voltage sequencer contacts close and pass low voltage to the next sequencer

30.14 Contactors to Control Electric Furnaces

a. Usually energize all heaters at one time
b. Time delay relays can be used to prevent this
c. Contactors are snap-action devices and are noisy
d. Common coil voltages are 24 V and 230 V

30.15 Airflow in Electric Furnaces

a. Qs = 1.08 x cfm x TD
b. Watts = amperes x volts
c. Btu/h = watts x 3.413

PREVENTIVE MAINTENANCE FOR ELECTRIC HEATING APPLIANCES

a. Check power cord
b. Do not operate heater near combustible materials

PREVENTIVE MAINTENANCE FOR CENTRAL ELECTRIC HEATING SYSTEMS

a. Units must be kept dust free
b. Thermostats should be cleaned periodically
c. Filters should be cleaned or replaced frequently as needed
d. Motors should be lubricated as needed
e. Belts should be checked regularly
f. Visually inspect contactor contacts
g. Line voltage connections should be check ed and tightened as needed

HVAC GOLDEN RULES/ADDED VALUE

a. Look and act like a professional
b. Get information from the customer
c. Check humidifiers
d. Repair frayed wired
e. Check and replace or clean air filters
f. Lubricate motors
g. Make certain all covers are secure

30.16 Service Technician Calls

a. Service call #1
   1. 20 kW electric furnace
   2. No heat. Fan comes on but the heat does not
   3. System has individual sequencers with a fan-starting sequencer
   4. Problem: the first stage sequencer has a burned out coil

5. Technician verifies that there is 24 V in the control circuit (the fan is operating)
6. Amperage is checked in the heater circuits (no current)
7. 24 V is present at the coil of the first stage sequencer
8. Contacts on the sequencer are open
9. Sequencer coil is checked and found to be open
10. Sequencer changed and system is started up

b. Service call #2
1. No heat. Customer smells smoke
2. Problem: fan motor has an open circuit
3. Heating unit is cycling on the limit control
4. Heater is pulling 40 amps but the fan is not on
5. Voltage is being supplied to the fan but it is not operating
6. Motor is changed and the system is restarted

c. Service call #3
1. Routine service call
2. Technician finds burned insulation on heater wires
3. Technician points this out to the store manager
4. Technician repairs the wiring

d. Service call #4
1. Package air-conditioning unit with 30 kW of electric heat
2. Heating system not putting out enough heat
3. First day of very cold weather
4. Thermostat set at 72°, space temperature is 65°
5. Two fusible links are open due to dirty filters
6. Technician finds that two of the six heaters are not drawing current
7. Technician checks the contacts of all the sequencers and they are closed
8. All stages have line voltage feeding them
9. Problem and solution

UNIT 31—Gas Heat

31.1 Introduction to Gas-Fired Forced Hot Air Furnaces

a. Heat-producing system
1. Manifold and controls—Meters the flow of gas to the burners
2. Burners, heat exchanger, and venting system
3. Flue gases are created when gas is burned
4. Venting system removes flue gases from structure

b. Heated air distribution system
1. Blower
2. Ductwork and ductwork assembly

31.2 Types of Furnaces

a. Upflow
1. Stands vertically
2. Hot air is discharged from the top of the unit

b. “Low boy”
1. Used in areas with low headroom
2. Both the return and supply air are at the top
3. Blower located behind the furnace

c. Downflow or counterflow
1. Air intake is at the top
2. Air discharge is at the bottom

d. Horizontal
1. Positioned on its side
2. Used in crawl spaces or attics and can be suspended from floor joists
3. Gas fuels

e. Multipoise or multipositional
1. Can be installed in any direction
2. Minimal field modification
3. Equipped with extra internal connections
4. Equipped with multiple safety controls

31.3 Gas Fuels

a. Natural gas
1. Composed of 90% to 95% methane and other hydrocarbons
2. Specific gravity is 0.60 so it is lighter than air
3. 1,050 Btu of heat energy is produced when one cubic foot of natural gas is burned
4. Natural gas has no color or odor
5. Displaces oxygen and can lead to suffocation
6. Can explode if it accumulates in an area
7. Sulfur compounds, called *odorants,* add a garlic smell to the gas for leak detection purposes
8. Gas flows to the burners through a small opening in a fitting called a *spud*

b. Manufactured gas
1. Specific gravity is 0.60 so it is lighter than air
2. 530 Btu of heat energy is produced when one cubic foot of manufactured gas is burned

c. Liquified petroleum
1. Liquified propane, butane, or a combination of both
2. Kept a liquid by keeping it under pressure until used

3. Utilizes a tank regulator
4. Should not be used alone in a natural gas furnace (it will overfire)

d. Propane
1. Boils at –44°F at atmospheric pressure
2. 2,500 Btu of heat energy is produced when one cubic foot is burned
3. Specific gravity is 1.52 and is heavier than air
4. Displaces oxygen so it can cause suffocation
5. Can explode when allowed to accumulate in an area

e. Butane
1. 3,200 Btu of heat energy is produced when one cubic foot is burned
2. When mixed with air, it is called *butane air gas*
3. Liquid butane has a high boiling temperature
4. Tank requires a heater because at any temperature below 31°F the tank will be in a negative pressure
5. Butane is not very popular, difficult to work with

f. Manifold pressures
1. Should be set according to manufacturer's specifications
2. Expressed in inches of water column (in. W.C.)
3. 27.7 in. W.C. = 1 psig
4. Natural gas and propane/air mixture: 3 to 3 1/2 in. W.C.
5. Manufactured gas (below 800 Btu quality): 2 1/2 in. W.C.
6. LP gas: 11 in. W.C.
7. Water manometer
   a. Used to measure gas pressure
   b. Standard manometers read in inches of water column
   c. Gas pressure is introduced to one side of the manometer
   d. The other side is open to the atmosphere
   e. Pressure is determined by the difference of these two pressures
8. Digital manometer
   a. Can measure positive and negative pressures
   b. No water to spill
   c. Displays pressure without calculations

31.4 Gas Combustion

a. Combustion requires fuel, oxygen, and heat
b. Rapid oxidation or burning
c. Ignition temperature for natural gas is about 1,100° to 1,200°F
d. Perfect combustion produces carbon dioxide, water, and heat
e. Imperfect combustion produces carbon monoxide, soot, and other products
   1. Carbon monoxide is a colorless, odorless, poisonous gas
   2. Soot lowers furnace efficiency
f. Atmospheric burners—Gas and air mixtures are burned at atmospheric pressure
g. Gas is metered to the burner through the orifice
h. Velocity of the gas pulls in the primary air
i. The burner tube diameter is reduced at the venturi
j. Gas and air are mixed in the mixing tube
k. The mixture is forced through the burner ports or slots and is ignited
l. Secondary air is drawn in to support combustion
m. Flame should be blue with orange, not yellow, tips
n. Yellow tips indicate an air-starved flame, not enough primary air, emitting carbon monoxide
o. Orange flames indicate burning dust particles
p. Gas pressure and primary air are the only adjustments that can be made
q. 0 to 4% natural gas in the gas/air mixture will not burn (mixture too lean)
r. 4% to 15% natural gas in the gas/air mixture will burn, but could explode when ignited if allowed to accumulate
s. 16% to 100% natural gas in the gas/air mixture will not burn or explode
t. Mixture percentages are called the *limits of flammability*
u. Limits of flammability vary for different gases
v. Perfect combustion requires two parts oxygen to one part methane
w. Excess primary air, usually 50%, is supplied for better combustion
x. Flame impingement is when the flame cools down below ignition temperature (usually caused by burner misalignment, flame hits the side of the chamber)
y. Flame impingement causes poor combustion and produces soot and carbon monoxide

31.5 Gas Regulators

a. Drops the gas pressure to the proper level
b. Maintains constant pressure at the outlet where the gas is fed to the valve at the appliance
c. LP gas regulators are located at the supply tank

d. Many regulators can be adjusted
e. Most regulators are built into the gas valve (combination gas valves)
f. Always consult manufacturer's specifications when setting regulators
g. Converting from natural gas to LP involves:
    1. Changing the regulator pressure
    2. Installing smaller burner orifices
    3. Installing new pilot orifice
    4. Possibly changing the ignition/control module

31.6 Gas Valve

a. Gas is piped from the pressure regulator to the gas valve and then on to the manifold
b. Gas valves equipped with pilot valves are called combination valves

31.7 Solenoid Valve

a. Usually normally closed valves
b. When the coil is energized, the plunger is pulled into the coil, opening the valve
c. Plunger is spring loaded to close the valve when the coil is de-energized, stopping the flow of gas to the appliance

31.8 Diaphragm Valve

a. Uses gas pressure to open the valve—*Pilot-operated valve*
b. Valve is closed
    1. Coil is de-energized
    2. Diaphragm is pushed down
    3. Gas pressure pushing down on diaphragm
    4. Atmospheric pressure pushing up on diaphragm
c. Valve is open
    1. Coil is energized
    2. Diaphragm is pushed up
    3. Gas above the diaphragm is vented to the pilot
    4. Gas pressure below pushes the diaphragm up
d. Thermally operated valve
    1. On a call for heat, a bimetal strip is heated, causing it to warp
    2. When the bimetal strip warps, it closes the valve to the upper chamber and opens the bleed valve
    3. The bleed valve sends the gas to the pilot where it is burned
    4. The pressure below the diaphragm pushes the valve open

31.9 Heat Motor-Controlled Valve

a. On a call for heat, a rod attached to the valve is heated
b. This rod expands or elongates and opens the valve
c. The rod is heated by resistance wire that is energized by the heating circuit
d. When the circuit is opened, the rod contracts and the spring closes the valve
e. It takes about 20 seconds to open the valve and 40 seconds to close it

