NORA Technician Certification

Review

Bob O’Brien, NORA Director of Education

Chapter 1

Liquid Fuel & its Properties

At the end of this lesson, you will be able to:

- Describe fuel oil and its properties
- Explain what viscosity is and how to improve fuel flow
- Explain what causes problems with fuel oil and how to solve them
- Explain why Bioheat® fuel is a good choice for customers

ASTM D396 defines one gallon of #2 oil as containing about 139,000 BTUs.

The American Society for Testing & Materials (ASTM) publishes specifications for many materials, including fuel oil.

Flash Point

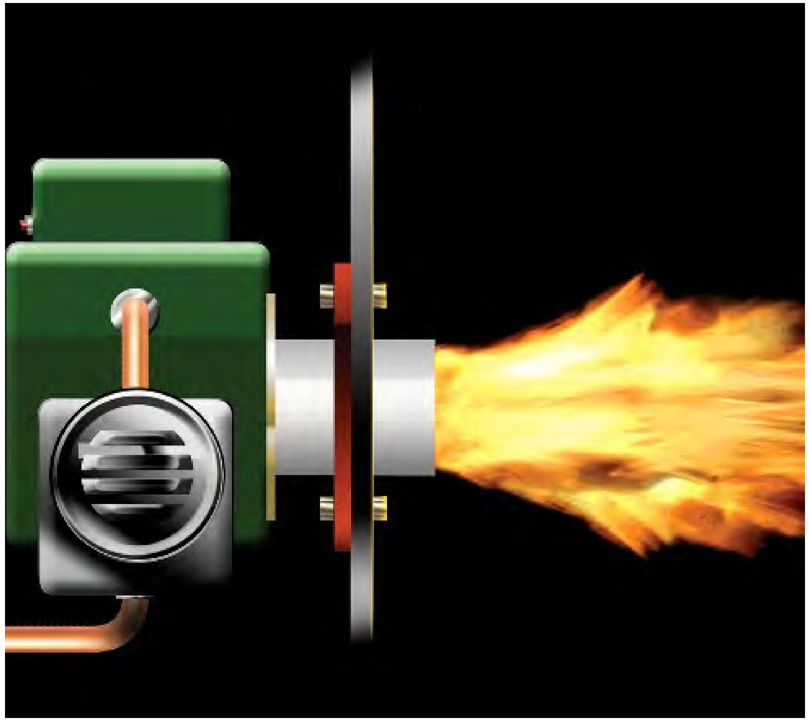
Flash point is the maximum temp a fuel can be safely stored & handled without serious fire hazard.

The **flash point** for **No.1** and **No.2** oil is **100°F minimum**.

When oil is heated to its flash point, some of the hydrogen flashes off but the fuel will ***not*** continue to burn.

Ignition Point

FIRE POINT (aka IGNITION POINT) is the lowest temperature at which fuel vapor will initiate and sustain combustion. (approx. 500^{o}F)



Pour Point

Pour point is the lowest temperature at which fuel will flow. Below this, it turns to waxy gel.

The **ASTM standard** for untreated **No. 2 oil is 21°F**.

Additives or kerosene are added to heating oil during the winter to ensure that it flows.

Cloud Point

Cloud point is the temperature at which wax crystals begin to form.

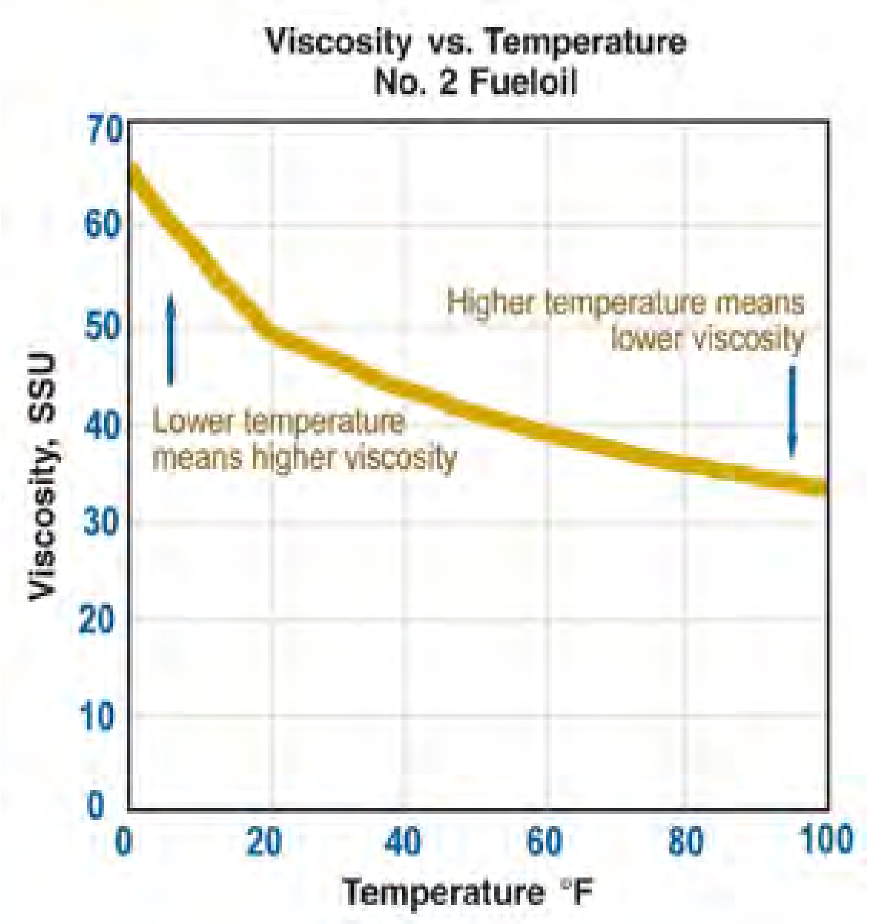
Crystals can restrict fuel flow by restricting fuel lines, filters and other components.

No standard exists, usually **10 to 20^{o}F** above pour point.

Viscosity

Viscosity is the "thickness" of a fuel and its resistance to flow.

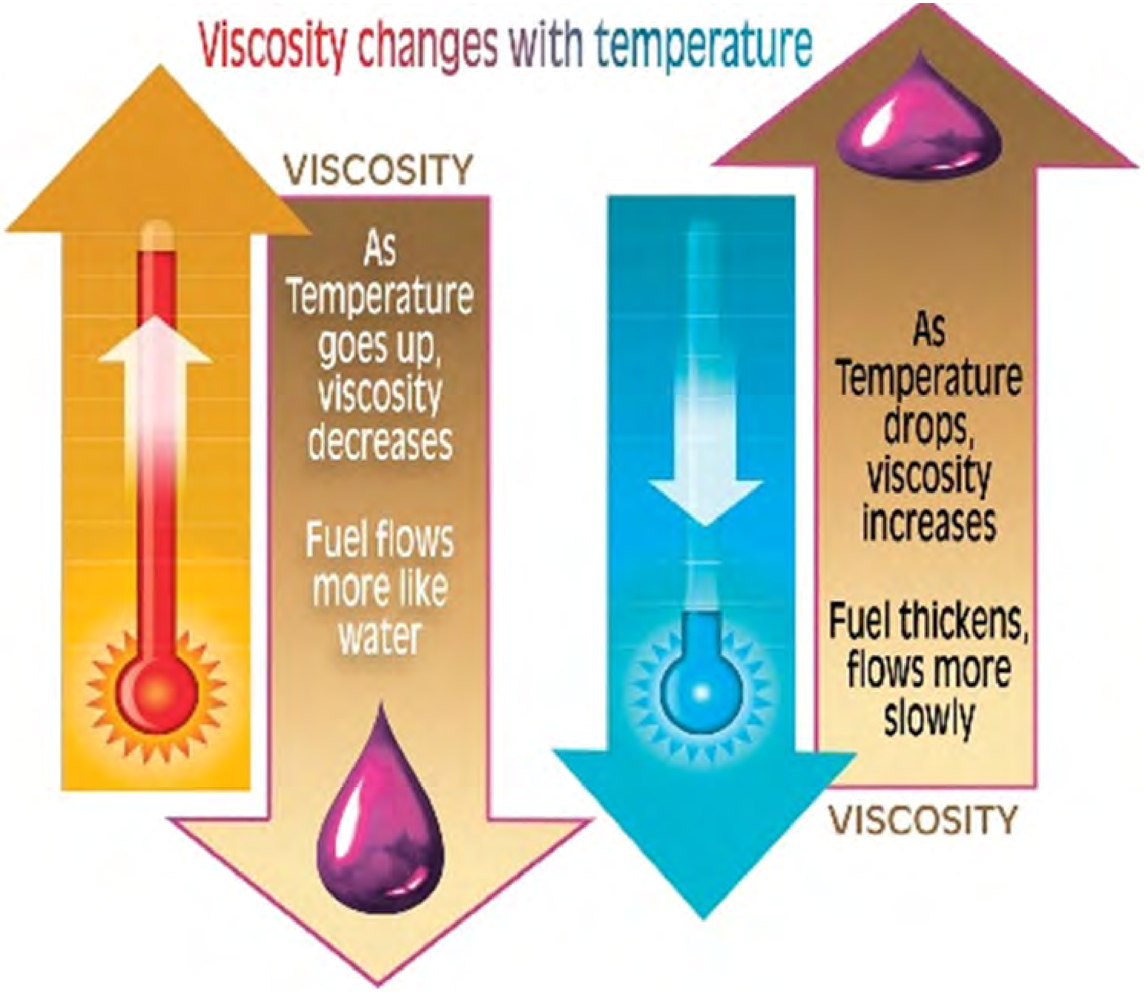
Heating fuel's viscosity changes dramatically with temperature.



Colder Oil = Higher Viscosity

When the viscosity of fuel entering the nozzle increases, the flow rate also increases.

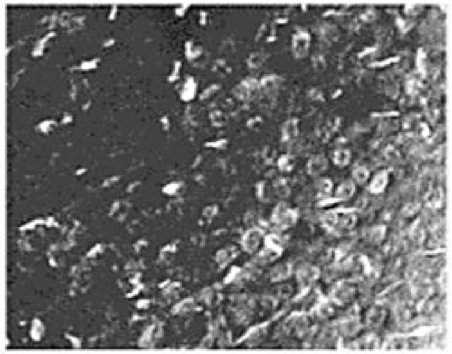
Cold fuel causes poor atomization, delayed ignition, noisy flames, pulsation and possible sooting.



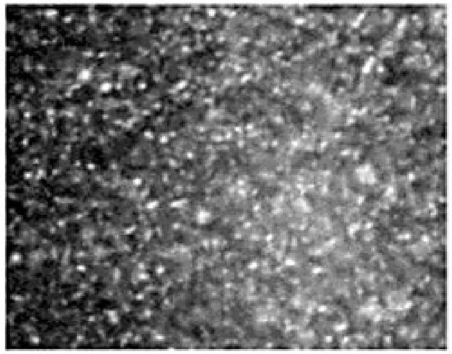
Diesel Fuel Under a Microscope

Diesel fuel 1°C above cloud point
No crystals

Diesel fuel at cloud point
A few wax crystals appear instantaneously



Diesel fuel at cloud point
one hour later
More crystals formed



Diesel fuel at 3°C below cloud point
Immediate and extensive crystal formation

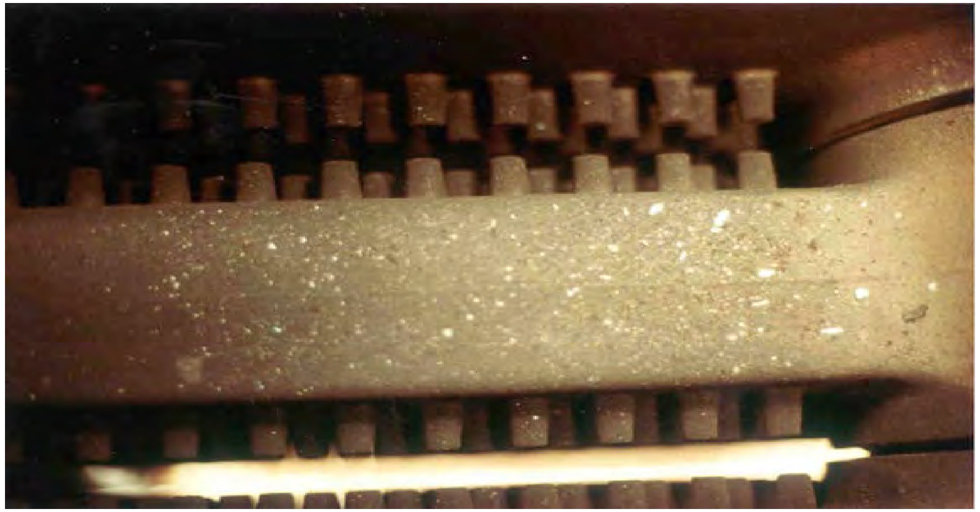
Cold Flow Solutions

Blending 25% kerosene, or using an additive, can lower pour and cloud points.

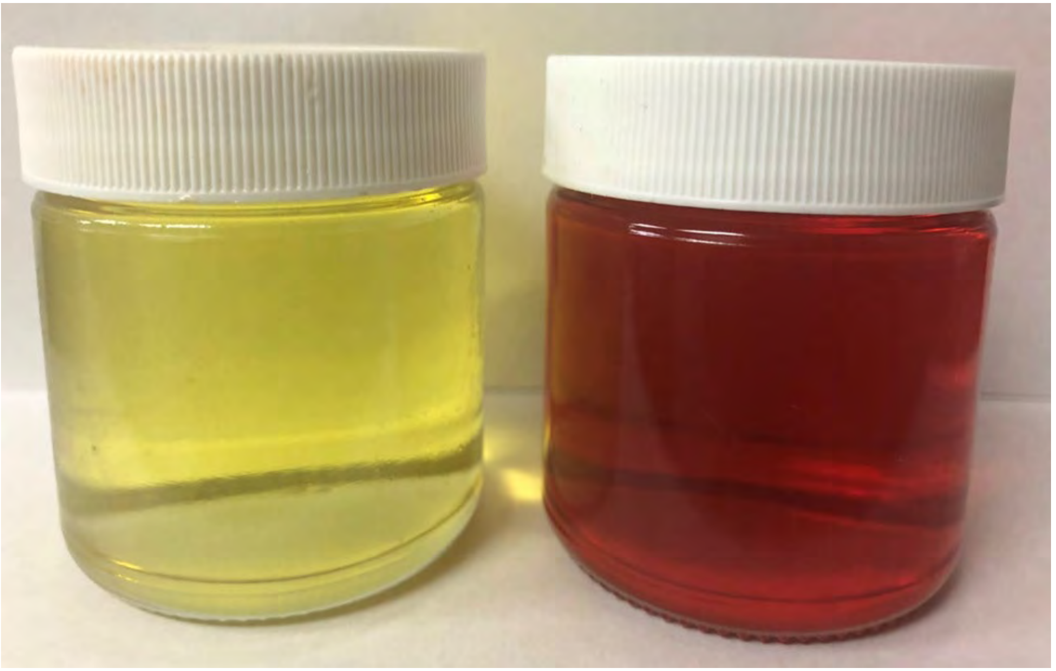
Sulfur

Sulfur exists in varying degrees in all fossil fuels. ASTM limits its content to 500 to 5,000 ppm.

Using ULSD (max. 15 ppm) all but eliminates scale and soot formation, it also leads to energy savings and reduced appliance service.



Color



#2 fuel used for heating purposes is dyed red to differentiate it from on-road diesel fuel for tax compliance reasons.

Problems with the fuel are not indicated by the darkness of the color.

Fuel Related Service Calls

The industry's top 2 service priorities:

- Improved reliability
- Reduced service costs

A significant number of "no-heat" calls are caused by fuel degradation and contamination.

Good housekeeping can dramatically reduce fuel related service calls.

Potential Problems “In-Tank”

1. Aging tanks – leads to rust & sediment build-up.

2. Fuel has a shelf life & breaks down over time.

3. Size & speed of delivery – during delivery sediment & rust that are stirred up can lead to burner shut-down.

Fuel Stability

- All fuels will eventually degrade in the presence of oxygen. If the fuel is contaminated, it will degrade even more quickly.

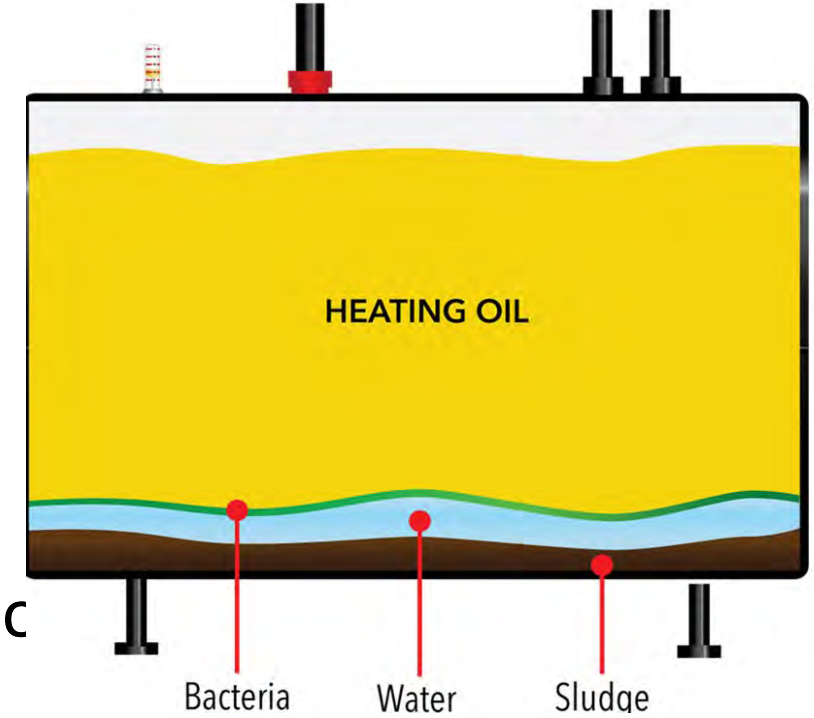
The stability of fuel depends a great deal on storage conditions. If it's stored for a long time and subjected to extreme temperatures it can form substances that plug filters, strainers and nozzles.

Water Problems

Lead to service problems tank failure.

Water enters tanks due to:

- Condensation
- Loose/missing fittings and caps or broken gauges (outside tanks)
- Leaking fill/vent piping or UG tank
- Pumping fuel from a tank being replaced intc



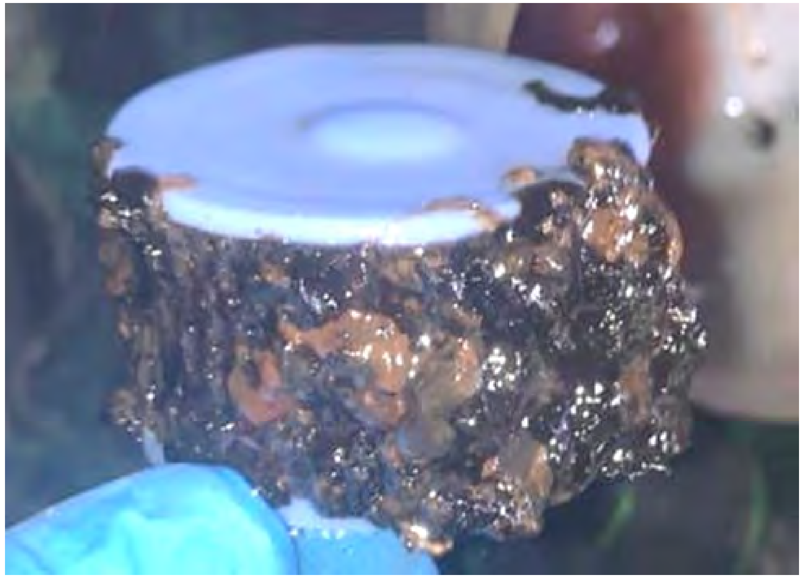
Sludge

To reduce sludge formation:

- **Do NOT** pump fuel from a tank being replaced into the new tank
- Routinely check the tank for water and remove it when found
- Whenever possible, draw fuel from the tank bottom, not the top

Sludge

A combination of water, bacteria, degraded fuel and other contaminants.

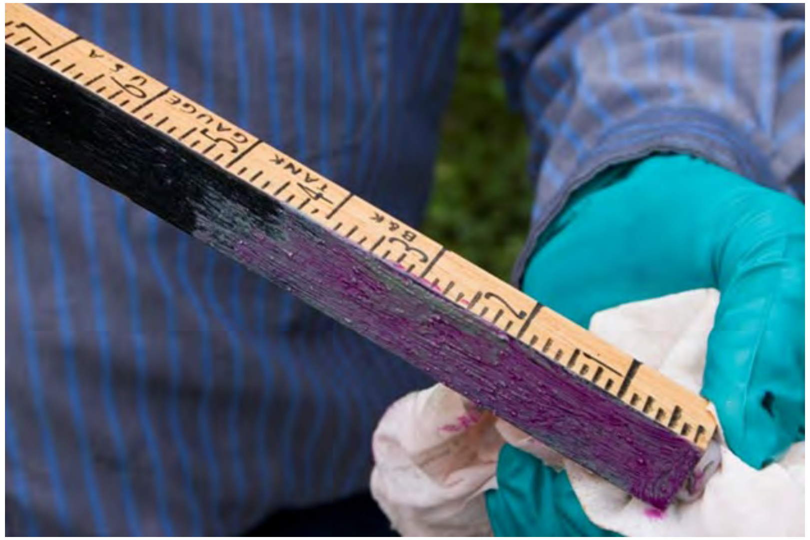


Deterioration of fuel is a natural occurrence, it can be slowed if proper maintenance, including the removal of water, is performed.

Sludge is acidic and may eventually destroy the tank from the inside.

Water Detection Paste

- Indicates the water level at the tank bottom
- Does NOT detect fuel-water emulsion
- Tanks should be checked annually & water removed ASAP
- Determine source of water



How much water is in this tank?

Fuel Additive Treatment

There are numerous additives available that are designed to treat or prevent fuel related problems.

A successful additive program for individual tank problems requires knowledge of the quality of the fuel in the tank and the specific service issues being encountered.

Selection of Additives

The multi-functional additives that are available for heating fuel that offer a range of properties.

They can be beneficial if these guidelines are followed:

1. Define the problem and determine the additive needed to resolve it.

2. Make sure the fuel sample being tested represents the fuel to be treated.

Selection of Additives

3. Determine if the additive is to be used once, or if continuous treatment is needed.

4. Determine if the additive performs more than one function.

5. Determine if the additive supplier can provide technical support and a way to measure the effectiveness in specific cases. For example, a reduction in the number of service calls that include fuel unit, nozzle, filter and/or strainer replacement.

Selection of Additives

6. Follow all safety and handling instructions.

7. Follow the recommended treatment rates. Adding more than recommended can make things worse.

8. Properly dispose of additive containers. Know and follow regulations concerning disposal of sludge and water bottoms.

Types of Additives

Pour Point Depressants

These are designed to lower the pour point of the fuel and avoid wax plugging the filter.

They must be added before the temperature reaches the fuel's pour point and will not perform as designed once wax has formed.

Types of Additives

Dispersants

These separate the particulates that form in the fuel, preventing them from clustering into large masses that plug filters, strainers and nozzles.

Types of Additives

Antioxidants and metal deactivators

Antioxidant additives slow the fuel degradation, caused by aging, that leads to gum deposits.

Dissolved metals (such as copper) speed aging and degradation and produce harmful gels. Metal deactivators combine with the metals and render them inactive.

Types of Additives

Biocides

These kill or prevent the growth of bacteria and other microorganisms that lead to sludge, acid (tank failure) and operational problems.

Since biocides are poisons, care must be taken when handling them.

Preventative Maintenance

Good housekeeping means doing everything possible to prevent dirt and water from entering tanks.

Water promotes the growth of microbes (which use the fuel as a food source) and accelerates the growth of sludge and internal corrosion of the tank.

Avoid using rags contaminated with sludge or microbes which can introduce these contaminants to a clean system.

Tank Cleaning

With large accumulations of sludge on the bottom and sides of a tank, mechanical cleaning, fuel filtration, additives and a preventative maintenance program are the only ways to remove the sludge.

Cleaning a residential tanks is expensive, and a replacement may be a more effective & economical option.

Tank Replacement

When contamination has gone too far, it's best to install a new tank.

Never pump fuel from the old tank into the new one. The contaminants that caused the failure will be transferred to the new tank along with the fuel & the new tank will quickly become as dirty as the old one.

Keep the Tank Full

Topping off tanks, especially outdoor above ground tanks in the spring helps prevent condensation and water build up.

The less air in the tank, the less condensation.

Biodiesel

Biodiesel is made from a mix of resources including recycled cooking oil, soybean oil and animal fats.

BIODIESEL®

Better. Cleaner. Now!

It is a renewable clean burning diesel and heating fuel replacement that is the nations first domestically produced, commercially available advanced biofuel.

Bioheat® fuel

Bioheat is a blend of biodiesel and ultra low heating fuel.

Various blends are available

B5 = 95% #2 fuel & 5% biodiesel

B20 = 80% #2 fuel & 20% biodiesel

Biodiesel

Bioheat has significant environmental benefits.

First, it lowers the carbon footprint of heating fuel at all blend levels, with higher blends providing greater carbon reductions.

Second, it's made from renewable, organic sources such as used cooking oil, inedible corn oil, rendered animal tallow, and the surplus byproduct oil from the processing of soybeans and canola.

Biodiesel

The US EPA and Dept. of Agriculture indicate that biodiesel reduces Greenhouse Gas emissions by up to 69 to 88% compared to traditional heating oil.

NORA research indicates that ultra-low sulfur heating oil blended with B20 significantly reduces Greenhouse Gas emissions.

Biodiesel

Bioheat® fuel has strong public appeal as a renewable low-carbon fuel.

It increases the USA's fuel source diversity, reducing dependence on foreign crude and is a potentially huge market for American agriculture.

With the implementation of carbon reduction standards, Bioheat ® fuel is being adopted to prevent the reduction and potential elimination of the residential heating liquid fuel market.

Review Questions:

- What are the properties of fuel oil?
- How can you improve fuel flow?
- Why is Bioheat® fuel a good choice for customers?

End Chapter 1

NORA Technician Certification

Review

Chapter 2

Introduction to Burners

Turning liquid fuels into heat

At the end of this lesson, you will be able to:

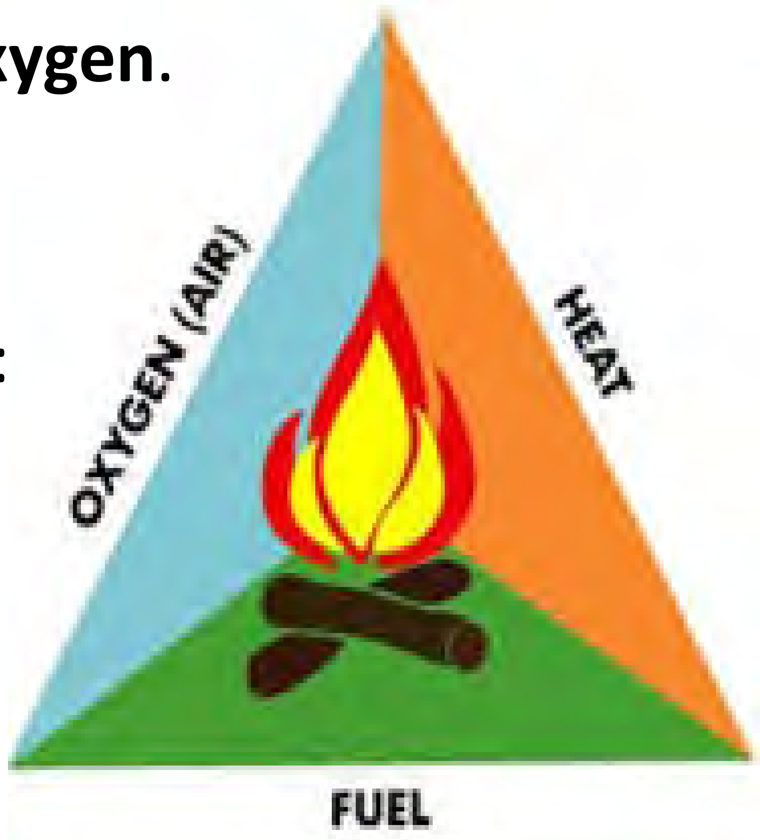
- Explain how combustion happens
- Label the components of an assembled burner chassis on a diagram

Combustion

Combustion is the rapid chemical combination of a fuel with oxygen.

For something to burn, three things are needed:

1. Oxygen.
2. Fuel.
3. Heat.



Combustion

Home heating fuel will NOT burn as a liquid,
it must first be converted to a vapor.

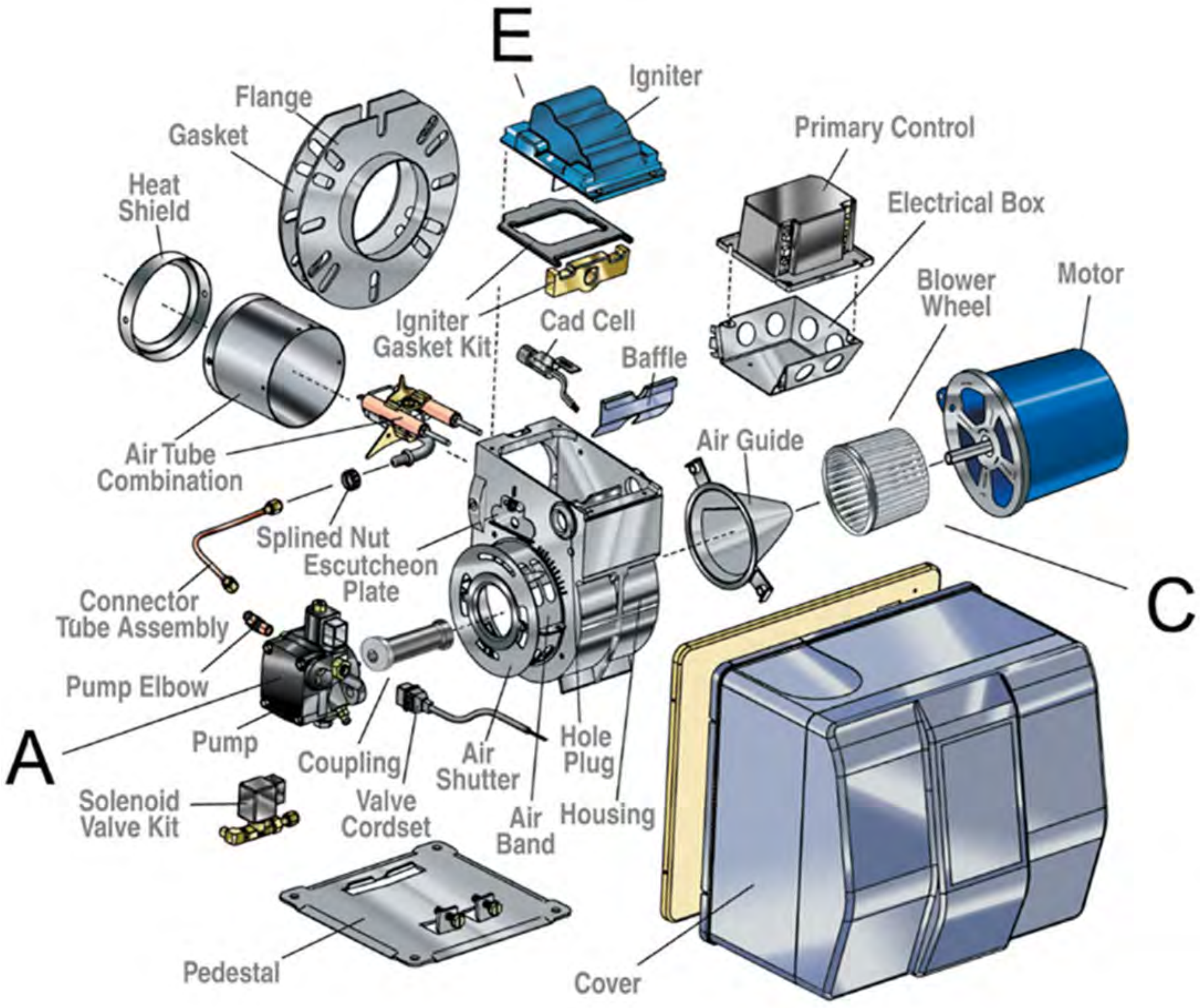
The burner atomizes the fuel, vaporizes it, mixes it with air,
and heats the mixture above its ignition point.

The following slides demonstrate the role of the various
burner components in creating combustion.

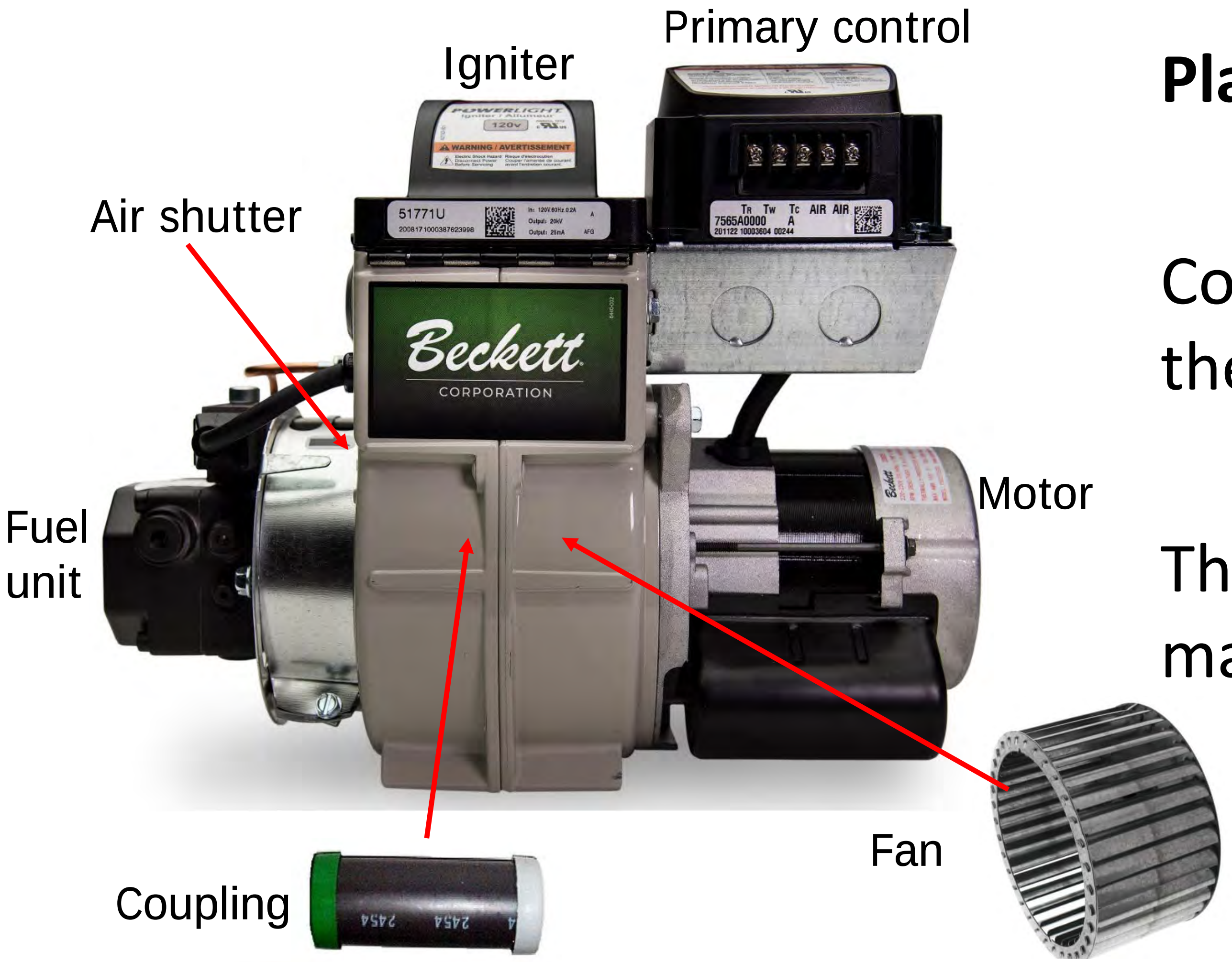
Burner Components

Oil Burners are made of many parts which work together to provide clean, controlled and safe combustion.

The following slides contain details about the major burner components.



Burner Components



Placement of major burner parts:

Coupling and fan are internal between the motor and fuel unit.

This configuration is common to most makes of modern burners.

Burner Motors

The motor drives a fan and a fuel unit.

In the event of motor failure, a new motor must be installed with the same rotation, frame size, and revolutions per minute (RPM).

Burner Motors

The motor drives a fan and a fuel unit.

In the event of motor failure, a new motor must be installed with the same rotation, frame size, and revolutions per minute (RPM

Oil burner motors turn at 3450 RPM

Some older burners in the field may still have motors which turn at 1725 RPM

Multiblade Fans & Air Shutters

A multiblade fan wheel within the burner housing is driven directly by the motor shaft and provides the necessary air to support combustion.

adjustable air shutter

An adjustable air shutter on the burner housing controls the volume of air handled by the fan.

Multiblade Fans & Air Shutters

A multiblade fan wheel within the burner housing is driven directly by the motor shaft and provides the necessary air to support combustion.

Keeping burner fans and air adjustments clean is extremely important for clean combustion

An adjustable air shutter on the burner housing controls the volume of air handled by the fan.

Fuel Units

The fuel unit (pump) moves fuel from the storage tank to the burner and pressurizes it for combustion. It has 3 main components:

- Strainer – to filter the fuel
- Gears – to lift fuel & deliver it to the regulating valve
- Regulating valve - to build up & maintain pressure

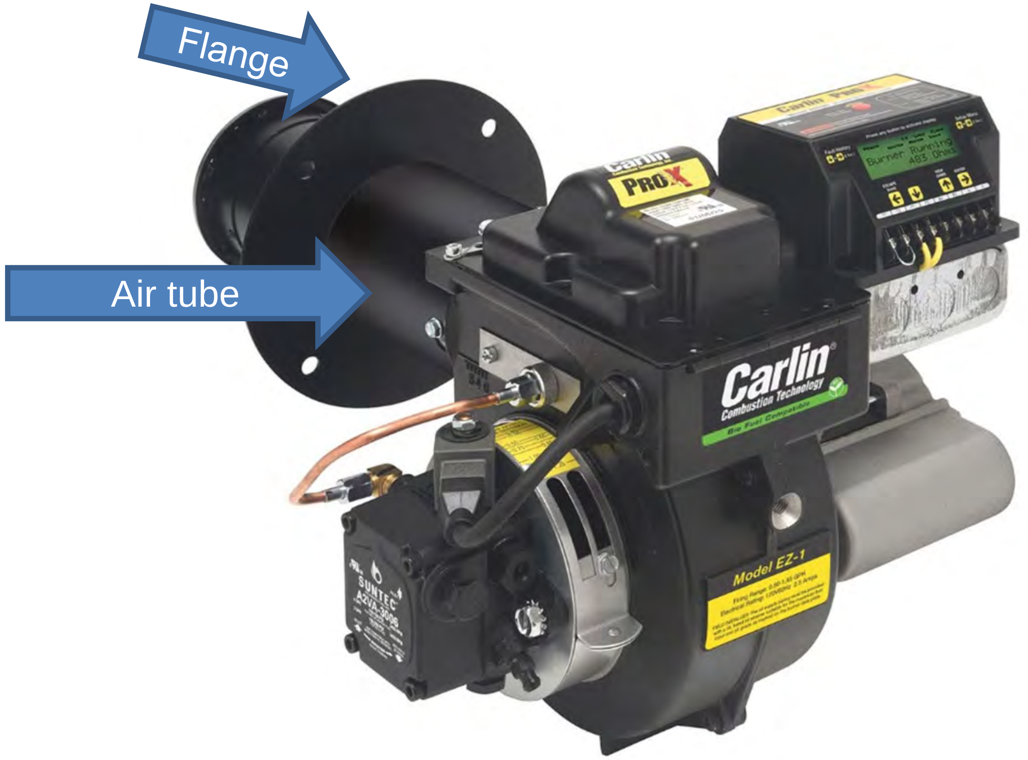
Igniters

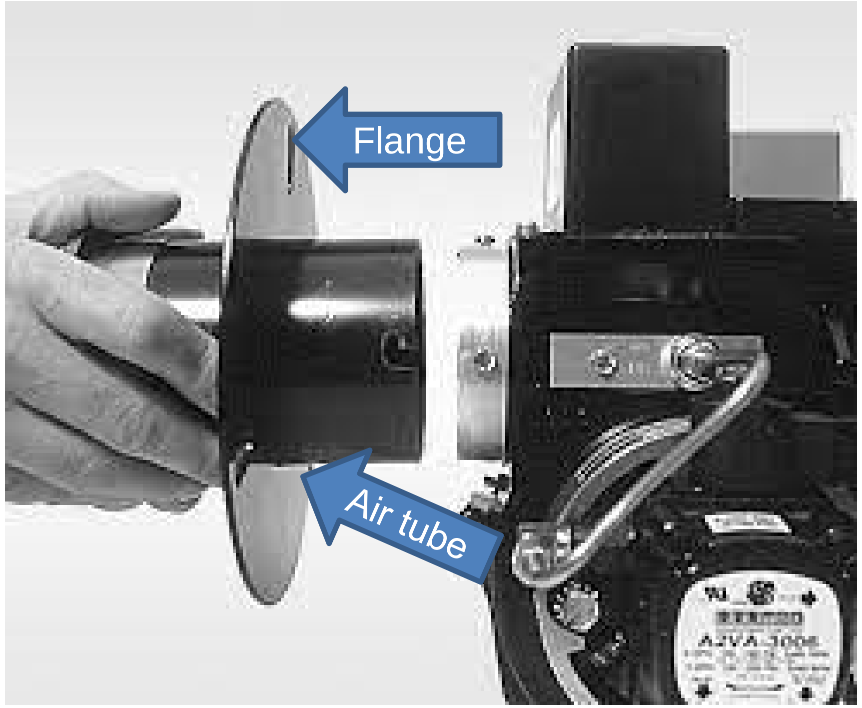
Initial heat to ignite the fuel is provided by a high voltage igniter or transformer (on older units) which creates a spark at the electrode tips until the flame is self sustaining.

Oil burner igniters and transformers provide between 10,000 and 21,000 volts to ignite the fuel.

Air Tube & Nozzle Assembly

Burners are typically attached to the appliance by a flange that is attached to an air tube.





Air Tube & Nozzle Assembly

The nozzle assembly, which includes the fuel feed pipe, nozzle, nozzle adaptor and electrodes is located inside the air tube.

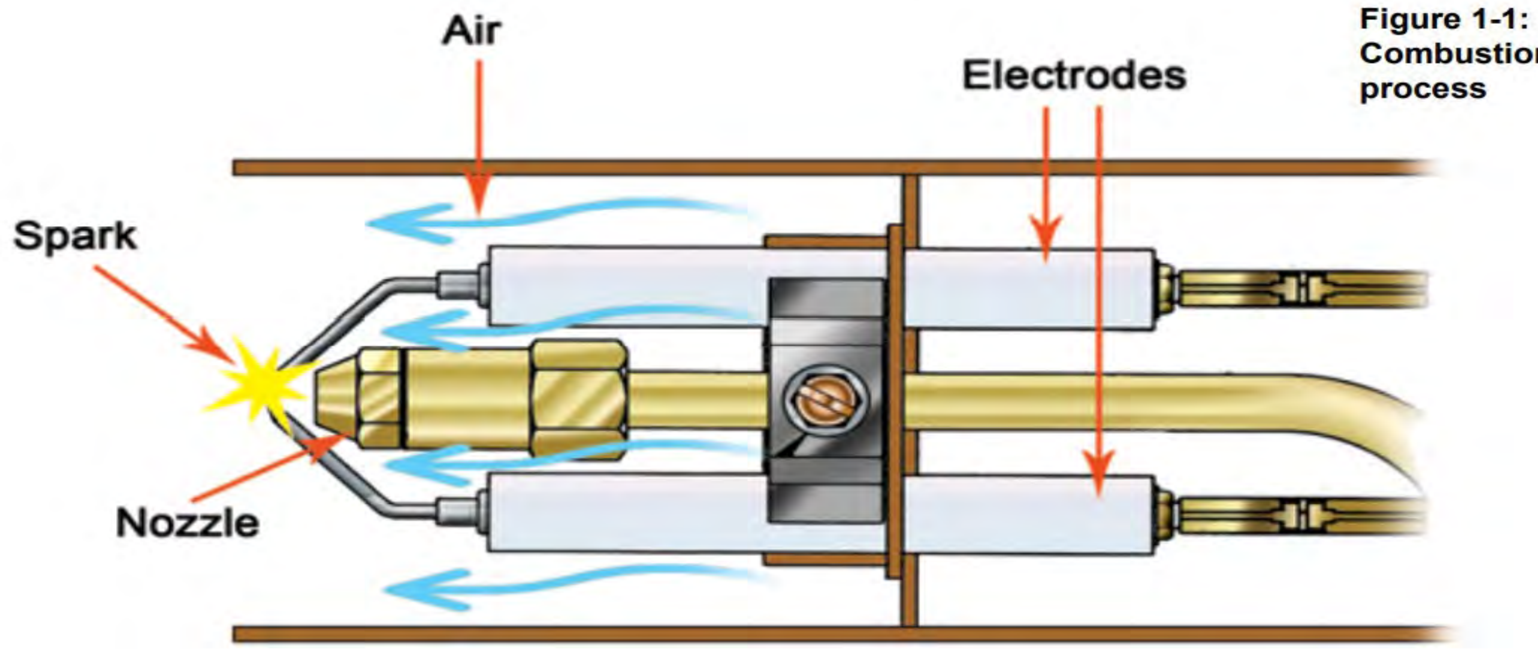
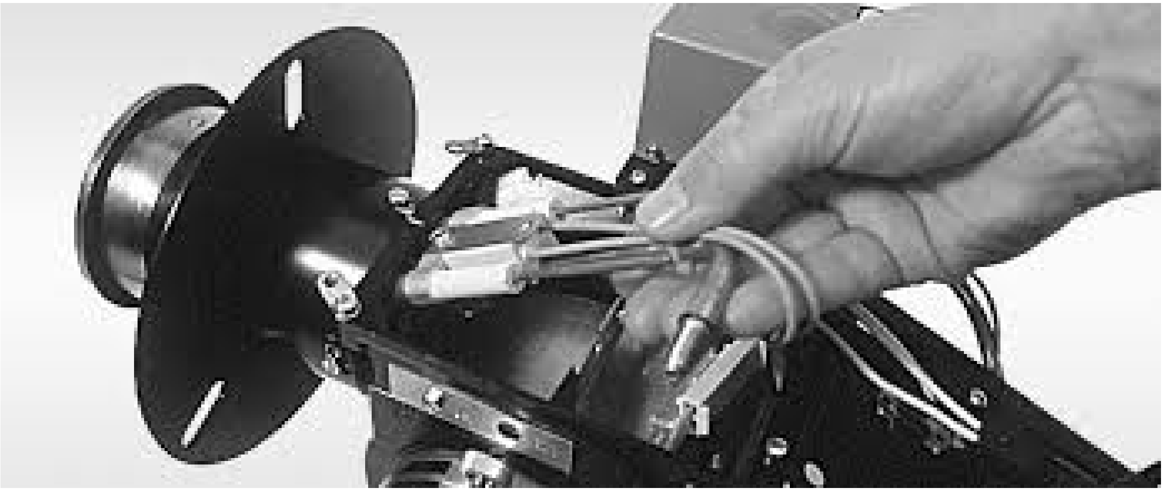


Figure 1-1: Combustion process

Air Tube & Nozzle Assembly

An opening in the burner housing, permits access to, and removal of, the nozzle assembly.



Elements needed for Combustion

Fuel, air and heat

The amount of fuel is based on the flow rate in GPH of the appliance

The size of the nozzle and the pressure setting of the fuel unit determine the flow rate

Elements needed for Combustion

Fuel, air and heat

Air is introduced into the air tube by the fan through the air intake , controlled by adjustable air bands.

Setting these bands is the key final adjustment for proper combustion.

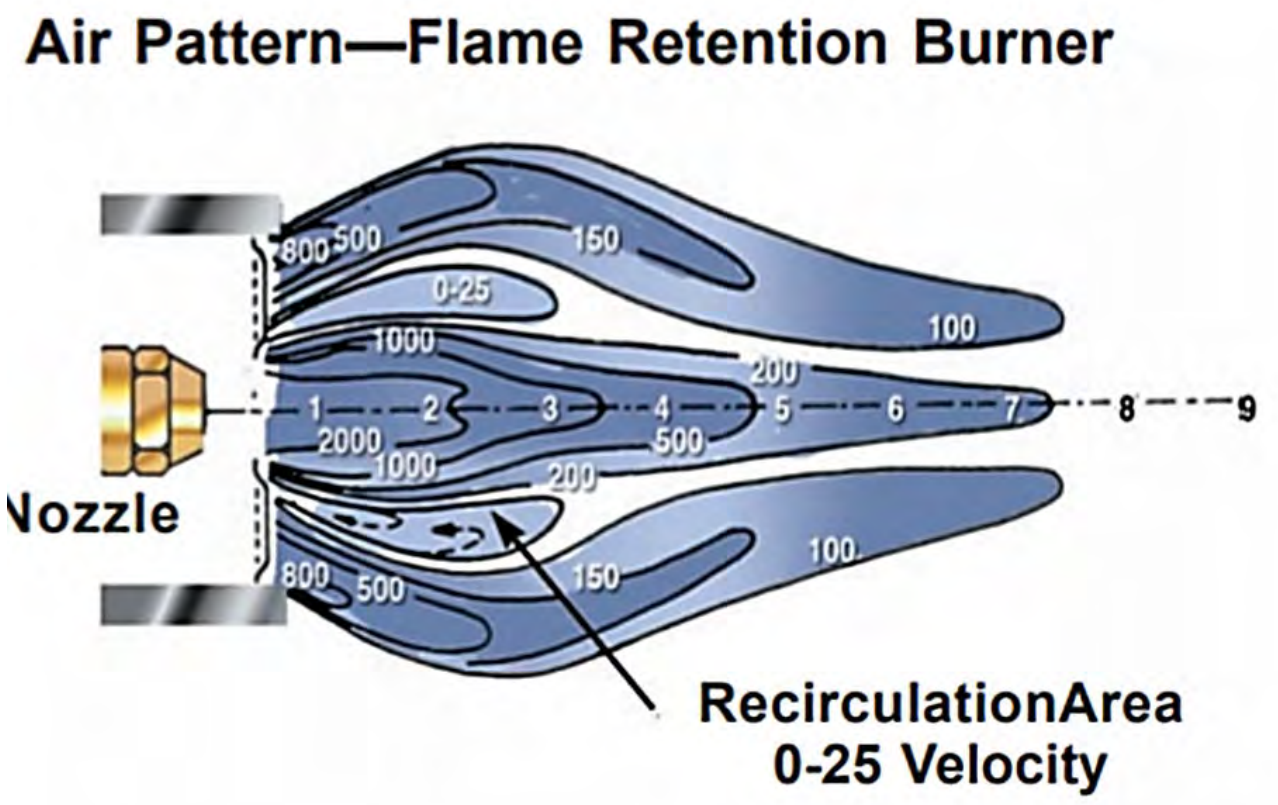
Elements needed for Combustion

Fuel, air and heat

Heat is supplied by a high voltage spark, generated by the ignitor, that "jumps" across the tips of the electrodes.

Combustion Heads

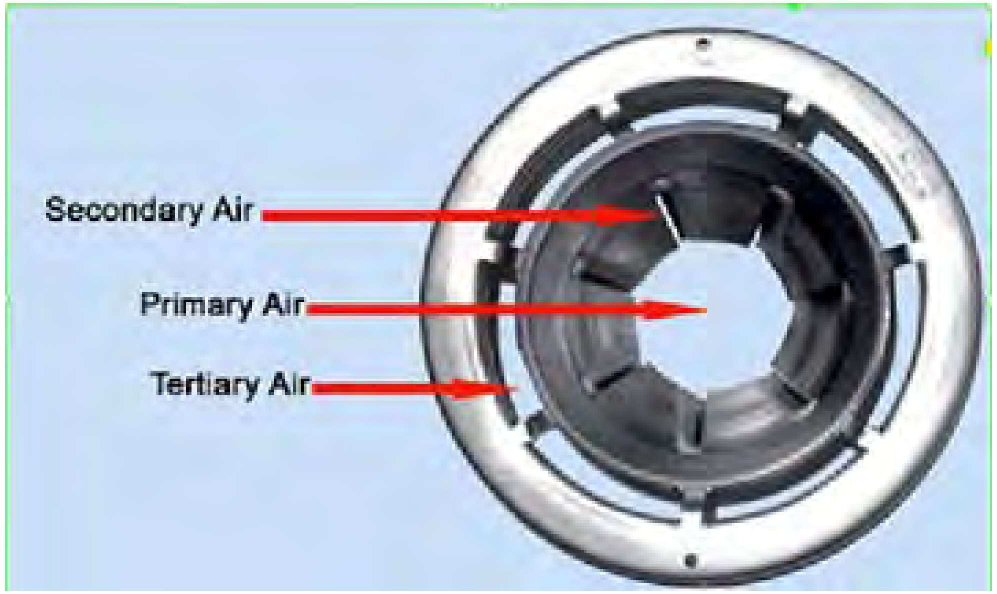
The combustion head creates a specific pattern of air at the end of the air tube. This forces air into the fuel spray providing oxygen.



Combustion Heads

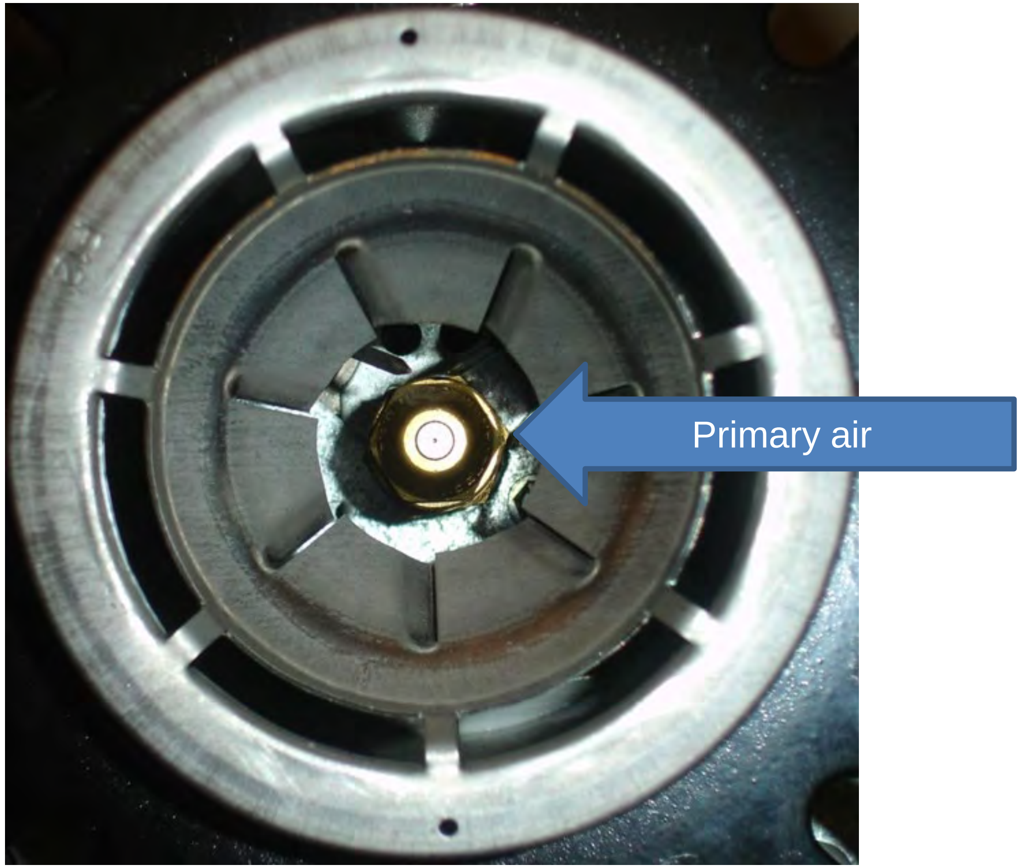
Flame retention heads incorporate three basic air directing elements:

- The primary air opening allows clearance for the fuel spray and electrode spark to pass through without interference
- The secondary slots radiate toward the outside of the head
- The tertiary openings follow the circumference of the head



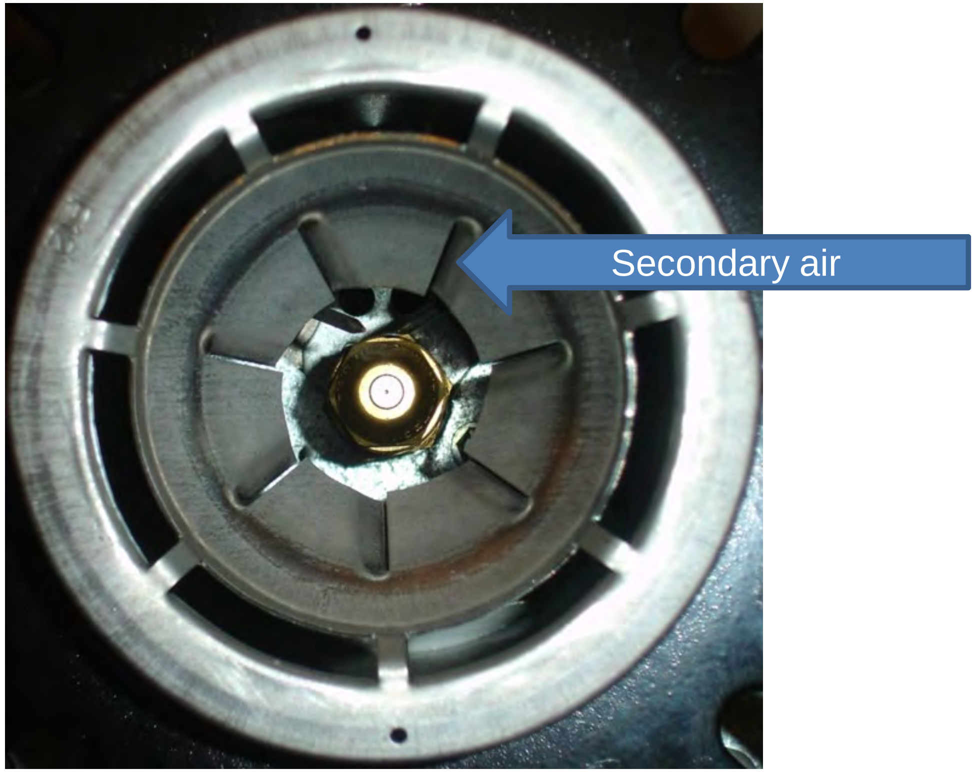
Combustion Heads – Primary Air

Primary air has the least desirable effect on combustion. Air takes the path of least resistance, the larger the opening the more air will pass through and push the flame away from the head.



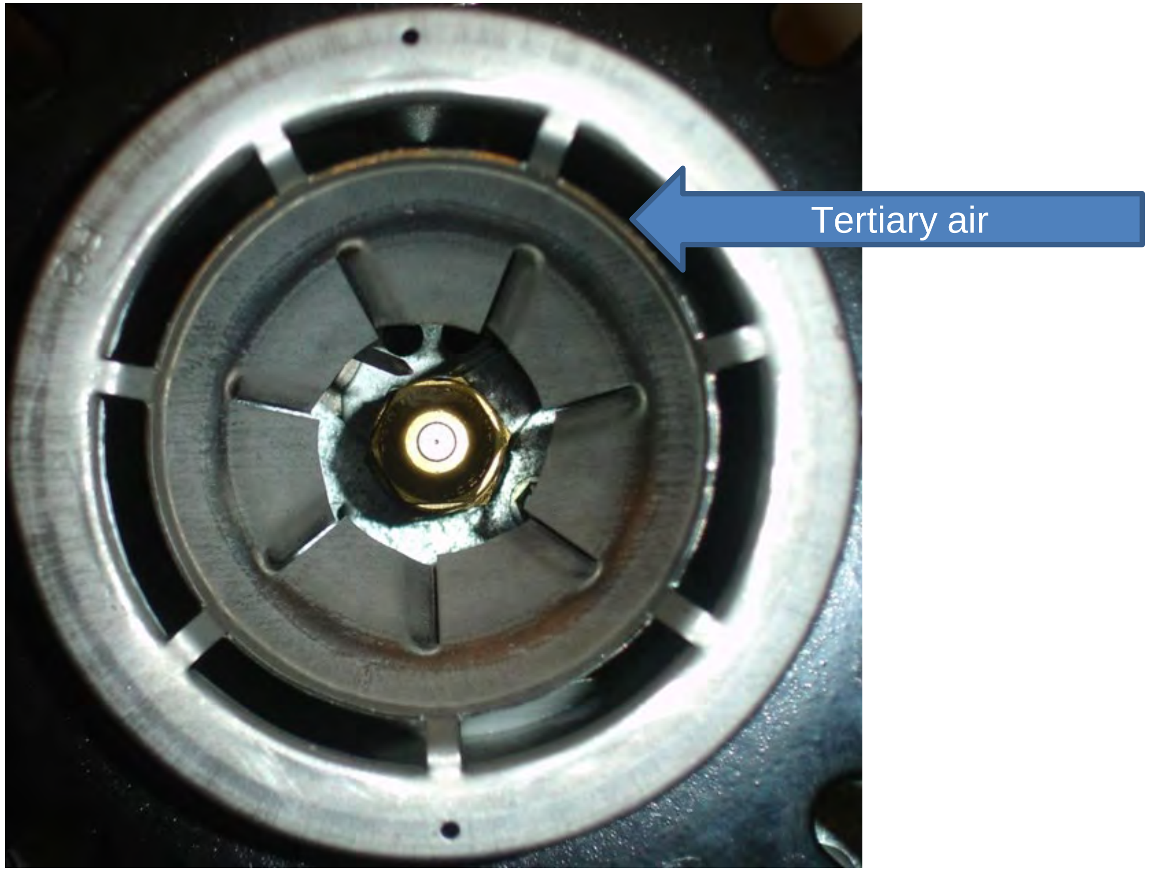
Combustion Heads – Secondary Air

Secondary air slots create a spinning action that leads to the best mixing of fuel and air to create a compact, intense and efficient flame



Combustion Heads – Tertiary Air

Tertiary air ensures that there will be an envelope of air between the flame and the walls of the combustion area so that every droplet of fuel is completely blanked with air.



