Gas and Oil Heating

Gas and Oil Heating NATE Review

Chapter 1: Introduction to Gas and Oil Heating

Lesson Objectives

- ➢ Discern key differences in gas and oil heating.
- ➢ Discover the specific fuel choices of each.
- ➢ See how capacity calculations are made.
- ➢ Learn the furnace air-flow configurations.

Furnace Operation

- Fuels are ignited in a combustion chamber.
- Heat is transferred through a heat exchanger.
- Air is heated by the exchanger.
- Air is supplied to the controlled space:
    - By gravity; or
    - Forced by a blower.

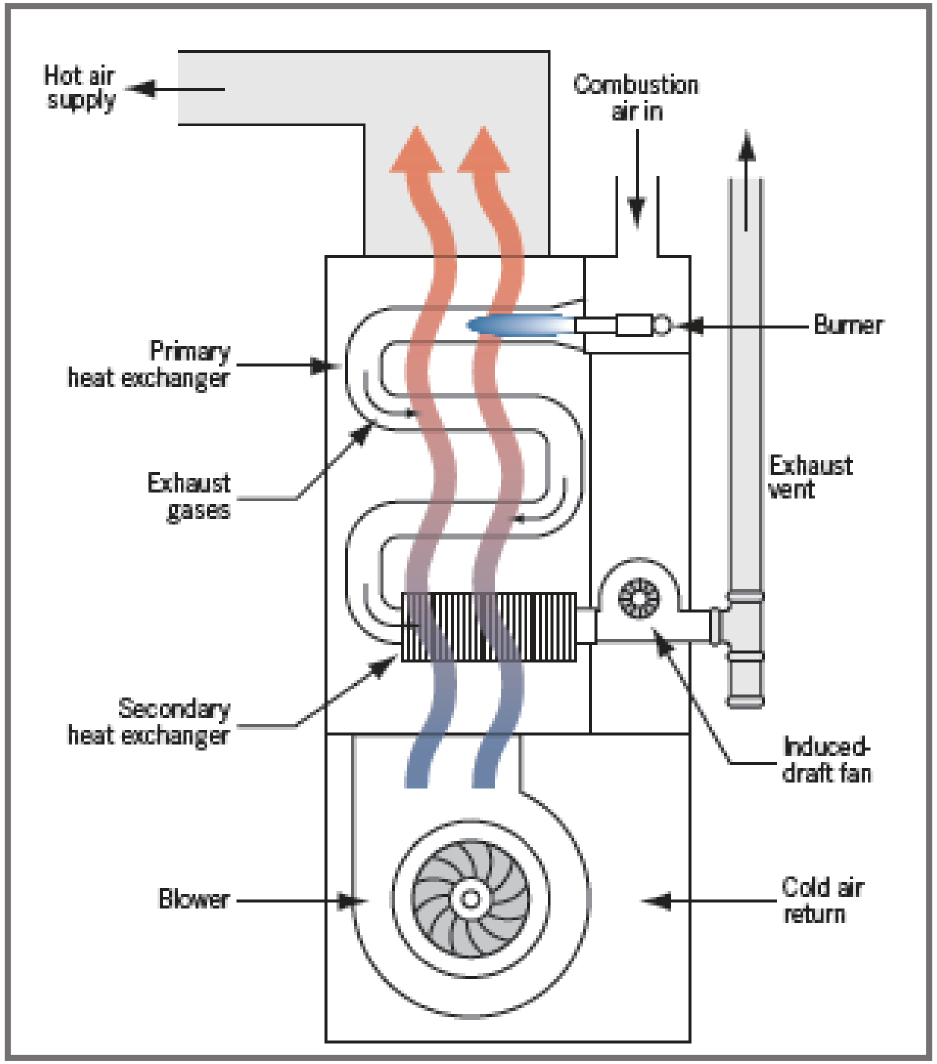
Typical Forced-air Furnace

- Modern 80% AFUE Furnaces
  - Use heat exchanger to transfer heat to indoor air.
  - The heat exchanger separates combustion process from circulating indoor air.
  - Use blower to move air across heat exchanger.

Modern-day Furnaces

High-AFUE (annual fuel utilization efficiency):

- Usually rated above 90%.
- Draws additional sensible heat.
- Also latent heat (causing condensation).
- Able to withstand acidic effects .
- Made of stainless steel or coated steel.
- Usually involves high-temperature plastics.



Gas Fuels

- There are three types:
  1. Natural gas;
  2. Liquefied petroleum (or LP) gas; and
  3. Manufactured gas.
- All three, to some extent, are blends.
- Pressures, density and heat content of each vary.

Gas-fuel Data

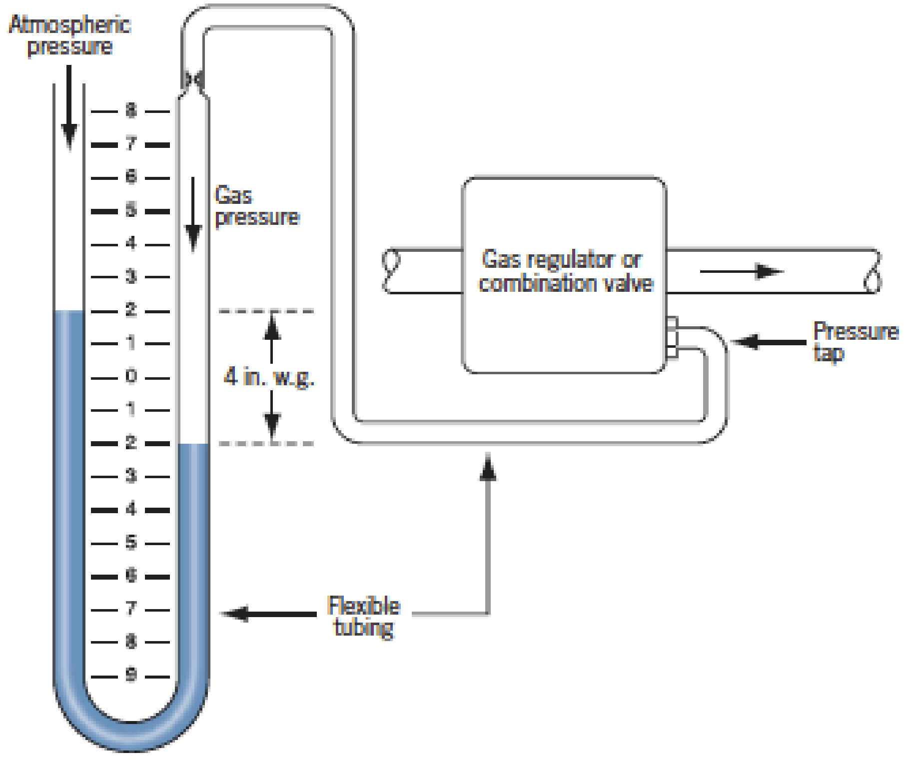
	Natural gas	Manufactured and mixed gases	Liquid petroleum (LP) gas
Contents	90% methane	Variable hydrocarbons	Primarily propane
Specific gravity	0.60 (lighter than air)	0.60 (lighter than air)	1.52 (heavier than air)
Heat content	1,050 Btu/ft^3	500 to 800 Btu/ft^3	2,500 Btu/ft^3
Manifold pressure	3.5 in. w.g.	2.5 in. w.g.	Up to 11 in. w.g.
Combustion air per cubic foot of gas	10 ft^3	10 ft^3 or less	24 ft^3

Fuel Oil

- Fuel oil is available in different grades, based on various characteristics.
- No. 2 fuel oil is most widely used.
- Oil is drawn from the tank by a pump and atomized into a fine spray.

Gas Pressures

- Usually measured (*by a manometer*).
- Values are in inches of water column (in. *w.c. or in. w.g.*).



U-tube manometer measuring pressures

Delivery Pressures

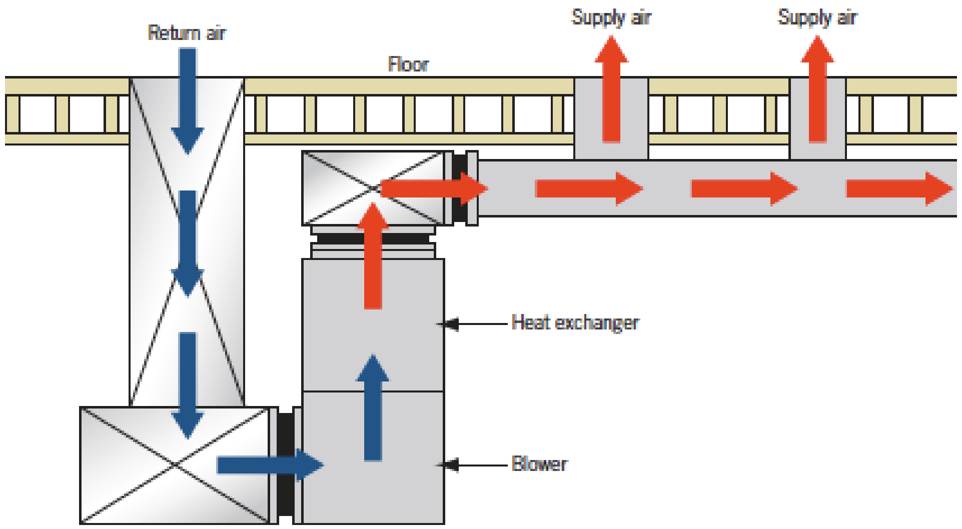
- Natural gas: main line < 0.5 psi (approx. 14 in. w.g.):
  - Burner manifold: usually 3.5 in. w.g.; and
  - Always verify manifold pressure with nameplate.
- LP gas: Burner manifold (approx. 11 in. w.g.):
  - Higher density usually requires more pressure;
  - Higher Btu/ft^3 = smaller burner orifices; and
  - Always verify manifold pressure with nameplate.

Furnace Configurations

- Many different configurations.
- Type of structure often dictates furnace style.
- Building codes also may influence design.

Upflow Furnace Configuration/Usage

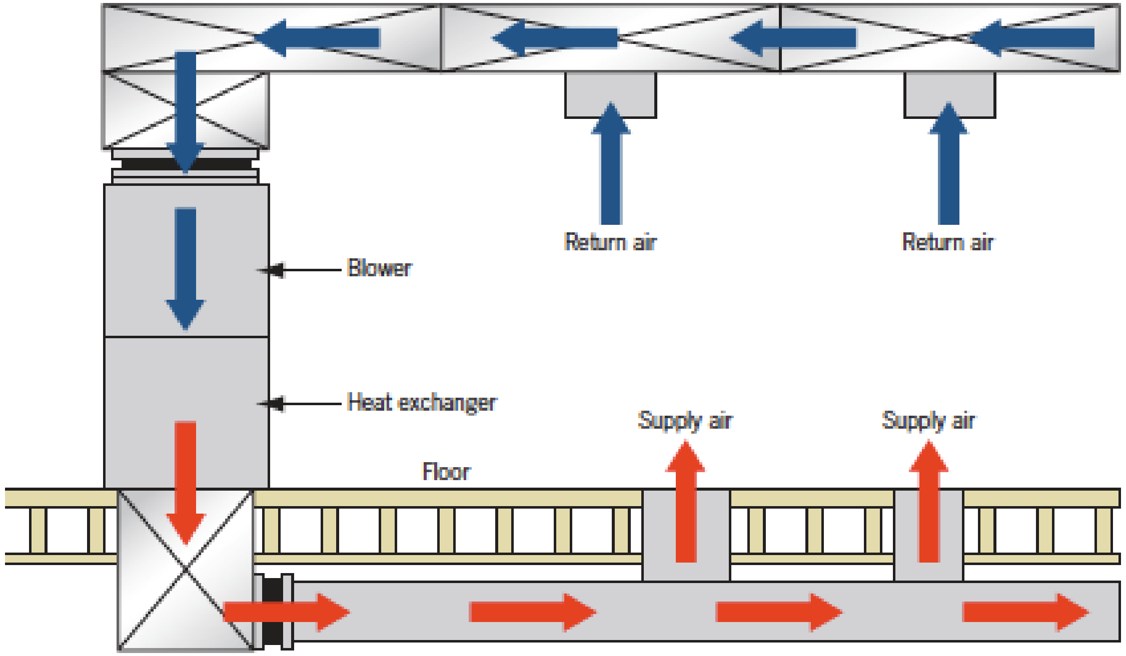
- Upflow furnace:
  - Usually installed in homes with basements.
  - Cool air enters at the bottom, and heated supply air exits through the top.



Upflow furnace configuration

Downflow Furnace Configuration/Usage

- Downflow furnace:
  - Usually installed in closets or utility rooms.
  - Return air is drawn in up top, and conditioned air is discharged down below.



Downflow furnace configuration

Horizontal Furnace Configuration/Usage

- Horizontal furnace:
  - Usually installed in attics and crawl spaces.
    – Return air is drawn in at one end, and conditioned air is expelled on the opposite side.

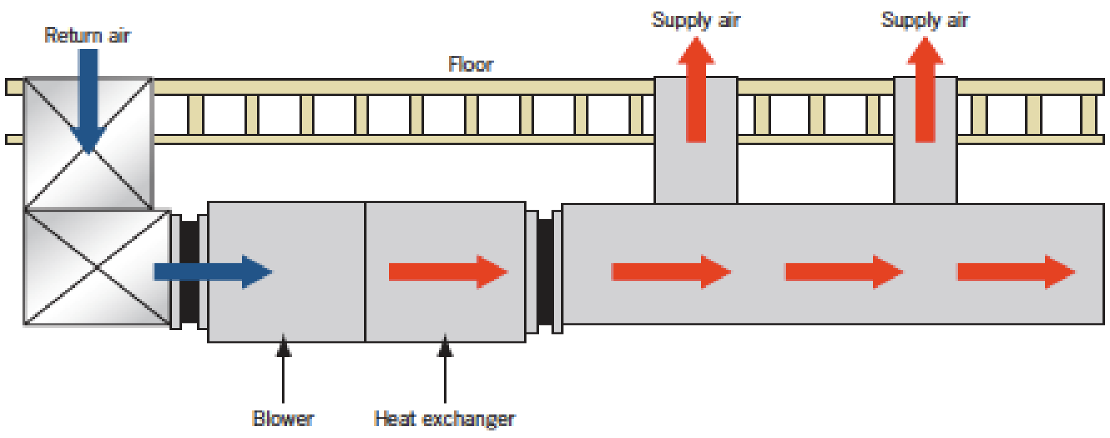


Illustration of a horizontal furnace configuration

Lowboy Furnace Configuration/Usage

- Horizontal furnace:
  - Usually installed in attics and crawl spaces.
    - Return air is drawn in at one end, and conditioned air is expelled on the opposite side.

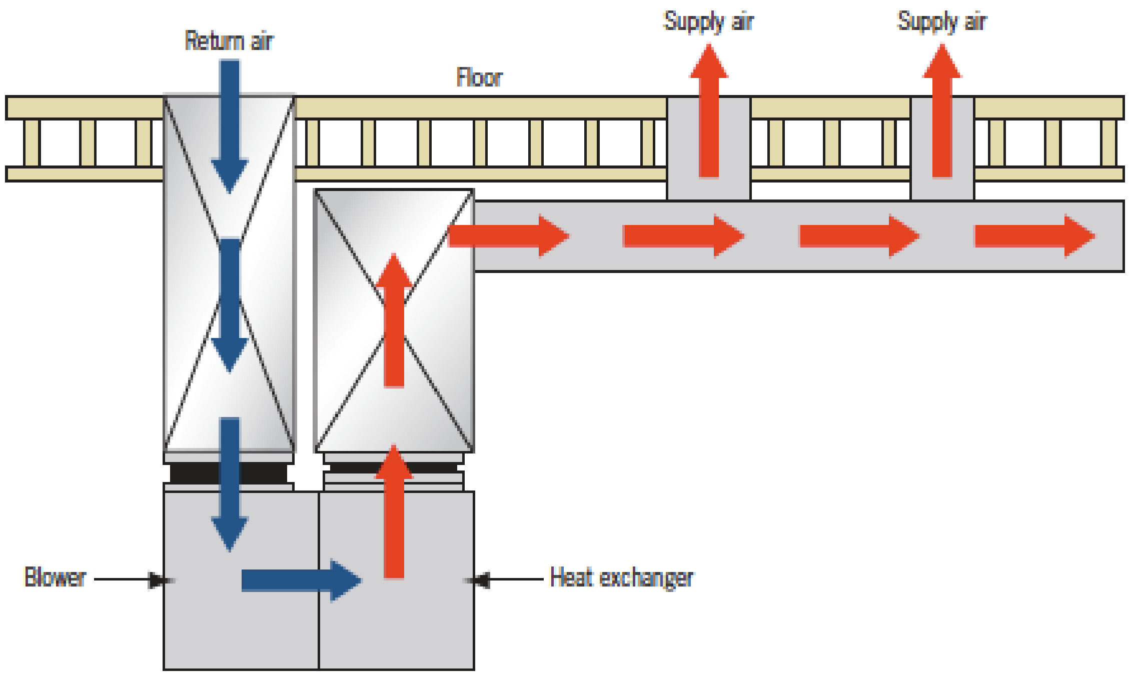


Illustration of a lowboy furnace configuration

Multipositional Furnaces

- Can be used in most applications.
- Field modified to fit configuration:
  - May be installed in upflow, downflow or horizontal position.
    - Installer make may make internal changes to the furnace when changing its configuration.

Configuration Keys

- Be sure to follow the manufacturer's recommendations regarding the application.
- Combustion products are always separated from the circulated air in the controlled space.
- The sequence of operation remains the same for all furnaces regardless of the configuration.

Summary

- Modern furnaces gas are designed to use any of several different fossil fuels.
- Delivery and manifold pressures vary with each type of gas.
  - Must be verified and set to insure proper operation
- Oil furnaces normally utilize No. 2 fuel oil.
- Furnaces are available in several configurations to fit installation needs.

Gas and Oil Heating NATE Review

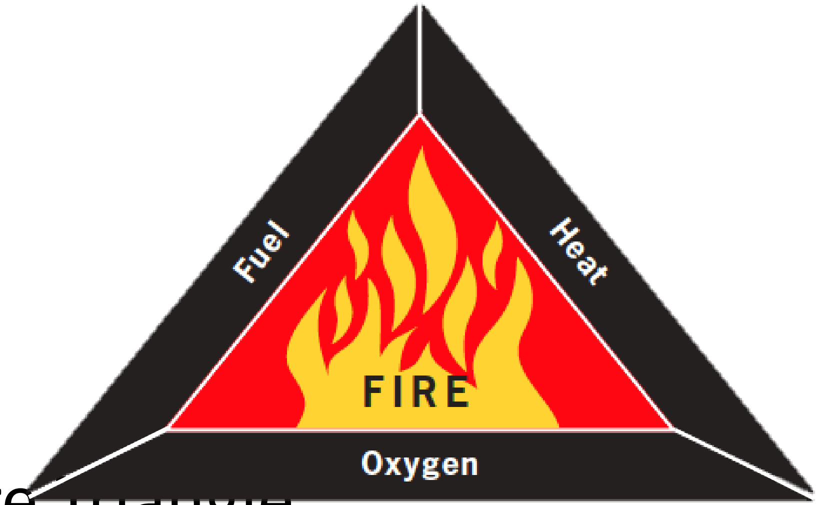
Chapter 2: Combustion

Lesson Objectives

- Discover the process of gas combustion.
- Examine the components involved.
- Learning the sequence of operation.
- Testing for proper efficiency of the process.

Combustion Chemistry

- Combustion is a chemical reaction.
- It involves three components:
    1. Fuel;
    2. Oxygen; and
    3. Ignition source (heat).



- The process is often called the “Fire Triangle.”

Complete Combustion

$$CH_4 + 2O_2 + \text{IGNITION SOURCE} \longrightarrow CO_2 + 2H_2O + \text{HEAT}$$

METHANE

OXYGEN

CARBON DIOXIDE

WATER (IN VAPOR FORM)

Incomplete Combustion

$$3CH_4 + 8O_2 + \text{IGNITION SOURCE} \longrightarrow 2CO_2 + 6H_2O + C + \text{HEAT}$$

METHANE

OXYGEN

CARBON DIOXIDE

WATER VAPOR

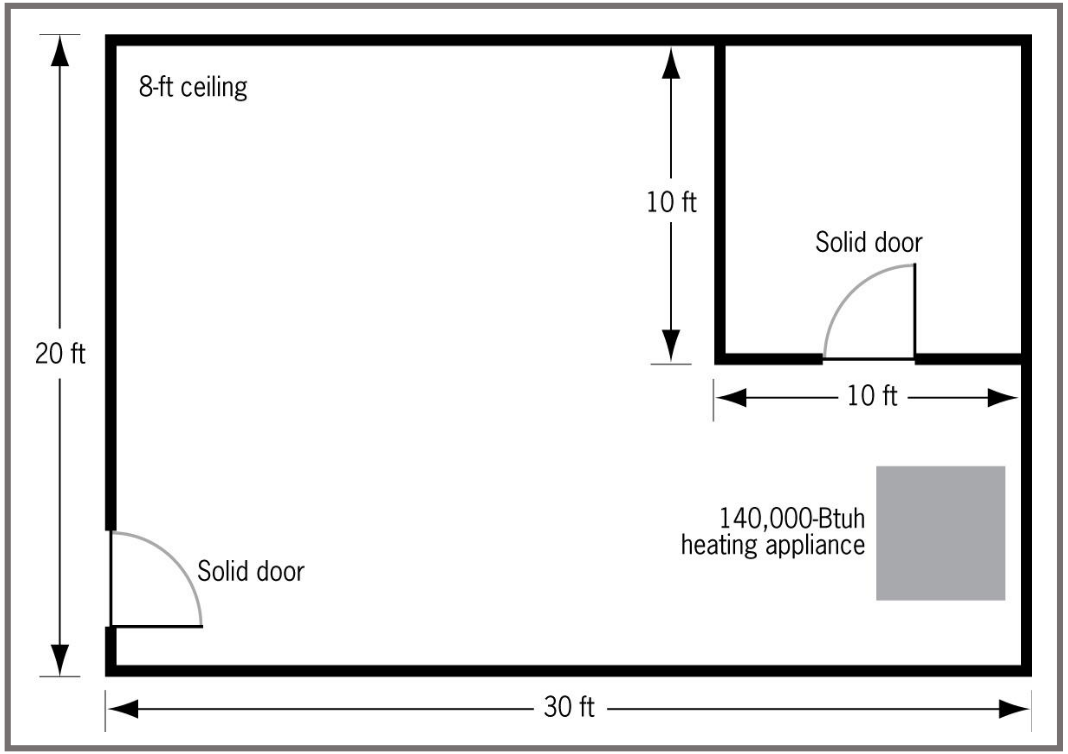
CARBON, OR SOOT

Combustion Air

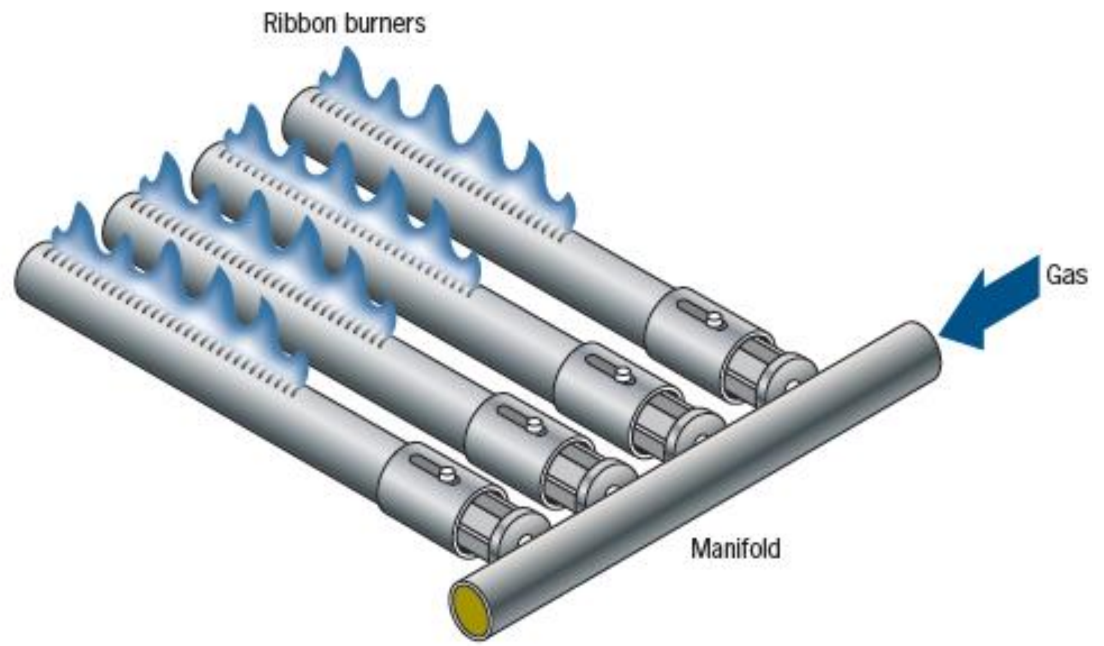
- Quality and quantity must be considered.
- In older homes, the construction was looser.
- Newer homes today are built tighter.
- Calculations must be made to determine need:
  - Furnaces in confined spaces:
    - Based on the total input rating of units in that space.

Combustion Air

- Floor plans and appliances help determine amount of combustion air needed.
- Direct vent systems may be preferred:
  - In confined spaces with significant contaminants.

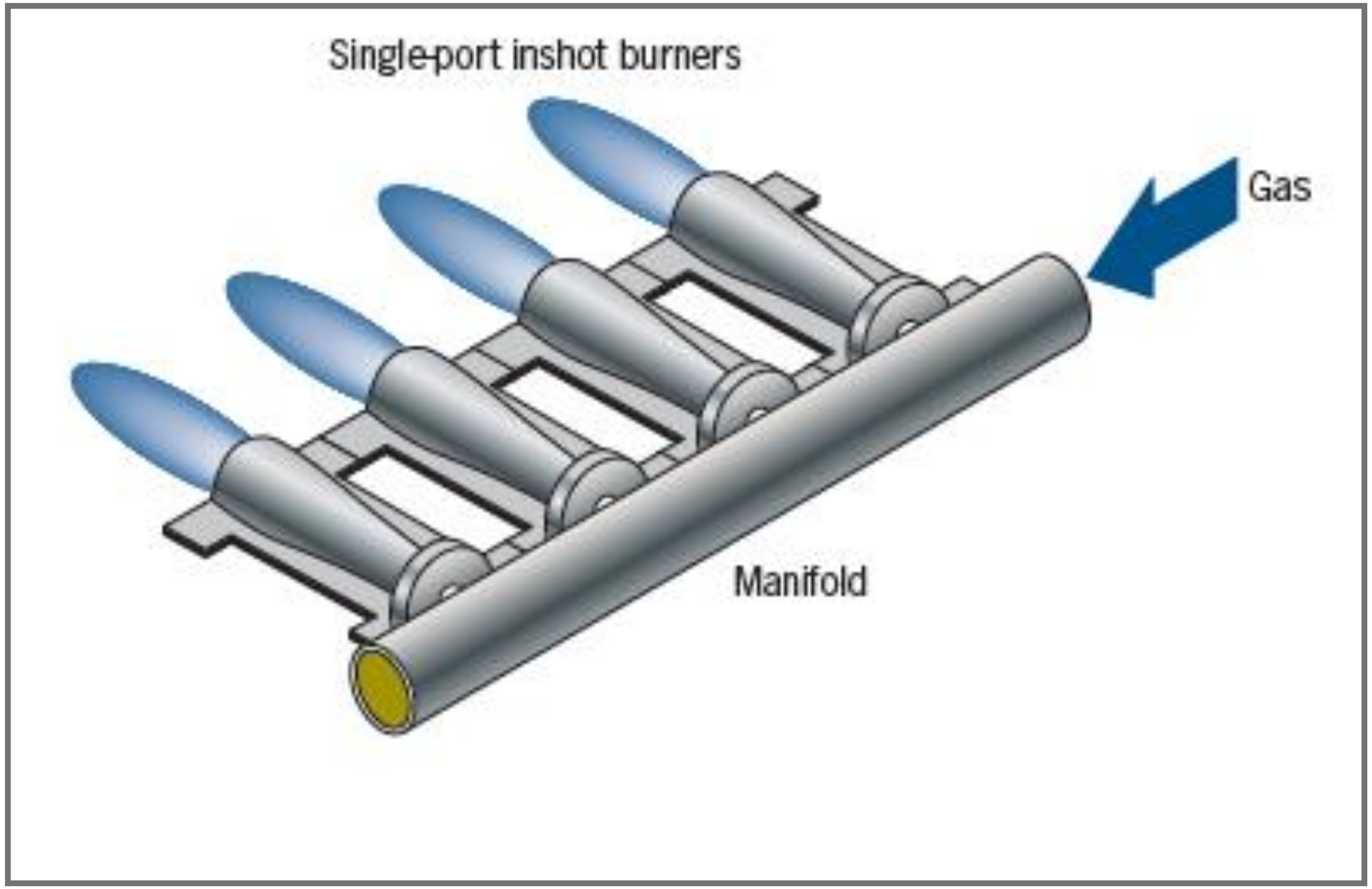


Gas Burners

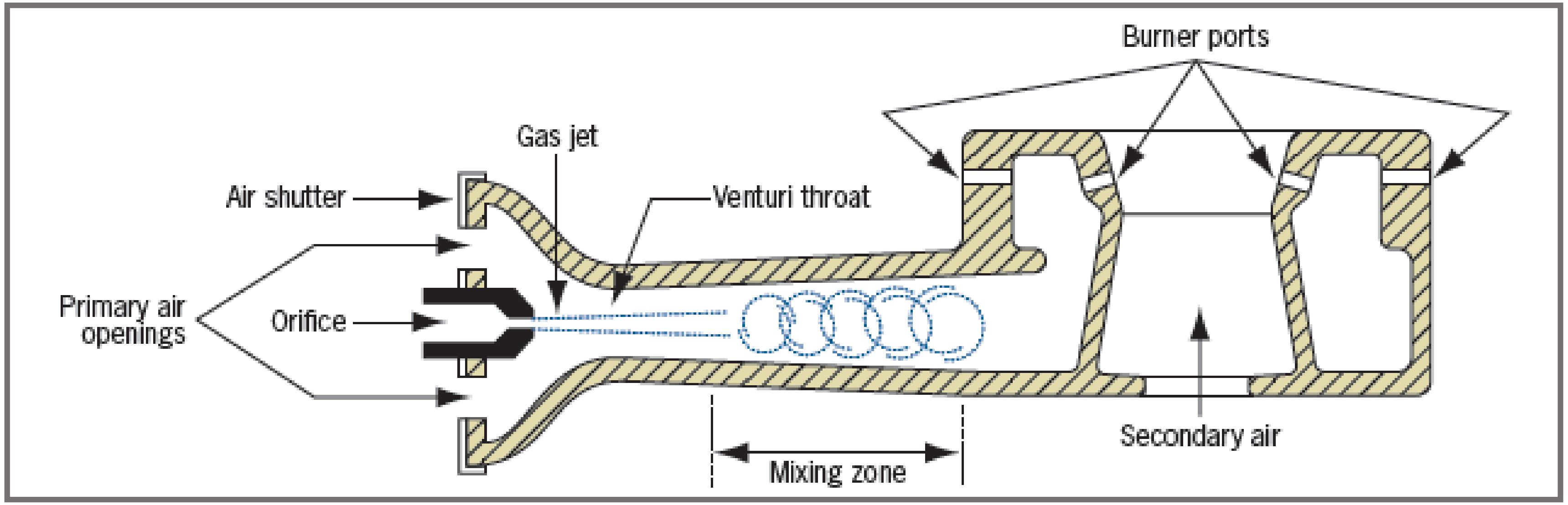


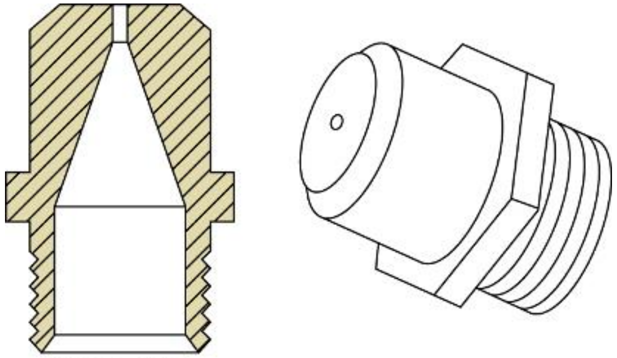
Ribbon Burners

Gas Burners



Gas Burners

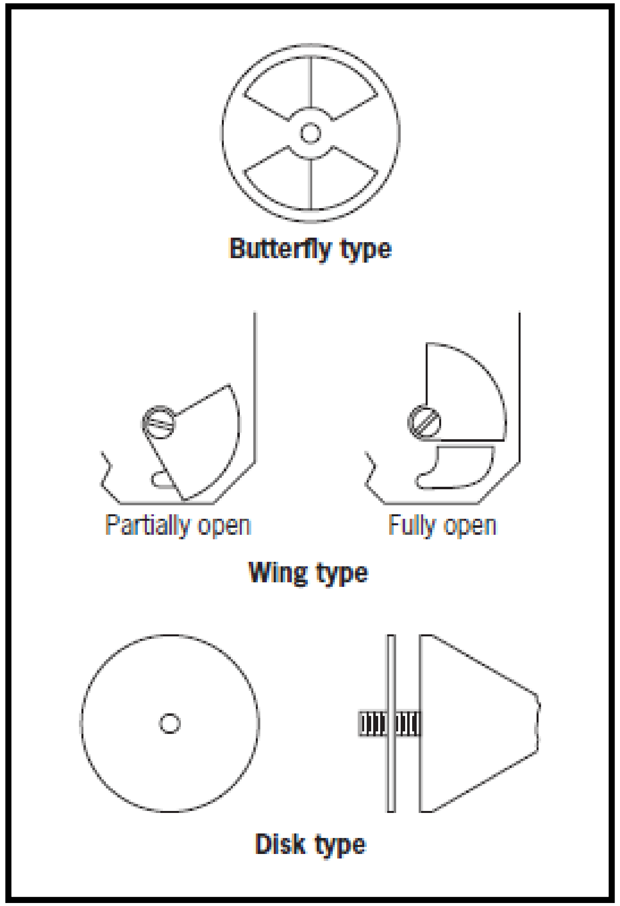




Orifice

Atmospheric gas burner

Air Shutters



Gas Burner Combustion Efficiency Tests

Input

Type of gas ____________

Btu content ____________ per ft^2

Orifice drill size ____________

Manifold pressure ____________

Meter time (in seconds) per revolution of test dial:

0.25 ft^2 ____________

0.5 ft^2 ____________

1 ft^2 ____________

2 ft^2 ____________

5 ft^2 ____________

Flame appearance

Type of primary adjustment:

- ☐ Wing
- ☐ Butterfly
- ☐ Disk

Flame before adjustment:

- ☐ Sharp blue
- ☐ Red tips
- ☐ Heavy yellow

Neutral point adjustment

- ☐ Factory-designed (not adjustable)

Conversion burner:

Below adjustment range ____________

Above adjustment range ____________

Incorrect adjustment range ____________

Air temperature rise

Supply air temperature ____________

Return air temperature ____________

Temperature rise ____________

CO_2

First test: CO_2% ____________

Second test: CO_2% ____________

Final: CO_2% ____________

Gas Burner Combustion Efficiency Tests

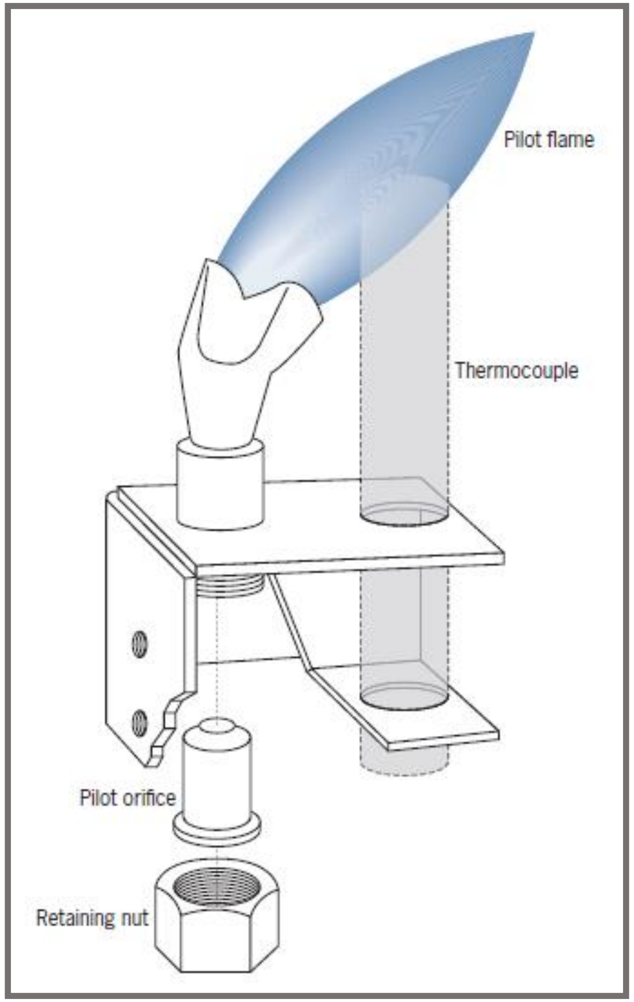
- Efficiency tests begin with the proper tools.
- Efficiency is the difference between the possible output and the actual output.
- The overall objective is to extract all the heat possible from the combustion process.