31.10 Automatic Combination Gas Valve

a. Used in most modern gas furnaces
b. Automatic combination valves are equipped with
    1. A manual control
    2. Gas supply for the pilot
    3. Pilot adjustment and safety shutoff feature
    4. Pressure regulator
    5. Main gas valve controls
    6. Programmed safe lighting features
    7. Servo pressure regulators
        1. Senses gas valve outlet pressure (working pressure)
        2. Maintains an even outlet pressure
c. Some valves have a dual shutoff and are called *redundant gas valves*
d. Standing pilot automatic gas valves
    1. Pilot burner is lit all the time
    2. Safety shutoff valve
    3. Lighting the pilot
        a. Push and hold reset button in "pilot" position
        b. Manually light the pilot
        c. Pilot flame engulfs the thermocouple
        d. Signal sent to valve's power unit
        e. Pilot valve remains open
    4. Two automatic valves
    5. First automatic valve
        a. Controlled by solenoid
        b. Thermostat controls the solenoid
        c. Spring-loaded valve
    6. Second automatic valve
        a. Thermostat controls the solenoid
        b. Servo-operated valve
        c. Monitors the gas pressure at the outlet of the gas valve
        d. Valve adjusts to maintain constant outlet pressure
        e. Self-balancing system
e. Intermittent pilot automatic gas valves
    1. Pilot lit when there is a call for heat
    2. When thermostat is satisfied, the pilot will go out
    3. No power unit, reset button, or thermocouple circuit
    4. Two automatic valves
        a. First valve is solenoid controlled
        b. Second valve is servo operated

5. First valve opens the passage for pilot gas
6. Pilot gas is ignited and the flame proved
7. Servo-operated valve opens for main gas
8. Both valves close when the call for heat ends

f. Direct burner automatic gas valves
1. Electronic module or integrated furnace controller lights the main burner directly
2. No pilot flame
3. Ignition by spark, hot surface igniter, or glow coil
4. No power unit or reset button
5. Two automatic valves
   a. One is solenoid controlled
   b. One is servo controlled
6. On a call for heat
   a. Both solenoids are energized
   b. Gas is ignited within 4–12 seconds
   c. Flame is proved and the burner stays lit
   d. If flame is not proved, gas valve will be de-energized

g. Slow opening valves
1. Second valve opens slowly
2. Main burner flame grows slowly
3. Slow and controlled ignition

h. Redundant gas valves
1. Two or three valve operators in series with each other
2. Operators are wired in parallel
3. Safety feature
4. Any one operator can block gas to main burner

31.11 Manifold

a. Manifold is attached to the outlet of the gas valve
b. Gas flows through the manifold to the burners
c. Burners are also mounted to the manifold

31.12 Orifice

a. Gas flow from the manifold to the burners through the orifice
b. Orifice is a precisely sized hole located in the spud, which is screwed into the manifold
c. The orifice allows the correct amount of gas into the burner

31.13 Burners

a. This is where combustion takes place
b. Uses primary and secondary air
c. Primary air enters the burner with the gas
d. Secondary air is provided to ensure proper combustion
e. Gas is ignited by the pilot
f. *Atmospheric burners* use air at atmospheric pressure
g. *Cast iron burners*—Drilled or slotted
h. Stamped steel slotted burners
i. Ribbon burners
j. Single-port burners
1. Upshot
2. Inshot
   a. Aluminized steel
   b. No primary or secondary adjustments
   c. Often used with induced draft systems

k. Induced-draft systems
1. Pull combustion gases through the heat exchanger
2. Slight negative pressure in the heat exchanger

l. Forced-draft systems
1. Combustion blower motor at inlet of heat exchanger
2. Combustion gases pushed through the heat exchanger
3. Positive pressure in the heat exchanger

31.14 Heat Exchangers

a. Many burners are located at the bottom of the heat exchanger
b. High-efficiency furnaces have burners located at the top of the furnace
1. Combustion gases are pulled through the heat exchanger
2. Combustion gases will condense and drain from the unit

c. Provide rapid heat transfer between air from the conditioned space and combustion gases
d. Each section of the heat exchanger has its own burner
e. Heat exchangers must have the proper air flow across them
1. Too much airflow can cause the flue gases to cool
   a. Flue gases may condense
   b. Condensing flue gases contain acid
2. Not enough airflow can overheat the exchanger

f. Temperature rise = leaving air temperature – return air temperature
g. Correct temperature rise can be found on the furnace nameplate
h. Normal temperature rise ranges from 40° to about 70°F
i. The temperature rise of the furnace decreases as the efficiency increases

j. Airflow across a gas furnace, cfm = $\frac{Qs}{1.08 \times TD}$
k. Gas furnaces are rated by input capacity
l. Furnace output capacity = furnace input capacity x efficiency percentage
m. Heat exchangers must not leak
n. The heated air must be separated from the combustion gases
o. Modern heat exchangers have serpentine paths to increase heat transfer
p. Transition and collection boxes
q. High-efficiency heat exchangers are subjected to condensing combustion gases
r. Condensing heat exchangers are designed to handle the condensation
s. Inshot burners are commonly found on systems with serpentine heat exchangers

31.15 Fan Switch

a. Turns the blower on and off automatically
b. Can be controlled by time or temperature
c. Fan does not start immediately so the heat exchanger has time to heat up
d. Fan does not turn off at the end of the cycle until the heat exchanger has cooled down
e. *Temperature-On-Temperature-Off*—The blower turns on and off depending on temperature
f. *Time-On-Temperature-Off*—The blower turns on after a time delay and off depending on temperature
g. *Time-On-Time-Off*—Uses a time delay to turn the blower on and off
h. Time-On-Time-Off switches mounted so the heat from the furnace heat exchanger will not influence it
i. Electronic modules can be used to control blower operation
j. DIP switches control the fan's off-cycle time
k. No external control over on-cycle time
l. Some controls have fixed blower on and blower off times

31.16 Limit Switch

a. Safety device
b. If the heat exchanger overheats, the limit switch will open the main gas valve circuit causing the valve to close
c. Limit switch will normally open between 200° and 250°F
d. Fan and high limit control
   1. Can be low voltage, line voltage, or a combination of both
   2. Fan and limit contacts controlled by the same bimetal strip
   3. Jumper is removed when each control is to be used at a different voltage
e. Limit controls can be snap-action, bimetallic switches
   1. Can be manual or automatic reset devices
   2. Snap-action discs can be used as flame rollout safety controls
      a. Wired in series with the high limit control
      b. Manually reset

31.17 Pilots

a. Most conventional gas furnaces use pilot lights to ignite the gas
b. *Aerated*—Air is mixed with the gas before entering the burner
c. *Nonaerated*—Use only secondary air at the point of combustion
d. Standing pilot light burns continuously
e. Provides heat for safety device that shuts gas valve if pilot goes out

31.18 Safety Devices at the Standing Pilot

a. *Flame proving devices* prevent gas from flowing through the gas valve if the pilot light goes out
b. Thermocouples and thermopiles
   1. Thermocouples are two dissimilar metals welded together at one end
   2. Thermocouple is connected to a gas shutoff valve
   3. When heated, a small voltage is generated (millivolts)
   4. Thermocouple is located next to the pilot (heat source)
   5. As long as the thermocouple is hot, the gas valve will remain open
   6. If the pilot goes out, the thermocouple will cool and the millivolt signal will be lost
   7. When the thermocouple cools, the gas valve will close in about 30 seconds
   8. A thermopile consists of several thermocouples wired in series to increase the voltage
c. Bimetallic Safety Device
   1. The bimetallic strip is heated by the pilot
   2. The strip, when heated, causes a set of contacts to close, opening the gas valve
   3. If the pilot goes out, the bimetallic strip will cool and warp, opening the contacts, causing the gas valve to be de-energized in about 30 seconds
d. Liquid-Filled Remote Bulb
   1. Includes a mercury-filled diaphragm, tube, and bulb

2. The bulb is heated by the pilot flame
3. When heated, the liquid expands, causing the diaphragm to expand
4. The pressure on the diaphragm closes a set of contacts in the gas valve circuit
5. When the pilot goes out, the liquid contracts and causes the contacts to open, closing the gas valve in about 30 seconds

31.19 Ignition Systems

a. Can ignite either the pilot or main burner
b. Intermittent pilot
   1. A spark ignites the pilot which in turn lights the main gas burners
   2. Pilot is on only when there is a call for heat
   3. Natural Gas
      a. Not considered a 100% shutoff system
      b. Pilot valve will remain open if pilot does not light
      c. Main gas will not open unless pilot is lit
      d. On a call for heat, 24 V are supplied to the ignition module which sends power to the pilot igniter and the pilot valve coil
      e. The coil opens the pilot valve and the spark ignites the pilot
      f. Main gas is opened
         1. Mercury vapor tube
            a. Remote thermal bulb located at the pilot
            b. When heated, the bellows or diaphragm is expanded
            c. Electrical contacts are closed
            d. Main gas opens
         2. Flame rectification system
            a. AC is converted to DC by the pilot's heat
            b. Main gas will open when DC is detected
      g. Spark arcs about one hundred times per minute
      h. Main gas opens approximately 50 to 70 seconds after initial call for heat (time varies depending on the control used)
   4. LP Gas
      a. Considered a 100% shutoff system
      b. 100% shutoff is necessary for fuels that are heavier than air
      c. If the pilot does not light, the system will lock out after 90 seconds
      d. System must be manually reset
c. Direct Spark Ignition (DSI)
   1. No pilot is used
   2. Components used are the DSI module and the igniter/sensor assembly
   3. Sensor rod sends a signal to the DSI module when the furnace has fired
   4. If the flame is not established within the specified time period, the system will go into a safety lockout
   5. After a safety lockout, the system normally has to be manually reset
   6. Ignition problems are usually caused by improperly adjusted spark gap, igniter positioning, and/or bad grounding
d. Hot Surface Ignition
   1. Uses high-resistance silicon carbide
   2. More durable than glow coils
   3. Silicon carbide is placed in the flow of the gas and is heated before the gas valve is opened
   4. When the gas valve is opened, there should be immediate ignition
   5. The hot surface ignition system is very brittle, avoid bumping it
   6. Igniter failure can be caused by
      a. Higher-than-rated supply voltage
      b. Dust and fiberglass accumulation
      c. Delayed ignition
      d. Overfiring
      e. Furnace short cycling
   7. Can be used to light the pilot or for direct ignition of the main burner
   8. Newer hot surface igniters are made from silicon nitride
      a. More durable
      b. Resist breakage
      c. Are still fragile
   9. Some hot surface igniters operate on 24 V
      a. Usually hot surface to pilot
      b. Less chance of high-voltage shock