Fixed and Adjustable Heads

Air Tubes

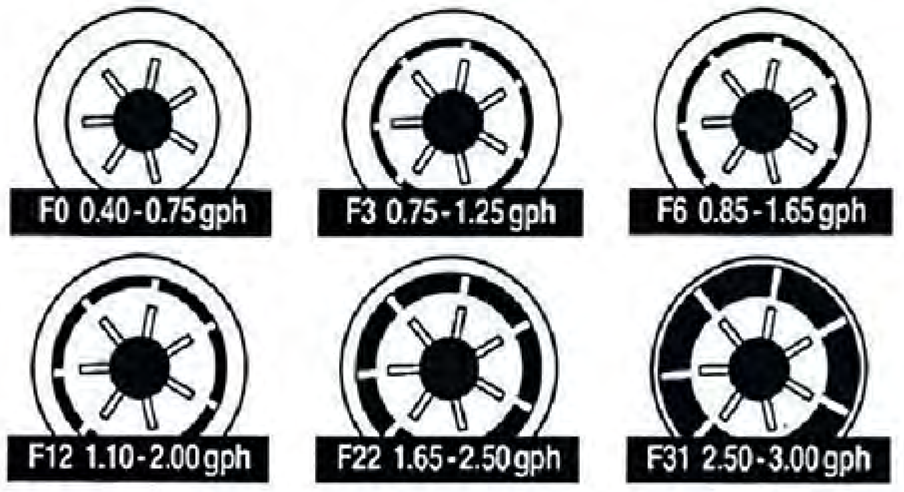
Fixed Head

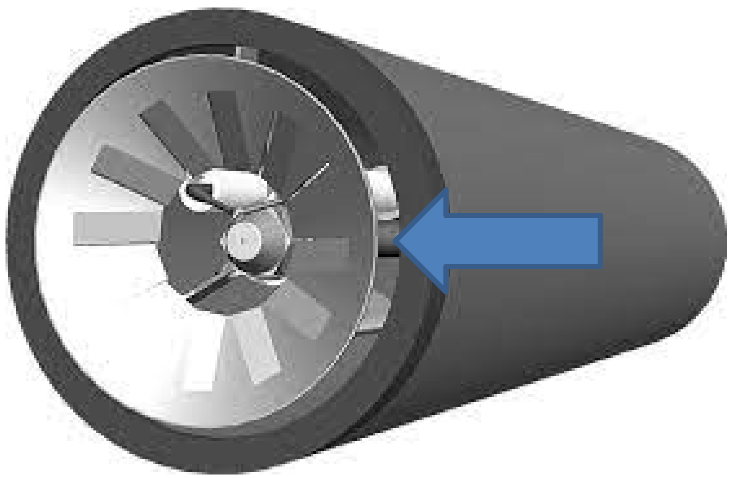
Adjustable Head

Fixed VS Adjustable Heads

The difference between fixed and adjustable heads is how they handle tertiary air.

Fixed heads tertiary openings are pre-set for a specific firing rate.

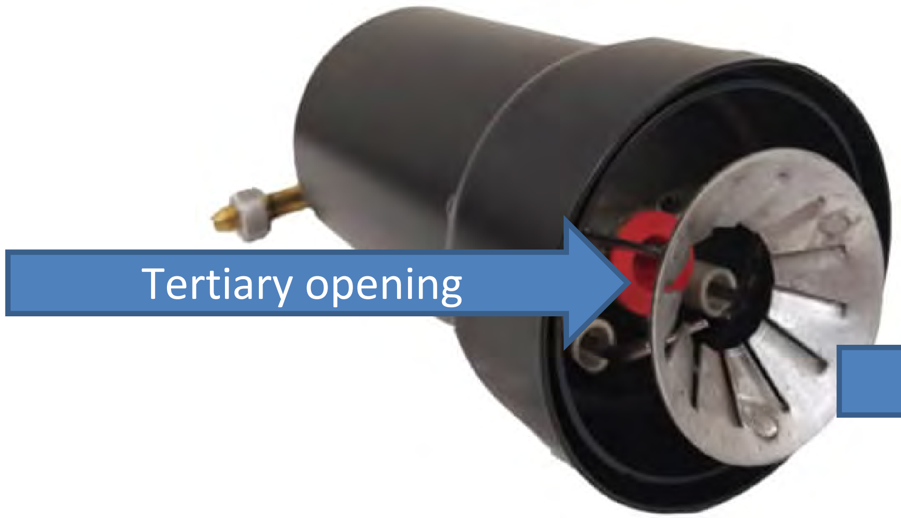


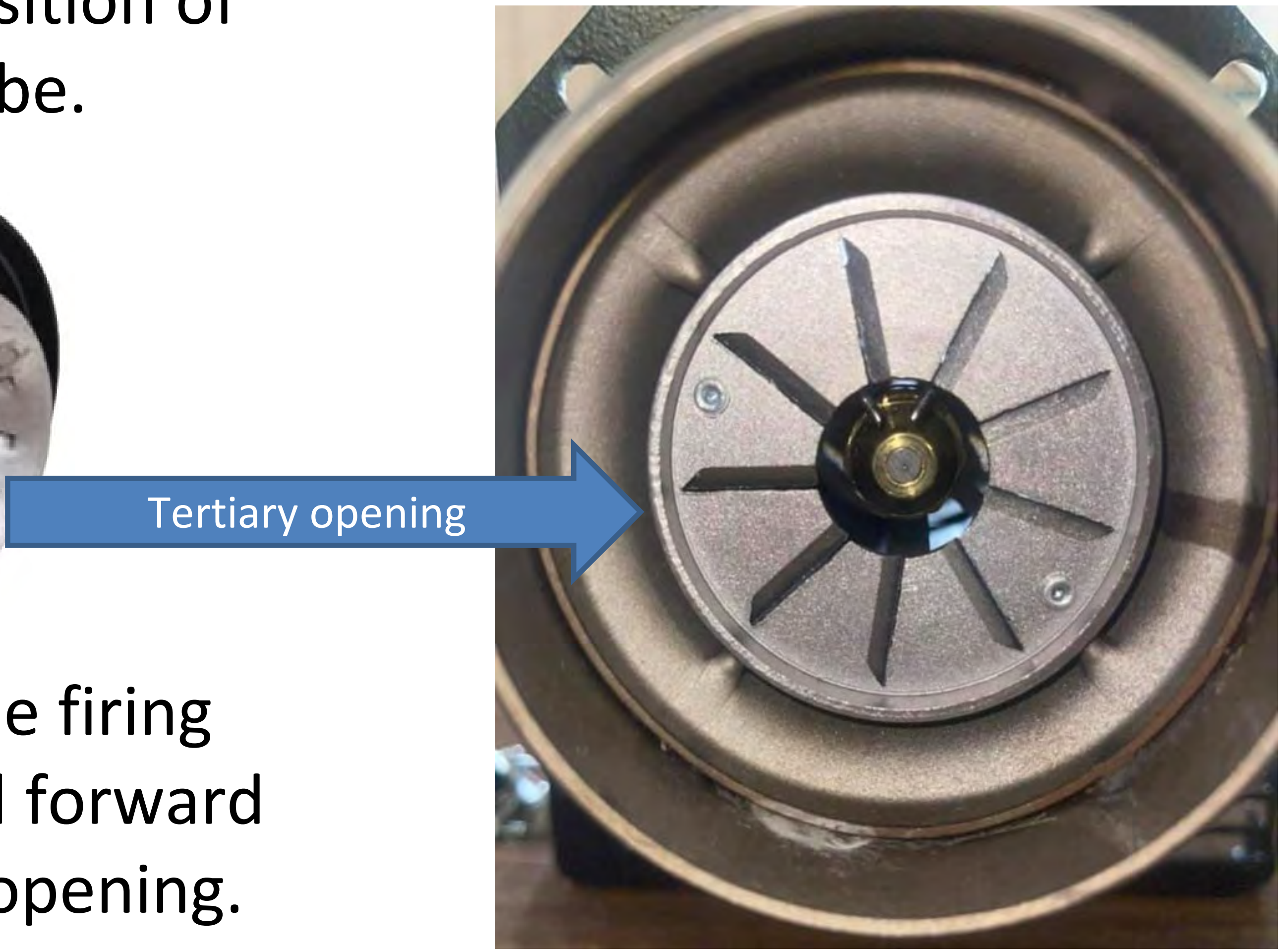


Adjustable heads tertiary opening can be adjusted by the technician.

Adjustable Heads

Tertiary air – set by position of assembly in air tube.

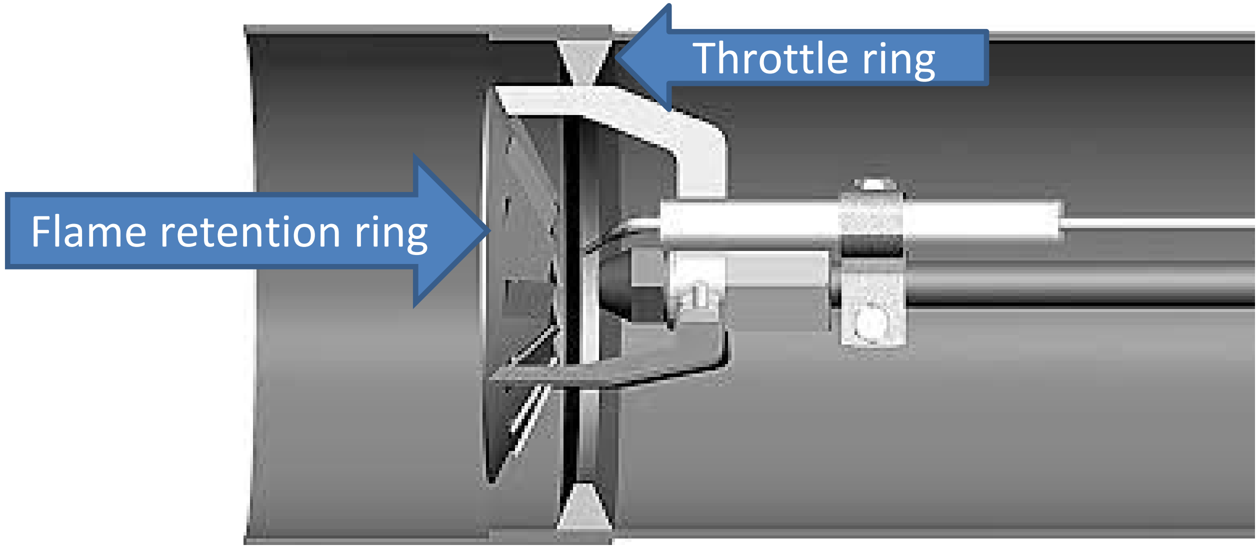


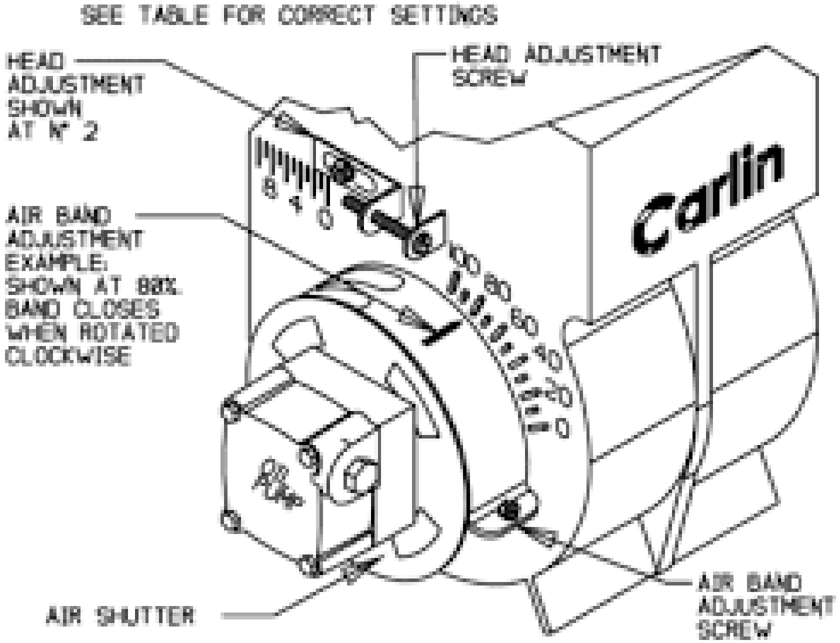


The technician moves the firing assembly backward and forward to change the tertiary opening.

Adjustable Heads

Operation is based on the relationship between the “throttle ring” and the “flame retention ring.”





Static Pressure

Static pressure is the means of producing and maintaining flow against resistance. Modern appliances have "tighter", more efficient heat exchanger passages that restrict flow and have higher draft losses, demanding a high static pressure burner.

1980s

2000s

Static Pressure

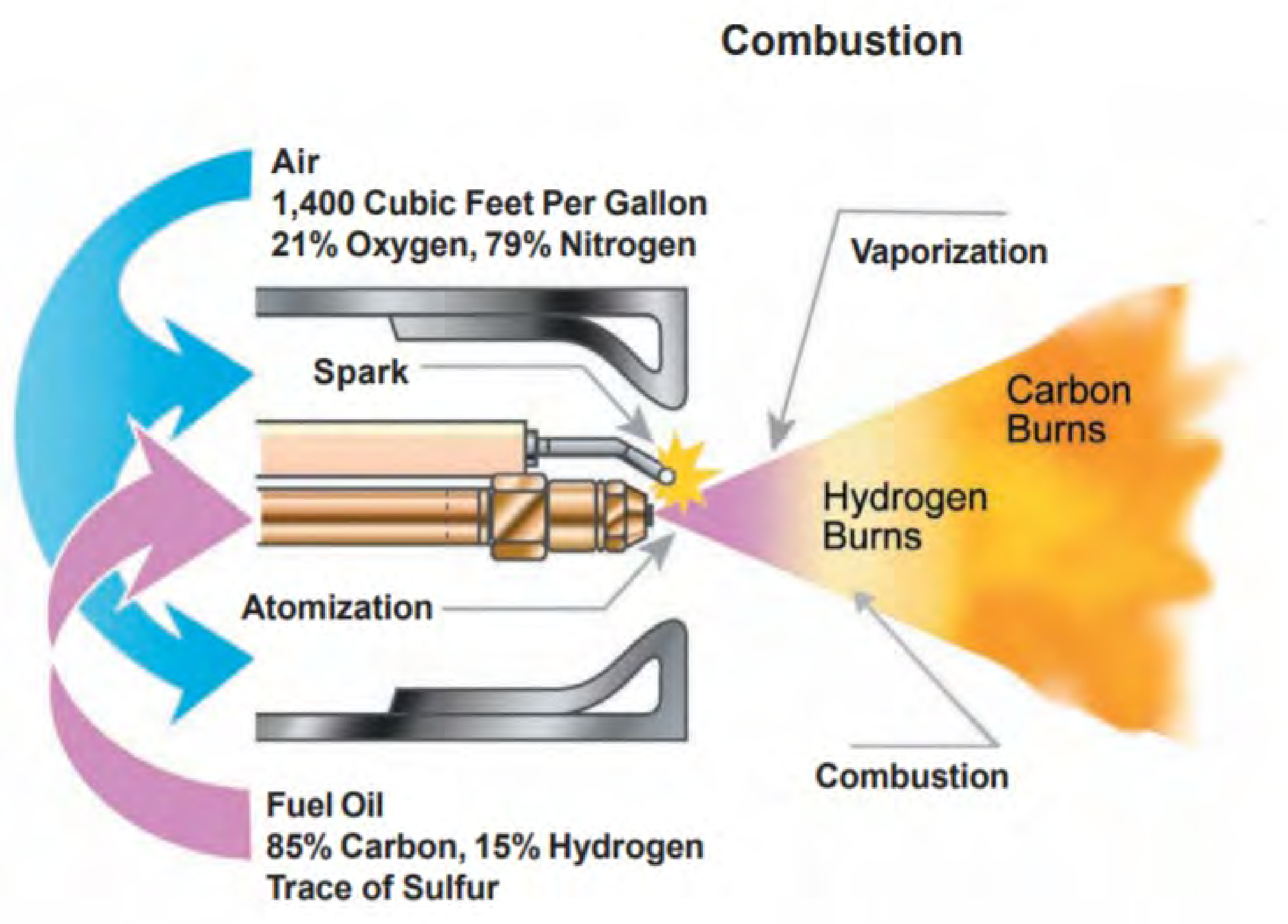
Higher static pressure burners have been developed to function on high efficiency appliances and to overcome poor draft conditions.

The blower in a high static pressure burner provides enough pressure to push the products of combustion through the heat exchanger when the chimney draft alone is not sufficient.

Today's burners operate at between 3-4 InWC (inches water column) up from 1.5-2.5 InWC of burners in the past

Combustion

All the elements needed for combustion are provided by the burner components and come together at the combustion head.



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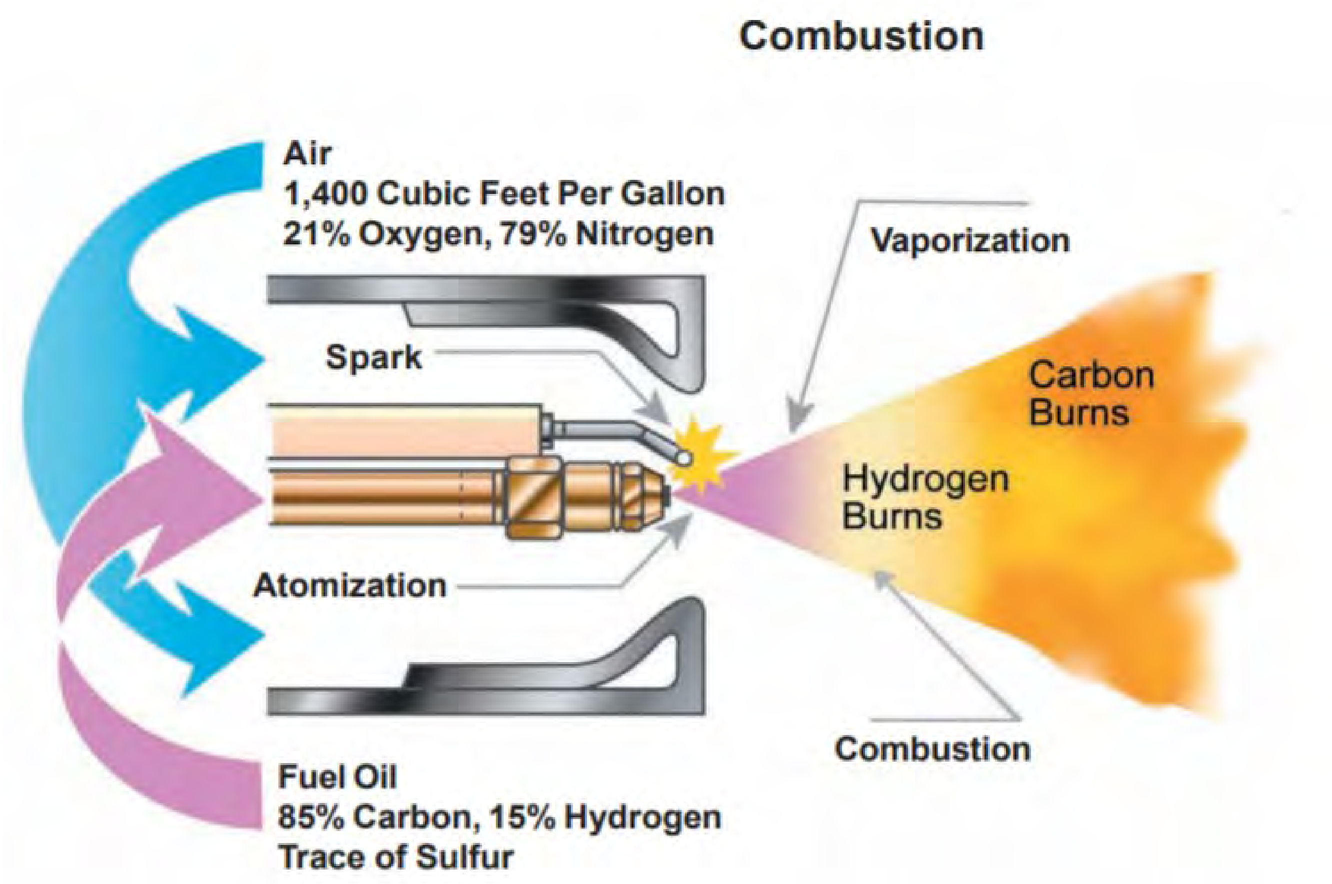

Review Questions:

- How does a burner create combustion?
- What are the components on a burner chassis?

End of Chapter 2

NORA Technician Certification

Review

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Chapter 3

Fuel Tanks & Piping

At the end of this lesson, you will be able to:

- Explain how to choose the right size tank for a customer
- Explain how to choose the best tank location
- Describe the types of tanks available
- List the steps for installing a fuel storage tank
- Explain why fuel storage tanks should be inspected regularly

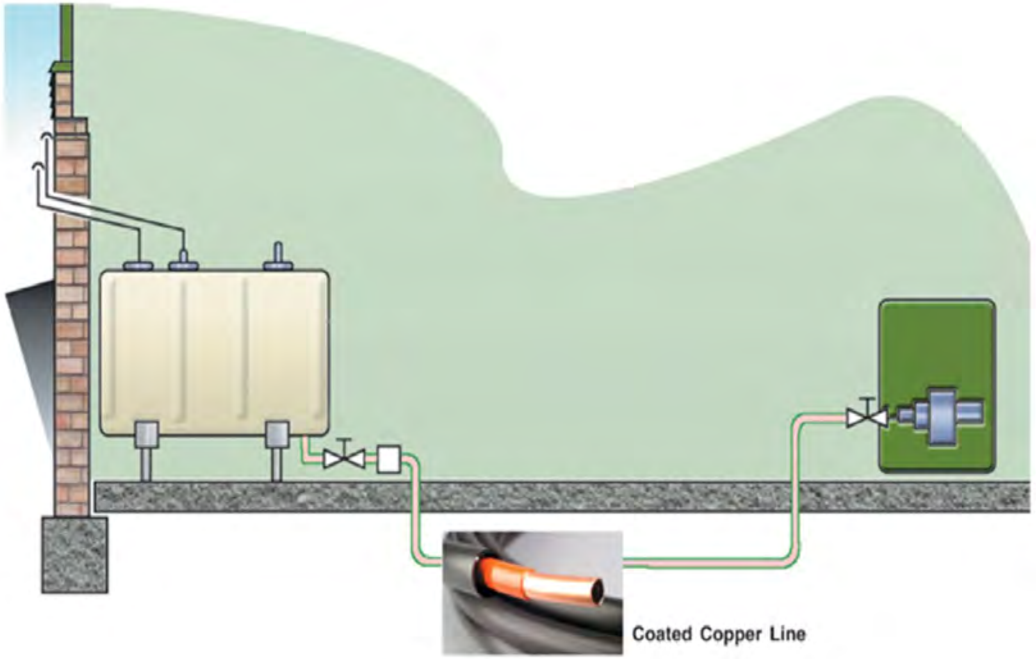
Fuel Tanks & Piping

The comfort, cleanliness & efficiency of today's systems rely on clean, uncontaminated fuel reaching the burner. To achieve this:

- Install tanks properly
- Maintain tanks by inspecting them & fixing minor defects ASAP
- Replace aging tanks before they fail

Proper Installation

- Manufacturer's Instructions
- NFPA 31 above ground up to 660
- NFPA 30 over 660 & in-ground
- ICC – residential and/or fire code



Why Tanks Fail

The most common cause of failure is corrosion – the deterioration of the tank due to reaction with its environment.

Fuel tanks are subject to both internal and external corrosion.

Why Tanks Fail

Corrosion is a natural process that causes metals to deteriorate.

If nothing is done to prevent it, nature will return a tank to its natural state.

Why Tanks Fail

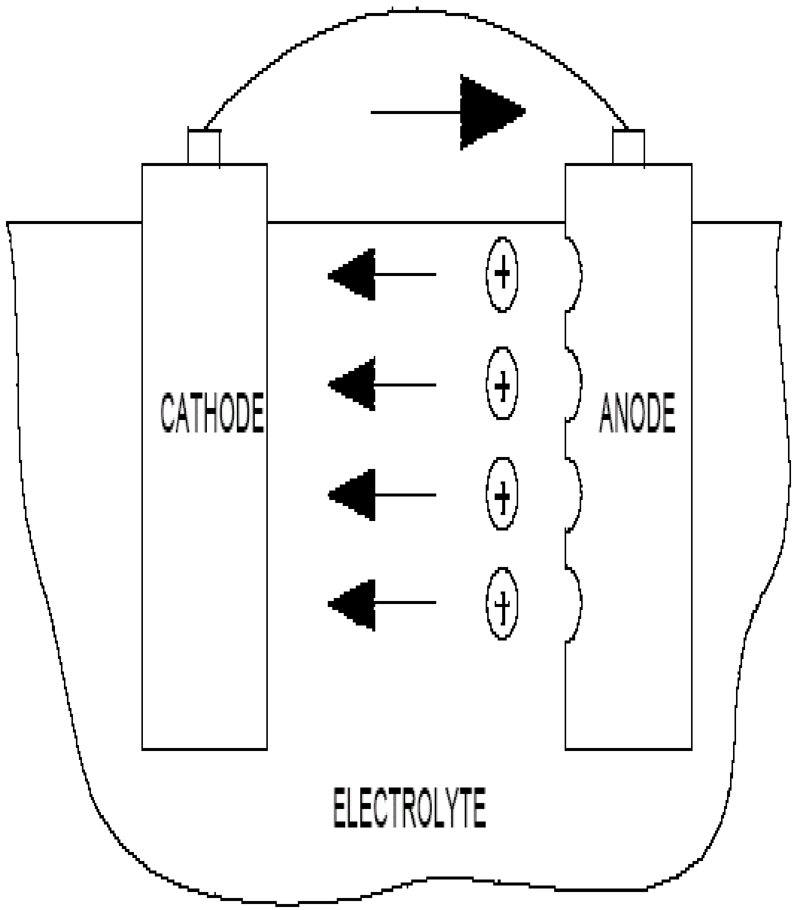
Unfortunately, when tanks corrode, they develop holes and leak.

Tank Corrosion

Which leads to unhappy customers, emergency service calls, and clean-up expenses.

EXTERNAL CORROSION

Buried Tanks



- External corrosion is caused by electrical activity between the tank & environment.
- In this case the tank is the anode
- The environment is the cathode
- Moisture is the electrolyte

Buried Tanks

Unfortunately, there's not much that can be done to prevent external corrosion in existing unprotected underground storage tanks (UST's).

Later in this chapter, UST's that can hold up underground will be shown.

Aboveground Tanks

Above ground storage tanks (AST's) are also susceptible to external corrosion……

Aboveground Tanks

To reduce exterior corrosion for AST's:

- Maintain clearance on all sides & bottom so debris can't accumulate & hold moisture against the tank
- Repair scratches & rust ASAP
- Paint regularly if appropriate

INTERNAL CORROSION

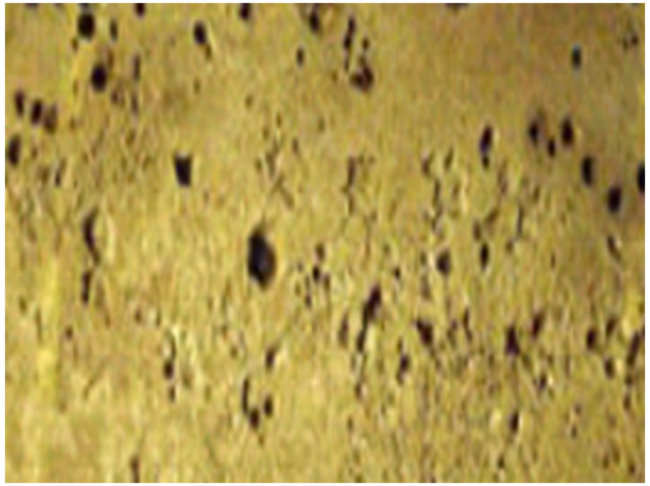
Internal Corrosion

Inside view

Outside view

Internal Corrosion

Internal tank corrosion is mainly due to bacteria (microbes) that thrive at the water/fuel interface. They "eat" the fuel and produce a substance that corrodes metal.

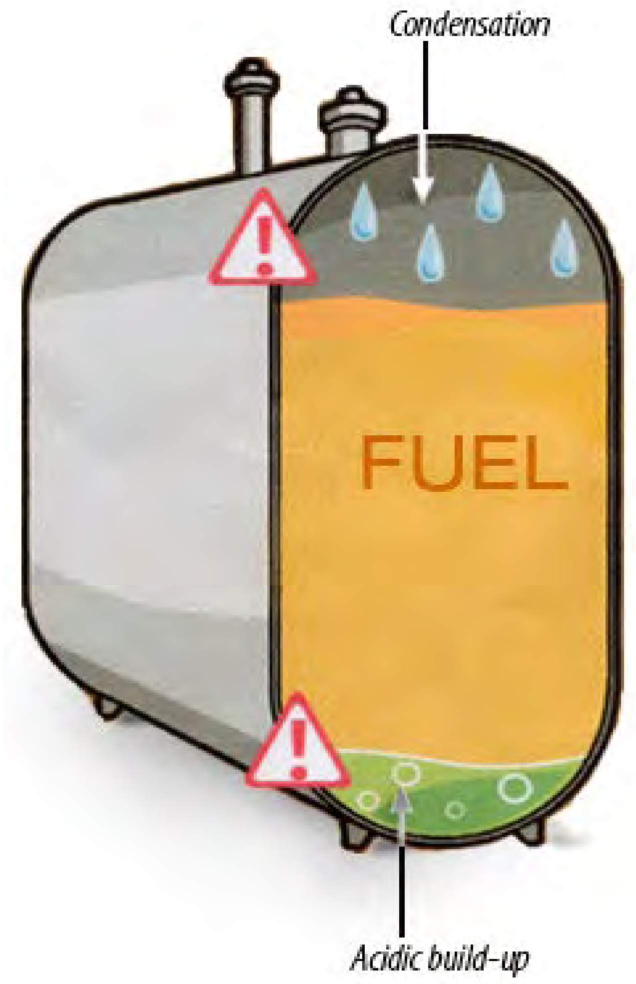


The best way to reduce internal corrosion is to eliminate water in tank bottoms, determine where it came from and take corrective steps to prevent it from building up again.

Internal Corrosion

The most common causes of water in tanks:

- Condensation
- Broken tank gauges (outside AST's)
- Loose or missing fill/vent caps
- Pumping fuel from an old tank into a new tank
- Failing to drain water from a new tank before installation



Reduce Condensation

- Install indoors whenever possible
- Install in an enclosure (outside)
- If outside, install out of direct sunlight and paint a light color
- Keep full in summer

Installation Considerations

There are many things that affect a tank's performance and longevity

that should be well thought out

before

an installation is scheduled, for example…

Installation Considerations

1. What SIZE tank will be best?

2. WHERE is the best place to install it?

3. What TYPE of tank will give the best performance?

4. Will the installation MEET REGULATIONS?

Tank Size

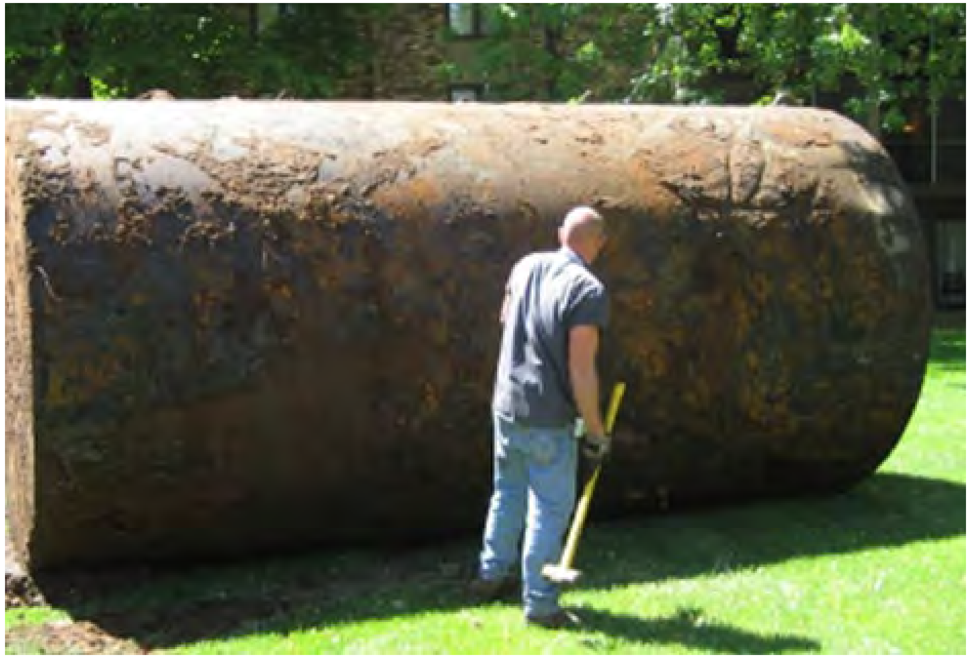
Liquid Fuel has a shelf life

&

degrades over time

Tank Size

TOO LARGE:



- ✓ Sludge
- ✓ Service Calls
- ✓ Annoyed Customers
- ✓ Shorter life of tank –due to corrosion

Tank Size

On the other hand, tanks that are

too small

require frequent deliveries that can cause operational problems.

Tank Size

$$\text{NORA recommended tank size} = \frac{\text{Annual Consumption}}{3}$$

Tank Size

Annual Consumption	Tank Size
1,000/3 = 333	275 or 330 gallon
800/3 = 266	

Tank Size

Of course, there are exceptions to every rule..

- Snow stops
- Hills
- Expected weather

Tank Location

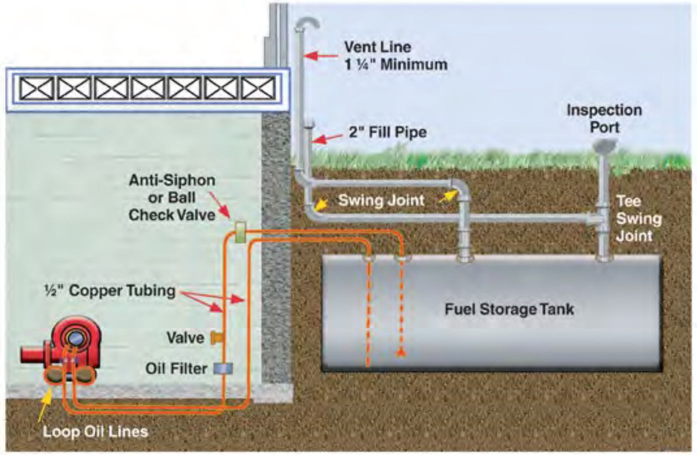
Once YOU know what size tank will be, you need to figure out where's the best place to install it.

Tank placement has a significant impact on

service requirements and *tank longevity.*

Three Possible Locations

- Inside – basement, utility room, garage
- Outside, above ground
- Outside, underground



Tank Location

4 main factors in deciding tank location:

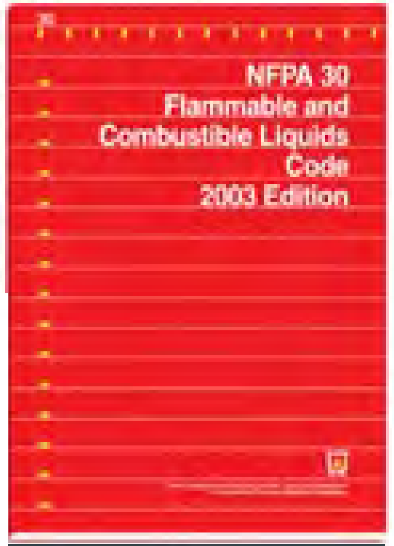
1. Codes and regulations
2. Safety
3. Spill prevention
4. Corrosion

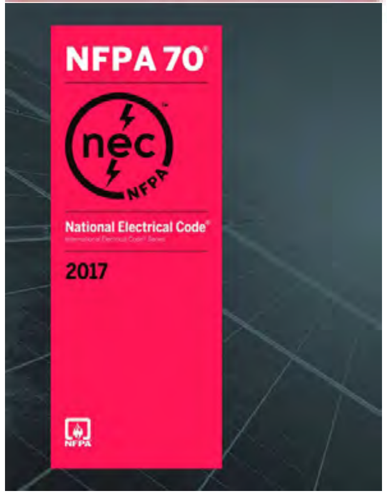
Codes & Regulations

Install in compliance with the local authority having jurisdiction.

Observe setbacks from:

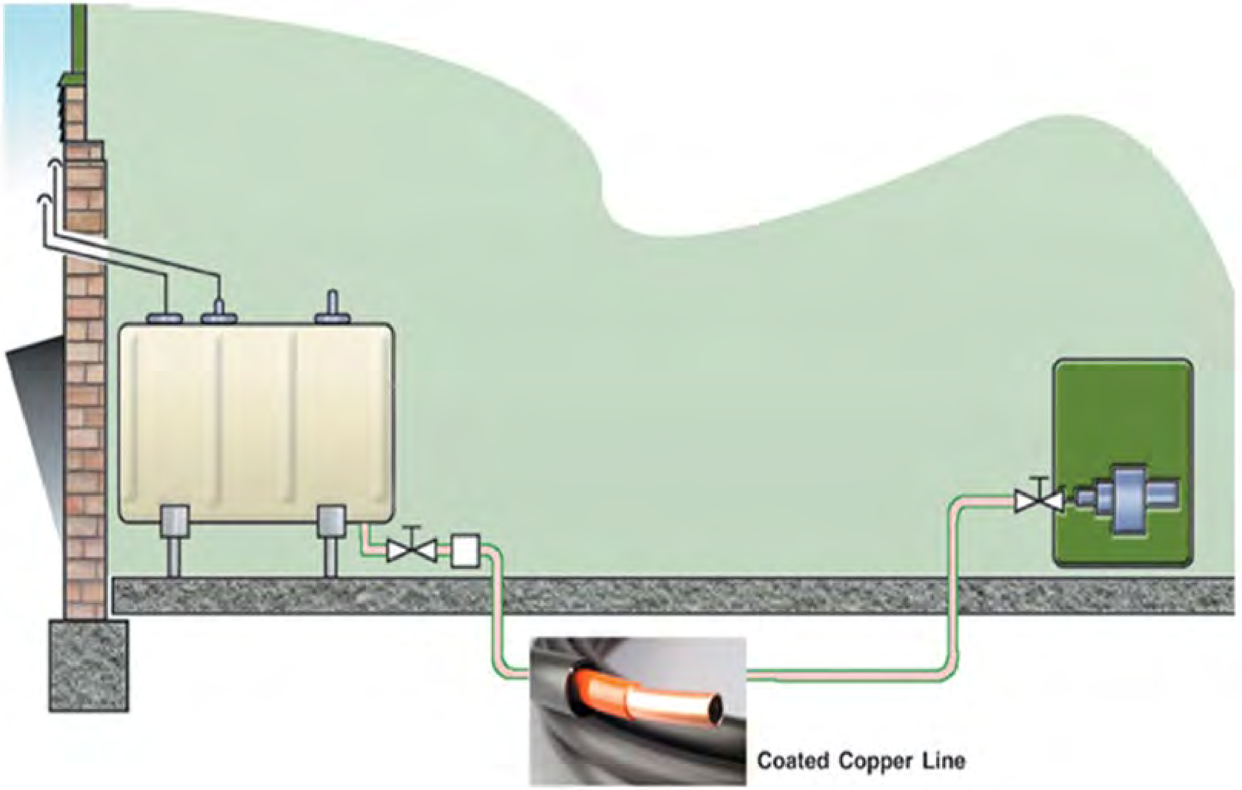
- Heating equipment (5’)
- Property lines (5’ to 10’)
- Buildings, doors, windows, vents, air intakes (2’ to 5’)
- Meters (3’ front, 2’ side)





Codes & Regulations

- Size, height and pitch of fill & vent pipes
- Fusible valves
- Vent alarm & gauge
- Oil filter(s)
- Coated lines – concrete or dirt
- No fittings under floor



Safety

- Delivery – safe parking
- Service & inspection
- Oil release – avoid drains, wells, waterways
- Corrosion factors – dripping water, falling ice, vehicles, etc.

Inside tanks

NORA recommends above ground, indoor tank installations whenever possible.

Advantages of Indoor ASTs

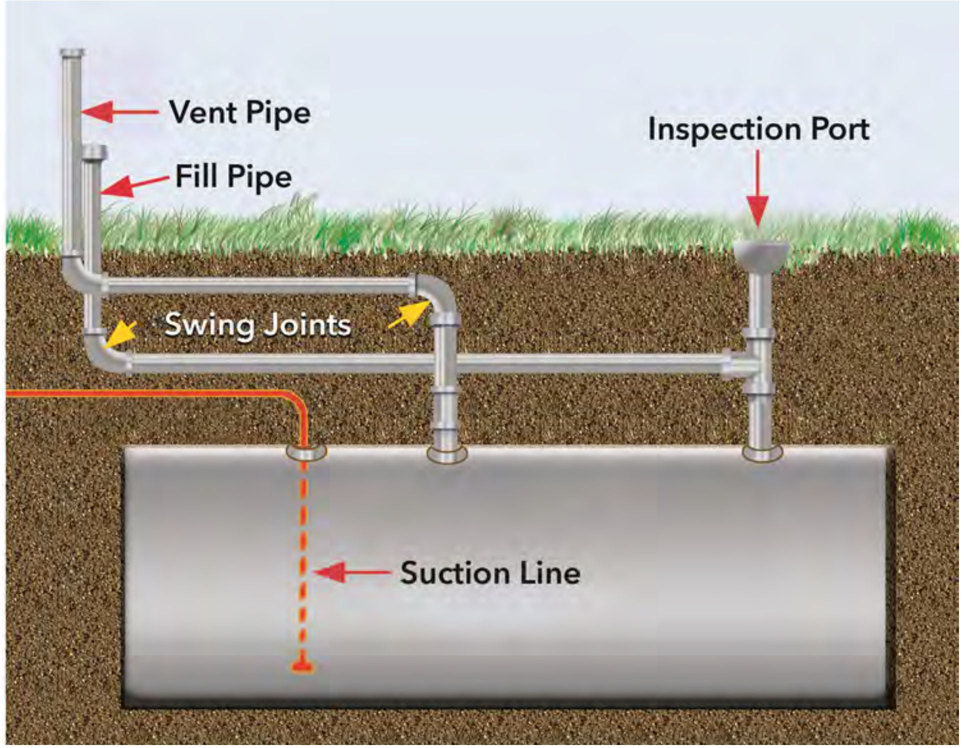
- Fuel is warmer, won't gel or have cold weather problems
- Fewer temperature swings, less degradation
- If leak develops, odor alerts us to problem
- Easier to inspect
- Less condensation

Outdoor ASTs

- Secondary containment is recommended
- Fuel line (s) should be insulated
- Install filter inside building

UST's

Environmental regulations and insurance concerns have greatly reduced the number of UST's.



NORA recommends above ground whenever possible.

Tank Types

Once the recommended size & location have been determined the customer has options based on price, warranty and environmental protection.

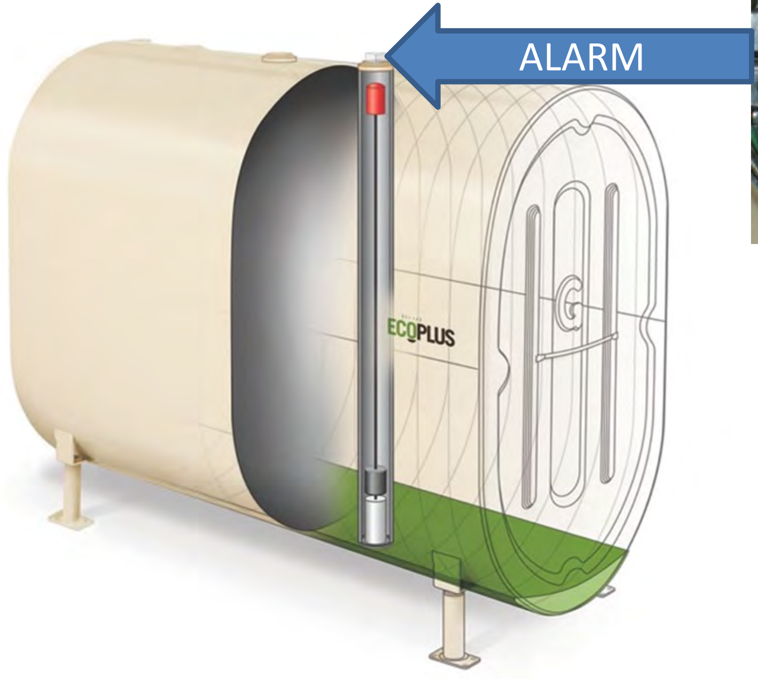
AST's

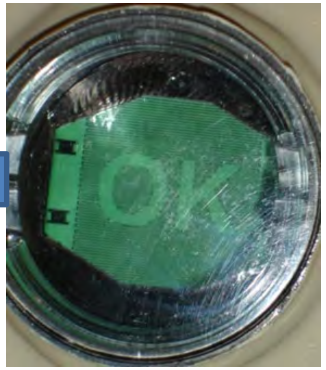
- Ob-round – 100 to 330 gallons
- 275 most common size
- Bottom draw since early 1990's to reduce condensation & sludge build-up.
- Also available with polyethylene coating to resist external corrosion

Double Bottom AST

Has a second bottom to contain a leak in the primary tank.

An alarm notifies that the inner tank has been compromised.



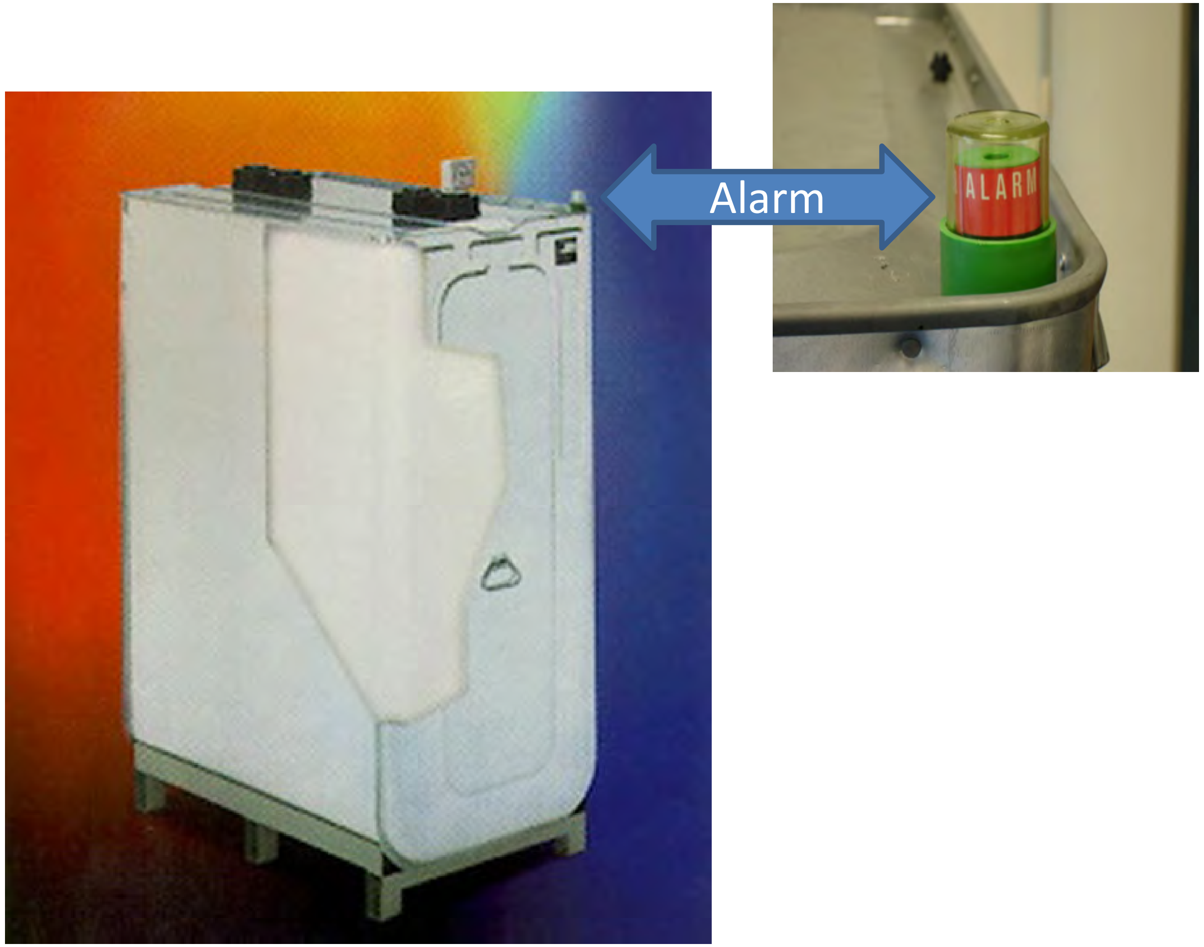


Fiberglass AST

- Corrosion proof fiberglass
- 240 & 300 gallons
- Single & double wall

Polyethylene/Steel AST

- Double wall
- Outer tank protects inner and provides secondary containment
- Alarm notifies that inner tank is compromised



UST's

STI-P3

1. Protective coating prevents external corrosion.

2. Sacrificial anodes protect the steel.

3. Nylon bushings isolate the tank.

UST's

ACT-100 & 100U

- Protection similar to STI-P3
- No anodes
- Thicker protective coating

UST's

- Fiberglass reinforced plastic (FRP)
- Made of corrosion resistant materials

Installation Procedures

Follow ***current*** manufacturer's instructions.

Follow all applicable codes & regulations.

Manufacturer Instructions

CAUTION: IMPORTANT INFORMATION - DO NOT REMOVE OR PAINT THIS LABEL

No.: S-324882 Model No.: 203701T

Model No: 203701T

Tank Size: 230
Date of manufacture: Aug / 2011
Min. capacity of tank: 223 US Gallons
Thickness of shell: 12 Gauge
Thickness of heads: 12 Gauge
Tested to: Seven (7) PSIG

UL LISTED

MH13819/1/1 UL-80

STEEL TANK FOR OIL-BURNER FUELS AND OTHER COMBUSTIBLE LIQUIDS - SINGLE WALL

No. : S-324882

GRANBY INDUSTRIES LIMITED PARTNERSHIP

MFG ID: G Mfg. Location: Andre-Line

MADE IN CANADA

WARNING

1) THIS TANK IS INTENDED FOR STATIONARY USE ONLY 2) TILT TANK ¼ INCH/FOOT (20.8 mm/meter) TOWARDS BOTTOM OPENING. 3) DO NOT REDUCE VENT CAPACITY BELOW 1¼ INCH (35 mm) PIPE SIZE. 4) INSPECTED TANK PERIODICALLY PER INSTRUCTIONS. 5) REMOVE ACCUMULATED WATER FROM TANK BOTTOM ANNUALLY. 6) DO NOT TRANSFER OIL FROM OLD TANK INTO THIS TANK 7) WARNING - DO NOT LEAK TEST AT MORE THAN 3 PSIG; EXCESSIVE PRESSURE WILL CAUSE TANK TO DISTORT. THE MANUFACTURER ASSUMES NO RESPONSABILITY FOR DAMAGE IN SUCH CASE.

Read completely before installing

This tank is designed for use in atmospheric pressure (2½ psi). Modern delivery pump capacities can cause pressure to build up in the tank unless the venting system is as efficient as the delivery system. Vent caps should be designed to not restrict flow. The venting system should be checked to be clear of debris before filling the tank.

Installation codes require this tank to be tested at the job site prior to putting into service

Tank should be pressurized and all seams areas soaped and inspected for leaks. Handling of tank in transit can cause defects that can only be detected at jobe site.

This tank is equipped with handles. These handles may not be adequate for all aspects of tank transportation and setting. Use of two-wheel hand trucks, rope looped through leg brackets, or basement tank carriers are some common methods of transporting tank to area of use. Installation crews assume all responsability for using prudent safety measures when installing tanks.

Refer to NFPA 31 for installation code and consult local authorities for other rules prior to installation of tank. If you have questions, call your local tank supplier or your local fire marshall.

EP0300_L

Manufacturer Instructions

MH13819/1/1 UL-80

LISTED

Mfg. ID: G

No. : xxxxxxxx
GRANBY INDUSTRIES LIMITED PARTNERSHIP
Mfg. Location: Andre-Line

MADE IN CANADA

WARNING

WARRANTY IS VALID PROVIDED MANUFACTURER'S INSTRUCTIONS ARE RESPECTED.
WARRANTY CERTIFICATE AND INSTALLATION GUIDE ARE AVAILABLE ON OUR WEB SITE:

WWW.GRANBYINDUSTRIES.COM

1) THIS TANK IS INTENDED FOR STATIONARY USE ONLY
2) TILT TANK ¼ INCH/FOOT (20.8 mm/meter) TOWARDS BOTTOM OPENING.
3) DO NOT REDUCE VENT CAPACITY BELOW 1¼ INCH (35 mm) PIPE SIZE.
4) INSPECT TANK PERIODICALLY PER INSTRUCTIONS.
5) REMOVE ACCUMULATED WATER FROM TANK BOTTOM.
6) DO NOT TRANSFER OIL FROM OLD TANK INTO THIS TANK
7) THIS PRODUCT IS NOT DESIGNED FOR DIRECT SALE TO THE CONSUMER.
8) THE MANUFACTURER SUBJECTS EACH TANK TO A PRESSURE TEST BEFORE SHIPMENT. HOWEVER THE MANUFACTURER REQUIRES THAT ALL PIPING CONNECTIONS AND WELD SEAMS BE CHECKED FOR INTEGRITY DURING THE INITIAL FILLING OF THE TANK.
9) WARNING - DO NOT LEAK TEST AT MORE THAN 3 PSIG; EXCESSIVE PRESSURE WILL CAUSE TANK TO DISTORT. THE MANUFACTURER ASSUMES NO RESPONSABILITY FOR DAMAGE IN SUCH CASE.

DO NOT PRESSURE TEST!

This tank has passed Granby's Pressure Certification Test of 5 PSI at the factory.

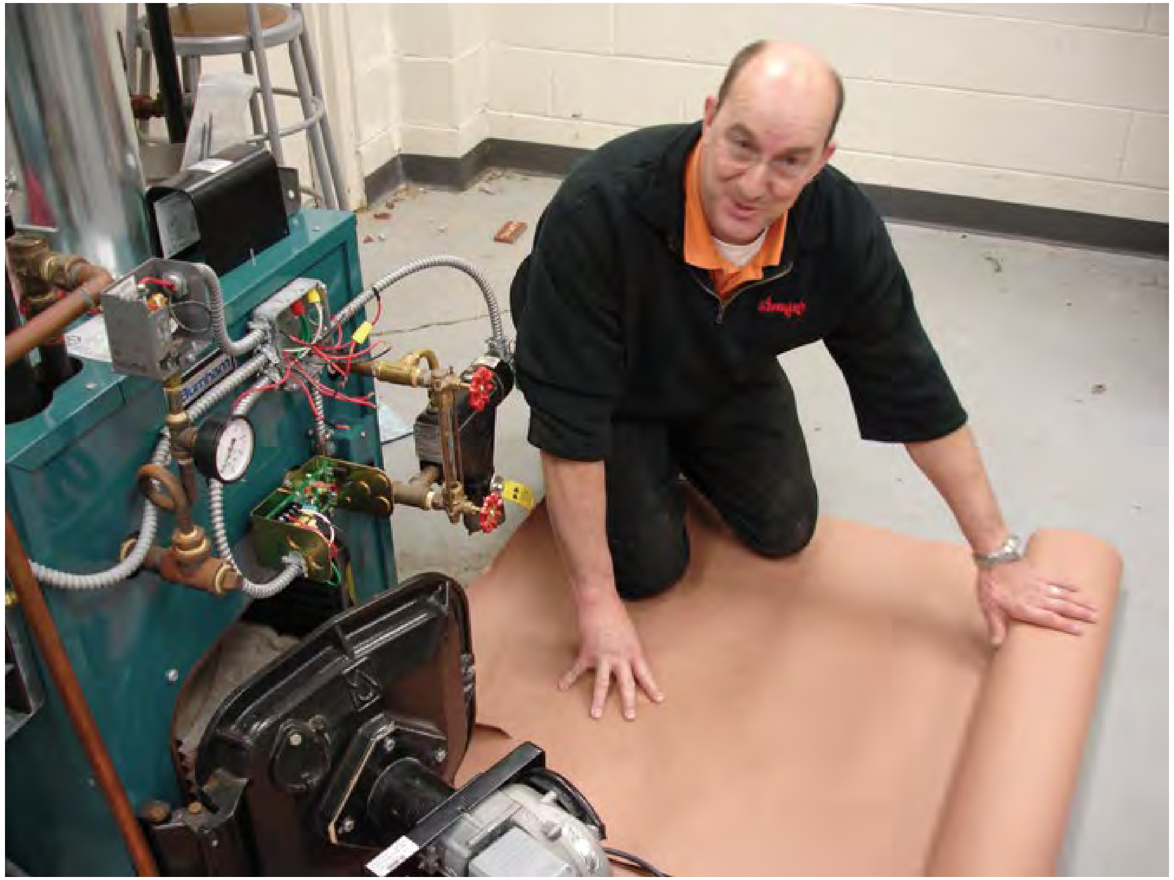
Installation Procedures

Be sure to follow the manufacturer's instructions and all applicable codes and regulations during the installation.

This next section emphasizes some of the important steps in the tank installation process.

Work Neat

- Protect customer's property
- Easier to prevent mess than to clean it up
- Use drop cloths, builder's paper, booties, etc



Piping Connections

- Tight & leak proof
- Proper pipe compound (biofuels)
- Wipe away excess compound

Fill & Vent Pipes

- Schedule 40 steel pipe (not PVC or copper) with approved fittings, no cast iron fittings
- Piping pitched toward tank (swing joints)

Fill & Vent Caps

- Fill cap should be clearly marked

- Vent cap needs a screen to prevent bugs from making nests. (how important?)

VERY IMPORTANT!

Vent Alarms

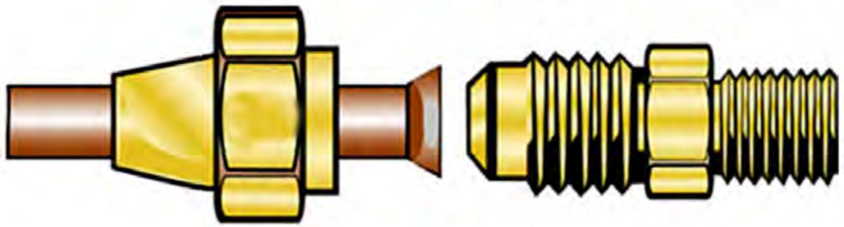
Every above ground tank needs one to alert the delivery person that the tank is full.

NOT always required for UST's because a special fill device that includes a vent alarm can be used.

Fuel Lines

- ½” OD recommended, 3/8” minimum
- Flare fittings, NOT compression (except slip fittings at tank)
- Least # of fittings possible
- Accessible – not buried, etc.
- Coated or sleeved when in contact with concrete or dirt

Flare Fitting



Compression Fitting

Thermal Shutoff Valves

Required by NFPA 31:

1. At the inside tank.
2. Where the line enters the building for an outside tank.
3. Upstream of & within 6” of the filter.
4. Within 12” of the burner.
5. At the de-aerator.

Fuel Filter

Required in the suction line.