Sequences of Operation

- Some variations from one manufacturer to another.
- The general sequence is the same for all.
- It all begins with the ignition system:
  - There are three types of ignition systems:
    - The standing pilot system;
    - Intermittent ignition system; and
    - The direct ignition system.

Standing Pilot

- Provides a constant flame for ignition times.
- Generally uses a thermocouple for proof.
- Voltage from the thermocouple holds the pilot valve open.
- The pilot flame ignites the main burner.

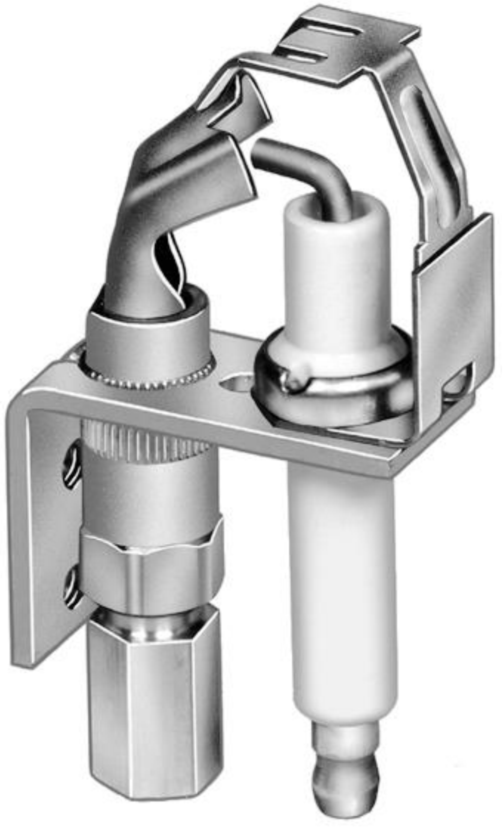


Standing Pilot

- Sequence of operation on a call for heat:
  1. The thermostat sends 24 V to gas valve.
  2. The main gas valve is energized, and as long as the thermocouple energizes the pilot valve.
  3. The gas then flows to the burners.
  4. After a brief warm-up period the blower runs.
  5. Once the thermostat is satisfied, the sequence is then reversed.
  6. The pilot valve and light will remain on ready for the next start up.

Intermittent Ignition

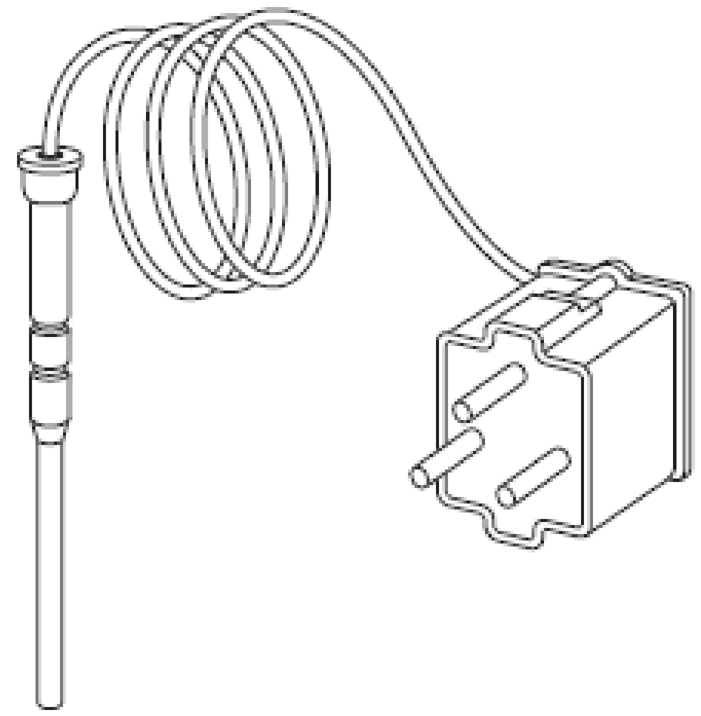
- An intermittent ignition system is one that
- Lights a pilot on a call for heat.
- Generally uses spark igniter to light the pilot.
- A flame rectifier proves pilot flame.
- Only after pilot flame is proven, main gas valve will open.



Spark Igniter

Intermittent Ignition

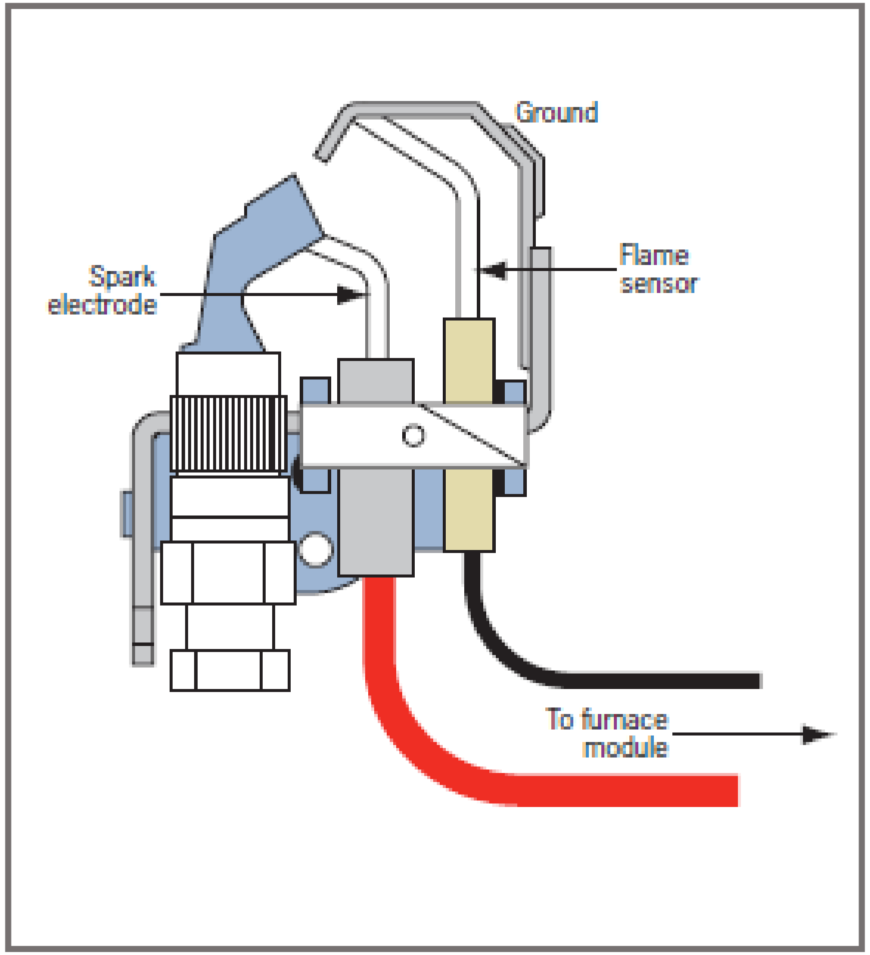
- The flame rectifier is used to prove the pilot flame.
- When pilot flame is proven,
- The main gas valve will open, and
- The pilot flame will then ignite the main burners.



Mercury Flame Rectifier

Intermittent Ignition

- Older systems may utilize a mercury-flame sensor to prove the pilot.

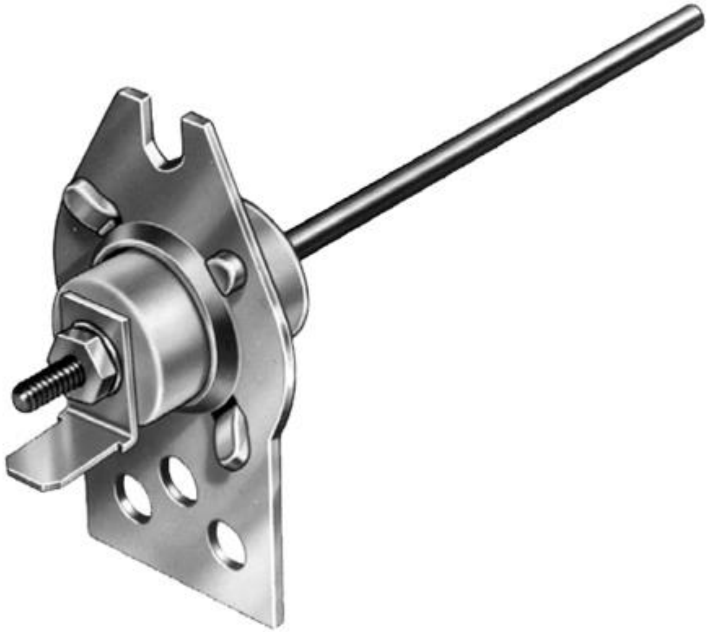


Intermittent Ignition

- Sequence of operation on a call for heat:
  1. The thermostat sends 24 V to the ignition module.
  2. If equipped, the induced-draft fan starts, closing a pressure differential switch, proving the fan function.
  3. The module then begins the spark and opens the pilot gas valve.

Intermittent Ignition

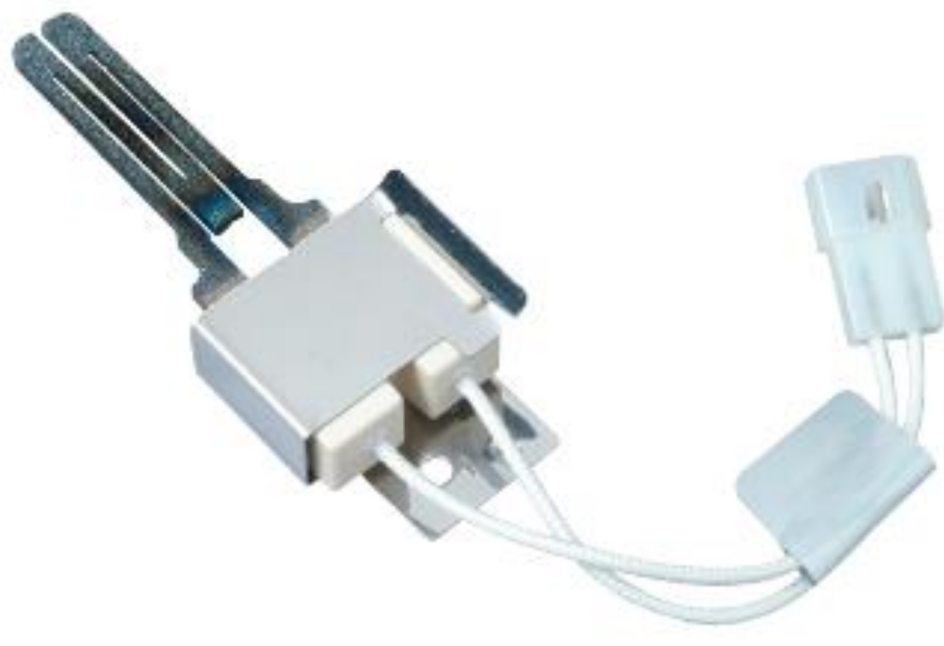
- Sequence of operation on a call for heat:
  4. Once the pilot is lit and is proved, the main gas valve opens. After a brief warm-up period the main blower runs.
  5. Once the thermostat is satisfied, the sequence is then reversed.



Flame Rectification Sensor

Direct Ignition

- Lights the burner directly.
- Commonly use hot-surface igniters.
- These use a flame-rectification method.
- Flame rectification provides a fast response.



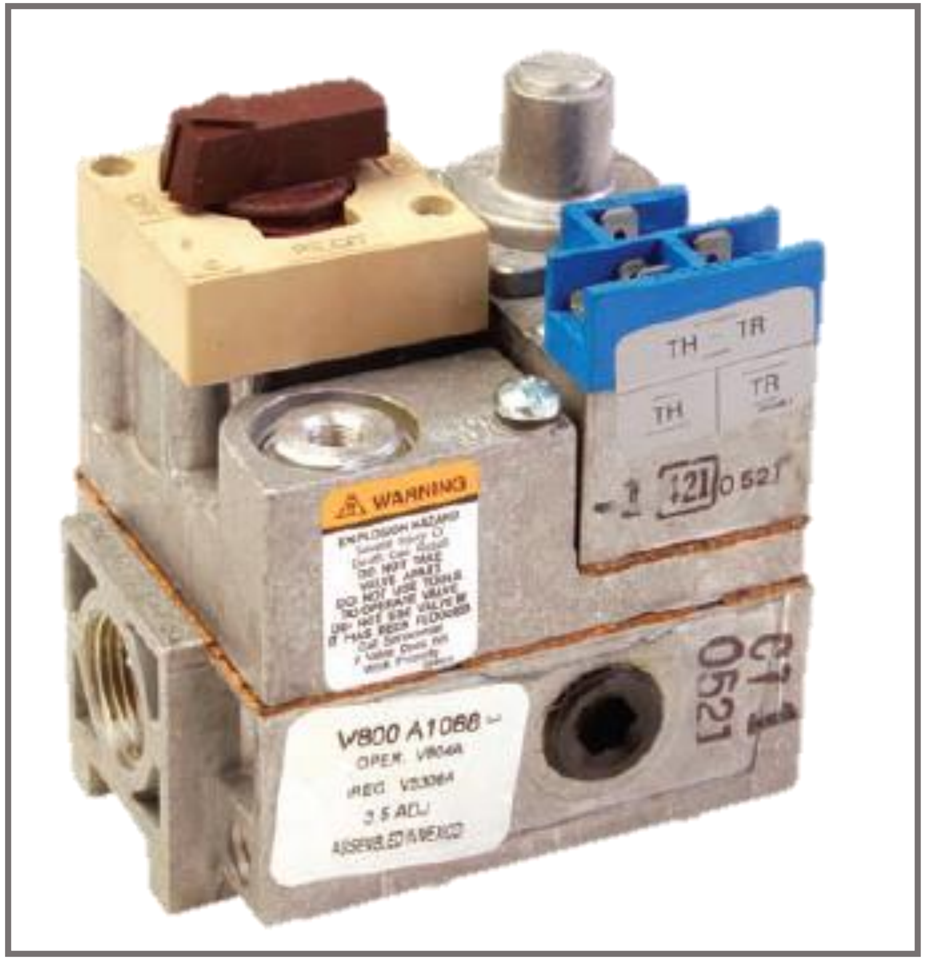
Hot-surface Igniter

SEQUENCE OF OPERATION

- Sequence of operation on a call for heat:
  1. The thermostat sends 24 V to the ignition module.
  2. The induced-draft fan starts, closing a pressure differential switch, proving the fan function.
  3. The module then energizes the igniter.
  4. After approximately 30 seconds the gas valve is opened and the burner is lit by the hot-surface igniter.
  5. After a brief warm-up period the main blower runs.
  6. Once the thermostat is satisfied, the sequence is then reversed.

Gas Valves

- Typical furnaces use a combination gas valve:
  - Main valve; and
  - Pilot valve.
- Also operates as a manual shutoff.
- Also has an internal pressure regulator.
- May have two stages for capacity reduction.



Gas and Oil Heating NATE Review

Chapter 3: Furnace Installation

Lesson Objectives

- Where to begin with the install process.
- Determine equipment location limitations.
- Learn electrical requirements and connections.
- Examine fuel piping designs.
- Discover the accessories available.
- Learn about zone controls.
- Discover fresh-air intake methods.

Proper Equipment Selection

- Start with a proper load calculation.
- Cooling calculations consider heat gains:
  - From the sun; and
  - From internal loads:
    - Such as lights, people and equipment.
- Heating calculations consider heat loss:
  - Heat loss to outdoors from structure.

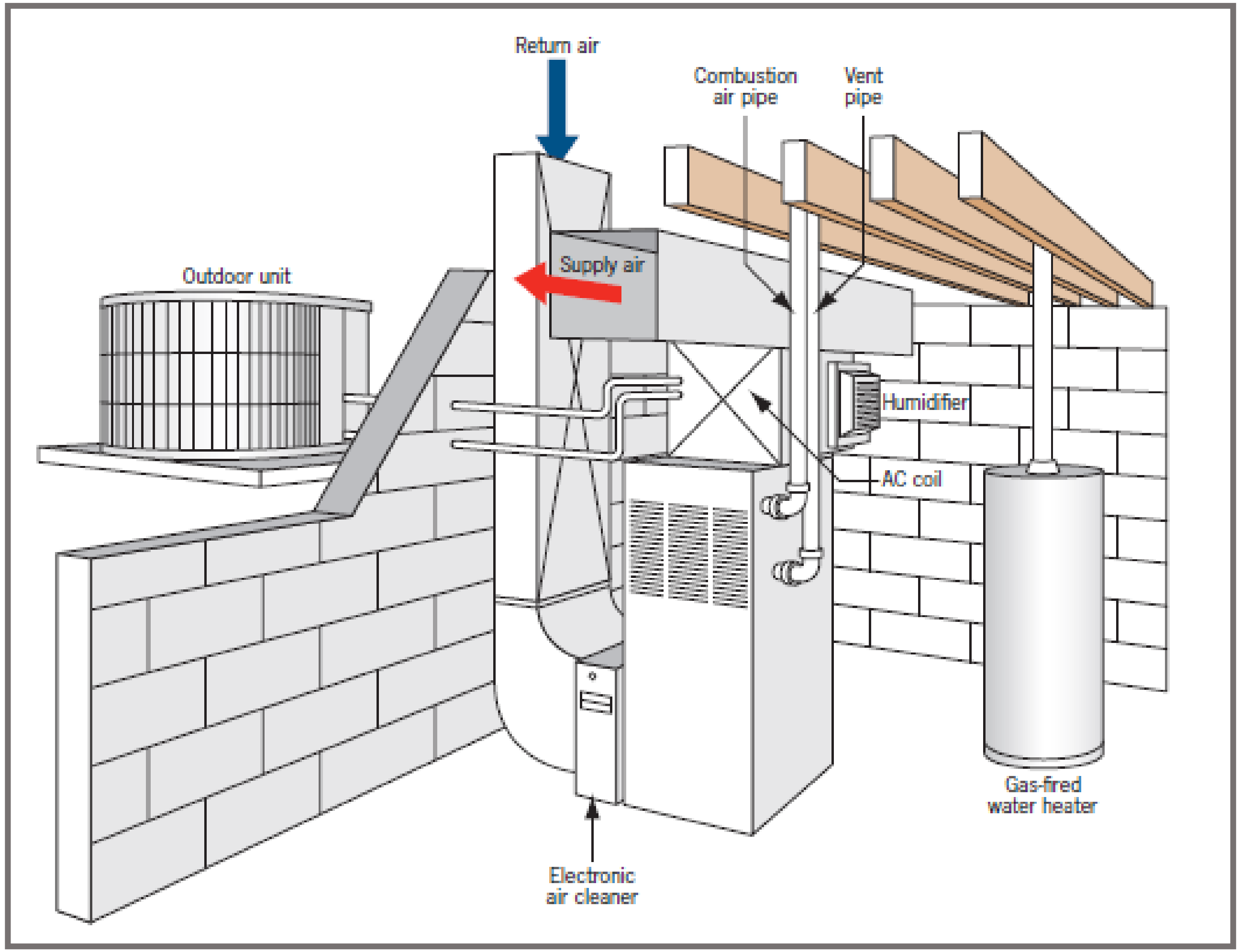
Furnace Selection

- Based on closely matched heat-loss calculation.
- An undersized furnace will not maintain desired comfort levels.
- An oversized furnace will short cycle*:*
  - Short cycling will shorten furnace life and reduce efficiency.
- When the furnace output matches the heat loss of the space, this result is called the balance point.

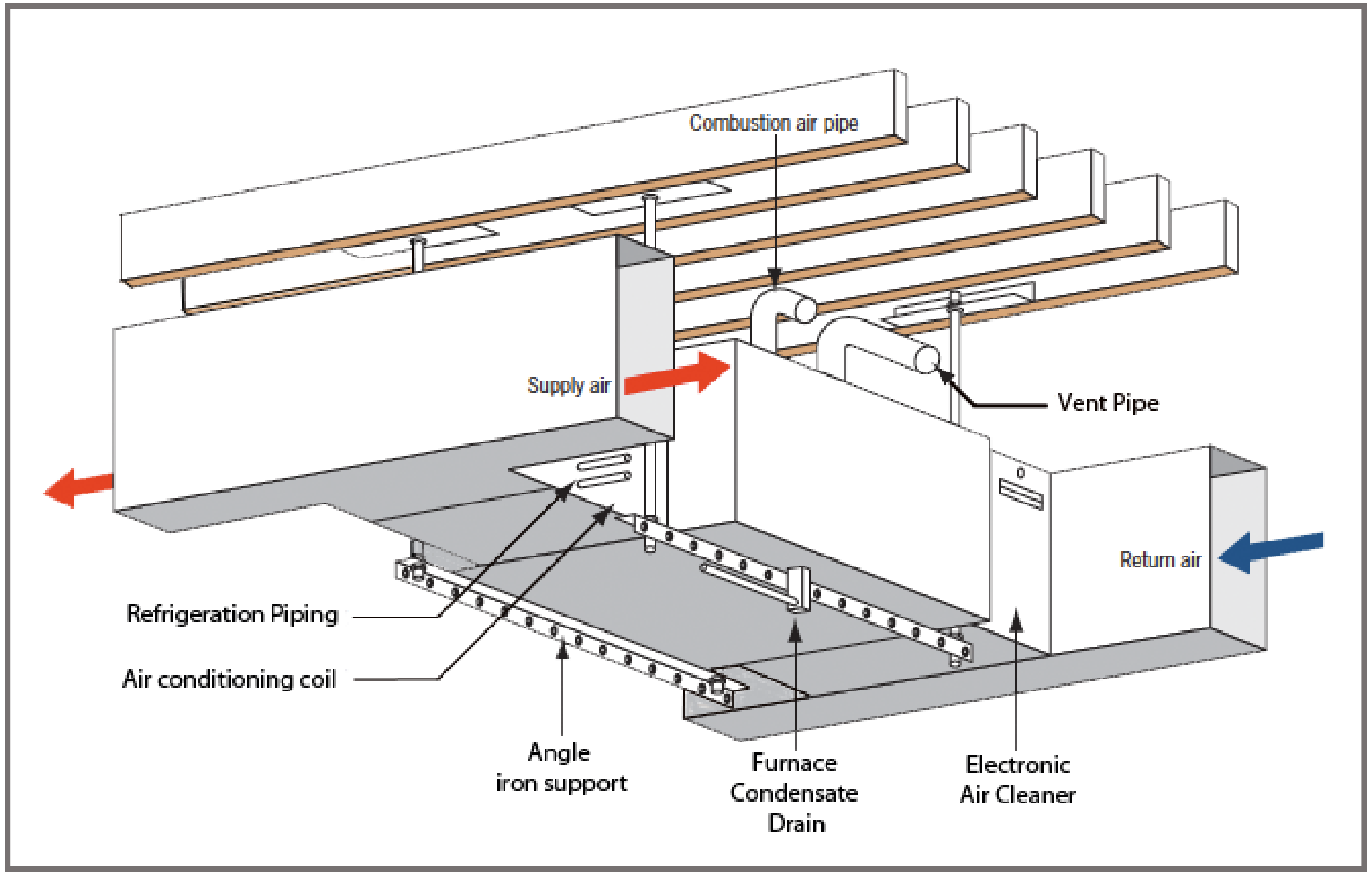
Furnace Location Choices

- Basements.
- Crawl spaces.
- Attics.
- Closets.
- Garages.

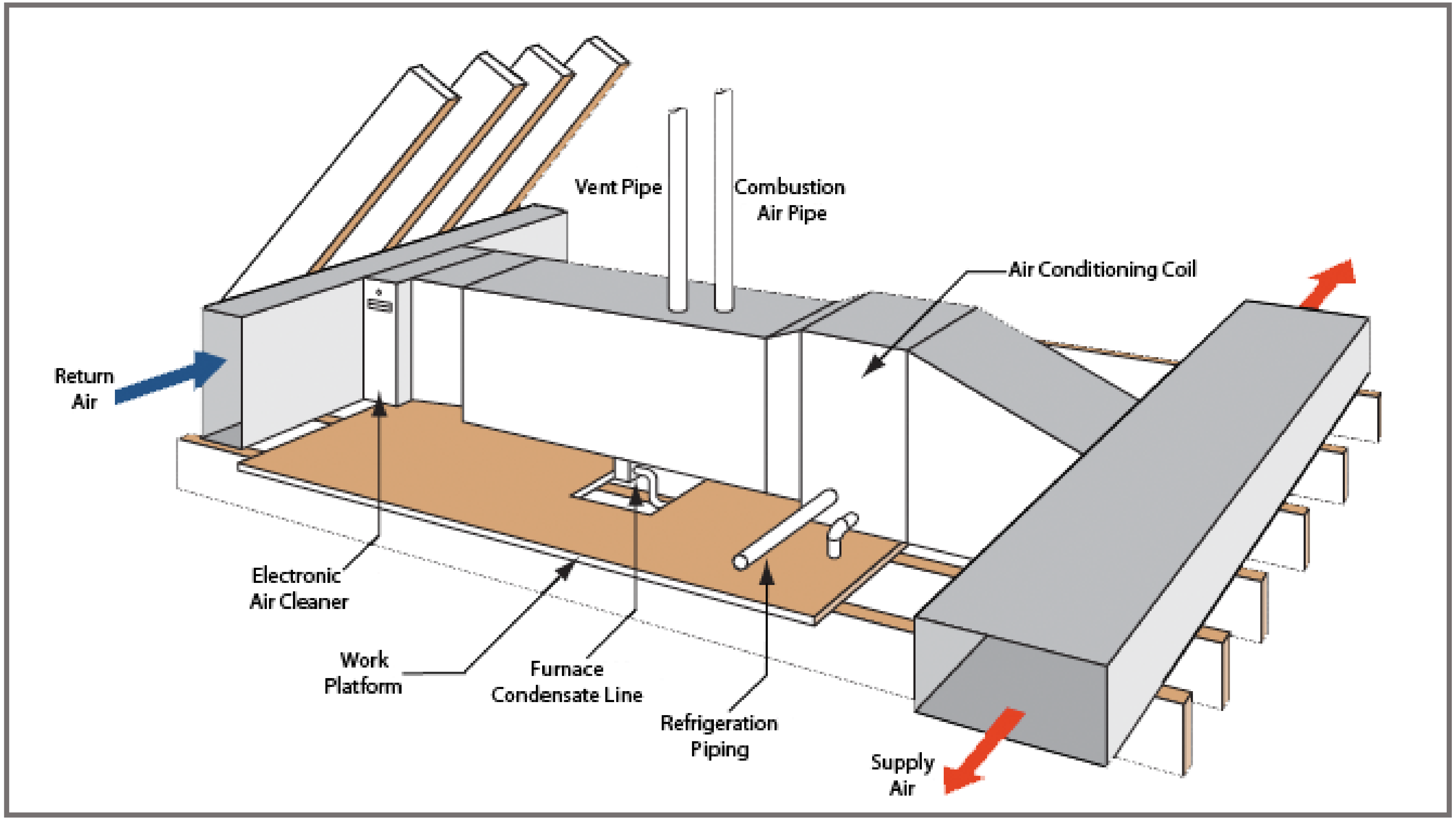
Basement Furnace Location



Crawl Space Furnace Location



Attic Furnace Location



Closet and Garage Furnace Locations

- Closet/Utility installations are typically near the center of the house.
  - Allows for a central return, eliminating the return duct system.
  - Reduces installation costs, but does not always provide good air distribution.
- A furnace installed in a garage must be mounted at least 18 in. off the floor.
- Ducts within the garage space must be sealed.
- Some locales may require fire dampers when ductwork passes between the house and garage. Always confirm code requirements.

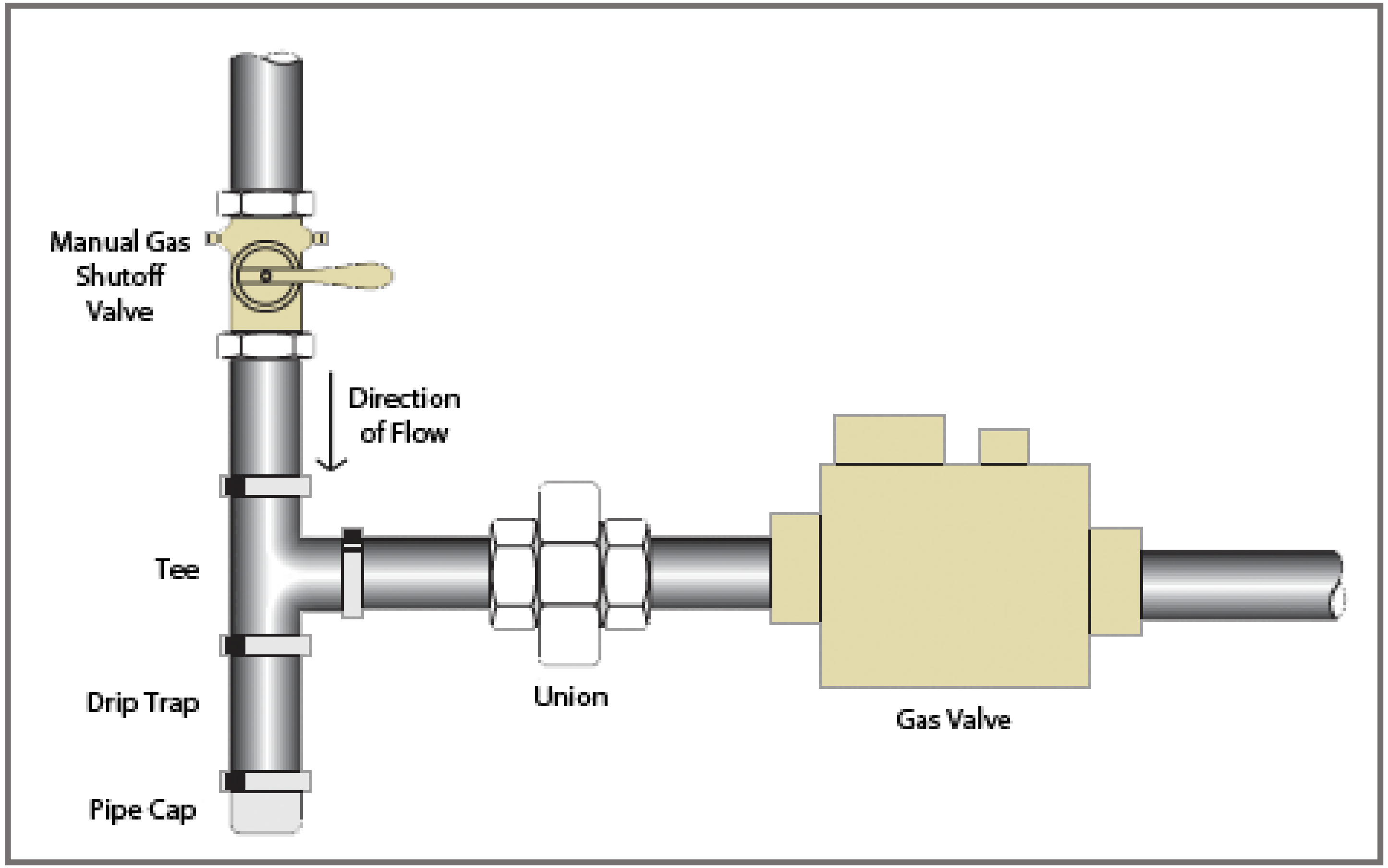
Electrical Connections

- Furnaces generally operate on 120-V circuit.
- A licensed electrician handles installation from the panel to the disconnect.
- Always check with the proper code authority before completing connections.
- A low-voltage connection between the furnace and thermostat must be run.
- Low-voltage wiring usually follows a color-coded sequence between wires and terminals.

Fuel Piping

- Low-pressure systems require proper sizing.
- For natural gas, black pipe is the usual choice.
- Oil-heating systems usually use copper tubing.
- In all piping systems, care must be taken to avoid any leaks.

Typical Gas Piping Layout



Gas Leak Detection

- After piping is complete, check for leaks.
- Use a combustible gas detector.
- Ultrasonic leak detectors and soap bubbles also can be used.
- Avoid getting moisture in the tip of an electronic leak detector.

Condensate Piping

- Carries condensate from condensing furnaces, air-conditioning coils to the drain.
- Should be sloped toward the drain.
- Drain line should be open-vented.
- Generally constructed from PVC.

Thermostats

- The main operating control for the furnace.
- Functions as a start-stop mechanism.
- It is operated by a temperature sensor device.
- When a call for heat is made, a switch closes.
- This energizes the “W” circuit to the furnace.
- Once the thermostat setpoint has been reached, the switch opens.
- This disconnects 24-V from the “W” terminal.

Thermostat Location

- Should be located in a central location.
- Locate it approximately five feet above the floor.
- Do not locate where it can be exposed to direct sunlight.
- Do not mount near supply registers.
- Do not mount it on or near outside walls.
- Do not mount it in or near the kitchen.

Typical Thermostat Terminals

- A basic mechanical thermostat is a set of switches.
- Electronic/mechanical thermostats with lights may require a power connection.
- If a fossil-fuel furnace is used with a heat pump, the furnace is connected to the W2 terminal.

Terminal	Function
R	24-V power
G	Fan circuit
Y	Cooling circuit
W	Heating circuit
C	24-V common

Electronic Thermostats

- Various models are available.
- Programmable thermostats allow automatic temperature setback.
- Some thermostats have an auto changeover function between heating and cooling modes.

Accessories

- Air conditioning is most often added to a heating system.
- Air conditioners reduce heat and humidity during summer.
- Humidifiers are added to increase the relative humidity level during winter months.

Humidifiers

- Humidifiers come in several varieties and with different delivery systems.

Steam Humidifier

Bypass Humidifier

Fan-powered Humidifier

Atomizing Humidifier

Zoning

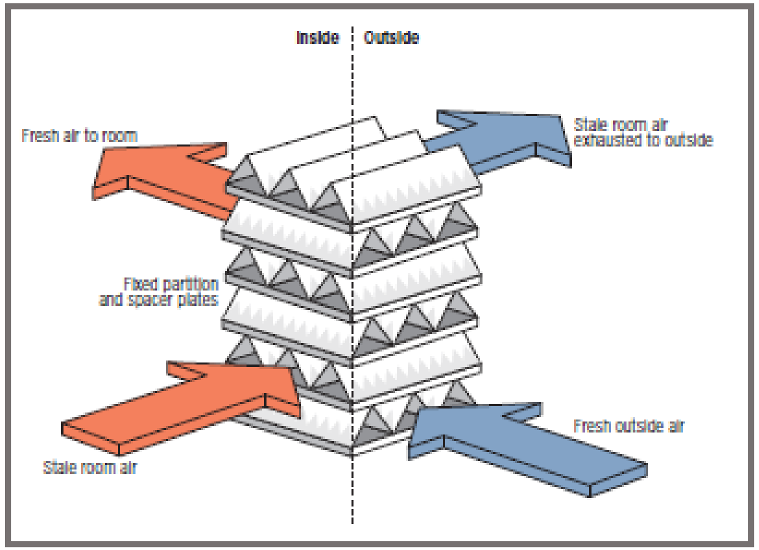
- Provides for multiple temperature-controlled areas within a single structure.
- These may be separate rooms or groups of rooms.
- Each “zone” is controlled by a separate thermostat.
- A bypass damper may need to be incorporated in the system.