31.20 Flame Rectification

a. Uses the flame as a switch
b. The flame contains ionized combustion gases
c. Flame located between to electrodes of different sizes
d. Alternating current is fed to the electrodes
e. When the flame is present, the circuit between the electrodes is completed
f. Spark to pilot ignition—Electrodes are the pilot hood and the flame rod
g. DSI—Electrodes are the main burners and the flame rod or sensor
h. Dual-rod systems (remote sensing)—One rod for ignition, one for sensing
i. Single-rod system (local sensing)—Uses a combination sensor and igniter
j. AC signal will resemble DC

k. Furnace recognizes the DC signal and allows main gas valve to open
l. DC signal is usually from 1 to 25 microamperes
m. Integrated furnace controllers (IFC)
n. Troubleshooting flame rectification systems
    1. If there is no flame, the problems lies with ignition, not flame rectification
    2. Flame present and goes out (closed gas valve)
        a. Dirty or corroded electrodes
        b. Loose or disconnected wire
        c. Improperly positioned flame rod
        d. defective flame signal amplifier
        e. Poor ground connection
    3. Must know the proper sequence of operations
    4. Flame rectification problems
        a. Misadjusted pilot burner
        b. Insufficient gas pressure
        c. Insufficient power to system
        d. Broken, loose, or disconnected wired or cables
        e. Broken electrode or hot surface igniter
o. Flame rectification maintenance
    1. Replace wires every 3 to 5 years
    2. Wires between electrodes and IFC or ignition module should be as short as possible
    3. Bent or warped electrodes should be replaced
    4. Check for proper gas pressure
    5. Check electrodes and ground terminals for dust and insulation buildup
p. Measuring flame current
    1. Microammeter in series with the flame rod or system ground
    2. Meter can be connected between the burner ground terminal and the module or IFC

31.21 High-Efficiency Gas Furnaces

a. Annual fuel utilization efficiency rating (AFUE) allows consumers to compare furnaces prior to purchase
b. Efficiency can be increased by keeping excessive heat from being vented to the atmosphere
c. All forced air gas furnaces have efficiency ratings
d. Furnace efficiency factors
    1. Type of draft
    2. Excess air
    3. Change in temperature across the heat exchanger
    4. Stack temperature
e. Conventional furnaces
    1. Standard efficiency
    2. 78% to 80% AFUE
    3. Atmospheric injection or draft hood
    4. 40% to 50% excess air
    5. 70° to 100° temperature rise across heat exchanger
    6. 350° to 450° stack temperature
    7. Non-condensing
    8. One heat exchanger
f. Mid-efficiency furnaces
    1. 78% to 83% AFUE
    2. Induced or forced draft
    3. 20% to 30% excess air
    4. 45° to 75° temperature rise across heat exchanger
    5. 275° to 300° stack temperature
    6. Non-condensing
    7. One heat exchanger
g. High-efficiency furnaces
    1. 87% to 97% AFUE
    2. Induced or forced draft
    3. 10% excess air
    4. 35° to 65° temperature rise across heat exchanger
    6. 110° to 120° stack temperature
    7. Condensing furnaces
    8. Two or three heat exchangers
    9. Use PVC of CPVC pipe for vent to avoid corrosion
h. As excess air increases, dew point temperature increases
i. Low temperature rises result from increased airflow through the exchanger
j. Pulse furnace
    1. Ignites minute quantities of gas 60 to 70 times per second
    2. Air and gas mixture enters the combustion chamber
    3. Mixture is ignited with a spark
    4. Ignition forces the combustion materials to the exhaust decoupler
    5. Pulse is reflected back to the chamber where more gas/air mixture is ignited
    6. The process is repeated
    7. Uses heat exchangers to absorb heat
    8. Air is circulated over the heat exchanger to the conditioned space
    9. Uses a condensing component

31.22 Electronic Ignition Modules and Integrated Furnace Controllers (IFC)

a. Used to control the ignition and sequence of operation
b. 100% shutoff system
    1. Pilot and main gas valves close on a failure of flame-proving device

2. In the past, commonly found only on LP systems
3. New systems have non-100% shutoffs on LP systems
   a. Short shutdown times
   b. Short time delay between ignition attempts

c. Non 100% shutoff system
   1. Main gas valve closes but pilot remains open on a failure of flame proving device
   2. Continually tries to relight the pilot
   3. Ignition retry sequences for both natural gas and LP
   4. Soft shutdown periods of 5 minutes are common

d. Continuous retry with 100% shutoff
   1. 100% shutoff with 90-second ignition trial
   2. Will continually try to light pilot after shutoff period

e. Soft lockout
   1. Allows a certain amount of time to light or re-light pilot
   2. If time elapses, module will shut down for a period of time
   3. Will keep trying to light the system
   4. Can last anywhere from 5 minutes to 1 hour
   5. After soft lockout period, system will go into hard lockout

f. Hard lockout
   1. Allows a certain amount of time to light or re-light pilot
   2. If time elapses, system will go into hard lockout
   3. Power must be interrupted and restored to reset

g. Pre-purge
   1. Energized combustion blower prior to ignition
   2. Used to remove any flue gases from flue pipe prior to ignition

h. Inter-purge
   1. Combustion blower operates for a period of time between ignition tries
   2. Helps remove unburned gas from previous ignition attempts

i. Post-purge
   1. Combustion blower operates at the end of each heating cycle
   2. Helps ensure that only air is present in the heat exchanger at the beginning of each cycle

j. Integrated furnace controller (IFC)
   1. Provides sequence of operations for the system
   2. Monitors system inputs
   3. Can be programmed for different functions

31.23 Two-Stage Furnaces

a. Two-stage gas valve

b. Two-stage combustion blower

c. Two pressure switches to prove flame
   1. Low-pressure switch for low blower speed
   2. High-pressure switch for high blower speed

d. First stage gas pressure is 1.75 in. W.C.
   1. First solenoid valve open
   2. 50% to 70% of total heating output

e. Second stage gas pressure is 3.5 in. W.C.
   1. Second solenoid valve is open
   2. 100% of total heating output

f. Provide better control of room temperature

31.24 Modulating Gas Furnaces

a. Follows the heat loss of the structure

b. Discharge air temperature is modulated to provide even space heating

c. Adjusts to changes in gas heating values and air density

d. Senses exact heating requirements of the space

e. Optimizes furnace efficiency and performance

f. Very small temperature swings in the occupied space

g. Utilize variable-speed blowers

31.25 Venting

a. Conventional gas furnaces
   1. Vent flue gases quickly to prevent them from cooling
   2. Cooling flue gases can condense and produce corrosive materials
   3. Furnaces lose efficiency since heat is lost up the flue
   4. Equipped with draft hoods
      a. Flue gases are mixed with room air (dilution air)
      b. Creates upward draft in the flue pipe
   5. Draft diverters alter the path of flue gases in the event of a downdraft
   6. Must use B-vent or approved masonry materials
      a. Double wall construction with air space in between
      b. Inner wall is aluminum; outer wall is aluminum or steel
      c. Vent should be properly sized and pitched
      d. Vent runs should be as short as possible

e. Venting codes must always be followed
7. Chimneys must be properly lined
    a. Condensation can cause damage to chimney mortar
    b. Condensation occurs at start-up and during short runs times in mild weather
8. Automatic vent dampers help prevent heat loss
    a. Are usually closed when the furnace is off
    b. When the vent is heated, the damper opens
    c. On high-efficiency furnaces, small blowers are used in the vent system (blower is on only when the furnace is on)

b. High-efficiency furnaces
    1. Recirculate flue gases through a heat exchanger to reclaim more heat
    2. Use small fans to remove flue gases
    3. Since the gases are cooled, they produce corrosive materials
    4. Plastic vent pipe is used because it is not damaged by the corrosive materials

c. All gas furnaces must be vented properly
    1. They must have the proper amount of combustion air
    2. They must have the proper amount of dilution air
    3. Example:
        a. 10 cubic feet of air is needed to burn 1 cubic foot of natural gas
        b. 5 cubic feet of air is needed for each cubic foot of natural gas to ensure there is enough oxygen
        c. 15 cubic feet of air is needed at the draft hood
        d. A total of 30 cubic feet of air is required for each cubic foot of natural gas

31.26 Gas Piping

a. Technicians should be familiar with national and local codes
b. Technicians should be familiar with the characteristics of natural and LP gas
c. Pipe sizing and furnace ratings vary according to the gas characteristics
d. Piping should be kept simple with as few fittings as possible
e. Long pipe runs and fittings add resistance to the flow of gas
f. Undersized pipe will cause a pressure drop
g. Systems should be designed for a maximum pressure drop of 0.35 in. W.C.
h. Steel or wrought iron pipe should be used
i. Make certain that all burrs are removed and that the threads are not damaged
j. All loose particulate matter should be removed from the inside of the pipes
k. Use pipe dope or teflon tape when joining pipes
    1. Be sure pipe dope does not enter the pipe
    2. Be sure teflon tape does not block the pipe
l. At the furnace, there should be the following components:
    1. Drip trap
        a. Installed to catch dirt, scale, and moisture
        b. Can be cleaned out if necessary
    2. Manual shutoff valve
        a. Required by most localities
        b. Should be within 2 feet of the furnace
    3. Union
        a. Makes part replacement easier
        b. Gas valve or entire furnace can be removed without disassembling other piping
m. Piping assembly must be leak tested
    1. Soap bubbles
    2. Manometer
    3. High-pressure test
n. System must be purged after leak test is complete

31.27 Gas Furnace Wiring Diagrams and Troubleshooting Flowcharts

a. Internal workings of IFC boards are not often evaluated in the field
b. Circuits feeding the IFC are evaluated
c. Circuits fed by the IFC are evaluated
d. Use input/output troubleshooting procedures
e. Static electricity can damage the IFC
f. Technicians should be physically grounded before touching the IFC
g. Furnace diagram and sequence of operation must be obtained
h. Flowcharts used in conjunction with the wiring diagrams
i. Avoid creating short circuits on the IFC board

31.28 Troubleshooting the Safety Pilot-Proving Device—The Thermocouple

a. When the thermocouple is heated, it generates a small current
b. This current holds a safety valve open
c. If the pilot goes out, the thermocouple cools and the valve closes

d. No-load thermocouple test
   1. Heat thermocouple for 5 minutes
   2. Read the voltage produced by the thermocouple
   3. Any voltage less than 20 mV indicates a defective thermocouple
e. Testing a thermocouple under load
   1. Use a thermocouple testing adapter
   2. Voltage readings can be taken while the unit is operating
   3. A voltage over 9 mV indicates that the thermocouple is good
   4. Check individual manufacturer's specifications