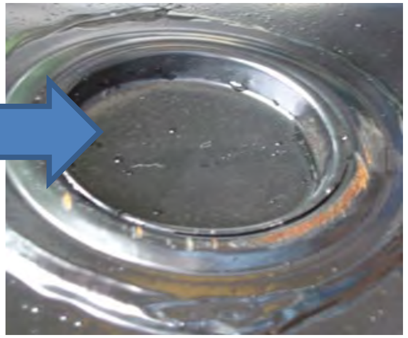
Two main types:

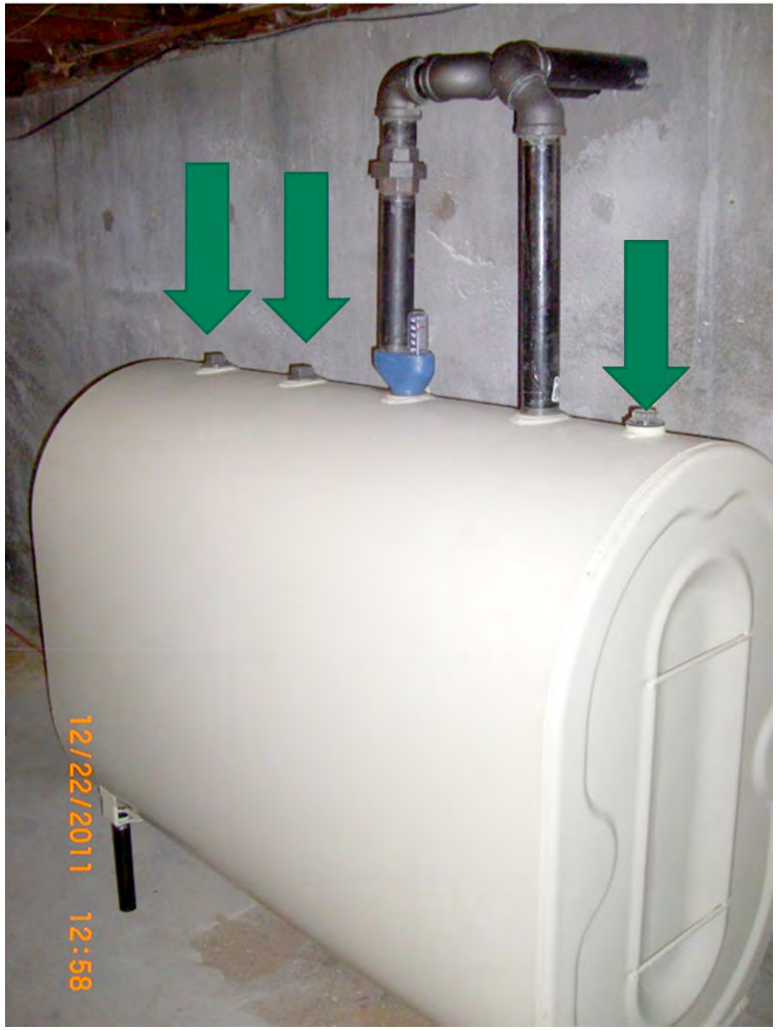
- Spin on
- Cartridge

Should be changed at least once a year

Plug or Cap

- Shipping caps keep water & debris out during shipping and storage
- Must be removed during installation
- Unused openings MUST be properly secured (PLUG)





Tank Inspection Procedures

NORA recommends three levels of inspection:

1. Initial
2. Routine
3. Pre-delivery

Tank

UL Label?		☐Yes ☐No
Tank location?		________
Tank size?		________
Tank height?		________
Amount of oil in tank?		________
Any water in tank?		☐Yes ☐No
If yes, how many inches?		________
Tank gauge properly installed & accurate?		☐Yes ☐No
Tank bottom at least 6" off ground?		☐Yes ☐No
Tank at least 5 feet from burner or other sources of fire or flame?		☐Yes ☐No
Tank condition satisfactory, including legs and pad or foundation?		☐Yes ☐No
Evidence of corrosion?		☐Yes ☐No
Tank securely mounted in flood prone areas?	☐N/A	☐Yes ☐No
Any evidence of historic oil spills?		☐Yes ☐No
Unused openings properly plugged?		☐Yes ☐No

Comments: ____

____

____

Fill Pipe

Pipe size?		________
Pitched toward tank?		☐Yes ☐No
Proper material?		☐Yes ☐No
In good condition?		☐Yes ☐No
Fill cap in place & in good condition		☐Yes ☐No
Fill positioned to avoid buildup of water and snow?		☐Yes ☐No
Properly piped, outside at least 2' from windows or openings?		☐Yes ☐No
Fill properly tagged?		☐Yes ☐No
Old fill pipe removed?	☐N/A	☐Yes ☐No

Comments: ____

____

____

INITIAL INSPECTION

Initial Inspection

This inspection should be performed

before

a delivery is made to a new customer or a new tank.

Initial Inspection

Be sure the tank appears to be in good condition and in compliance with local codes & regulations.

Initial Inspection

The customer may be switching companies because their current supplier has recommended tank upgrades that they aren't willing to pay for!

Routine Inspection

Nora recommends that routine inspections be conducted during preventative maintenance tune-ups.

Routine inspections can detect problems that occur after the tank has passed the initial inspection. For example, a tank gauge may have become defective, a tank leg may start to corrode, etc.

In many situations, routine inspections detect minor problems that have recently started and that can be easily corrected before they cause a problem.

Pre-delivery Inspection

Fuel delivery personnel should perform a brief visual inspection of the components that are visible from the delivery point before and after each delivery.

While this inspection normally is not documented, it's important for delivery personnel to verify addresses and check visible components for obvious defects before delivery and after delivery.

NORA recommends a "no whistle-no fill" policy.

Review Questions:

- How do you choose the right size tank for a customer?
- How do you choose the best location for a tank?
- What types of tanks are available?
- What are the steps for installing a fuel storage tank?
- Why should fuel storage tanks be inspected regularly?

End Chapter 3

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 4

Fuel Units & Valves

At the end of this lesson, you will be able to:

- Describe what a fuel unit/pump does
- Explain why and how vacuum is created in a system
- Explain what vacuum gauge readings mean
- Describe how to adjust the fuel unit pressure to reach desired setting
- Explain the advantages and disadvantages of a 1-pipe and 2-pipe system

At the end of this lesson, you will be able to:

Continued…

- Perform the steps to conduct a field pressure test, field vacuum test, and a pump vacuum test in the correct order
- Explain the important things to consider when replacing a fuel unit
- Describe the most common valves on fuel lines
- Recognize signs of problems in a fuel unit, line, or tank

Introduction

Fuel units (aka fuel pumps):

- Draw fuel from the tank to the burner
- Deliver it at a constant and regulated pressure to the nozzle
- Provide fast and complete cutoff of fuel on burner shutdown

Introduction

Fuel units develop both:

- Vacuum to draw fuel from the tank
- Pressure to deliver fuel to the nozzle

They are available in either single stage or two stage models

Two stage models provide higher lift capacity than single stage.

One Stage VS Two Stage

Single Stage (A) or (J)

Has one set of gears that draws fuel from the tank and pressurizes it for delivery to the nozzle

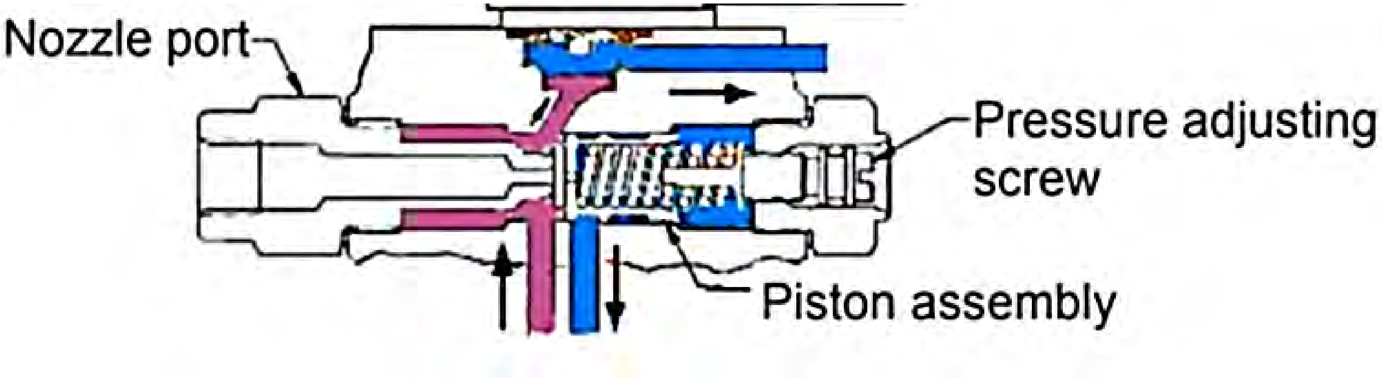
Two stage (B) or (H)

Has two sets of gears, one to draw fuel from the tank and return it, the other to pressurize it for delivery to the nozzle

Component Parts

Machined gears, which provide vacuum and pressure.

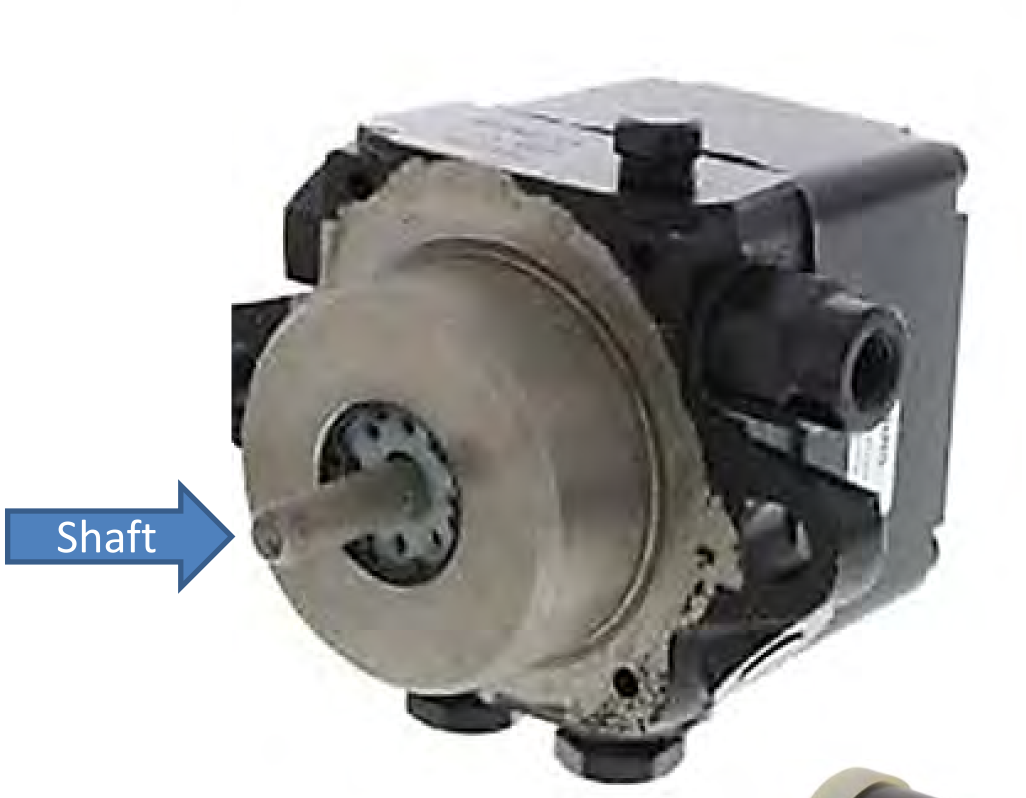
A pressure-regulating valve, which controls the pressure of the fuel discharged to the nozzle and provides clean cutoff of the flow of fuel.



Component Parts

A strainer which filters incoming fuel to protect the gears and prevent contaminants from reaching nozzle.

Component Parts



A solid shaft that extends through the housing seal and drives the gears.

The end of the shaft is connected to the burner motor by a flexible coupling.

Component Parts

A shaft seal to prevent fuel from leaking out of the housing around the rotating shaft.

Lubrication is provided to this seal through internal porting.

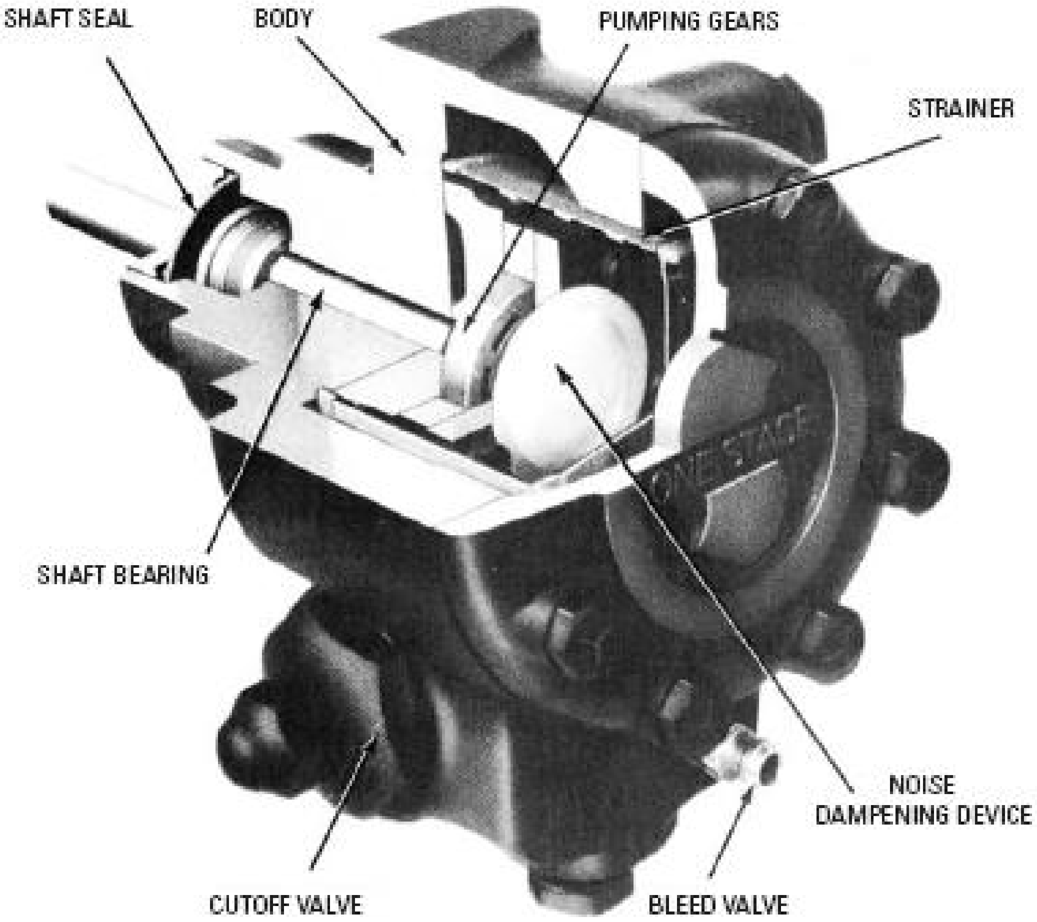
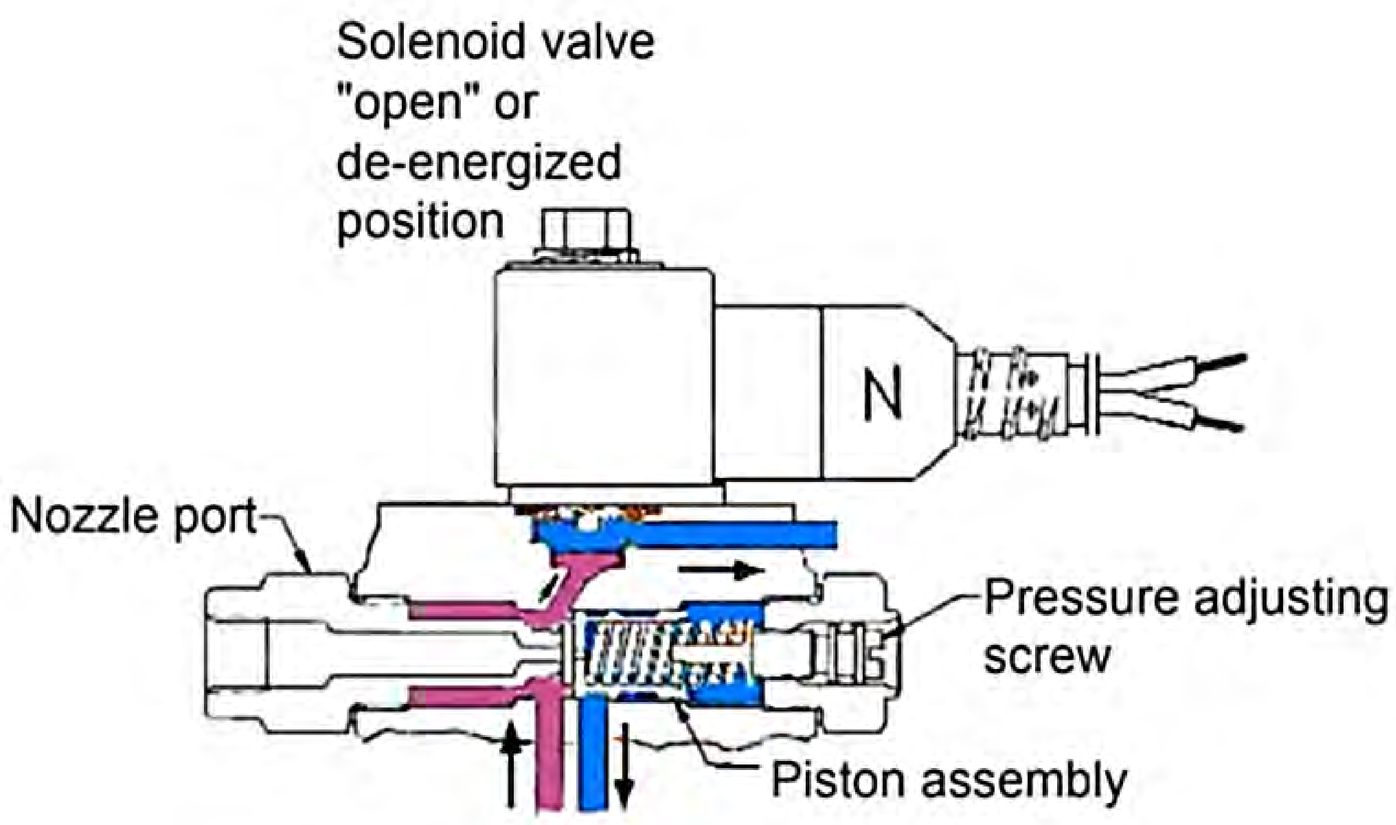


Figure 1-23 Cutaway view of a single-stage fuel pump.
(Courtesy Sundstrand Hydraulics)

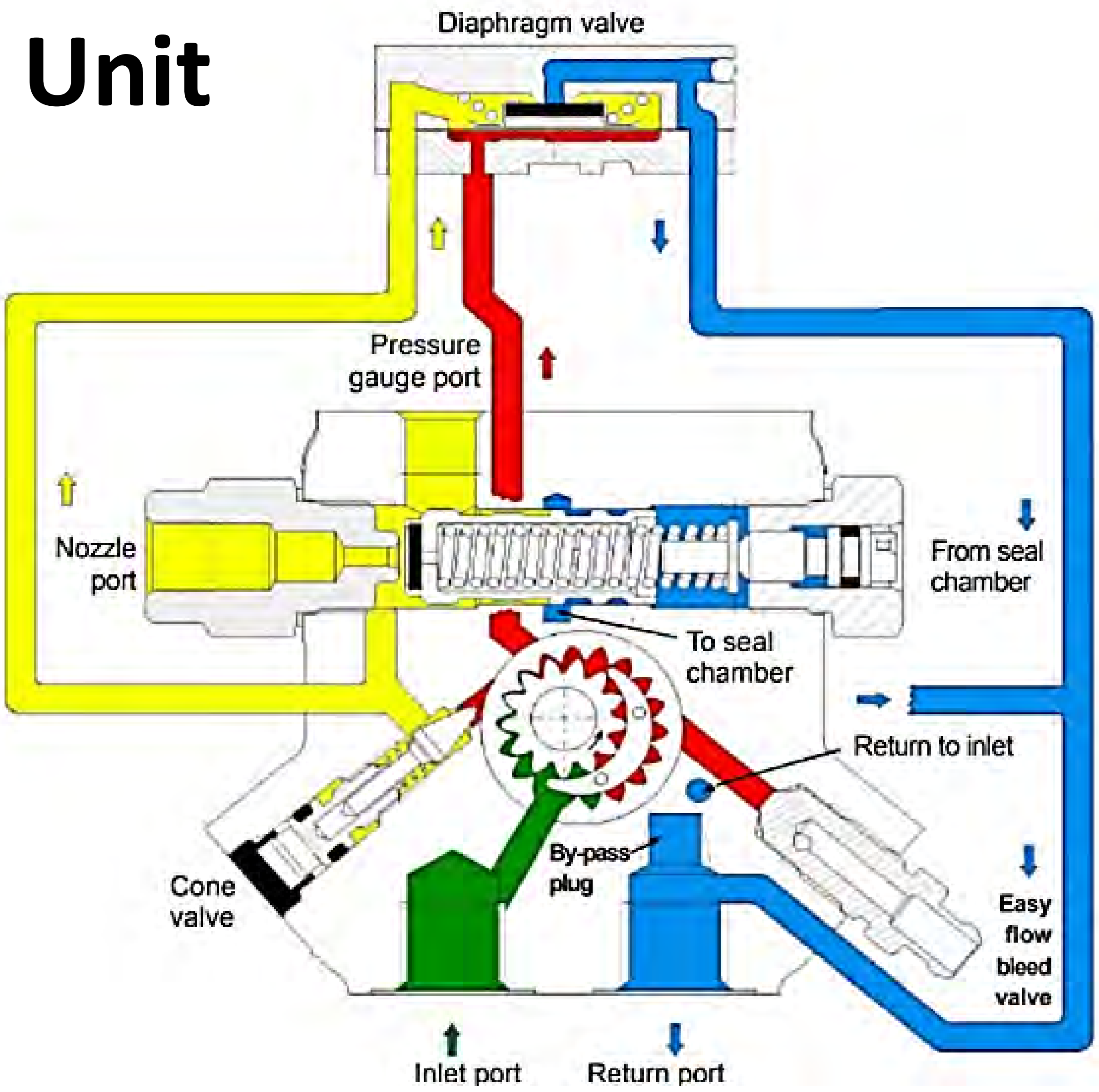
Component Parts



In addition, most fuel units introduced since 2001 have integral solenoid valves to provide faster cutoff and provide valve-on and motor-off delays.

1-Stage Fuel Unit

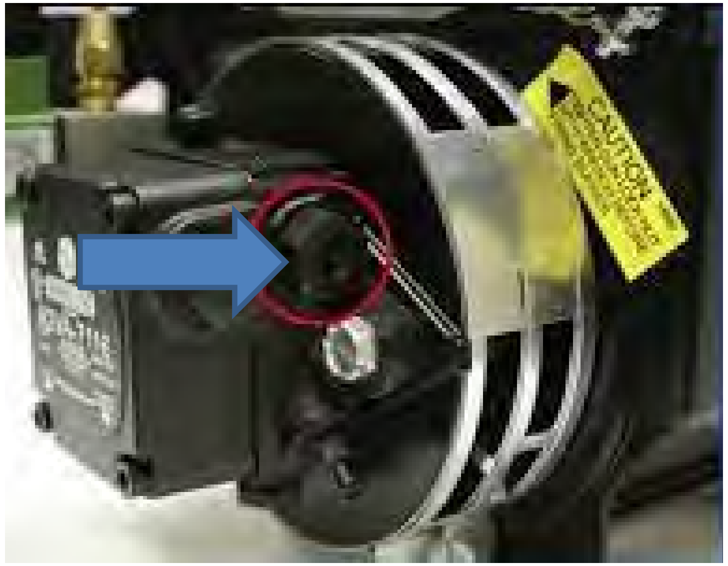
- 1 set of gears for both pressure and vacuum.
- Vacuum brings fuel to pump from tank.
- Pressure moves oil from pump to nozzle.

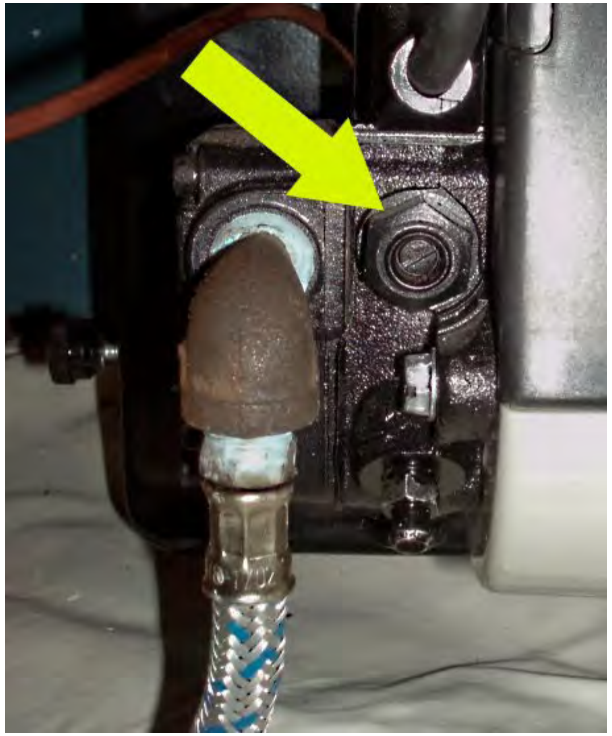


Understanding Fuel Unit Pressure

- Fuel unit pressure is the force created by meshing the gears, it moves fuel from the fuel unit to the nozzle
- Pressure is expressed in pounds per square inch (PSI)
- A typical fuel unit can provide up to 200 -300 psi, it should be set to the manufacturers recommendations and NEVER be adjusted to less than 100 PSI

Understanding Fuel Unit Pressure





Fuel unit pressure can be adjusted by turning a screw on the pressure regulating valve.

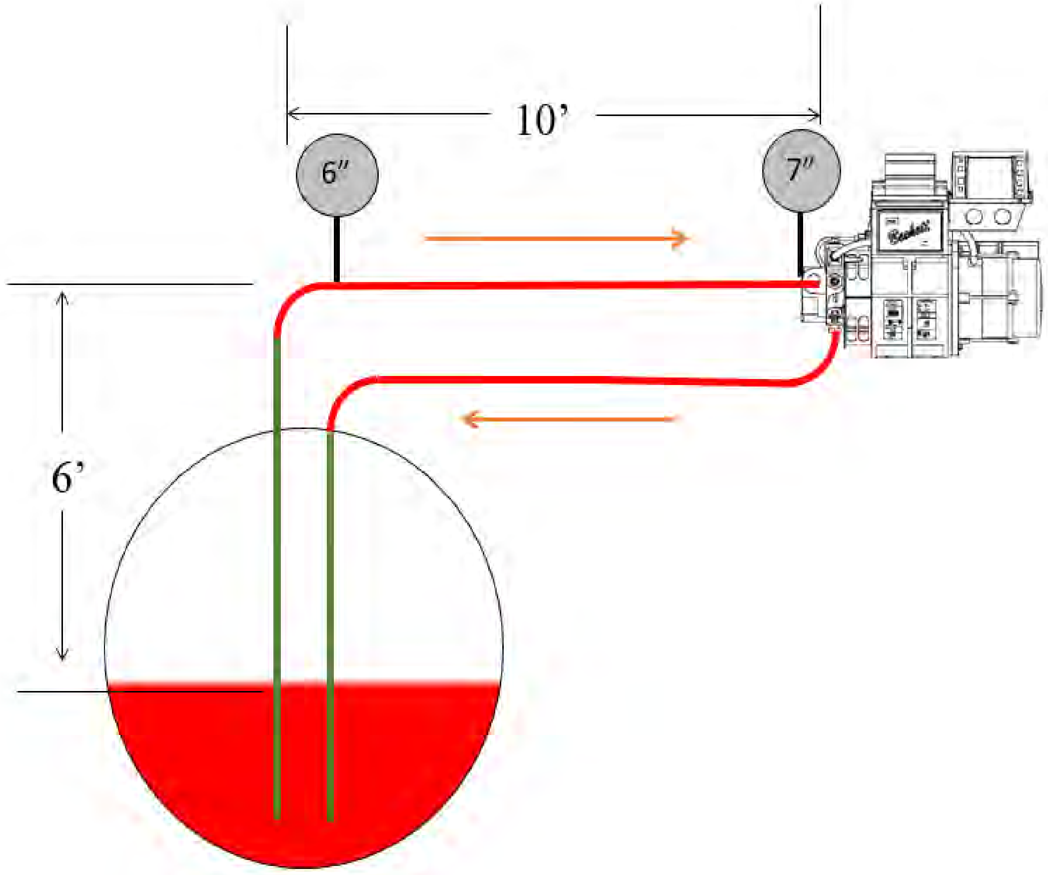
Understanding Vacuum

- Vacuum is "negative pressure" and is measured in inches of mercury (inHg)
- Normally the numerical value of the vacuum is shown with an inch (") mark. Example: 5" of vacuum
- It is a function of the resistance the fuel unit must overcome to draw fuel from the tank

Understanding Vacuum

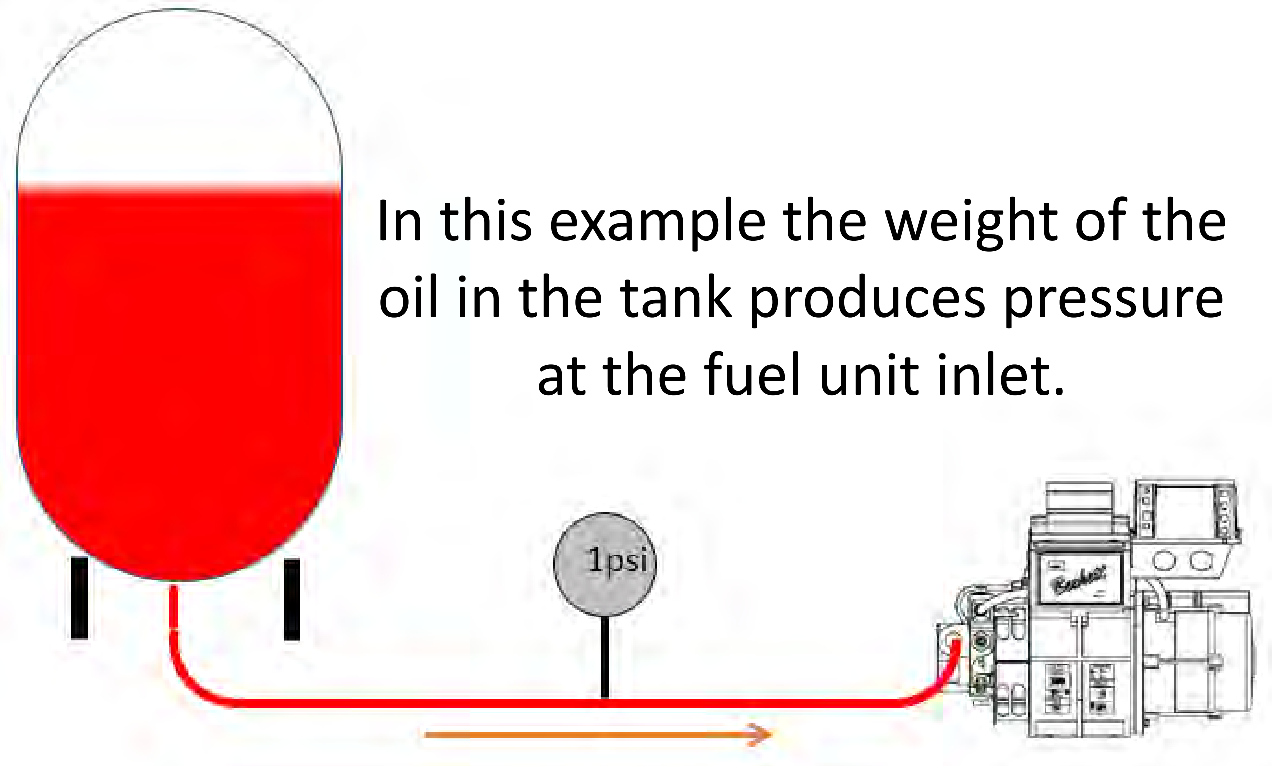
- Approximately ¾" to 1" Hg of vacuum is generated for each foot fuel is lifted
- 1" of vacuum for each 10 feet of horizontal run
- 2" to 4 " for an oil safety valve
- ½" for a clean fuel filter.

In this situation, a gauge reading of 4" to 7" is normal.



Understanding Vacuum

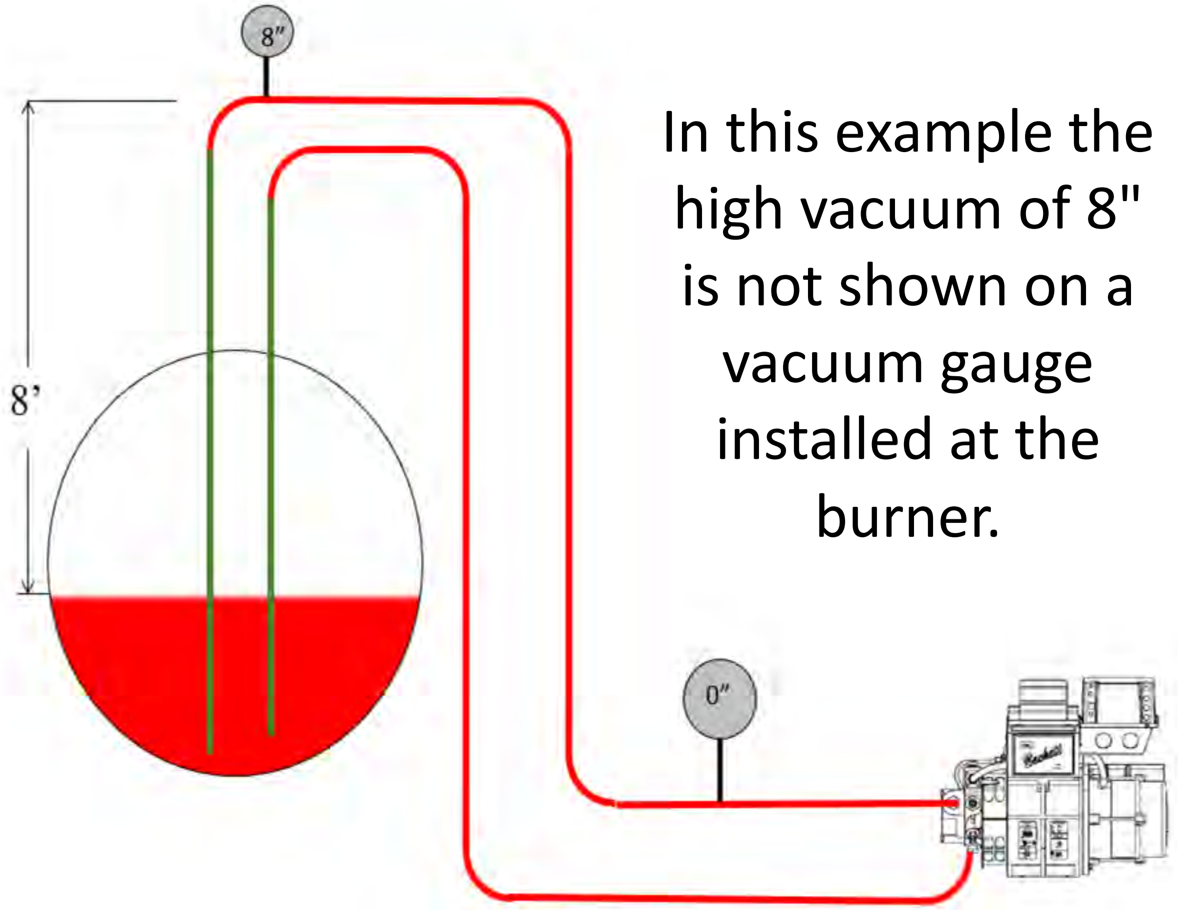
- If the tank is above the burner (and fuel doesn't have to be lifted), fuel flows to the burner by gravity and there is no vacuum generated.
- This type of arrangement is ideal because vacuum can cause air bubbles to be released from fuel and cause combustion problems and/or burner shutdown.



In this example the weight of the oil in the tank produces pressure at the fuel unit inlet.

Understanding Vacuum

On a system that siphons (fuel unit is below level of fuel in a top feed tank) a vacuum gauge installed at the burner will typically read 0" although there is higher vacuum at the high lift point out of the tank.



In this example the high vacuum of 8" is not shown on a vacuum gauge installed at the burner.

Operation of the Fuel Unit

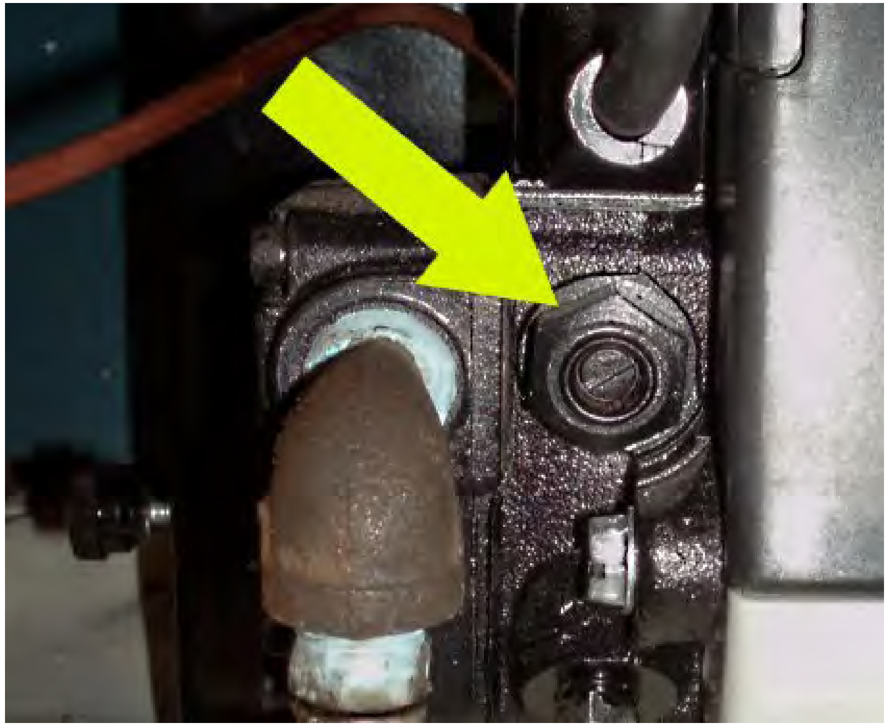
- When the motor turns the shaft, fuel enters through the intake port by either gravity or vacuum
- Gears rotate & move fuel to the pressure regulating valve
- Pressurized fuel forces the piston open & fuel flows to the nozzle port.

Operation of the Fuel Unit

- The fuel unit can deliver as much as 40 times the amount of fuel required by the nozzle
- All the fuel that enters the gears ***MUST*** be discharged by the gears
- Any fuel not sent to the nozzle must be bypassed either internally (single pipe – back to the strainer) or externally (2 pipe – back to the tank)
- For the excess fuel to return to the tank, a bypass plug must be installed in the fuel unit to prevent the fuel from going back to the strainer chamber. With the bypass plug in place, the excess fuel travels through a "return line" from the fuel unit back to the tank.

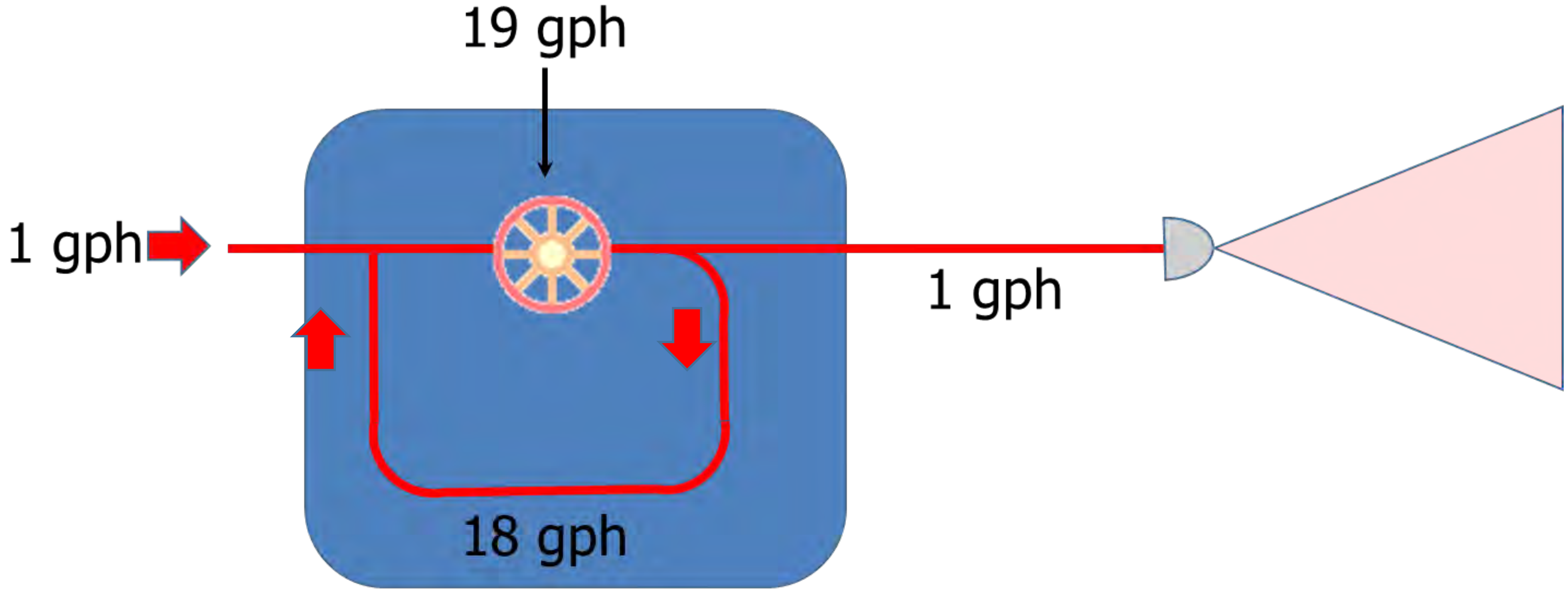
Pressure Regulating Valve Operation

- This assembly consists of a valve body and matching piston
- The pressure adjusting screw regulates the spring tension to control the pressure of the fuel discharged to the nozzle, normally 100 – 200 PSI
- On startup, the piston opens to let fuel flow at 80-95% of operating pressure (Min. operating pressure is 100 psi)
- On shutdown, it closes shutting off fuel flow at approximately 20% below operating pressure



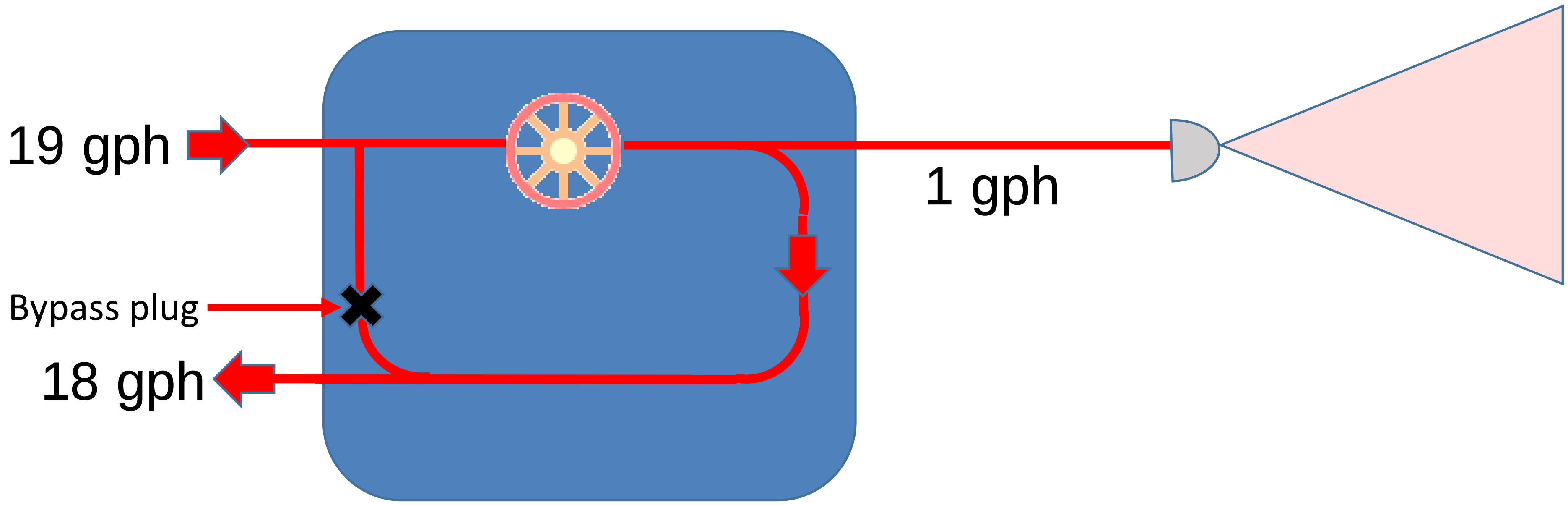
One-Pipe Systems – Internal Bypass

The full capacity of the gearset is pumped through the internal bypass and only what is needed for the firing rate is brought in from the tank.



Two-Pipe Systems – External Bypass

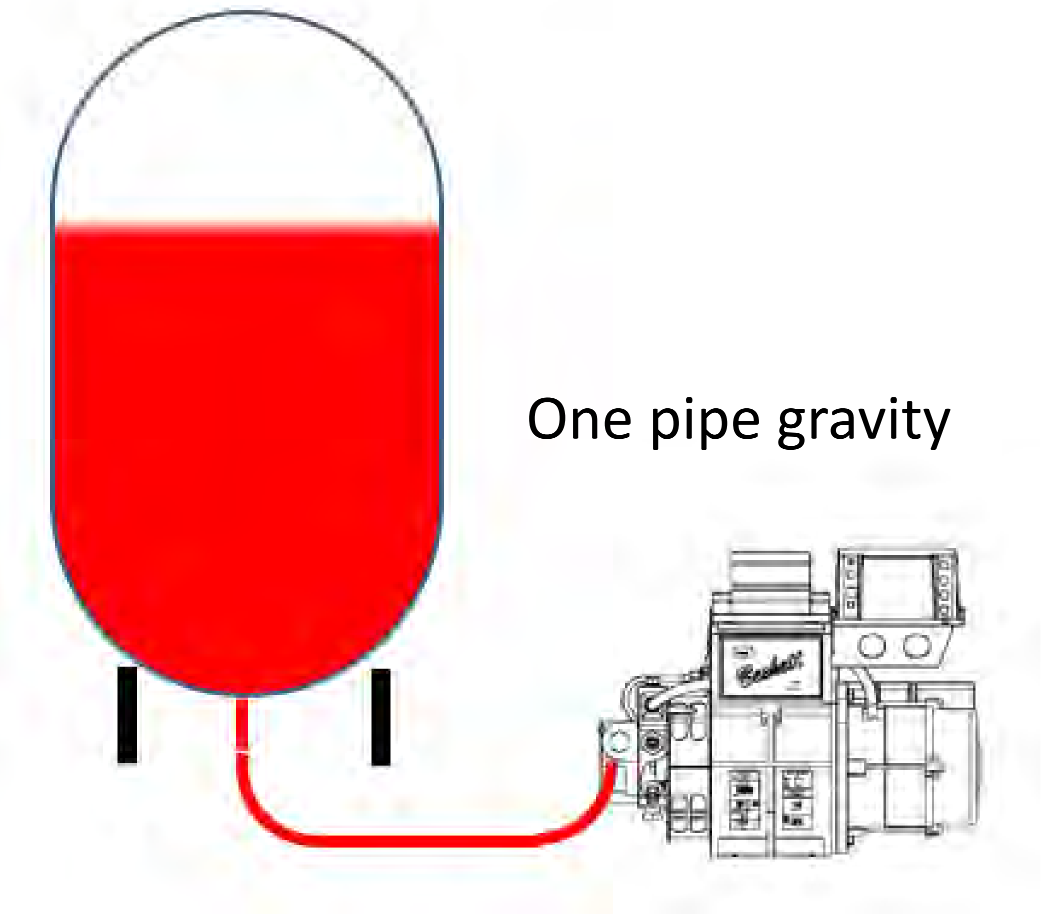
The full capacity of the gearset is pumped from the tank, what's not burned is returned to the tank.



One-Pipe Systems

- Most of today's Oilheat systems require only one fuel line to bring the fuel from the tank to the burner

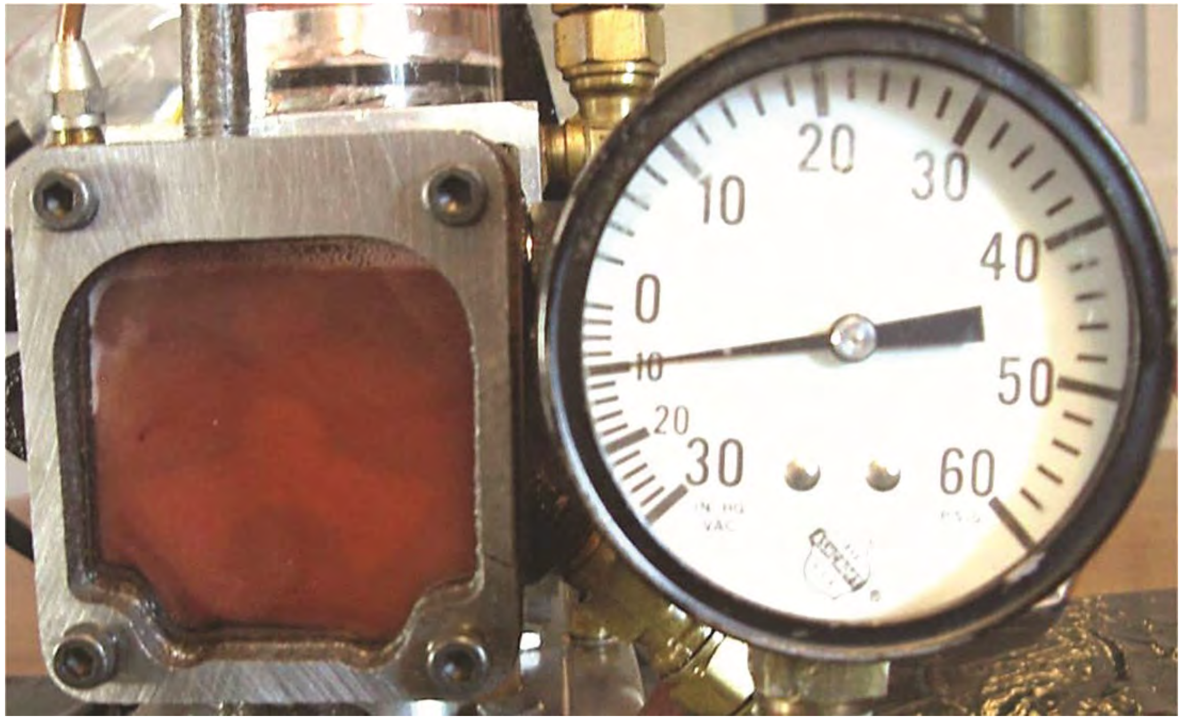
- Single stage fuel units operate at a maximum of 6" of vacuum on a one pipe system. They can create much higher vacuum, but the fuel will begin to foam over 6"Hg



One pipe gravity

One-Pipe Systems

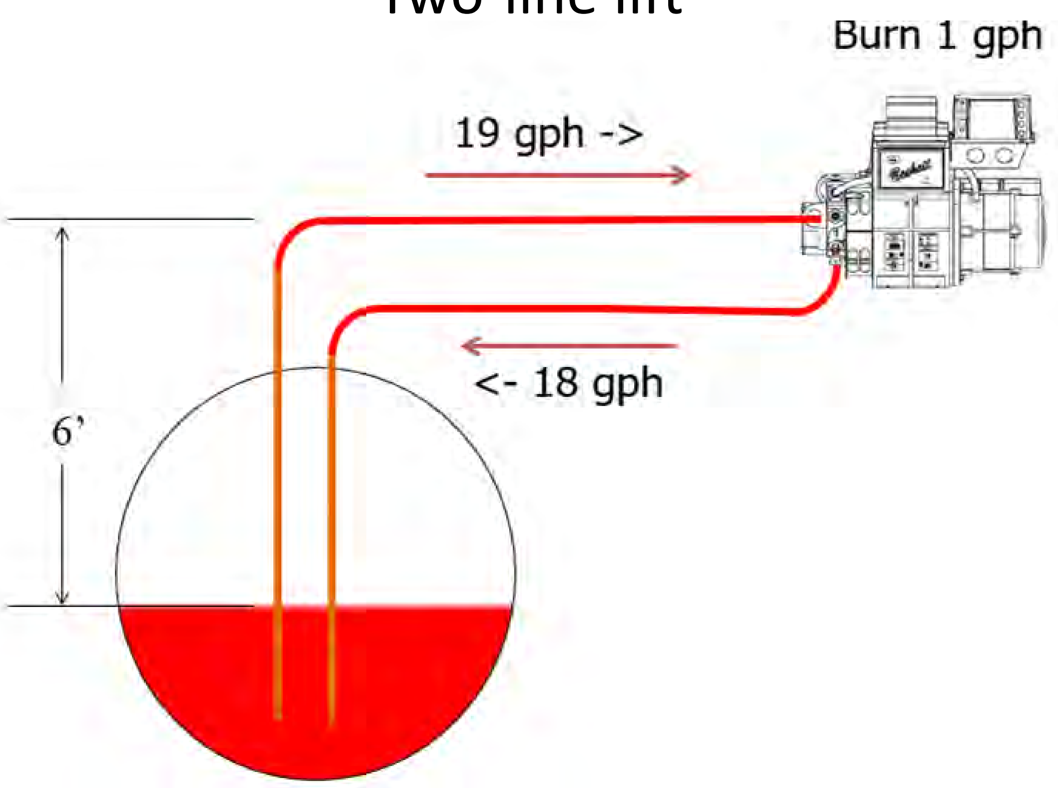
When foamy fuel collects in a single stage fuel unit, it is sent directly to the nozzle, causing unstable atomization, an after-burn, smoke & soot.



Two-Pipe Systems

- If more than 6" of vacuum is required, a single stage fuel unit can be piped with a return line to the tank
- If a single stage fuel unit on a two-pipe system has an operating vacuum over 12", unstable flame conditions, a carboned-up firing assembly, an after fire, and/or a noisy flame may result

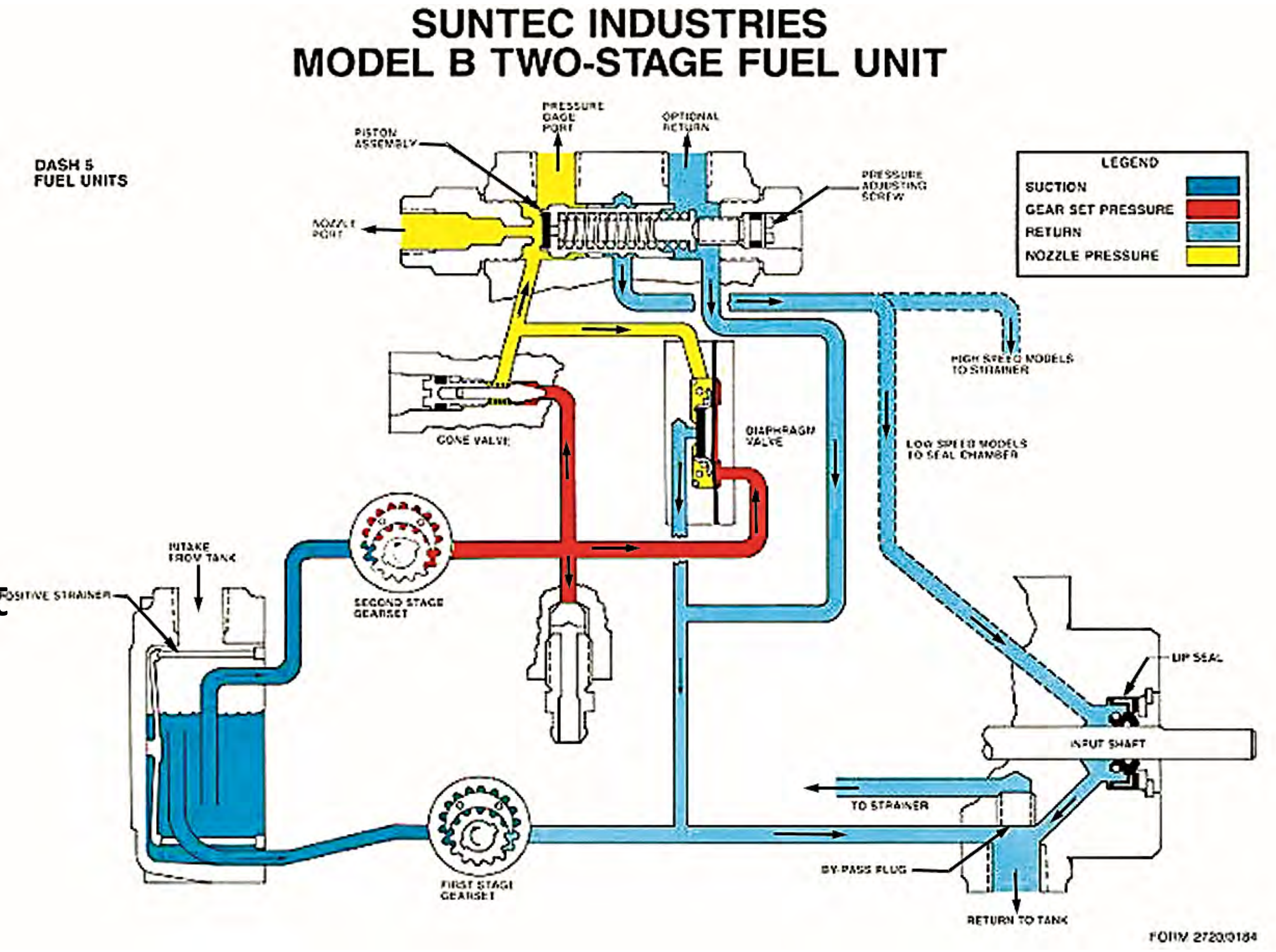
Two-line lift



Two-Stage Fuel Unit

- If more than 12" of vacuum is required, a two-stage fuel unit, designed to correct the foaming fuel problem by sending foam back to the tank, can be installed

- The two-stage fuel unit has two sets of gears. The first set purges the unit of air and supplies an uninterrupted flow of fuel to the second stage which pressurizes the fuel to the nozzle

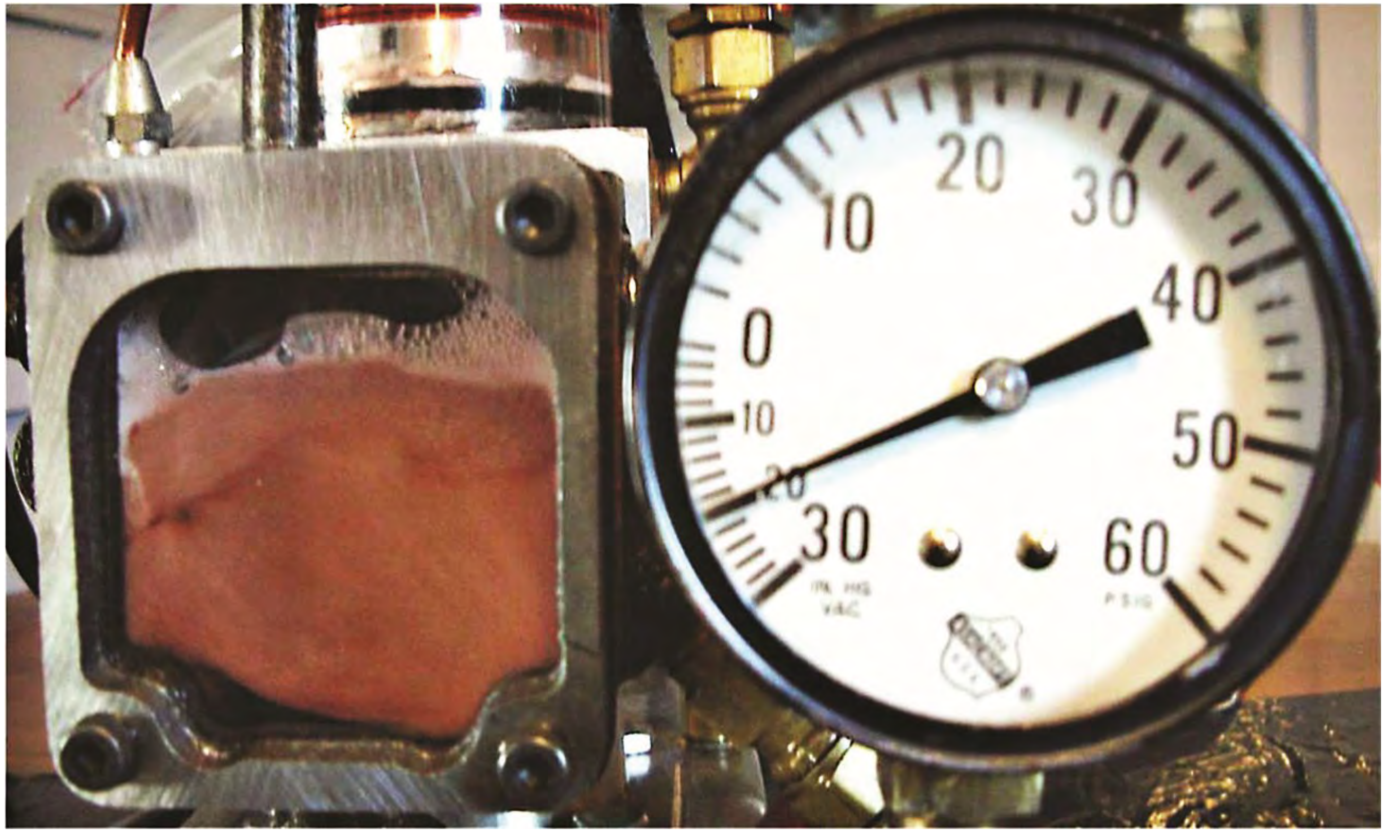


Internal diagram of 2 stage fuel unit

Two-Stage Fuel Unit

- In 2 pipe systems with a two-stage fuel unit, it is not advisable to exceed 17" of vacuum

- At such high vacuum, the use of a fuel de-aerator is advised



Two-Pipe Systems

2-pipe systems should be avoided whenever possible because:

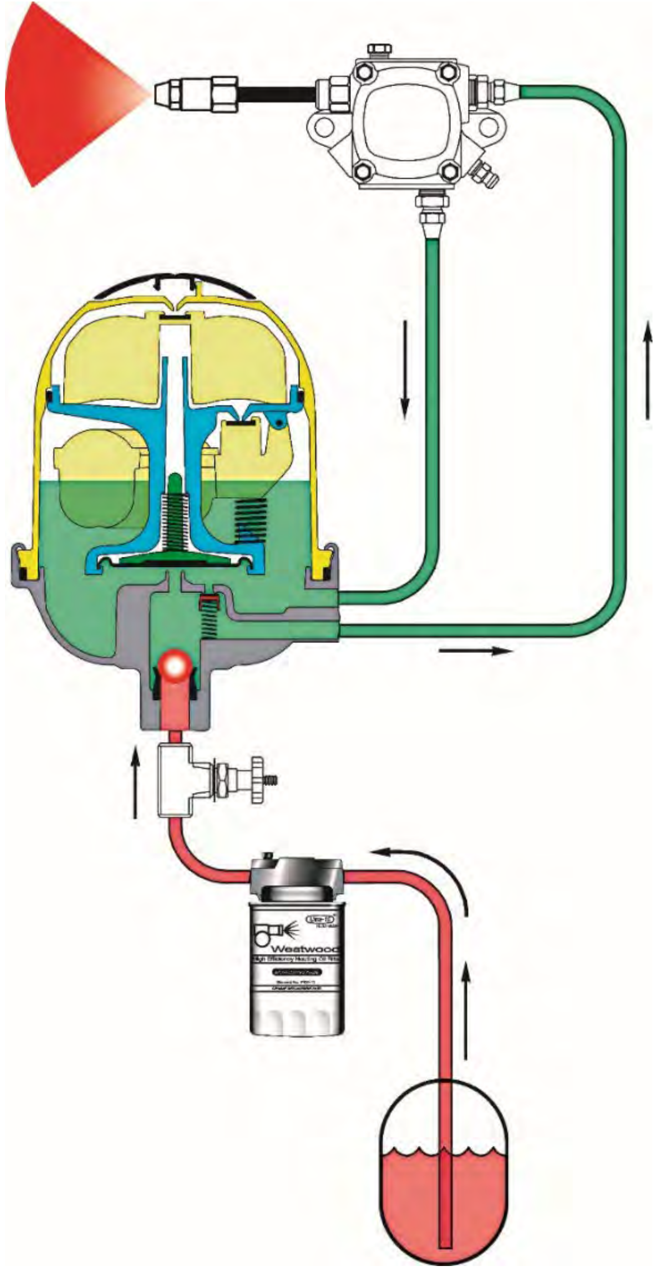
- Filters become clogged faster than with one pipe systems
- If a suction line develops a leak, the burner malfunctions but when a return line leaks there are no symptoms except an oil spill
- They facilitate sludge formation

Deaerators

Deaerators are a good alternative to 2-pipe systems, they are installed as a combination of a 1-pipe and 2-pipe system.