A bypass damper

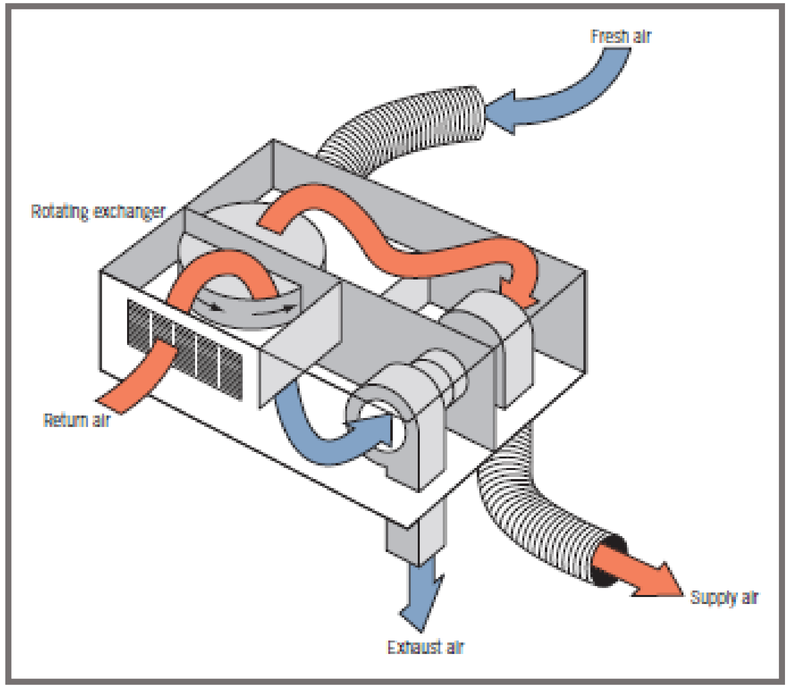
Fresh-air Intakes and Economizers

- Systems may require fresh air to provide proper ventilation to the structure.
- Economizers act as fresh air intakes.
- Also known as “free cooling,” using outdoor-air to condition during cooler ambient conditions.
- Economizers incorporate an outdoor-air damper system with the return air.

Heat-recovery/Energy-recovery Ventilators



Heat Recovery Ventilator (HRV)



Energy Recovery Ventilator (ERV)

Gas and Oil Heating NATE Review

Chapter 4: Venting

Lesson Objectives

- Learn the basic procedures to proper venting.
- Discover the different ANSI categories of gas appliances.
- Learn the different elements of proper vent design.
- Understand the need to follow the equipment manufacturers guidelines for proper vent sizing, materials and installation.

Venting Importance

- Proper venting is very important for proper operation.
- Improper venting can reduce system efficiency.
- Leaking combustion products must be avoided.
- Safety of building occupants is a prime consideration with design, installation and operation.

National Fuel Gas Code 10.4.1

"Category II, III, and IV gas utilization equipment shall be vented using materials furnished or specified by the gas utilization equipment manufacturer. The venting system shall be installed in accordance with the gas utilization equipment manufacturer's installation instructions."

Gas-appliance ANSI Categories

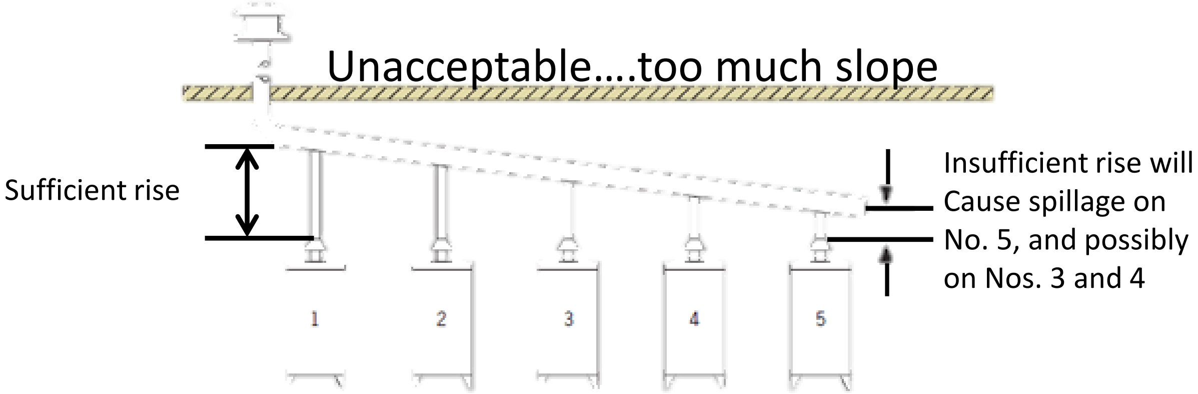
- Category 1: Non-positive vent static pressure (S.P.), and AFUE in the 55–82% range.
- Category 2: Non-positive vent S.P. and vent temperature range that may cause excessive condensate production.
- Category 3: Positive vent S.P. and a vent temperature that avoids excessive condensate.
- Category 4: Positive vent S.P. and low vent temperature with AFUE in the 87–97% range.
- All equipment must specify the equipment's category and the mark

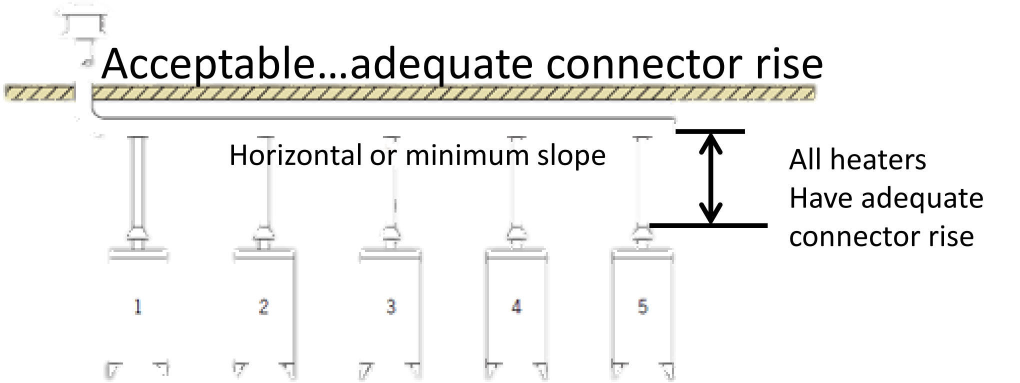
> "This appliance requires a special venting system. Refer to installation instructions No. _____ for parts list and method of installation."

Venting Category I Appliances

- Flue pipe must be same diameter as flue connection of unit.
- Flue pipe must run as directly as possible, with a minimum number of turns.
- The pipe must have a minimum upward slope of at least ¼ in. per linear foot for horizontal runs.
- It must extend through the chimney wall.
- The pipe must be adequately supported.

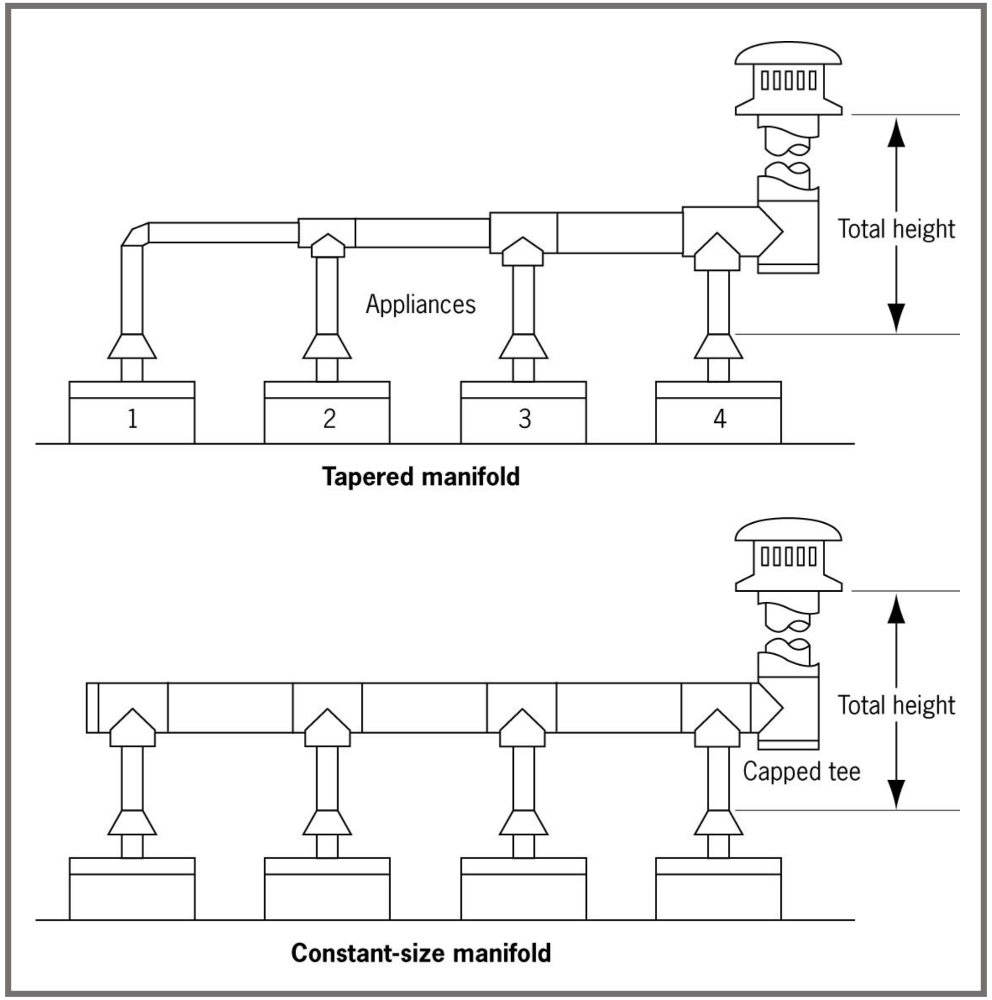
Flue Pipe Slope





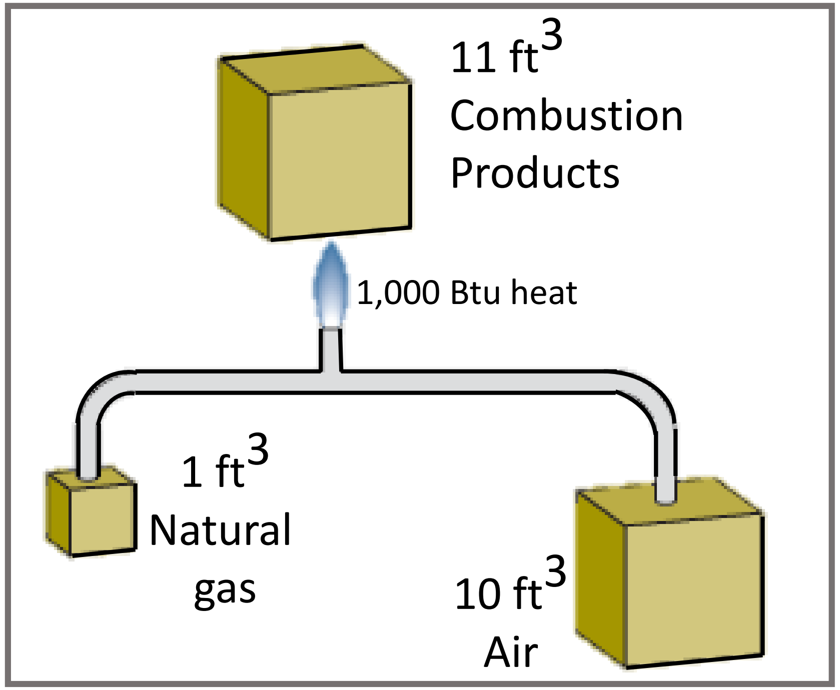
Manifold Differences

- Tapered manifolds are sized to accommodate appliances below and beyond the connection.
- Constant-size manifolds can accommodate all appliances in the system.



Venting of Gas-Burning Equipment

- The process total of 11 ft^3 of combustion products for every cubic foot of natural gas includes:
  - 1 ft^3 of carbon dioxide;
  - 2 ft^3 of water vapor; and
  - 8 ft^3 of nitrogen.



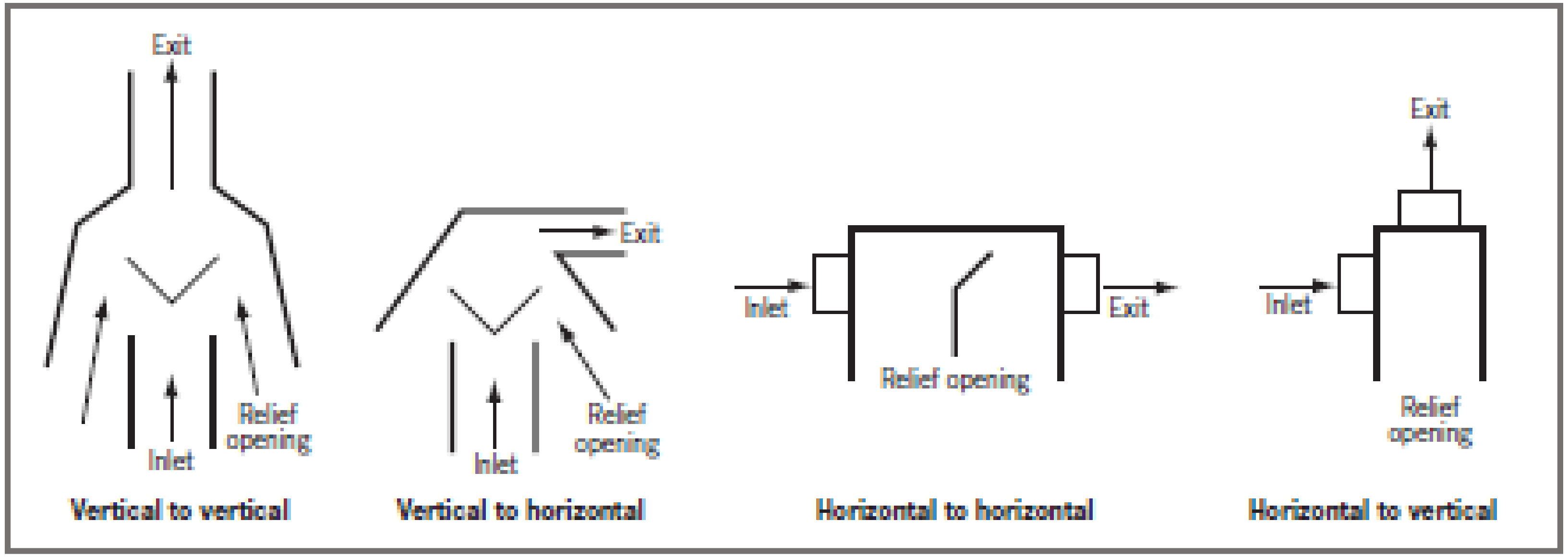
Venting of Gas-Burning Equipment

- The main purpose of venting is to completely remove all combustion gases to the outside of the conditioned space without spillage.
- There are two basic types of venting:
  1. Power venting; and
  2. Atmospheric venting.

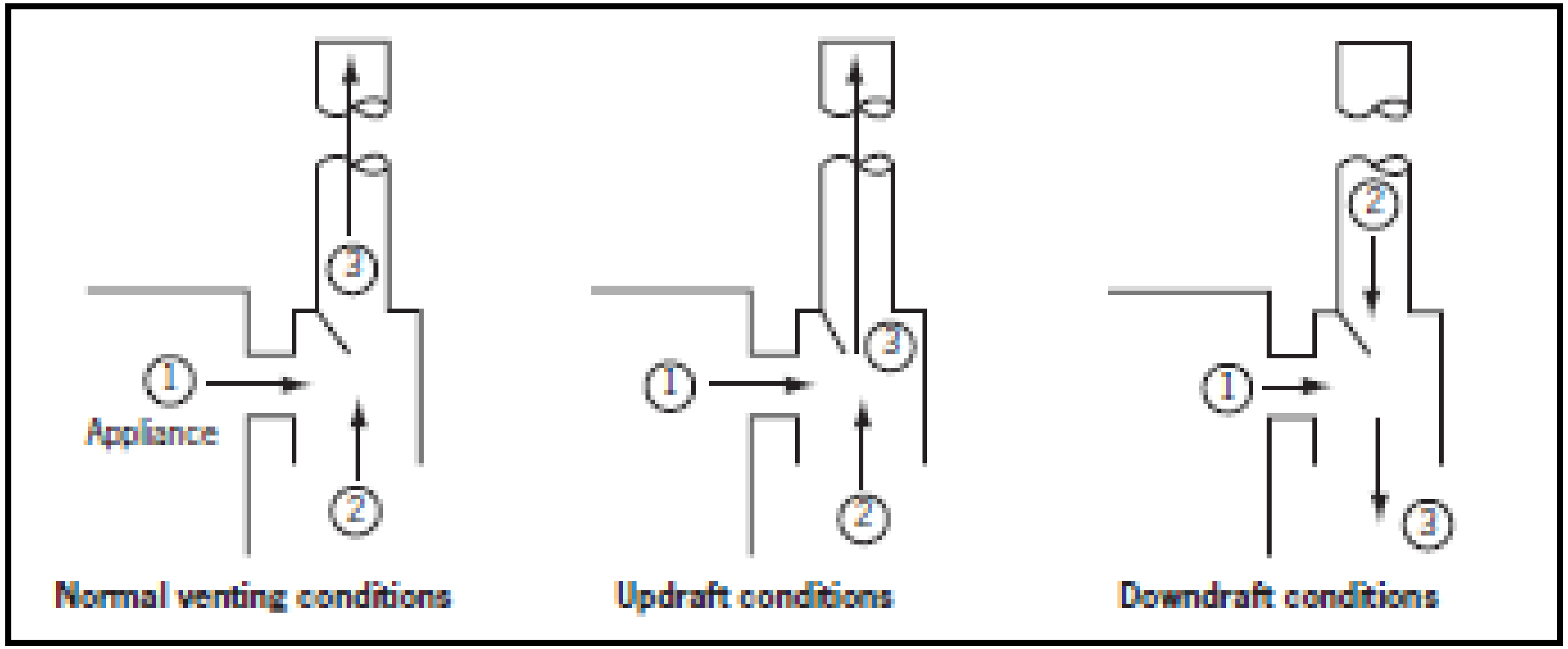
Gravity Vent Process

- Venting force is directly related to two factors:
    1. The density of the hot gases in the vent.
    2. The height of the gravity vent.
- Poor venting conditions usually translate to poor burner operation.
- Gravity vents are exposed to outdoor winds.
- A secondary air or draft hood must be implemented into the design of the unit.

Typical Draft Hoods



Draft Hood Operation

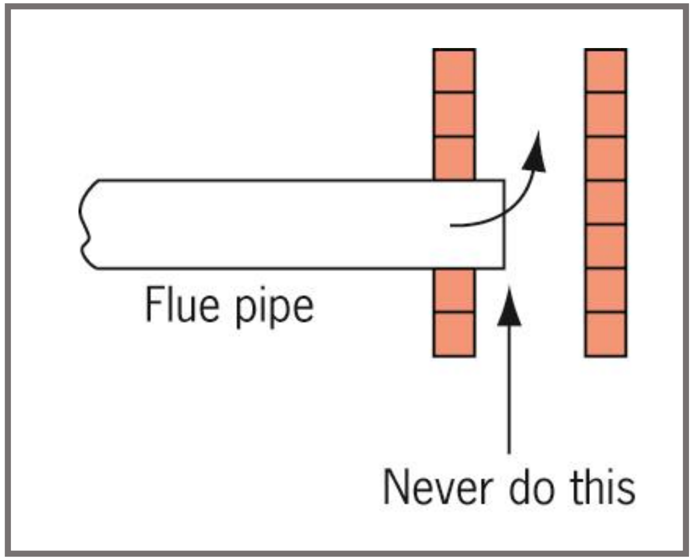


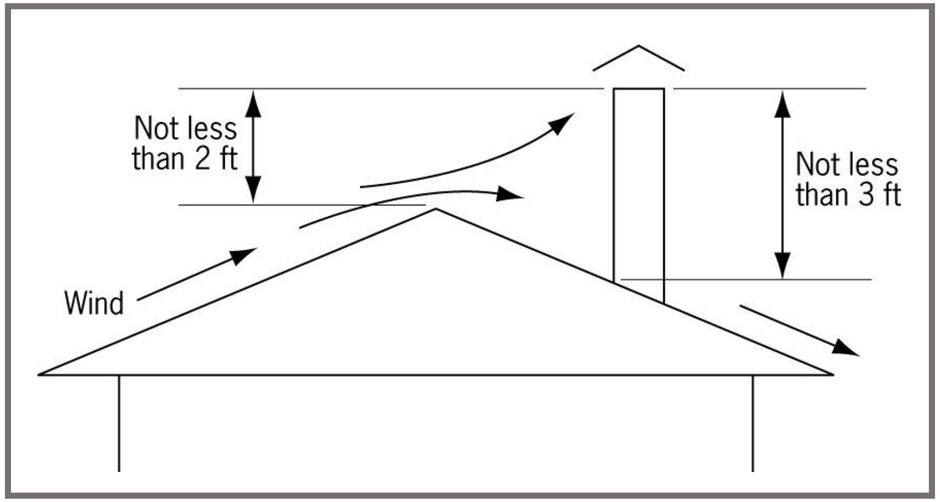
Updraft/Downdraft/Fan-assistance

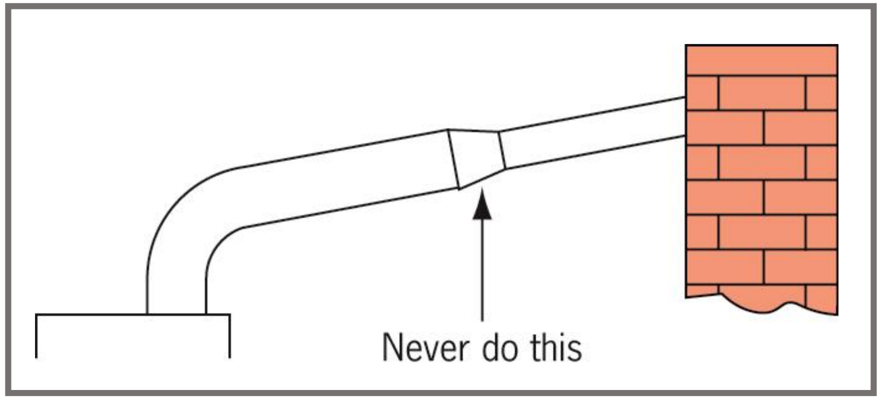
- Updraft can be increased via the use of a higher stack, or intermittently by wind action.
- A draft hood prevents positive-pressure buildup under downdraft conditions.
- Fan-assisted systems:
  - Forced-draft: Places a fan at the inlet side of the burner to push air into the combustion chamber.
  - Induced-draft: Places a fan at the outlet of the combustion chamber to pull combustion gases out.

Flue System Design

- Proper installation and maintenance are important for correct flue-system operation.

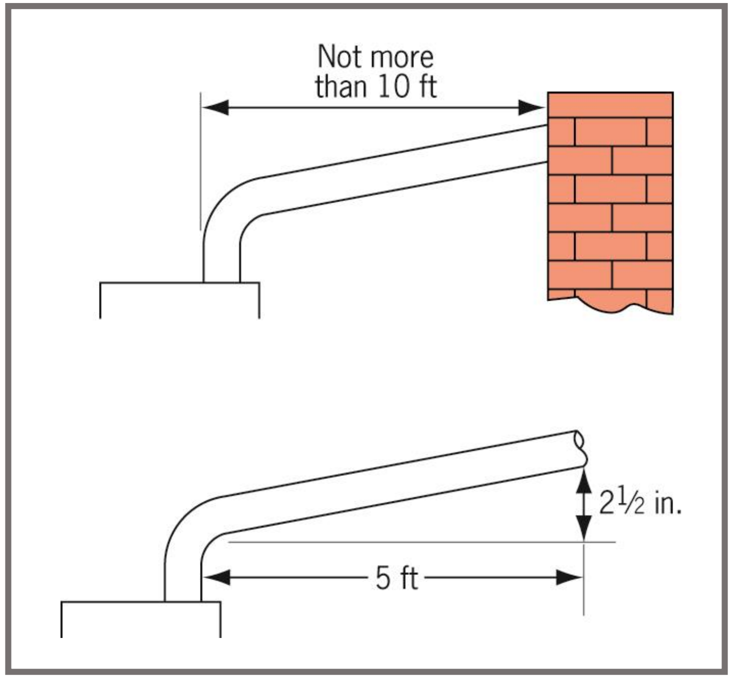


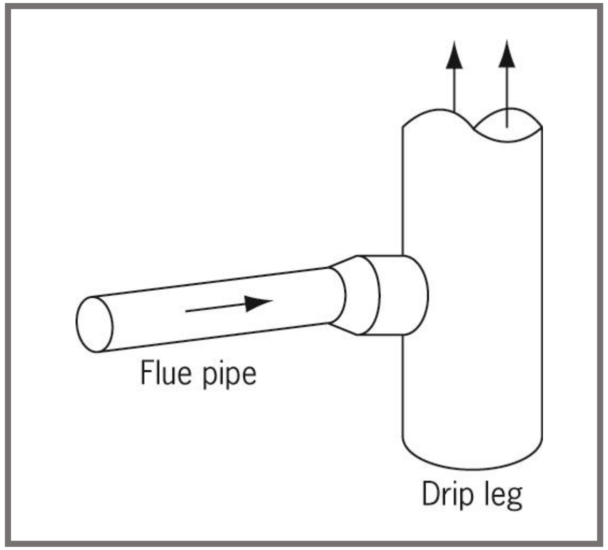


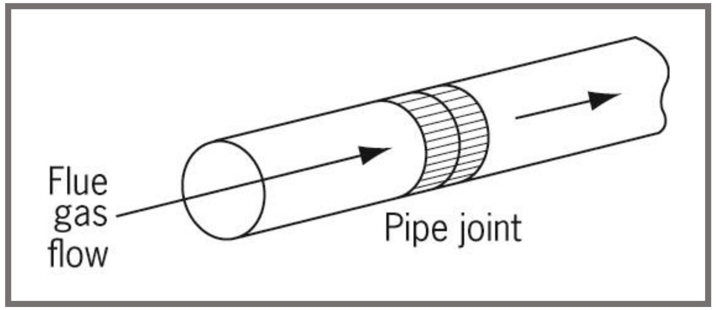


Flue System Design

- Proper installation and maintenance are important for correct flue-system operation.

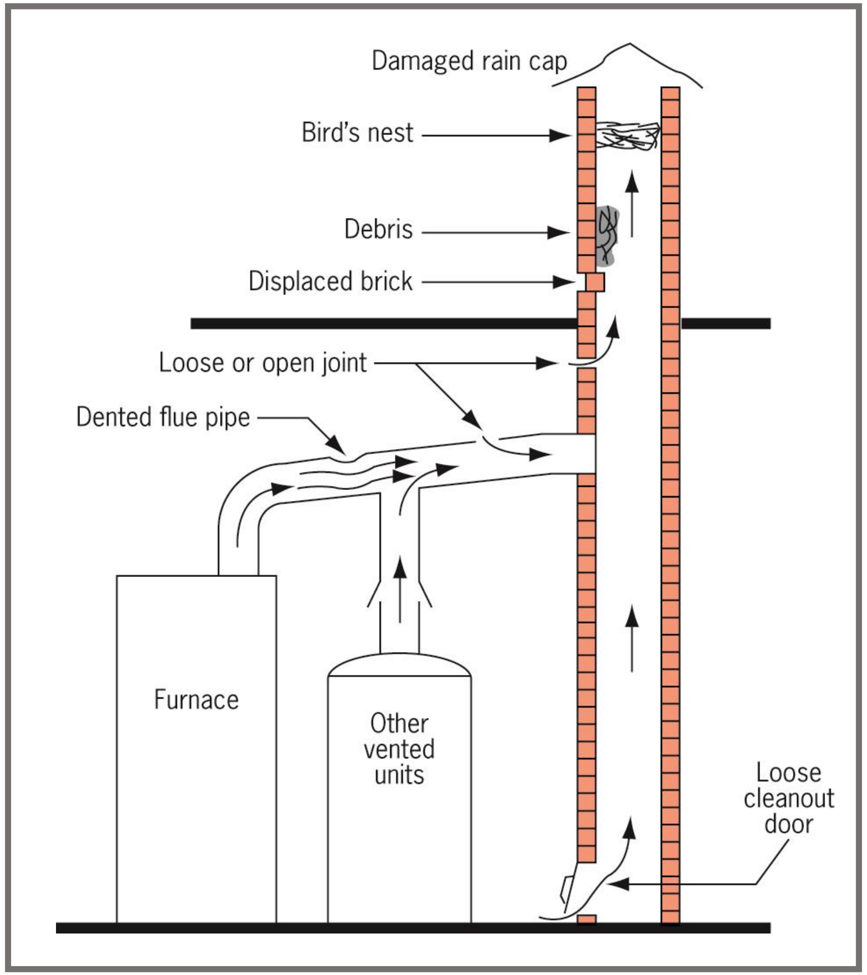






Flue System Design

- The chimney and flue pipes must be clear of all obstructions.
- Poor draft conditions, or excessive flue height or horizontal runs can cause condensation to occur in the flue pipe.



Combustion Air

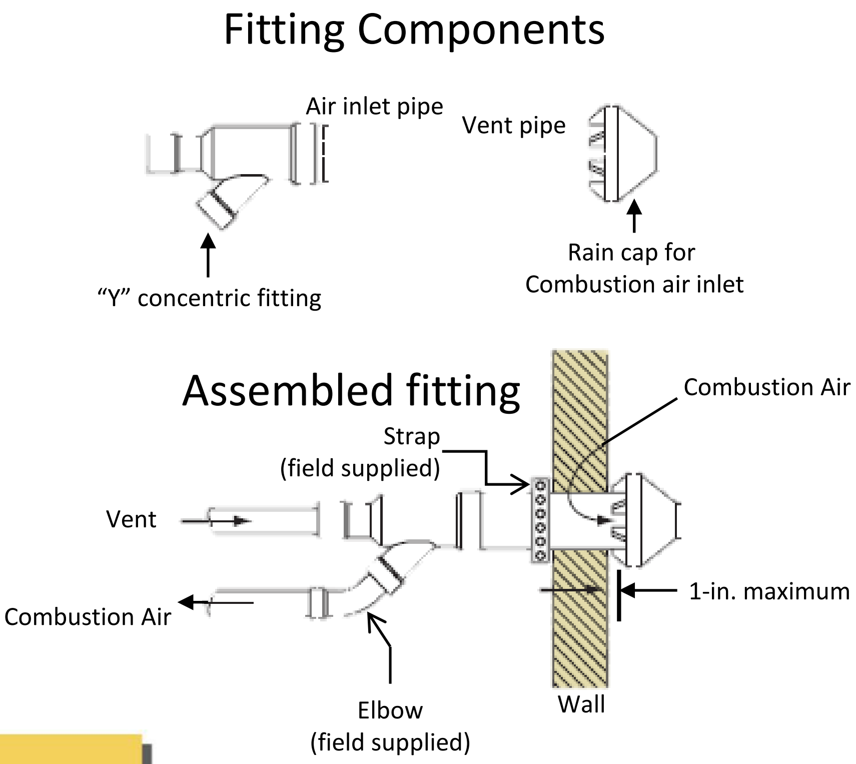
- Tightly constructed buildings can cause venting problems due to low infiltration of air.
- Other vented appliances, as well as exhaust fans, also may limit combustion air.
- A combustion-air pipe may be necessary:
  - This pipe would need to connect to the outside and then terminate near the furnace location.

Direct Venting System

- Draws 100% of the combustion air directly from the outside.
- Eliminates contamination from indoor air.
- Piping must be installed per manufacturer's guidelines.

Category IV Venting

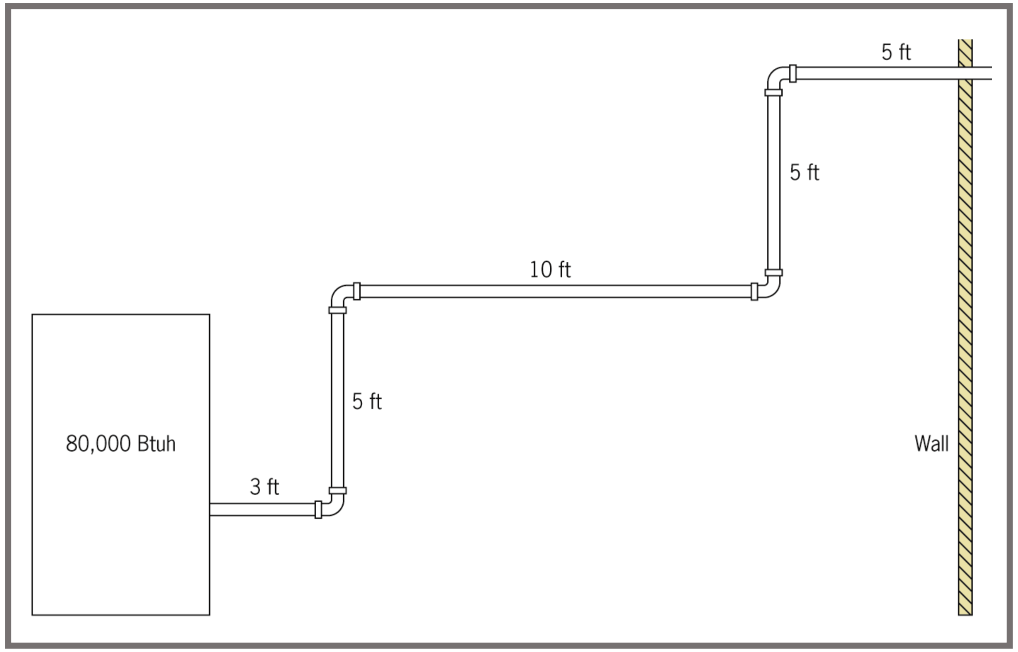
- Fan forces the combustion gases through the vent piping.
- All joints have to be properly sealed to avoid leakage.
- Some special fittings may be available to improve installation.



National Fuel Gas Code 10.4.2
"Plastic piping used for venting equipment listed for use with such venting materials shall be approved."

Category IV Venting

- Pitch is very important on CAT IV venting.
- Provision for condensate removal must be provided.
- As condensation forms in the vent it must drain back to the equipment.
- Sizing of pipe should follow manufacturers' tables (included with the equipment).
- Proper termination is vital to system operation.



National Fuel Gas Code 10.9
"Provision shall be made to collect and dispose of condensate from venting systems serving Category II and IV gas utilization equipment."

Category IV Venting

This table illustrates combustion air and vent piping for direct vent (2-pipe) and non-direct vent (1-pipe) applications.

Altitude (ft)	Unit maximum input rate (Btuh)	Direct vent (2-pipe only)		Non-direct vent (1-pipe only)	Maximum allowable pipe length (ft) Number of 90° elbows					
		Termination type	Pipe diameter (in.)	Pipe diameter (in.)	1	2	3	4	5	6
0–2,000	60,000	2-pipe or 2-in. concentric	1½ 2	1½ 2	20 70	15 70	10 70	5 70	NA 70	NA 70
	80,000	2-pipe or 2-in. concentric	1½ 2 2½	1½ 2 2½	10 55 70	NA 50 70	NA 35 70	NA 30 70	NA 30 70	NA 20 70
	100,000	2-pipe or 3-in. concentric	2 2½	2 2½	5 40	NA 30	NA 20	NA 20	NA 10	NA NA
	120,000	2-pipe or 3-in. concentric	2½ one disk 3* 3* no disk	2½ NA 3*	10 45 70	NA 40 70	NA 35 70	NA 30 70	NA 25 70	NA 20 70
2,001–3,000	60,000	2-pipe or 2-in. concentric	1½ 2	1½ 2	17 70	12 67	7 66	NA 61	NA 61	NA 61
	80,000	2-pipe or 2-in. concentric	2 2½	2 2½	49 70	44 70	30 70	25 70	25 70	15 70
	100,000	2-pipe or 3-in. concentric	2½ 3	2½ 3	35 70	26 70	16 70	16 70	6 66	NA 61
	120,000	2-pipe or 3-in. concentric	3 NA 3* no disk 4* no disk	NA 3* NA 4* no disk	14 63 70 70	9 62 70 70	NA 62 63 70	NA 61 56 70	NA 61 50 70	NA 61 43 70
3,001–4,000	60,000	2-pipe or 2-in. concentric	1½ 2	1½ 2	16 68	11 63	6 62	NA 57	NA 57	NA 56
	80,000	2-pipe or 2-in. concentric	2 2½	2 2½	46 70	41 70	28 70	23 70	22 70	13 70
	100,000	2-pipe or 3-in. concentric	2½ 3	2½ 3	33 70	24 70	15 70	14 66	5 61	NA 56
	120,000	2-pipe or 3-in. concentric	3* no disk NA	NA 3*	65 59	58 59	51 58	44 57	38 57	31 56
		4* no disk	4* no disk	4* no disk	70	70	70	70	70	70

*See explanatory notes at end of manufacturer's table.