31.29 Troubleshooting Spark-Ignition or Intermittent Pilot Systems

a. If the trouble is in the circuit board, the entire board needs to be replaced
b. Flame rectification uses the flame to convert AC to DC
c. The DC is sensed by the circuit to prove the pilot and open the gas valve
d. Line voltage should be present at the transformer primary
e. 24 V should be present from "C" to "LIM-1," "R," "W," and "GAS-1"
f. The ignition system should be sparking (pilot trying to light)
g. 6H relay should have changed over (NO contacts closed, NC contacts open)
h. There should be 24 V between "C" and "GAS-3"
i. If the gas valve does not open, there is a problem with it
j. If there is no voltage at the "W" terminal, a jumper can be placed from "R" to "W" to see if there is a spark. If so, the problem is in the thermostat or associated wiring
k. The fan is controlled by a time delay relay

31.30 Combustion Efficiency

a. Incomplete combustion produces carbon monoxide
b. Atmospheric burners use primary and secondary air
c. Correct air adjustments are essential for combustion efficiency
d. Carbon dioxide tests aid in the adjusting of the secondary air
e. Carbon dioxide percentage increases as secondary air decreases
f. Ultimate percentages of carbon dioxide content for various gases
   1. Natural gas: 11.7% to 12.2%
   2. Butane gas: 14.0%
   3. Propane gas: 13.7%
g. Correct flame
   1. Should burn blue (not yellow) with small orange tips
   2. Should extend directly upward from the burner port

HVAC GOLDEN RULES

a. Always carry proper tools
b. Make and keep firm appointments
c. Keep customers informed
d. Always leave furnace and surrounding area clean
e. Check standing pilots
f. Check, clean, and/or replace air filters
g. Lubricate bearings
h. Check burner compartment

PREVENTIVE MAINTENANCE

a. Rust, dust, and scale should be removed from the burner
b. Burner and manifold can be removed for extensive cleaning
c. Compressed air can be used for cleaning
d. Check burner alignment (no flame impingement)
e. Flame should burn blue (not yellow)
f. Check burner for correct ignition
g. Observe pilot flame and burner flame with blower operating
h. Examine venting system for obstructions
i. Check forced draft blower (high-efficiency furnaces)
j. Check condensing portion of the furnace (condensing furnaces)
k. Check operation of limit switch (disconnect fan and allow unit to run)

31.31 Service Technician Calls

a. Service call #1
   1. Upflow furnace, standing pilot, air conditioning
   2. Complaint: no heat
   3. Problem: shorted gas valve caused transformer to burn out
   4. Technician notices:
      a. Fan will not start when thermostat is set to FAN ON
      b. Secondary winding of transformer reads 0 V
   5. Secondary winding of transformer is checked (open winding)
   6. Resistance of low-voltage circuit is checked (only 2 ohms)
   7. Normal resistance of a gas valve coil is at least 20 ohms
   8. Gas valve and transformer are replaced
   9. Air filters are replaced and system is started up

b. Service call #2
    1. Customer complaint: furnace fumes are being smelled
    2. Unit has not run for a couple of weeks because weather was mild
    3. Technician performs a match test and notices flue gases are not rising up the flue
    4. Technician checks the burner and heat exchanger and finds everything to be clear
    5. Technician goes to the roof and finds a shingle on top of the chimney
    6. Shingle is removed and match test is repeated
    7. Air filters changed, blower lubricated, and furnace restarted
c. Service call #3
    1. Customer thinks his gas bill is too high and wants his system checked
    2. Furnace is turned on (standard efficiency furnace)
    3. A flue gas sample is taken (drawn into the sample chamber)
        a. Blower has been running for at least 5 minutes
        b. Flue gas temperature has stabilized
    4. Flue gas reading shows an efficiency of 80% (normal)
    5. The furnace is turned off and allowed to cool
    6. Burners, draft diverter, and flue pipe are disconnected and inspected
    7. Heat exchanger is vacuumed out and the burners are blown out with compressed air
    8. Fan motor is oiled and filters are changed
    9. The furnace is restarted, still running at about 80% efficiency
d. Service call #4
    1. Pilot light goes out after it has been lit for a few minutes
    2. Problem: the heat exchanger has a small hole in it, close to the pilot
    3. Technician sets thermostat to call for heat
    4. Technician notices the standing pilot is not lit
    5. Pilot light is re-lit
    6. Furnace starts up, but the pilot blows out when the blower comes on
    7. Technician notices the hole in the heat exchanger
    8. Customer is instructed that the furnace cannot be operated due to the potential danger
    9. Furnace is replaced
e. Service call #5
    1. Customer complaint: no heat
    2. Electronic intermittent ignition system
    3. Main gas valve coil is shorted and the low voltage transformer is burned
    4. Technician notices that the blower runs continuously (even in OFF)
    5. Secondary voltage is checked at the transformer (0 V)
    6. Transformer is replaced, but it becomes very hot
    7. Electronic circuit board and fuse are replaced, transformer still hot
    8. All amperages are normal until the gas valve is energized
    9. Amperage rises to 3 amps when the gas valve is energized
    10. Resistance of the gas valve is checked and found to be too low
    11. Gas valve is replaced and the system is restarted
f. Service call #6
    1. Gas furnace
    2. Complaint: cold air being blown into the occupied space at the end of the heating cycle
    3. Problem: blower motor's off-delay timing set too long
    4. Furnace has an IFC with DIP switches
    5. Technician operates the furnaces and then cycles it off
    6. Technician measures the amount of time between the end of the cycle and when the blower cycles off
    7. Time is 180 seconds
    8. Technician adjusts DIP switches for a 60 seconds off-delay
    9. Technician operates the furnaces and then cycles it off
    10. Technician measures the amount of time between the end of the cycle and when the blower cycles off
    11. Time is now 60 seconds
g. Service call #7
    1. Complaint: furnace not heating the house
    2. There is no airflow from any of the supply registers
    3. Problem: combustion blower burned and system is not firing
    4. Technician observes self-diagnostic lights and determines that the draft pressure switch is open
    5. Defective combustion blower prevents pressure switch from closing
    6. The combustion blower is removed from the unit and checked with an ohmmeter
    7. Reading is infinite resistance

8. Combustion blower is replaced
9. System is restarted and checked

h. Service call #8
1. Complaint: blower operational but no heat in the space
2. Dirty air filter caused high limit to open
3. Self-diagnostic lights indicate that the limit switch is open
4. The blower motor is operating
5. Technician checks the air filter and finds it completely clogged
6. Technician resets the IFC
7. Filter is replaced
8. System is restarted and checked

i. Service call #9
1. Furnace stopped in the middle of the night
2. Furnace is old and has a thermocouple for the safety pilot
3. Technician notices that the thermostat is set 10° higher than the room temperature
4. Fan comes on when the thermostat is set to FAN ON
5. Technician notices that the pilot light is not on
6. Gas valve is a 100% shutoff
7. The pilot light is lit while the red button is held down
8. After 30 seconds the red button is released and the pilot goes out
9. Problem and solution

j. Service call #10
1. Furnace is not heating the house (furnace is hot, but no heat is moving into the house)
2. Room thermostat is set to call for heat
3. Furnace heats up but the fan does not come on
4. Problem and solution

k. Service call #11
1. Customer complaint: no heat and there is a sound like a clock ticking
2. Technician hears the arcing sound
3. Burner shield is removed and the pilot is lit manually
4. The arcing stops and the burner lights after the proper time delay
5. Problem and solution

UNIT 32—Oil Heat

32.1 Introduction to Oil-Fired, Forced-Warm Air Furnaces

a. Two main systems in a warm air oil-fired furnace
1. Heat producing system
2. Heat distribution system

b. Heat producing system consists of
1. Oil burner
2. Fuel supply components
3. Combustion chamber
4. Heat exchanger

c. Heat distributing system consists of
1. Blower fan which moves air through the system ductwork
2. Related components

32.2 Physical Characteristics

a. Low-boy
b. Upflow
c. Downflow
d. Horizontal

32.3 Fuel Oils—Heating Oils

a. Fuel oil delivered in liquid form
b. Six grades of fuel oil
c. The lower the number, the lower the weight of the oil
d. Made up mostly of hydrogen and carbon (hydrocarbons)
e. Number 2 oil is the most common
f. Approximately 140,000 Btu/gal. for number 2 oil
g. Flash point
1. Lowest temperature at which fuel will ignite for a short period of time
2. Heavier oils are harder to ignite

h. Fire point
1. Temperature at which fuel will continue to burn
2. Higher temperature, than the flash point

i. Viscosity
1. Thickness of oil
2. The lower the temperature, the higher the viscosity

j. Carbon residue
k. Water/sediment content
l. Pour point
1. Lowest handling temperature of oil
2. Pour point for number 2 oil is 20°F

m. Ash content
n. Distillation quality

32.4 Preparation of Fuel Oil for Combustion

a. For combustion to take place, the liquid oil must be turned to a gaseous state
b. *Atomization* is the process of breaking the oil down into tiny droplets by forcing the oil under pressure through a nozzle
c. The oil droplets are mixed with air which contains oxygen

d. The transformer provides the spark through the electrodes to provide the heat needed to ignite the oil droplets
e. Combustion also produces carbon monoxide, soot, and unburned fuel
f. High-pressure burners are used to produce atomization
g. Most high-pressure burners force the oil through the nozzle under pressure

32.5 By-Products of Combustion

a. Proper fuel to air ratio must be maintained
b. 1 pound of fuel requires 14.4 pounds of air
c. 14.4 pounds of air is about 192 cubic feet at standard conditions
d. Excess air is desirable and often required (50%)
e. One gallon of #2 fuel oil weighs approximately 7 pounds
f. One gallon of #2 fuel oil produces about 144,000 btu of heat
g. About 25% of the 144,000 btu is lost up the chimney
h. By-products of combustion result from the chemical reaction that takes place during combustion
i. By-products of combustion include nitrogen, oxygen, carbon dioxide, water vapor, and carbon monoxide