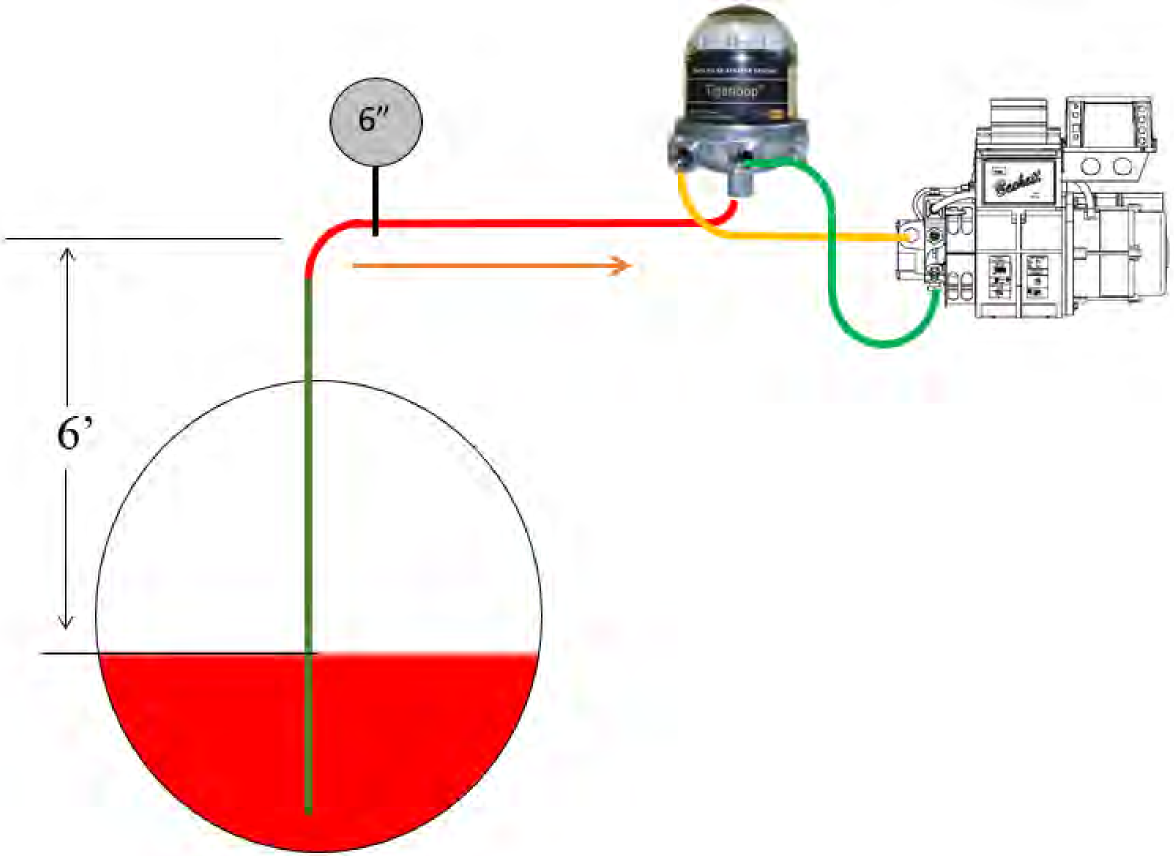
They have a 1-pipe connection to the tank and a 2-pipe connection to the burner.

They eliminate the liability of a return line leak, greatly reduce the amount of fuel circulating from the tank to the burner and extend the life of fuel filters.



Deaerators

Fuel de-aerators have been developed to eliminate air problems caused by excessive vacuum.



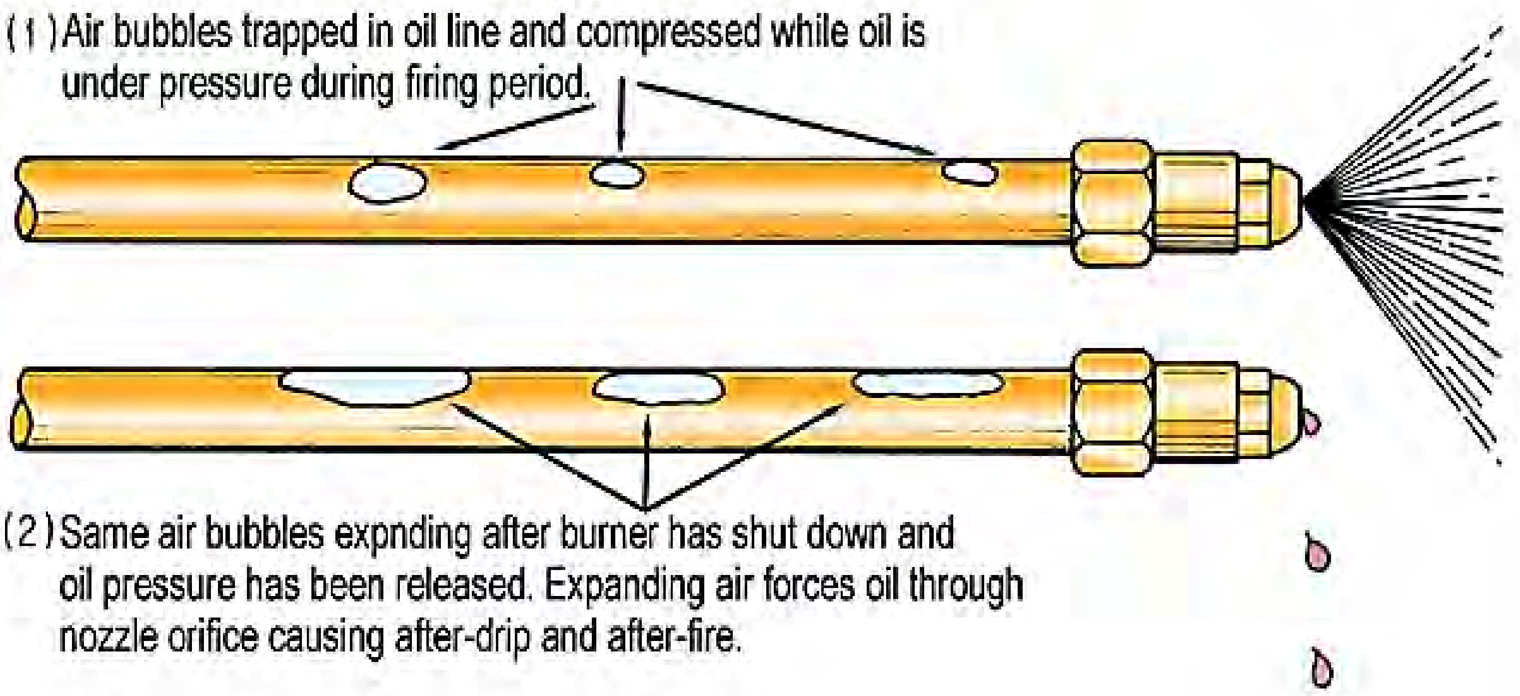
Deaerators

Many service experts recommend that de-aerators be installed on all systems in which the burner is above the fuel supply and anytime the fuel lines are run overhead from a tank to the burner

Deaerators

De-aerators correct problems caused by excessive vacuum:

- Poor atomization
- Smoke & soot
- After-burn



How De-aerators Work

1. Fuel is drawn from the tank to the de-aerator though a single line so that only the amount of fuel that is burned is replaced from the tank.

2. The surplus fuel is pumped back from the fuel unit to the de-aerator.

3. A surplus fuel cycles through the de-aerator loop, it absorbs heat from friction and its surroundings, reducing cold fuel problems.

Fuel Unit Limitations

- NFPA 31 limits shaft seal pressure to 3 PSI, although most fuel units are rated at 10 PSI by their manufacturers
- Single stage fuel units should not be operated beyond 6” of vacuum on 1-pipe systems or above 10” of vacuum on 2-pipe systems
- Although manufacturers rate two-stage fuel units at up to 17” of vacuum, NORA recommends they should operate below 12” to minimize noise & foaming.

Integral Solenoid Valves

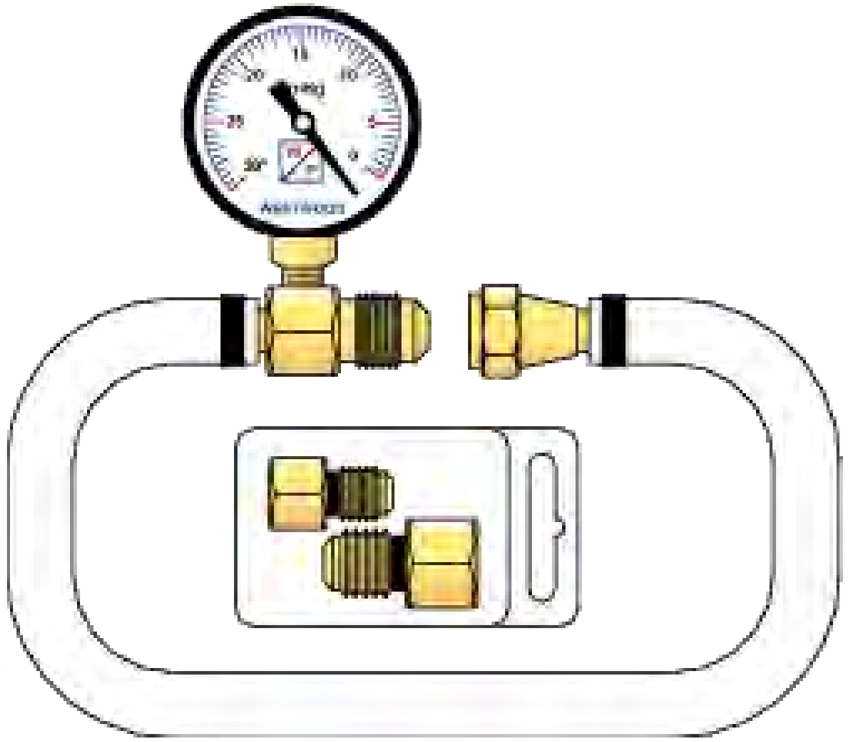
- When the burner shuts off, it is important to shut the fuel off quickly and completely
- While the piston does this well, most fuel units currently in production incorporate an integral solenoid valve to enable a clean, quick cut-off of fuel
- These can also be used to enable cleaner start-ups

Integral Solenoid Valves

Fuel units with solenoids require a delay period before being energized to allow the burner to come up to speed. This will be described in the primary control section of this program.

Servicing and Testing the Fuel Unit

Tools of the trade



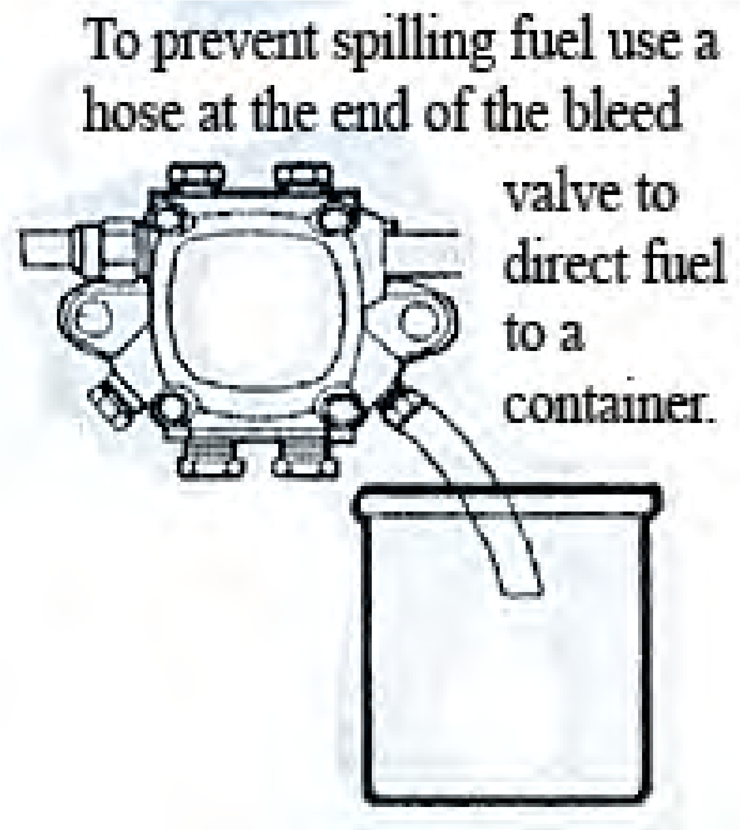
Bleeding Fuel Units


Figure 4-14: Bleed valve

When air enters a one-pipe system it must be bled from the fuel unit to restore the burner to proper operation.

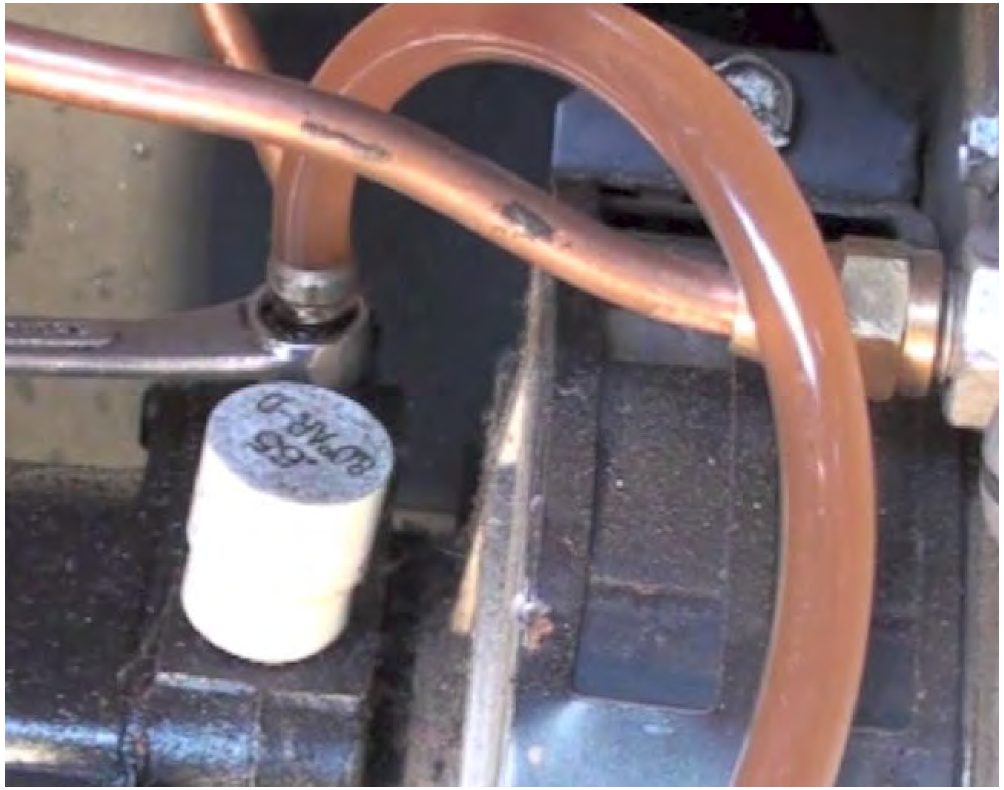
Fuel units are equipped with bleed valves to facilitate bleeding.

Bleeding Fuel Units



- Attach a small hose to the bleed valve and connect the other end to a suitable container
- Open the valve one turn clockwise
- Run the burner until foam and air bubbles stop and clear fuel flows for 15 seconds, then close the valve.

Bleeding Fuel Units



Manual venting of air is normally not necessary in a two-pipe system or systems with de-aerators, but it may be done faster if the bleeder valve is opened to help expel air.

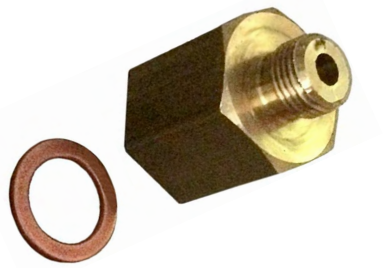
Field Pressure and Cutoff tests

Two of the most important service checks for a fuel unit are:

- Output pressure check
- Cutoff pressure check

These checks can be made on most fuel units by inserting a pressure gauge into the nozzle port, with Riello burners a gauge adapter is necessary.

Pressure gauge with 3/16 flare adapter



Riello gauge adapter

Pressure test kit

Output Pressure Check

1. Attach a pressure gauge to the end of the nozzle line and operate the burner.

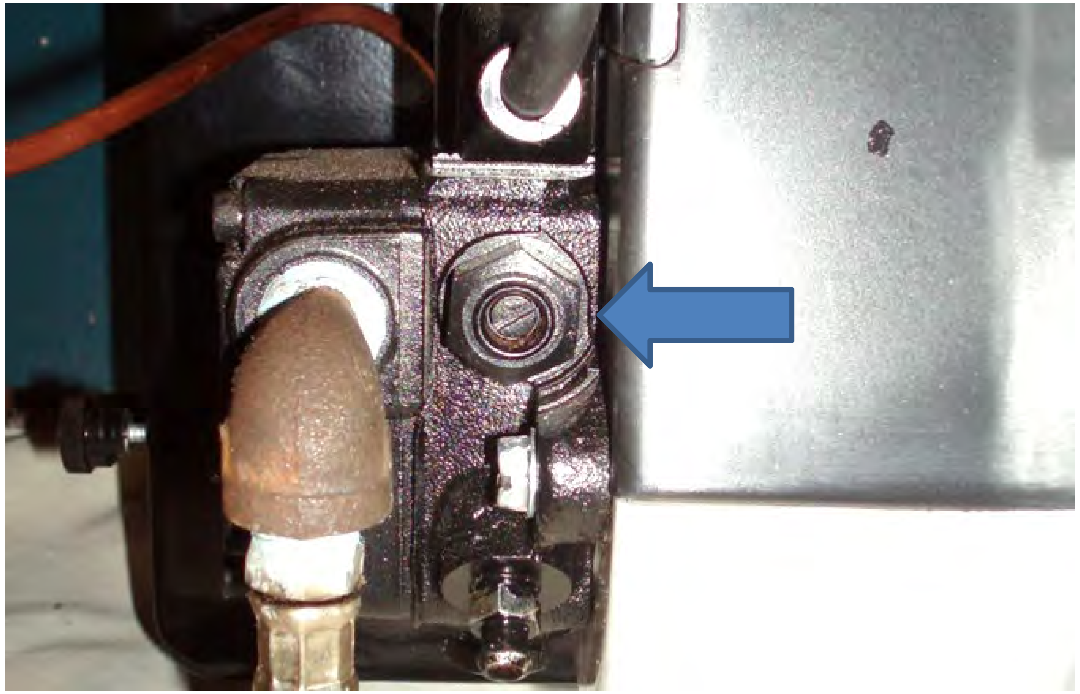
Output Pressure Check

2. Set correct pump pressure found in OEM guide or on burner housing.

Appliance Model	Basic Burner Setup Information						
	Burner Type	Head Type	Static Plate/ Stop Screw	Nozzle Type	Low Fire Rate Baffle	Std. Air Tube	Pump Pressure
V-83	AFG	L1	3-3/8"	0.85 X 60°A	—	AFG70MMAQN	140
V-83S	AFG	L1	3-3/8"	0.60 X 60°A	5880	AFG70MMAQN	140
V-84	AFG	V1-0	2-3/4"	1.10 X 60°B (H)	—	AFG70MDAQN	140
V-84	AFG	V1-0	2-3/4"	1.00 X 60°B (H)	—	AFG70MDAQN	140
V-84S	AFG	V1-0	2-3/4"	0.85 X 60°A	—	AFG70MDAQN	140
V-85	AFG	V1-2	2-3/4"	1.35 X 60°B	—	AFG70MDASN	140
V-85S	AFG	V1-0	2-3/4"	1.10 X 60°B	—	AFG70MDASN	140
V-86	AFG	V1-3	2-3/4"	1.50 X 45°B	—	AFG70MDASN	160

Output Pressure Check

3. Turn the pressure regulator adjusting screw clockwise until the pressure increases 40 to 50 psi(but not above 200 psi).



If the fuel unit cannot achieve at least 150 psi, the gears or regulating valve are worn out and the fuel unit should be replaced.

After confirming that the pressure can be raised to an appropriate level, back off the pressure adjusting screw to the pressure listed by the manufacturer.

Output Pressure Check

Fluctuating pressure leads to combustion problems - possible causes:

- ✓ Partially clogged filter, strainer or suction line
- ✓ Air in fuel unit – bad gasket or loose cover, suction leak
- ✓ Excessive vacuum
- ✓ Slipping coupling

Burner couplings can wear and slip around pump or motor shafts causing fluctuations.

Cutoff Pressure Check

- Once the operating pressure test is completed, leave the gauge in the nozzle port
- Run the burner until the fuel unit reaches its pressure setting & turn the burner off
- The pressure should drop quickly by 10 to 20% and then hold that pressure

If pressure doesn't hold, internal seals are failing, and the fuel unit should be replaced.

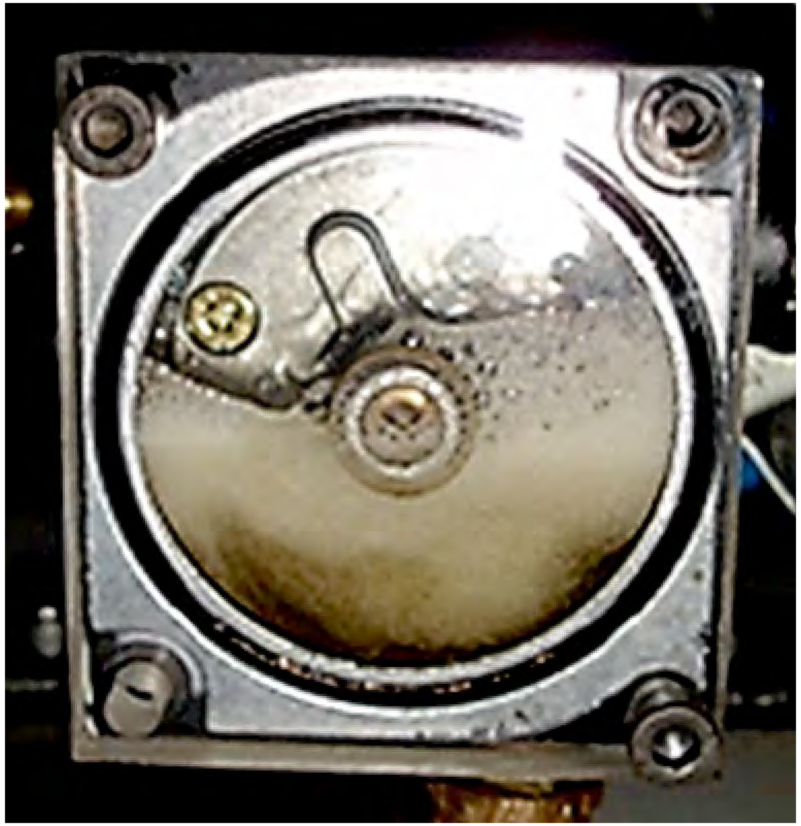
Field Vacuum Check

There are several situations that can indicate either an air leak in the fuel system or outgassing due to high vacuum.

If there is no obvious cause for the situations listed on the next slide, an operating vacuum test should be conducted to diagnose the problem.

Field Vacuum Check

Outgassing and suction lines leaks cause many problems, among them are:



- Pulsating fuel unit pressure
- Fuel unit noise
- Delayed ignition
- Poor flame retention
- Noisy fire
- Loss of flame during run cycle
- After-burn
- Burner won’t start after long shut-down (overnight)

Checking System Vacuum

- Before starting, be sure that a *clean* filer and *strainer* are in place

NO!

YES!

- Calculate what the vacuum should be, test to see what it is, and compare the two

- For the calculation – remember the "rules of thumb" (which are?)

Checking System Vacuum

Securely insert a vacuum gauge into an unused inlet port, then:

1. Run the burner.

2. Bleed the fuel unit.

3. Read the vacuum.

4. The gauge reading should approximate the calculated vacuum.

Checking System Vacuum

If the gauge reading is substantially ***above*** the calculated vacuum, there is a restriction in the fuel supply:

- Plugged fuel filter
- Kinked or plugged suction line
- Partially closed fuel supply valve
- Check or foot valve inoperative or sticking

Checking System Vacuum

If THE GAUGE reading is significantly ***below*** the calculated vacuum:

- Clogged fuel unit strainer (if not previously checked)
- Air leak in the suction line or suction line fittings
- A suction leak around strainer chamber cover plate and gasket
- Defective fuel unit

Vacuum Test

If the operating vacuum is significantly less than the calculated figure, determine if the fuel unit itself or if the fittings up to the shut off valve are leaking by performing a Vacuum Test.

The test is slightly different for single VS two pipe systems.

Vacuum Test – 1-Pipe System

1. Remove the inlet line from the fuel unit, fill the unit with fuel and install a vacuum gauge in the inlet port.
2. Turn the burner on and open the bleeder.
3. When the vacuum reaches 15", close the bleeder.
4. Turn the burner off, the fuel unit should hold the vacuum level for 5 minutes.

If the fuel unit can't attain 15", or hold that vacuum for 5 minutes, it should be replaced.

Vacuum Test – 2-Pipe System

1. Remove the inlet line from the fuel unit, fill the unit with fuel and install a vacuum gauge in the inlet port.
2. Remove the return line and it's fitting. Apply pipe dope to a fuel unit plug and put aside.
3. Turn the burner on.
4. When the vacuum reaches 15", insert the plug into the return port.
5. Turn the burner off, the fuel unit should hold the vacuum level for 5 minutes.

If the fuel unit can't attain 15" or hold that vacuum for 5 minutes, it should be replaced.

Vacuum Test

If the vacuum holds on either system, the fuel unit is ***NOT*** the problem.

1. Remove the vacuum gauge and reconnect all fittings and fuel lines.
2. Insert the vacuum gauge into an unused suction port.
3. Shut off the valve at the tank OR at the wall where the suction line enters the building and do the test again.
4. If the vacuum holds, the fuel unit and the suction line between the fuel unit and the valve are NOT leaking – the leak is between the valve and the tank.

Clearing Plugged Fuel Lines

NORA recommends that fuel lines and tanks should not be pressurized during service.

This includes blowing out the lines with a CO_2 cartridge.

To clean a plugged fuel line, suck the blockage out using a “push-pull” (aka hand) pump.

SELECTION OF REPLACEMENT FUEL UNITS

Replace failed fuel units with the manufacturer's specified model.

Consider the following:

- Shaft rotation*
- Rotational speed
- Nozzle discharge port location*
- Shaft sizes
- Installation requirements

*NOTE: these are determined while looking at the shaft, ***not*** the label.

Visual Test for Air in Fuel Lines

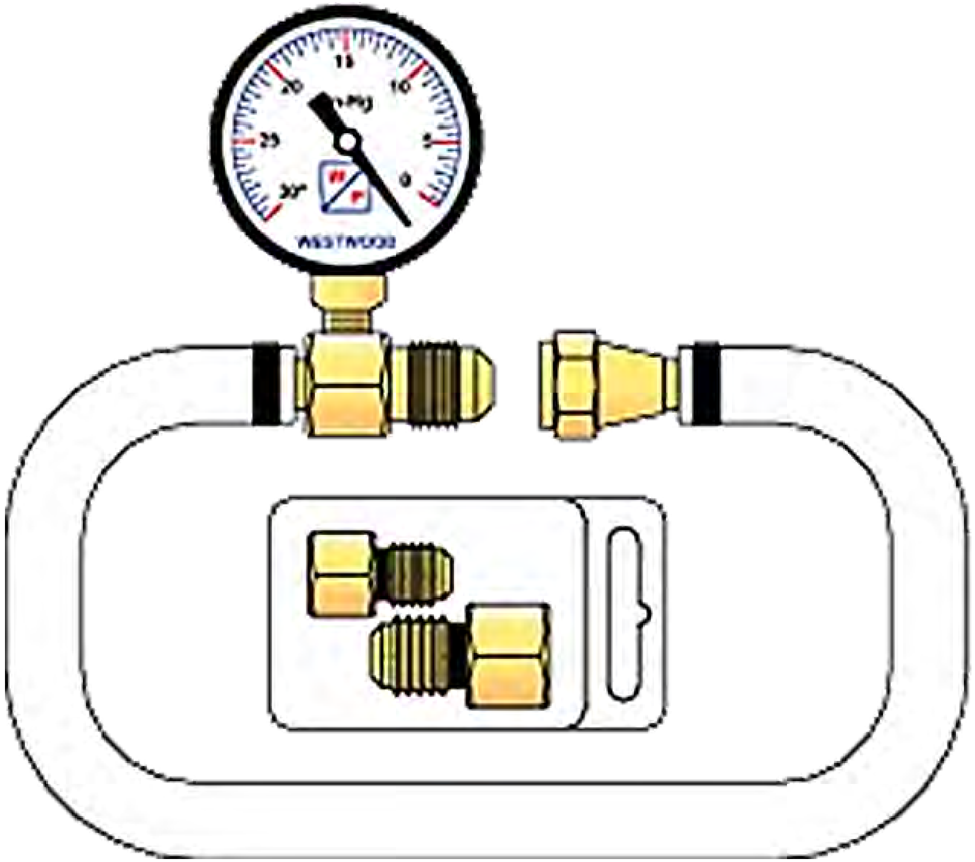
- When an air leak is detected in the suction line, the source must be found.
- The first step is to tighten all fittings in the line and tighten unused port plugs in the fuel unit.
- Be sure there are no compression fittings in the line.
- Check the filter cover and gaskets to verify that there are good gaskets and the bolts are properly tightened.

Visual Test for Air in Fuel Lines

If none of this eliminates the problem, confirm that there is a leak and pinpoint its source by using a vacuum gauge with plastic tubing.

Install the device between the fuel unit shut off valve and the suction line.

Run the unit, bleed all air from the line and look for bubbles……



Visual Test for Air in Fuel Lines

- If bubbles appear in the plastic tubing, there is a leak.
- One at a time, heading toward the tank, coat each fitting with lithium grease which will temporarily seal the leak.
- When the leaking fitting is covered, the air bubbles will disappear.
- Repair the leaking fittings & clean the grease off all fittings.

Selection of Replacement Fuel Units

Failed fuel units should be replaced with the manufacturers specified model. Typically, this is the same as the model as that being replaced.

- When replacing fuel units consider:
- Shaft rotation
- Rotational speed
- Nozzle discharge port location
- Shaft sizes

Selection of Replacement Fuel Units

Shaft rotation

Fuel units are designed for either clockwise or counterclockwise rotation and rotational direction is shown on the unit identification plate.

Both units rotate clockwise
Note: When facing the **<u>shaft,</u>** clockwise rotation is to the right, counterclockwise is to the left.

Selection of Replacement Fuel Units

Rotational Speed

Most residential burners operate at 3450 RPM, some older burners operate at 1725 RPM

The motor and the fuel must both operate at the same speed,
but in opposite directions.

Selection of Replacement Fuel Units

Nozzle discharge port location

Fuel units are built with either right- or left-hand nozzle ports. As with shaft rotation, the port location is determined while facing the ***shaft.***

Nozzle left

Nozzle right

Selection of Replacement Fuel Units

Shaft sizes

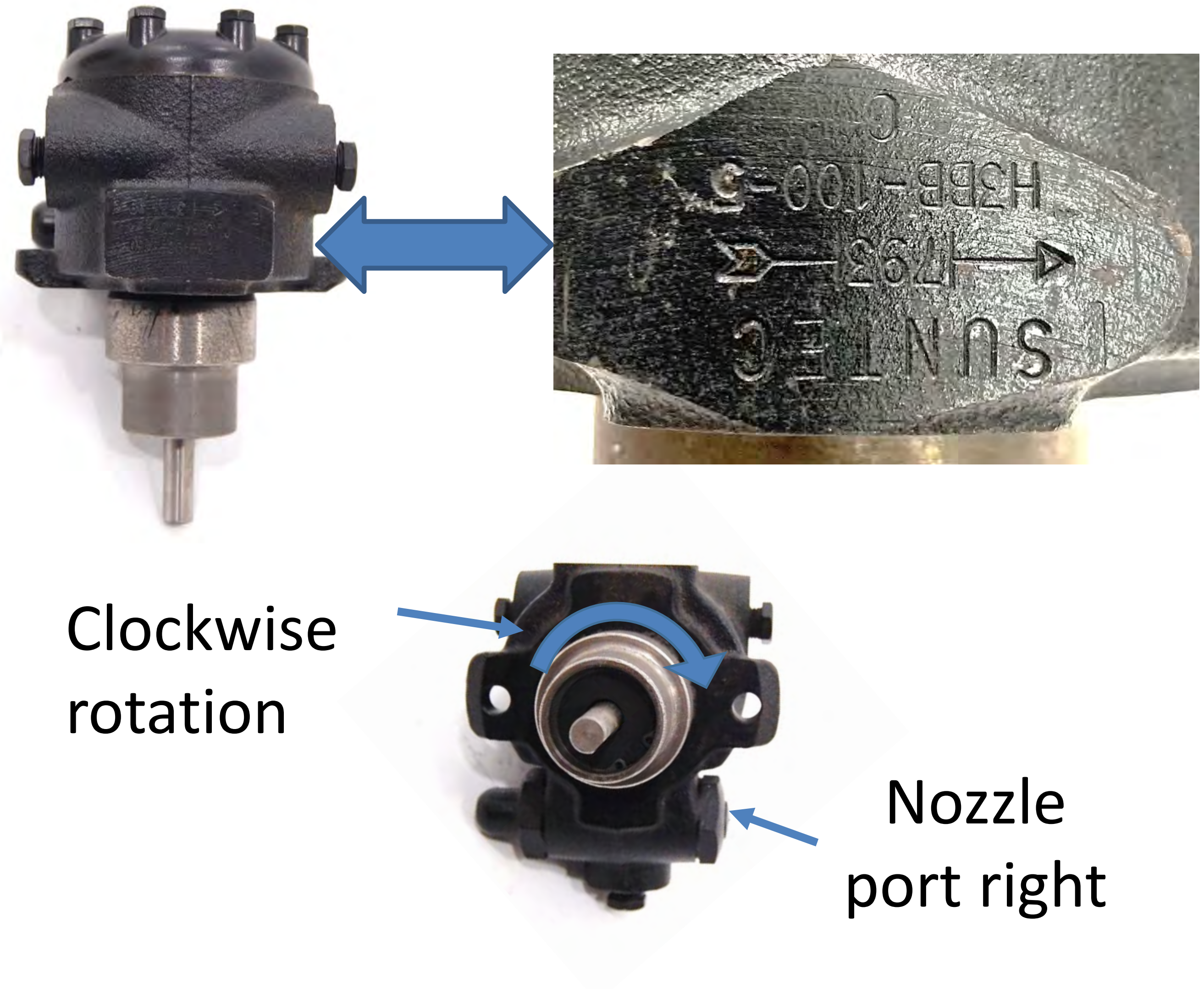
Most fuel units have either a 5/16" shaft or a 7/16 " shaft.

The smaller shaft can be “bushed up” for substitute replacement.

Selection of Replacement Fuel Units

Older burners

- Typically ran at 1725 RPM and had various rotations and nozzle port locations
- The fuel unit configuration is determined by viewing from the shaft end
- The fuel unit shown here would be a "clockwise, nozzle right" model



Selection of Replacement Fuel Units

Installation requirements

Be sure the replacement fuel unit is properly mounted and in-line with the burner coupling.

If the coupling has hex screws, first tighten the fuel unit mounting bolts, then securely tighten the hex screw to the motor shaft.

Strainers

- Must be cleaned or replaced periodically
- Whenever the cover is taken off to access the strainer, the gasket MUST be completely scraped off and replaced
- All cover bolts must be tightened evenly after reinstalling

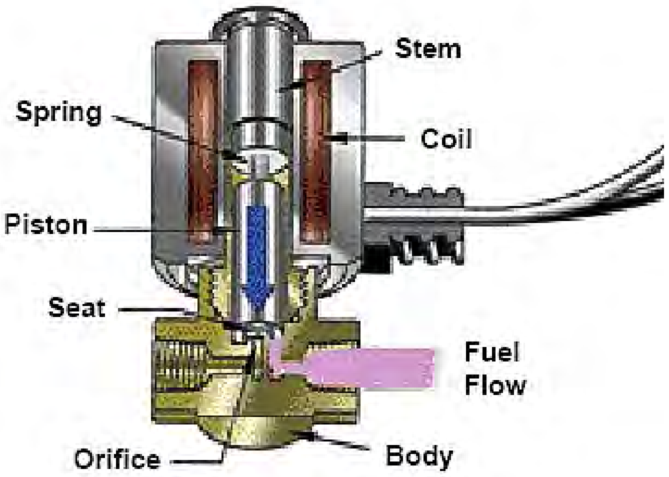
Solenoid Valves

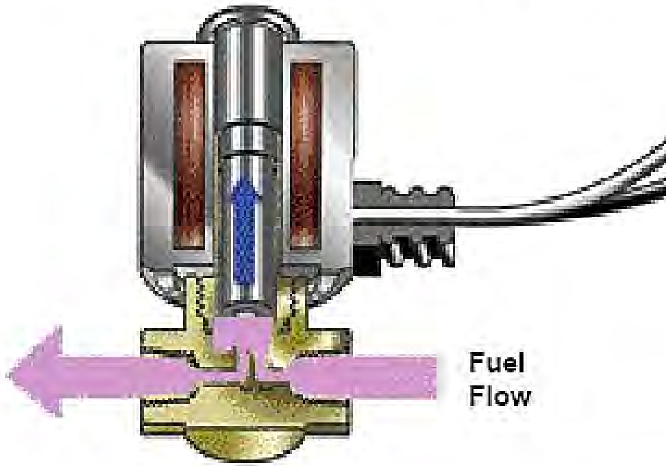
Most fuel units manufactured since 2000 include integral solenoid valves.

If a fuel unit does not include an internal solenoid, an external solenoid may be present on the system or added to provide the features and benefits that solenoid valves provide.

External Solenoid Valves

- Solenoid valves enable cleaner burner start-ups by preventing the flow of fuel until the burner is generating full air flow and full fuel pressure
- They also enable cleaner burner shutdowns by immediately shutting off the fuel supply before the pressure regulating valve closes
- Installed in the nozzle port of the fuel unit





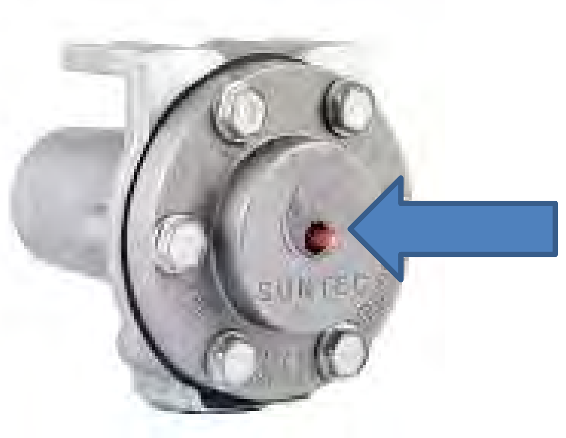
Oil Safety Valves

When the tank is above the burner, some codes require (and NORA recommends) an automatic valve that will break the siphon if a leak develops.

Oil safety valves protect against line leaks & also protect the fuel unit against excess inlet pressure.

When the burner starts the vacuum opens the valve.

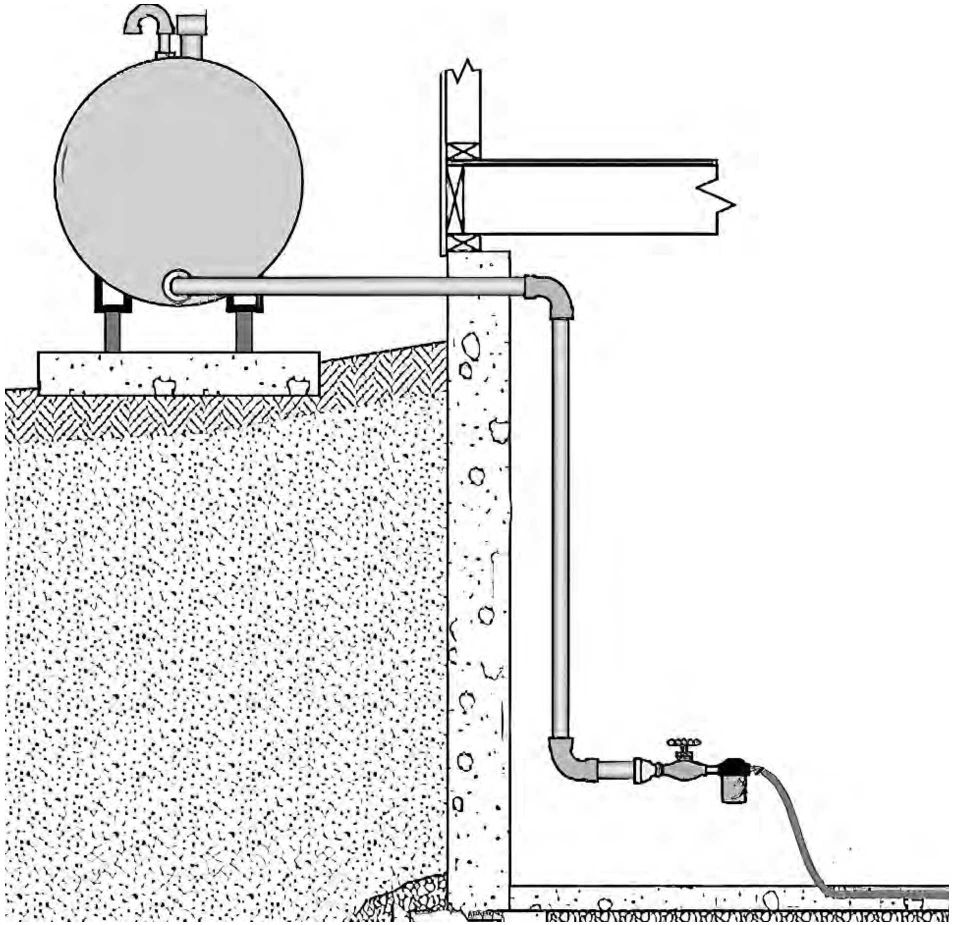
When the burner shuts down the valve will stay open unless there is a leak between the valve and the burner. Some valves have a red stem that sticks out if a loss of vacuum has occurred.



Oil Safety Valves

If the top of the tank is more than 8' above the fuel unit, which is common for an outside above-ground tank at a house that has the heating system in the basement, an oil safety valve MUST be installed.

The NFPA rating for inlet pressure is only 3 PSI, which is equivalent to a distance of approximately 8' between the top of a standard tank and the fuel unit.



Thermal Safety Valves

Also known as "fusible link safety shutoff valves" these are required by NFPA to be installed:

- As close as practical to the fuel tank (indoor tanks)
- Where the fuel line enters the building for an outdoor tank
- Within 6 in. of the filter, on the tank side
- At the burner

Check Valves

Properly installed heating systems do NOT require check valves or foot valves for proper operation.

Check valves prevent fuel flow back to the tank through the suction line.

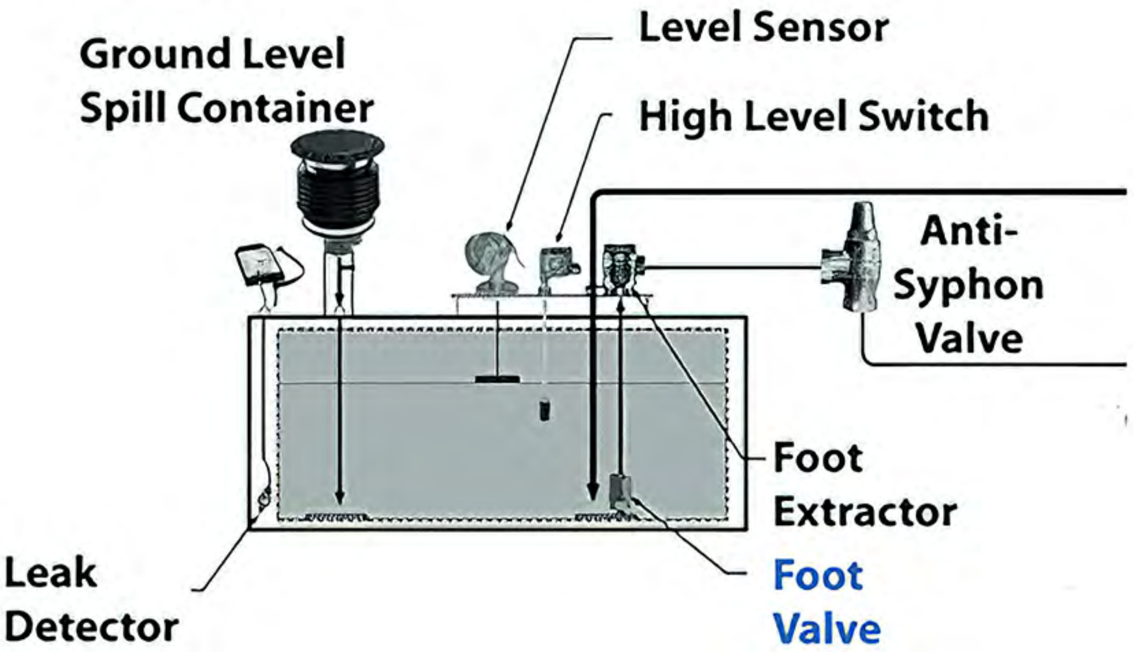
In cases of thermal expansion, inlet line pressure may increase, and the high pressure can result in shaft seal damage.

Foot Valves

Foot valves are check valves installed on the end of the suction line in underground tanks.

They were common on older installations, and some are still in use.

It is not unusual for them to get stuck in the closed position, preventing fuel flow.



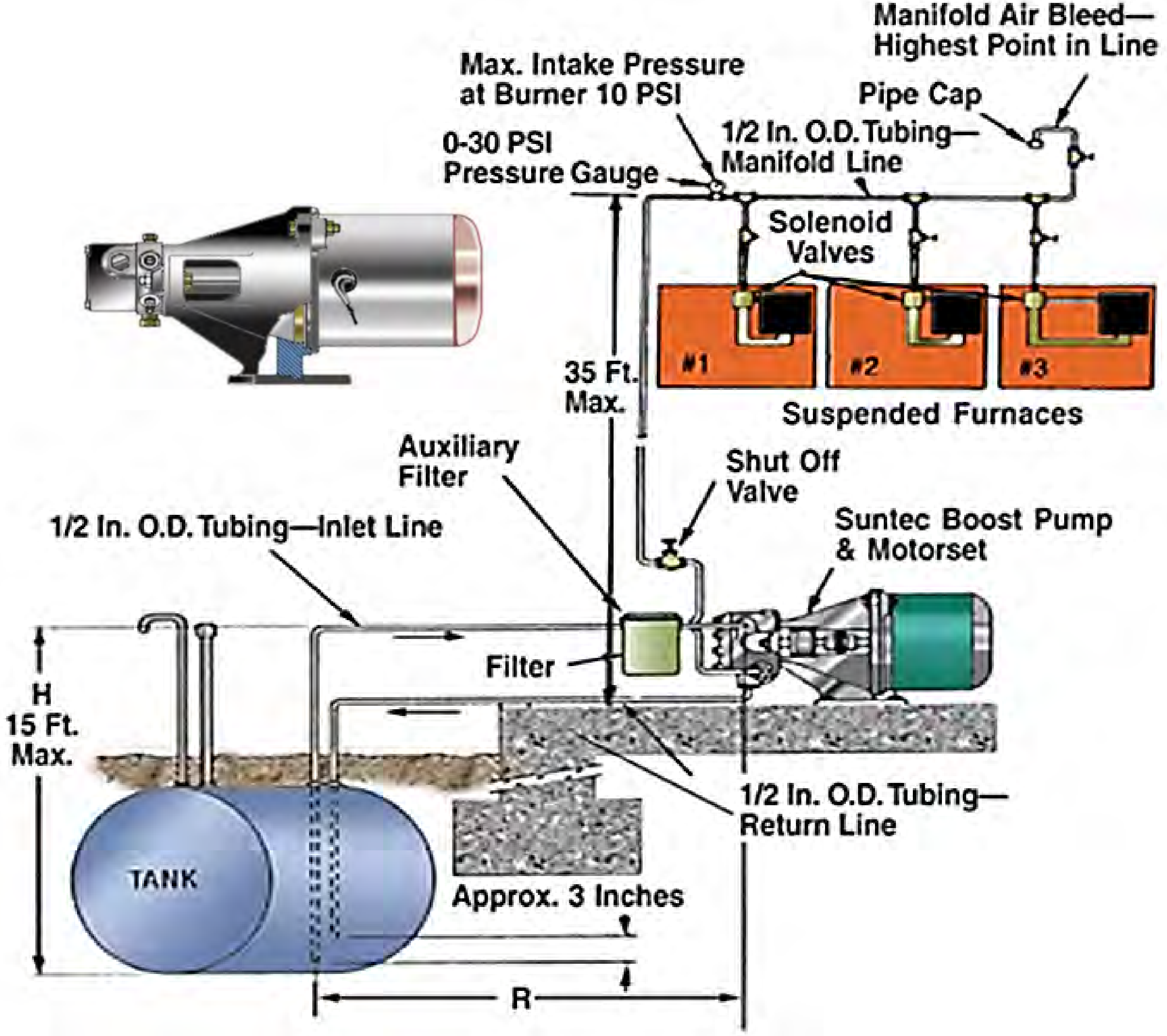
Fuel Oil Storage Tank

Booster Fuel Units

Booster fuel units are normally used to assure an adequate supply of fuel to one or more overhead furnaces.

They are usually capable of lifting fuel 15 feet and supplying that fuel up to 35 feet above the fuel unit.

They can be used as continuous or intermittent duty transfer units for filling a small overhead feeder tank or for other similar purposes.



Noise Problems In Fuel Units, Lines or Tanks

Noise generated as a result of fuel unit operation, or noise transmitted by fuel lines, is annoying to the customer and should be corrected.

Fuel unit noise: In addition to noise created by worn internal parts, misalignment of the burner coupling, or loose bolts may be the source of noise problems. All fittings and bolts should be tightened securely.

Fuel line noise: This is often the result of improperly fastened lines which vibrate against surrounding objects such as sheet metal appliance covers, duct work, etc. If the suction and return lines touch each other they can also create line noise .

Noise Problems In Fuel Units, Lines or Tanks

Tank Noise: This is not a common source of complaints. The cause can normally be traced back to transmission of noise by the fuel lines.

A commonly overlooked source of noise is improper installation of a return line. The end of a return line should be located approximately 3" above the suction line.

This prevents air from the return line from entering the suction line while also eliminating the noise caused by fuel returning to the tank.

Potential Leaks in Fuel Lines

Leaking fuel lines can cause serious problems, be aware of the following symptoms:

- Air bound fuel unit (loss of prime)
- Poor cut-off
- Noisy operation
- Loss of flame retention (flame pulsates on the end cone)
- Rough starts or shutdowns
- Fuel unit whine and pressure fluctuation
- After-drip

Review Questions:

- What does a fuel unit do?
- Why and how is vacuum created in a system?
- What do vacuum gauge readings mean?
- How do you adjust the fuel unit pressure to desired setting
- What are the advantages and disadvantages of 1-pipe and 2-pipe systems?

Review Questions:

Continued…

- What are the steps to perform a field pressure test, field vacuum test and a pump vacuum test?
- What are the important things to consider when replacing a fuel unit?
- What is the purpose of the two most common valves on fuel lines?
- What are signs of a problem in a fuel unit, line, or tank?

End Chapter 4

NORA Technician Certification

Review

Bob O’Brien, NORA Director of Education

Chapter 5

Nozzles & Chambers

At the end of this lesson, you will be able to:

- Describe the three things a nozzle does
- Describe what happens to the spray when you increase the pressure
- Explain when you would install a specialty nozzle.
- Explain what you can do to improve nozzle performance

Nozzles

Proper nozzle selection is key to clean, efficient combustion.

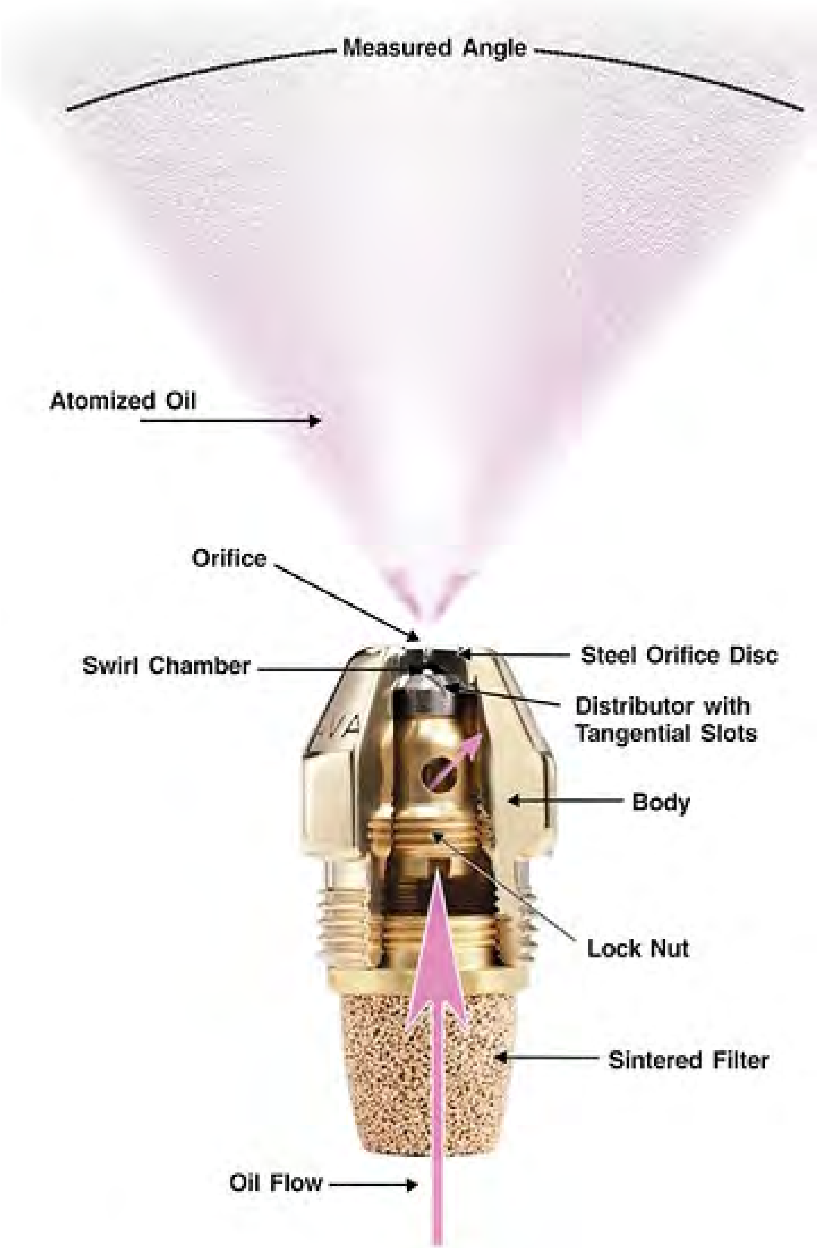
Installing nozzles with the proper firing rate, right spray angle, and the appropriate spray pattern ensures reliable combustion.

Construction

- Very close tolerance (+ or – approx. 5%)
- Atomize and meter fuel in spray patters and angles required by appliance
- Made of stainless steel or stainless steel & brass to withstand heat, pressure, etc.

Functions

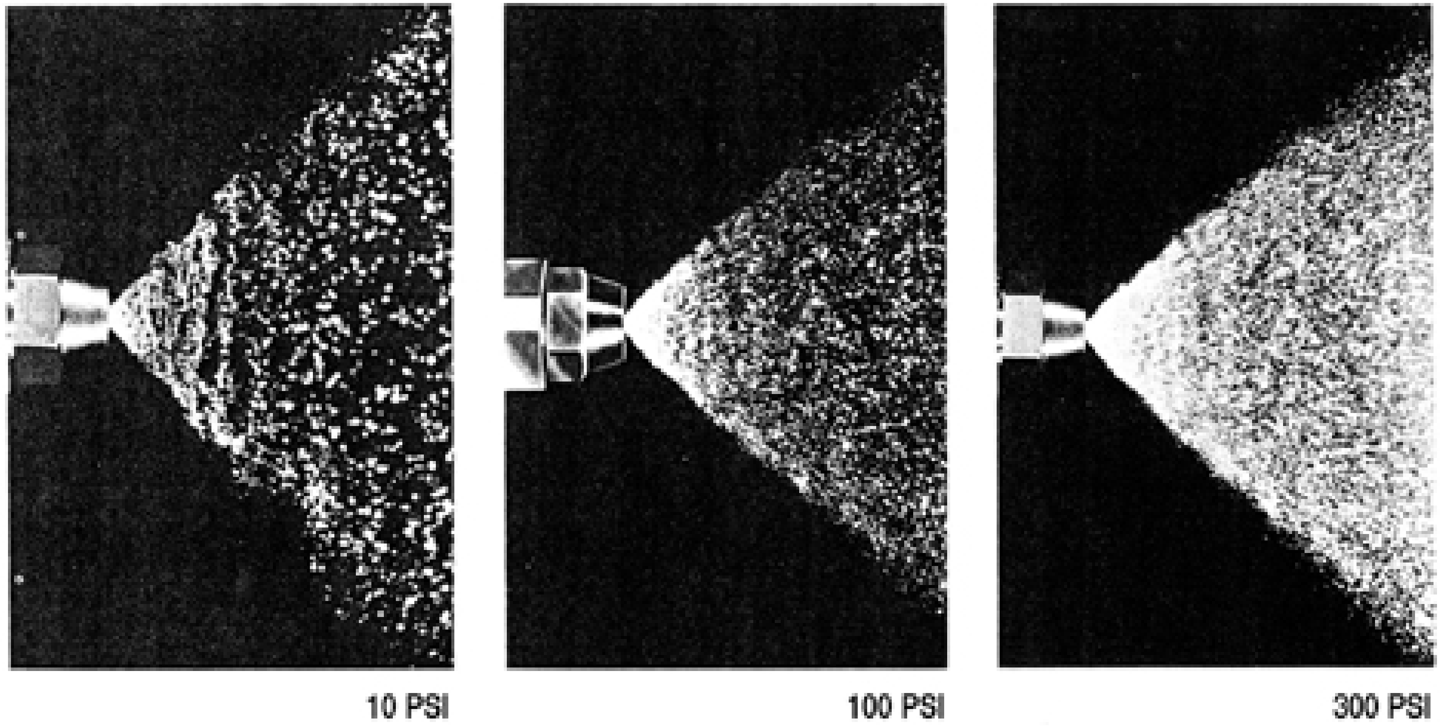
1. Atomizes – breaks fuel down into tiny droplets.
2. Meters – delivers a fixed amount of fuel, rated in gph @ 100 psi.
3. Patterns – delivers fuel in a uniform spray pattern and angle best suited to burner and combustion area.