CARRIER CORPORATION

Insulation of Vent Piping

- Vent piping run through an unconditioned space can result in condensate freezing in the vent.
- If piping exceeds the maximum length that can be exposed to an unconditioned space, insulation should be added per the manufacturer's requirements.

CARRIER CORPORATION

Unit maximum input rate (Btuh)	Winter design temperature* (°F)	Maximum pipe diameter (in.)	Without insulation	With 3/8-in. or thicker insulation*
60,000	20	2	44	70
	0	2	21	70
	–20	2	20	57
80,000	20	2	55	55
	0	2	30	55
	–20	2	16	55
	20	2½	58	70
	0	2½	29	70
	–20	2½	14	67
100,000	20	2½	40	40
	0	2½	38	40
	–20	2½	21	40
	20	3	63	70
	0	3	30	70
	–20	3	12	70
120,000	20	3	70	70
	0	3	38	70
	–20	3	19	70
	20	4	65	70
	0	4	26	70
	–20	4	5	65

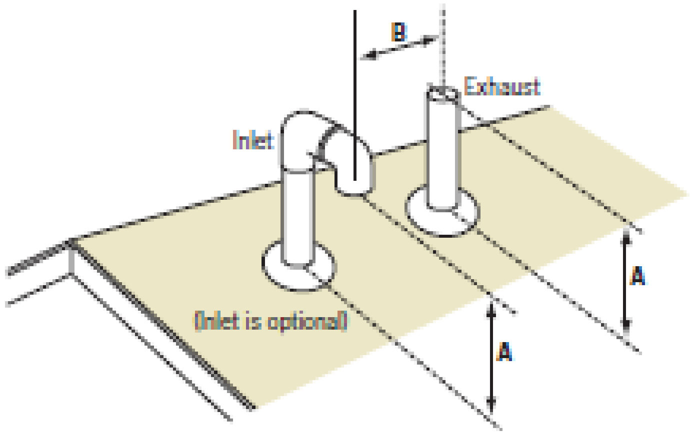
*See explanatory notes at end of manufacturer's table.

Category IV Terminations

National Fuel Gas Code 10.8.3
"A direct vent appliance with an input of over 50,000 Btuh shall have at least a 12-in. vent termination clearance from any air opening into the building. The bottom of the vent terminal and the air intake shall be located at least 12 in. above grade."

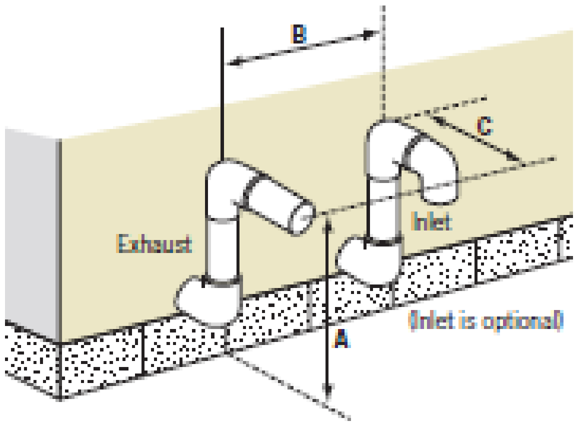
National Fuel Gas Code 10.8.4
"Through-the-wall vents for Category IV appliances shall not terminate over public walkways or over an area where condensate or vapor could create a nuisance or hazard or could be detrimental to the operation of regulators, relief valves, or other equipment."

Rooftop termination



A = 12 in. above roof or snow accumulation level
B = 8-in. minimum, 20-in. maximum, except in areas with extreme cold temperatures (sustained below 0°F), then 18-in. minimum

Sidewall termination



A = Minimum 12 in. above expected snow accumulation level
B = 8-in. minimum, 20-in. maximum, except in areas with extreme cold temperatures (sustained below 0°F), then 18-in. minimum
C = 8-in. minimum

Category IV Condensate Drains

- Category IV equipment allows flue gases to condensate.
- A condensate drain must be provided.
- A trap must installed in condensate line.
- PVC piping is normally used.
- Must not be piped solidly to sewer.
- Should terminate at an open site drain.

Codes

- United States and Canada follow very similar Codes.
- All venting must follow manufacturer's requirements.
- Also check Local Codes.

Gas and Oil Heating NATE Review

Chapter 5: Air Flow

Lesson Objectives

- ➢ Determine the proper amount of air flow needed for the system to operate efficiently.
- ➢ Learn the methods of air-flow measurement.
- ➢ Discover the delivery system design and installation (ductwork).
- ➢ Survey the different types of air filters and their efficiencies.

Introduction

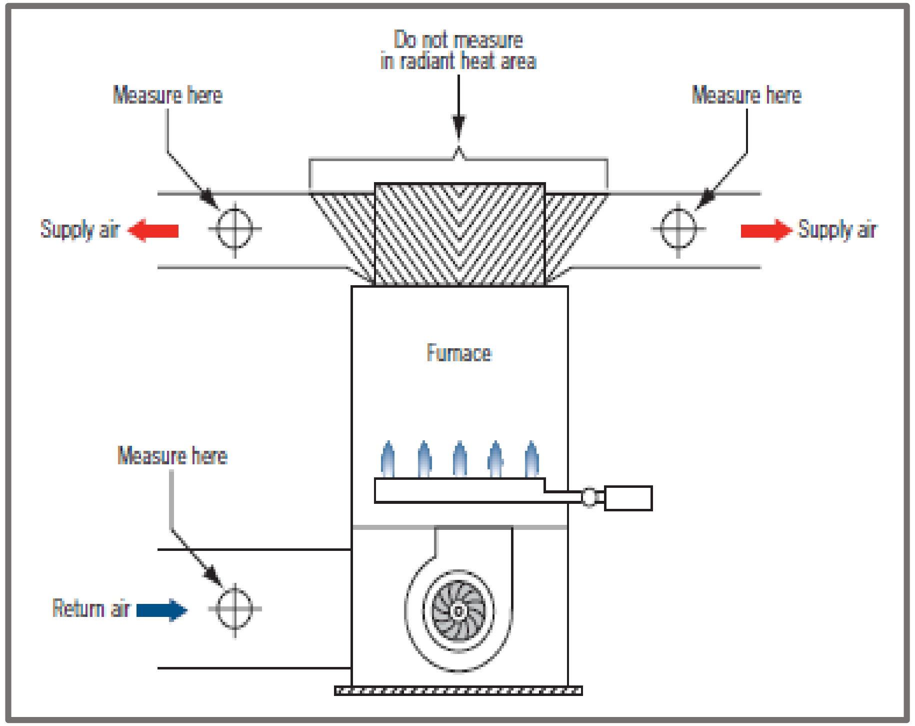
- Air is the medium for transferring heat from the exchanger to the conditioned space.
- Too little air moving through the system will cause the equipment to overheat.
- Too much air flow will cause efficiency issues and may result in drafty and noisy distribution systems.
- Many factors affect the amount of air being delivered from the equipment.

Measuring Air Flow

- Begin with a check of the blower.
- Also check the air filter condition.
- Three methods can be used to measure air flow:
  - Temperature rise;
  - Blower performance data; and
  - Direct measurement.

Temperature Rise Method

- First check the burner output or electric heating element rating.
- Allow the equipment to operate long enough to achieve steady-state conditions.
- Take temperature measurements as per the illustration and compare results to nameplate.



Blower Performance Data

Air flow, cfm	External static pressure (in. w.g.)											
	Vertical*						Horizontal**					
	230 V			208 V			230 V			208 V		
	HI	MED	LO	HI	MED	LO	HI	MED	LO	HI	MED	LO
500						0.55						
550						0.51						0.60
600					0.67	0.41						0.58
650			0.54		0.60	0.23			0.60			0.51
700			0.53		0.52	0.00			0.57		0.51	0.47
750		0.48	0.44	0.65	0.41			0.54	0.53		0.48	0.35
800	0.52	0.47	0.27	0.59	0.30		0.60	0.52	0.46	0.59	0.41	0.05
850	0.50	0.41	0.00	0.52	0.10		0.57	0.47	0.32	0.55	0.32	
900	0.47	0.30		0.42	0.01		0.54	0.40	0.03	0.52	0.21	
950	0.41	0.15		0.29			0.49	0.31		0.45	02	
1000	0.33	0.00		0.14			0.41	0.19		0.33		
1050	0.22			0.00			0.32	0.04		0.19		
1100	0.10						0.23			0.00		
1150	0.00						0.12					
1200							0.02					

* Vertical installation: With filter, no horizontal drip tray. Small apex baffle. Subtract 0.06 in. w.g. for downflow.
** Horizontal installation: As shipped, but without filter. Subtract 0.05 in. w.g. for horizontal left.

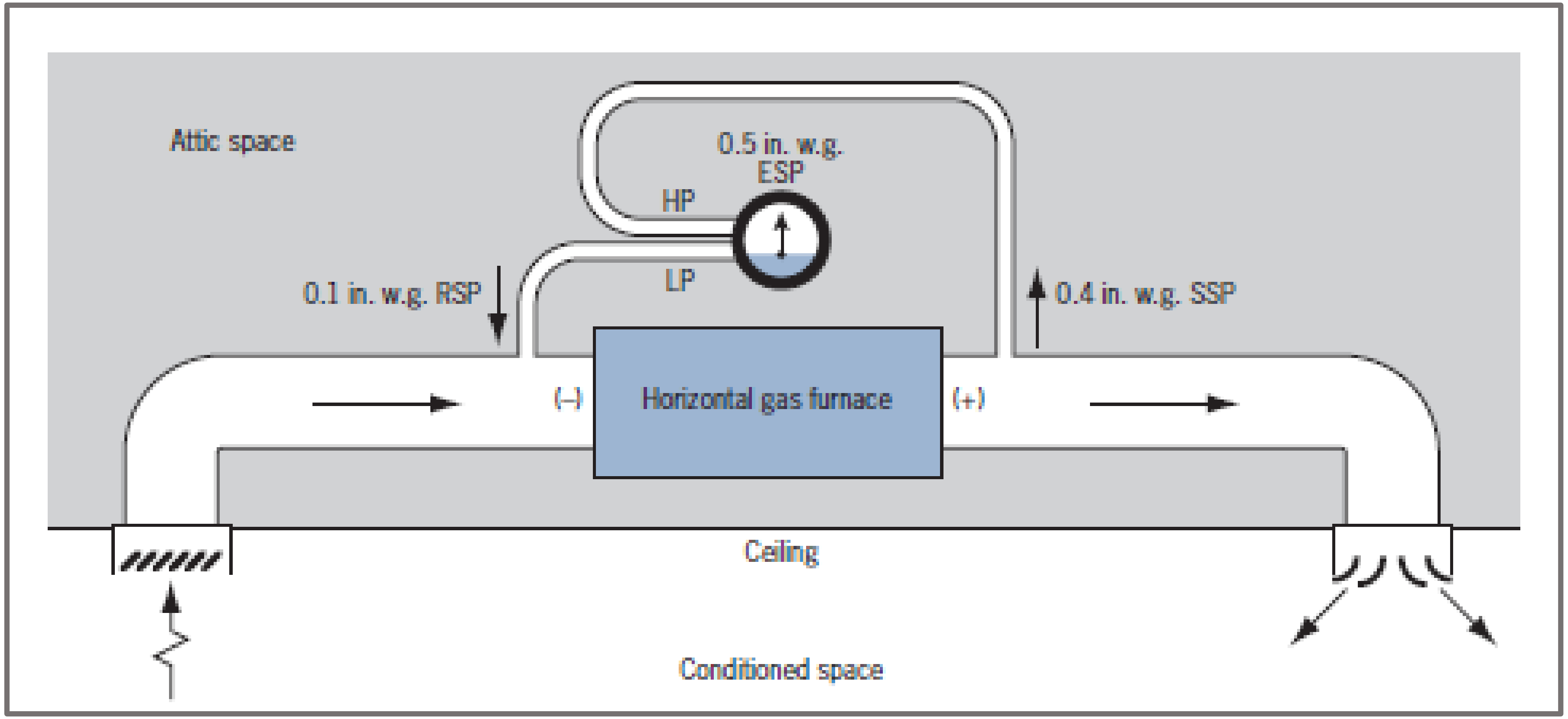
Blower Performance Data

- Begin by checking the ESP of the unit.
- Compare this with the blower curve data listed in the manufacturer's service literature.
- If the ESP rises above the listed data, the unit will not be able to deliver the proper air.

Digital Manometer

Magnehelic Gauge

Blower Performance Data



Measuring External Static Pressure (ESP)

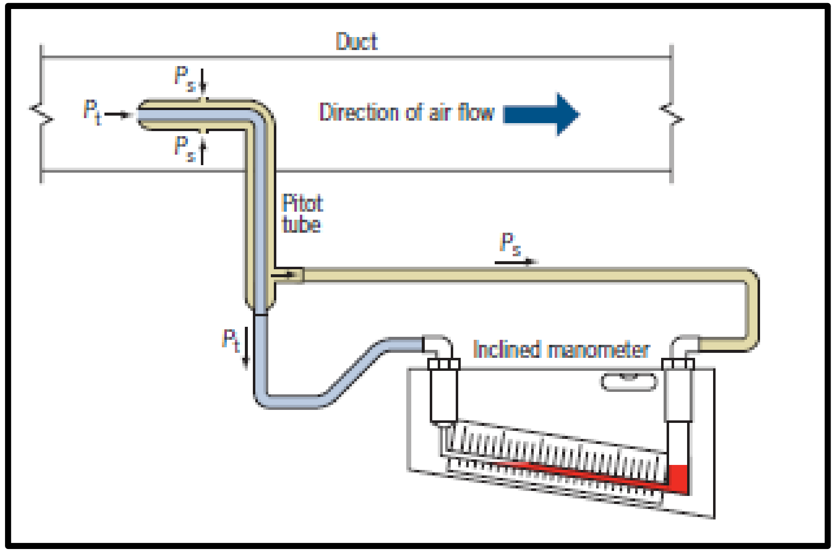
Direct Measurement

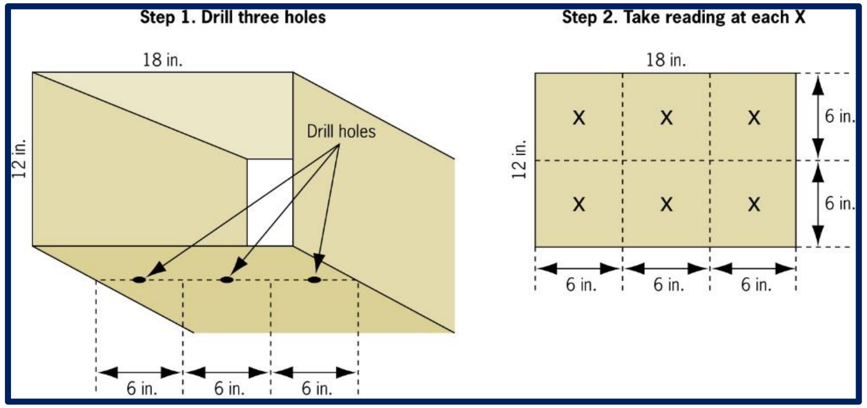
- Usually involves measuring the air velocity in FPM, then multiplying by duct ft^2.
- The Anemometer measures the velocity directly in ft/min.
- When multiplied by the area of the duct results in cfm (ft^3 per minute) air flow in the duct.

Rotating-vane Anemometer

Direct Measurement

- Another method measures velocity pressure.
- This data is then converted to velocity using the formula FPM = 4005 $\sqrt{P_v}$ the resulting values are then averaged.
- The resulting average is multiplied by duct area to obtain the final cfm value.





Recommended Air Velocities

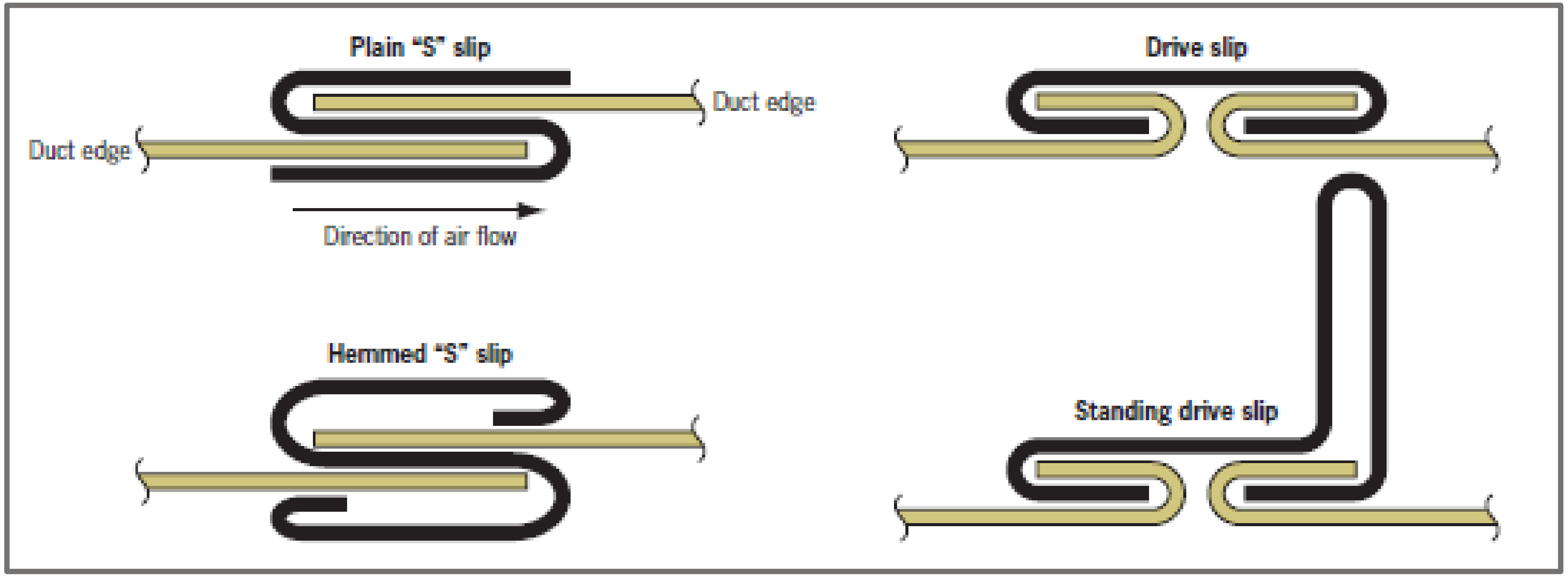
- Air speeds across filters:
  - Disposable filters: 700 to 750 ft/min;
  - HEPA filters: 250 ft/min; and
  - Electronic air cleaners: 500 ft/min.
- Air speeds across coils:
  - Evaporators: 400 to 600 ft/min;
  - Condensers: 1,000 ft/min; and
  - Hot water coils: 700 ft/min.

	Offices	Residences	Quiet areas
Trunk ducts	1200	1000	800
Branch ducts	800	600	500
Supply outlet face velocity	700	600	400

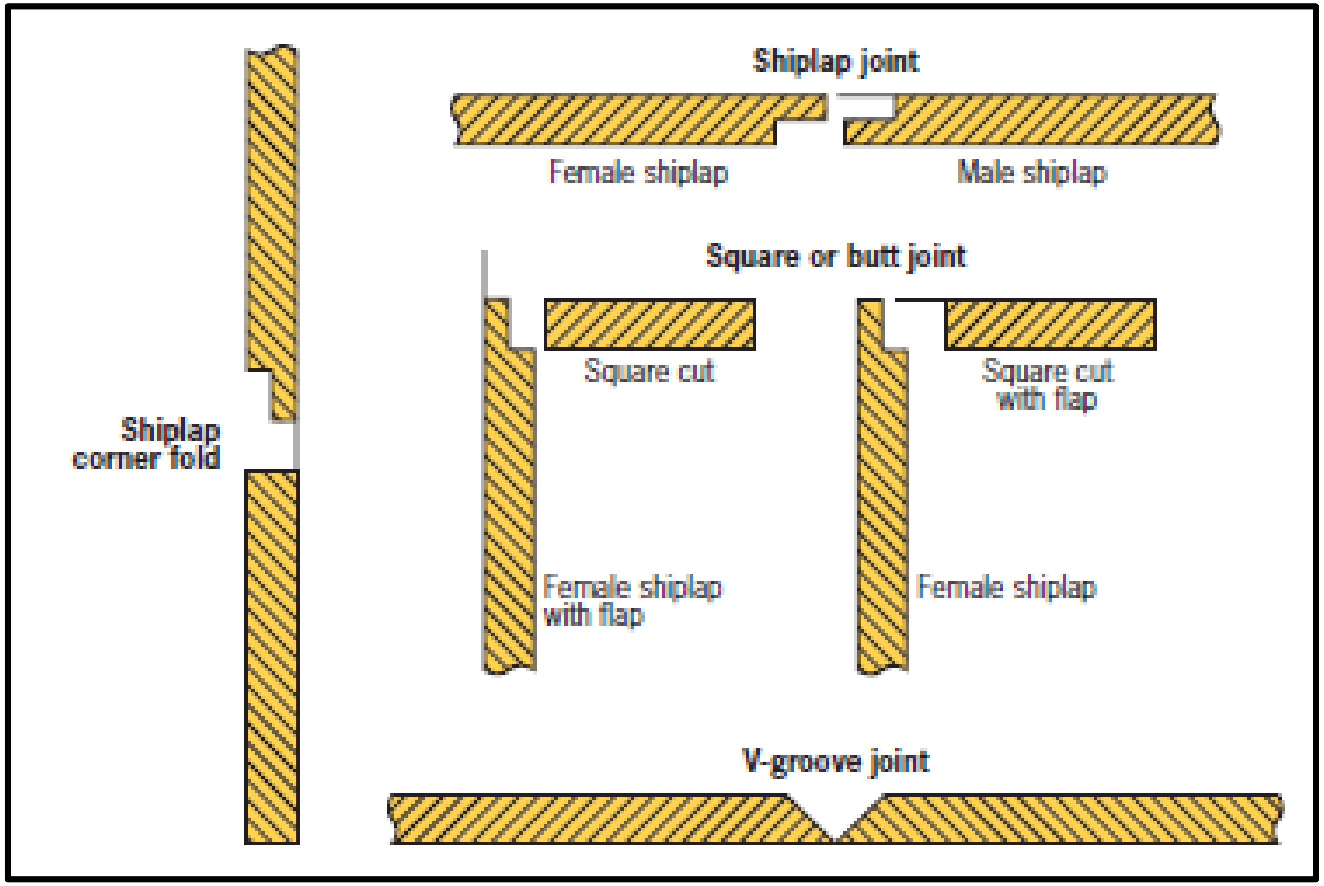
Duct Systems

- Critical part of delivering proper air flow.
- Too small causes low air flow and noisy system.
- Too large makes it difficult to balance system.
- Leakage is a common problem.
- Duct support system must be adequate.
- Type and placement of diffusers is critical.
- Duct insulation also plays an integral part.

Common Sheet-metal Duct Joint Designs



Common Ductboard Joint Designs



Diffusers

- Choosing the right type/placement of diffusers ensures proper air distribution.
- If heating is the predominant need, diffusers are placed in the floor.
- System primarily used for cooling will have diffusers located high in the wall.
- Face velocity also is key in room air distribution.

Air Filtration

- Filters are another important component of the air-distribution system.
- Come in a large variety of types and sizes depending on the application.
- Filters are rated on their ability to remove particulates.
- This rating is known as MERV (minimum efficiency reporting value).

Electronic Air Cleaner

- Electrically charges particles, causing them to be drawn to oppositely charged collector plates.
- Can remove very small particles.
- Plates require regular cleaning.

Gas and Oil Heating NATE Review

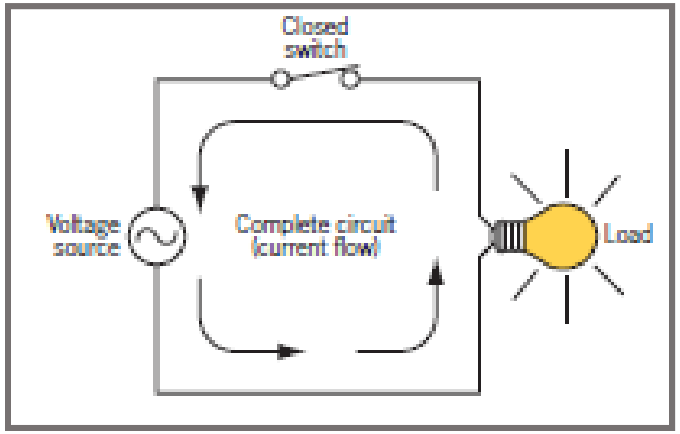
Chapter 6: Troubleshooting

Lesson Objectives

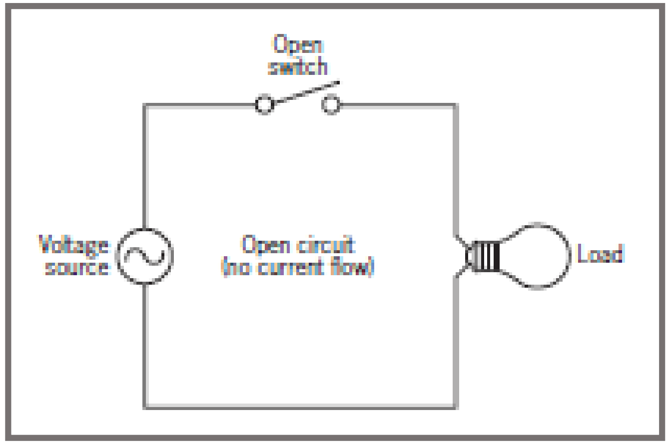
- Anywhere from 75 to 80% of all service calls involve electrical components.
- A good basic understanding of electrical systems is very important.
- This lesson examines some of the individual electrical components in gas and oil heating units.
- Proper testing of circuits will also be examined.
- Utilizing an electrical diagram and using proper test equipment also will be reviewed.

Primary Electrical-component Categories

- A load is a device that uses electricity to do some type of useful work such as:
  - Turn a motor;
  - Generate heat;
  - Or turn on a light.
- A switch is a device that acts as a "gatekeeper" in an electric circuit:
  - A closed switch allows electric current to pass; and
  - An open switch prevents the flow of electric current.



Closed switch



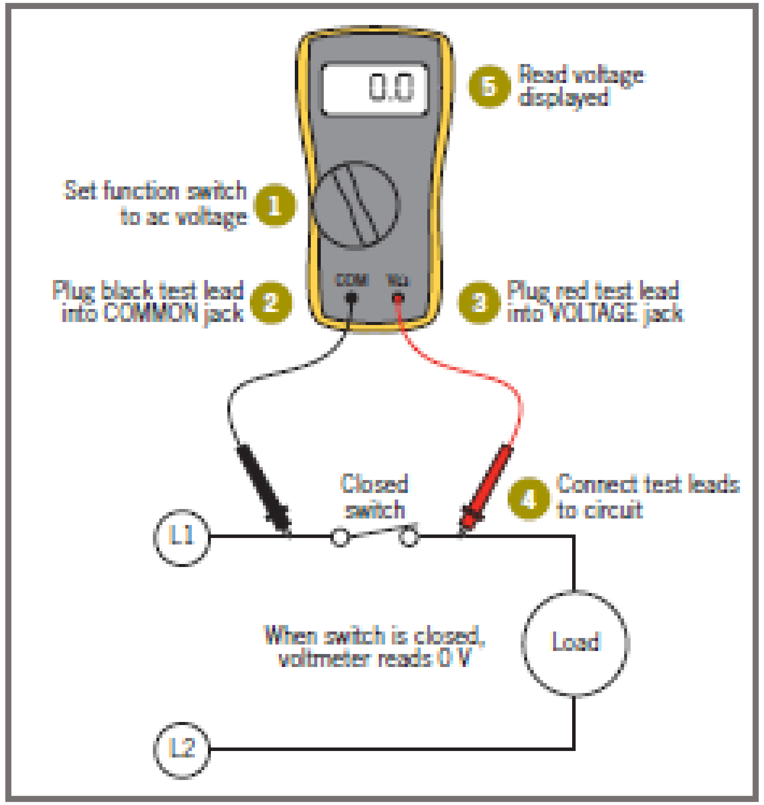
Open switch

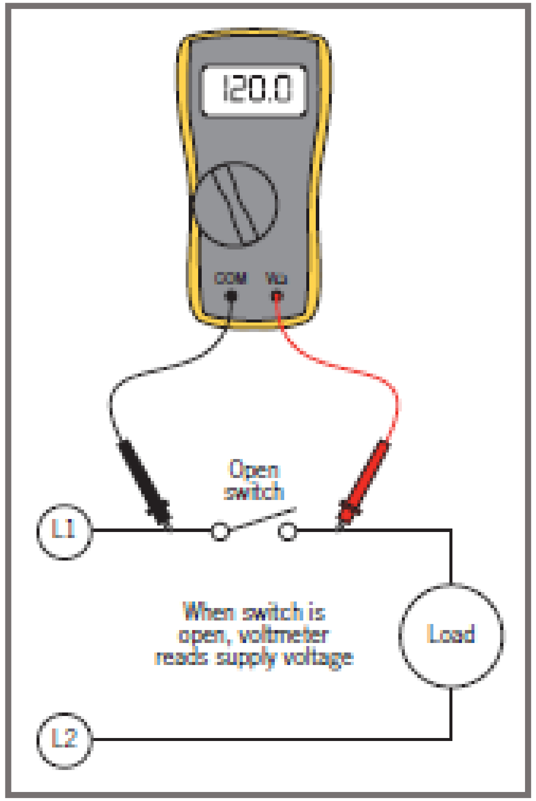
Testing Circuits

- Circuits can be tested in two basic ways:
  1. With it energized, use a voltmeter to check that the circuit flow is complete; or
  2. With it de-energized, use an ohmmeter to measure resistance throughout the circuit.
- Components being tested must be isolated from the rest of the circuit.

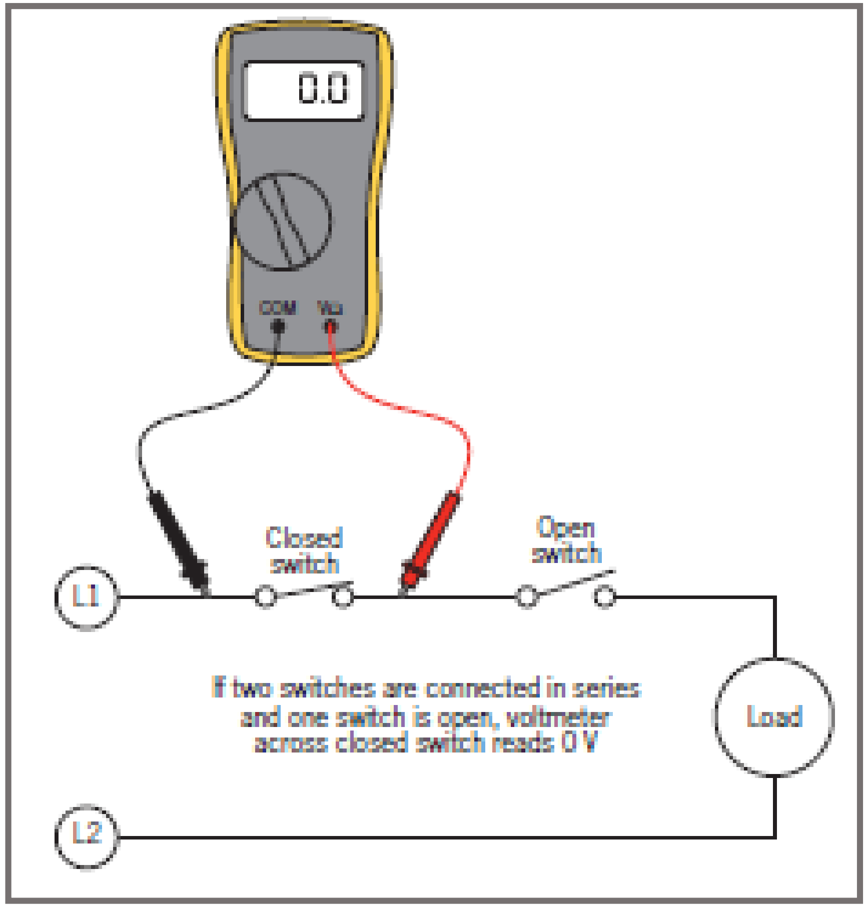
Voltage Testing

SAFETY FIRST! **Always** wear the proper personal protective gear when testing voltage.