32.6 Gun-Type Oil Burners

a. Oil and air forced into burner for mixing and ignition
b. Low-pressure and high-pressure gun-type burners
c. Burner motor
   1. Usually a split-phase fractional horsepower motor
   2. Provides power for the fan and the fuel pump
   3. Flexible coupling connects the motor to the pump
   4. 1,750 or 3,450 rpm are the normal motor speeds
   5. Pump should always match the motor rpm
d. Burner fan or blower
   1. A squirrel cage fan
   2. Adjustable air inlet opening
   3. Fan forces air through the air tube to the combustion chamber
   4. The air is mixed with the atomized fuel oil to provide the oxygen for combustion
e. Fuel oil pumps
   1. Single-stage or two-stage pumps
   2. Each pump has a built-in pressure regulator valve
   3. The pressure regulator can be adjusted to provide the proper pressure to the nozzle
   4. Oil pressures range from 100 psig to over 140 psig
f. Single-stage pumps
   1. Used when the fuel oil storage tank is above the burner
   2. Fuel oil travels to the burner by gravity
   3. Pump provides oil pressure to the nozzle
   4. Single-pipe supply system from the tank to the burner
   5. Excess fuel oil not used by the nozzle is returned to the low-pressure (inlet) side of the pump
   6. Air must be bled at the pump on a single-pipe system any time the line is opened
   7. Bypass plug must be removed from the pump for a single-pipe supply system
g. Dual or two-stage pumps
   1. Used when the oil is stored below the burner
   2. One stage of the pump is used to lift the oil to the pump inlet
   3. The other stage provides oil pressure to the nozzle
   4. Does the same job as a single-stage pump
   5. Has an extra pump gear called the suction pump gear
   6. Suction pump gear produces a greater vacuum for lifting the oil
   7. The supply system should have two pipes
   8. One pipe is used on the vacuum side to lift the oil from the oil tank
   9. The other pipe is a return pipe for the excess oil not used by the nozzle
   10. The bypass plug must be installed for a two-pipe system
   11. Two-pipe systems are self-venting
   12. Pumps are normally replaced and not repaired
h. Nozzle
   1. Prepares the oil for combustion by atomization
   2. Atomization is the process of breaking the oil down into tiny droplets
   3. Smallest droplets are ignited first
   4. Larger droplets provide more heat transfer to the heat exchanger when they are ignited
   5. Bore size determines amount of oil used to produce the Btu output

6. 140,000 Btu in 1 gallon of #2 fuel oil at 60°
7. Three basic spray patterns: hollow cone, solid cone, semi-hollow cone
8. Spray angles of nozzle patterns are 30° to 90°
9. Replace nozzles rather than cleaning them
10. Use a nozzle changer to remove and replace nozzles

i. Hollow cone nozzle
   1. Used where the flow rate is under 1 gph
   2. More stable angle and pattern than a solid cone

j. Solid cone nozzle
   1. Often used in larger burners over 1 gph
   2. Distributes droplets fairly evenly throughout the spray pattern

k. Semi-hollow cone nozzle
   1. Often used in place of hollow and solid cones
   2. Higher flow rate nozzles tend to produce a more solid spray pattern
   3. Lower flow rate nozzles tend to produce a more hollow spray pattern

l. Air tube
   1. Air is blown into the combustion chamber through the air tube
   2. Air is changed to a circular motion opposite that of the circular motion of the fuel oil pattern
   3. Static disc increases the static air pressure and reduces the air volume
   4. The increase in static pressure causes an increase in air velocity for mixing with the atomized oil droplets

m. Flame retention device
   1. Located in the front of the air tube
   2. Designed to provide greater burner efficiency
   3. Creates more turbulence within the air-oil mixture

n. Electrodes
   1. Located within the air tube
   2. Electrodes are metal rods insulated with ceramic insulators
   3. Electrode ends make firm contact with the transformer terminals
   4. Provide the high-voltage spark used to ignite the atomized oil droplets
   5. Continuous (constant ignition) or intermittent ignition
   6. Continuous ignition is where the electrodes provide the high-voltage spark for ignition during the entire burning cycle
   7. Intermittent ignition is designed to provide a spark for ignition for a short period of time at the beginning of the burner cycle

o. Ignition transformers/electronic ignitors
   1. Are step-up transformers
   2. Step up 120 V to 10,000 V or more
   3. Provide the high voltage to the electrodes which produces a spark for ignition
   4. Cannot be field serviced
   5. Spark can be checked

p. Primary control unit
   1. Operates the burner and safety functions whereby the burner is shut down in the event that combustion does not occur
   2. Low voltage is used to activate the primary control to turn the oil burner off and on
   3. Can use cad cell to detect flame in the combustion chamber
   4. Sights flame through the air tube
   5. Cad cell has a high resistance to current flow when not sensing light
   6. Cad cell has a low resistance to current flow when sensing light
   7. Cad cell controls the safety switch function of the primary control

q. Stack switch or stack relay
   1. A bimetal-actuated switch
   2. Used as a safety switch
   3. Installed in the stack pipe between the heat exchanger and the draft damper
   4. Is used to shut down the burner if heat is not detected in a pre-designated amount of time
   5. Hot wire to primary control
   6. Neutral wire (white)
   7. Orange wire energizes the burner motor and ignition transformer

32.7 Oil Furnace Wiring Diagrams

a. Includes wiring for the fan, the oil burner primary, and 24-V control circuits
b. Fan relay prevents the high and low speeds from being energized at the same time
c. When the heat exchanger reaches about 140°, the fan relay switches over to low speed
d. The burner is wired through the limit switch "A"
e. The limit switch is a safety device
f. The limit switch passes power to the primary control
g. On a call for heat, power is passed to the ignition transformer, burner motor, and fuel valve

h. The safety device will shut the burner down in case of a problem
i. When air conditioning is added
   1. The transformer may need to be changed
   2. An isolating subbase may be needed
   3. A fan relay will also be required

32.8 Stack Switch Safety Control

a. Positioned in the flue pipe
b. Bimetal is heated by the combustion flue gases
c. The heat causes the bimetal to expand and push the drive shaft to close the hot contacts
d. Hot contacts allow the burner motor to continue to operate
e. Cold contacts allow current to flow through the safety switch heater
f. Cold contacts must be opened within 90 seconds or the safety switch heater opens the safety switch, shutting down the burner
g. Allow 2 minutes for the safety switch heater to reset before attempting to restart
h. Depress manual reset button to restart system

32.9 Cad Cell Safety Control

a. The resistance of the device drops as it senses more light
b. Can be used in conjunction with a triac
c. The triac passes power when the resistance of the cad cell is high
d. When there is no flame, the triac will pass power to the safety switch heater
e. The safety switch can shut down the burner
f. A cad cell that senses no light will have very high resistance
g. A cad cell that senses light should have a resistance of 600–1000 ohms

32.10 Fuel Oil Supply System

a. Fuel systems are either one-pipe or two-pipe systems
b. One-pipe systems are used when the tank is above the burner
c. Two-pipe systems are used when the tank is below the burner
d. One-pipe systems must be bled when supply system is opened
e. Two-pipe are self-venting
f. Fuel filter should be installed on oil supply line to burner pump
g. *Viscosity* is the thickness of the oil
h. Oil viscosity will change as the temperature changes
i. Viscosity affects the oil flow rate
j. Booster pumps are used in some installations
k. Check valves are used with booster pumps to maintain the prime in the booster pump
l. Filter should be located between tank and the pump

32.11 Combustion Chamber

a. Atomized oil is burned in suspension in the combustion chamber
b. Oil not ignited in suspension will hit the chamber walls and condense
c. Oil vapor hitting chamber walls and condensing will lower combustion efficiency
d. Chambers are built of steel or refractory material
e. The burner must be matched to the chamber
f. Cracked combustion chambers can be repaired

32.12 Heat Exchanger

a. Exchangers transfer the heat from combustion to the air that is circulated to heat the structure
b. Most exchangers are sheet steel and coated with a substance to avoid corrosion
c. Heat exchangers also separate flue gases from the air circulated to heat the structure
d. Heat exchangers should be inspected during normal service for cracks
e. Some states allow cracked heat exchangers to be welded, but most do not
f. Correct airflow is important across the heat exchanger
g. The air temperature rise method can be used for checking for correct airflow

32.13 Condensing Oil Furnace

a. More efficient
b. Has heat-producing system and heated air circulation system
c. Combustion system includes
   1. Burner and related components
   2. Combustion chamber
   3. As many as three heat exchangers
   4. Vent fan and pipes
d. Heated air circulation system includes
   1. Blower fan
   2. Housing
   3. Motor
   4. Plenum
   5. Duct system
e. Operation
   1. Burner forces air and fuel oil into the combustion chamber where they are mixed and ignited

2. The combustion heat is transferred to the main heat exchanger
3. Combustion gases still containing heat are forced through a second heat exchanger
4. Combustion gases still containing heat are forced through a third heat exchanger
5. Third heat exchanger is a coil type where the gas temperatures are reduced below dew point
6. At the dew point temperature, a change of state occurs
7. Water vapor in flue gases condenses
8. Change of state from water vapor to water is a release of latent heat
9. About 1,000 Btu are transferred to the air stream for each pound of moisture condensed
10. Remaining exhaust gases are vented to the outside through PVC pipe
11. The circulated air is moved across all three heat exchangers

32.14 Service Procedures

a. Pumps
   1. Connect vacuum and pressure gages to pump
   2. If oil tank is above the burner, the vacuum gage should read 0 in. Hg while in operation
   3. Formula for supply tank below the burner
   4. The vacuum gage should read
      a. 1 in. Hg for every foot of vertical lift
      b. 1 in. Hg for every 10 ft of horizontal run
      c. The combination of vertical lift and horizontal run should not exceed 17 in. Hg
      d. Vacuum readings in excess of this formula may indicate tubing too small for the run
      e. Pressure gage indicates the performance of the pump and its ability to supply a steady even pressure to the nozzle
      f. Nozzle pressure should be steady at 100 or 140 psi, depending on burner assembly
      g. With the burner shut off, the standing pressure on the pump should drop about 15 psi and hold

b. Burner motor—If burner motor does not operate
   1. Press the reset button
   2. Check for voltage across the orange and white wire of the primary control
   3. Check for voltage at the black and white wire of the burner motor

c. Bleeding a one-pipe system
   1. Bleeding a one-pipe system would have to be done under the following conditions
      a. Starting a one-pipe system for the first time
      b. When the fuel line filter is replaced
      c. When the fuel pump is replaced or repaired
      d. If the fuel tank becomes empty
   2. Attach a flexible transparent hose to the vent or bleed port
   3. Place the free end into a container
   4. Turn the bleed port one eighth or one quarter turn counterclockwise
   5. Start burner, allowing fuel to flow into the container
   6. Allow fuel to flow until it is steady and there is no evidence of air in the system
   7. Close the valve

d. Converting a one-pipe system to a two-pipe system
   1. Shut down all electrical power to the unit
   2. Close the fuel oil supply valve at the tank
   3. Remove inlet port plug from the pump
   4. Insert bypass plug
   5. Replace inlet port plug
   6. Install flare fitting and copper line returning to the fuel tank

e. Nozzles
   1. When nozzle problems are apparent, the nozzle should be replaced
   2. Do not try to repair a nozzle
   3. Nozzles are often replaced annually
   4. Use proper tools to remove nozzles
   5. Nozzles should not overheat; oil can break down
   6. After-drip can result in the clogging of the nozzle

f. Ignition system
   1. To check the transformer
      a. Turn power off
      b. Swing back the ignition transformer
      c. Shut off fuel supply to the burner
      d. Turn power back on the burner
      e. Check for output voltage of 10,000 V using a voltmeter with high-voltage leads
   2. To check the electrodes
      a. Ensure that the three-spark gap settings of the electrodes are set properly
      b. Check electrodes' insulators for cracks
      c. Wipe and clean electrodes' insulators with a cloth