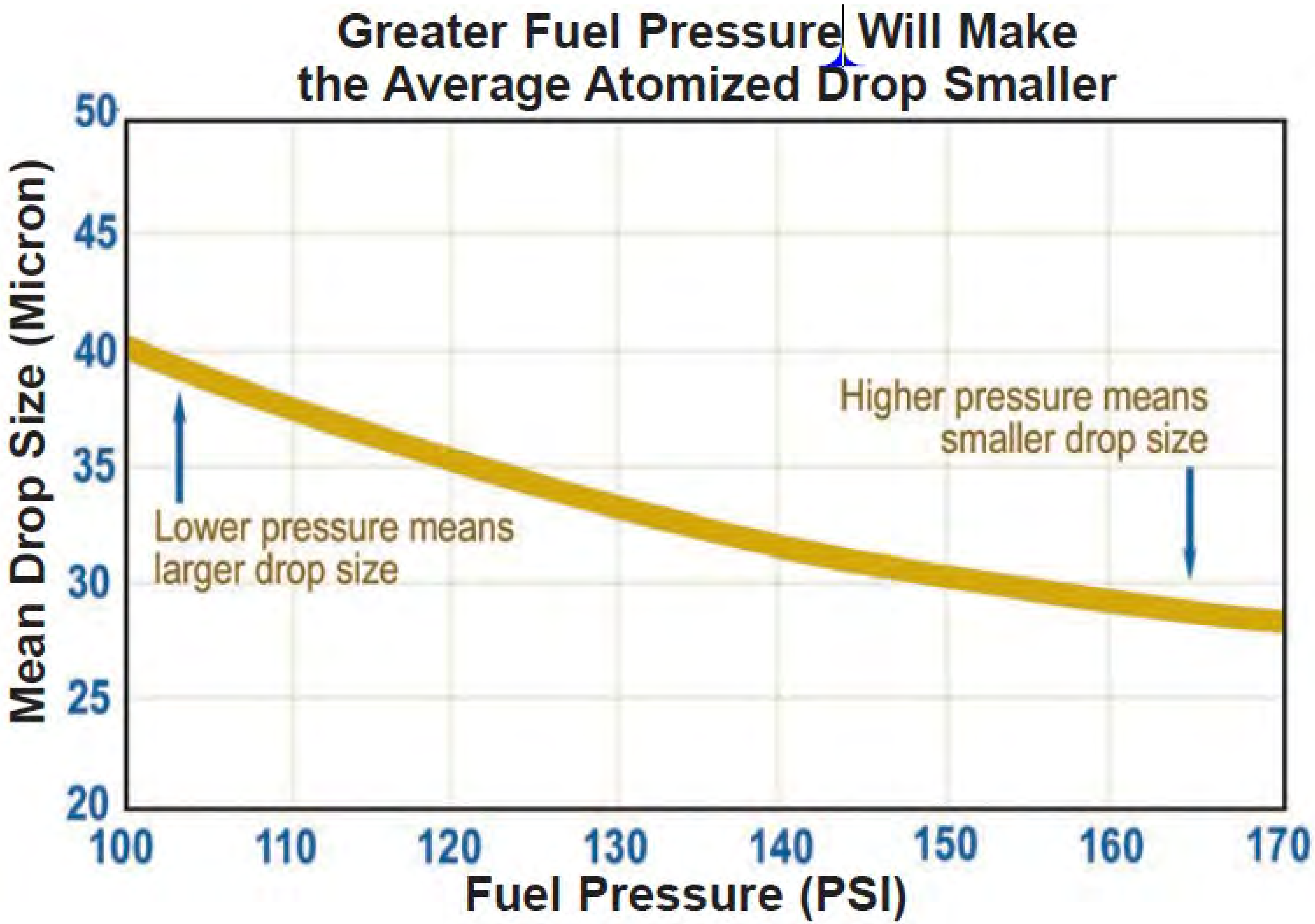
Effects of Pressure

- 100 psi is "standard" (& minimum)
- Higher pressure creates better atomization and increases flow rate.
- 1.00 @ 100 psi = 1.00 gph

  @ 150 psi = 1.23 gph



Effects of Pressure

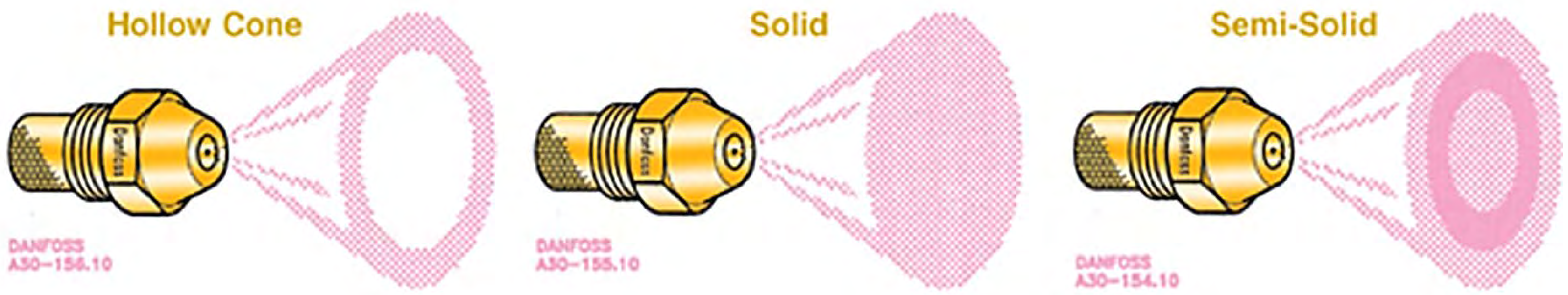


Effects of Pressure

Flow Rating USGPH@ 100PSI	Flow Rates in US GPH Pressures PSI					
GPH	125	145	175	200	250	300
0.40	0.45	0.48	0.53	0.57	0.63	0.69
0.50	0.56	0.60	0.66	0.71	0.79	0.87
0.60	0.67	072	0.79	0.85	0.95	1.04
0.65	0.73	0.78	0.88	0.92	1.03	1.13
0.75	0.84	0.90	0.99	1.06	1.19	1.30
0.85	0.95	1.02	1.12	1.20	1.34	1.47
1.00	1.12	1.20	1.32	1.41	1.58	1.73
1.10	1.23	1.32	1.48	1.56	1.74	1.91
1.20	1.34	1.44	1.59	1.70	1.90	2.08
1.25	1.40	1.51	1.65	1.77	1.98	2.17
1.35	1.51	1.63	1.79	1.91	2.13	2.34
1.50	1.68	1.81	1.98	2.12	2.37	2.60
1.65	1.84	1.99	2.18	2.33	2.81	2.86
1.75	1.96	2.11	2.32	2.47	2.77	3.03
2.00	2.24	2.41	2.65	2.83	3.16	3.46
2.25	2.52	2.71	2.98	3.18	3.56	3.90
2.50	2.80	3.01	3.31	3.54	3.95	4.33
2.75	3.07	3.31	3.84	3.89	4.35	4.76
3.00	3.35	3.61	3.97	4.24	4.74	5.20
3.25	3.63	3.91	4.30	4.60	5.14	5.63
3.50	3.91	4.21	4.63	4.95	5.53	6.06
3.75	4.19	4.52	4.96	5.30	5.93	6.50

Spray Pattern

Three general categories – **hollow**, **semi-solid** and **solid**.

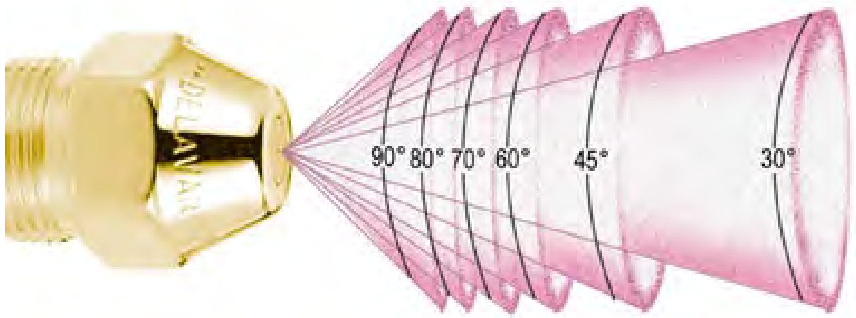


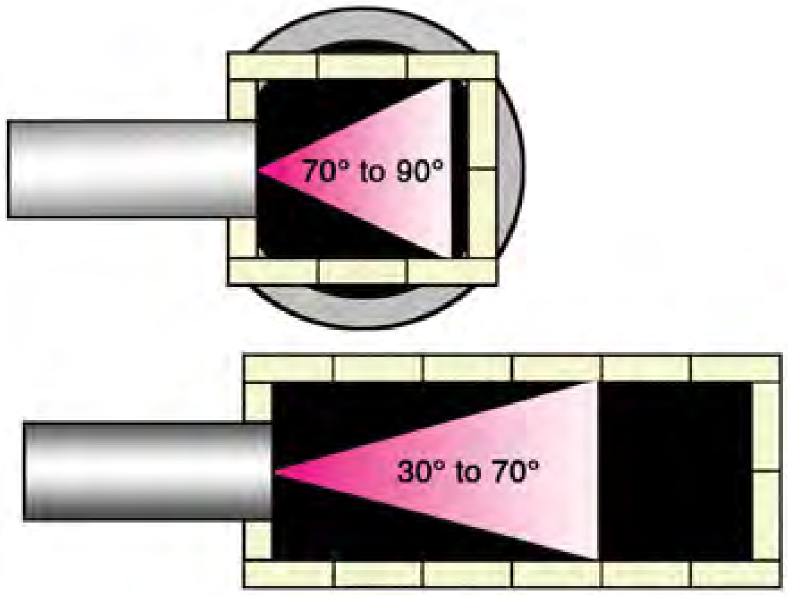
Hollow: droplets concentrated at outer edge of the spray.

Solid: droplets uniform throughout the spray.

Semi-solid: compromise between hollow and solid.

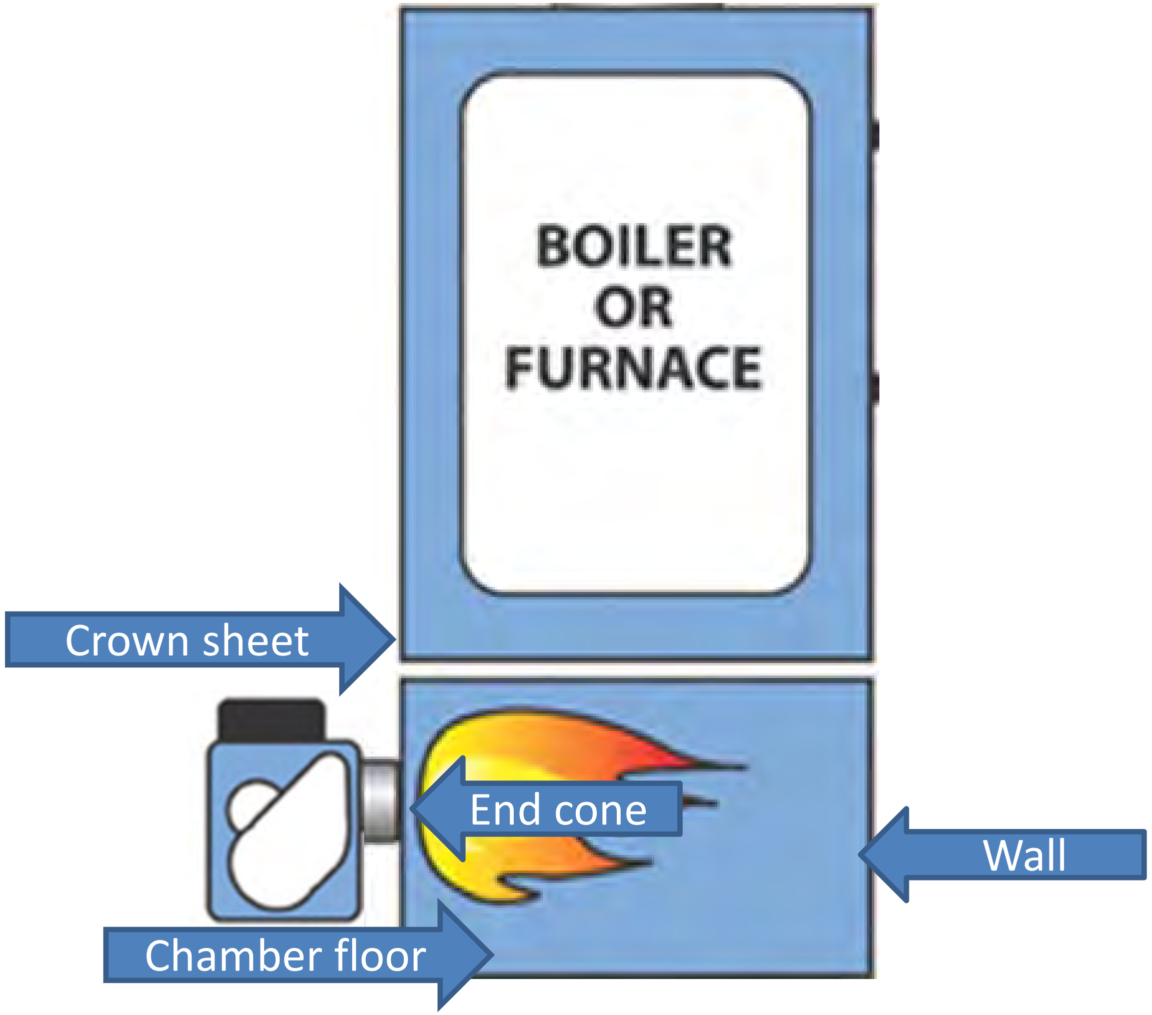
Spray Angles





- Angle of cone spray
- Available from 30° to 90°
- Long narrow chambers 30° to 70°
- Round or square 70° to 90°
- Follow appliance manufacturers recommendations

Spray Angle - Impingement



Fuel must burn completely in suspension without touching (impinging on) the:

- Crown sheet
- Chamber floor or walls
- End cone

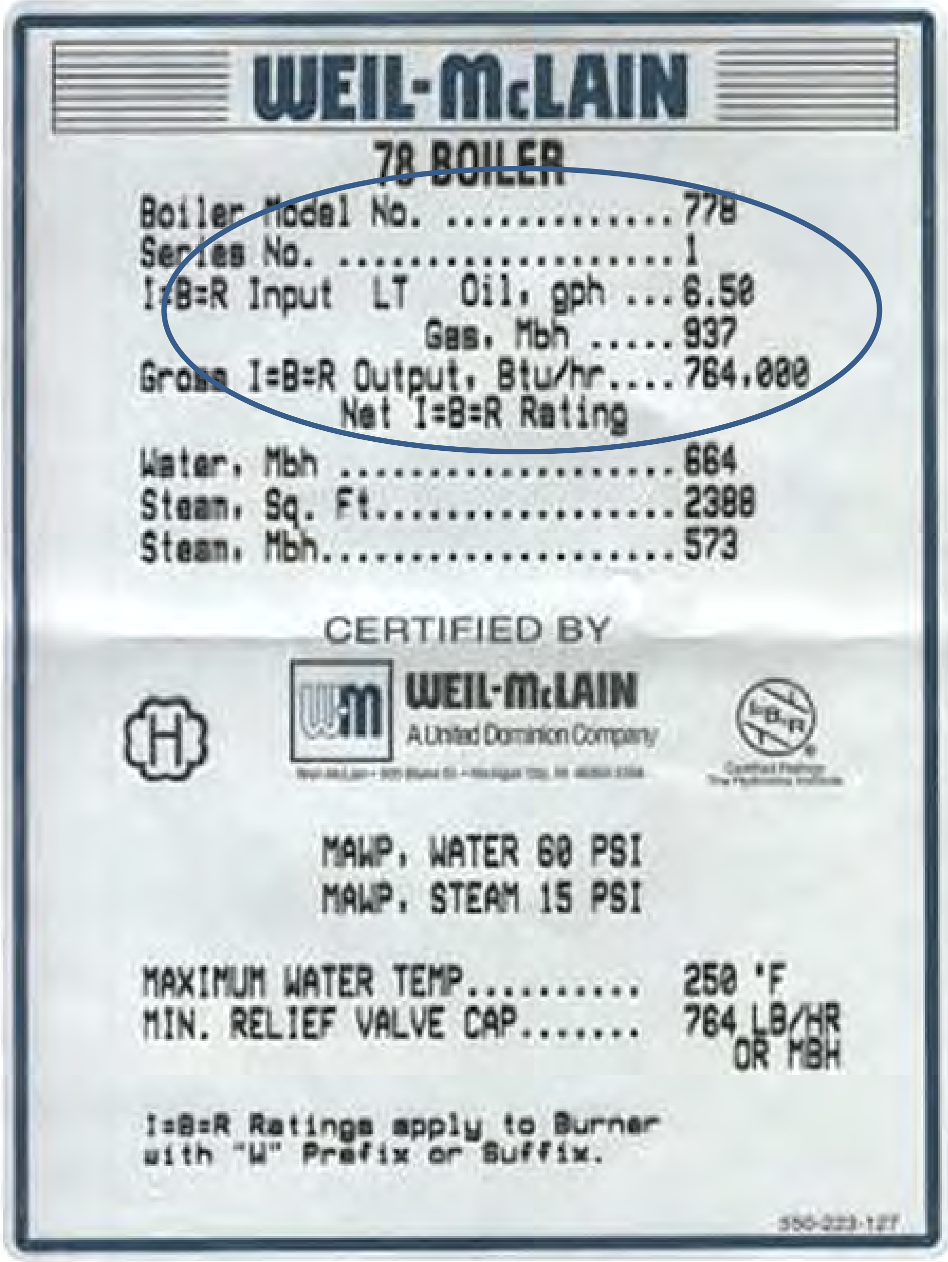
Spray Angle - Impingement

Impingement of unburned fuel leads to:

- Smoke
- Soot
- Service calls

Flow Rate

- The flow rate of the nozzle determines the BTU input into the appliance
- Too little input causes a lack of heat and/or hot water
- Too much input leads to inefficiency and wasted fuel
- Follow the manufacturer's recommendation on nozzle and pump pressure recommendations
- Never "over-fire" an appliance



Specialty Nozzles - Del-O-Flo

- For appliances with very low firing rates (mobile homes)
- Secondary internal filter gives 35% more filtration
- Del-O-Flo Plug resistant includes different interior design that flushes contaminants through the orifice.

Specialty Nozzles - Del-O-Flo

Iron oxide contamination build up in the standard nozzle

Dark streaks on the Del-O-Flo show a discoloration from sand with no contamination build up

Nozzle Brand Interchange

Replacing nozzles of one brand with those of another can sometimes present problems because there are subtle differences between brands that affect burner performance.

NOZZLE MANUFACTURERS AND SPRAY PATTERNS

DANFOSS	DELAVAN	HAGO	MONARCH	STEINEN
AS-SOLID	**A**-HOLLOW	**ES**-SOLID	**R**-SOLID	**S**-SOLID
AH-HOLLOW	**B**-SOLID	**P**-SOLID	**NS**-HOLLOW	**SS**-SEMI-SOLID
AB-SEMI-SOLID	**W**-ALL PURPOSE	**SS**-SEMI-SOLID	**AR**-SPECIAL SOLID	**H**-HOLLOW
	SS-SEMI-SOLID	**H**-HOLLOW	**PLP**-SEMI-SOLID	
		B-SOLID	**PL**-HOLLOW	

Nozzle Brand Interchange

When in doubt refer to burner manufacturer's OEM guides – keep a copy in your service truck.

These guides include the appliance manufacturers recommended nozzle and, in some cases, an alternate……

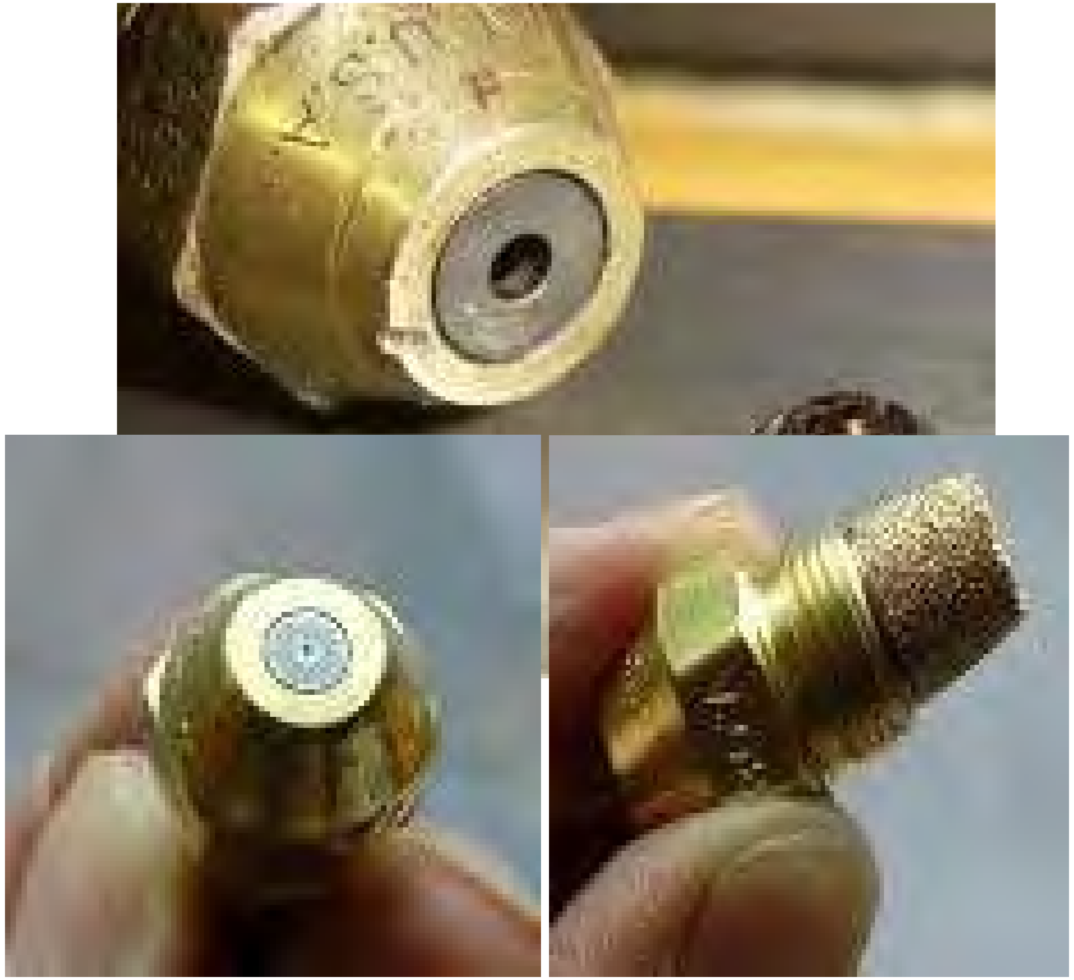
Nozzle Brand Interchange

Biasi / Neca / Vega / QHT

Model	Burner	Nozzle	Alt. Nozzle	Pump (PSIG)	Air Settings	Baffle	Head	Static Plate / Stop Screw	Air Tube Combination	Depth	Welded Insertion	See note
B10/3	NX	0.50 X 60°A		180	0.75	32229	6-Slot		NX70LC	3½"	58020213	15
B10/3	AFG	0.50 X 60°B		180	S-8 / B-0	5880	L2	3⅜"	AFG70MQASN	2¾"	58020201	9, 16
B10/3 - DV	NX	0.50 X 60°A	0.50 X 60°H	180	1.25	32229	6-Slot	-	NX70LC	3½	58020213	3, 15
B10/4	NX	0.65 X 60°B	0.65 X 60°B* (H)	180	2.75	32229	9-Slot		NX90LB	6"	58020214	40
B10/4	AFG	0.75 X 60°B	0.75 X 60°B* (H)	150	S-10 / B-0		L2	3⅜"	AFG70MQASN	2¾"	58020201	9, 16
B10/4 - DV	NX	0.65 X 60°B	0.65 X 60°B* (H)	180	3	32229	9-Slot		NX90LB	6"	58020214	3, 40
B10/5	NX	0.75 X 60°B		180	3.75	32229	9-Slot		NX90LB	6"	58020214	40
B10/5	AFG	0.75 X 60°B	0.75 X 60°B* (H)	175	S-7 / B-0		V1-0	2¾"	AFG90MDASN	6"	58020262	9
B10/5 - DV	NX	0.75 X 60°B	0.75 X 60°B* (H)	180	4	32229	9-Slot		NX90LB	6"	58020214	3, 40
B10/6	NX	0.90 X 60°W	0.90 X 60°B* (H)	180	3.75		9-Slot		NX90LB	6"	58020214	40
B10/6	AFG	1.10 X 60°B	1.10 X 60°B* (H)	125	S-10 / B-1		V1-0	2¾"	AFG70MDASN	3½"	58020241	9
B10/6 - DV	NX	0.90 X 60°W	0.90 X 60°B* (H)	180	4.25		9-Slot		NX90LB	6"	58020214	3, 40
B10/7	AFG	1.35 X 60°B	1.35 X 60°B* (H)	125	S-10 / B-3		V1-2	2¾"	AFG70MDASN	3½"	58020241	9

Nozzle Care & Service

- Never interchange inner parts
- Handle carefully, don’t touch strainer or orifice
- Check adapter & flush nozzle line
- Screw into adapter approx. 1/8 to 1/4 turn after hand tight



Nozzle Overheating

Nozzles are normally cooled by the air and fuel travelling past them.

They may overheat from:

- Poor over-fire draft
- Air tube extending into chamber
- After drip
- Hard brick chamber reflecting heat (older units)

Flame Patterns – Air/Fuel Mixture

What constitutes a perfect burner flame?

Theoretically:

- Each droplet of fuel would mix *completely* with oxygen
- Air volume, generated by the fan, would be delivered to the exact amount needed

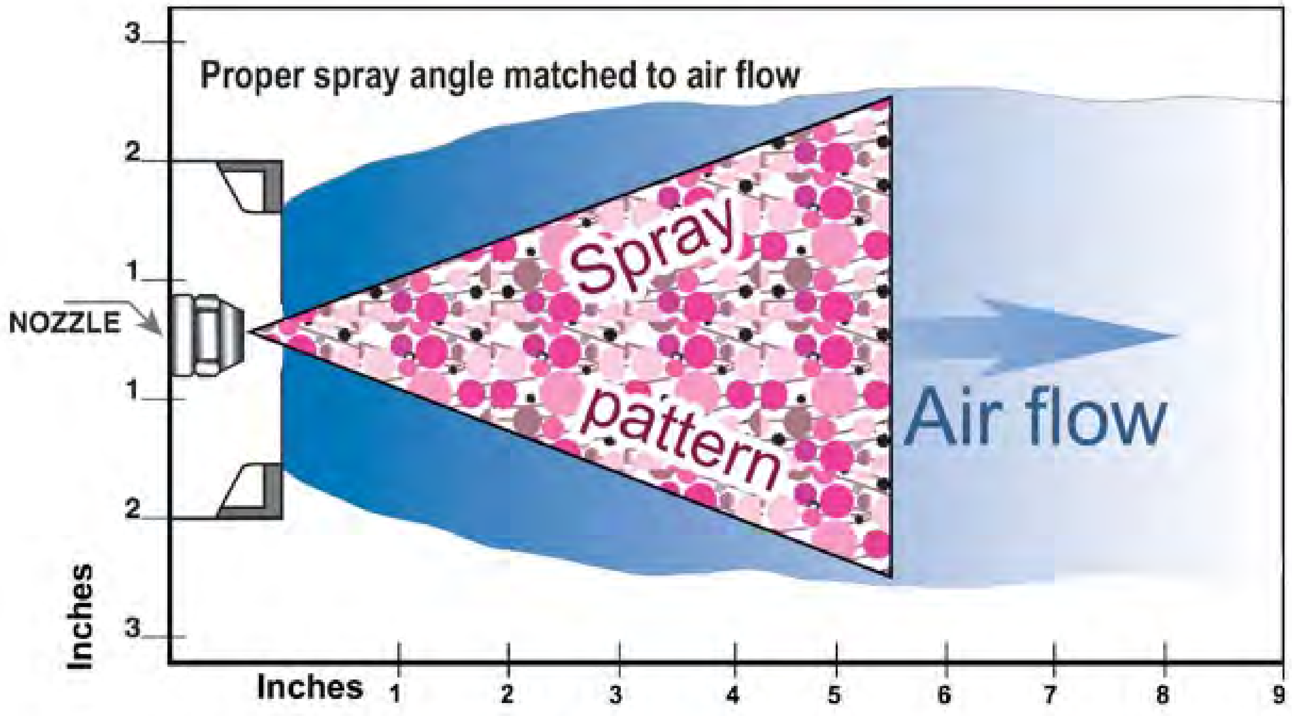
Is this theoretical air-oil mix possible?

Air-Fuel Mixing &Flame Patterns

No, it's ***not*** possible, but a good target.

Elements needed:

- Air volume
- Fuel volume
- Fuel pressure
- Fuel spray pattern
- Fuel spray angle
- Burner air pattern



Which of these can't be adjusted?

Air-Fuel Mixing & Flame Patterns

The burner air pattern can't be seen or adjusted. The tools required to get best air/fuel mix, which is smoke-less & sootless with a minimum amount of excess air are:

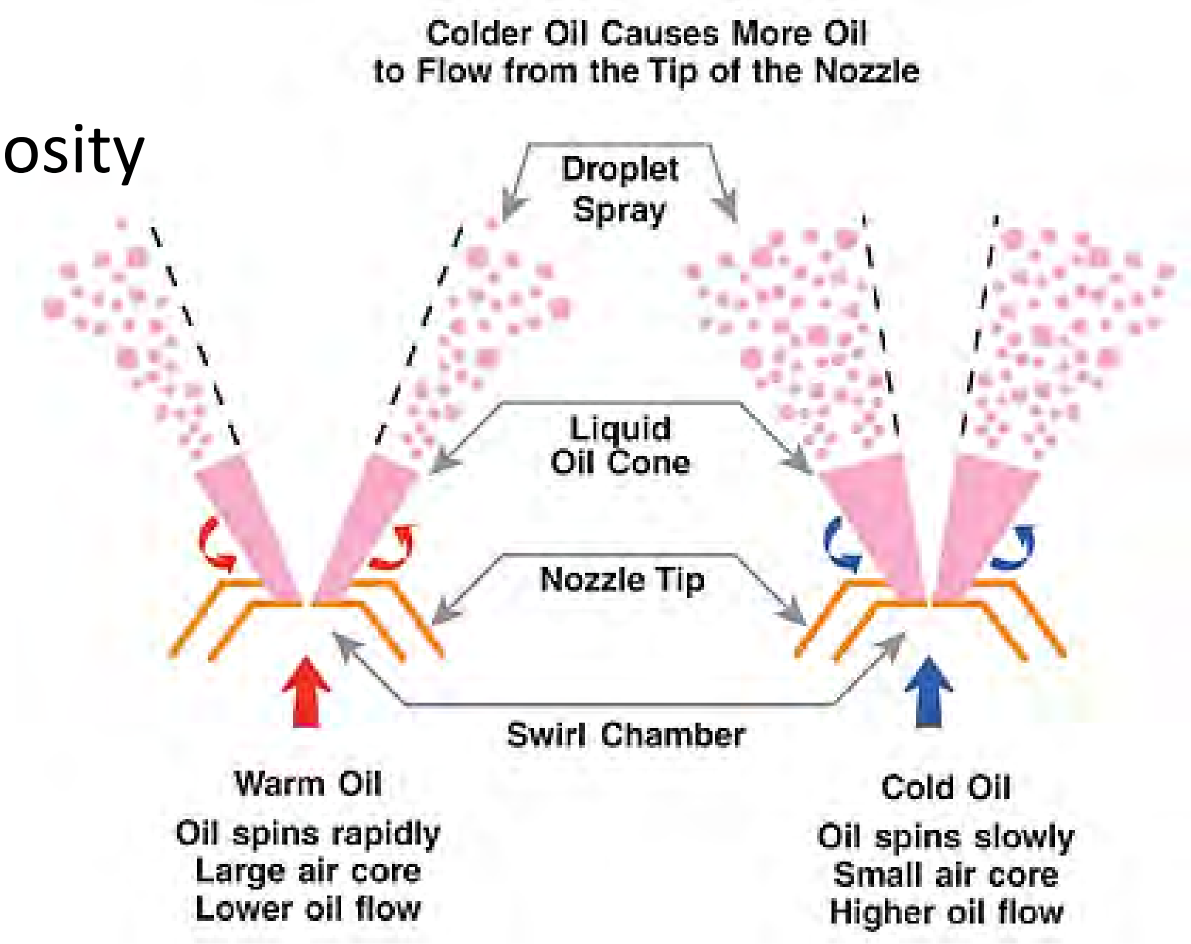
- Combustion analyzer
- Pressure gauge
- OEM specs

Viscosity – Cold Fuel

Nozzle performance is affected by the viscosity (thickness) of the fuel which increases as temperature decreases, then:

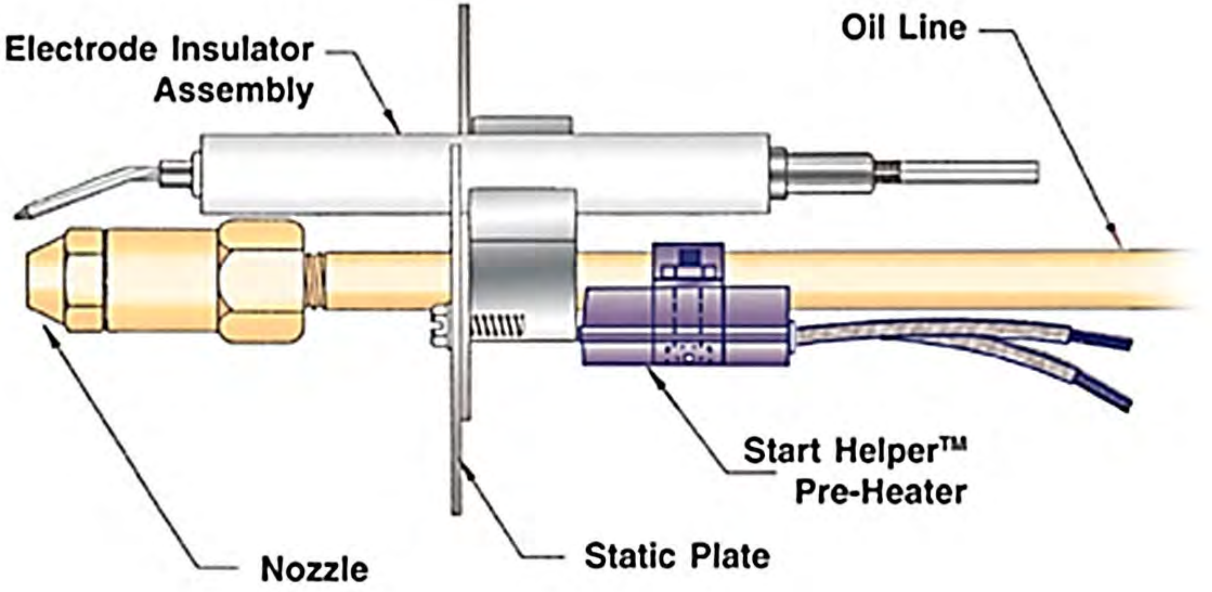
- The flow ***rate*** increases
- It becomes harder to ignite the fuel
- The angle of spray decreases

All of which can lead to incomplete combustion, smoke & soot.



Reducing the Effects of Cold Fuel

- Increase pump pressure – which decreases the droplet size ***BUT*** also increases the flow rate so decrease the nozzle size at the same time
- Add a nozzle line heater which increases the temperature of fuel at the nozzle to approximately 130 degrees

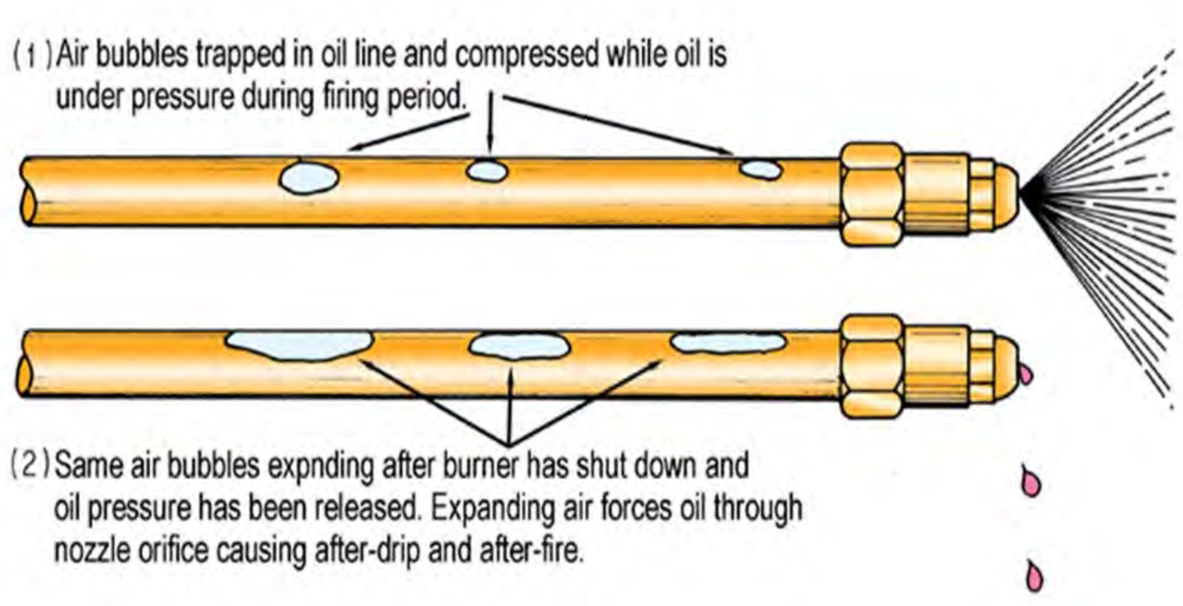


Nozzle After Drip

After-drip is when fuel drips from the nozzle orifice after burner shutdown.

There are 3 possible causes:

1. A defective fuel unit shut-off valve.
2. Air entrapped in the nozzle line, typically due to high vacuum.
3. Fuel expansion in the nozzle line caused by excessive radiated heat at shutdown.



Troubleshooting Nozzle After Drip

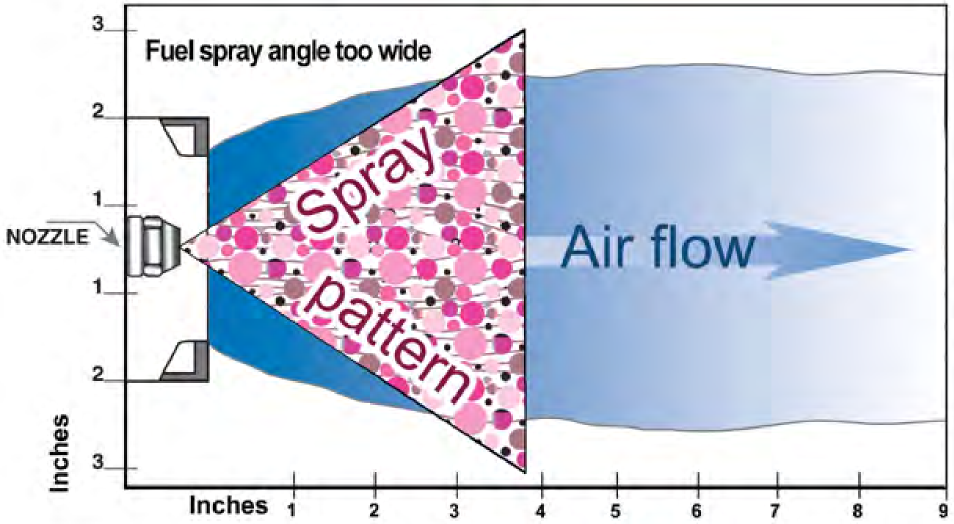
- To check for a defective fuel unit shutoff valve, perform the cutoff vacuum test described in chapter 4
- To check for high vacuum, perform the operating vacuum test described in chapter 4
- If the cutoff and operating vacuum tests don’t indicate a problem ***and*** the appliance has a hard brick chamber, consider installing a ceramic liner to reduce the amount of radiated heat

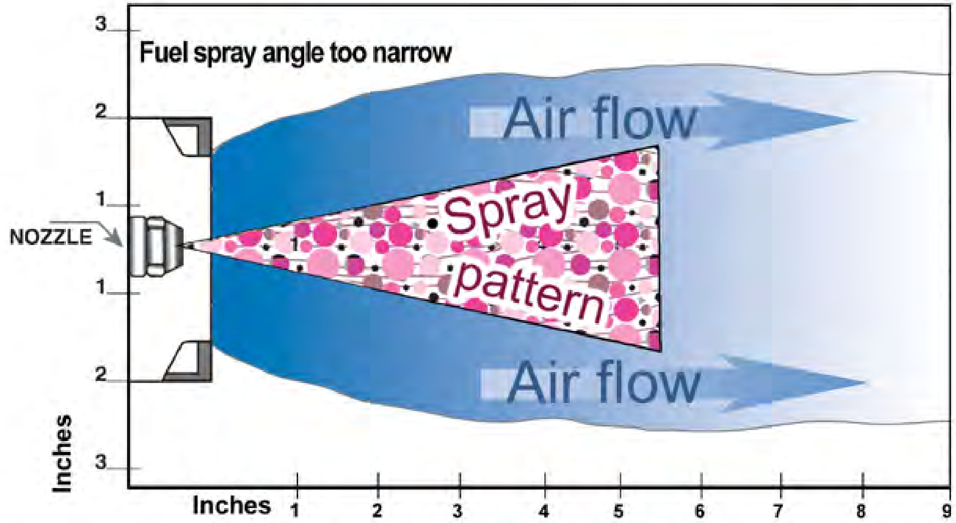
Combustion Chambers

The burner flame is contained in the combustion chamber.

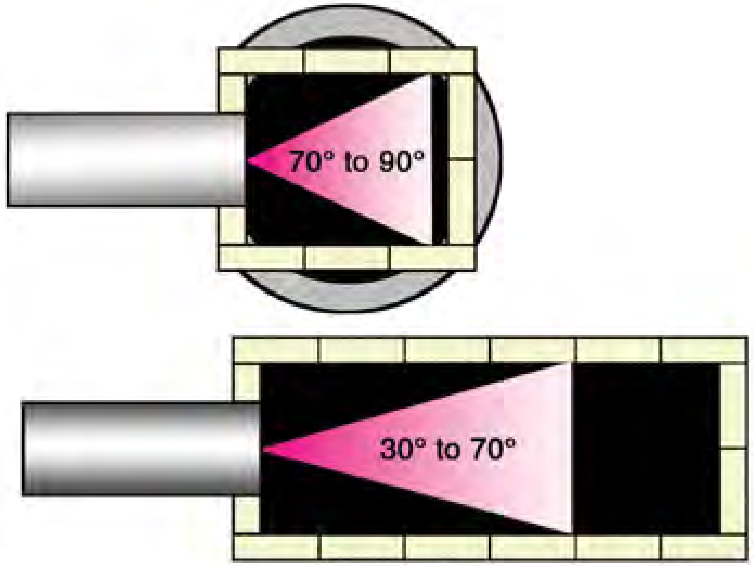
It must be properly sized and the correct shape for the burner air pattern.

Modern chambers are designed to heat up quickly, reflect heat back into the combustion zone and cool off quickly on shutdown.





Combustion Chamber Materials



- Insulating brick
- Hard brick
- Metal
- Ceramic
- Molded (OEM)

Modern Chambers

Most manufacturers now install molded chambers in their appliances, but a technician can still encounter older installations with brick or metal chambers

Some modern wet-base boilers operate without chambers because heat transfer to the water improves when there is no insulating chamber material between the heat exchanger and the fire

Review Questions:

- What are the three things a nozzle does?
- What happens to the spray when you increase the pressure?
- When would you install a specialty nozzle?
- What can you do to improve nozzle performance?

End of Chapter 5

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 6

Draft & Venting

Draft & Venting

- A properly operating venting system removes all the combustion gases from an appliance and safely directs them outside the building.

- An improperly functioning system will prevent the system from operating efficiently, and may be dangerous to the inhabitants

Draft & Venting

What's the first thing you think of when you hear the word

DRAFT?

Draft

Draft

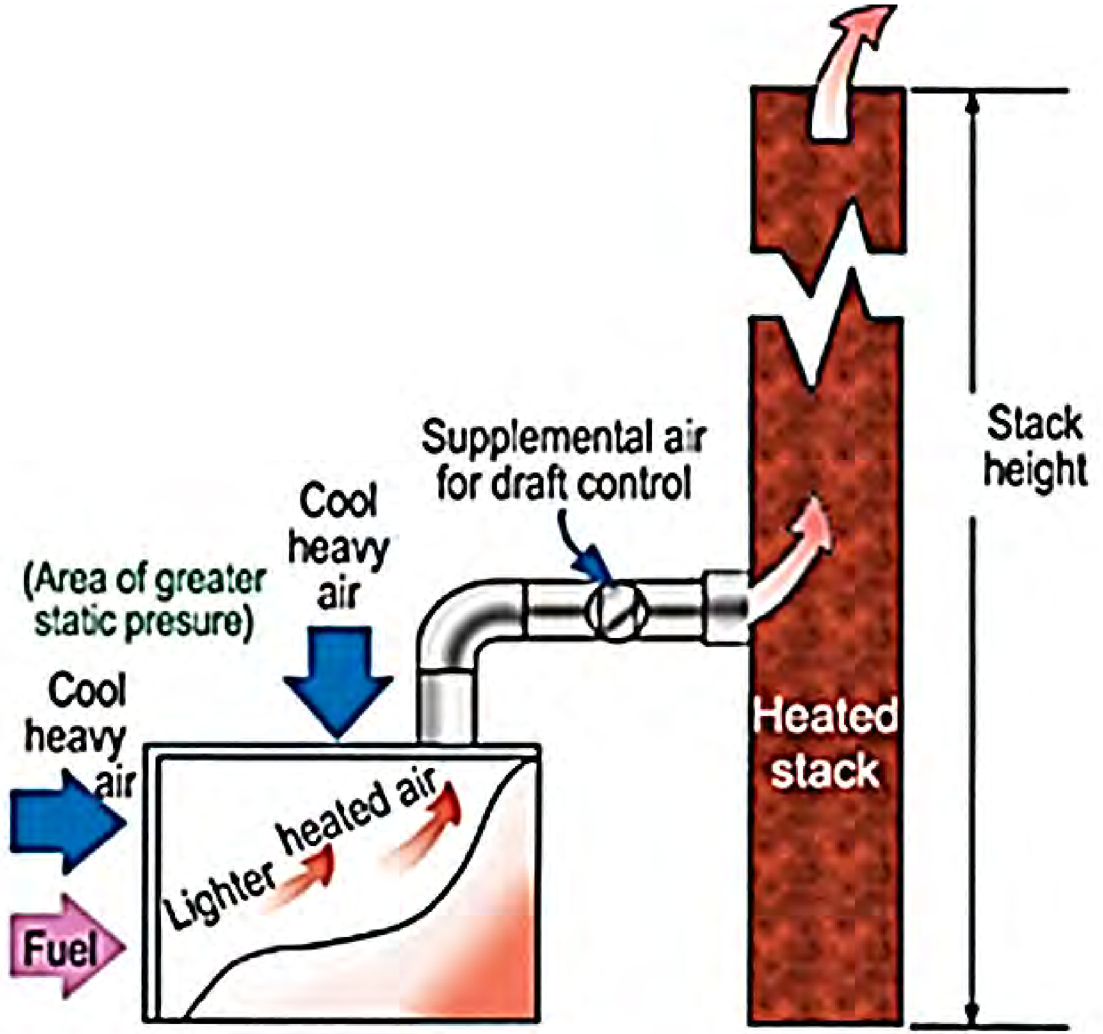
Draft is the pressure difference that causes gases or air to flow through a chimney, vent, flue or appliance.

It is a force that "pulls" or "sucks" the exhaust gases out of a heating unit and sends them up the chimney."

Draft

- During the combustion process, hot gases rise trough the appliance to the flue then travel up the chimney creating negative pressure (suction) AKA “negative draft” at the chimney bottom

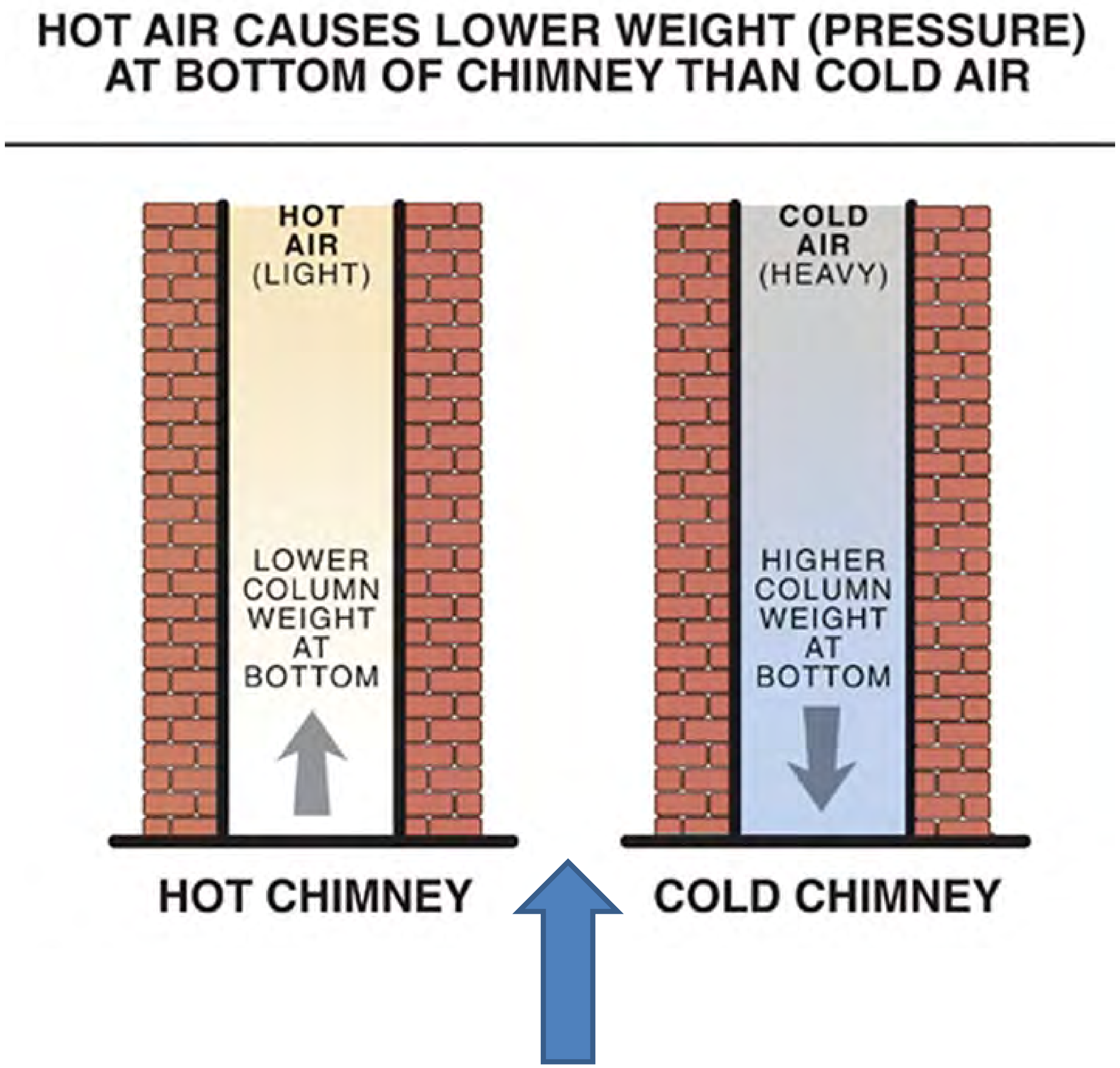
- This “negative draft” is created because…



Draft

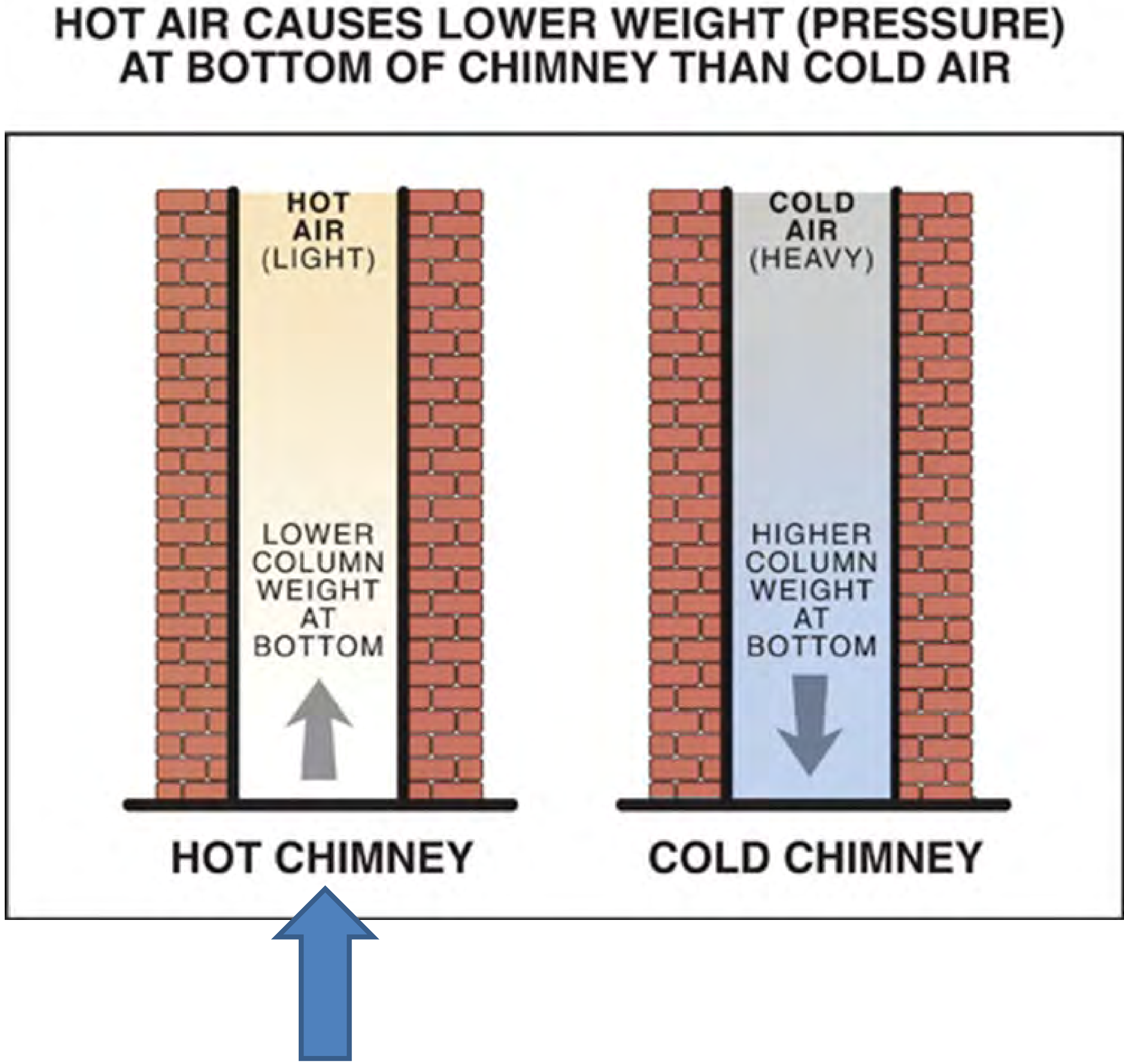
- When burner is off and chimney is cold, air in combustion area, heat exchanger, flue and chimney is at atmospheric pressure

- When the burner starts, the burner fan creates "static pressure" forcing air into the combustion area where it combines with fuel to create a fire



Draft

- Temperature rises dramatically
- Combustion gases expand to >2X volume
- Fan, plus expansion, pushes gases through heat exchanger
- As gases travel up the chimney, they create a pressure drop that sucks the gases out of the heat exchanger



Draft

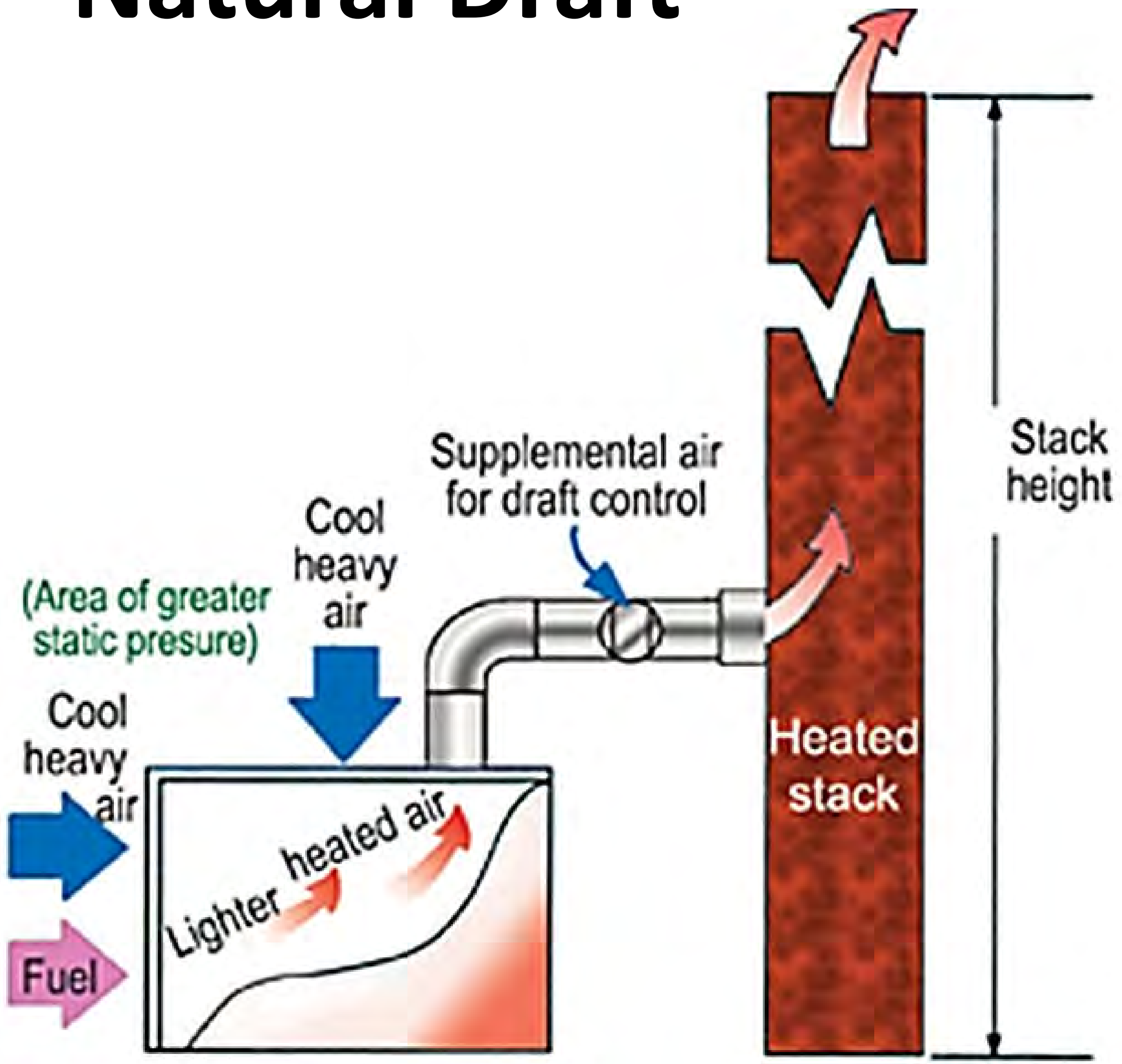
On a specific job site, draft is the total effect of:

- The positive pressures of the fan
- The expansive pressure of the flame and
- The negative pressure of the hot gases exiting the chimney

Chimney Venting - Natural Draft

There are 2 types of natural draft:

1. **Thermal draft** is created when the air in the chimney is hotter (lighter) than outside air. As the lighter air moves up the chimney, air moves in from the surrounding area to replace it.