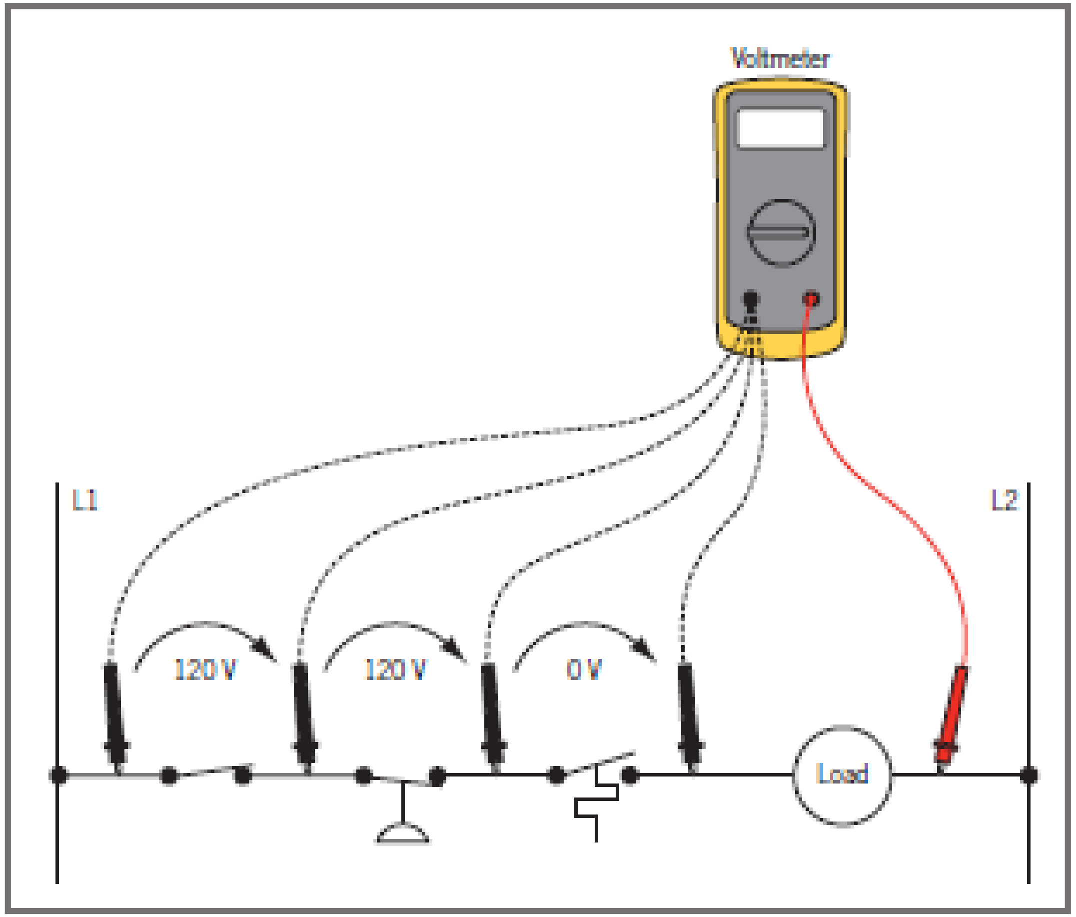
Voltage Testing



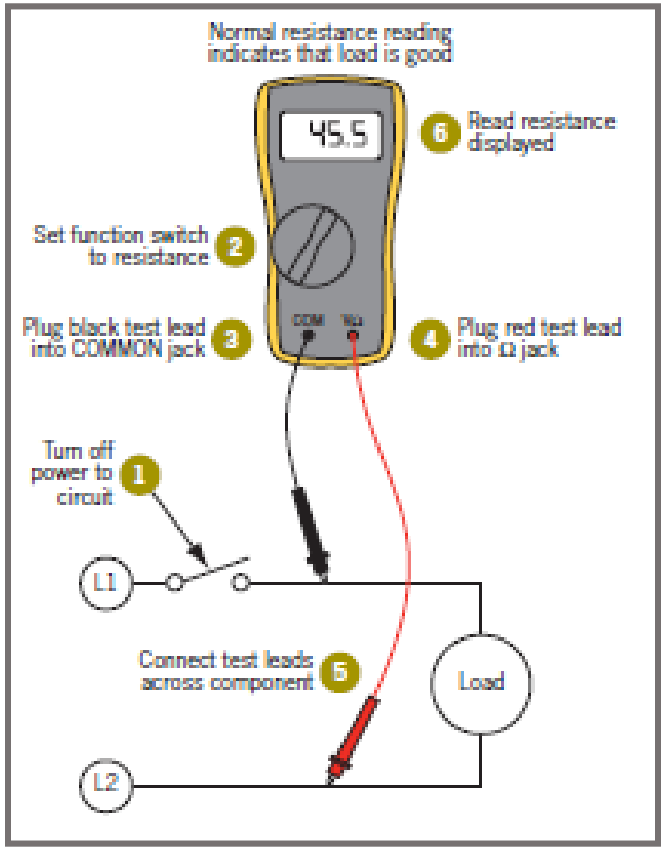
Switches connected in series

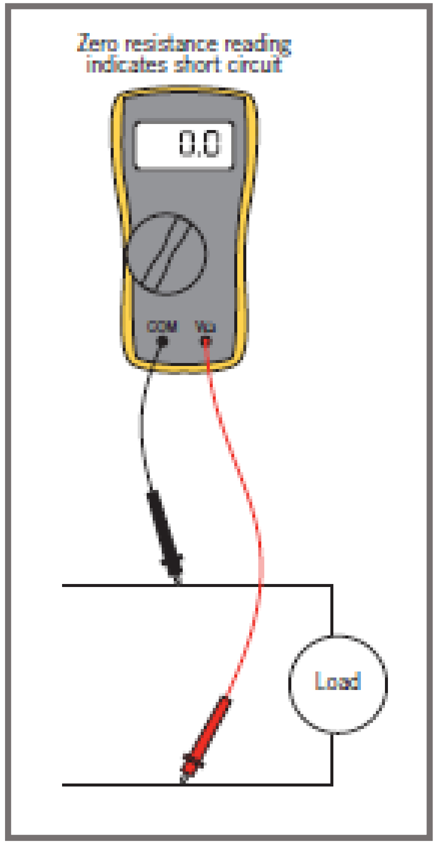
Voltage Testing

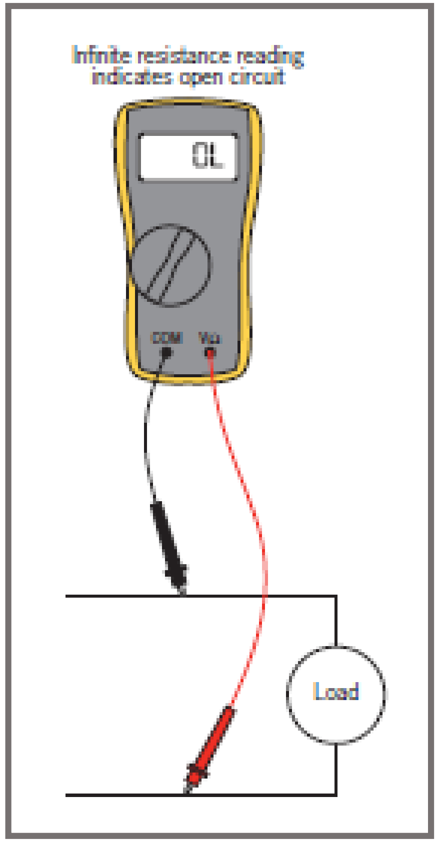
“Hopscotch method”



Resistance Testing



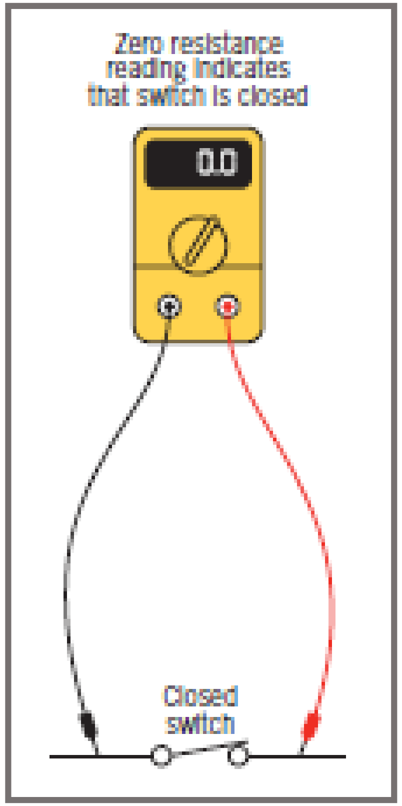


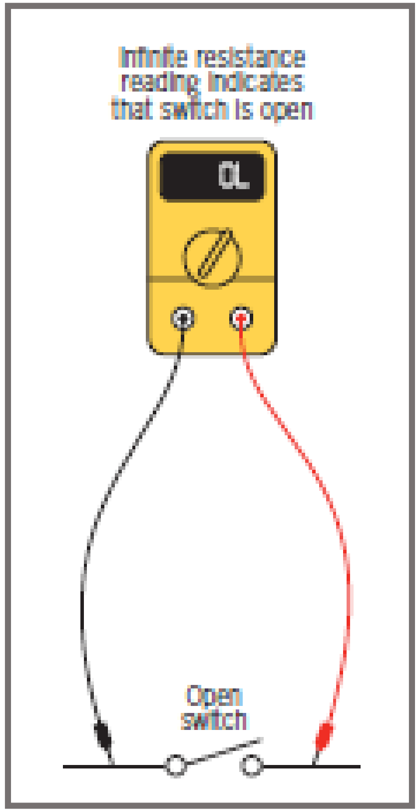


Resistance Testing Switches

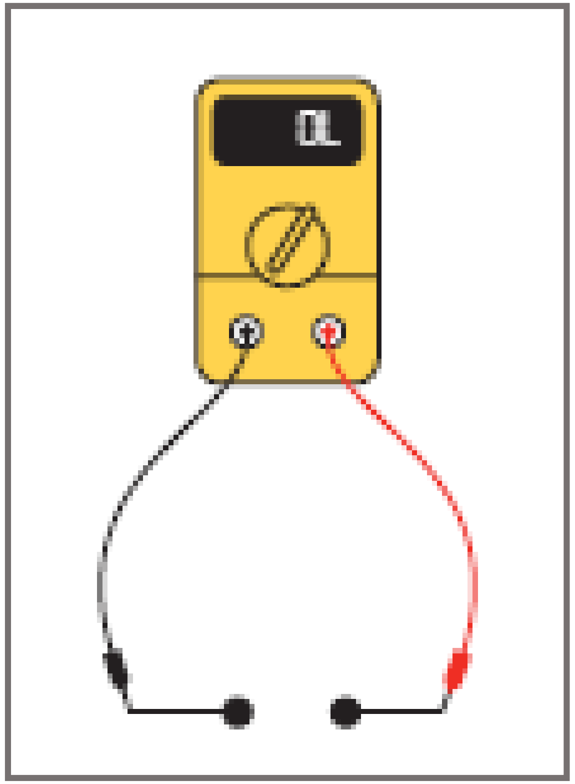
Possible ohmmeter outcomes:

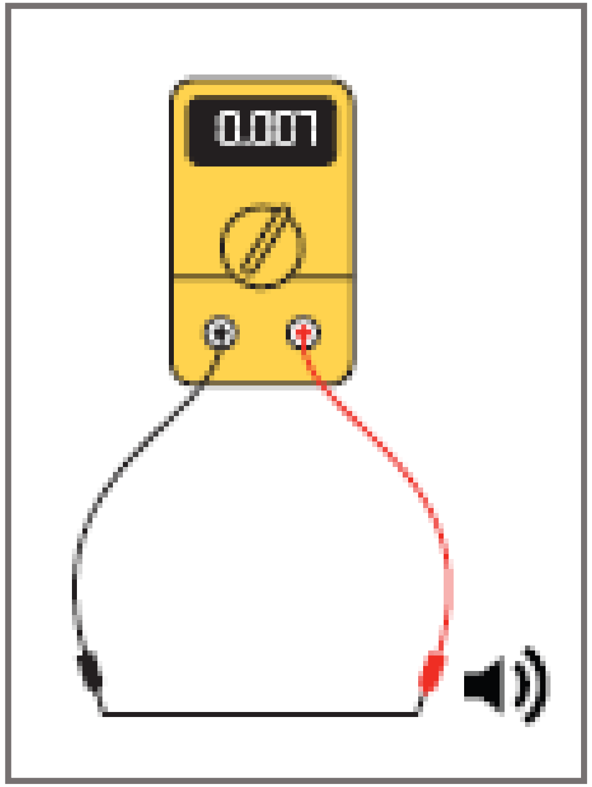
- A measurement of 0 Ω indicates that the switch is closed.
- An infinite resistance reading indicates that the switch is open.
- A closed switch that produces a measurable resistance reading probably has pitted contacts and should be replaced.





Continuity Testing





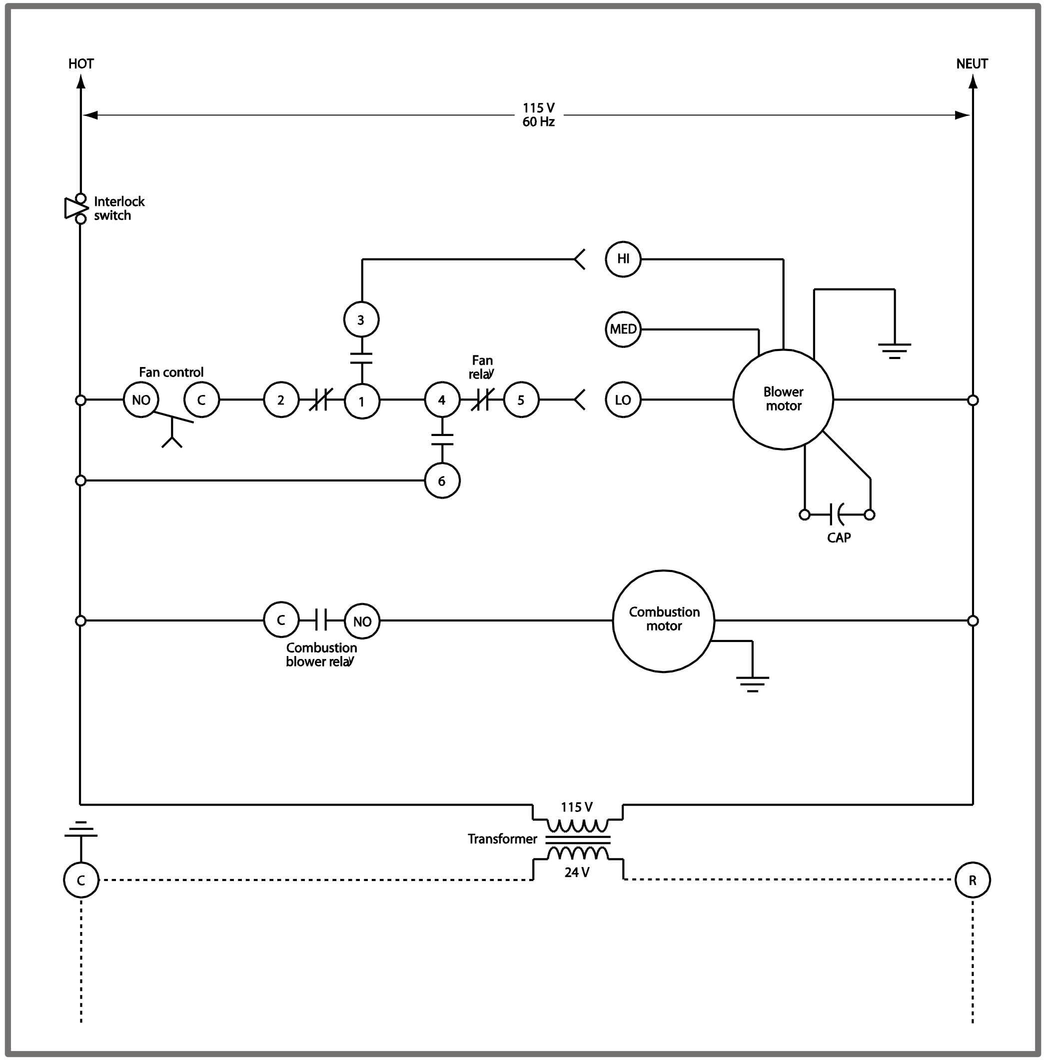
General Electrical Checks

- Visually inspect all electrical connections.
- Watch for evidence of overheated conductors.
- Check for any corrosion at connections.
- Measure the voltage to the unit with no load.
- Check the voltage during start-up.
- Measure the voltage while the load is running.

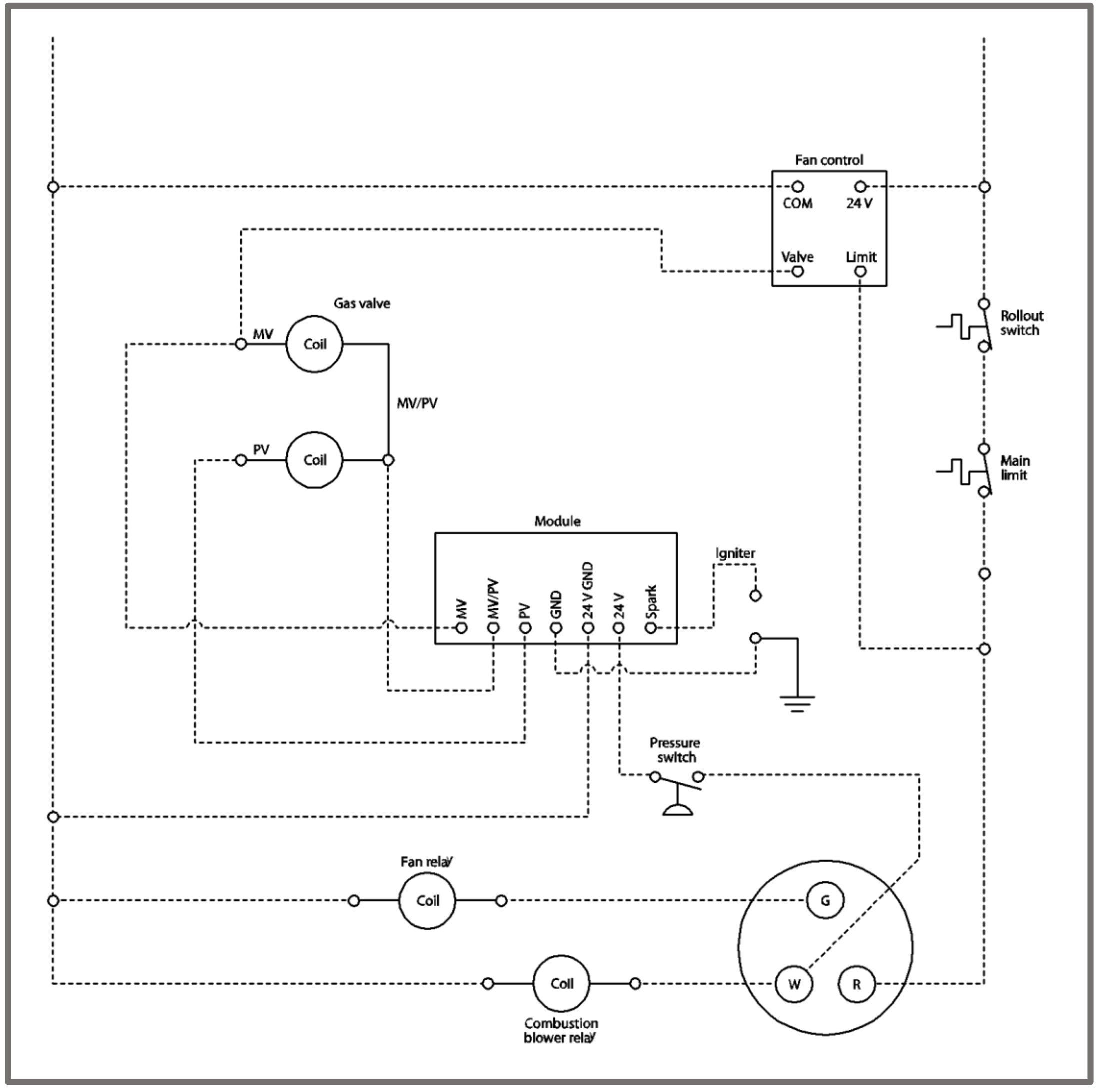
Wiring Diagrams

- Are an important tool for troubleshooting an electrical system.
- Provides a “road map” that shows all components and connections.
- If a diagram is missing, you may have to trace out the wiring and sketch your own map.

Typical Ladder Diagram

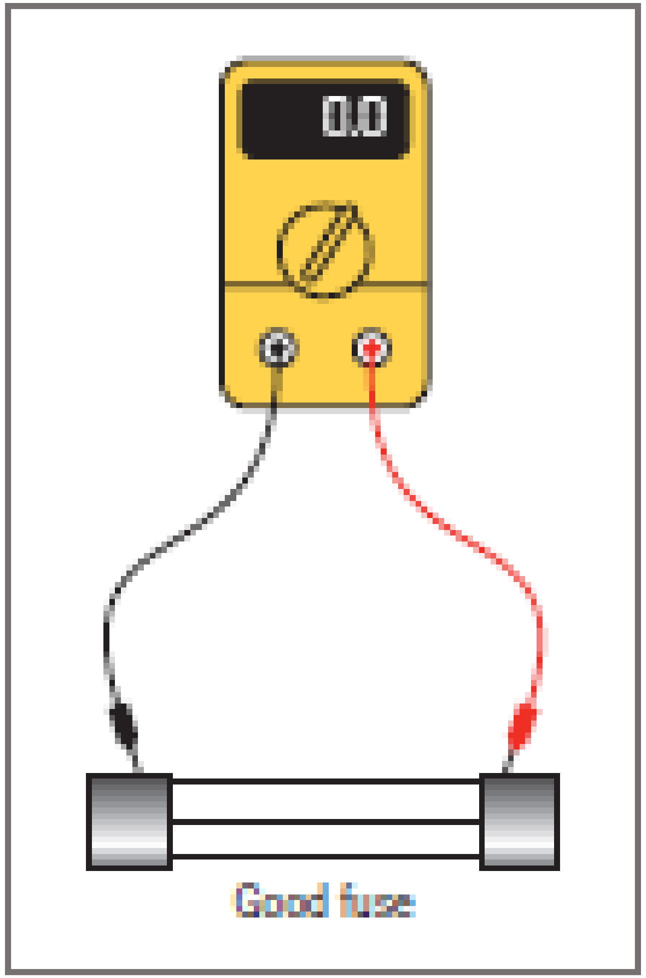


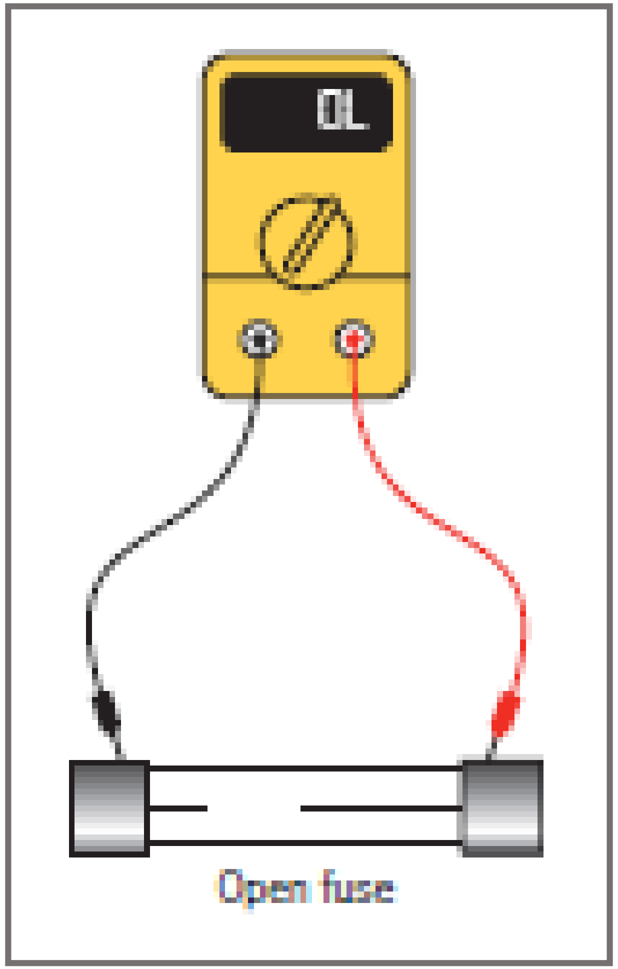
Typical Ladder Diagram



Fuses

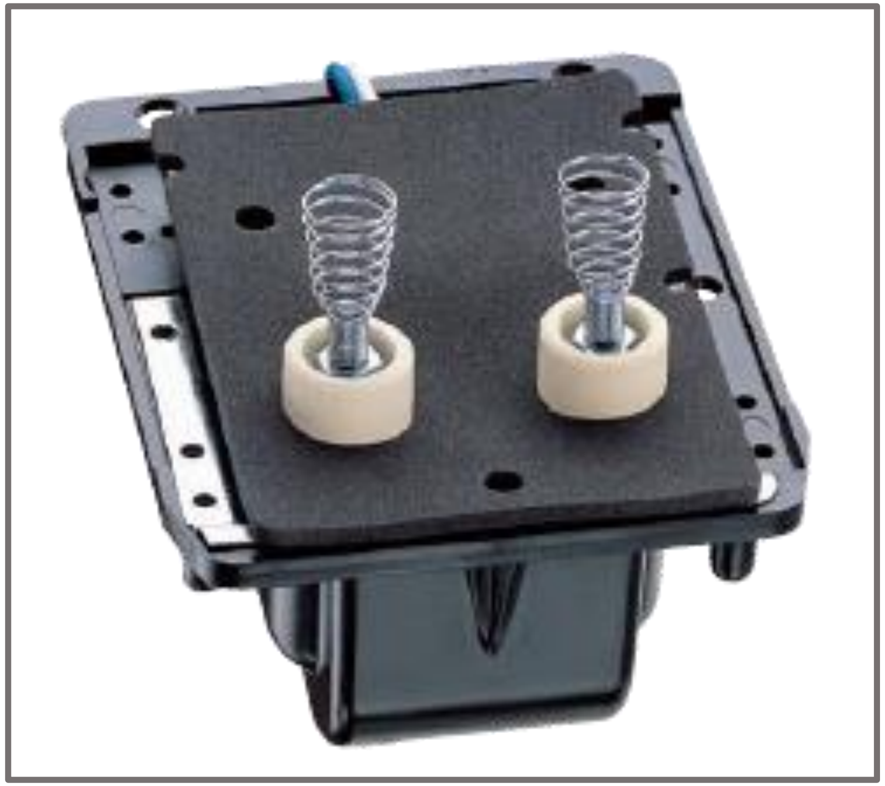
Fuses





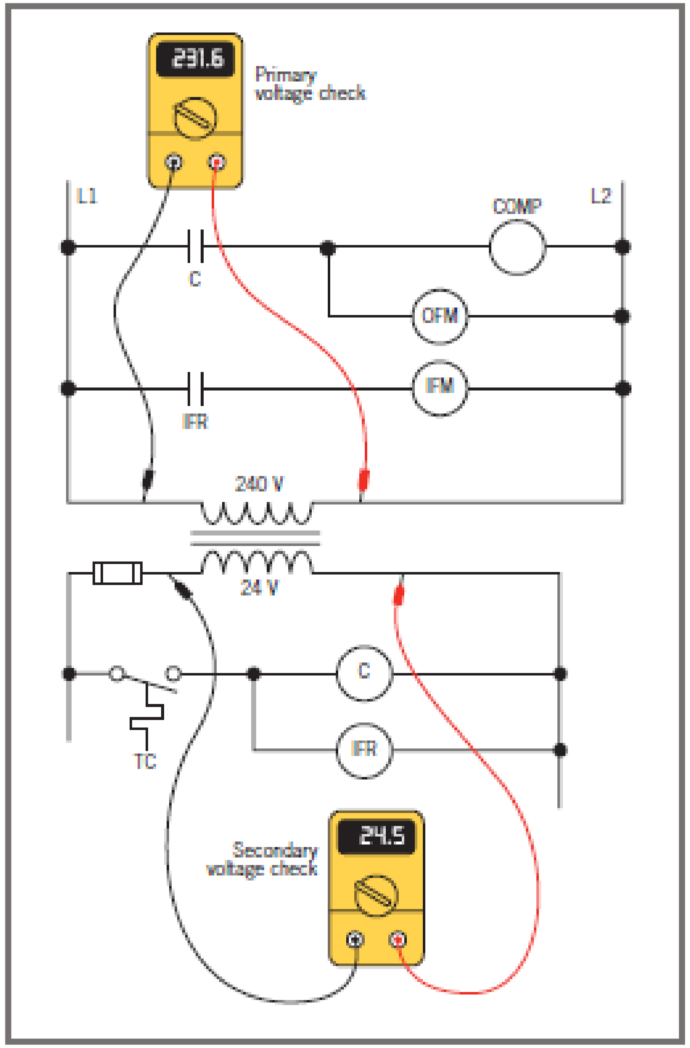
Transformers

Furnace control transformer, (step down)
120-V Supply – 24-V control voltage.



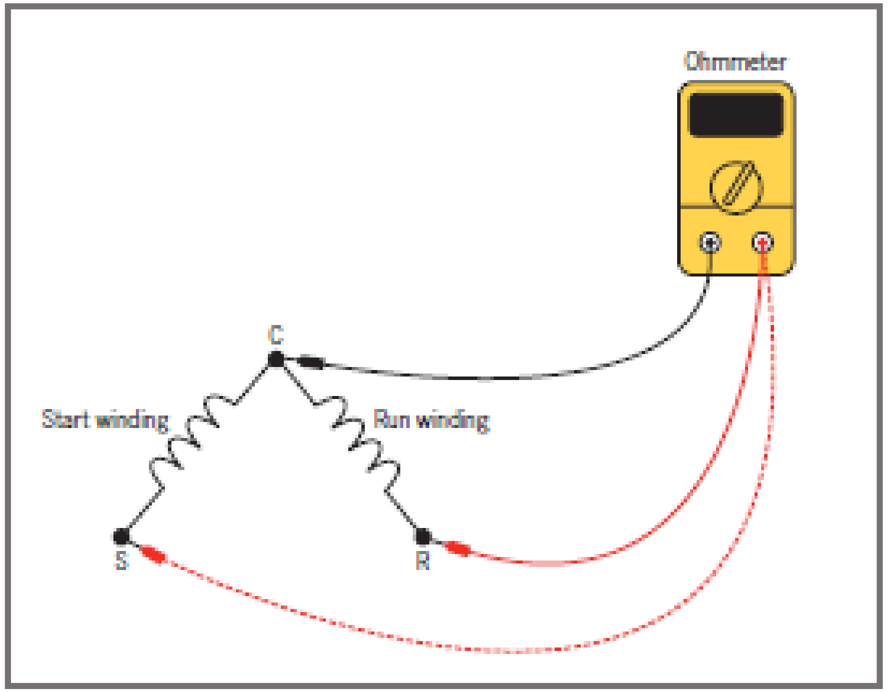
Ignition transformer, (step up).

Transformers

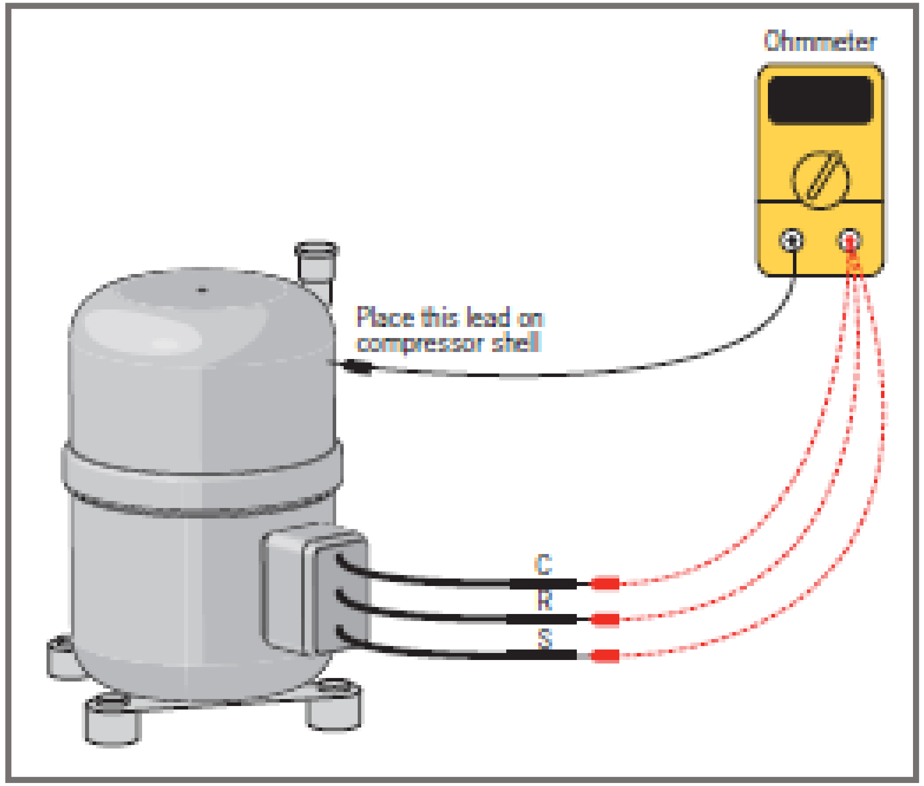


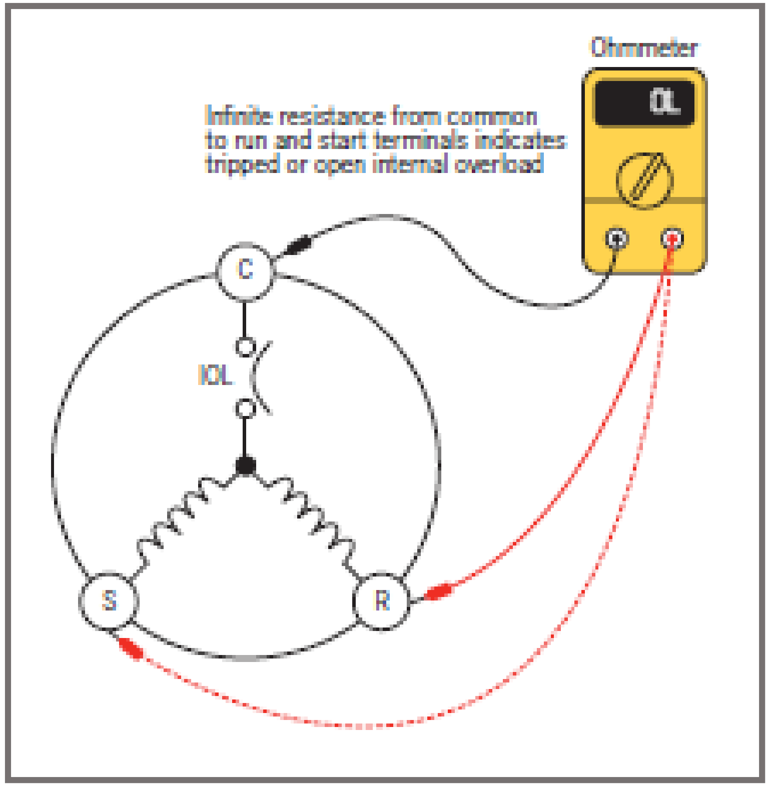
Motors

- Measure Ω's
  - 'C'-'R' – 'S' to Ground should show *infinity*.
  - 'C' to 'R' = 3 Ω's
  - 'C' to 'S' = 5 Ω's
  - 'R' to 'S' = 8 Ω's
  - C to R + C to S = R to S
  - Motor is electrically sound and should run.
  - An *infinity* reading between any two terminals indicates an open winding or open overload.
  - A reading of 0 Ω's indicates a shorted winding.



Motors

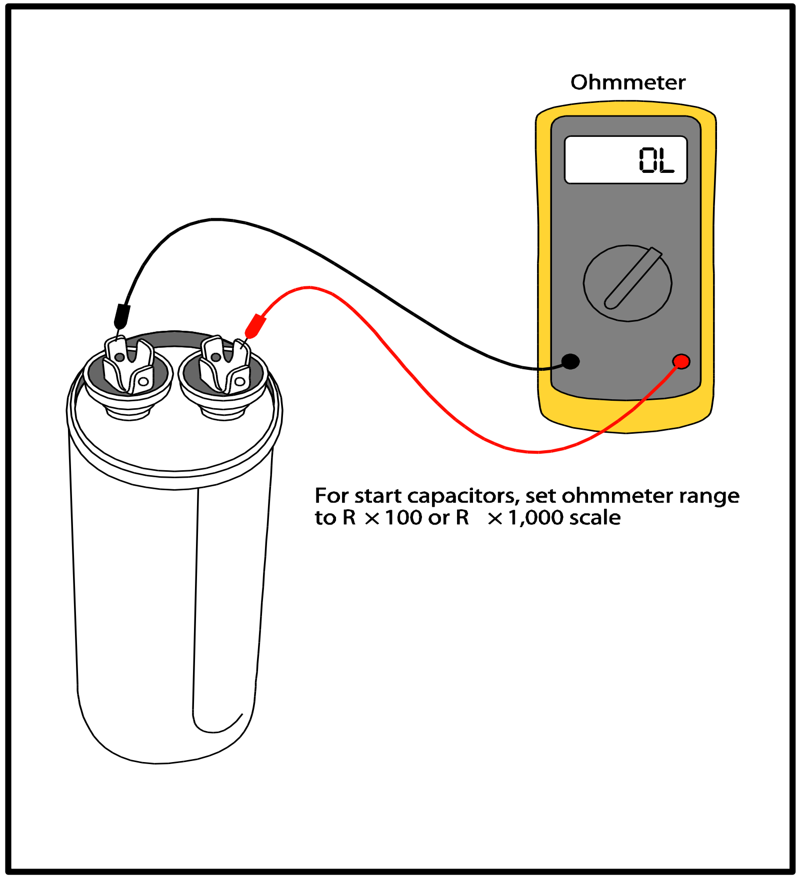

Ohmmeter
Place this lead on compressor shell
C
R
S


Ohmmeter
OL
Infinite resistance from common to run and start terminals indicates tripped or open internal overload
C
IOL
S
R

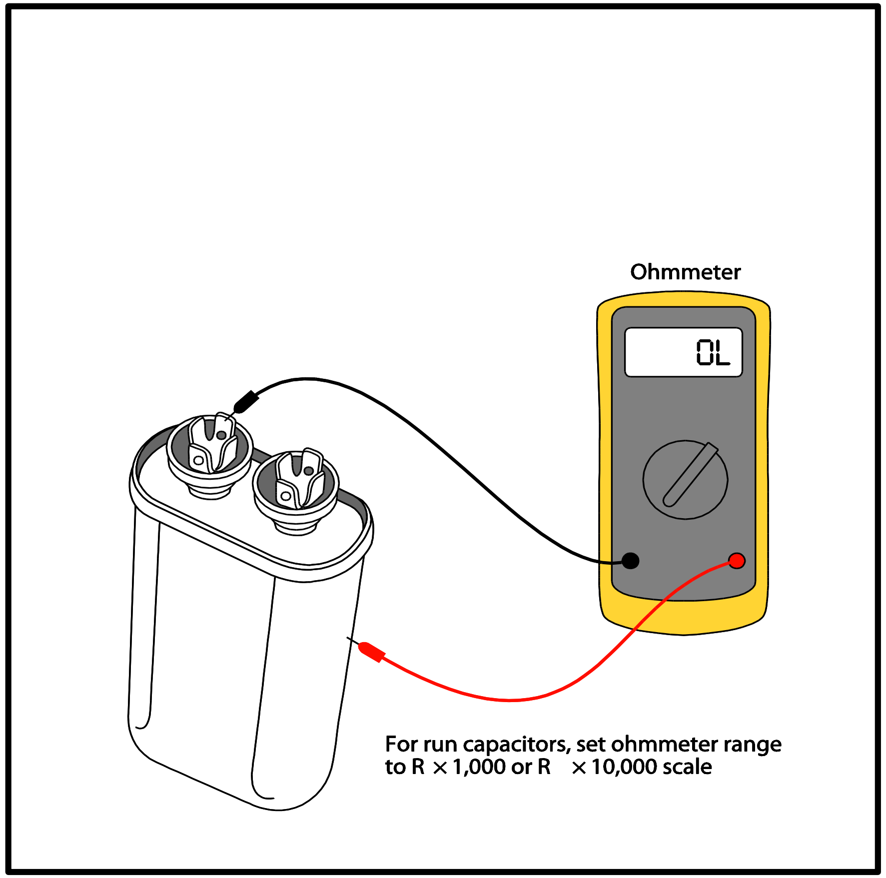
Motors

- Start capacitors are added to inductive motors to improve torque.
- Run capacitors are added to inductive motors to improve the power factor.