32.15 Combustion Efficiency

a. Tests for proper combustion
   1. Draft
   2. Smoke
   3. Net temperature (flue stack)
   4. Carbon dioxide
b. To make these tests, a hole must be drilled in the flue pipe 12 in. from the furnace breaching, on the furnace side of the draft regulator, and at least 6 in. away from it
c. Draft test
   1. Correct draft is essential for efficient burner operation
   2. Draft determines the rate at which combustion gases pass through the furnace
   3. Draft governs the amount of air supplied for combustion
   4. Draft is created by the difference in temperatures of the hot flue gases
   5. Draft is negative pressure in relation to the atmosphere
   6. Excessive draft can increase the stack temperature and reduce the amount of carbon dioxide in flue gases
   7. Insufficient draft may cause pressure in the combustion chamber
   8. Insufficient draft may result in smoke and odors around the furnace
d. Procedures—Overfire draft test
   1. Drill a hole into the combustion area for overfire draft reading
   2. Place draft gage on a level surface near the furnace and adjust to 0 in.
   3. Turn the burner on and let system run for at least 5 minutes
   4. Insert draft tube into the combustion area to check the overfire draft
   5. Overfire draft should be at least –0.02 in. W.C.
e. Procedures-Stack draft test
   1. Drill a hole into the stack pipe
   2. Place draft gage on a level surface near the furnace, adjust to 0 in.
   3. Turn the burner on and let system run for at least 5 minutes
   4. Insert draft tube into the stack pipe
   5. Most residential oil burners require a stack draft of –0.04 to –0.06 in. W.C. to maintain the proper overfire draft
   6. Longer flue passages require a higher flue draft than shorter flue passages
f. Smoke test
   1. Excessive smoke is evidence of incomplete combustion
   2. Excessive smoke also results in soot buildup on the heat exchanger
   3. A $^{1}/_{16}$ in. layer of soot can cause a 4.5% increase in fuel consumption
g. Procedures—Smoke test
   1. Turn system on and let unit operate for at least 5 minutes or until stack temperature stops rising
   2. Insert filter paper into smoke tester
   3. Insert smoke tester tube into stack flue sample hole
   4. Pull the tester handle ten times
   5. Remove smoke tester tube from flue stack
   6. Remove the filter paper and compare with smoke test scale
   7. A good smoke reading is 0 to # 1 smoke
h. Net stack temperature
   1. Net stack temperature is important because abnormally high temperatures indicate furnace may not be operating efficiently
   2. Net stack temperature is determined by subtracting the air temperature around the furnace from the measured stack or flue temperature
i. Procedures—Net stack temperature test
   1. Insert the thermometer stem into the stack pipe sample hole
   2. Turn the burner on and allow to run for at least 5 minutes
   3. Subtract the surrounding ambient air temperature from the recorded stack temperature to determine net stack temperature
j. Carbon dioxide test
   1. A high carbon dioxide reading is good
   2. A low carbon dioxide reading is an indication that the fuel oil has not been burned efficiently or completely
   3. Under normal conditions, a 10+% carbon dioxide reading should be obtained
   4. A carbon dioxide reading of 8% could be acceptable if the furnace is safe and the net stack temperature is 400°F or less
   5. A carbon dioxide reading of at least 9% should be obtained if the net stack temperature is over 500°F
k. Procedures—Carbon dioxide test
   1. Turn the burner on and let operate for at least 5 minutes
   2. Insert thermometer and wait for the temperature to stop rising
   3. Insert the CO_2 sampling tube into the stack sampling hole
   4. Zero the CO_2 scale on the CO_2 cylinder
   5. Remove a test sampling of the gases by squeezing the actuator eighteen times

6. Hold actuator closed on the eighteenth squeeze and remove actuator from the CO_2 cylinder
7. Mix the fluid in the CO_2 cylinder with the flue gases by turning cylinder upside down at a 45-degree angle
8. Turn CO_2 cylinder upright and allow the mixed fluid to flow back to the other end of cylinder
9. Read the percentage of carbon dioxide

PREVENTIVE MAINTENANCE

a. Oil heating equipment requires consistent and regular maintenance
b. Improper burning causes the formation of soot
c. Annual service
   1. Check oil tank for water accumulation
   2. Oil lines should be checked for kinks, bends, and rust
   3. A vacuum test can be performed on the lines to check for leaks
   4. A pressure test can also help leak check the oil lines
   5. Gun burner should be removed and inspected
   6. The interior of the chamber should also be inspected
   7. Oil nozzle should be replaced
   8. Check burner head, insulators, static tube, and cad cell
   9. Make certain all components are clean
   10. Change the in-line oil filter
   11. Check the draft
   12. Perform a combustion analysis

HVAC GOLDEN RULES

a. When making a service call
   1. Ask customer about the problem
   2. Check and service humidifiers
   3. Be prepared
   4. Do not allow any oil to leak onto the floor
b. Added value to the customer
   1. Check the flame characteristics
   2. Replace all panels and use correct fasteners
   3. Inspect heat exchanger for soot

32.16 Service Technician Calls

a. Service call #1
   1. New customer requests a complete oil furnace checkup
   2. Efficiency test is performed
      1. Thermostat is set 10° higher than room temperature
      2. Stack temperature is taken
      3. Sample of combustion gas is taken
      4. Smoke test is performed
   3. Efficiency test shows a 65% efficiency
   4. Burner is de-energized and the furnace is cooled
      a. Nozzle is replaced
      b. Electrode spacing is checked
      c. Oil filter is changed
      d. Air filter is changed
      e. Motor is oiled
   5. Another efficiency test is performed
   6. Efficiency test shows 67% efficiency
   7. Technician checks the nameplate and realizes that the original nozzle was the wrong size
   8. The correct nozzle is installed and the oil pressure is checked
   9. The oil pressure was changed to compensate for the wrong nozzle
   10. The oil pressure is adjusted
   11. Another efficiency test shows an efficiency of 73%
b. Service call #2
   1. Customer complaint: oil furnace makes a noise when it shuts off
   2. Problem: oil pump not shutting off properly
   3. Technician notices that the flame shuts down slowly, making a noise
   4. A solenoid is installed in the oil line from the pump to the nozzle
   5. The solenoid will be energized only when the burner operates
   6. The system is started up and tested
   7. Upon de-energizing the burner, the system shuts off properly
c. Service call #3
   1. Customer complaint: no heat
   2. Problem: the customer is out of fuel
   3. Technician notices
      a. Thermostat set above room temperature
      b. Furnace is off, primary control has tripped
      c. No excess oil in the combustion chamber
      d. Unit does not fire when the reset button is pushed
      e. No oil comes out of the bleed port when the motor is turned on
      f. There is no oil in the line entering the pump
      g. There is no oil in the tank
   4. Oil is delivered, the pump is bled
   5. The unit is serviced and started up
d. Service call #4
   1. Customer complaint: smell of smoke
   2. Technician notices
      a. System is not serviced annually

b. Puff of smoke on startup
c. Draft gage reads +0.01 in. W.C. positive pressure
3. Problem and solution
e. Service call #5
1. Customer complaint: no heat
2. Technician notices
a. Thermostat is calling for heat
b. Unit needs to be reset
c. No oil accumulation in combustion chamber
3. Unit is reset and runs for only 90 seconds
4. Problem and solution
f. Service call #6
1. Customer complaint: no heat and unit will not start when reset
2. Technician notices
a. Thermostat calling for heat
b. 120 V being supplied to the primary control
c. There is no voltage from the orange wire leaving the primary control to neutral
3. Problem and solution

UNIT 33—Hydronic Heat

33.1 Introduction to Hydronic Heating

a. Hydronic heating systems are those where water or steam carries the heat through pipes to the areas to be heated
b. A *terminal unit* is the heat transfer component of the system, such as a radiator or a finned tube baseboard unit
c. Hot water systems are generally used in residential and light-commercial installations
d. Systems can be designed to handle individual zones
e. The water is heated at the boiler using an oil, gas, or electrical heat source
f. Sensing elements in the boiler start and stop the heating source according to the boiler temperature
g. The water is circulated with a centrifugal pump

32.2 Boiler

a. Designed to use some energy source to heat water
b. Some commercial boilers may use two energy sources for heating the water when one fuel is more readily available than another
c. The part of the boiler containing the water is usually constructed in sections or in tubes when oil or gas heat sources are used
d. Reasons for eliminating air from the water in a boiler
1. Air in water at normal atmospheric temperatures causes corrosion
2. Air pockets can also form in the system, blocking water circulation
3. Air in the system can also cause undesirable noise
e. Venting of air in a boiler
1. Air in the boiler can be eliminated by trapping it and forcing it to be vented to the outside air or into an expansion tank
2. Once air is vented, there is always a certain amount of new air that enters the system through the water makeup system
3. Most water systems for homes and small commercial buildings are low-pressure types that operate below 30 psig and 200°F

33.3 Limit Control

a. Shuts down the heating source if the boiler water temperature becomes too high
b. Limit control is immersed in the water in the boiler or in a dry well in the boiler water for the best temperature sensing results
c. Would be set at a point less than 200°F
d. Normally not adjustable (preset at the factory)

33.4 Water-Regulating Valve

a. Water heating systems should have an automatic water makeup system in case water is lost due to leaks within the system
b. Water-regulating valves are used to reduce the city water pressure down to a working pressure for the boiler
c. Water-regulating valves are installed in the water line leading to the boiler and are set to maintain the pressure on its leaving side (entering the boiler)
d. The water-regulating valve pressure should be set at less than the pressure of the relief valve on the boiler
e. Low-pressure boilers have a working pressure of 30 psig