Chimney Venting - Natural Draft

2. **Currential draft** is caused by the suction created as wind passes over the chimney top, creating negative pressure in the chimney. Because wind is variable, currential draft is unpredictable & must be controlled.

Occasionally, wind can blow down a chimney causing a "down draft".

Draft is Affected by…

Draft is created by a pressure difference between the top & bottom of a chimney and varies depending on:

- Chimney height & location
- Temperature of outside air
- Temperature of flue gases
- Barometric pressure
- Humidity

Draft is Affected by…

- **Chimney location** – outside VS inside. A chimney with walls outside heats up slowly and cools quickly, so it does not work as well as an inside chimney

- Chimneys must extend at least 2’ above objects (trees, roof peak, other buildings) within 10’

Draft is Affected by….

It is also affected by

- The chimney height
- The temperature of the flue gases
- The outside air temperature.

Theoretical Chimney Draft for Various Conditions

Case 1 OUTSIDE AIR = 60°F

AVG CHIMNEY TEMP. °F	CHIMNEY HEIGHT IN FEET 10	15	20	25	30
100	0.01	0.02	0.02	0.03	0.03
200	0.03	0.05	0.06	0.08	0.09
300	0.05	0.07	0.09	0.12	0.14
400	0.06	0.09	0.12	0.14	0.17
500	0.07	0.10	0.13	0.17	0.20
600	0.07	0.11	0.15	0.19	0.22
700	0.08	0.12	0.16	0.20	0.24
800	0.09	0.13	0.17	0.22	0.26
900	0.09	0.14	0.18	0.23	0.27

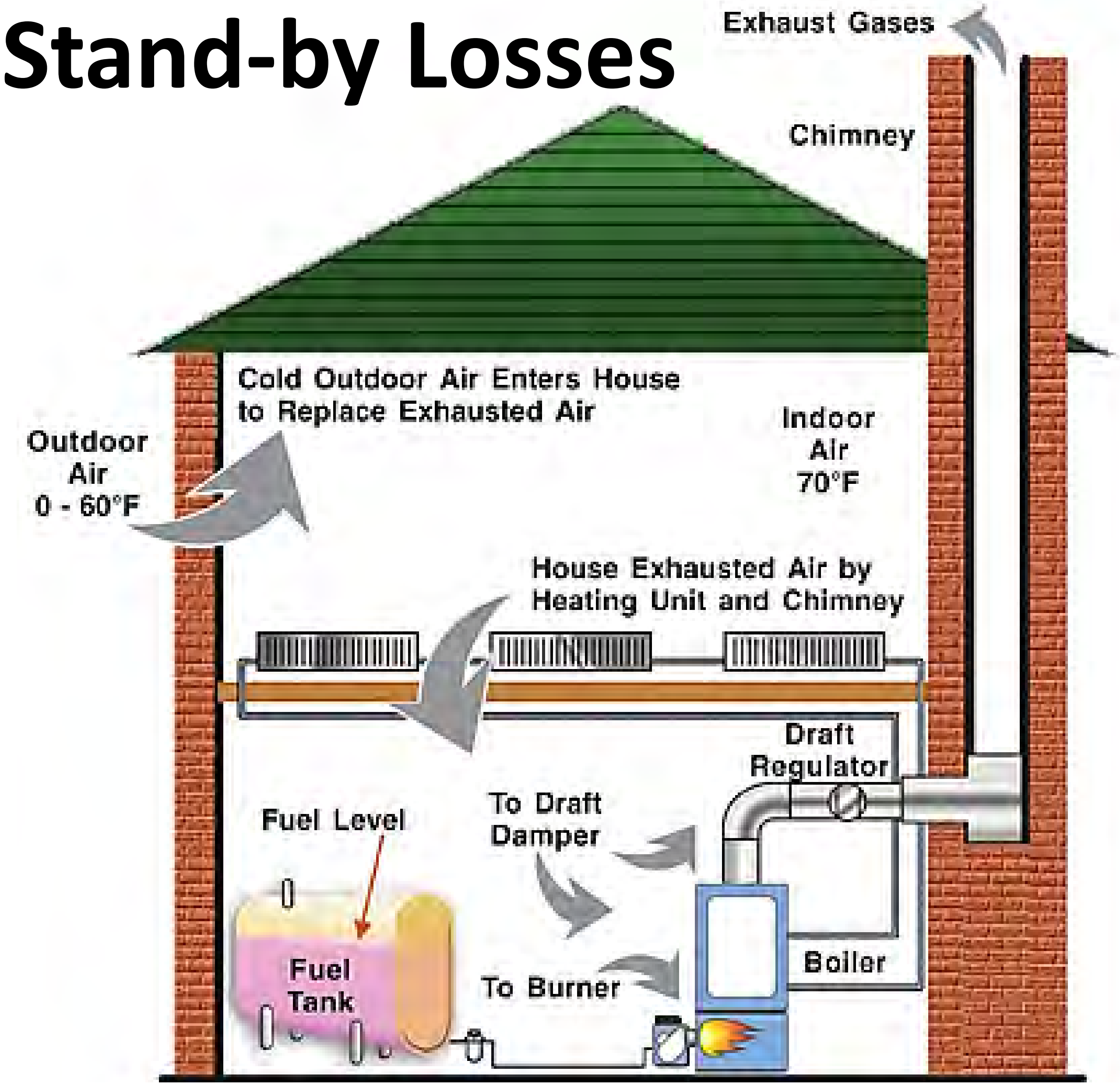
Case 2 OUTSIDE AIR = 0°F

AVG CHIMNEY TEMP. °F	CHIMNEY HEIGHT IN FEET 10	15	20	25	30
100	0.03	0.04	0.05	0.07	0.08
200	0.04	0.05	0.09	0.11	0.13
300	0.06	0.09	0.12	0.14	0.17
400	0.07	0.10	0.14	0.17	0.20
500	0.08	0.11	0.15	0.19	0.23
600	0.07	0.12	0.17	0.21	0.25
700	0.09	0.13	0.18	0.22	0.27
800	0.09	0.14	0.19	0.23	0.28
900	0.10	0.15	0.19	0.24	0.29

Drafts effect on Stand-by Losses

- Warm chimneys create thermal draft that draws room air into the appliance in the off-cycle

- Modern equipment has lower stand-by losses because appliances are “tighter” and air intakes are not as open



Draft Regulators Aka Barometric draft controls

Burners need steady draft for proper operation. Variable draft can affect efficiency and cause operational problems. For example:

- **Insufficient draft** reduces combustion air delivery to the burner and can cause noisy operation and smoke

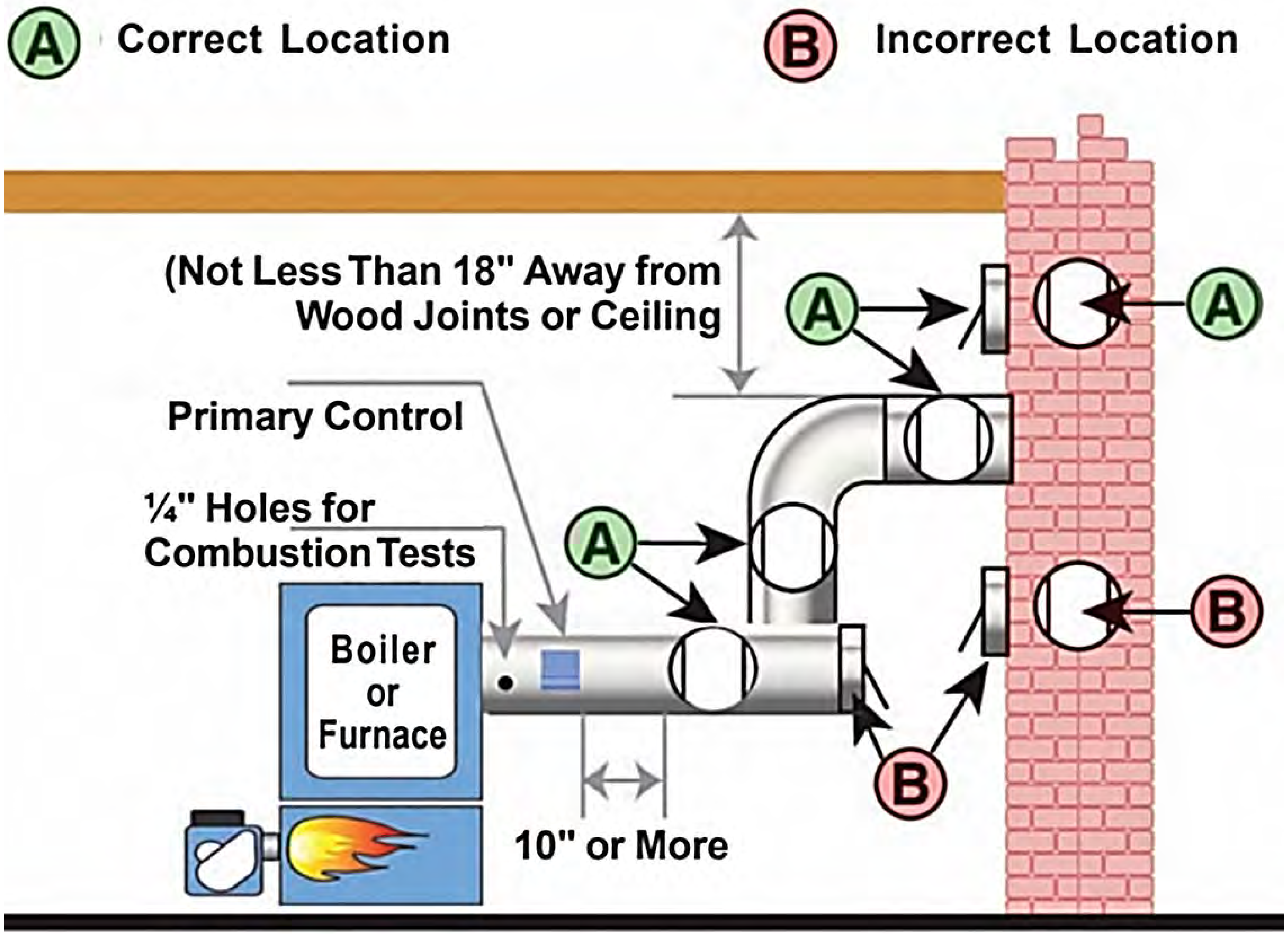
- **Excessive draft** increases combustion air delivery to the burner and decreases efficiency

Draft *must* be regulated because natural draft is so variable.

Draft Regulators

- Stabilize over-fire draft for proper combustion
- ***Lower*** draft by allowing room air to enter flue
- Slow gas flow through heat exchanger
- Lower stack temperature
- Increase efficiency

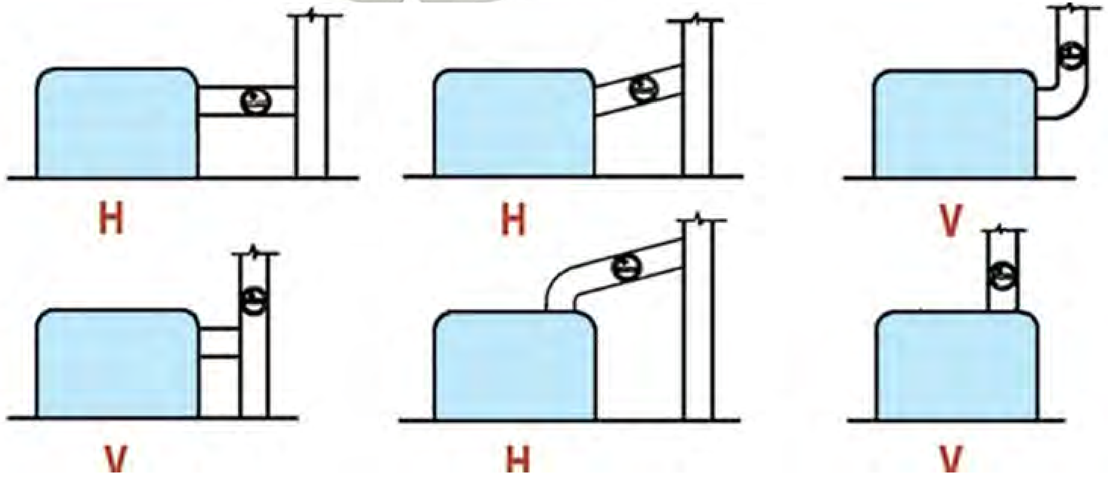
Recommended Locations



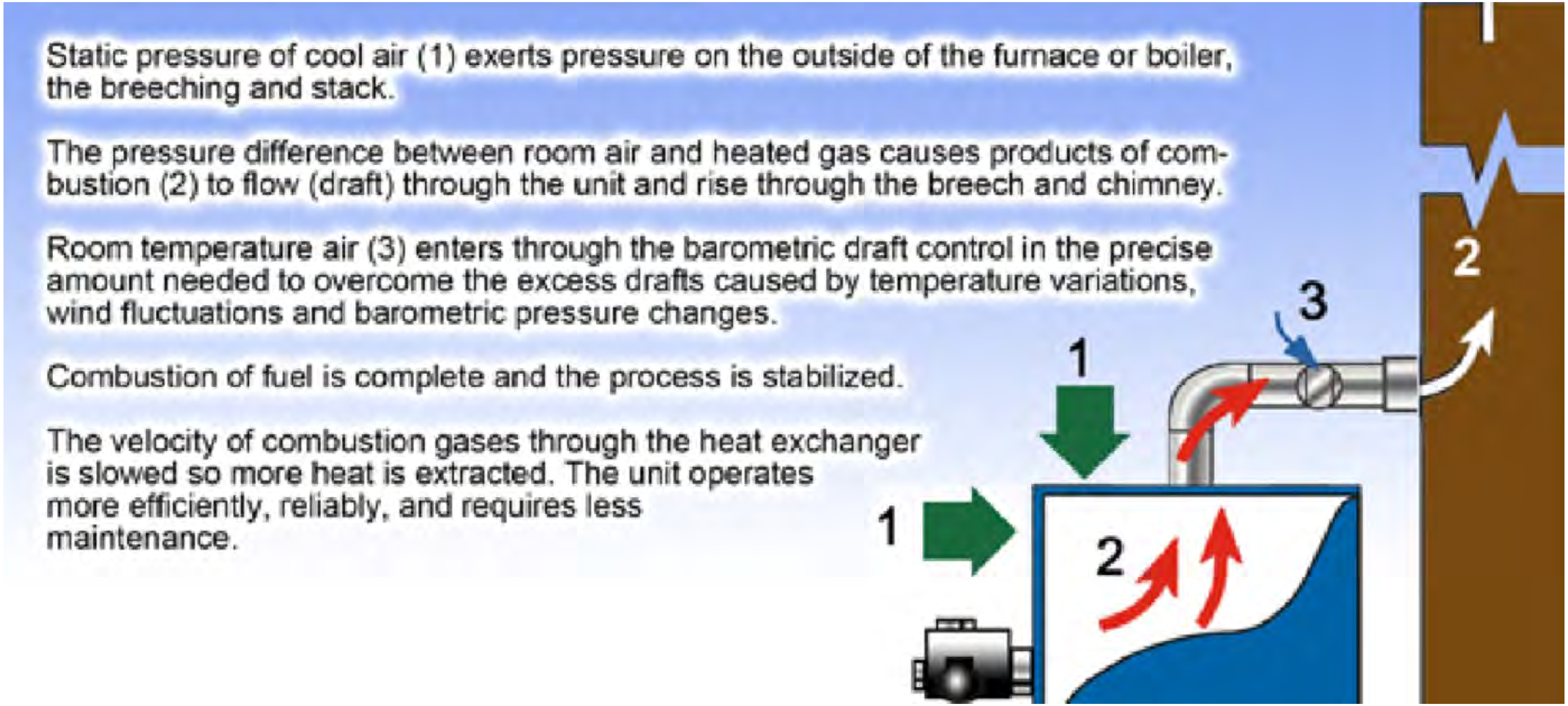
Draft Regulators

- As with all appliances and components, it's important to understand and follow manufacturer's instructions

- This draft regulator includes a weight that is inserted in different locations based on whether it's installed vertically or horizontally. It will NOT operate properly if the weight is installed in the wrong slot



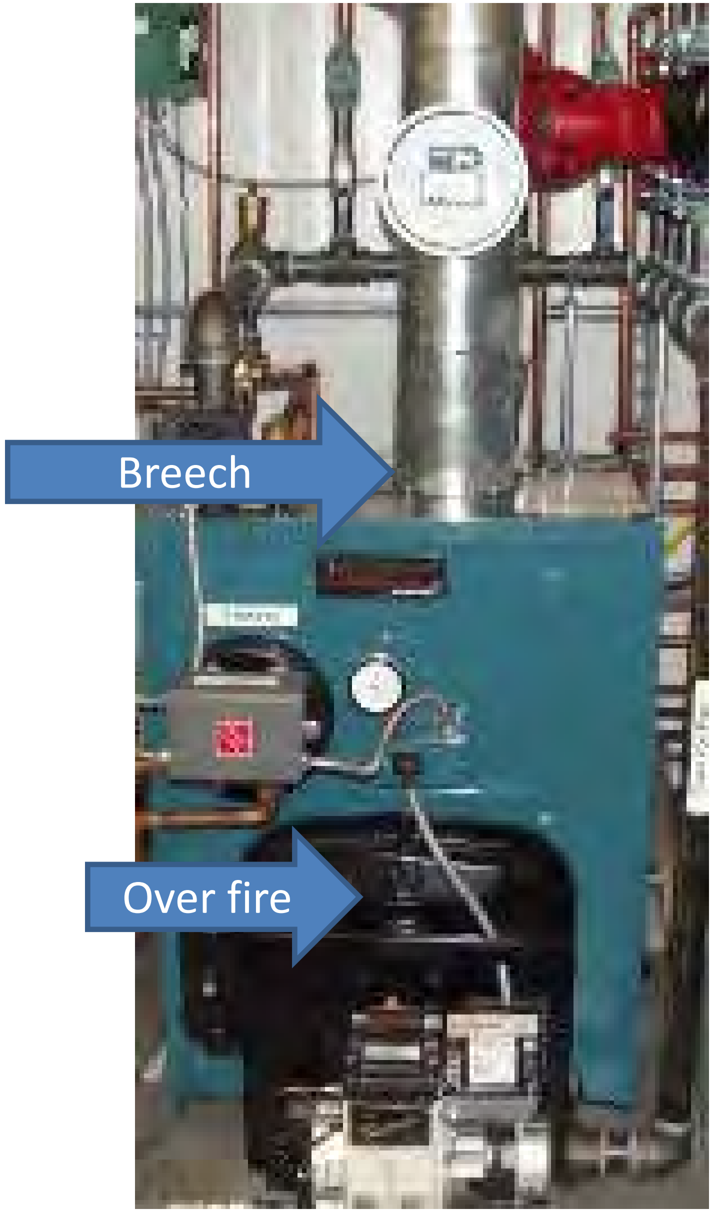
How Draft Controls Work



Measuring Draft

Draft is measured in "inches of water column" at two locations:

- In the flue pipe, as close to the breech as possible
- Over the fire, at the top of the combustion area

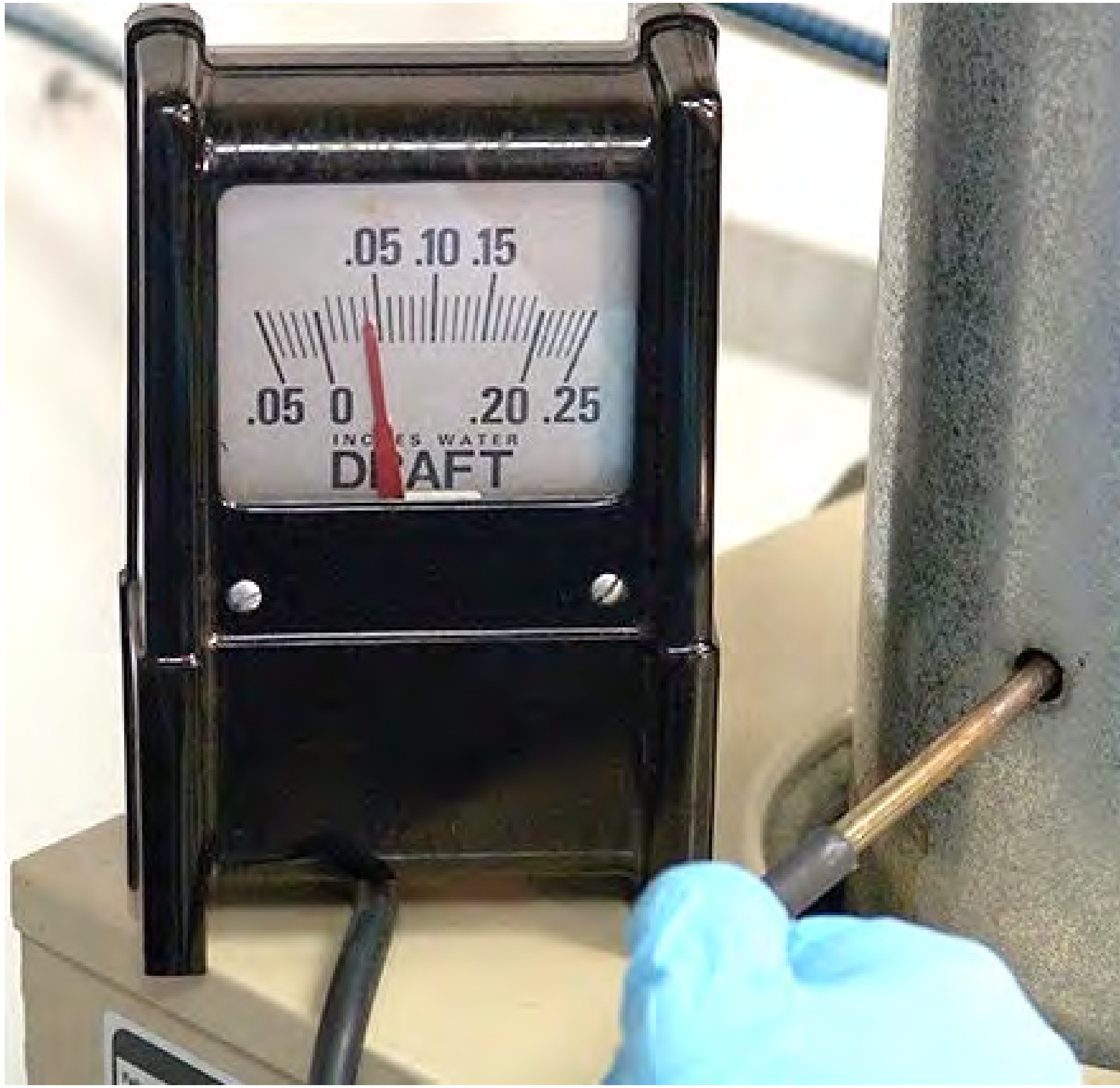


Over the Fire

- Most important reading.
- Set to manufacturers specs
- -.01" to -.02" most common.
- Some appliances operate on positive draft.

At the Breech

- Higher than over the fire
- Difference between over the fire and breech is "draft drop"
- Excessive drop may indicate soot & scale in heat exchanger



Draft Drop

These are a specific manufacturers draft drop specifications for one boiler model, notice the different specs for different size boilers.

A drop of .02” is recommended for a 3-section boiler but only .01” for a-4 section boiler

Sections	Draft Loss Through Boiler (in. w/c) (7)
2	.020
3	.020
4	.010
5	.015
6	.015
7	.015
8	.025
9	.030

Chimney Sizing

Chimney sizing requirements vary depending upon the size and design of the appliance, the manufacturer's instructions must be followed.

Sample manufacturers sizing chart:

MINIMUM RECOMMENDED BREECHING AND CHIMNEY SIZE

BOILER MODEL	MINIMUM BREECHING DIA. (INCHES)	MINIMUM CHIMNEY REQUIREMENTS		
		ROUND I.D. (IN.)	SQUARE. TILE SIZE (NOMINAL)	HEIGHT (FT.)
FWZ060	5	6	8 X 8	15
FWZ080	5	6	8 X 8	15
FWZ100	6	6	8 X 8	15
FWZ130	6	7	8 X 8	15
FWZ160	7	7	8 X 8	15

Draft Regulator Sizing

Diameter of Flue or Breeching	If Chimney Height is	Use This Size Control	If Chimney Height is	Use This Size Control	If Chimney Height is	Use This Size Control
4	15' or less	4"	16' or more	5"		
5	15' or less	5"	16' or more	6"		
6	15' or less	6"	16' or more	7"		
7	15' or less	7"	16' or more	8"		
8	15' or less	8"	16' or more	9"		
9	15' or less	9"	16'-30'	10"	31' or more	12"
10	20' or less	10"	21'-40'	12"	41' or more	14"
11	20' or less	12"	21'-40'	12"	41' or more	14"
12	20' or less	12"	21'-40'	14"	41' or more	16"
13	22' or less	14"	23'-45'	16"	46' or more	18"
14	22' or less	14"	23'-45'	16"	46' or more	18"
15	22' or less	16"	23'-45'	16"	46' or more	18"
16	30' or less	16"	31'-50'	18"	51' or more	20"
17	30' or less	18"	31'-50'	20"	51' or more	20"
18	30' or less	18"	31'-50'	20"	51' or more	20"
19	30' or less	20"	31'-50'	20"	51' or more	24"
20	30' or less	20"	31'-50'	20"	51' or more	24"

Flue Pipe

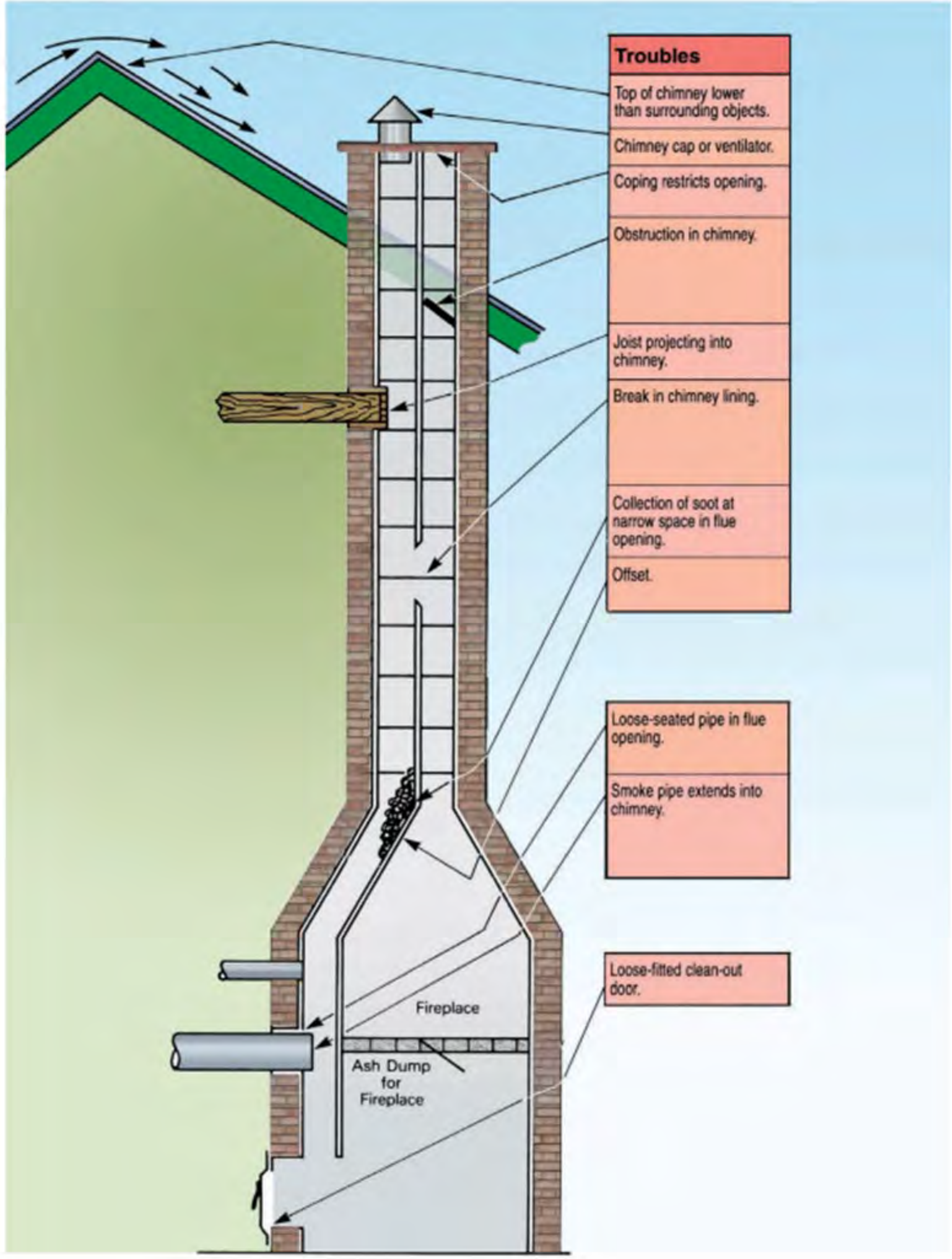
- The condition of the flue pipe should be checked during each service call
- Combustion gases can enter a building if the pipe is porous or disconnected

Flue Pipe

- Minimum 18” from combustibles
- Minimum ¼” pitch upwards toward chimney
- Sheet metal screws at each joint. (minimum 3)
- Supported with straps if appropriate

Chimney & Draft Problems

Insufficient draft can occur when obstructions such as soot, loose bricks, animal nests or other foreign objects build up in the chimney and restrict flow.



Chimney & Draft Problems

Insufficient draft can also occur with too many appliances connected to a chimney.

When connecting 2 or more appliances to a chimney, verify that there is sufficient draft for safe operation of all units.

Chimney & Draft Problems

Lack of air in the combustion zone.

Modern building requirements can reduce the amount of air entering a building.

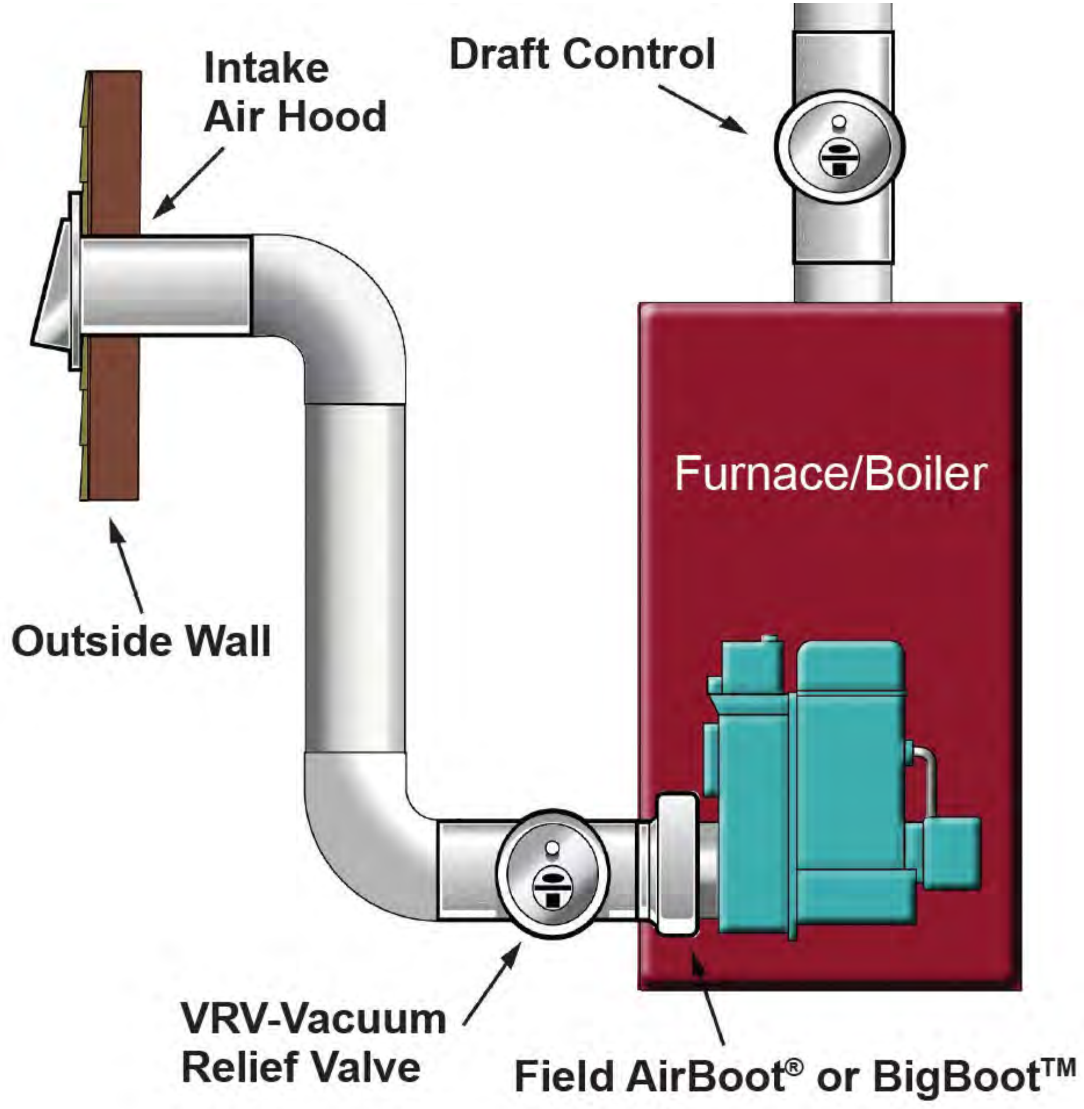
There may not be enough air to support combustion.

Also, clothes dryers, exhaust fans & other devices compete with heating appliances for air….

Chimney & Draft Problems

When this occurs, negative pressure can be created in the building and air can be pulled down the chimney causing odors, smoke, soot and CO.

"**Isolated combustion**" is the best solution to this issue……



Multiple Appliance Connections

In some situations, two appliances (i.e., furnace & water heater), are connected to the same chimney.

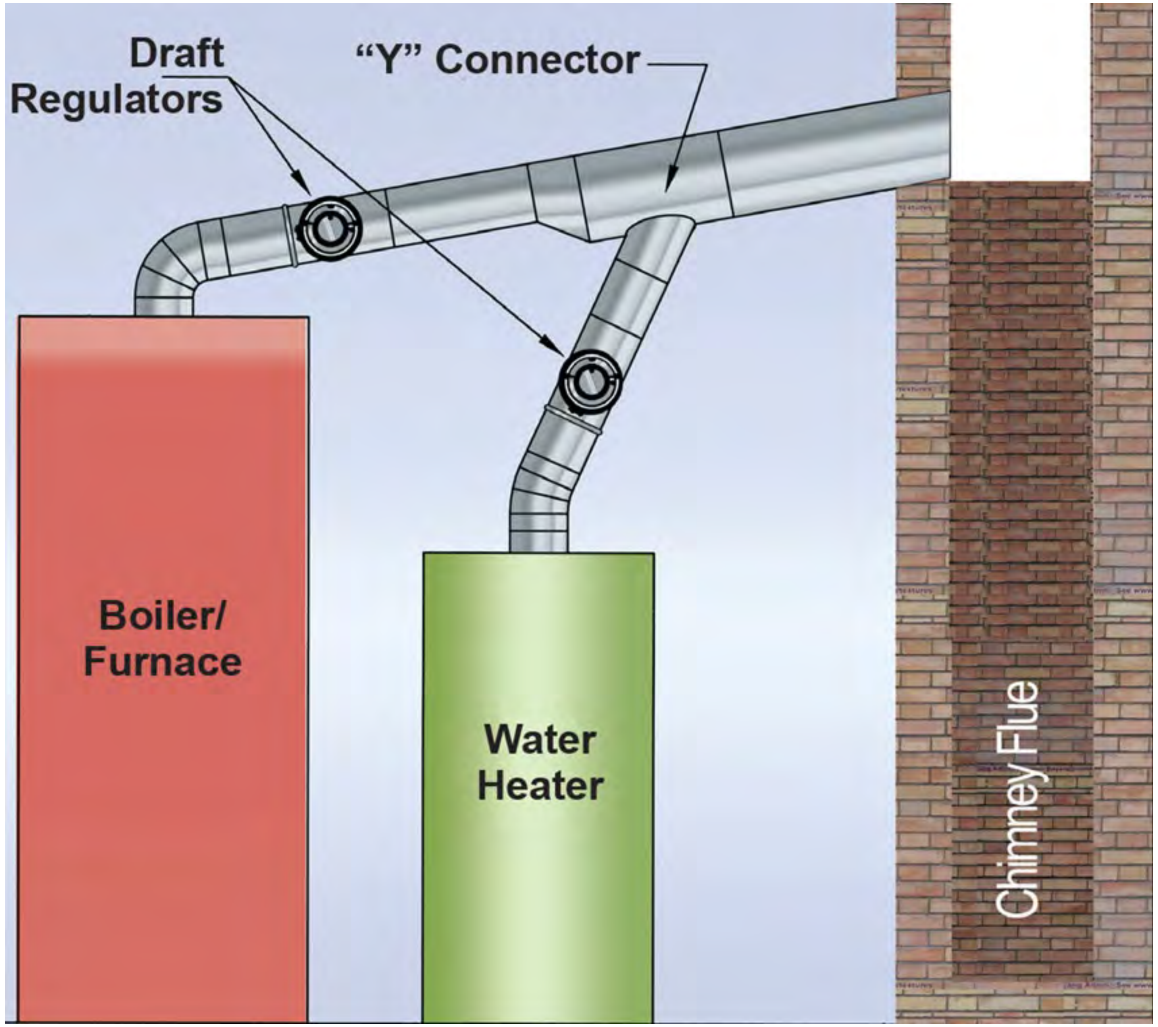
There are 2 ways to do this:

1. The two flue pipes can be joined together.
2. A second opening can be made into the chimney…

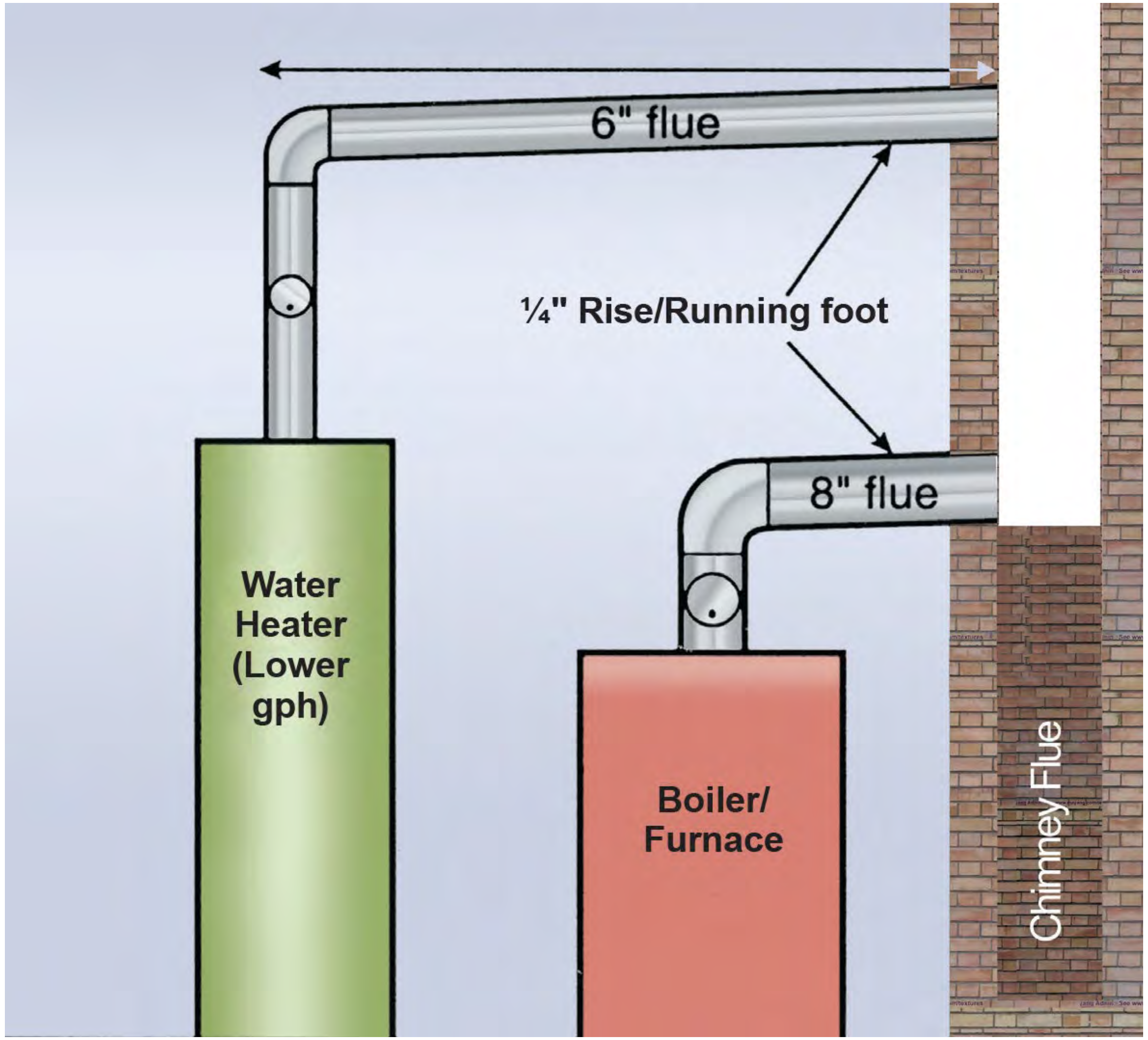
Either way, a separate draft regulator should be installed for each appliance.

Two Flue Pipes Joined Together

It's best to use a "Y" connector rather than a "Tee" because Tees often cause venting problems for both appliances.



Second Opening



When 2 or more openings are provided into 1 chimney, they must be at different levels.

The flue pipe from the appliance with the lower firing rate should enter at the higher level.

Effects of High Efficiency Appliances

High efficiency boilers and furnaces (including cold-start appliances) offer many advantages including:

- Lower flue gas temperatures
- Reduced firing rates
- Reduced fuel consumption

However, some of the effects of these improvements reduce draft and can cause operational problems.

Effects of High Efficiency Appliances

The most serious consequence of lower flue gas temperatures is condensation in the chimney which can lead to:

- Corrosion of the flue pipe
- Scale in the heat exchanger
- Chimney damage

A chimney liner is recommended when flue gas condenses in the chimney

Effects of High Efficiency Appliances

A corrosion resistant chimney liner is recommended

when flue gas condenses in the chimney.

Chimney Check

In our industry a “chimney check” is intended to identify obvious and serious chimney problems. If anything is found that would inhibit the safe operation of the heating system, the property owner should be notified immediately so a qualified chimney professional can be contacted.

Although the chimney check is not a detailed inspection, the following steps are recommended:

Chimney Check

Step 1

If there is one, visually inspect the clean-out door at the chimney base for excessive or abnormal debris.

Debris, mortar, brick or pieces of liner material at the base are signs of trouble.

Be sure the door is shut tight and sealed before leaving the job site.

Chimney Check

Step 2

Remove the flue pipe and inspect the inside of the chimney with a light and mirror for signs of damage or deterioration.

Chimney Check

Step 3

Observe the exterior of the chimney. If damage or deterioration is observed, or if the chimney is leaning, further inspection by a chimney professional is required.

Chimney Caps

Chimneys can suffer variable draft due to changes in wind or air turbulence. A simple & easy solution is to install a cap.

Note that caps can rust and discolor roofs, so high-grade stainless caps are recommended.

Draft Inducers

An alternative to using a chimney cap for variable draft due to changes in wind/turbulence is to install a draft inducer.

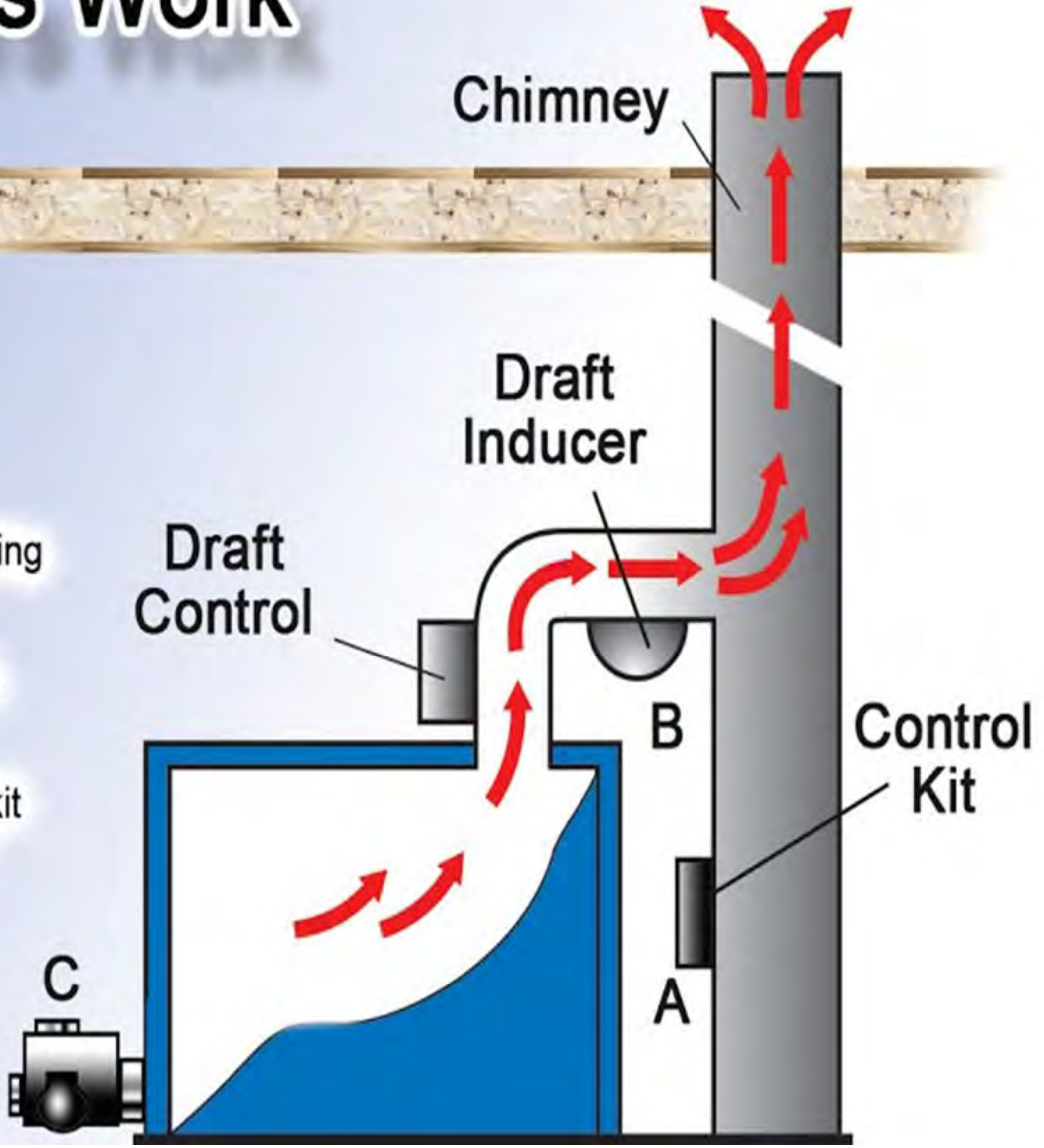
These are electrically powered fans installed in the flue pipe.

They help pull air from the appliance & push it up the chimney.

They can also be used to boost draft if the chimney draft is weak.

How Draft Inducers Work

1. The thermostat calls for heat.
2. Control kit (A) energizes draft inducer (B).
3. Draft inducer forces air flow in chimney, creating negative pressure in the combustion chamber.
4. Once negative pressure (draft) is established, the control kit allows the burner (C) to start.
5. When the thermostat is satisfied, the control kit shuts down the burner. The draft inducer shuts down after a post-purge cycle.



Alternative Venting

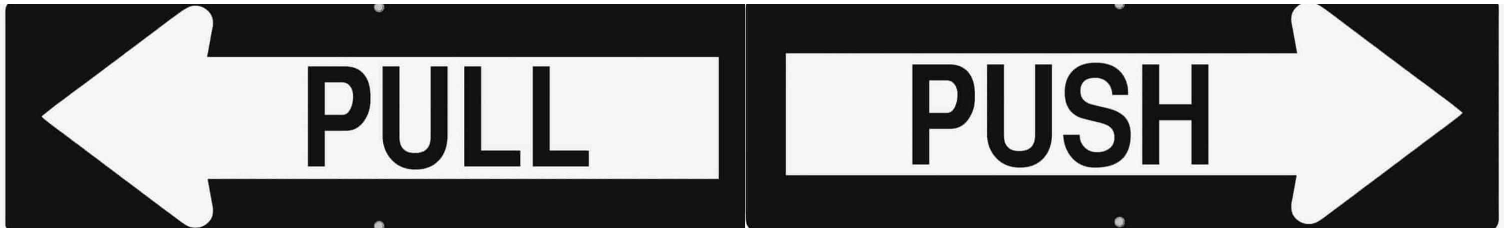
There are two types of alternative venting systems available that do not use a chimney, **power venting** and **direct venting**.

They have several advantages, including:

- More positive control of draft
- No chimney “warm up” problems
- Lower initial cost vs a chimney
- Minimized back drafts
- Reduced standby losses

Alternative Venting

Power vent systems use a motor and fan to **PULL** the combustion gases from the appliance to the outside. These gases are under negative pressure, so if there are any leaks, air leaks **into** the flue pipe and gases do **NOT** spill into the building.



Direct vent systems use the power of the burner fan to **PUSH** the combustion gases from the appliance to the outside.

These gases are under positive pressure, so if there are any leaks, gases leak **into** the building.

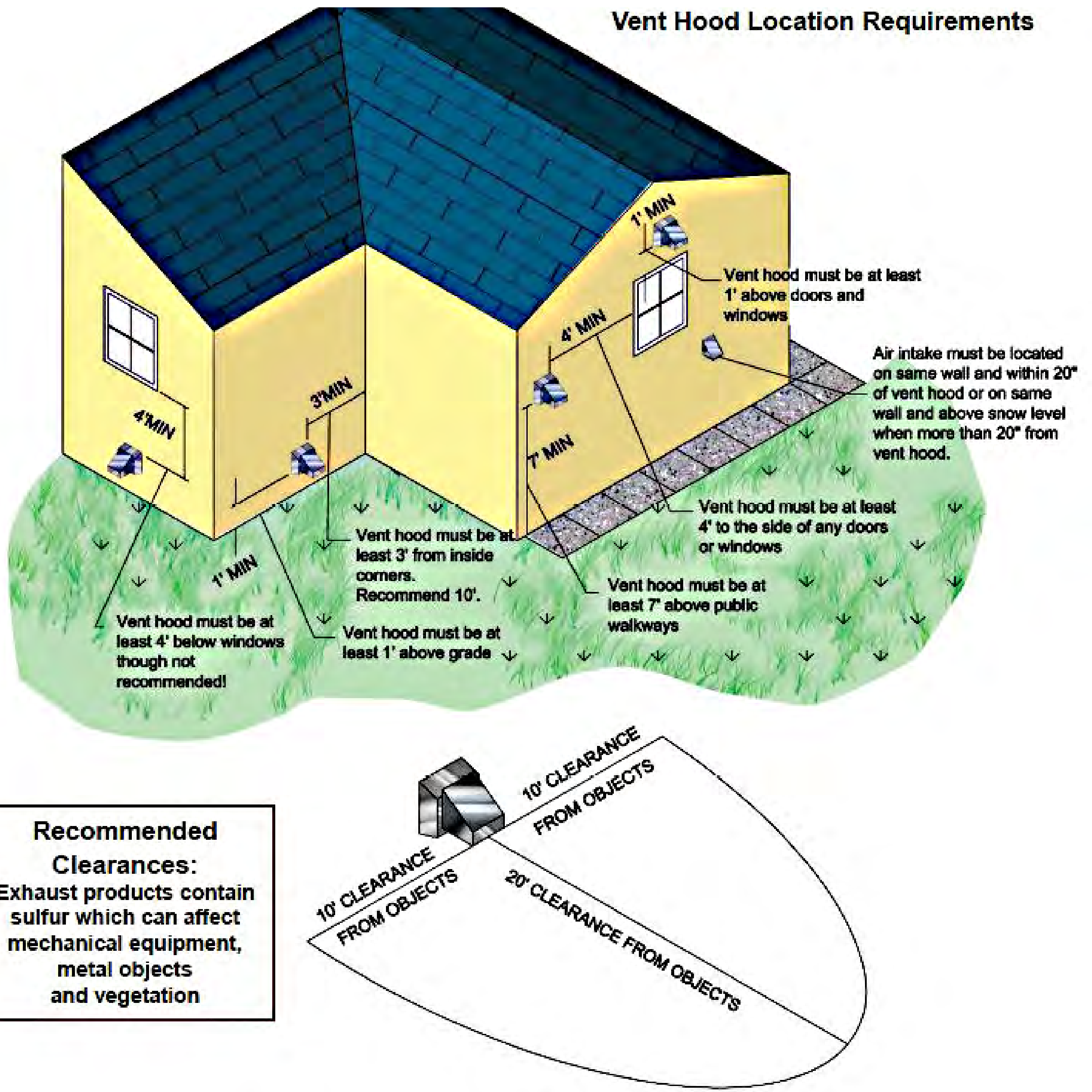
Terminal (Vent Hood) Location

As with all heating equipment, the installation and use of alternative venting systems must follow:

- Manufacturer’s instructions
- NFPA 31
- Local authority

In general, they must be……..

Terminal
(Vent Hood) Location



Recommended Clearances:
Exhaust products contain sulfur which can affect mechanical equipment, metal objects and vegetation

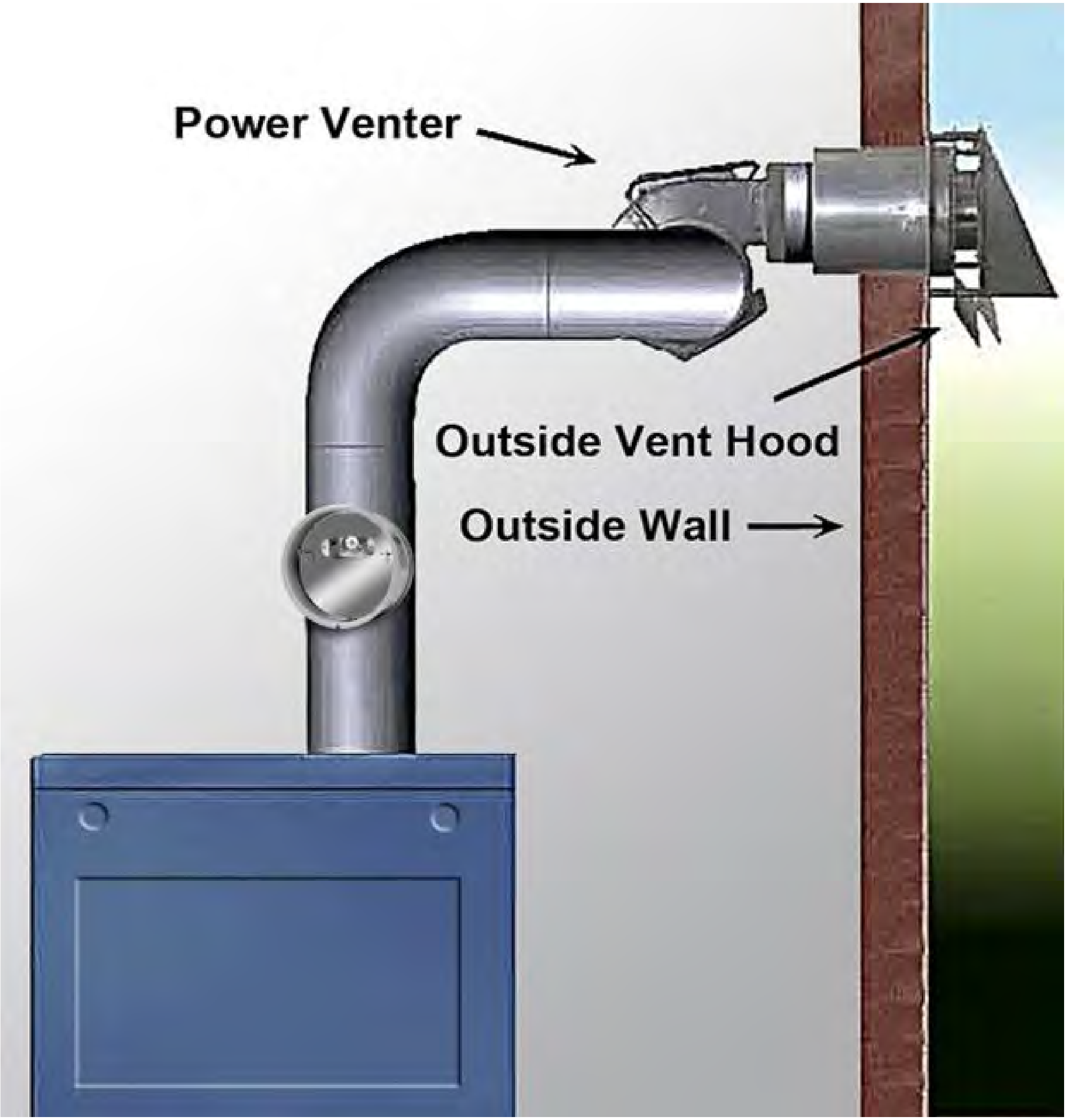
Terminal Location

- At least 4’ below windows
- 1’ above grade level or snow load
- 3’ from any inside corner (10’ recommended)
- Not less than 3’ above, 4’ horizontally, or 1’ above any door/window
- At least 7’ above public walkways
- At least 4’ to the side of doors or windows
- At least 1’ above doors and windows
- Not directly above or within 3’ horizontally from gas meter, electric meter or air conditioning condenser.
- At least 5’ from the vent outlet of a liquid fuel tank

Power Venting

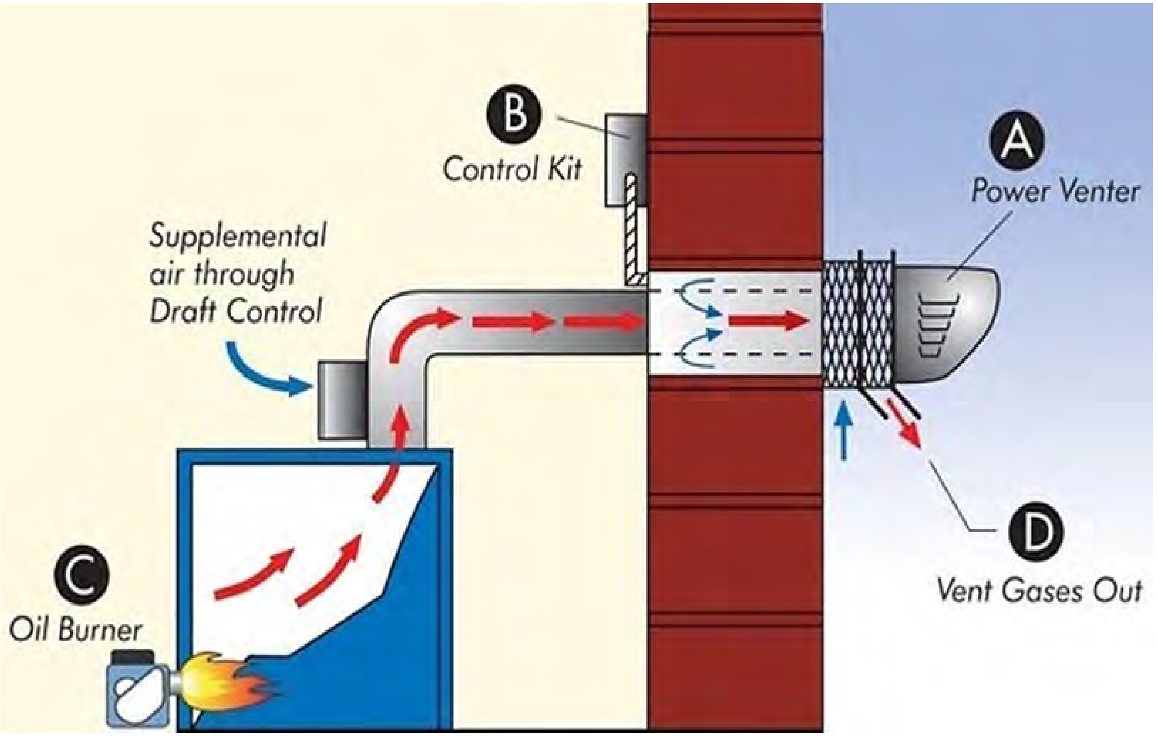
A fan, attached to the flue pipe where it exits the building.

<u>Pulls</u> combustion gases from the appliance and releases them outdoors.