Motors



Ohmmeter
0L
For start capacitors, set ohmmeter range
to R × 100 or R × 1,000 scale



Ohmmeter
0L
For run capacitors, set ohmmeter range
to R × 1,000 or R × 10,000 scale

Motors

A typical capacitance meter.

Motors

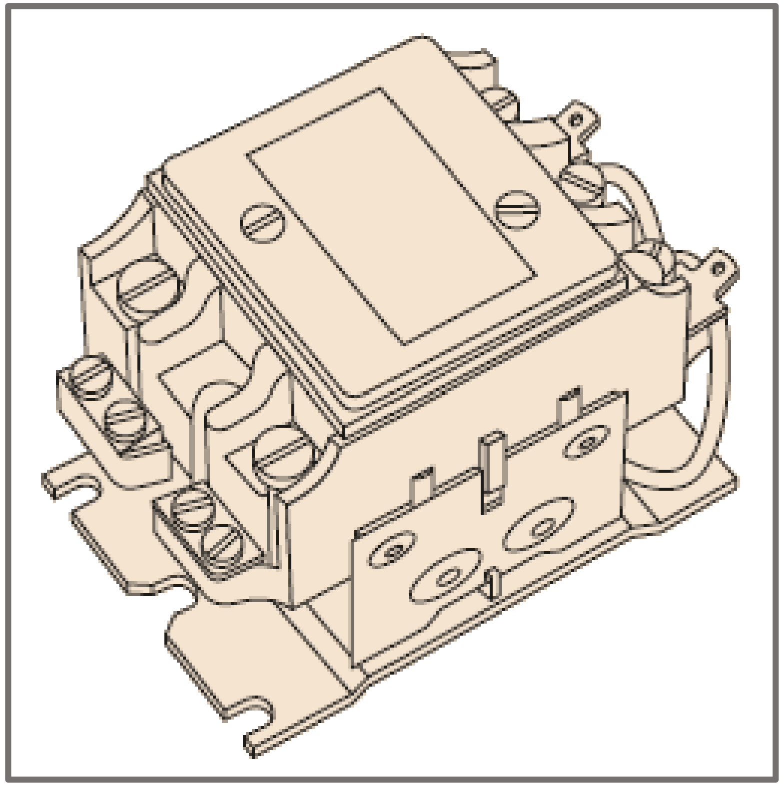
- Motors require mechanical checks.
  - Inspect shaft to make sure it turns freely.
  - Any up-and-down movement or in-and-out movement (end play) indicates bearing wear.
  - Check lubrication;
    - Sleeve beatings are used in smaller hp motors and require light weight, non-detergent oil.
    - Ball bearings are normally use in larger Hp motors and some will require the addition of grease periodically (*do not over lubricate*)
    - Some motors are considered permanently lubricated and do need additional lubrication.
    - Always check the manufacturer's lubrication requirements.

Motors

- If a motor needs to be replaced, the following information needs to be collected from the old motor:
  - Horsepower;
  - Voltage;
  - Frame size;
  - Rotation; and
  - Shaft size.
- The manufactures and model number can be very helpful to a cross-reference for the proper motor selection.

Relays and Contactors

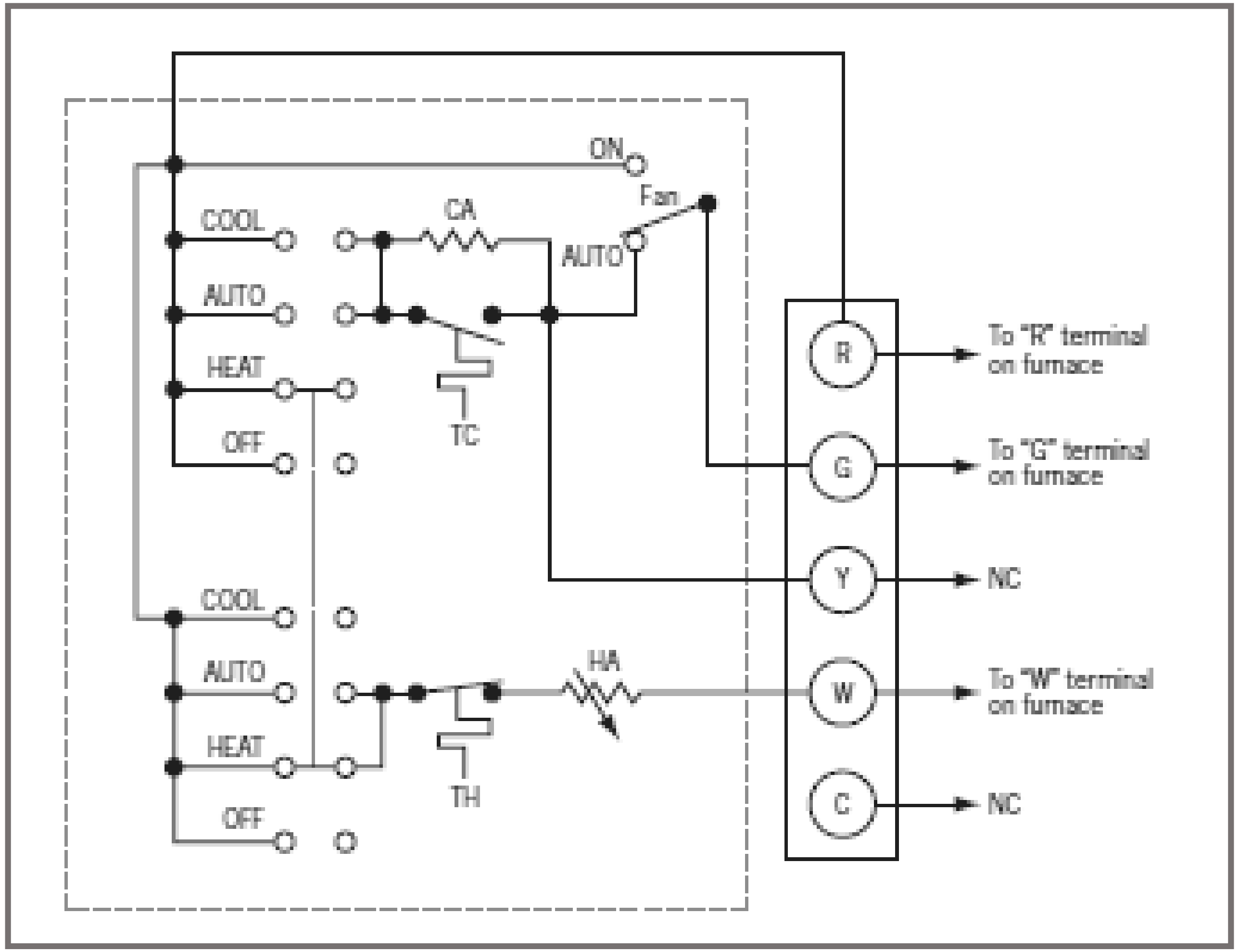
- Contain sets of switches that are operated by electrical signals.
- The relay coil is an inductive load that creates the magnetic field to move the switches.
- They may have any number of switches which can be normally open or closed.
- The “normal” position is the position of the switch with no power applied.



Thermostats

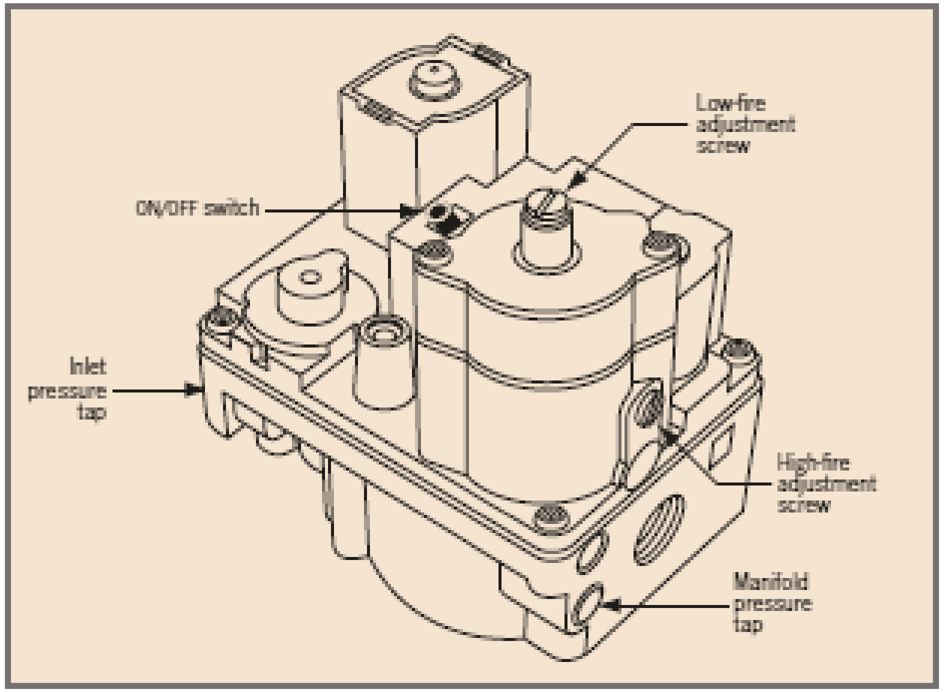
- The thermostat is the primary control for starting and stopping furnace operation based on the temperature within the conditioned space.
- Low-voltage wiring connects the thermostat to the furnace with the following color codes:
  - Red: 24-V power from the transformer;
  - Green: fan circuit;
  - Yellow: cooling circuit; and
  - White: heating circuit.

Thermostats



Gas Valves

- The gas valve is a load made up of two magnetic coils.
- When energized, the coils open the valve.
- In a standing-pilot gas valve, the pilot valve is operated by millivolt power.
- When testing, make sure all manual gas valves are open .
- If the valve has proper voltage and fails to open, check for resistance on the coil.



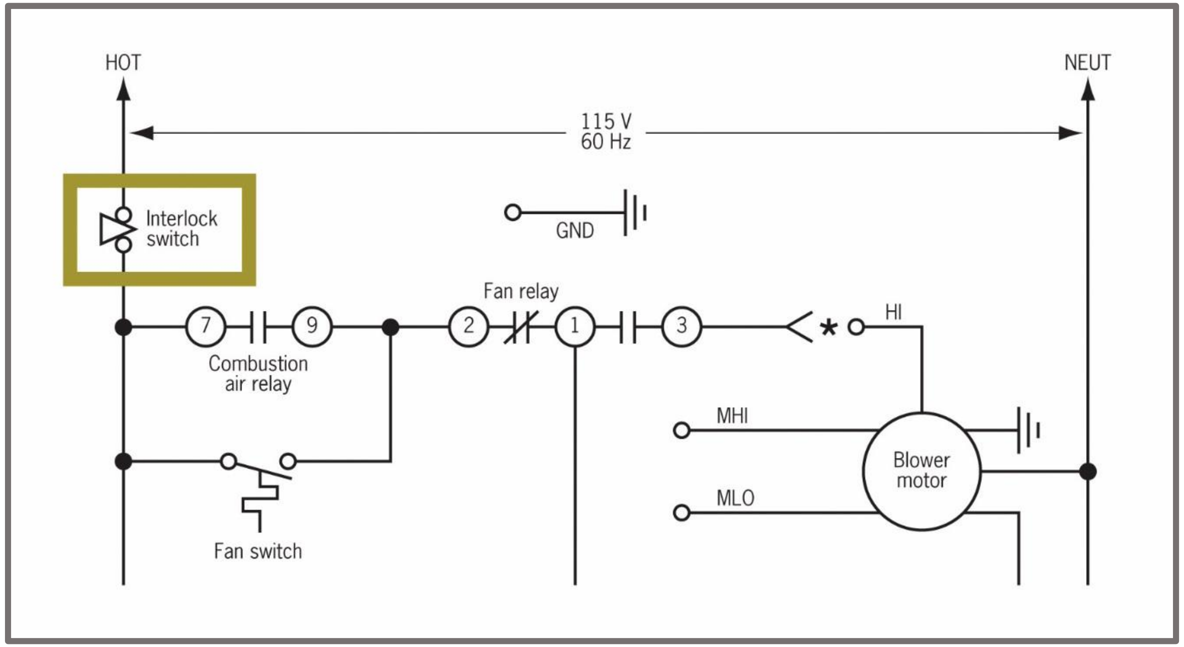
Electronic Control Boards

- To troubleshoot, first determine if the proper inputs are being fed to the control.
- If the inputs are there, check for proper outputs.
- If both the inputs are there and the outputs test good, the board is functioning properly.
- Many electronic control boards also have their own built-in diagnostic systems.

Hot-surface Igniters

Safety Switches

Door switch



A furnace wiring diagram (door switch highlighted in green).

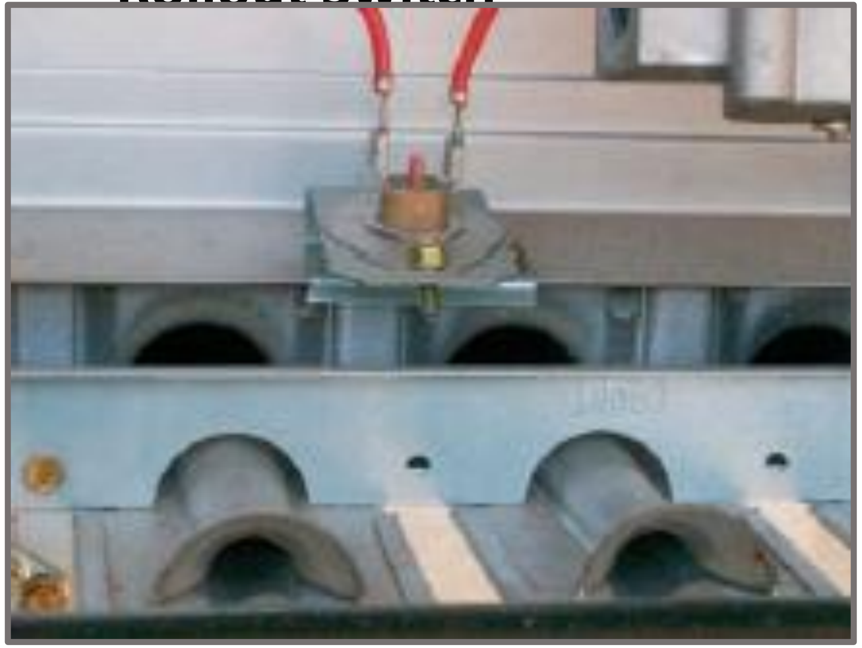
Safety Switches

Differential Pressure Switch

Dual-port Manometer

Safety Switches

Rollout Switch



Vent Spill Switch

OIL BURNERS

Chapter 7

LESSON OBJECTIVES

- Learn about the most common grades of fuel oil.
- Study the combustion process of oil burners and the importance of an efficient combustion chamber.
- Understand the operation of fuel pumps.
- Examine the draft and venting procedures for oil furnaces.
- Discover the design and operation of oil burner nozzles and their proper maintenance.

FUEL OIL GRADES

- There are six grades of fuel oil,
- The most common grade for oil furnaces is #2.
  - This grade of oil is accepted in high and low pressure gun burners.
- Fuel oil reaches the furnace within a series of tanks, pipes, and pumps.

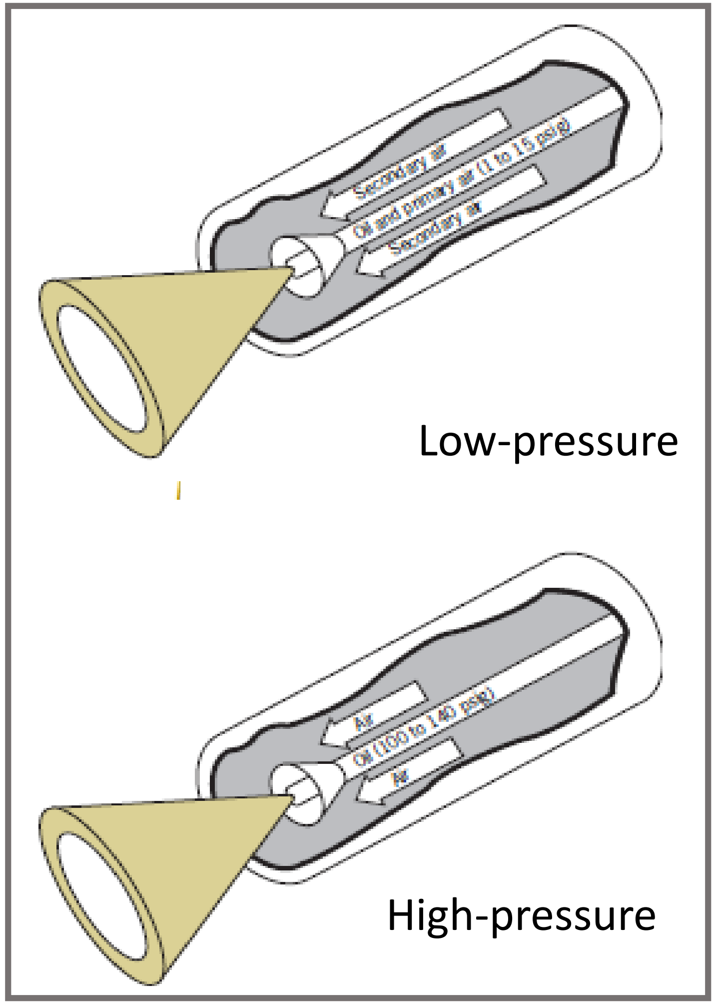
FUEL OIL COMBUSTION

- Adequate combustion air must be present for proper combustion to take place.
- The mixture of fuel and air needs to be properly distributed to maintain proper efficiency.
- Too little combustion air creates carbon monoxide and its byproduct (soot).
- Proper air/fuel mixture creates carbon dioxide.
- One gallon of #2 fuel oil equals 140,000 Btu.

THE OIL IGNITION PROCESS

- Being a liquid, oil must be converted a form that can be easily ignited.
- This conversion involves two procedure types:
  1. Atomization
     - Breaking up oil into small droplets.
     - More widely used in oil furnaces.
     - Two methods are used: high-pressure and low-pressure.
  2. Vaporization

ATOMIZATION METHODS



- Both low and high pressure methods break oil up by pressurizing it and then passing it through a small orifice or nozzle.
- Low pressure guns operate 1-15 psig.
- High pressure guns operate at 100-140 psig.

TYPICAL OIL BURNER OPERATION

- Complete combustion involves these factors:
  - Aspiration by the velocity of oil movement,
  - Air pressure,
  - Turbulence and
  - Ignition.
- The mixture of atomized fuel and air is ignited and leaves the end of the burner as a flame.

Venting

- During the normal combustion process of an oil burner in a furnace or boiler:
  - 1 lb. of fuel oil requires
  - 14 lbs. of air for complete combustion
  - For total of approximately 15.3 lbs. In flue gases

VENTING COMPONENTS

- Vent system consists of:
  - Flue pipe (or stack)
  - Chimney
- Transport flue gases from the furnace or boiler to the atmosphere.

DRAFT

- The movement of flue gases up the chimney
  - If activated by temperature differences or natural air currents, it is known as natural draft;
  - If it is created by heat, it is called thermal draft;
  - If it is created by wind blowing across the chimney top, it is called currential draft.
- If chimney conditions doesn’t provide proper thermal draft, a draft inducer may need to be employed.

WHY DRAFT IS NEEDED

- Natural draft is not required to draw combustion air into the flame of a high-pressure burner.
  - This is handled by the motor-driven blower.
- Vaporizing oil burners do depend on draft to pull air into the flame.
- Draft can be measured easily with modern direct-reading gauges.

Measuring Draft

- The vacuum chimney draft is:
  - Exceedingly low,
  - Is measured in in. w.g.
- Draft can be measured easily with modern, direct reading instruments.

Measuring Draft

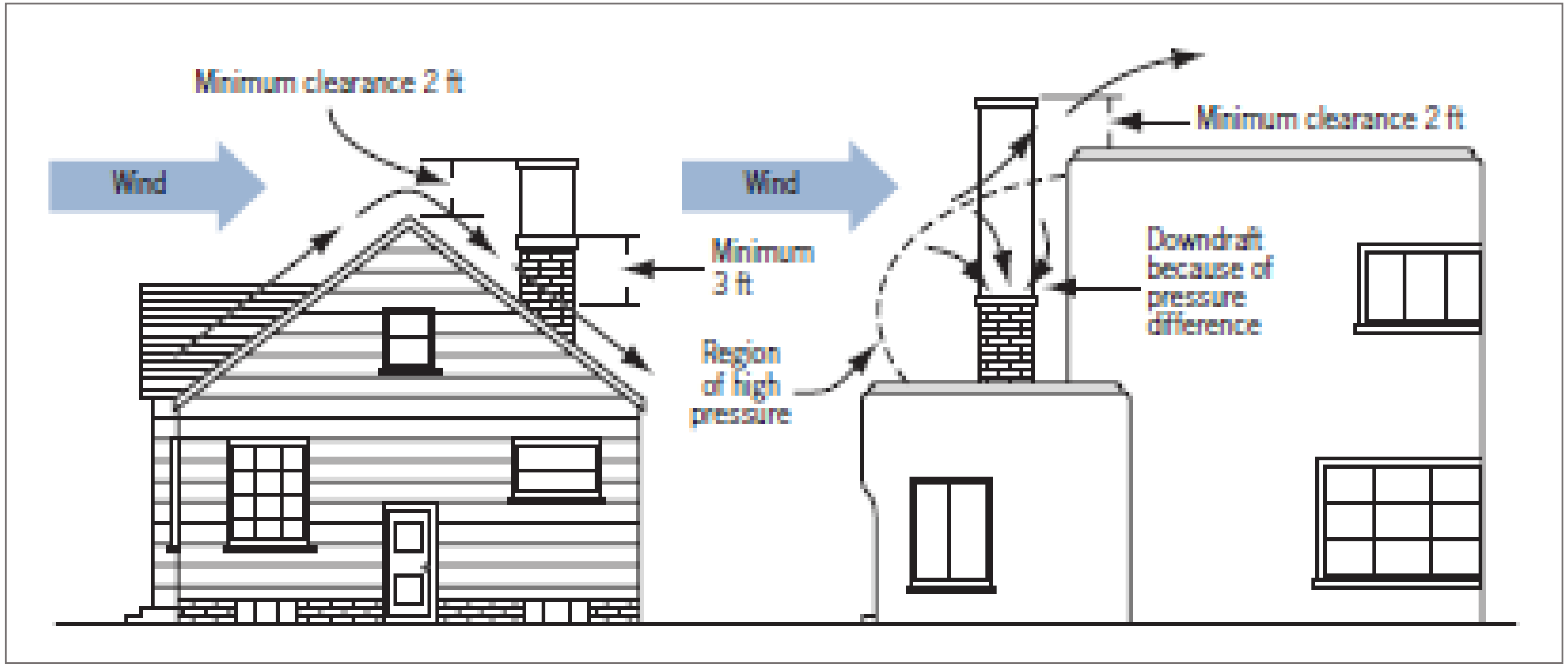
- An over fire draft reading of –0.01 in. w.g. is – $^1/_{100}$ in. water gauge (negative draft).
- An instrument reading of +0.01 in. w.g. is + $^1/_{100}$ in. water gauge(positive draft).
- A positive draft can sometimes result operating problems, although some burners will work with a positive draft.

Outside Chimney

- Chimney must be warm and dry to produce draft.
  - A chimney completely exposed the elements, does not function as well as an inside chimney.
  - The outside chimney is slow to heat up and cools down rapidly.

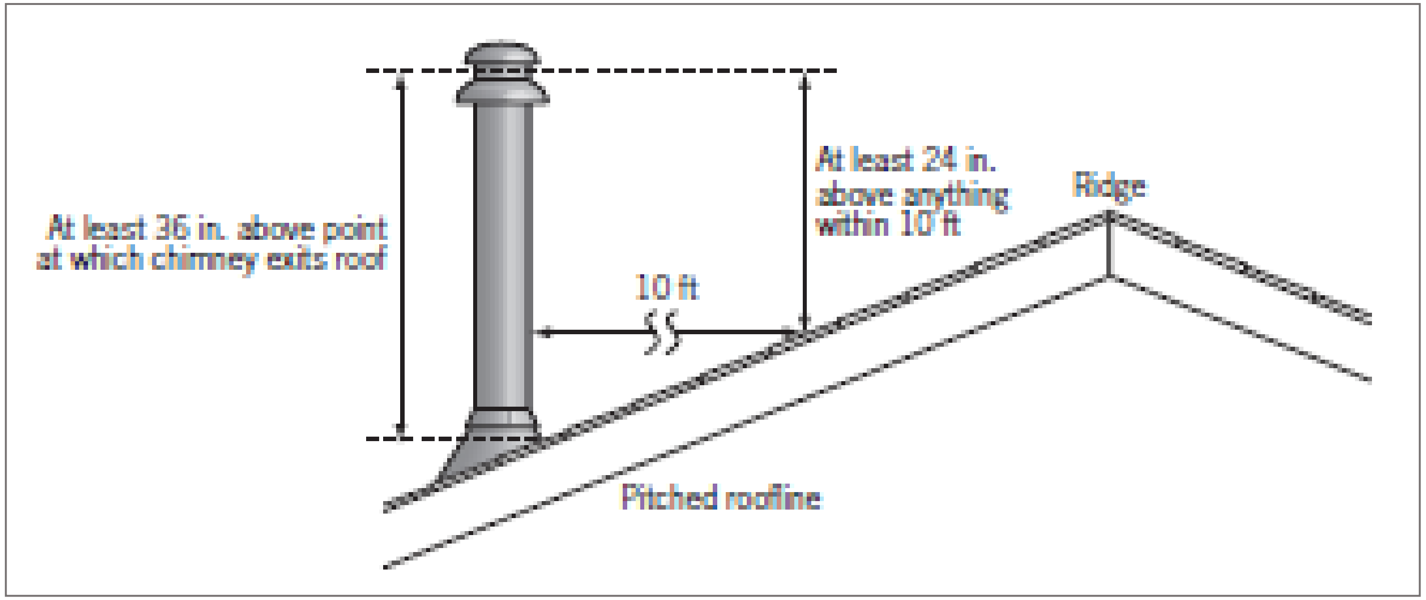
Chimney Termination

- Chimneys must extend at least 2 ft. above objects within a 10-ft radius.
  - Otherwise winds can produce positive drafts over the fire.



Chimney Spec's Pitched Roof

- The chimney must extend at least 2 ft above any portion of any structure within 10 ft (measured horizontally),
- Extend at least 3 ft above the roof penetration,
- And should be straight and vertical



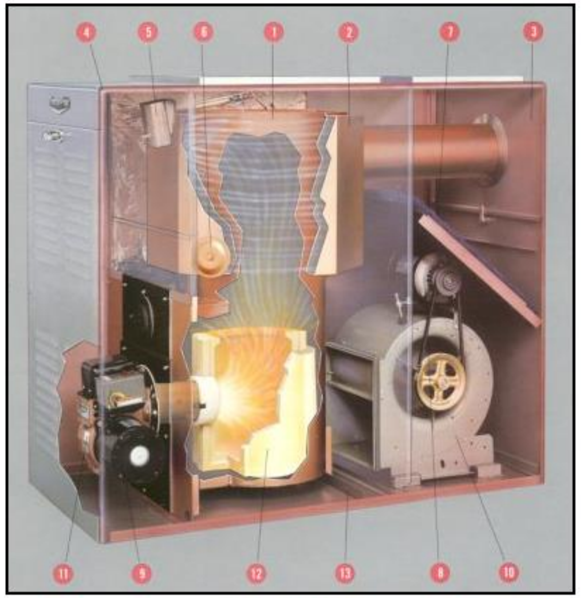
COMBUSTION CHAMBERS

- Satisfies the requirements of combustion:
  - Oil as a fuel must burn completely in suspension
  - A hot refractory (material lining the chamber)
    - Made of the right material
    - Sized properly for the required firing rate
    - Shaped correctly to match the flame pattern
    - The proper height
  - A minimum amount of air must be supplied

OIL FIRED FURNACE ILLUSTRATION

Thermo Pride®

OIL FIRED FURNACES

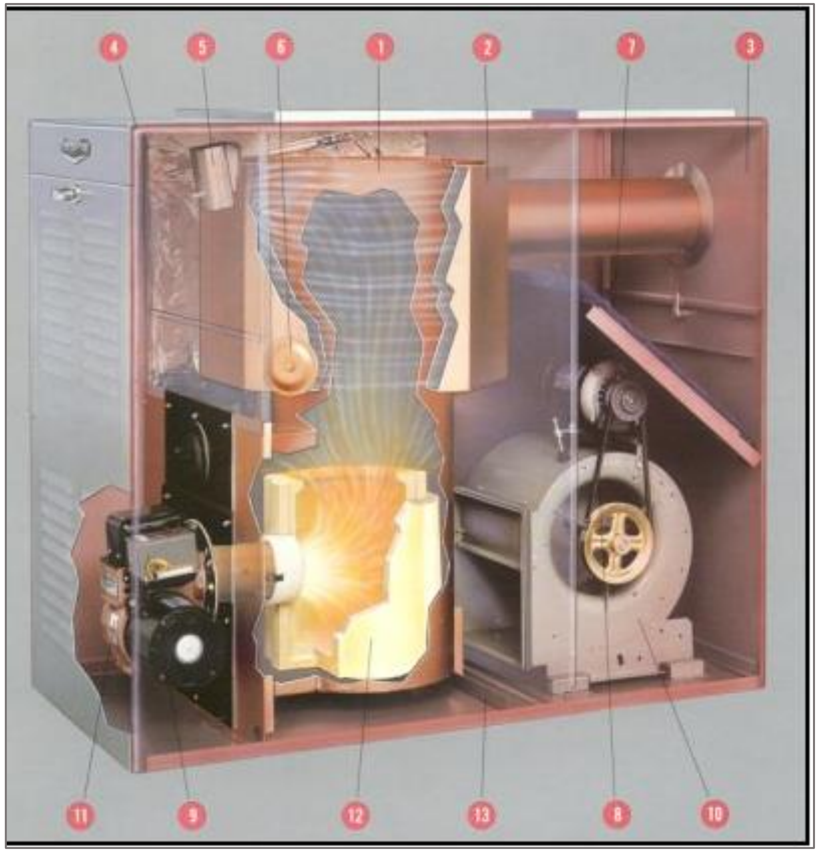


SPECIFICATIONS

1. Exclusive 13 Gauge Steel "Octatherm" Design Heat Exchanger
2. Copper Coating on Heat Exchanger
3. Interlocking Insulated Furniture Steel Casing
4. Distinctively Styled Rounded Corners
5. Automatic / Manual Fan & Limit Control
6. Conveniently Located Inspection Ports
7. Permanent Air Filter
8. Quality High Efficiency Split Phase Belt Drive Blower Motor
9. Primary Control Module
10. Versatile, Full Width Belt Drive Blower
11. THERMO PRIDE Flame Retention, High Efficiency Oil Burner
12. Ceramic Refractory
13. Elevated, Solid Furnace Base

OIL FIRED FURNACE ILLUSTRATION

Oil Fired Furnace



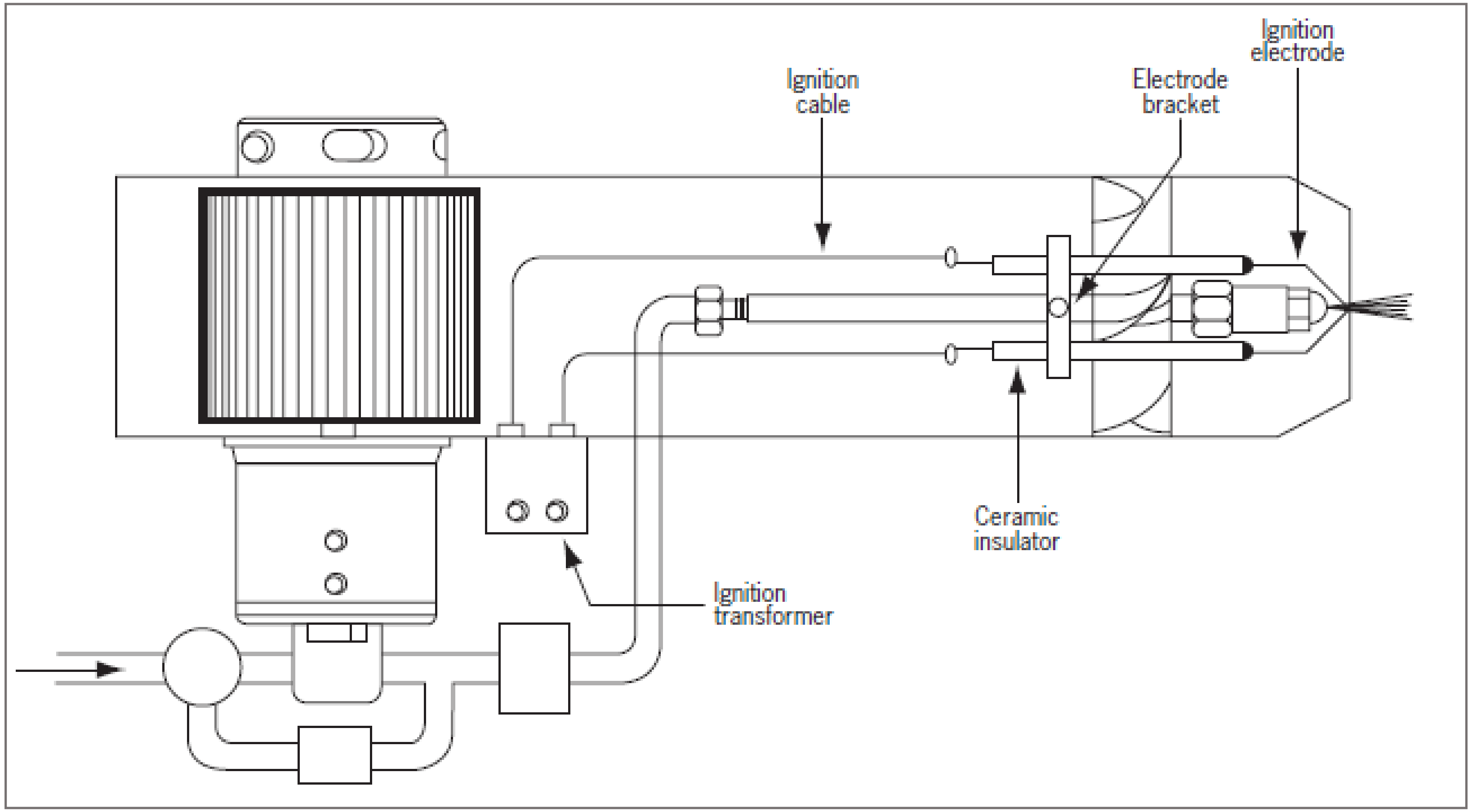
Specifications

1. 13 gauge steel "Octatherm" Design Heat Exchanger.
2. Copper coating on Heat Exchanger.
3. Interlocking Insulated Furniture Steel Casing.
4. Distinctively Styled Corners.
5. Automatic/Manual Fan & Limit Control.
6. Conveniently Located Inspection Ports.
7. Permanent Air Filter.
8. Quality High Efficiency Split Phase Belt Drive Blower Motor.
9. Primary Control Module.
10. Versatile, Full Width Belt Drive Blower.
11. THERMO PRIDE Flame Retention, High Efficiency Oil Burner.
12. Ceramic Refractory.
13. Elevated, Solid Furnace Base

OIL BURNER IGNITION SYSTEMS

- The high-pressure gun burner is completely automatic;
  - The burner operates unattended, therefore it must be properly maintained for safety reasons.
- There are 2 types of electric ignition systems;
  - Intermittent ignition,
    - The ignition spark remains on for only a short time at the beginning of the operation cycle.
  - Constant ignition,
    - The spark that ignites the oil vapors remains on while the burner is firing.