33.5 Pressure Relief Valve

a. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Codes require that each hot water heating boiler have at least one officially rated pressure relief valve set to relieve at or below the maximum allowable working pressure of the low-pressure boiler

b. The working pressure would be 30 psig
c. Discharges excessive water when pressure is created by expansion
d. Releases excessive pressure if there is a runaway overfiring emergency

33.6 Air Cushion Tank or Expansion Tank

a. Water expands when it is heated
b. Water systems operate with all components and piping full of water
c. Water heated to over 200°F will expand
d. Air cushion tanks or expansion tanks are used for water expansion
e. The tanks are airtight and are located above the boiler
f. The tanks provide space for air initially trapped in the system and for the expanded water when heated
g. The tank should provide the only air space within the system
h. Tanks should be vented when initially filling a boiler system
i. Some tanks have a vent tube through which air can be vented one time
j. Some types have a flexible diaphragm to keep the air and water separated
k. The air above the diaphragm tank is compressed when water from expansion is pushed up into the tank

33.7 Zone Control Valve

a. Zone control valves are thermostatically controlled valves that control water flow to the various zones in a system
b. Many zone valves are heat motor operated
c. When the thermostat calls for heat, a resistance wire around the valve heats and causes the valve's bimetal element to expand and open slowly
d. Some valves are electric motor operated, which allows slow opening and closing of the valve
e. Zone valves usually have a manual open feature to allow the technician to open the valve by hand to check for water flow
f. The manual open feature of the valve also allows the technician to provide heat for a customer in cases where the valve heater or motor burns out

33.8 Centrifugal Pumps

a. Centrifugal pumps are referred to as *circulators*
b. They force the hot water from the boiler through the piping to heat transfer units and back to the boiler
c. Circulating pump
    1. Pumps use centrifugal force to circulate the water through the system
    2. Centrifugal force is generated whenever an object is rotated around a central axis
    3. The force increases proportionately with the speed of rotation
    4. Pumps are not positive displacement pumps
    5. Do not add much pressure to the water from the inlet to the outlet of the pump
d. The impeller
    1. Part of the pump that spins and forces the water through the system
    2. Proper rotation direction of the impeller is essential
    3. Vanes or blades must slap and then throw the water
    4. Closed impellers are those which have sides enclosing the impeller vanes
e. Bronze fitted pumps
    1. Used in closed systems where makeup water is used
    2. Generally have cast iron body with impeller
    3. Moving parts are made of bronze or nonferrous metals
    4. Some are stainless steel or all bronze

33.9 Finned-Tube Baseboard Units

Two-piped, finned-tube baseboard units

a. Air enters the bottom and passes over the hot fins
b. The heat is given off to cooler air, causing it to rise by convection
c. Heated air leaves the unit through the damper area
d. Dampers can be adjusted to regulate the heat flow
e. Finned-tube heating units are rated in Btu/ft of pipe at two different flow rates:
    500 lb/h
    2,000 lb/h
f. One gallon of water has a weight of 8.33 lbs
g. 500 lb/h is equivalent to 1 gallon of water flow per minute
h. 2,000 lb/h is the equivalent of 4 gallons of water flow per minute
i. Manufacturers rate the finned-tube radiation at so many Btu/ft at different temperatures
j. Provide for expansion when installing baseboard terminal units
k. Install expansion joints for long runs of baseboard terminal units
l. Review

33.10 Balancing Valves

a. Consideration must be given to the flow rate of water and friction in the system
b. Friction is caused by the resistance of the water flowing through the piping, valves, and fittings in the system
c. Flow rate is the number of gallons of water flowing each minute through the system
d. *System balance*—When the resistance to water flow is the same in each flow path
e. The system should be balanced by installing a balancing valve on the return side of the system
f. Balancing valves are adjustable, and manufacturer's instructions should be followed when setting the valve

33.11 Flow Control Valves

a. Flow control valves are also known as *check valves*
b. Flow control valves are necessary so that the water will not flow by gravity when the circulator is not operating

33.12 Horizontal and Vertical (Downflow) Forced-Air Discharge Unit Heater

a. Used generally in commercial and industrial applications
b. Have fans to blow the air across the heat transfer element
c. Heating elements are normally heavy copper tubing through which the hot water flows
d. Copper tubes are surrounded with aluminum fins to more efficiently give off heat to the air blown across them

33.13 Hydronic Heating Piping Systems

a. Most residential systems use a series loop or a one-pipe system layout for each zone
b. Hot water heating systems installed in floors and ceilings are known as *panel systems*
c. Series loop hydronic heating system
    1. In the series loop system, all the hot water flows through each heating unit
    2. The temperature or the amount of flow cannot be varied from one unit to the next without affecting the entire system
    3. Water temperature in the last unit will be less than in the first unit
    4. This system is simple but does not give much flexibility
d. One-pipe hydronic heating system
    1. One-pipe systems have a main supply with branches to each of the individual heating units
    2. The piping for the individual heating units is smaller than the main supply loop
    3. The tee to each of the branch heating units is called a *one-pipe fitting*
    4. The one-pipe fitting tee forces some of the water in the line to go through the heating unit and the rest to continue in the main supply line
e. Two-pipe reverse return system
    1. Has two pipes running parallel with each other
    2. The water flows in the same direction in each pipe
    3. The water going into the first heating unit will be the last returned to the boiler
    4. The water going into the last heating unit will be the first returned to the boiler
    5. This system equalizes the distance of water flow in the system
f. Two-pipe direct return system
    1. The water flowing through the nearest heating unit to the boiler is the first back to the boiler
    2. This heating unit would have the shortest pipe run
    3. The farthest away from the boiler would have the longest piping run
g. Radiant panel system
    1. Installed in the floor or ceiling
    2. Normally, each coil is an individual zone or circuit
    3. Each zone or circuit is balanced individually
    4. Each unit is balanced at the terminal unit
h. Pipe sizing
    1. Determines how much water will flow in each circuit
    2. If the pipe is too large, the low-limit flow requirements for converters may not be met
i. Minimum design flow rates for different converter pipes
    1. Flow rates below the minimum design rates at the converters will cause the heat exchanger between the water and the air to be less
    2. Velocity of the water in the converter helps the heat exchange
    3. Flow that is too slow is called *laminar flow*
    4. If flow rate is too fast, the pipe will be too small and velocity noise of the water will be heard

33.14 Tankless Domestic Hot Water Heaters

a. Most boilers can be furnished with a domestic hot water heater consisting of a coil inserted into the boiler

b. Domestic hot water is contained within the coil and heated by the boiler quickly, which eliminates the need for a storage tank

PREVENTIVE MAINTENANCE
a. Natural draft convectors should be vacuumed
b. Routine filter check and change on forced draft systems
c. Fan blades and wheels should be clean
d. Water side can be drained and flushed
e. Water treatment should be added when the system is filled
f. All water leaks must be repaired
g. Water pumps must be maintained and properly lubricated
h. Check electrical service

HVAC GOLDEN RULES
a. Do not block the customer's driveway
b. Look and act like a professional
c. Check and service humidifiers
d. Fix water leaks
e. Check equipment for service needs
f. Check for water treatment
g. Lubricate pumps and fans

33.15 Service Technician Calls
a. Service call #1
  1. Customer complaint: No heat in the hotel
  2. Problem: Air trapped in the system, the automatic vent valves have rust and scale in them
  3. Technician notices
    a. Boiler is hot
    b. Water pump is running
    c. No heat on top floor units (coils are room temperature)
  4. Technician concludes that there is air in the line
  5. The system vent is checked and no air or water escapes when the stem is pressed
  6. The automatic vent is removed and the system is bled
  7. The automatic vent is replaced
b. Service call #2
  1. Customer complaint: one section of a small building has no heat
  2. Problem: one of the four circulating pumps is locked up
  3. Technician notices
    a. The thermostat is calling for heat
    b. One pump is not operating
    c. The pump motor is cool to the touch
    d. Three-phase power feeding the starter
    e. The starter is tripped
    f. Motor is not grounded or shorted
    g. Overload is reset and the motor draws locked rotor amperage
  4. There is either a pump problem or a motor problem
  5. The pump coupling is disassembled
    a. The motor turns freely
    b. The problem is with the pump
  6. The pump impeller housing and bearings are replaced
  7. The system is re-assembled and started up
c. Service call #3
  1. Customer complaint: building manager has no heat in one apartment
  2. Problem: one zone valve is defective
  3. Technician notices
    a. Room thermostat set above room temperature
    b. No heat in the coil and no water flowing
    c. The zone valve motor is supplied 24 V
    d. Water flows when the valve is opened manually
  4. The valve assembly is replaced and the unit checked
d. Service call #4
  1. Customer complaint: boiler pump making noise
  2. House has three pumps
  3. Technician notices metal filings around the pump shaft
  4. Problem and solution
e. Service call #5
  1. Customer complaint: water on the floor around the boiler, relief valve is relieving water
  2. Technician notices
    1. Boiler relief valve seeping
    2. Boiler gage reads 30 psig
  3. System normally operates at 20 psig
  4. Technician notices burner flame burning at low fire
  5. There is no voltage to the gas valve coil
  6. Problem and solution

UNIT 34—Indoor Air Quality

34.1 Introduction
a. Indoor air may be more polluted than outdoor air
b. Many people spend as much as 90% of their time indoors

c. ASHRAE Standard 62-2001 determines acceptable indoor air quality levels

34.2 Sources of Indoor Air Pollution

a. Potential pollution sources

Moisture	Carpets	Pressed Wood Furniture
Humidifiers	Drapes	Pressed Wood Flooring
Fireplaces	Dustmites	Unvented Clothes Driers
Pesticides	Paneling	Dry Cleaned Goods
Radon	Car Exhaust	Household Chemicals
Stored Fuels	Air Fresheners	Pressed Wood Cabinets
Wood Stoves	Tobacco Smoke	Unvented Gas Stoves
Moth Repellents	Paint Supplies	Stored Hobby Products
Asbestos Tiles	Asbestos	Personal Care Products
Mold	Pipe Wrap	Carbon Monoxide

b. Older homes have many areas for pollutants to infiltrate
c. Newer homes and offices are more air tight
d. Sufficient amounts of outside air must be supplied
e. Inadequate ventilation can cause
   1. Moisture condensation on windows and walls
   2. Smelly and stuffy air
   3. Dirty air-conditioning equipment
   4. Formation of mold