How Power Venting Works

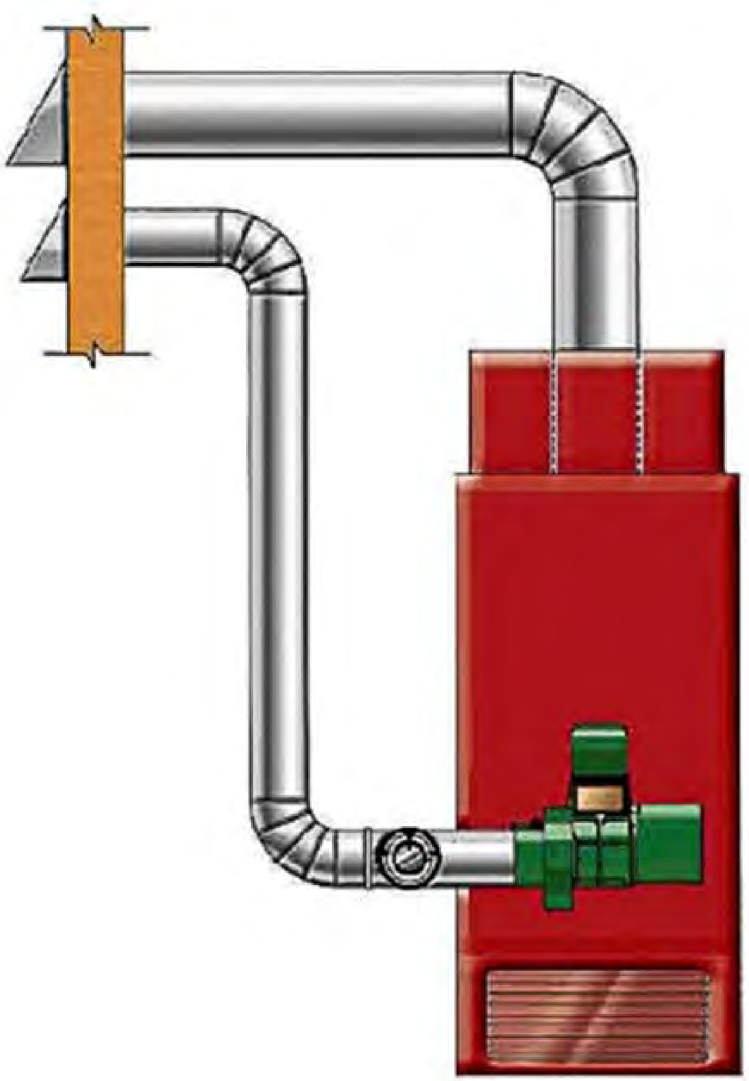
- A call for heat energizes the power vent motor
- Motor comes up to speed & pressure switch closes, powering primary control
- Burner fires after pre-purge
- When call for heat is satisfied burner enters post purge
- Oil valve closes but power venter & burner motor continue to run through post-purge cycle



Direct Venting

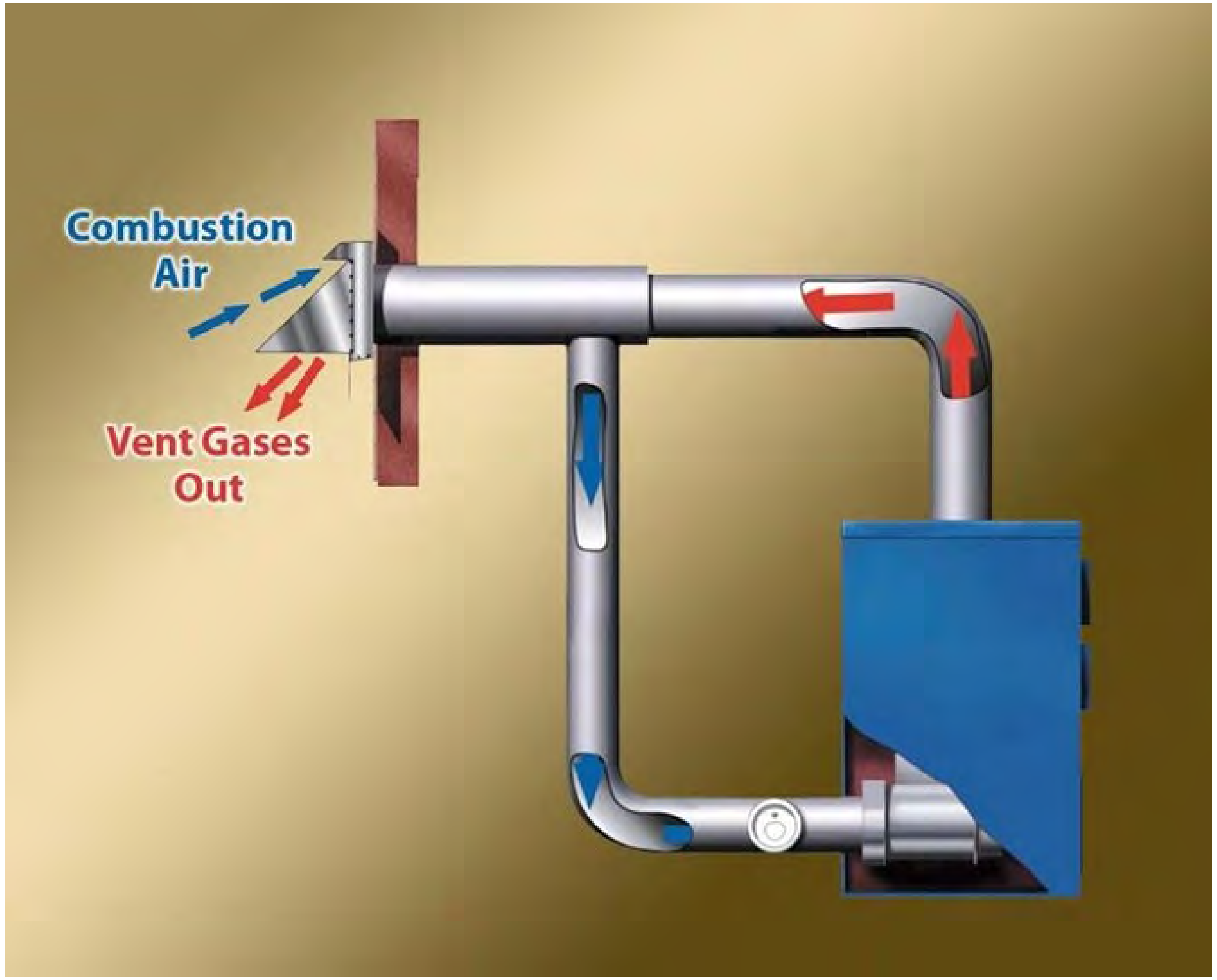
Static pressure created by the burner pushes combustion gases through the appliance and out though the flue.

Direct vent systems are sold as a complete package including the appliance and vent system. Do NOT mix and match, it can void the warranty and may create a hazardous situation.



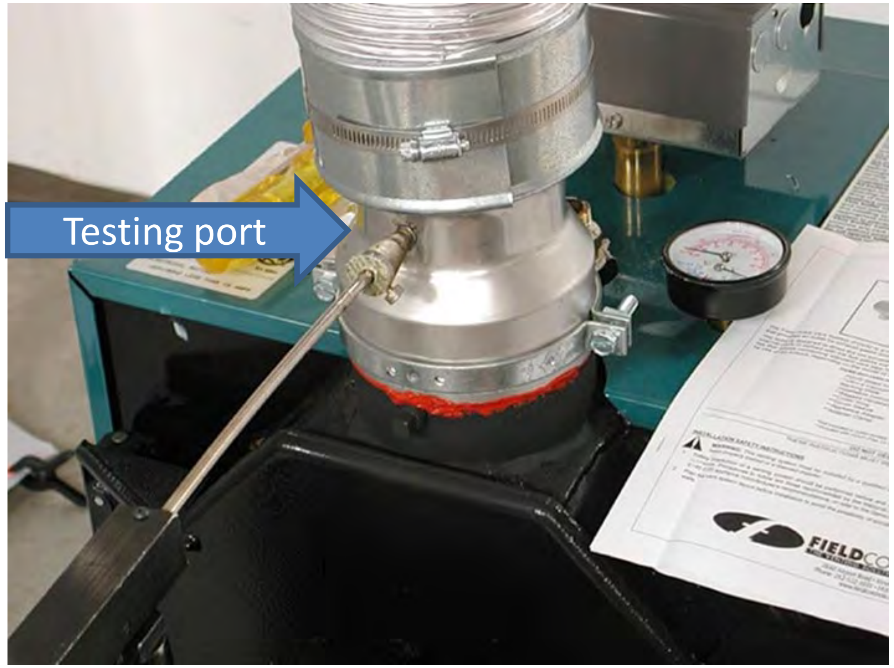
Direct Venting

Requires "high static pressure burners" & outside combustion air.



Direct Venting

All joints must be sealed with a high temperature sealant.



Combustion testing is done at the port provided by the manufacturer.

Do NOT puncture the vent tubing!

Advanced Venting Technology

As appliance manufacturers strive to increase efficiency, new developments continue to appear.

Some of the major challenges to making higher efficiency appliances is venting low-temperature flue gases, the effects of condensation and the effect of draft regulators on standby losses.

1940's

1970's

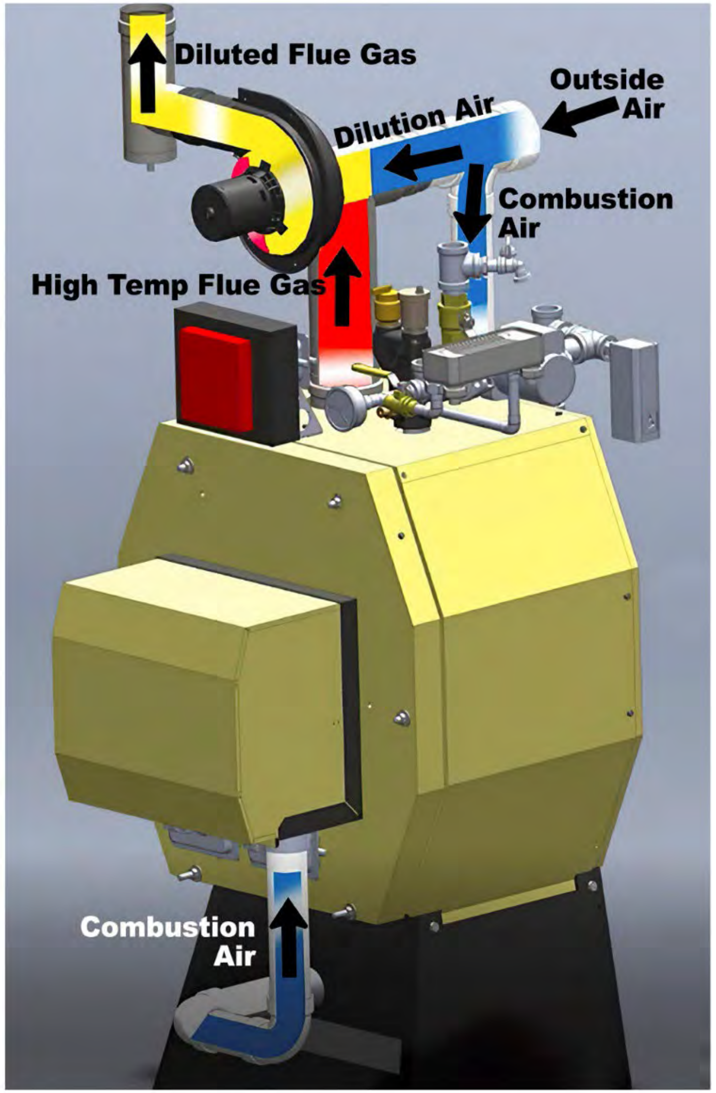
2030's

???

Advanced Venting Technology

Adding dilution (outside) air to exhaust gases lowers their temperature which:

- Enables the use of less expensive venting materials
- eliminates the draft regulator and reduces condensation in the venting system



End of Chapter 6

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 7

Combustion

At the end of this lesson, you will be able to:

- Explain what creates combustion in a burner
- Explain why the ratio of oil to air is critical
- Explain what measurements you take to test combustion
- Use a manual “wet” kit and electronic kit to test combustion
- Adjust a burner to get optimal test results

At the end of this lesson, you will be able to:

Continued…

- Explain what causes insufficient combustion air and how to perform a worst-case draft test
- Explain what causes improper air-fuel mixing and how to fix it
- Explain what causes flame impingement and how to fix it
- Explain what causes smoky shut-down and how to fix it

Combustion

Technicians have an obligation to ensure that customer's equipment operates at peak performance levels.

Understanding Combustion theory is the basis for adjusting Oilheat systems for safe, clean, reliable and economical operation.

What is Combustion?

"Combustion is the rapid oxidation of any material that will combine rapidly with oxygen."

In a liquid fuel fired appliance it's a chemical reaction that's controlled by adding or subtracting air, adjusting fuel unit pressure, moving the firing assembly and/or changing the nozzle specifications.

A visible flame is the result of many variables. To properly adjust a burner, it's essential to understand both what's seen and unseen in the combustion process.

Combustion

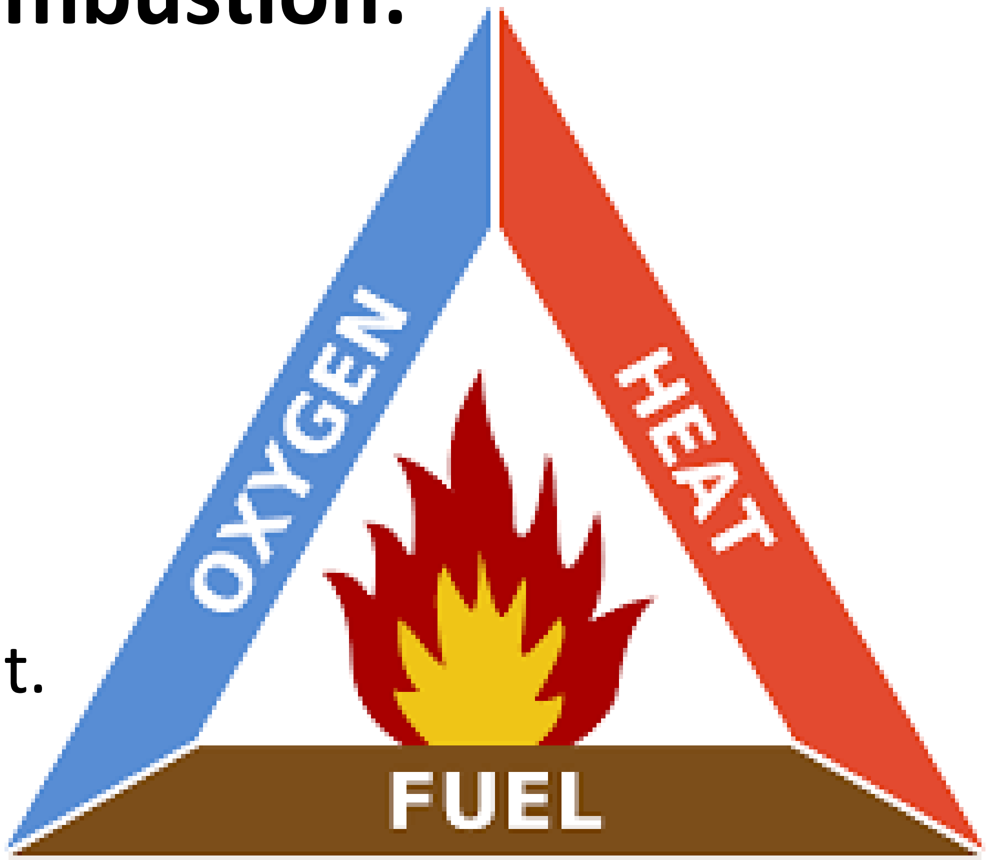
Three things are needed for combustion:

Oxygen, heat & fuel.

The oxygen is contained in the air that is delivered by the burner fan.

The spark generated by the ignitor and delivered by the electrodes provides the heat.

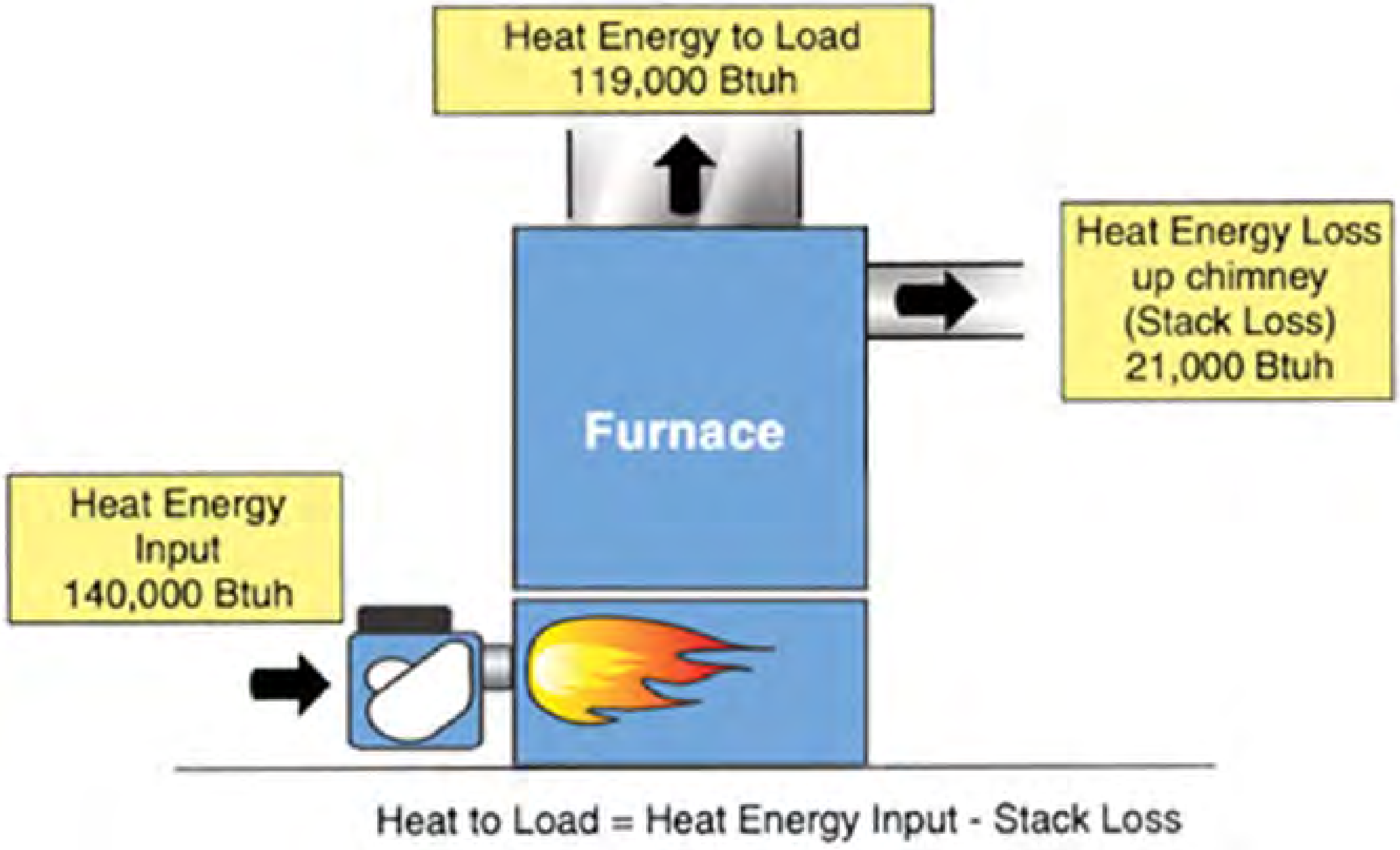
The nozzle delivers the atomized fuel.



Combustion

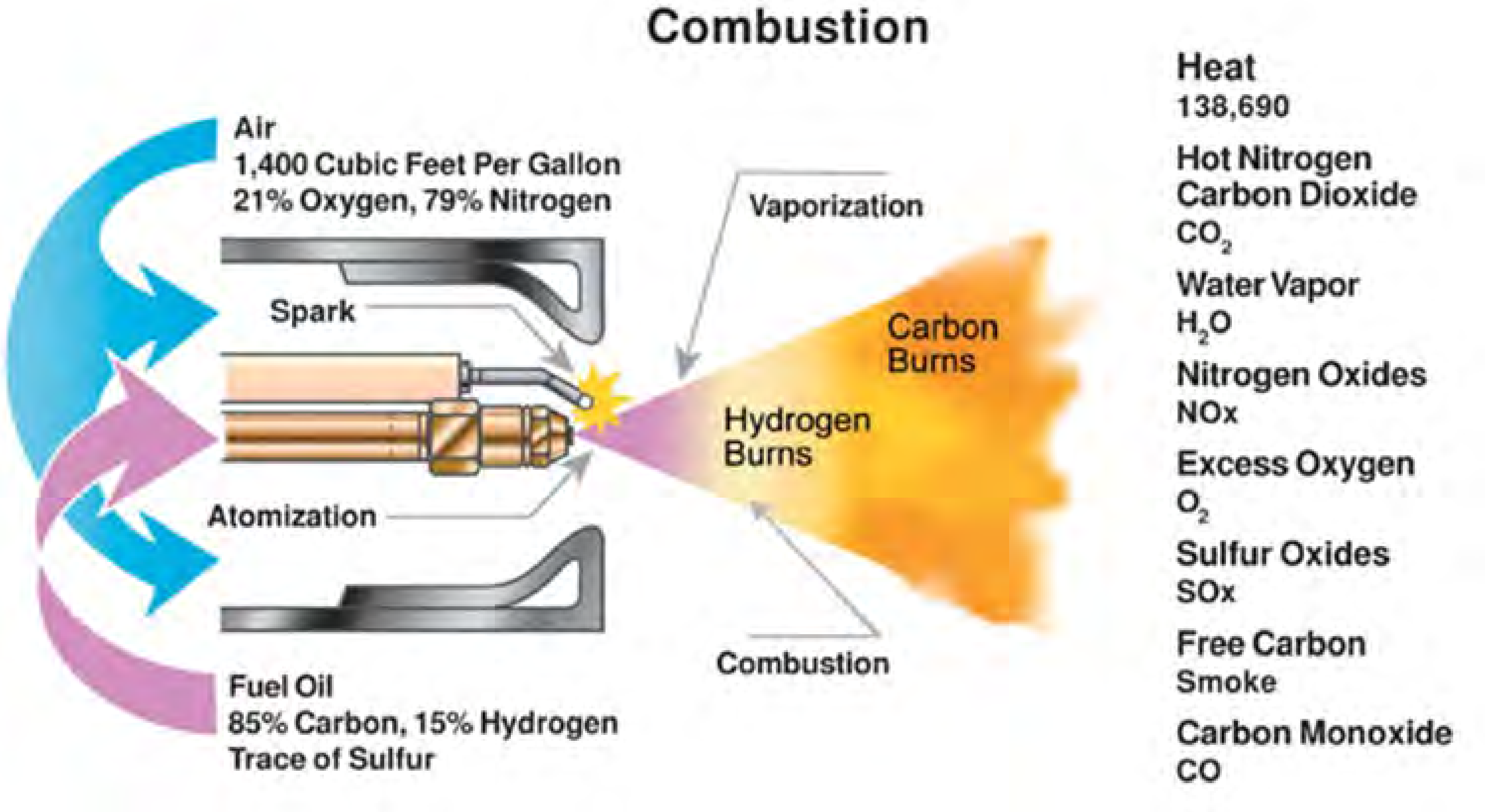
The sole purpose of the burner is to combine the fuel and oxygen in a manner that will result in safe, clean and efficient combustion.

Heat from the combustion gases is extracted by the heat exchanger in the appliance for space and/or domestic water heating.



Air & Fuel Mixture

- Liquid fuel needs to be ***precisely*** mixed with air for complete combustion, the better the mix, the better the combustion
- Too little air causes incomplete combustion, smoke & excess CO
- Too much air also causes incomplete combustion & excess CO. It also lowers the flame temperature & the heat content deliverable by the fuel



Too Little, Too Much – What's Right?

With today's equipment, about 1360 cubic feet of air is required to burn a gallon of fuel.
(a room that's 14'X12'X8').

If perfect (stoichiometric) combustion could be achieved less air would be required, however:

- "Excess air" is required to provide for changes such as air bands and burner fans becoming clogged with animal hair, lint, dust, etc….

Excess air is required (continued)

- Varying air temperatures can affect the volume of air, warmer air is less dense and provides less oxygen, colder air is denser and provides more oxygen
- Draft variations can occur that are beyond the barometric damper's ability to compensate
- Variations in the heating content (BTU's) of the fuel delivered – kerosene blends, bio-blends

Combustion Testing and Analysis

Combustion testing is one of the most important tasks technicians perform.

It is done to determine the quality of the combustion process and the results are used to analyze, diagnose and make needed adjustments to the burner.

Combustion Testing and Analysis

Combustion testing is required by code and provides numerous benefits to both the customer and the service technician, including:

- Increased efficiency
- Lower environmental emissions
- Reduced maintenance
- Fewer call-backs
- Limiting liability
- Maintaining equipment warranties
- Providing confidence
- Increased comfort
- Increased safety

If you're not testing...
You're guessing!

Combustion Testing and Analysis

- It’s critical that technicians leave equipment operating at the safest and cleanest way possible

- Adjusting the flame “by eye” is prone to mistakes that could lead to property damage and personal injury

Principles of Combustion Testing

Combustion testing includes measuring draft and the composition and temperature of flue gases as they exit the appliance.

It should be performed after a tune-up and any time a combustion related component has been serviced or replaced. For example, after cleaning or adjusting an air inlet/burner fan or replacing a nozzle, burner motor, filter, fuel unit, retention head, etc.

It can be, but is not normally, preformed after a component such as circulator or limit control is replaced.

Principles of Combustion Testing

Prior to starting the test procedure, the burner should be set to manufacturer specifications, then:

- Perform a brief visual inspection of the combustion chamber for integrity, remove any soot & scale & make any necessary repairs
- If there's an inspection port, fire the unit & check for flame impingement. If it's found, determine the cause & correct it.

Note: opening the inspection port while the burner is running allows extra air to affect the flame & test results.

Basic Testing Measurements

- Temperature of the flue gases
- Draft – in the flue “breech” and “over-the-fire
- Smoke – adjust to zero
- CO_2

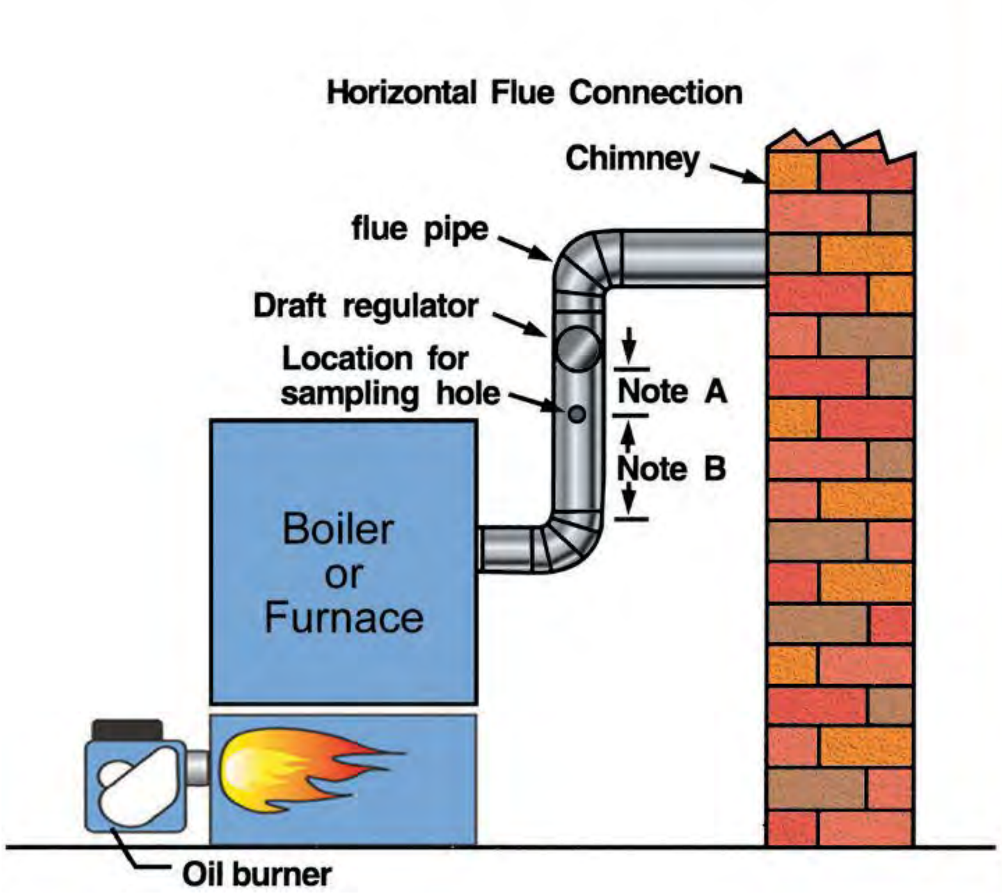
Each measurement has a range that can be used to properly set-up burners and diagnose problems.

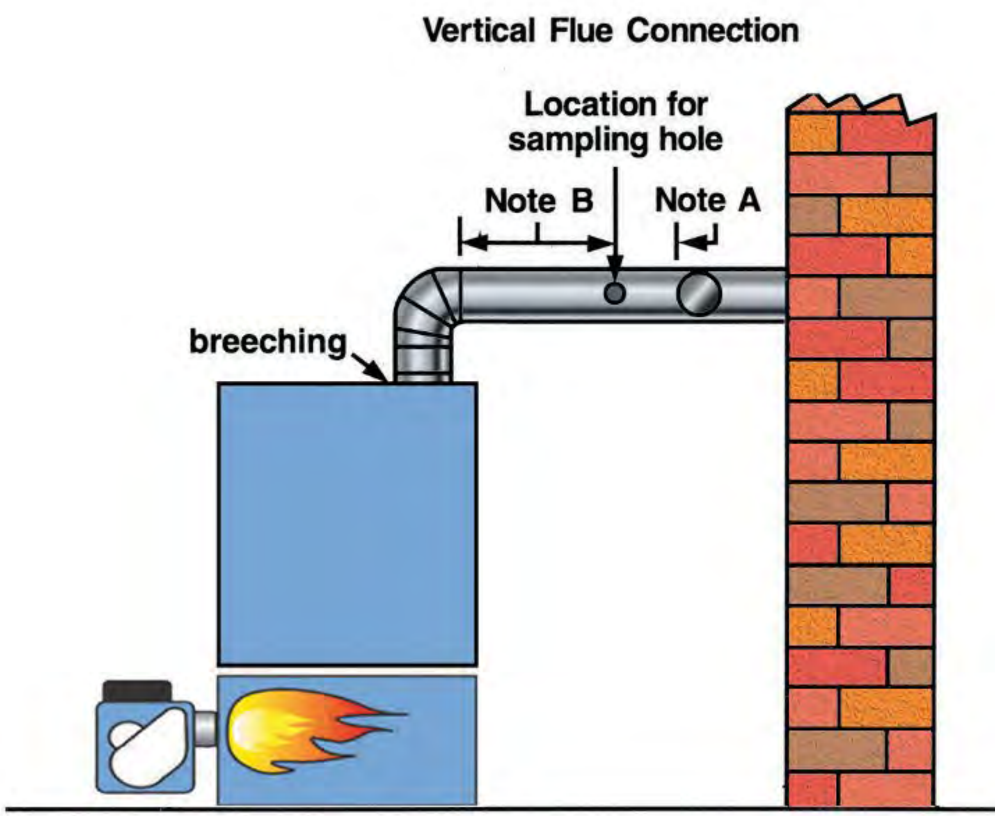
Steady State

For accurate results, measurements should be taken after the appliance has reached "steady state", the point at which the stack temperature stops rising

- At steady state, the appliance has thoroughly warmed up
- Testing before will not give accurate results
- May require the burner to run for 5 – 10 minutes

Holes for Testing





A. Locate hole at least one flue pipe diameter on the appliance side of the draft control

B. Ideally, hole should be at least two flue pipe diameters from breeching or elbow

Combustion Test Equipment

- Manual (wet kits) VS electronic
- Electronic analyzers sample continuously, giving real time results as adjustments are made. Electronic analyzers do NOT include smoke tester

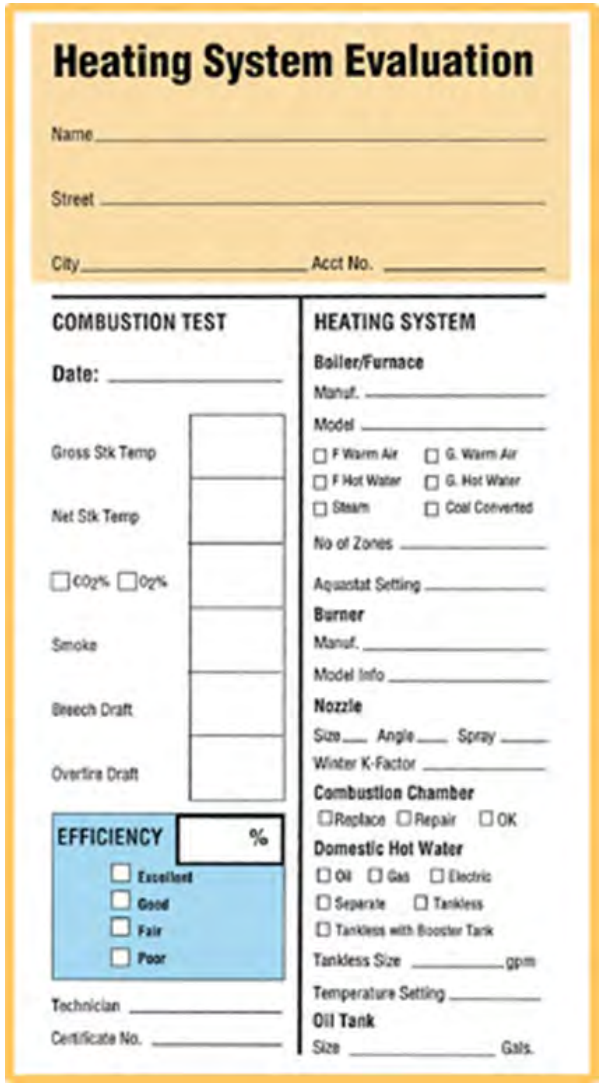
Step by Step Procedure with a Wet kit

Manual testing

MUST

be completed in the

proper sequence.



Heating System Evaluation

Name ______

Street ______

City ______ Acct No. ______

COMBUSTION TEST

Date: ______

Gross Stk Temp

Net Stk Temp

☐ CO2% ☐ O2%

Smoke

Breech Draft

Overfire Draft

EFFICIENCY %

☐ Excellent
☐ Good
☐ Fair
☐ Poor

Technician ______

Certificate No. ______

HEATING SYSTEM

Boiler/Furnace

Manuf. ______

Model ______

☐ F Warm Air ☐ G. Warm Air
☐ F Hot Water ☐ G. Hot Water
☐ Steam ☐ Coal Converted

No of Zones ______

Aquastat Setting ______

Burner

Manuf. ______

Model Info ______

Nozzle

Size ___ Angle ___ Spray ___

Winter K-Factor ______

Combustion Chamber

☐ Replace ☐ Repair ☐ OK

Domestic Hot Water

☐ Oil ☐ Gas ☐ Electric
☐ Separate ☐ Tankless
☐ Tankless with Booster Tank

Tankless Size ______ gpm

Temperature Setting ______

Oil Tank

Size ______ Gals.

Proper Sequence (Wet)

1. Measure stack temperature after operating unit long enough to reach steady state operating temperature.
2. Ensure adequate draft.
3. Perform smoke test.
4. Measure CO_2.
5. Measure stack temperature. (again)
6. Calculate combustion efficiency.
7. Plug test hole. (optional)

Stack Temperature

This is done first to be sure unit has reached steady state:

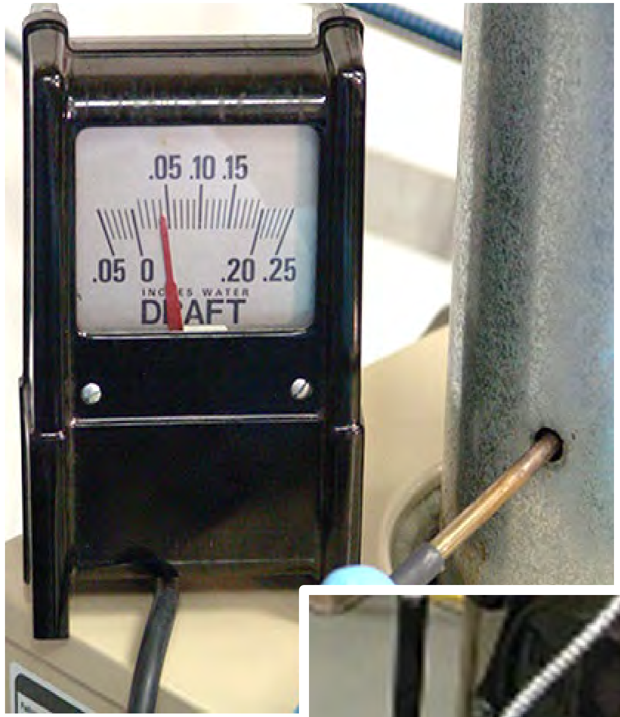
- Insert the thermometer into the flue so that the its tip is in the center of the flue pipe (the "hot spot")
- Operate the burner until the reading rises no more than 3°F per minute and record the reading

NOTE: If the temperature approaches 1,000° F, remove the thermometer to prevent damaging it.

Draft

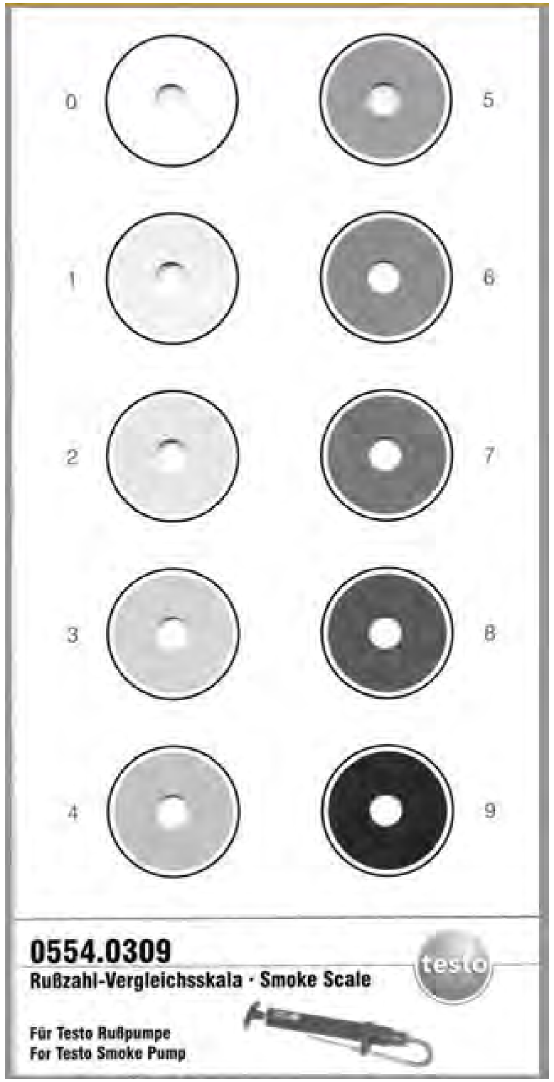
Draft is measured second because the rest of the results will be changed by an increase or decrease in draft.

- Insert the probe into the hot spot in the flue and measure the “breech draft”
- Then insert it in the opening at the flame observation door
- If necessary, adjust the draft regulator to set the draft to manufacturer’s specs, typically -.04 at-the- breech and -.02 over-the-fire



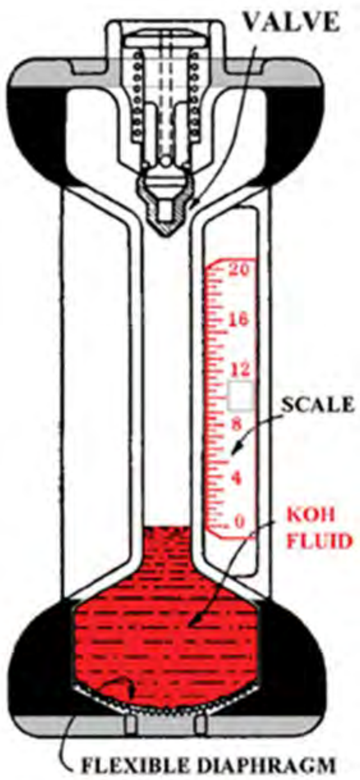
Smoke- Goal is a “zero” reading

- Insert a clean piece of smoke test paper into the tester and then insert the tube to the hot spot in the flue
- Slowly pull the handle 10 full pump strokes,
- Remove the paper and match the color of the sample to the closest spot on the smoke scale
- If the test shows zero on the first try, adjust burner for a trace of smoke (between 0-1) then add slightly more combustion air



Carbon Dioxide (CO_2)

CO_2 is measured after draft & smoke tests because adjustments made to correct draft or smoke issues affect the CO_2 reading.



Using the CO_2 Analyzer

1. Hold upright, depress & release plunger, adjust scale.
2. Insert tube into hot spot, connect pump to analyzer and pump 18X, release while pump collapsed.
3. Turn analyzer over 2X, hold at 45^{o} angle to complete draining of fluid into reservoir.
4. Hold upright for a few seconds & immediately read CO_2 on the scale.

Note: a 5-10 second delay in reading the scale may decrease the accuracy slightly, longer delays may cause a substantial error.

Stack Temperature

- Although the temperature was measured during the first step in this process, the burner adjustments made to address draft, smoke and CO_2 issues affect the temperature reading.
- Record the temperature displayed on the stack thermometer and subtract the combustion air temperature to determine "net stack temperature."

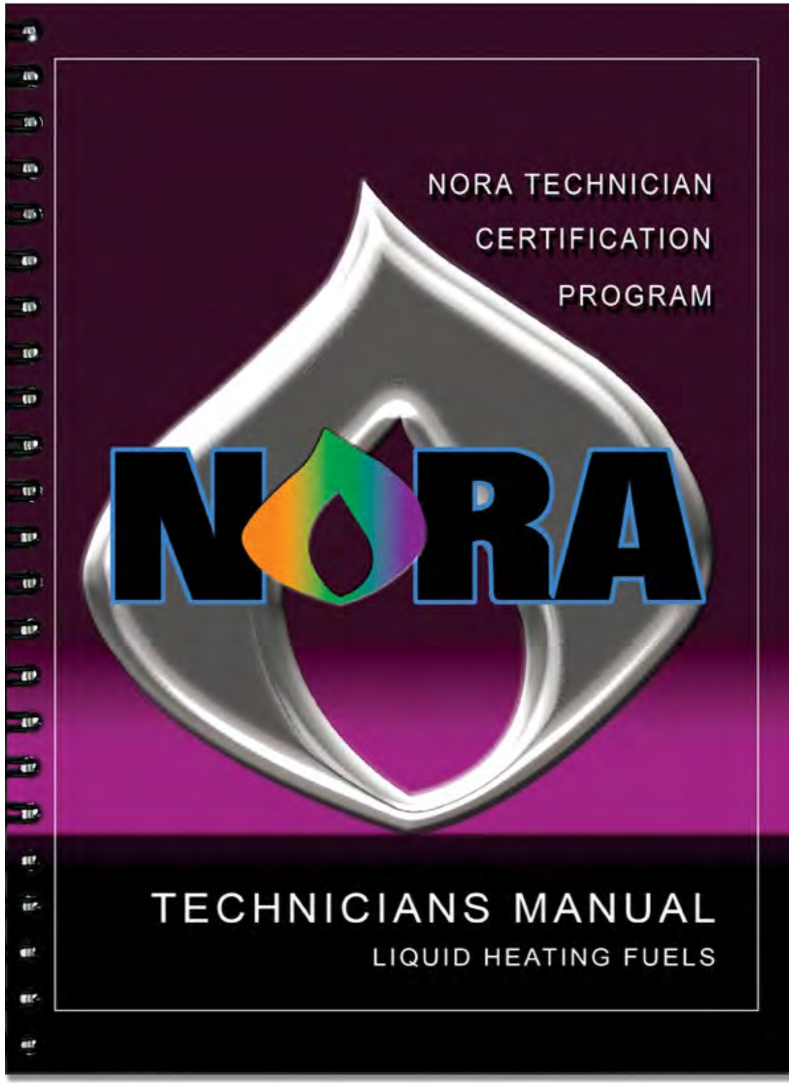
Combustion Efficiency Calculations

Use the kits Fire Efficiency Finder with the fuel slider to determine the combustion efficiency by lining up the CO_2 and net stack temperature

Alternative Procedure

The NORA Technicians Manual includes a slightly different procedure for conducting a combustion analysis with a wet kit.

The procedure is detailed starting on page 105 of the manual.



Alternate Procedure (Wet)

1. Measure stack temperature after operating unit long enough to reach steady state operating temperature.
2. Ensure adequate draft.
3. Perform smoke test.
4. Measure CO_2.
5. Measure stack temperature. (again)
6. Calculate combustion efficiency.
7. Plug test hole. (optional)

Alt. Procedure: Stack Temperature

This is done first to be sure unit has reached steady state:

- Insert the thermometer into the flue so that the its tip is in the center of the flue pipe (the “hot spot”)
- Operate the burner until the reading rises no more than 3°F per minute and record the reading

NOTE: If the temperature approaches 1000°F, remove the thermometer to prevent damaging it.

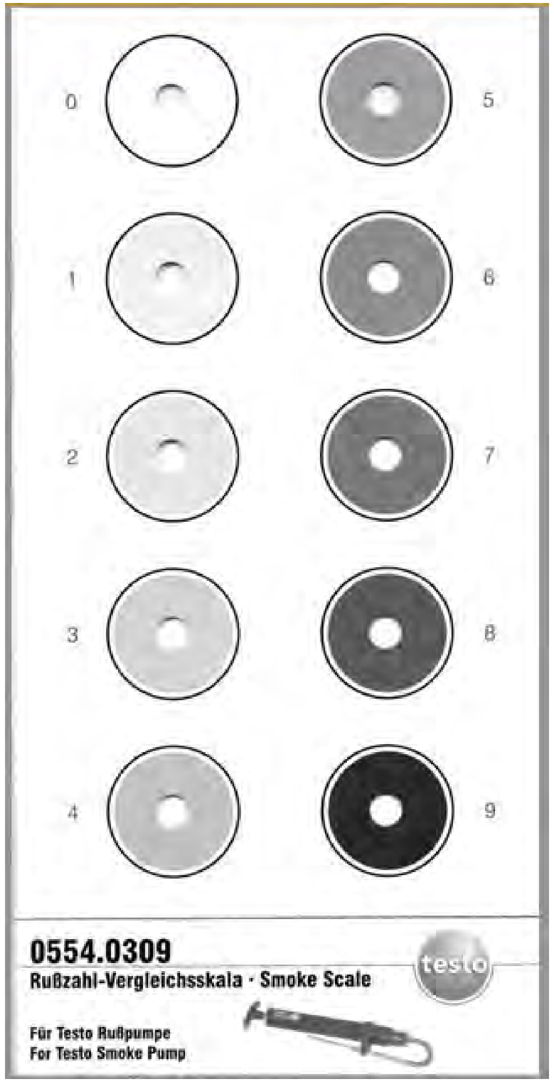
Alternate Procedure: Draft

Draft is measured second because the rest of the results will be changed by an increase or decrease in draft.

- Insert the probe into the hot spot in the flue and measure the “breech draft”
- Then insert it in the opening at the flame observation door
- If necessary, adjust the draft regulator to set the draft to manufacturer’s specs, typically -.04 at-the-breech and -.02 over-the-fire

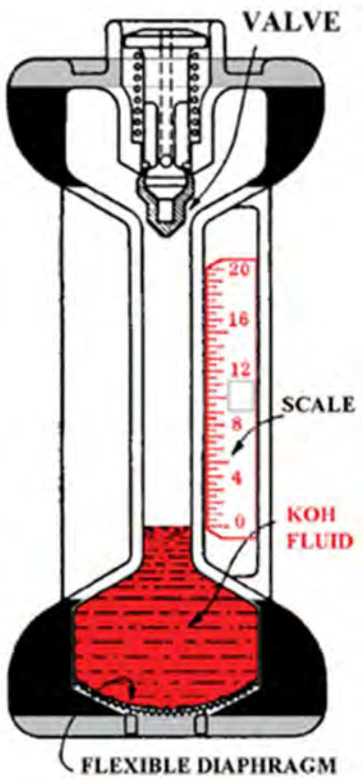
Alternate Procedure: Smoke

- Insert a clean piece of smoke test paper into the tester and then insert the tube to the hot spot in the flue
- Slowly pull the handle 10 full pump strokes, remove the paper and match the color of the sample to the closest spot on the smoke scale
- ***To properly adjust for zero smoke, adjust the burner for a trace (between 0 -1) smoke and move to the next step***



Alternate Procedure: Carbon Dioxide (CO_2)

CO2 is measured after draft & smoke tests because adjustments made to correct draft or smoke issues affect the CO2 reading.



Alternate Procedure: Carbon Dioxide (CO_2)

1. Hold upright, depress & release plunger, adjust scale.
2. Insert tube into hot spot, connect pump to analyzer and pump 18 X, release while pump collapsed.
3. Turn analyzer over 2 X, hold at 45^o angle to complete draining of fluid into reservoir.
4. Hold upright for a few seconds & immediately read CO_2 on the scale.

Note: a 5-10 second delay in reading the scale may decrease the accuracy slightly, longer delays may cause a substantial error.

Alternate Procedure: Carbon Dioxide (CO_2)

5. Increase combustion air until the CO_2 is 1% to 1.5% lower than recorded AND make sure that it is lowered below 12.5% to assure safe carbon monoxide levels.

For example: If the trace level recorded is 12.5%, increase air to lower the CO2 between 1% to 1.5% so it is between 11% to 11.5%.

This procedure creates a safety margin of excess air to ensure that variations in combustion conditions (air, fuel or draft) don't create problem situations……

Alternate Procedure: Carbon Dioxide (CO_2)

For safety reasons, perform another smoke test to be sure the reading is zero.

Stack Temperature

- Although the temperature was measured during the first step in this process, the burner adjustments made to address draft, smoke and CO_2 issues affect the temperature reading.
- Record the temperature displayed on the stack thermometer and subtract the combustion air temperature to determine "net stack temperature."

Combustion Efficiency Calculations

Use the kits Fire Efficiency Finder with the fuel slider to determine the combustion efficiency by lining up the CO_2 and net stack temperature

Testing with Electronic Analyzers

Electronic analyzers reduce the time needed for combustion testing and provide more information than wet kits.

They show real time test results that enable the technician to make adjustments and see the results within seconds.

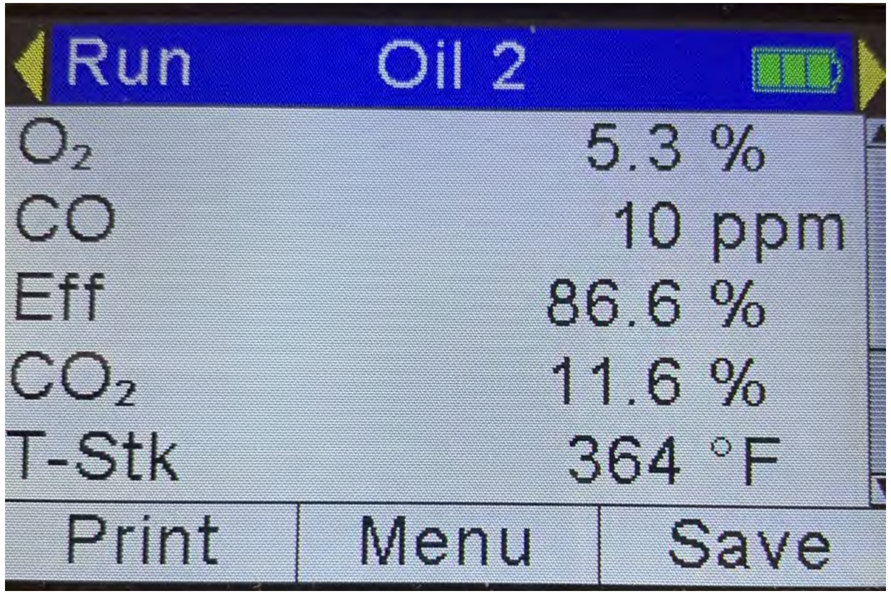
With the optional printer, data can be recorded that allows for accurate tracking of system changes & provides valuable information for servicing the equipment in the future.

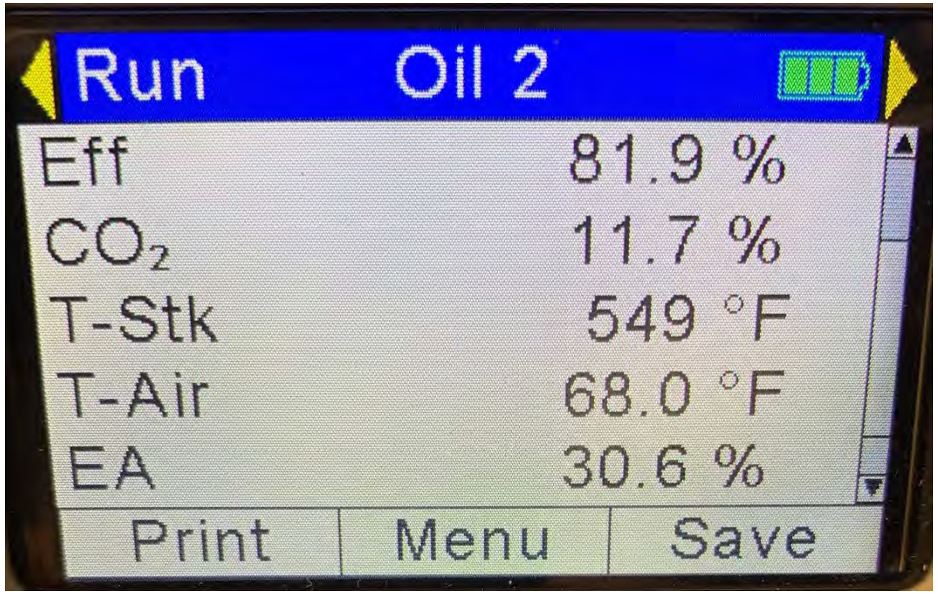
Electronic Analyzers

Technicians should NOT leave their testers in a cold vehicle overnight, freezing temperatures have an impact on sensor life.

How Electronic Analyzers Work

Most analyzers have sensors that ***measure*** oxygen, draft, stack and ambient temperatures. CO_2 and excess air are **calculated**.



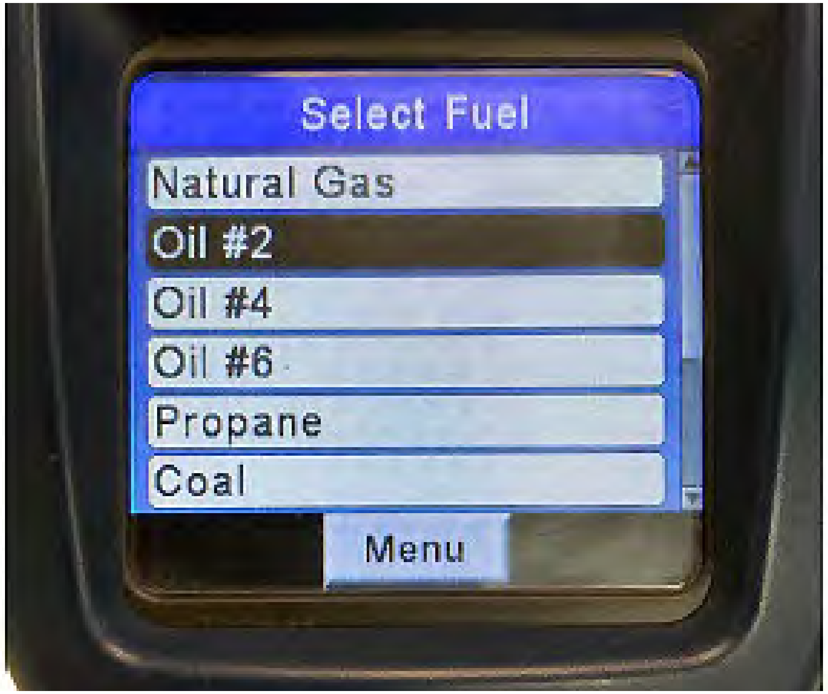


To extend the life of the sensors, always perform a smoke test and adjust for zero smoke before using an electronic analyzer.

Step-by-Step Procedure with Analyzer

Step 1. Start the analyzer and allow it to calibrate in room air. Set fuel selection to the fuel in use. CO should read zero and O_2 should be 20.9%, if they're not, move the analyzer to the outdoors and let it recalibrate.

If the readings outside are zero CO and 20.9% O_2 , the combustion zone air is unsatisfactory. If they are not, either the analyzer needs service or there could be CO outside.



Step-by-Step Procedure with Analyzer

Step 2. Operate the burner and once it reaches steady state perform a smoke test and adjust to zero smoke.

All other measurements are made with the analyzer probe inserted in the flue gas hot spot.

Step-by-Step Procedure with Analyzer

<u>Step 3.</u> Adjust draft, using a separate draft gauge if the analyzer doesn't include that feature.

Be careful when using an analyzer to measure over-fire draft, it can be damaged by exposure to extreme heat. Use a pigtail and follow the manufacturer's instructions.

Step-by-Step Procedure with Analyzer

Step 4. Perform a smoke test again to confirm zero smoke after th draft adjustment.

Step 5. Re-insert the probe in hot spot.

Step 6. When the unit reaches steady state again, observe the readings:

- **Ambient temperature** – the temperature of the incoming combustion air, either room temperature or the temperature of the air being delivered by a combustion air kit….

Step 6, continued

- **Stack temperature** – the temperature of the flue gas **minus** the ambient temperature
- **Oxygen** – The vast majority of analyzers use an O_2 sensor and use that reading to calculate CO_2 and excess air based on the fuel selected
- **Carbon monoxide** – Analyzers measure this value directly using a CO sensor and then use the excess air to calculate the CO air-free…

Step 6, continued

- **Carbon monoxide air free** – The amount of CO in the flue gas calculated as if there were no excess air. This allows an equal comparison between units with widely varying excess air levels

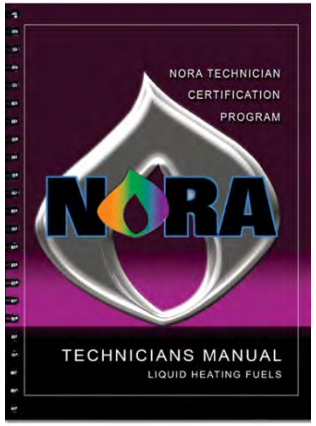
- **Excess Air** – Calculated from the O_2 content of the flue gas for the fuel selected. This is a measure of the amount of air present above the stoichiometric quantity and includes the "safety margin" in case of adverse conditions

Step-by-Step Procedure with Analyzer

Step 7. If the optional printer is being used, print a record of the readings. If it is not being used, record the readings on the service ticket.

As with the wet-kit alternative procedure, the NORA *Technicians Manual* includes a slightly different procedure for conducting a combustion analysis with an electronic analyzer.

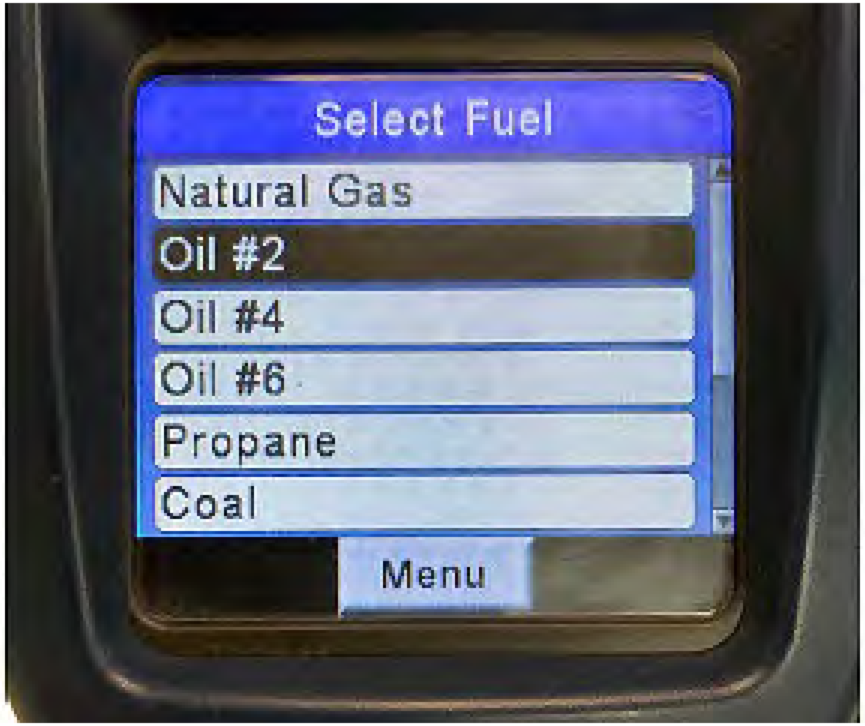
The procedure is detailed starting on page 108 of the manual.



Alternate Procedure Using an Analyzer

<u>Step 1.</u> Start the analyzer and allow it to calibrate in room air, set fuel selection to the fuel in use. CO should read zero and O_2 should be 20.9%, if they're not, move the analyzer to the outdoors and let it recalibrate

If the readings outside are outside are zero CO and 20.9% O_2 , the combustion zone air is unsatisfactory. If they are not, either the analyzer needs service or there could be CO outside.