AUTOMATIC ELECTRIC IGNITION



OIL-BURNING ACCESSORIES

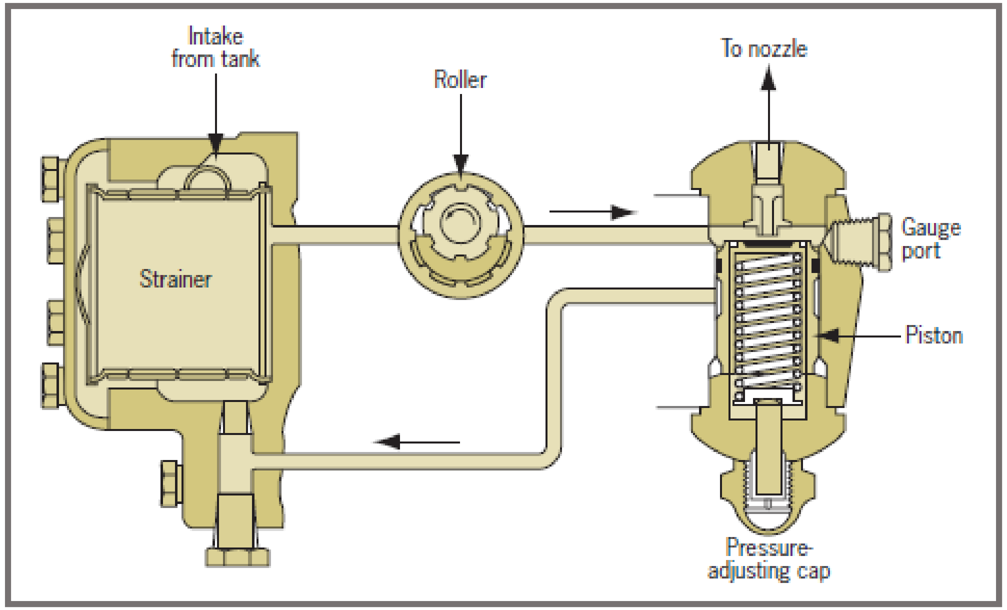
- High-pressure fuel pumps;
  - Single stage or two stage design.
- Burner motors.
- Combustion air systems.
- Ignition systems.
- Fuel nozzles.

HIGH-PRESSURE FUEL PUMPS

- All pumps used in high-pressure gun burners are rotary pumps.
- Pumps have a shaft seal since they are driven by an external motor.
- Its purpose is to create high pressures for the burner system.
- Contains a pressure regulating valve to maintain proper oil pressure to the oil nozzle.

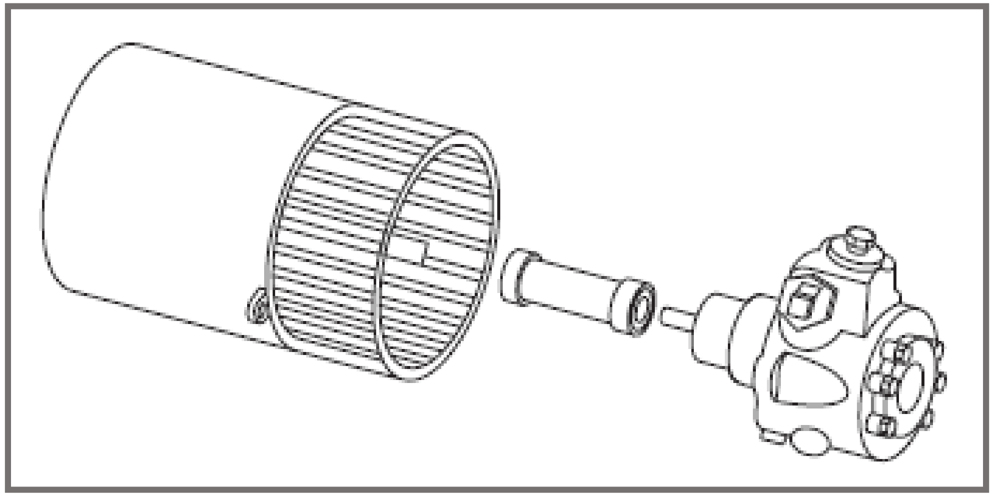
FUEL PUMP DESIGNS

- Single stage pumps;
  - Normally used when fuel tank is located above the burner.
- Two-stage pumps;
  - In a two-pipe design, can lift fuel oil 17 ft.
  - Must have the bypass plug installed inside the pump.



BURNER MOTORS

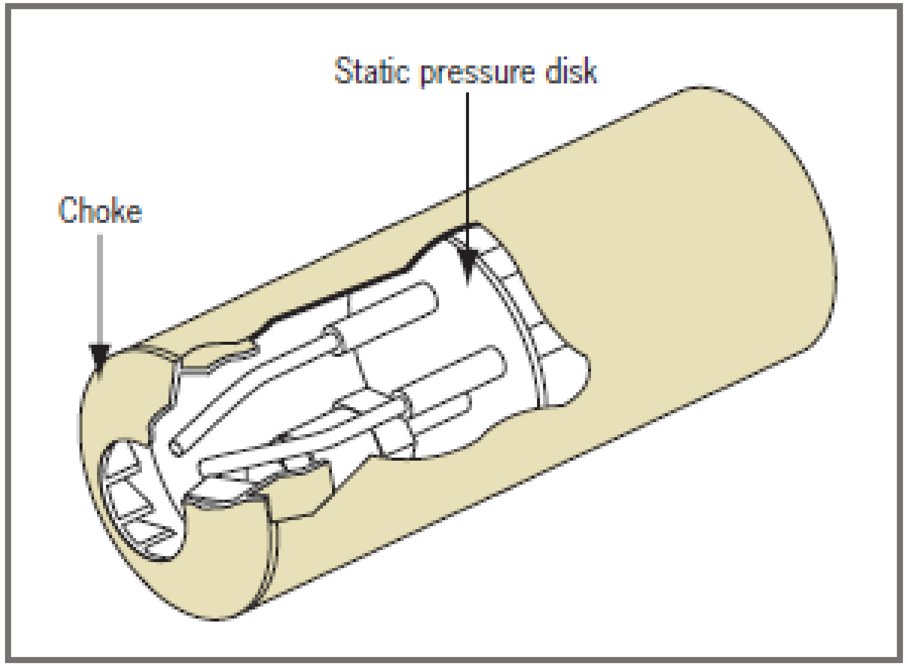
- Drives the fuel pump and also the fan.
- Older systems used 1,725 rpm motors.
- Newer systems use 3,450 rpm motors.
- Fans are typically squirrel-cage design.



Typical squirrel-cage oil burner fan

COMBUSTION AIR SYSTEMS

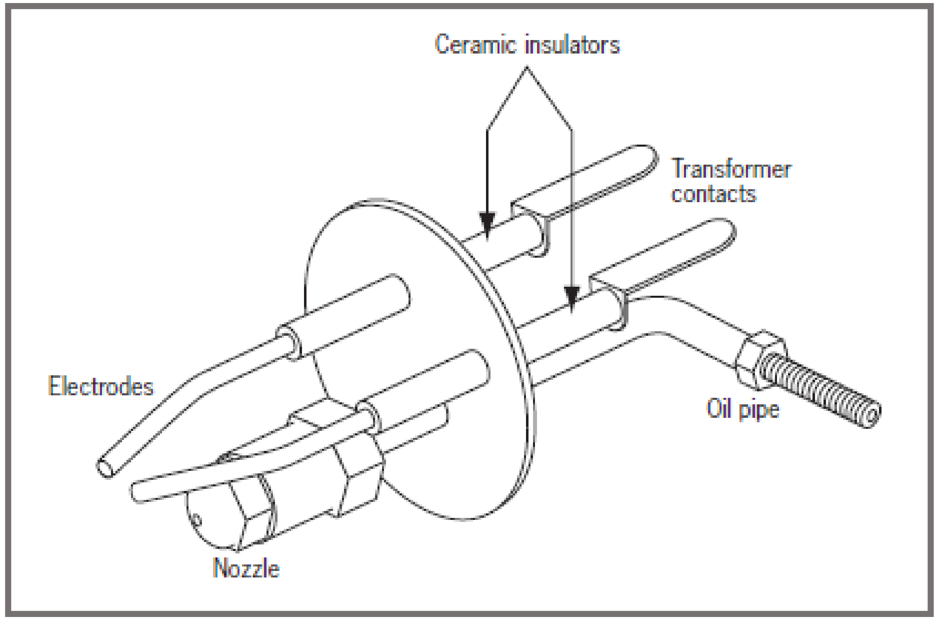
- Along with the blower, the combustion air system contains two important parts:
    1. The static pressure disk;
        - Located within the blast tube.
    2. The choke;
        - Inserted at the furnace end of the blast tube.



Typical blast tube showing choke and static pressure disk

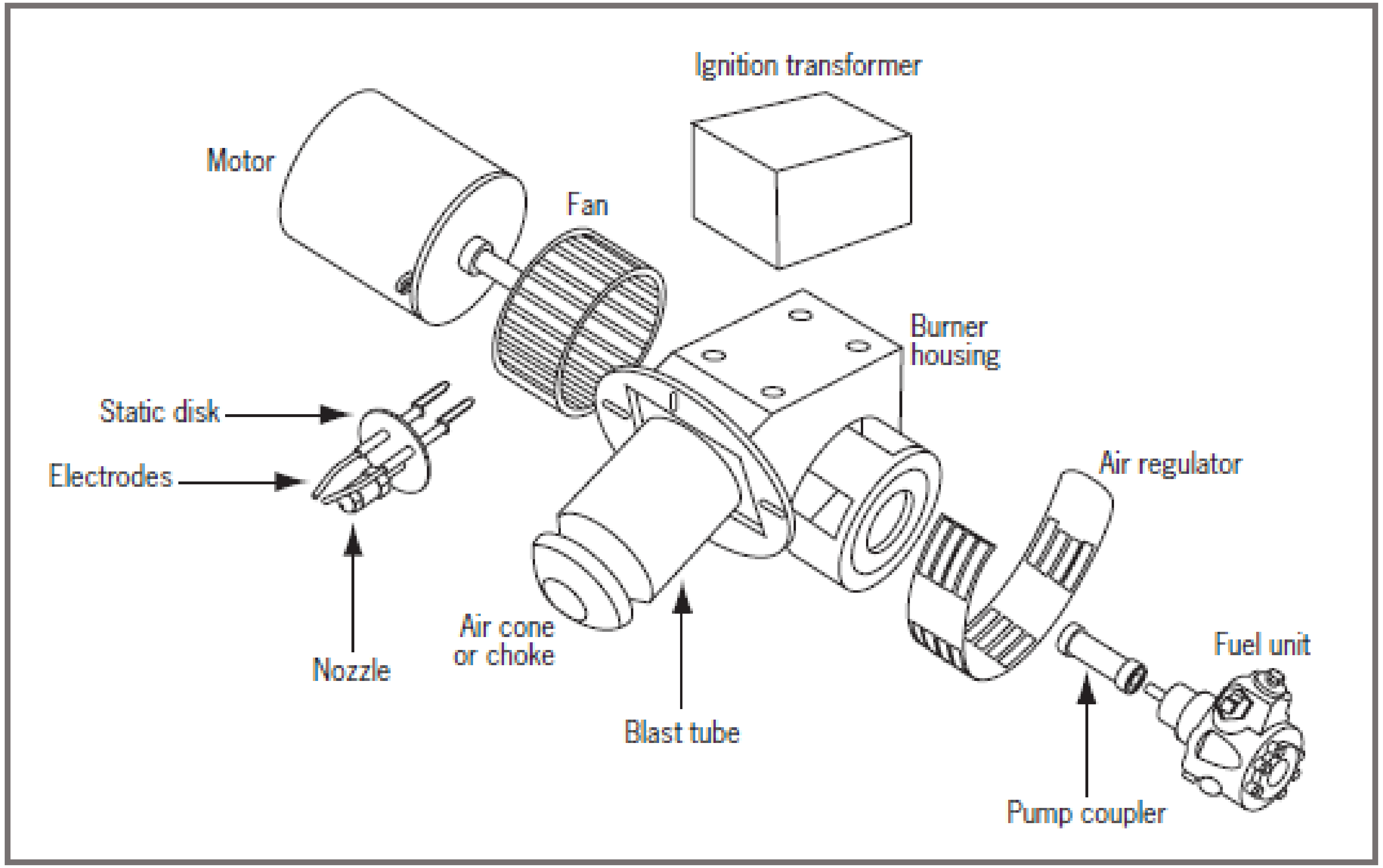
IGNITION SYSTEMS

- Utilizes a step-up electrical transformer to supply high voltage to the electrodes;
  - The high voltage creates the spark for ignition.
- Ceramic insulators protect the electrodes and allow for proper positioning.



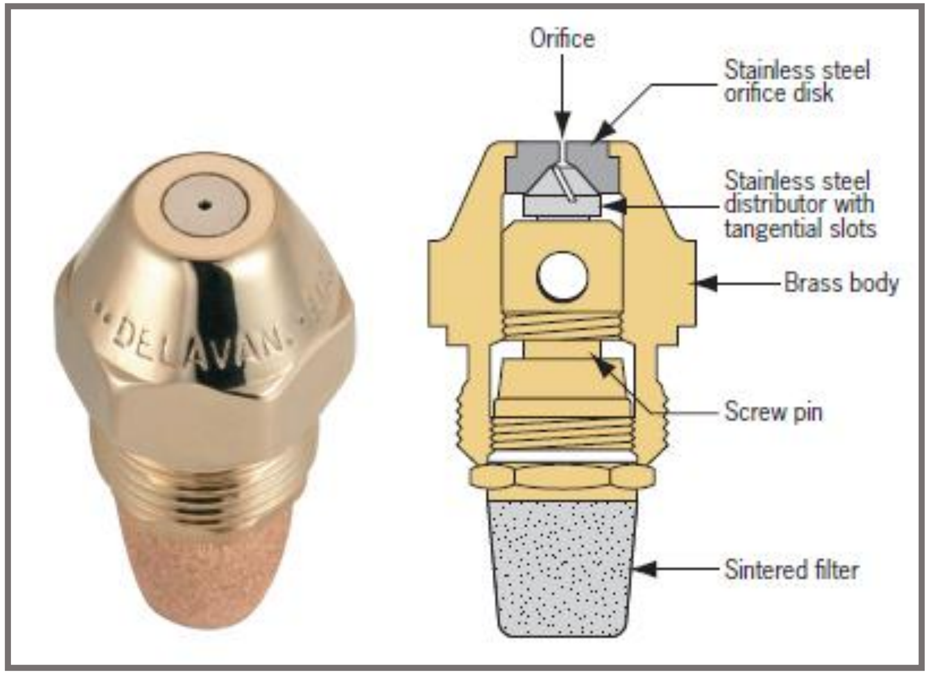
Burner Assembly

Exploded view of the Burner assembly.



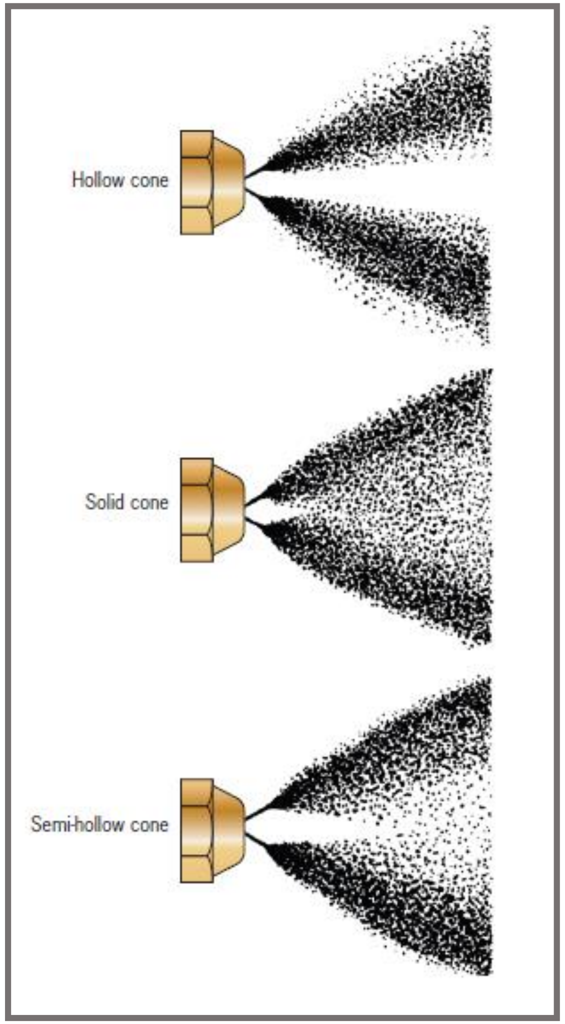
FUEL NOZZLES

- The metering device of the combustion process.
- Performs flow rate and atomization of the fuel.
- Nozzles contain their own strainers.
- Orifice causes velocity increase.
- Cone shape forms spray pattern.



NOZZLE SPRAY PATTERNS

- Typically 3 types:
  1. The hollow type.
  2. Solid type.
  3. Semi-hollow type.
- Must match air pattern.
- Not choosing proper spray pattern usually results in inefficient operation.



WRONG NOZZLE?

- When nozzles are undersized….
  - Burner may appear to be operating normally but be unable to produce sufficient heat.
- When nozzles are oversized….
  - Can cause over-firing, which may result in impingement or damage to the heat exchanger.

OIL TANKS

Chapter 8 – Oil Tanks

LESSON OBJECTIVES

- Examine oil tank installation practices.
- Discover physical location choices.
- Understand the regulatory restrictions.
- Understand the materials used in oil tank design as they relate to their installed location.
- Learn piping design considerations.

DESIGN CONSIDERATIONS

- Installation must be done correctly.
- Must comply with all local fire ordinances.
- All local regulations must be thoroughly investigated before work is begun.

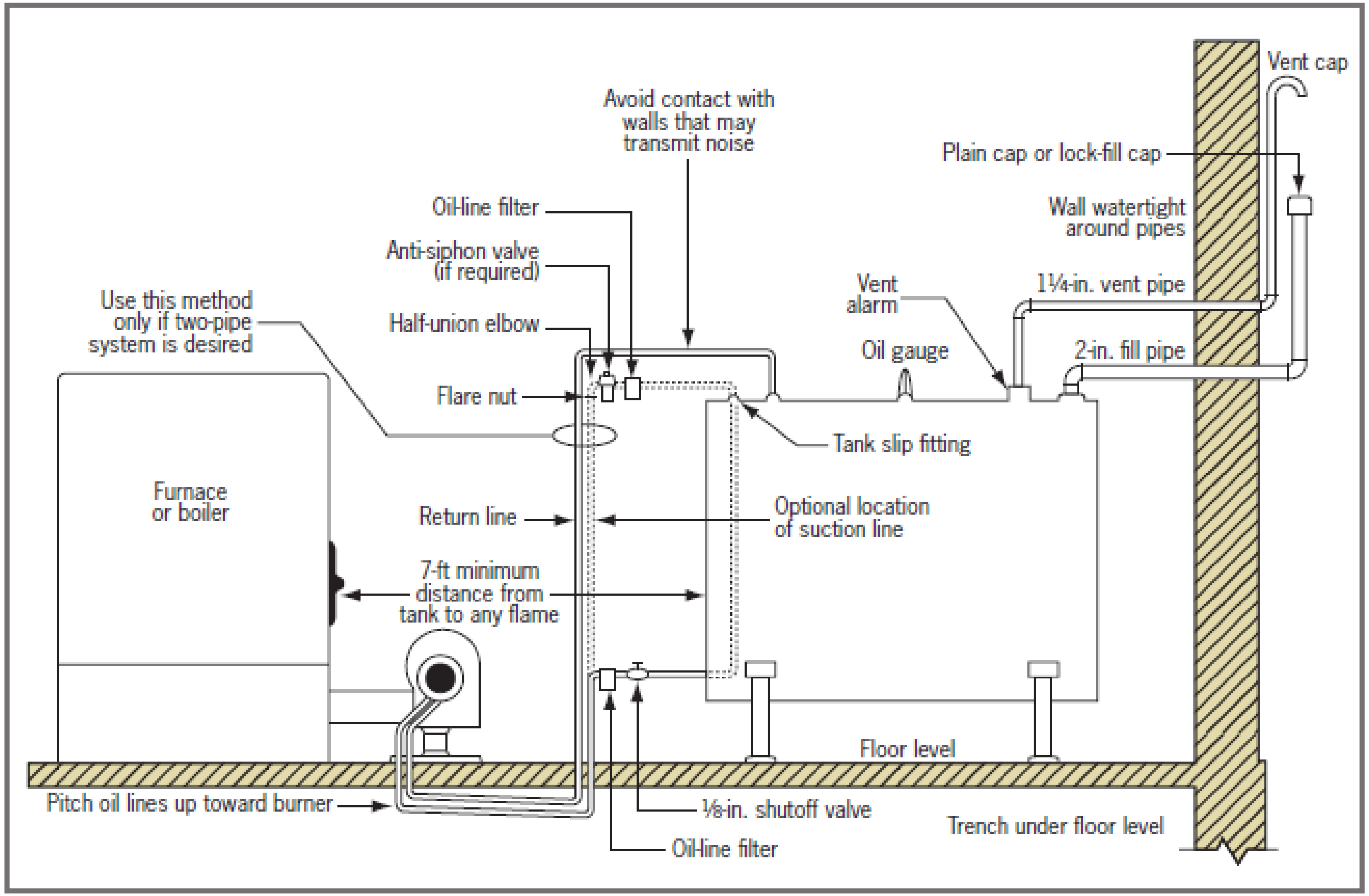
OIL TANK LOCATIONS

- Inside the basement or furnace room.
- Outside the building, above grade.
- Outside, below grade.

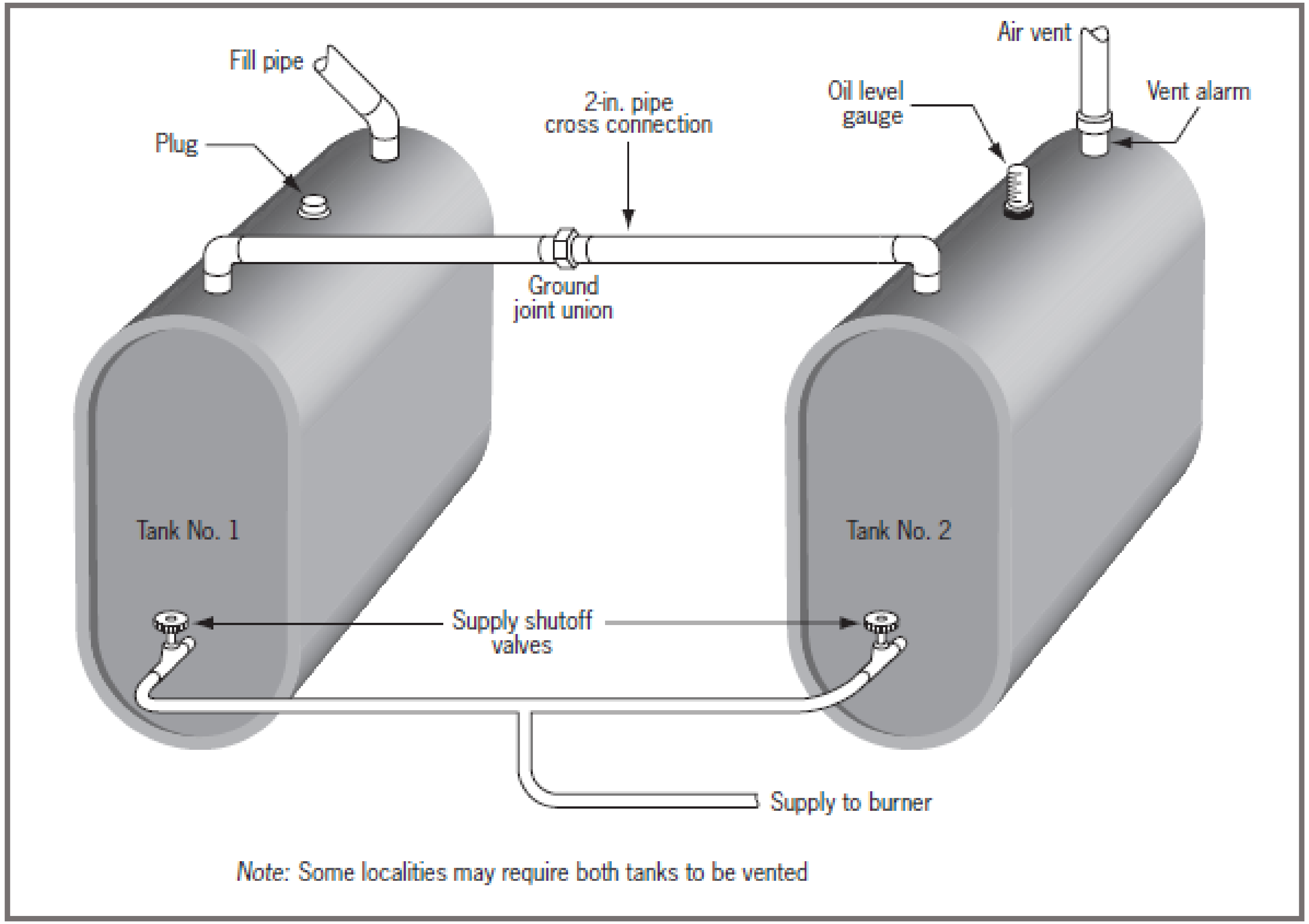
INDOOR TANKS

- The 275-gal capacity tanks is most common.
- Low cost and long tank life are advantages.
- Another plus is the ease of running pipe to the furnace and providing constant viscosity fuel.
- Tanks must be small enough to fit through doors for installation/removal.
- Twinning tanks is also a consideration.

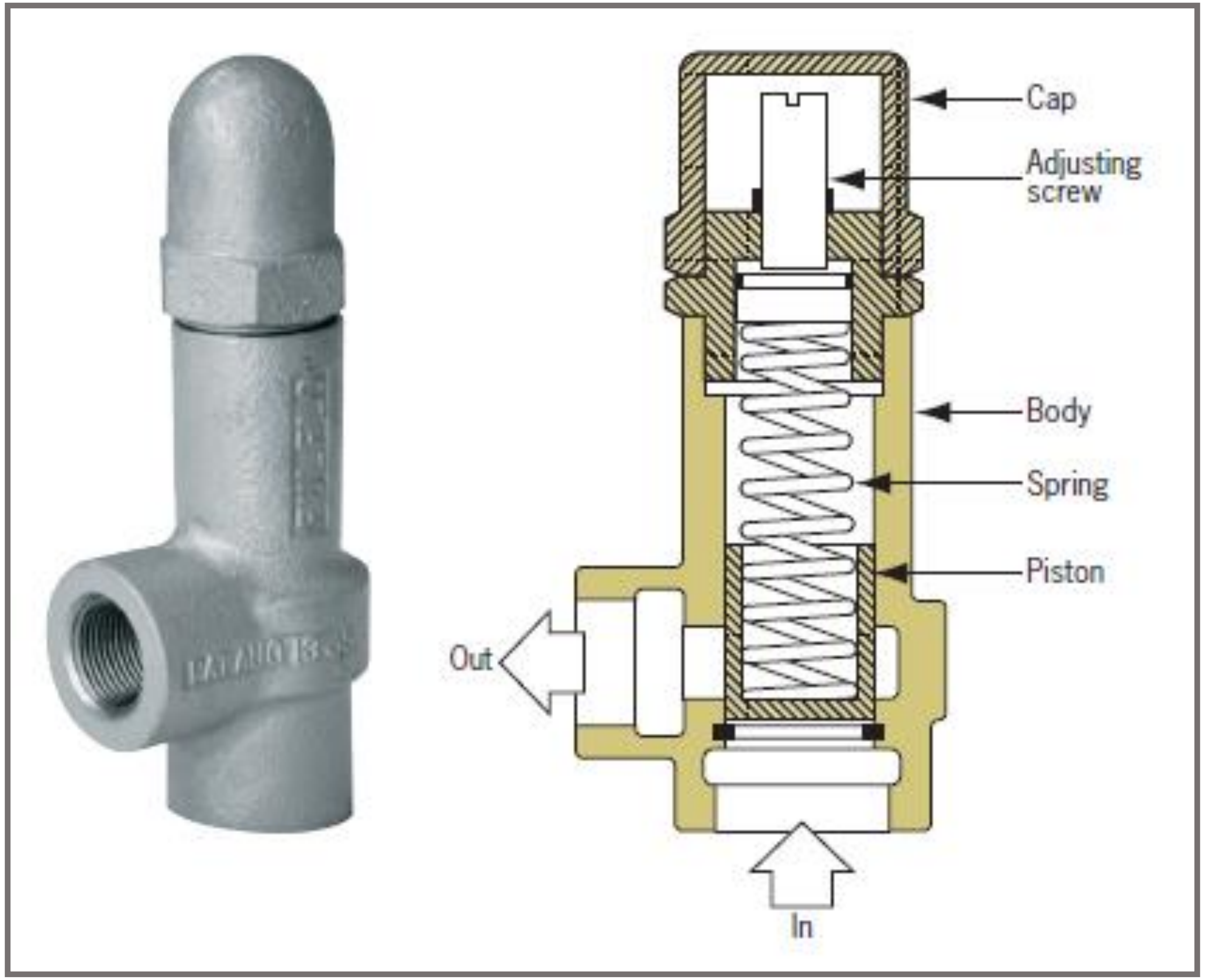
TYPICAL INSIDE TANK INSTALLATION



TWO-TANK INSTALLATION

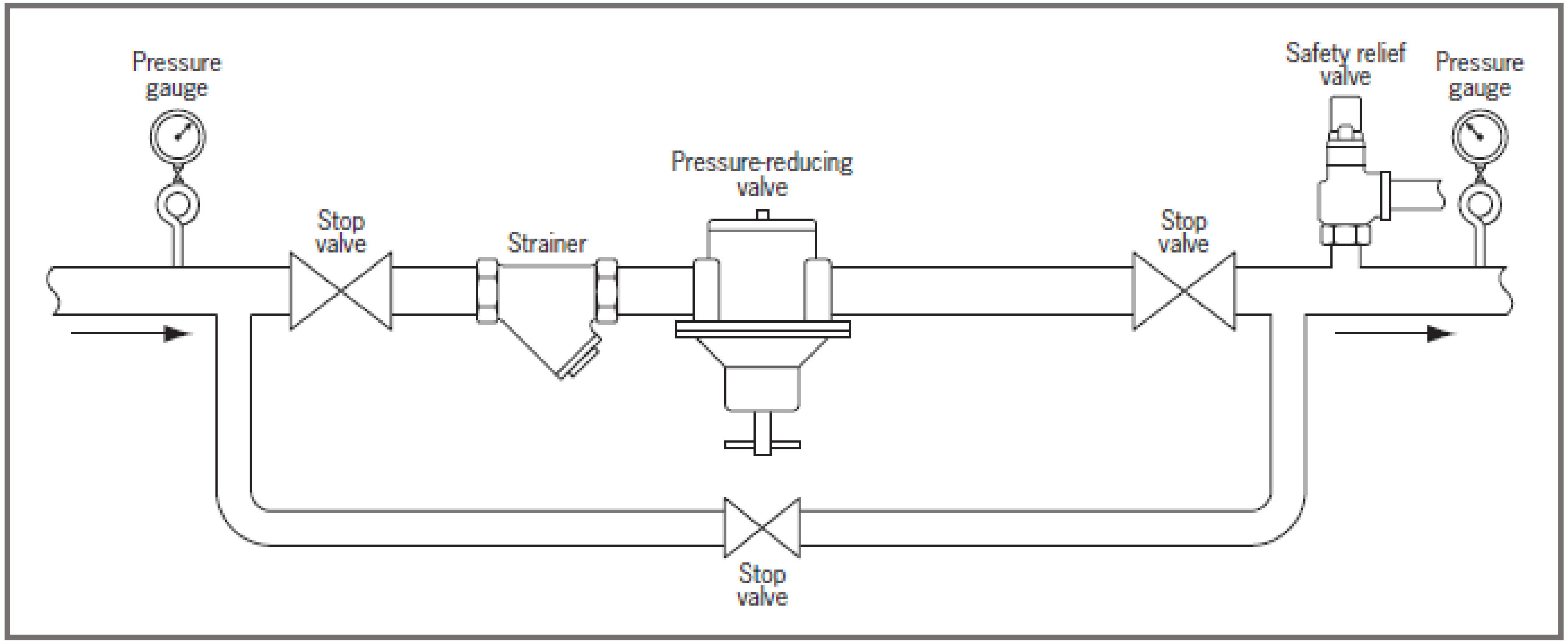


PRESSURE-REDUCING VALVE



Oil Safety Valve

PRESSURE-REDUCING VALVE PIPING



TYPICAL OIL TANK GAUGE

- A suitable UL-approved gauge should be installed in the top of the tank to indicate the oil level at all times.

PIPING PRACTICES

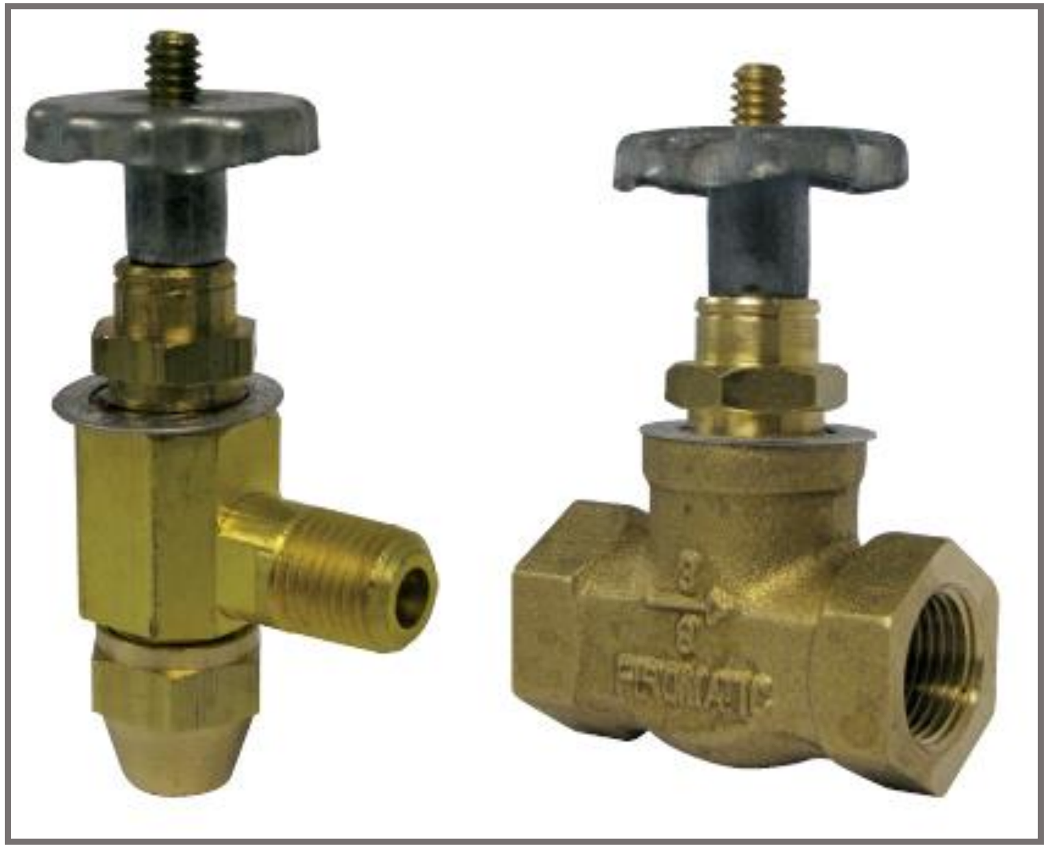
- The fill line should be a 2-in. pipe;
  - Should be located at least 2 ft away horizontally from any window or building opening.
- The vent line must be a min. of 1 ¼-in. pipe or one pipe size larger than the fill pipe;
  - It must pitch upward from the tank.
- The vent riser must terminate not less than 5 ft vertically and 2 ft horizontally from any building opening.