34.3 Controlling Indoor Air Contamination

a. Eliminate the source of contamination
b. Provide adequate ventilation
c. Provide a means to clean the air

34.4 Common Pollutants

a. Radon
   1. Colorless, odorless radioactive gas
   2. Causes lung cancer
   3. Common source of radon is uranium in rock and soil
   4. Testing equipment should be EPA or state approved
b. Environmental tobacco smoke
   1. Referred to as “second-hand smoke”
   2. Comes from burning ends of cigarettes, pipes, and smoke exhaled by smokers
   3. Mixture of over 4,000 components
   4. Smoking should not be permitted indoors
c. Biological contaminants
   1. Air-conditioning systems can grow mold, mildew, and other contaminants
   2. Dust mites are commonly found in carpeting, bedding, and other fabrics
   3. Allergens can become airborne when dried
   4. Water-damaged materials encourage growth of mold, mildew, and bacteria
   5. Mold consists of filaments called hyphae
   6. Reproduce by producing spores
   7. Spores need moisture and food to germinate and grow
   8. Some individuals are allergic to these spores
   9. Molds can lead to health problems
   10. Mycotoxins
   11. Sick Building Syndrome
       a. May be caused by ventilation, bacteria, or mold problems
       b. U.S. Toxic Mold Safety and Protection Act of 2202
   12. Many legal issues surrounding the mold issue
   13. Mold Remediation
       a. Remove the source of moisture
       b. Repair leaks
       c. Adjust humidity
       d. Surface cleaning is often insufficient
       e. Certified contractors should be brought in to do the cleanup
       f. Air-conditioning equipment should not be oversized
       g. Air-conditioning condensate pans should be cleaned regularly
       h. Humidification equipment should be cleaned regularly
d. Pollutants from combustion products
   1. Burning fuels can be the source of pollutants
   2. Carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulates
   3. Carbon monoxide
       a. Produced by incomplete combustion: lack of oxygen or poor mixture of fuel and air
       b. Colorless, odorless, tasteless, non-irritating, lighter than air, toxic
       c. Concentration of CO is determined by testing
       d. Concentration measured in parts per million
       e. Headaches, dizziness, nausea, vomiting, disorientation, loss of consciousness, or death
e. Household products containing organic chemicals
   1. Compounds are released during use and improper storage
   2. Paints, varnishes, and cleaning products
f. Formaldehyde
   1. Contained in household products and combustion gases
   2. Urea formaldehyde and phelolformaldehyde
g. Pesticides
   1. Microbes in disinfectants are considered pesticides

2. Most pesticide exposures occur indoors
3. Use only as instructed by the manufacturer

h. Asbestos
1. Usually found in older homes and buildings
2. Found in pipe insulation, tiles, and textured paint
3. Causes lung cancer and other diseases
4. Removal by certified contractors

i. Lead
1. Contained in air, drinking water, food, soil, paint, and dust
2. Lead dust forms from outdoor sources and lead solder
3. Removal by certified contractors

34.5 Contamination Source Detection and Elimination

a. Radon test kits
1. Test canister is sent to a laboratory for analysis
2. Corrective action should be taken if necessary

b. Various monitoring instruments can detect

Carbon Dioxide	Sulfur Dioxide	Nitric Oxide
Carbon Monoxide	Chlorine	Hydrogen Cyanide
Hydrogen Sulfide	Nitrogen Dioxide	Ammonia
Ethylene Oxide	Hydrogen	Ozone
Hydrogen Chloride	Oxygen	

34.6 Ventilation

a. Process of supplying and removing air by natural or mechanical means
b. Proper ventilating will improve indoor air quality by removing some contaminated air and diluting the remaining air
c. Outside air must be filtered and heated or cooled
d. Commercial buildings have mechanical ventilation equipment
e. Very few residences have mechanical equipment that bring outside air into the structure
f. Bathroom and kitchen fans exhaust air to the outside
g. ASHRAE Standard 62-2001
h. Energy recovery ventilators (ERV)
1. Allow fresh air to enter the building
2. Remove stale air from the structure

34.7 Air Cleaning

a. Mechanical filters, electronic air cleaners, ion generators, and UN light (C)
b. Air cleaners contain absorbent or adsorbent materials
1. *Absorption*—When one substance is absorbed by another
2. *Adsorption*—When a film or liquid or gas adheres to a solid
3. Charcoal is commonly used as and adsorber

c. High-loft polyester filter media
1. Spray bonded
2. Purchased in bulk

d. Fiberglass throwaway filters
1. Coated with dust-holding adhesive
2. Become more dense as air passes through it

e. Pleated filters
f. Cube filters
1. High dust-holding capacity
2. Three filter layers heat-sealed together

g. Pocket filters
h. High-efficiency particulate arrestor filters (HEPA)
1. Provide highest degree of filtration
2. Average dust particles are about 20 to 30 microns
3. HEPA filters can filter 0.3 micron particles or smaller

i. Electrostatic precipitators or electronic air cleaners
1. Can be mounted at the furnace
2. Can be mounted in a filter frame
3. Can be mounted within the duct system
4. Can be standalone units
5. Usually have three sections
   a. Pre-filter that traps large particles
   b. Ionizing section positively charges particles and attracts them to negatively charged plates
   c. Charcoal filter removes odors and gases

j. Activated charcoal air purifier
1. Also called *activated carbon*
2. Used to remove odors by adsorption
3. Gases and odors are held by the charcoal until it is replaced
4. Can remove alcohols, aldehydes, and acids from household products
5. Can remove waste, pet, human, and waste storage odors

k. Ion Generators
1. Charge particles that are then attracted to walls, floors, and drapes
2. Collectors may be used to gather the particles

l. Ultraviolet light
1. UV-A, UV-B, and UV-C ranges
2. UV-C destroys microbes that create unhealthy air
3. UV-C can penetrate and damage the microbe's DNA

4. Used near cooling coils in air-conditioning systems
5. Never look at the UV light
6. Follow all manufacturers' safety guidelines

34.8 Duct Cleaning

a. Ducts should be cleaned if
   1. There is visible growth of mold in air-conditioning equipment
   2. They are infested with rodents or insects
   3. They are clogged with dust and/or debris
b. Includes the cleaning of
   1. Ductwork interior
   2. Grilles and diffusers
   3. Heat exchangers and coils
   4. Condensate drain pans
   5. Fan motors and housings
   6. Humidifiers and components
c. Vacuum system should be vented outside
   1. Brushes should be used to dislodge dust
   2. Soft bristle brushes should be used on fiberglass ductwork and lining
d. Upon completion, all access holes should be resealed
e. National guidelines should be followed

34.9 Air Humidification

a. Homes are dry in the cooler months because the air expands and the moisture is spread out when heated
b. Relative humidity = percentage of moisture in the air compared to the air's ability to hold moisture
c. Relative humidity decreases as the temperature increases (1 cubic foot of air can hold more moisture at warmer temperatures)
d. Recommended humidity for a home is between 40% and 60%
   1. High humidity makes bacteria, viruses, and fungi more active
   2. Low humidity dries out furniture, plants, and people
e. People can be comfortable at lower temperatures if the humidity is higher
f. Pans of water on radiators or stoves were used to raise the humidity
g. Evaporative humidifiers
   1. Use a wet media
      a. Drum design
      b. Disc design
      c. Plate or pad type
   2. Air is passed over or through the media
   3. Air is drawn through the humidifier by the pressure difference
   4. Plenum-mount humidifier
      a. Mounted in the supply or return duct
      b. Furnace fan forces air through the media
   5. Under-duct-mount humidifier
      a. Mounted on the underside of the supply duct
      b. Media extends into the airflow
h. Electrically heated humidifiers
   1. Used in heat pumps and electric furnaces
   2. Water is evaporated with heating elements
i. Infrared humidifiers
   1. Mounted in the duct
   2. Equipped with infrared lights that are reflected onto the water
   3. Uses a great deal of electrical energy
j. Humidistats
   1. Control motor and heating elements
   2. Sense humidity in the conditioned space
   3. Some are electronic devices controlled by humidity-sensitive resistors
k. Atomizing humidifiers
   1. Discharge tiny droplets of water into the air
   2. Should only operate when the furnace is operating
      a. Moisture can accumulate
      b. Corrosion and mildew can result
   3. Spray nozzle type
      a. Water is sprayed through a fixed bore nozzle
      b. Usually mounted in the supply duct
   4. Centrifugal type
      a. Uses an impeller or slinger
      b. Water is thrown and broken into particles
l. Self-contained humidifier
   1. Used in areas with hydronic, baseboard, or unit heating system
   2. Can be evaporative, atomizing, or infrared type
   3. Are equipped with fans to distribute the moisture
   4. Can use steam
m. Pneumatic atomizing systems
   1. Relies on air pressure
   2. Pressure breaks water into tiny droplets
   3. Used in areas that do not have to be kept clean

34.10 Sizing Humidifiers

a. The volume of the space is needed
   1. Volume = area of house x ceiling height

2. Ex: 1,500 square ft house with 8-ft ceiling occupies 12,000 cubic feet

b. Know the construction of the structure
c. Know the lowest outdoor temperature
d. Know the desired humidity level
e. Know the amount of air change per hour

34.11 Installation

a. Manufacturer's directions must be followed
b. Evaporative humidifiers can operate independent of the furnace
c. Atomizing units must operate with the furnace
d. Duct clearances should be observed
e. Try to mount humidifiers in the largest supply duct

34.12 Service, Troubleshooting, and Preventive Maintenance

a. Components that come in contact with water must be cleaned
b. The harder the water, the more often cleaning is required
c. Algaecides are used to neutralize algae growth
d. The reservoir should be drained and cleaned periodically
e. Follow manufacturer's cleaning suggestions
f. Humidifier not running
   1. Check circuit breaker, humidistat, low-voltage control circuit, and overload protection
   2. Unit could be mechanically bound
g. Excessive dust
   1. White buildup on the media
   2. Media should be cleaned or replaced
h. Moisture in or around ducts
   1. Usually associated with atomizing humidifiers
   2. Unit should only operate when the furnace is on
   3. Check control circuit to verify operation
   4. Could be caused by restricted airflow
i. Low or high levels of humidity
   1. Check humidistat calibration
   2. Use a sling psychrometer to measure actual humidity
   3. Check operation of humidifier
   4. Check location of humidistat