PIPING PRACTICES (CONT.)

- Install a valve at the tank outlet on the oil feed line (suction line) that is run to the burner.
- Slope the tank towards the outlet end about 1 in. lower than the opposite end.
- Install a cartridge line filter in the suction line at the burner side of the globe valve.
- Install a Firomatic safety valve in the suction line ahead of the burner, (on next slide).

FIROMATIC FUSIBLE VALVES

- The valve represents a safety factor in that it is spring-closed.
- It should be mounted close to the inlet of the fuel pump, but outside the furnace or appliance.



OUTDOOR TANKS ABOVE GROUND

- May be approved under certain conditions.
- Piping method is the same as a two-pipe basement installation.
- Installer must provide a substantial masonry foundation on which to set the tank.
- Due to weather changes, it may cause some operational problems.
- The fuel filter housing must be installed indoors.

UNDERGROUND TANKS

- Installation process may involve many regulations relating to underground tanks.
- Familiarity with EPA rules and regulations is a necessity.
- If an oil leak occurs, it may go unnoticed for an extended time and contaminate the soil.
- The average life of an underground tank is 20 years.

PREVENTIVE MAINTENANCE

Chapter 9

LESSON OBJECTIVES

- Examine the operational sequences of the oil burner including proper oil flame and oil pump pressure.
- Discover the purpose of conducting combustion efficiency tests and the needed instruments to perform the tasks.
- Learn how to interpret the tests results and the steps needed to correct any deficiencies.

BURNER OPERATION

- A call for heat starts the burner motor;
  - This then starts the oil pump and draft fan.
- A pre-purge cycle begins (if equipped).
- If the cad cell has a high resistance, indicating a dark combustion chamber, the oil solenoid opens.
- Once the call for heat is satisfied, the oil solenoid closes and the burner stops. The fan will continue to run and perform a post-purge.

PROPER OIL FLAME

- Oil spray pattern produces proper flame shape.
- Flame should burn relatively quietly.
- A flame with yellow tips generally is lacking combustion air.
- Carbon buildup on walls of chamber indicates:
  - Oil pressure may be too high,
  - The size or angle of the nozzle may be incorrect,
  - The firing rate may need to be adjusted.

OIL PUMP PRESSURE CHECK

- After checking for proper nozzle sizing, check the oil pump pressure.
- Always consult the specifications on the unit data plate or in the manufacturer’s literature.
- Some manufacturers still use 100 psi, but others may use different pressures.

COMBUSTION EFFICIENCY TESTING

- Should be conducted on new equipment shortly after start-up and sequences proven.
- Such tests cannot be made without the use of appropriate testing instruments and gauges.
- Always use a complete combustion test kit, not just a single instrument.

COMBUSTION TESTING EQUIPMENT

- Tools should include:
  - Smoke tester,
  - Stack thermometer,
  - Draft gauge,
  - CO_2 or oxygen indicator,
  - Efficiency charts,
  - Slide rule calculators.

USING COMBUSTION TESTING EQUIPMENT PROPERLY

- Always use instruments in sequence.
- The first step is the draft test and adjustment.
- The next step is the smoke test.
- Measure stack temperature after all draft and burner adjustments have been made.

FLUE GAS TEMPERATURE CHECK

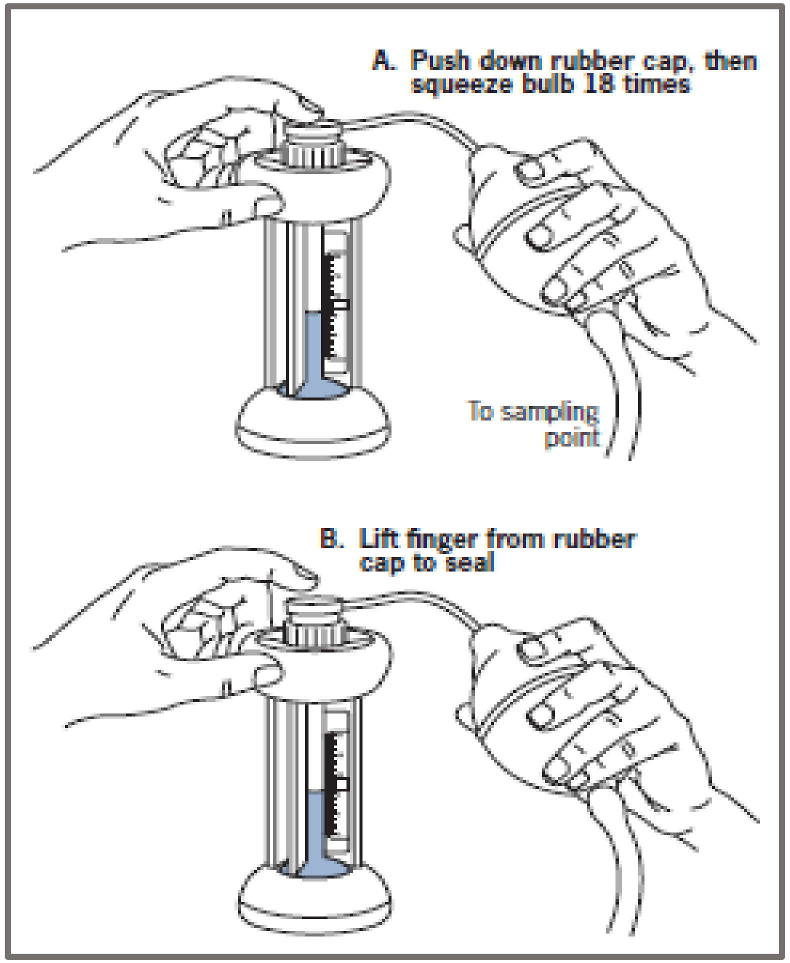
- Drill a ¼" hole in flue and insert stack thermometer about 12 in. from the boiler breaching and 6 in. before draft regulator.
- Allow the burner to operate for 5-10 min.
- After recording temp. subtract the surrounding air temperature from the reading for the proper end result.

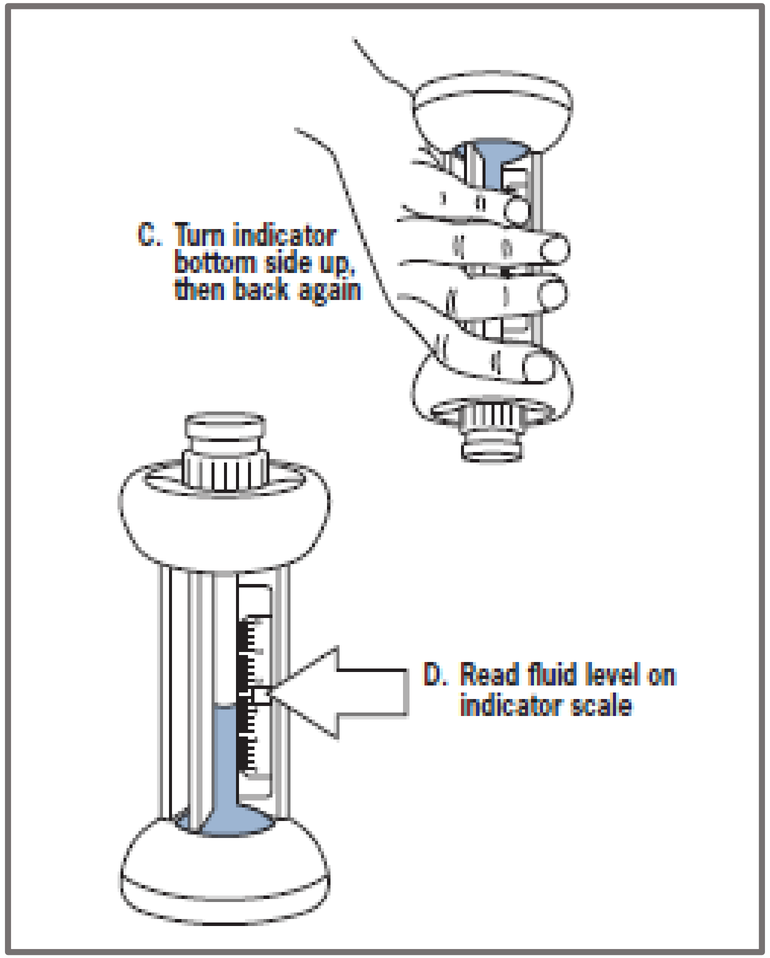
Typical Stack Thermometers

CO_2 INDICATORS

- Proper percentage of CO_2 in the flue gas is another factor in determining proper combustion.
- The "dumbbell" testing fluid for CO_2 is red and is blue for oxygen.

PERFORMING CO_2 TEST





Oil Burner Operation Diagnosis Chart

Overfire Draft	
Condition 1: Overfire draft is too low (less than –0.01 in. w.g.). **Result:** 1. Odors. 2. Pulsations, poor ignition.	**Caused by:** 1. If stack draft also is low (–0.02 to –0.04 in. w.g. or less): a. Defective or blocked chimney. b. Leaks in smoke pipe. c. Defective or improperly adjusted draft regulator. 2. If stack draft is high (–0.05 in. w.g. or more): a. Soot in heat exchanger. Unit needs cleaning. b. Poorly designed unit. Might need even higher stack draft.
Condition 2: Overfire draft is too high (greater than –0.02 in. w.g.). **Result:** 1. High heat loss when unit is not firing. 2. Gas flow too high through furnace (poor efficiency).	**Caused by:** 1. Defective or improperly adjusted draft regulator. 2. No draft regulator present. 3. Draft inducer being used when not required.

Oil Burner Operation Diagnosis Chart

Smoke in Flue Gas	
Condition 1: Smoke too high (greater than No. 2 spot). **Result:** 1. Soot deposits in furnace (causes high stack temperatures and poor efficiency). 2. Soot and smoke discharge from home chimney.	**Caused by:** 1. If CO_2 is high (10 to 12%): a. Overfiring of unit (oil rate too high). b. Not enough excess air. c. Dirty fan or air-handling parts. 2. If CO_2 is low (less than 8%): a. Faulty nozzle operation. b. Combustion chamber trouble (too large, poorly installed, broken, etc.).
Condition 2: Smoke too low (less than No. 1 spot). **Result:** 1. Without oil on smoke disk: a. Low CO_2 (wasted heat). b. Excessive odors. 2. With oil on smoke disk: a. Lacquer and oil on furnace surfaces and controls. b. Strong odors in basement and outside home.	**Caused by:** 1. Without oil on smoke disk: a. Air leaks into furnace. b. Air shutter open too much. c. Excessive draft. 2. With oil on smoke disk: a. Excess air set too high. b. Poor nozzle operation.

Oil Burner Operation Diagnosis Chart

CO_2 in Flue Gas	
Condition 1: CO_2 is too low (less than 8%). **Result:** 1. Heat loss up chimney (poor efficiency).	**Caused by:** 1. With low smoke: a. Underfiring combustion chamber. b. Nozzle is too small. c. Air leaks into furnace. d. Air gate open too wide. 2. With high smoke: a. Faulty nozzle operation. b. Poor combustion chamber.
Condition 2: CO_2 is too high. **Result:** 1. Smoke may be too high (greater than No. 2 spot). 2. Pulsations and other noises may occur, particularly on cold starts.	**Caused by:** 1. Not enough air (air gate closed too far). 2. Dirty fan or air-handling parts.. 3. Not enough draft. 4. Burner being overfired.

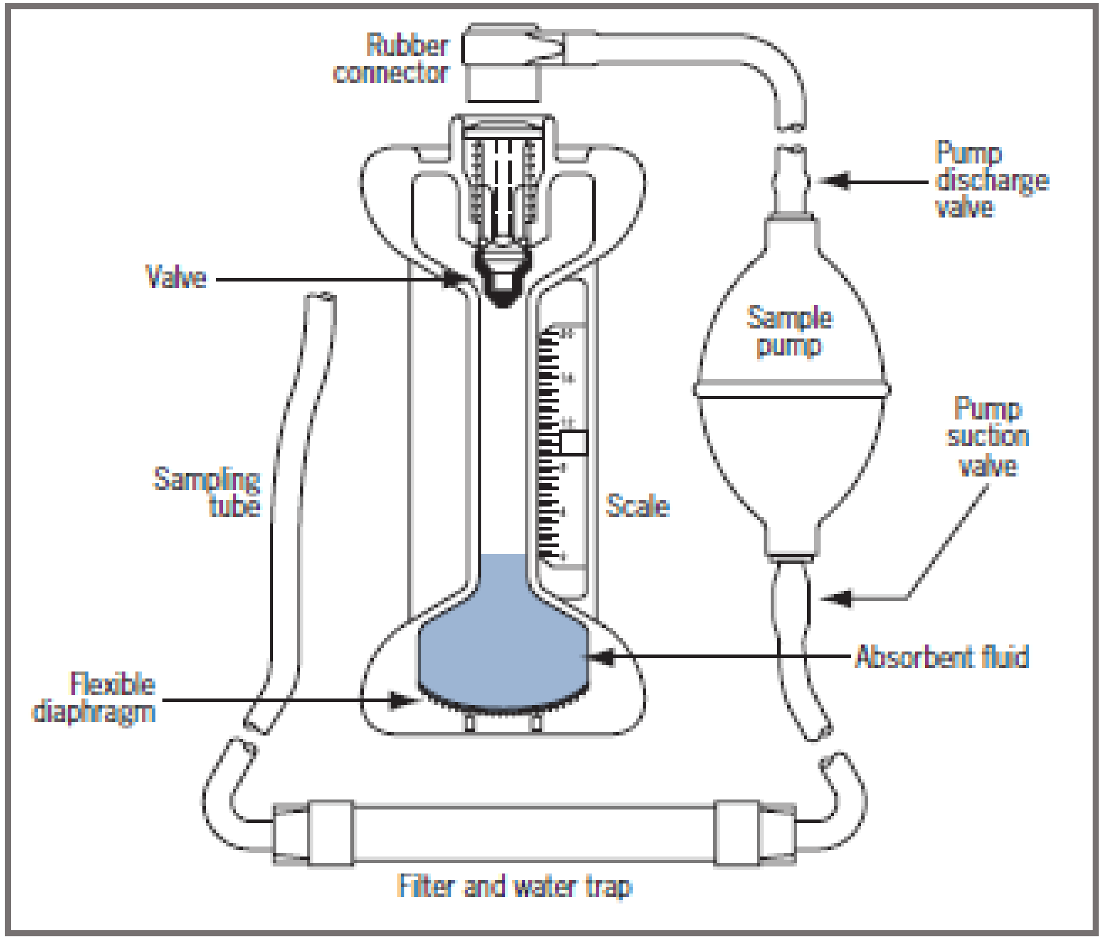
Oil Burner Operation Diagnosis Chart

Flue Gas Temperature Too Low	
Condition 1: Stack temperature too high (greater than 630°F net). **Result:** 1. High heat loss up chimney (excessive oil consumption).	**Caused by:** 1. Dirty heat exchanger (possibly high smoke and high draft loss). 2. Overfiring furnace (accompanied by high CO_2). 3. Poor furnace design (baffles needed). 4. Poor combustion chamber. 5. Excessive draft.
Condition 2: Stack temperature too low (less than 380°F net). **Result:** 1. Moisture condensation (rusting and deterioration of smoke pipe and chimney). 2. Poor draft.	**Caused by:** 1. Underfiring furnace.

LOW CO_2 CONDITIONS

- High draft,
- Excess combustion air,
- Incorrect or defective fire box,
- Air leakage,
- Poor oil atomization,
- Worn, plugged or incorrect nozzles,
- Excessive air leaks in the furnace or boiler,
- Incorrect air-handling parts,
- Erratically operating draft regulator,
- Incorrectly set oil pressure.

"Dumbbell" CO_2 TESTER



Handheld Combustion Analyzer

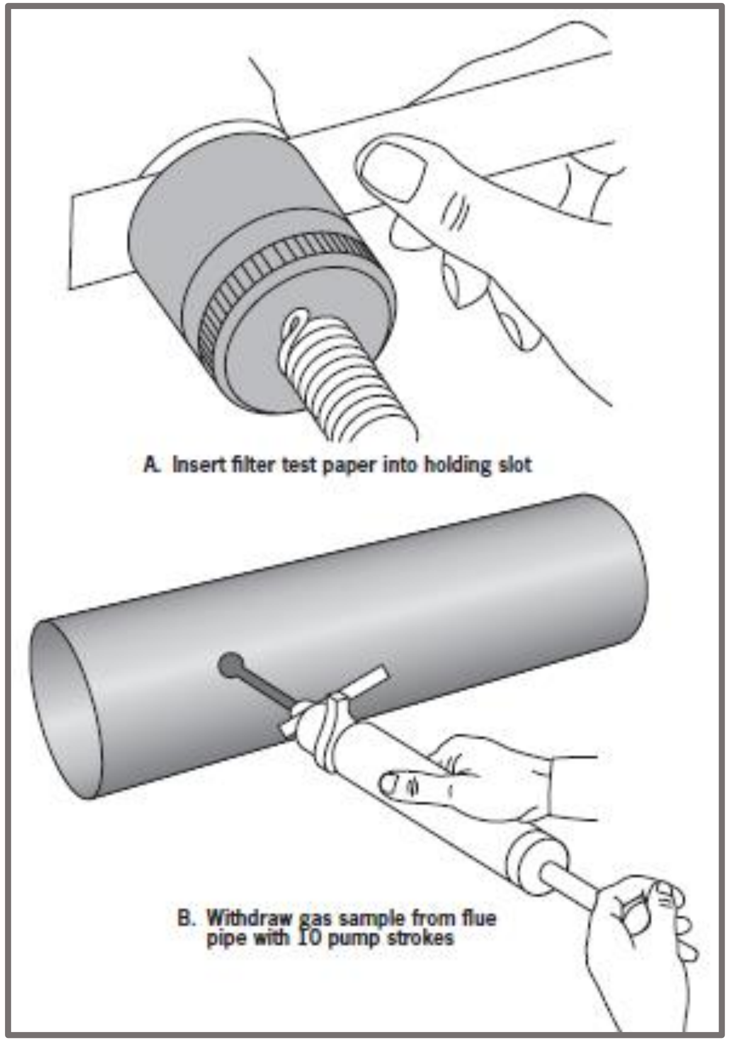
Residential Combustion Analyzer

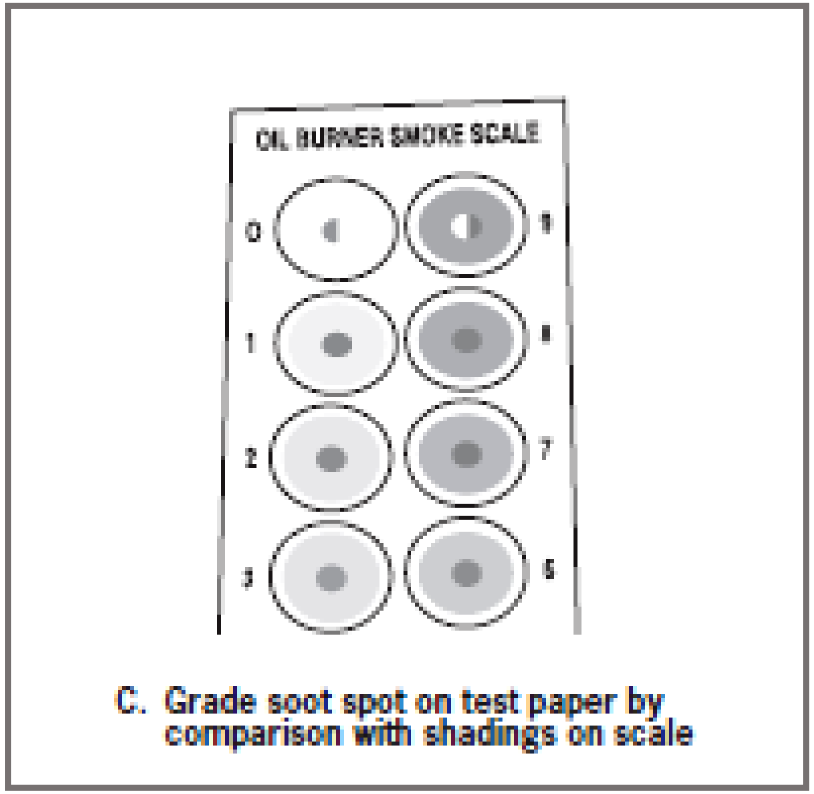
Combustion Analyzer

SMOKE SPOT TESTERS

- This tester gives the service technician an accurate indication of the smoke content in the flue gases.
- A smoky fire results in excessive soot formation and impedes heat transfer in the system.

PERFORMING A SMOKE TEST





EXCESSIVE SMOKE CAUSES

- Improper fan delivery,
- Insufficient draft,
- Poor fuel supply,
- Oil pump not functioning properly,
- Defective nozzle or nozzle of incorrect type,
- Excessive air leaks in the boiler or furnace,
- Improper fuel-air ratios,
- Defective fire box,
- Improperly adjusted draft regulator,
- Improper burner air-handling parts.

SMOKE TEST RESULTS

Smoke scale spot No.	Rating	Sooting produced
1	Excellent	Extremely light if at all
2	Good	Slight sooting which will not increase stack temperature appreciably
3	Fair	May be some sooting, but will rarely require cleaning more than once a year
4	Poor	Borderline condition—some units will require cleaning more than once a year
5	Very poor	Soot rapidly and heavily

DRAFT GAUGES

- Draft requirements vary with each type of installation. Consider the following in regard to draft levels:
  - Excessive draft can increase the stack temperature and reduce the percentage of CO_2 in the flue gases.
  - Insufficient draft may cause pressure in the combustion chamber, leading to the escape of smoke and odor to the basement area.
  - Insufficient draft also makes it impossible to adjust the burner for maximum efficiency.

DRAFT GAUGES (CONT.)

- Provide direct readings in 0.01-in. w.g. increments
- Can be used to measure both over-fire draft and flue or breech draft
- Measures negative draft from 0 to -0.25 in. w.g. and positive draft from 0 to 0.05 in. w.g.

DRAFT GAUGE OPERATION

- Select a location in the combustion area over the fire for the overfire draft check;
  - Results of not less than -0.01 in. w.g. is considered sufficient.
- Use the ¼” hole in the flue for checking flue pipe draft;
  - Must be sufficient to prevent positive pressure in the combustion chamber.
  - Results should be between -0.04 and -0.06 in. w.g.

INTERPRETING COMBUSTION RESULTS

- High efficiency can be accomplished with stack temps at 600-700^{o}F for conversion oil burners and 400-500^{o}F for packaged units when the following levels are reached:
- CO_2 reading of 9 to 12 %.
- Smoke scale reading of No. 1 or No. 2.
- Overfire draft of -0.01 to -0.02 in w.g.

DIAGNOSTIC CHARTS

Overfire draft	
Condition 1: Overfire draft is too low (less than –0.01 in. w.g.). **Result:** 1. Odors. 2. Pulsations, poor ignition.	**Caused by:** 1. If stack draft also is low (–0.02 to –0.04 in. w.g. or less): a. Defective or blocked chimney. b. Leaks in smoke pipe. c. Defective or improperly adjusted draft regulator. 2. If stack draft is high (–0.05 in. w.g. or more): a. Soot in heat exchanger. Unit needs cleaning. b. Poorly designed unit. Might need even higher stack draft.
Condition 2: Overfire draft is too high (greater than –0.02 in. w.g.). **Result:** 1. High heat loss when unit is not firing. 2. Gas flow too high through furnace (poor efficiency).	**Caused by:** 1. Defective or improperly adjusted draft regulator. 2. No draft regulator present. 3. Draft inducer being used when not required.

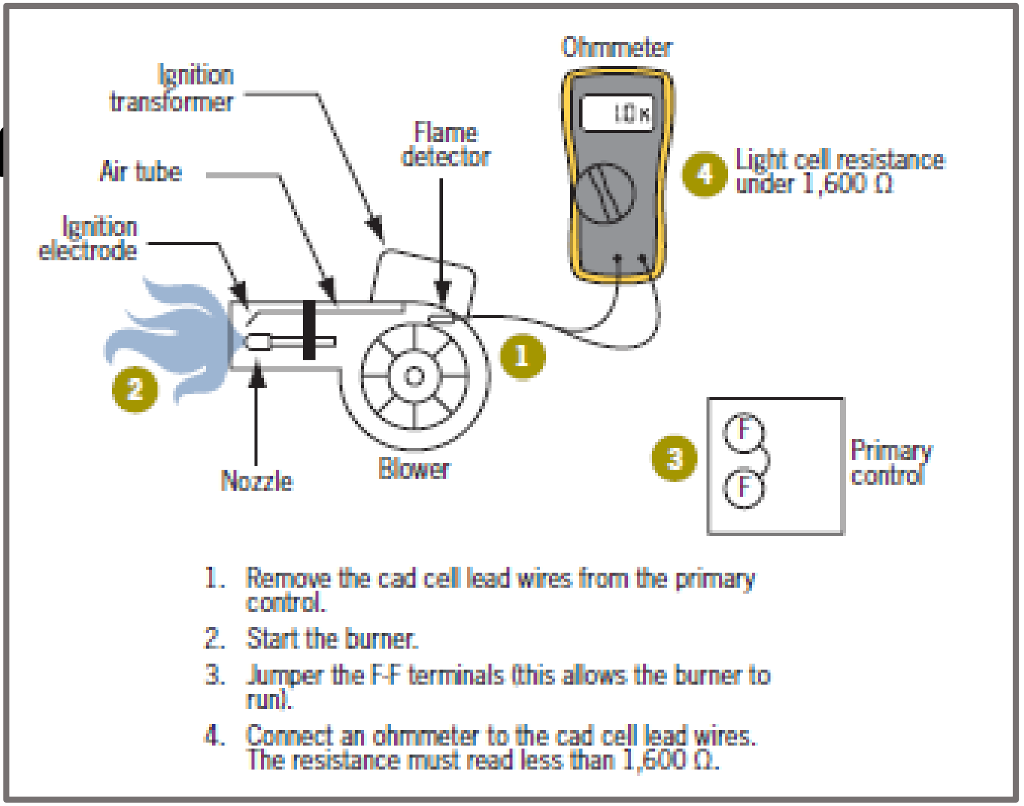
Smoke in flue gas	
Condition 1: Smoke too high (greater than No. 2 spot). **Result:** 1. Soot deposits in furnace (causes high stack temperatures and poor efficiency). 2. Soot and smoke discharge from home chimney.	**Caused by:** 1. If CO_2 is high (10 to 12%): a. Overfiring of unit (oil rate too high). b. Not enough excess air. c. Dirty fan or air-handling parts. 2. If CO_2 is low (less than 8%): a. Faulty nozzle operation. b. Combustion chamber trouble (too large, poorly installed, broken, etc.).
Condition 2: Smoke too low (less than No. 1 spot). **Result:** 1. Without oil on smoke disk: a. Low CO_2 (wasted heat). b. Excessive odors. 2. With oil on smoke disk: a. Lacquer and oil on furnace surfaces and controls. b. Strong odors in basement and outside home.	**Caused by:** 1. Without oil on smoke disk: a. Air leaks into furnace. b. Air shutter open too much. c. Excessive draft. 2. With oil on smoke disk: a. Excess air set too high. b. Poor nozzle operation.

CO_2 in flue gas	
Condition 1: CO_2 is too low (less than 8%). **Result:** 1. Heat loss up chimney (poor efficiency).	**Caused by:** 1. With low smoke: a. Underfiring combustion chamber. b. Nozzle is too small. c. Air leaks into furnace. d. Air gate open too wide. 2. With high smoke: a. Faulty nozzle operation. b. Poor combustion chamber.
Condition 2: CO_2 is too high. **Result:** 1. Smoke may be too high (greater than No. 2 spot). 2. Pulsations and other noises may occur, particularly on cold starts.	**Caused by:** 1. Not enough air (air gate closed too far). 2. Dirty fan or air-handling parts.. 3. Not enough draft. 4. Burner being overfired.

Flue gas temperature	
Condition 1: Stack temperature too high (greater than 630°F net). **Result:** 1. High heat loss up chimney (excessive oil consumption).	**Caused by:** 1. Dirty heat exchanger (possibly high smoke and high draft loss). 2. Overfiring furnace (accompanied by high CO_2). 3. Poor furnace design (baffles needed). 4. Poor combustion chamber. 5. Excessive draft.
Condition 2: Stack temperature too low (less than 380°F net). **Result:** 1. Moisture condensation (rusting and deterioration of smoke pipe and chimney). 2. Poor draft.	**Caused by:** 1. Underfiring furnace.

CHECKING CAD CELL PERFORMANCE

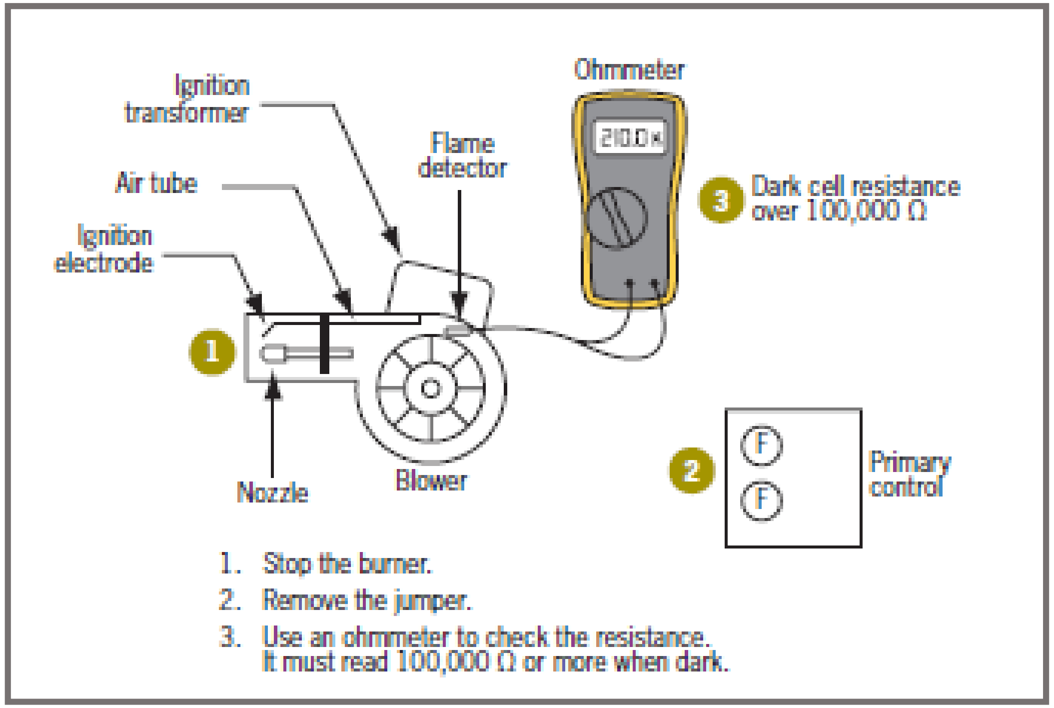
- A bad cad cell may prevent burner from lighting or may shut off due to incorrect resistance .
- Cad cells change resistance as light varies.
- An ohmmeter is necessary for testing cad cell operation.



Checking Cad Cell (Light Cell)

CHECKING CAD CELL PERFORMANCE

- After checking the light cell,
- Check the dark cell resistance.
- This is to insure no flame exist and the cell is not being affected by external light.
- Stop the burner and remove the F-F Jumper.
- Resistance of the Dark Cell Should be Greater than 100,000 Ω.



Checking Cad Cell (Dark Cell)

CHECKING CAD CELL (DARK CELL)

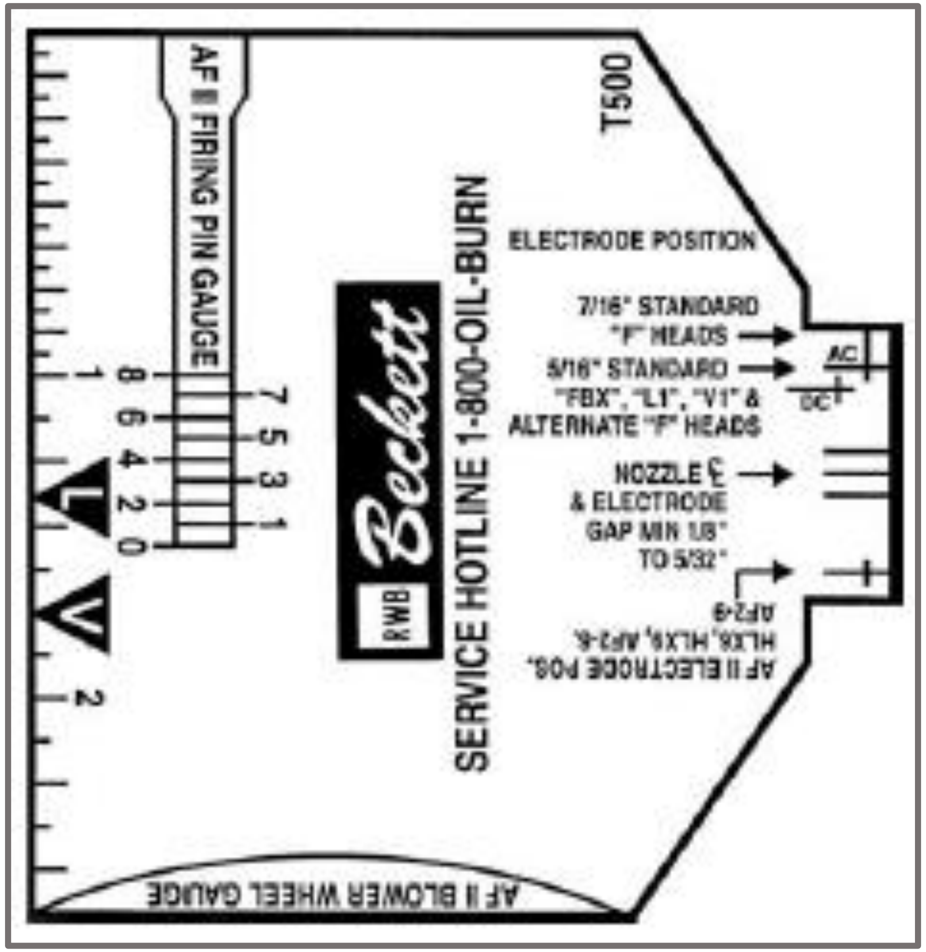
- This check is to make sure that when no flame exists, the cell is not being affected by external light.
- The resistance of the dark cell should be over 100,000 Ω.

NOZZLE CLEANING

- A quality nozzle should last a normal heating season, provided the fuel is reasonably clean.
- For best results, replace the nozzle annually.
- Cleaning the nozzle is a time-consuming job.
- At lower flow rates, it is practically impossible to determine if the distributor slots are thoroughly clean without a microscope.

ELECTRODE TESTING AND SETTING

- Consult the mfg. for the electrode gap settings
- Some burners come supplied with a gauge like the one shown
- These electrodes are located in front of the nozzle
- They should never touch the oil spray



SETTING ELECTRODE GAPS

- **If the burner is older and there is not information available from the manufacturer, the electrodes may be set according to data shown on this chart.**

Nozzle	gal/hr	A, in.	B, in.	C, in.
45°	(0.75 to 4.0)	1/8 to 3/16	1/2 to 9/16	1/4
60°	(0.75 to 4.0)	1/8 to 3/16	9/16 to 5/8	1/4
70°	(0.75 to 4.0)	1/8 to 3/16	9/16 to 5/8	1/8
80°	(0.75 to 4.0)	1/8 to 3/16	9/16 to 5/8	1/8
90°	(0.75 to 4.0)	1/8 to 3/16	9/16 to 5/8	0

Note: Above 4.0 gal/hr, it may be advisable to increase dimension "C" by 1/8 in. to ensure smooth starting.

When using double adapters:

1. Twin ignition is safest and is recommended. Settings same as above.
2. With single ignition, use the same "A" and "B" dimensions as above. Add 1/4 in. to dimension "C." Locate the electrode gap on a line midway between the two nozzles.