Alternate Procedure Using an Analyzer

<u>**Step 2.**</u> Operate the burner and once it reaches steady state perform a smoke test and adjust to a trace of smoke.

All other measurements are made with the analyzer probe inserted in the flue gas hot spot.

Alternate Procedure Using an Analyzer

Step 3. Adjust draft, using a separate draft gauge if the analyzer doesn't include that feature.

Be careful when using an analyzer to measure over-fire draft, it can be damaged by exposure to extreme heat.

Use a pigtail and follow the manufacturer's instructions.

Step-by-Step Procedure Using an Analyzer

Step 4. Perform a smoke test again to confirm a trace of smoke after the draft adjustment.

Step 5. Re-insert the probe in the hot spot.

Step 6. When the unit reaches steady state again, observe the readings:

Ambient temperature – the temperature of the incoming combustion air, either room temperature or the temperature of the air being delivered by a combustion air kit…..

Step 6, continued

- **Stack temperature** – the temperature of the flue gas **minus** the ambient temperature
- **Oxygen** – The vast majority of analyzers use an O_2 sensor and use that reading to calculate CO_2 and excess air based on the fuel selected
- **Carbon monoxide** – Analyzers measure this value directly using a CO sensor and then use the excess air to calculate the CO air-free…

Step 6, continued

- **Carbon monoxide air free** – The amount of CO in the flue gas calculated as if there were no excess air. This allows an equal comparison between units with widely varying excess air levels

- **Excess Air** – Calculated from the O_2 content of the flue gas for the fuel selected. This is a measure of the amount of air present above the stoichiometric quantity and includes the "safety margin" in case of adverse conditions

Step-by-Step Procedure Using an Analyzer

Step 7. Increase combustion air until the CO_2 shown on the screen is 1% to 1.5% lower than recorded plus make sure that it is lowered below 12.5% to assure safe CO levels.

For example: If the trace level recorded is 12.5%, increase air to lower the CO_2 between 1% to 1.5% so it is between 11% to 11.5%.

This procedure creates a safety margin of excess air to ensure that variations in combustion conditions (air, fuel or draft) don't create problem situations.

Step-by-Step Procedure Using an Analyzer

Step 8. If the optional printer is being used, print a record of the readings.

If it is not being used, record the readings on the service ticket.

It's Better to use an Electronic Analyzer

- Faster, more accurate, more reliable and higher repeatability
- Data is recorded and printable
- Smoke test MUST be done first

It's Better to use an Electronic Analyzer

Wet kits have been used for many years & can produce reasonably reliable results ***if*** used & maintained properly

It's Better to use an Electronic Analyzer

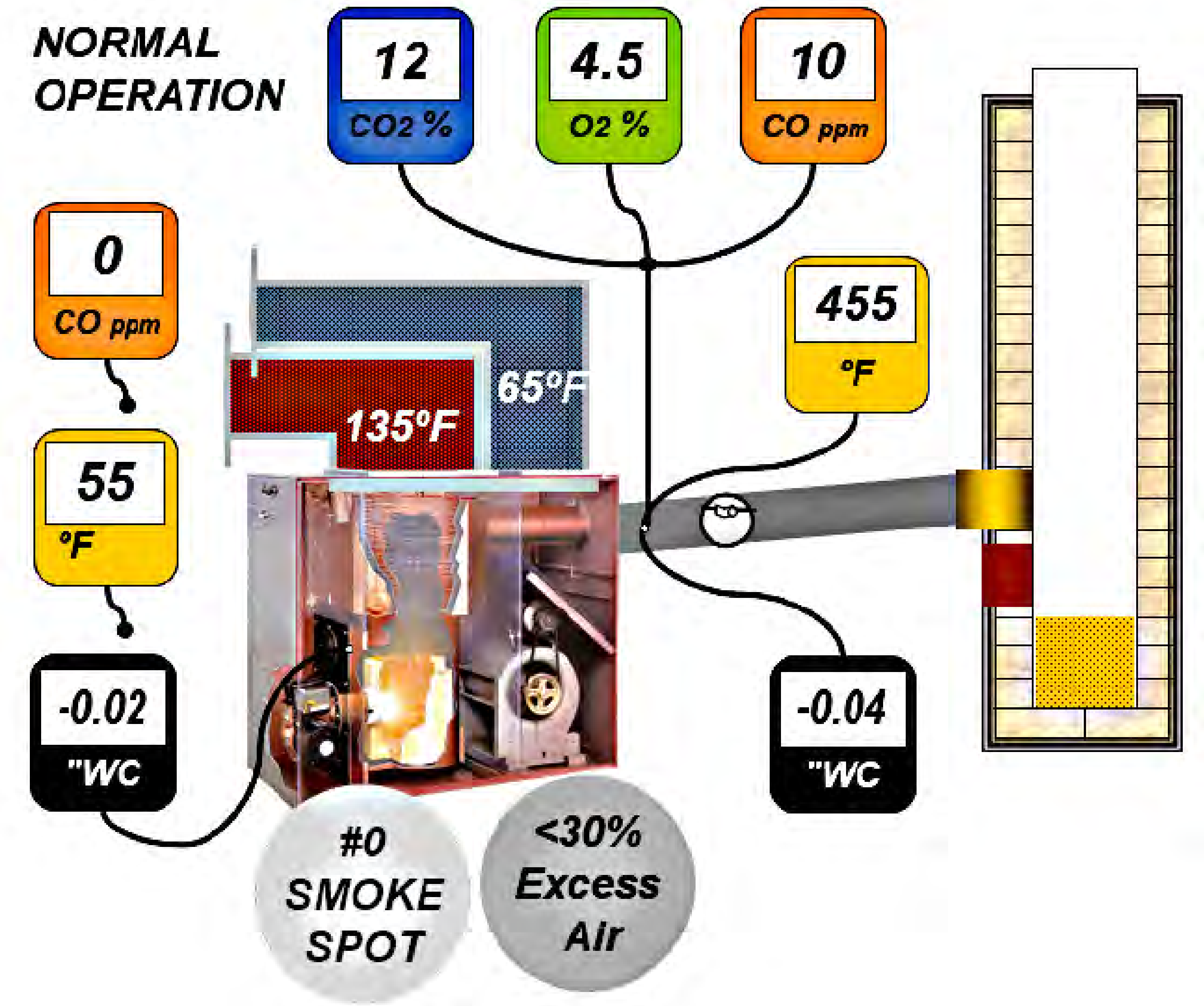
There are several reasons why technicians should use electronic analyzers:

1. Using a wet kit is time consuming and only gives a vague snapshot of burner performance…

It’s Better to use an Electronic Analyzer

2. Wet kits can’t perform CO testing.
3. Wet kits can’t calculate excess air.
4. Electronic analyzers provide readings much quicker and perform efficiency calculations automatically.
3. Electronic analyzers sample flue gas continually in real time, technicians can see results change as adjustments are made.

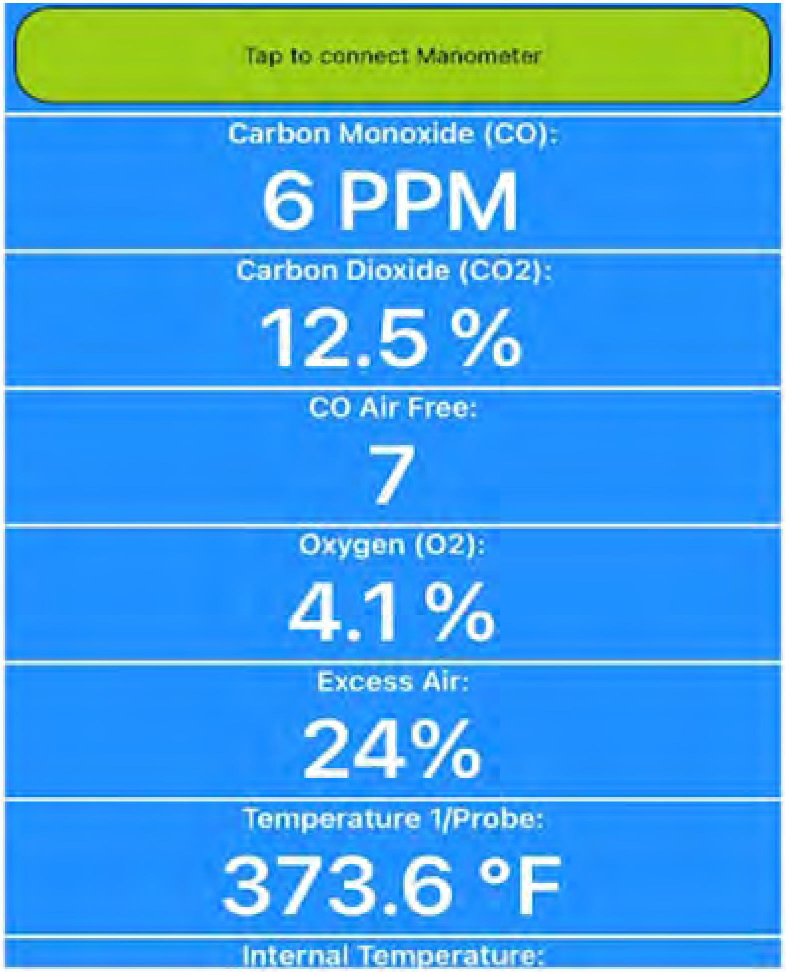
Interpreting the Results



Interpreting the Results

While it's important for a technician to understand ***how*** to properly perform a combustion test, it's equally important to understand ***what the results mean.***

The following "ranges" are provided as a guide for typical appliances; however, individual manufacturer's guidelines MUST be followed.



Stack Temperature

Typical range: 350°F to 500 350°F net

- This is the temperature of the combustion gases leaving the appliance.
- Measures the heat exchanger's ability to draw heat from combustion gases.
- Managing it is a delicate balance of fuel-air mixture ratios, the efficiency & condition of the heat exchanger and draft.

High Stack Temperature

If stack temperature is high, check for:

- **Soot deposits** – soot insulates the heat exchanger & prevents good heat transfer
- **Excess air** – cools and increases volume of combustion gases
- **Over-firing** – causes high rates of gas flow through heat exchanger
- **Excessive draft** – causes gases to travel too quickly through the heat exchanger leaving little contact time to absorb heat

Draft

Typical ranges:

- -.04 at breech,
- -01 to -.02 over-fire

<u>**Too high**</u> – gases travel too quickly through heat exchanger, lowering efficiency

<u>**Too low**</u> – combustion air flow is reduced, causing incomplete combustion & possible smoke

NOTE: Some appliances operate with positive draft over fire.

Common Causes of Low Draft at Breech

- Air leaks – chimney, stack, thimble or breeching
- Obstructions in chimney or at top of chimney
- Improper draft regulator adjustment

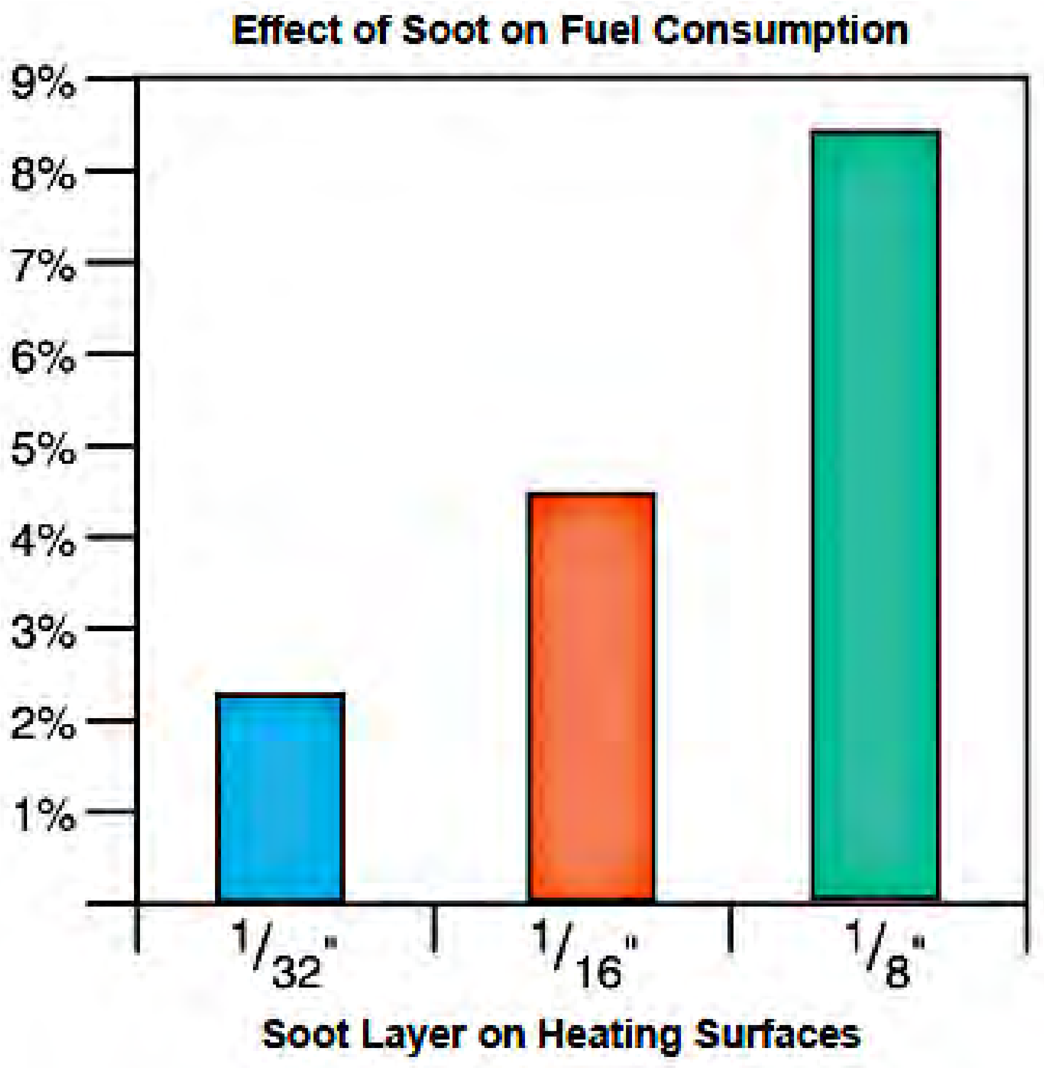
Common Causes of Low Draft Over-Fire

- Heat exchanger passages clogged with soot/scale
- Appliance is overfired – the volume of combustion gases is too great
- Appliance is underfired - the flue gases never get hot enough to create normal draft conditions

Smoke

Typical Range: 0

- Smoke & soot are unburned carbon created by out of adjustment burners & outdated burners.
- Soot insulates the heat exchanger & limits its ability to extract heat from combustion gas.
- 1/8” of soot reduces efficiency by 8%



Common Causes of Smoke & Soot

Poor fuel atomization

Large droplets do not atomize well & are caused by:

- Damaged/worn nozzles
- Low fuel unit pressure
- Cold fuel

Inadequate combustion air

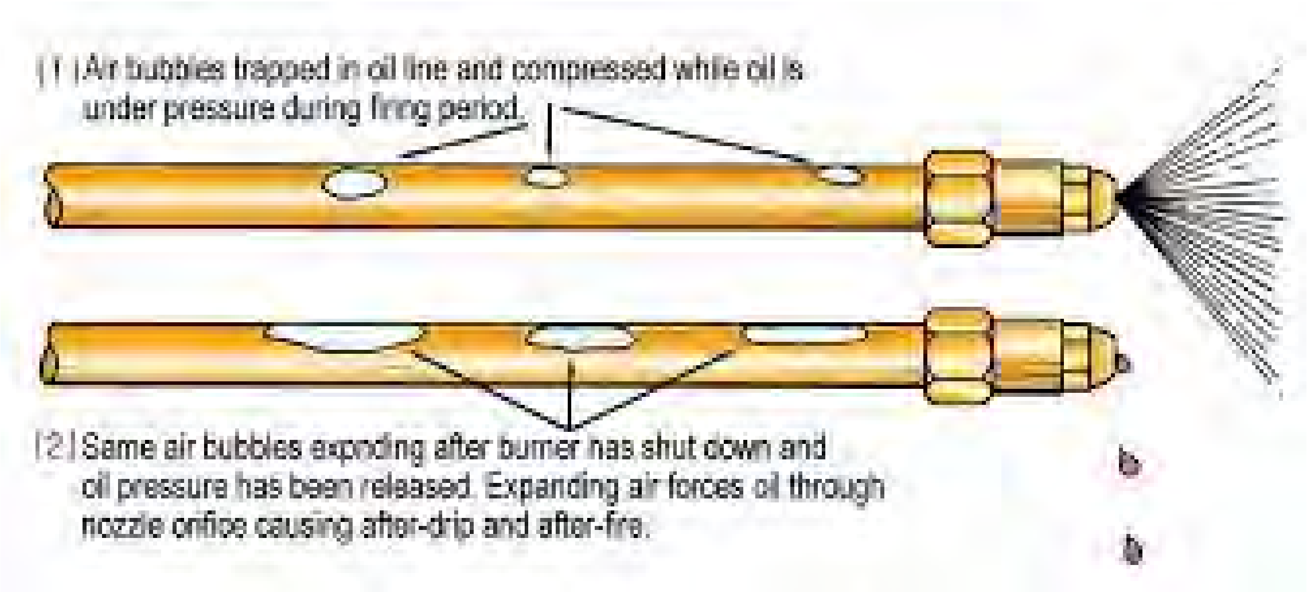
- Air band not open enough
- Soot & scale in heat exchanger
- Lint, hair, etc. on air shutter & fan
- Poor air flow in combustion area, exhaust fans…. AND??

Common Causes, continued

Air in the fuel

Air in the fuel can lead to dripping from the nozzle on shut-down, leading to a “after burn”

High vacuum can lead to fuel changing from a liquid to a foam.



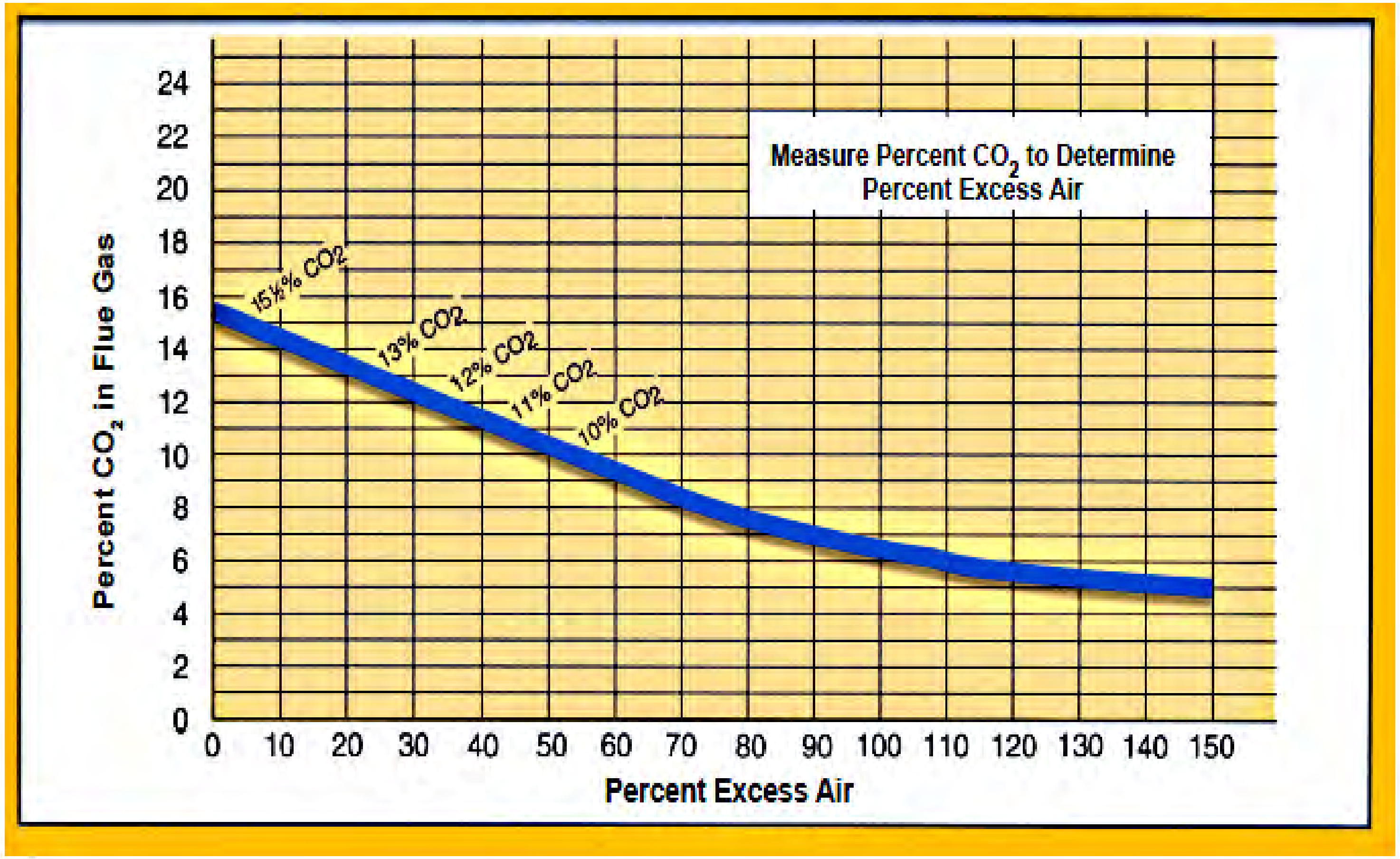
CO_2/O_2 & Excess Air (EA)

Typical ranges:

- CO_2: 11.5 -13%
- O_2: 4.0 – 5.3%

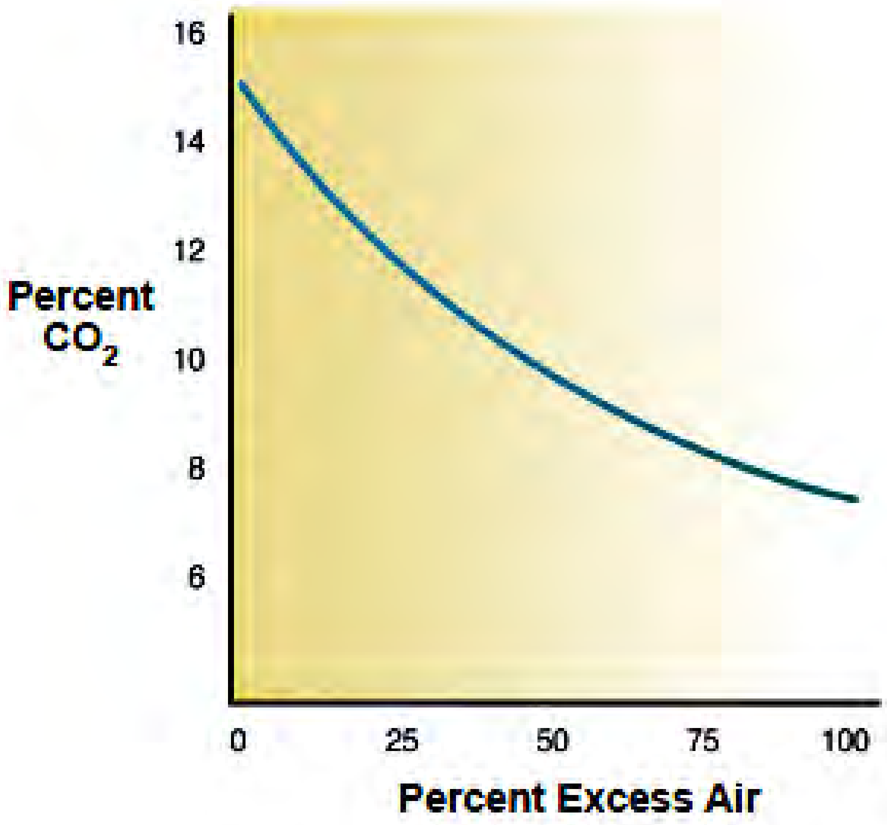
  EA: 25 - 35%

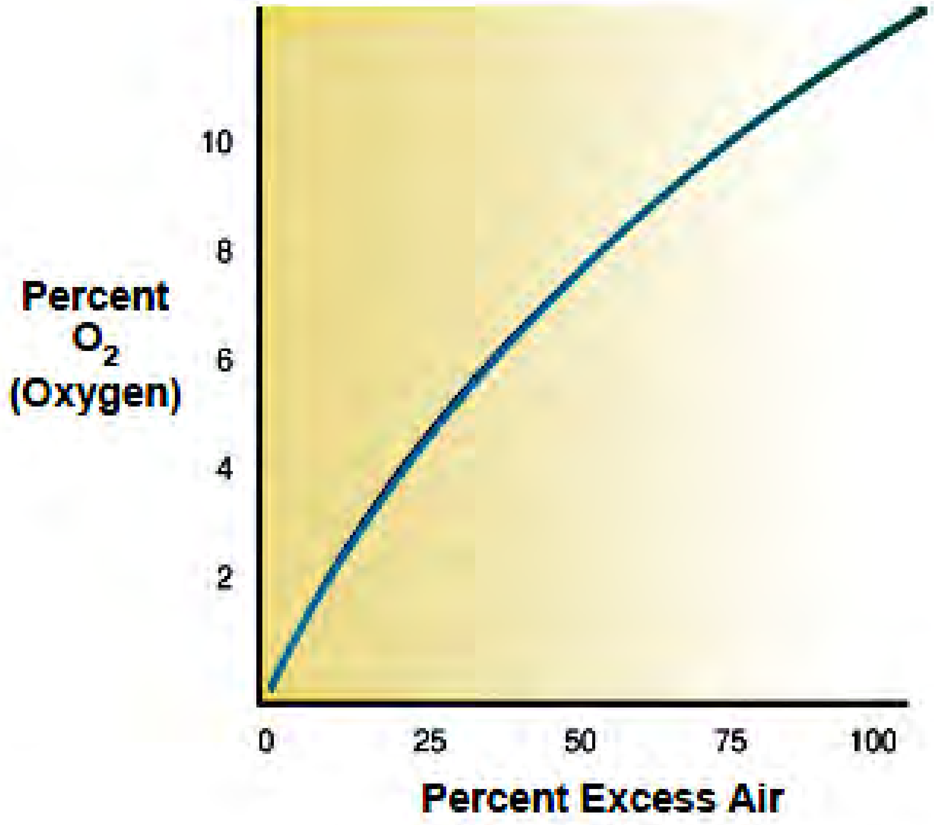
O_2 and CO_2 are used to calculate combustion efficiency, but they're just indicators of how much EA is being provided to the combustion process.



CO_2/O_2 & Excess Air (EA)

As EA is added the O_2% in the gases increases and the CO_2% decreases





Correlation of CO_2, O_2 and EA

The most common recommendations are between 25 and 35% Excess Air.

Correlation of Percent of CO_2, O_2 and Excess Air

Carbon Dioxide	Oxygen	Excess Air (Approx.)
15.4	0.0	0.0
15.0	0.6	3.0
14.5	1.2	6.0
14.0	2.0	10.0
13.5	2.6	15.0
13.0	3.3	20.0
12.5	4.0	25.0
12.0	4.6	30.0
11.5	5.3	35.0
11.0	6.0	40.0
10.5	6.7	45.0
10.0	7.4	50.0

Excess Air Must be Controlled

- While EA is needed for reliable, clean operation, it reduces efficiency
- Too much EA increases the amount of gases that must be vented, causing them to flow faster through the heat exchanger, leading to higher stack temperature & lower efficiency
- Too much EA also cools the flame, reducing efficiency and possibly causing CO levels to rise

Excess Air Must be Controlled

Finally, too much EA can cause “flame detachment” which pushes the flame from the retention head and causing:

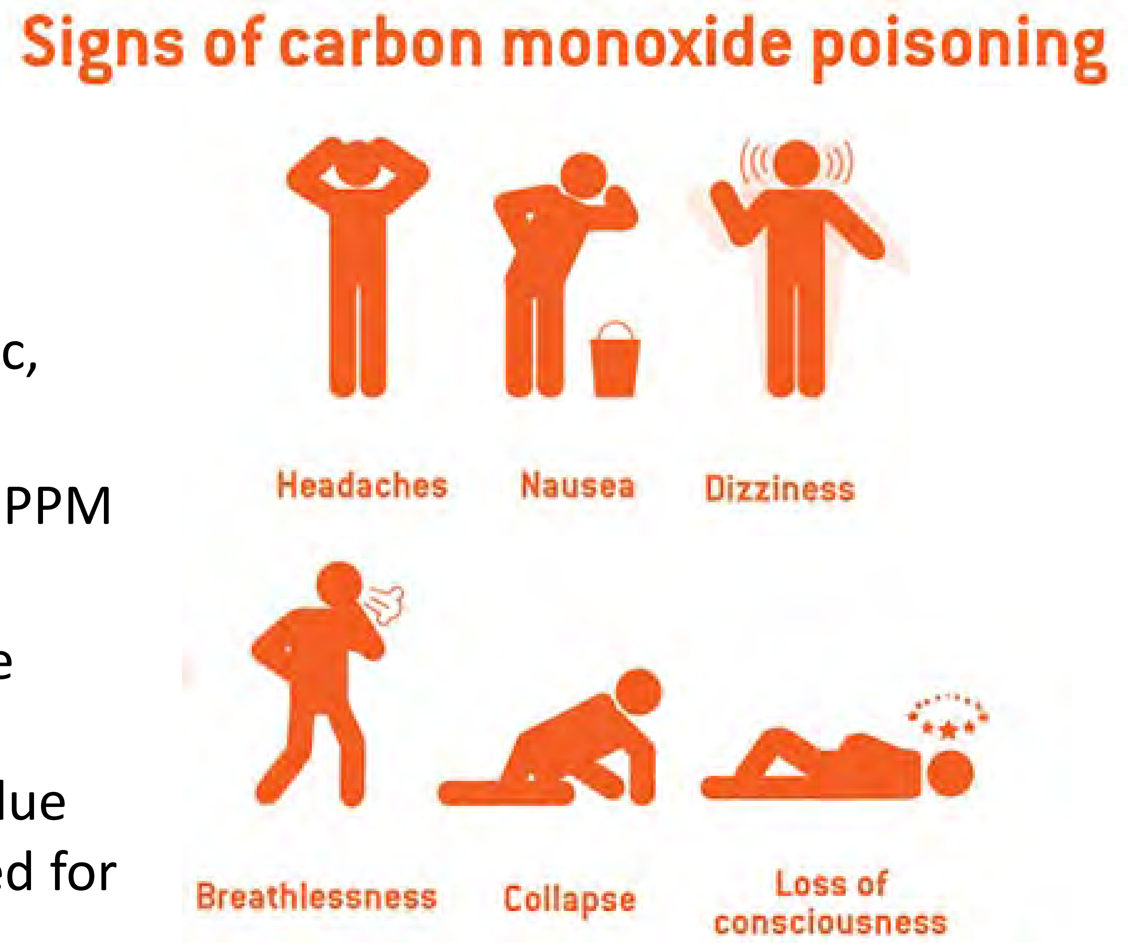
- Smoke
- Soot
- Primary control lockout
- Heat exchanger fouling
- Burner head coking

The amount of EA must be properly set and the only way to do that is by using combustion test equipment!

Carbon Monoxide (CO)

Typical ranges:

- Flue gas single digits to 30 PPM
- Ambient: 0 - 5 PPM



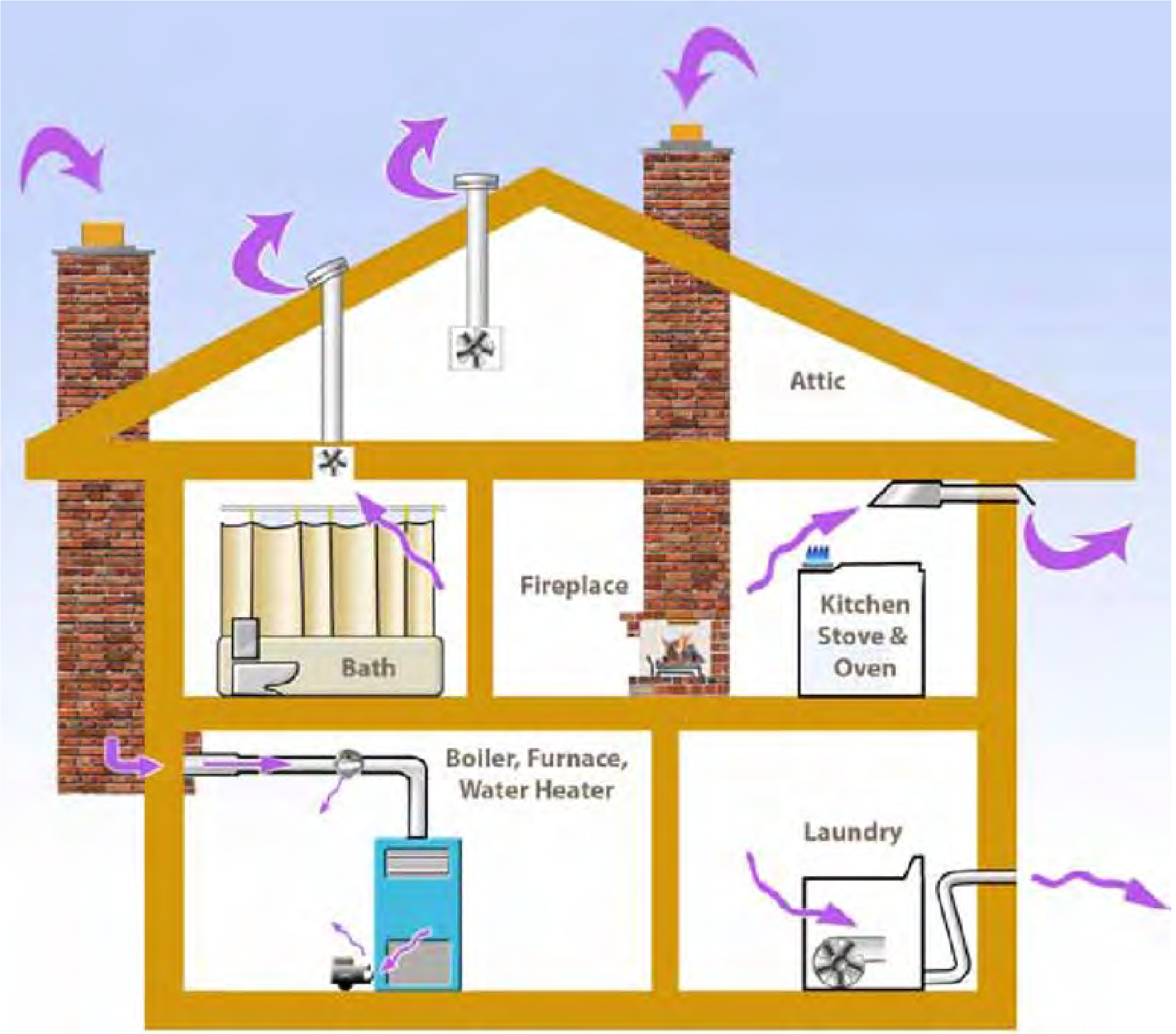
- CO is a result of incomplete combustion, it is a toxic, colorless, odorless tasteless gas that can be fatal.
- CO levels in the flue gas should be kept below 100 PPM air-free.
- Safety should always be the primary goal of service technicians and extra attention should be given to determine that proper CO levels are contained in flue gases and all appliances should be carefully checked for flue gas spillage.

Carbon Monoxide (CO)

Can be produced by:

- Too much combustion air
- Too little combustion air
- Impingement

Carbon Monoxide from Heating Systems



Inadequate air supply to the burner area is increasingly common but difficult to diagnose.

WHY?

CO Warning Signs

- Odors/smoke/soot in building
- Soot, rust or scale buildup on/around appliances or vents
- Loose, corroded, disconnected vent components
- Excessive moisture on inside surfaces
- Chalky white powder on the chimney or vent

Initial Start-up CO Levels

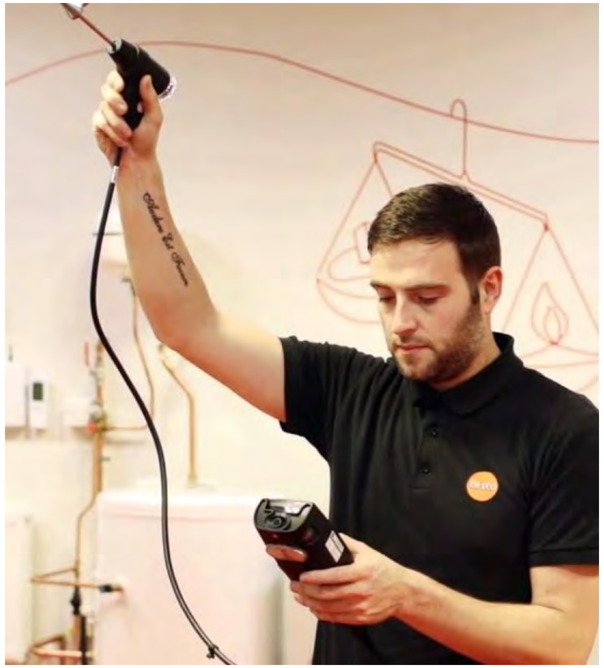
When a new appliance is installed, manufacturing residue often causes temporarily elevated CO levels.

These levels typically drop after 15 minutes of operation.

CO Ambient Air Testing

- CO is always a potential hazard when combustion is taking place.
- Ambient levels should be checked and the appliance should be run through a complete cycle if combustion problems are suspected.
- High CO levels in a home are often the result of auto exhaust in an attached garage, depressurization of the home (whole house fan?) or insufficient air in the combustion zone.
- A blocked flue can also cause high co readings.

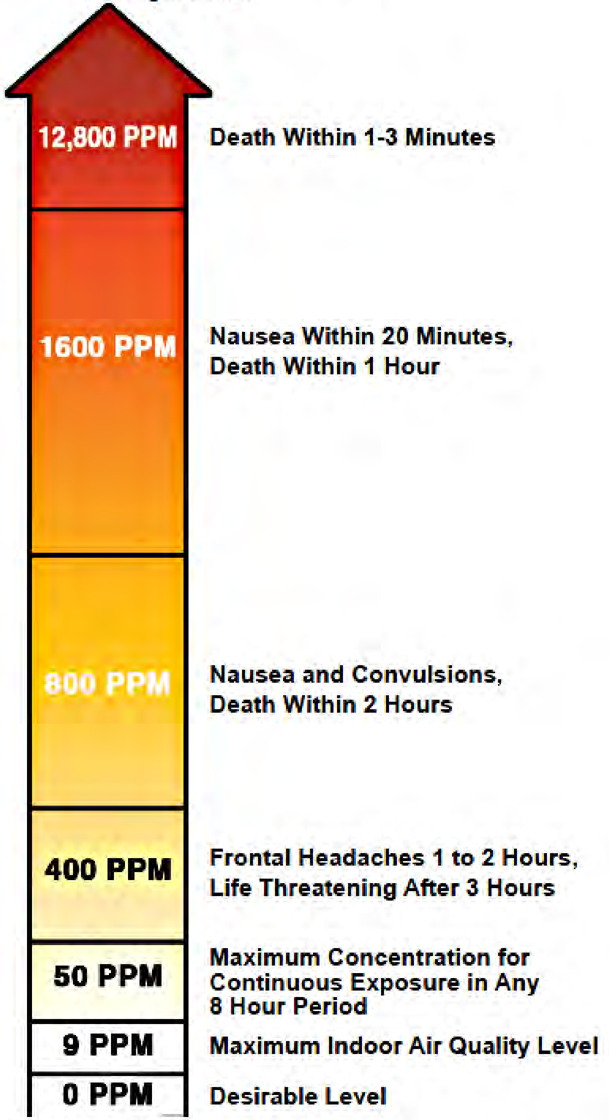
CO Ambient Air Testing



To check ambient CO levels, start the analyzer in fresh air, run it through the start cycle and, verify safe levels in the home & around the appliance.

Suppose 25 PPM is measured inside and 17 PPM outside, the main problem may be caused by something outdoors, but there could still be something generating 8 PPM indoors.

Carbon Monoxide (CO) Levels
Figure 7-24



Ambient CO Limits

- **0 PPM:** most desirable
- **1 to 9 PPM**: normal acceptable level (candles, cigarettes, gas stoves, etc.)
- **10 to 35 PPM :** advise occupants, check for symptoms, check all appliances
- **36 to 99 PPM:** recommend fresh air and medical attention
- **100+:** evacuate, call 911, do NOT ventilate, short term exposure can cause permanent physical damage

Typical Combustion Challenges

This section addresses four combustion issues:

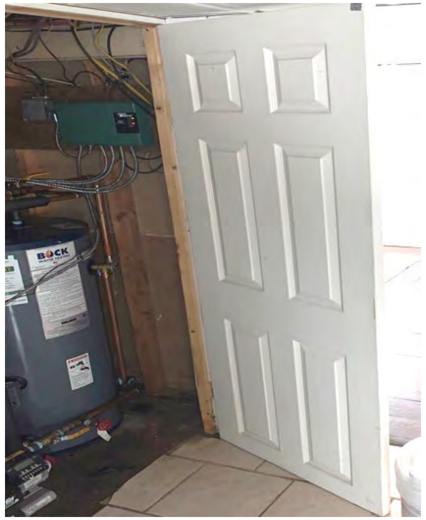
1. Insufficient combustion air
2. Improper air-fuel mixing
3. Flame impingement
4. Smoky shut-down

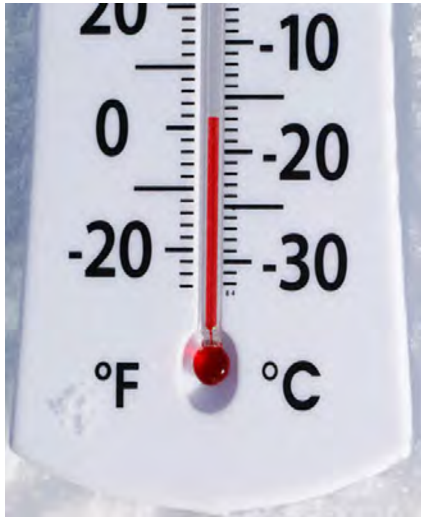
1. Insufficient Combustion Air

With energy saving improvements, Houses have become “tighter”.

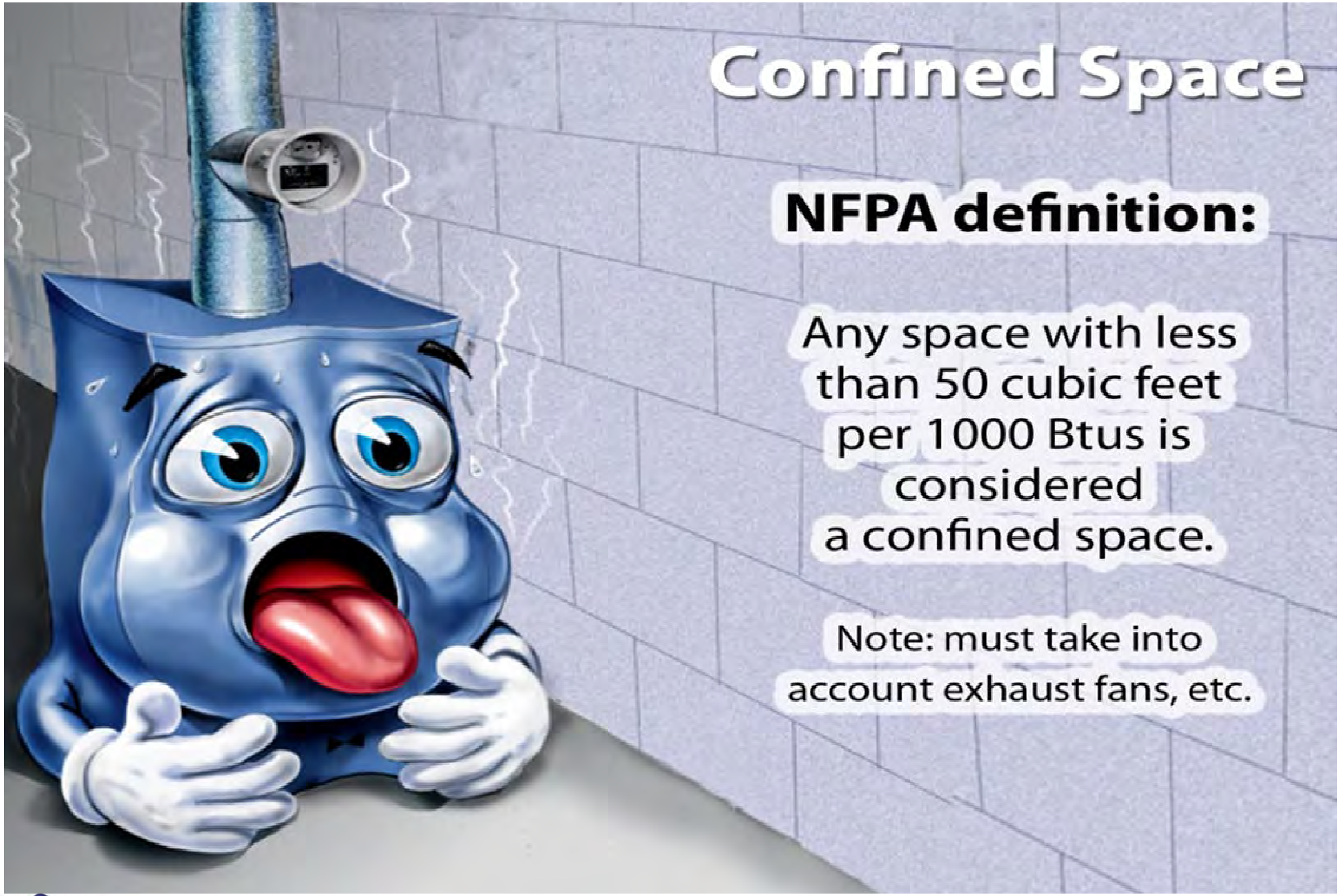
Utility rooms have gotten smaller and often include other appliances which consume a lot of air

Insufficient air issues are most noticeable on the coldest days when heat loss is the greatest, windows & doors are closed for extended periods of time and the burner consumes more oxygen because it runs for extended periods





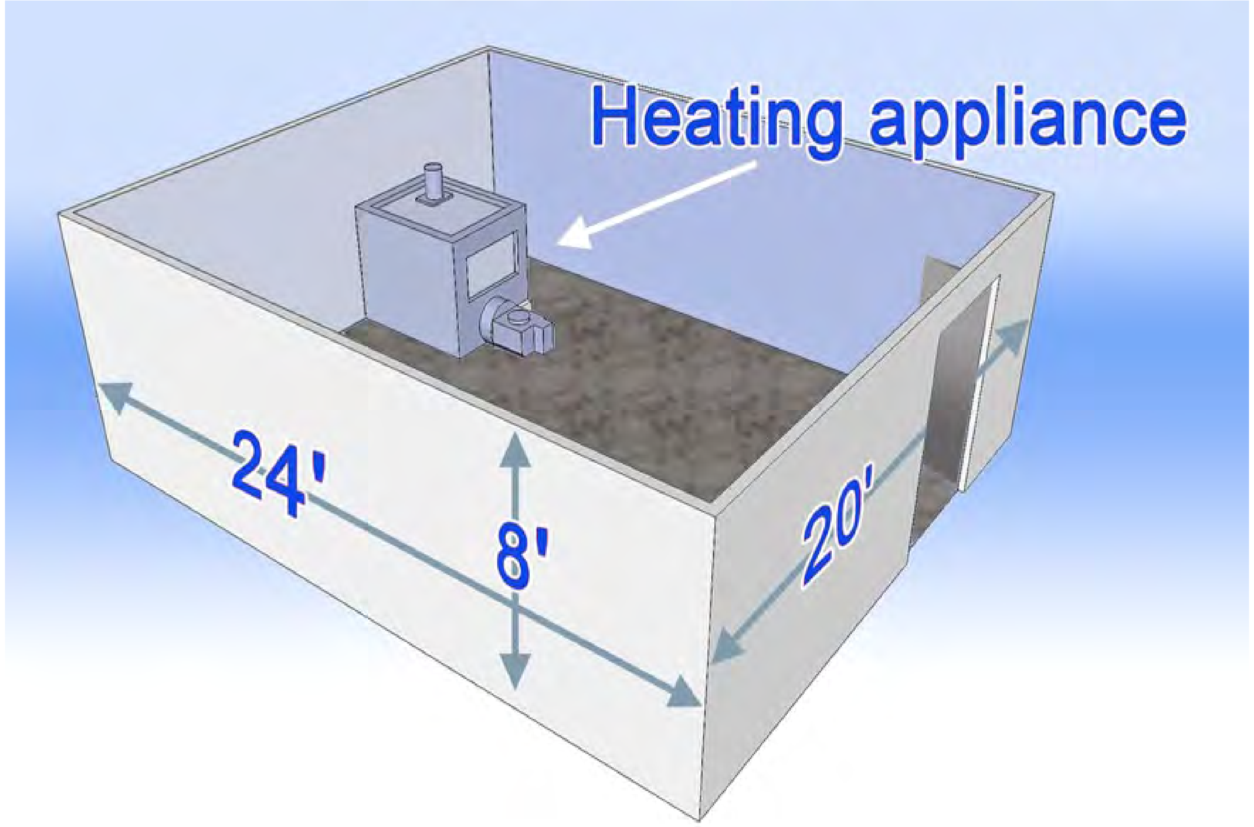
Insufficient Combustion Air



Confined Space

Length X Width X Height = Cubic Feet

24’ X 20’ X 8’ = 3,840 cu. Ft.



Confined Space

L x W x H = 3,840

3,840 x 1,000 = 3,840,000

3,840,000/50 = 76,800 max BTU input

(50 cu. ft. per 1,000 BTU)

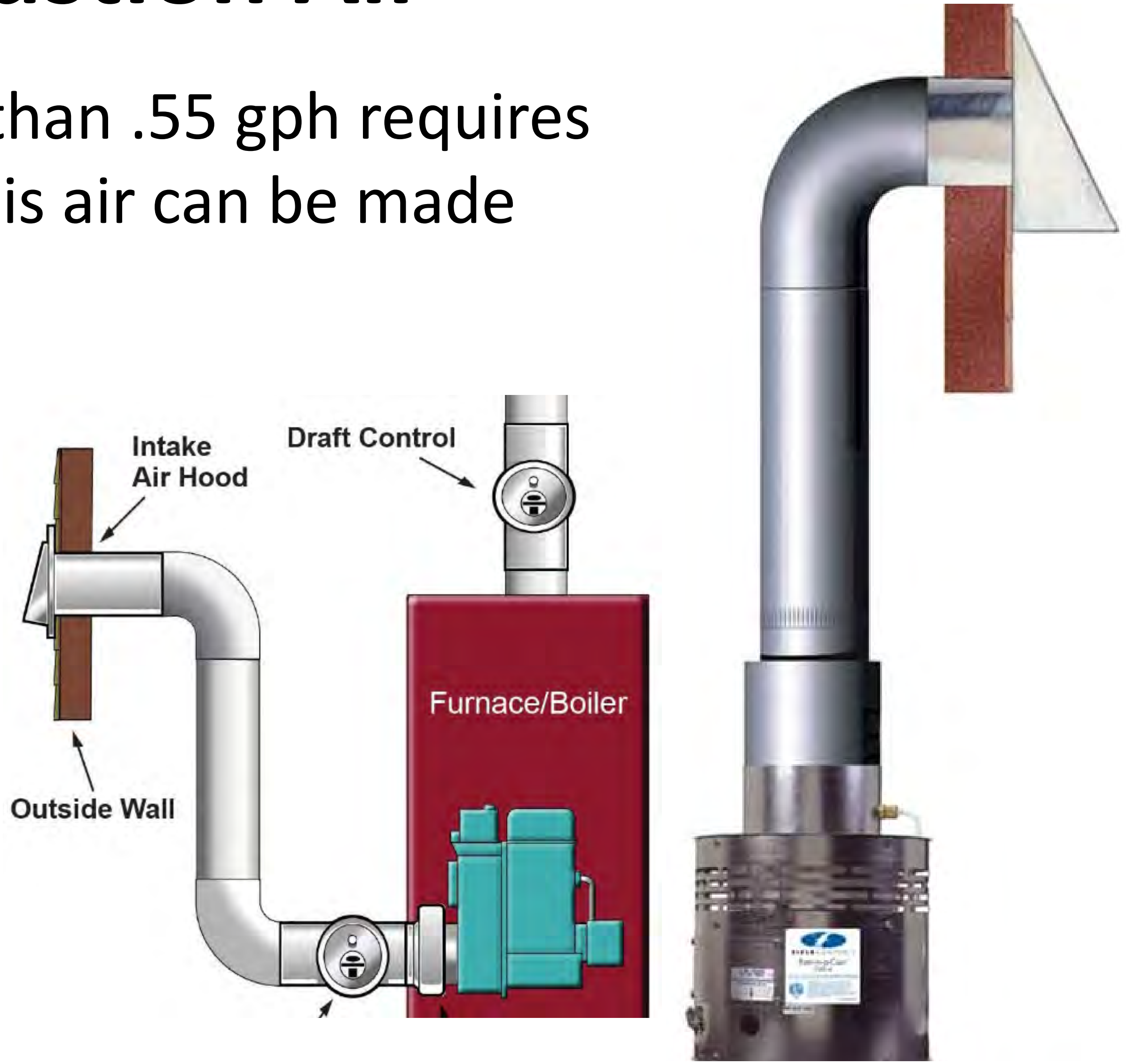
76,800/139,000 = .55 gph.

(Max firing rate of ***all*** appliances in the area)

Insufficient Combustion Air

Any appliances with a higher firing rate than .55 gph requires that additional air be made available. This air can be made available by installing:

- Permanent openings in accordance with NFPA 31
- Ducts to bring air from other parts of the building/outside
- Mechanical devices like a "fan in a can"
- An outside air intake kit

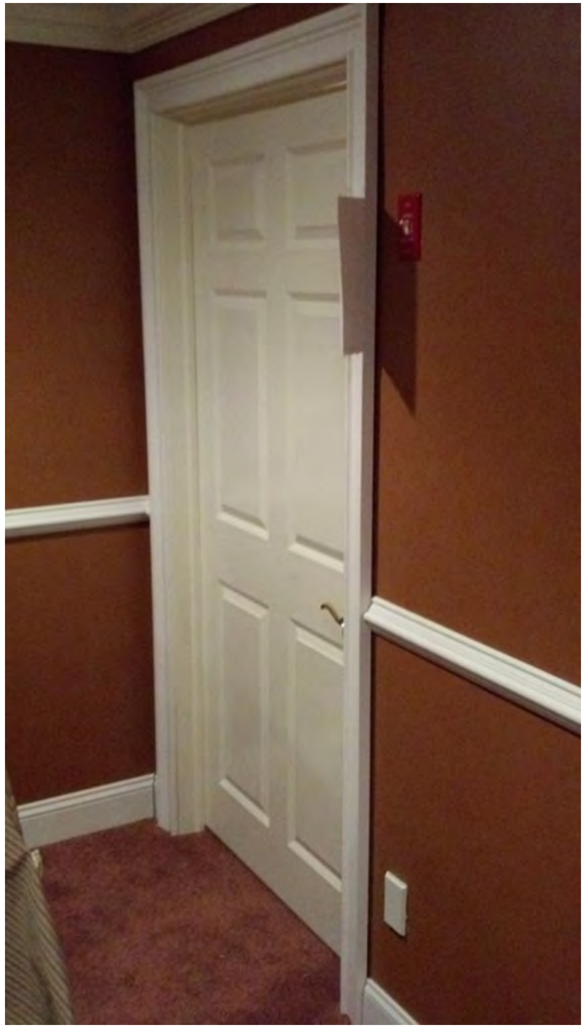


Insufficient Combustion Air

A service call caused by insufficient air is the only call a technician can "fix" just by showing up.

How is that possible?

Insufficient Combustion Air



NFPA has developed a "worst case draft test" that is ***required*** after new installations and ***recommended*** when troubleshooting insufficient air situations.

Worst Case Draft Test - Step 1

Close:

- ✓ All fireplace doors/dampers
- ✓ All exterior doors/windows
- ✓ All interior doors

Worst Case Draft Test - Step 2

Turn all exhaust systems on at highest speed:

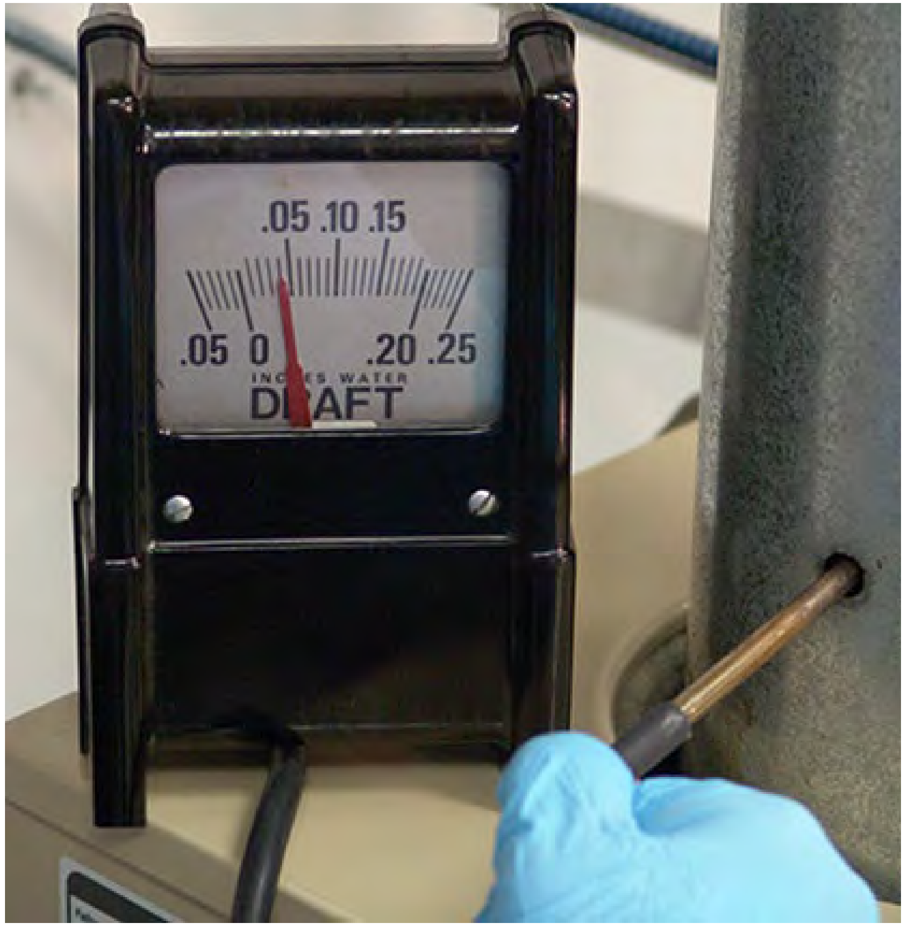
- Clothes dryers
- Range hoods
- Exhaust fans
- Mech. ventilation & heating/cooling blowers

(***NOT*** whole house fan!)

Worst Case Draft Test - Step 3

Operate the burner in the smallest oil heating appliance first, then others in order of increasing capacity.

Measure draft at breech & over fire, check for spillage.



Worst Case Draft Test - Step 4

Check that the breech & over-fire draft are at the manufacturer's recommended levels.

Worst Case Draft Test - Step 5

If the draft *is* maintained at the manufacturer’s recommended level, return doors, windows, fans, etc. to their previous conditions.

Worst Case Draft Test - Step 6

If the draft is *NOT* maintained at the manufacturer's recommended level, take action as needed to correct excessive depressurization.

If additional steps are necessary, shut the appliance down until the situation can be corrected.

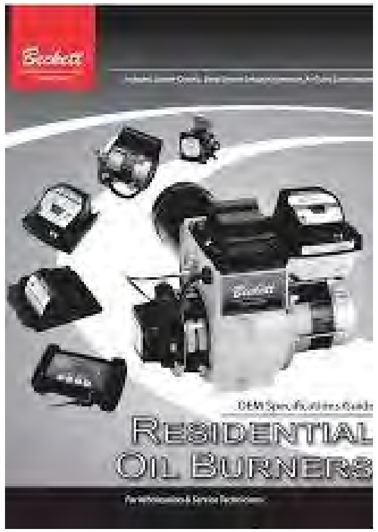
Notify the owner of the situation and of all corrective actions that are required to allow for proper draft to be maintained.

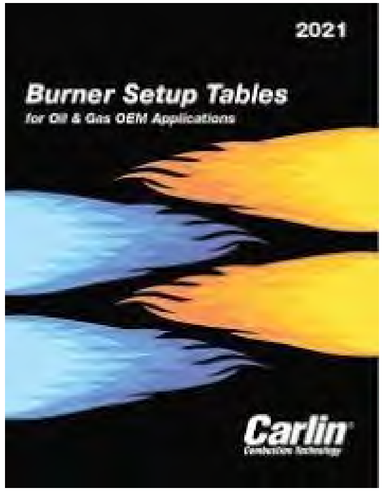
#2 – Improper Air-Fuel Mix

Improper mixing creates "fuel rich" (too much fuel) and "fuel lean" (too little fuel) pockets in the combustion area. Some of the causes:

Mismatch of the fuel spray & burner air pattern.

Refer to the manufacturers guide to determine the correct nozzle spray angle and pattern.





Improper Air-Fuel Mix (continued)

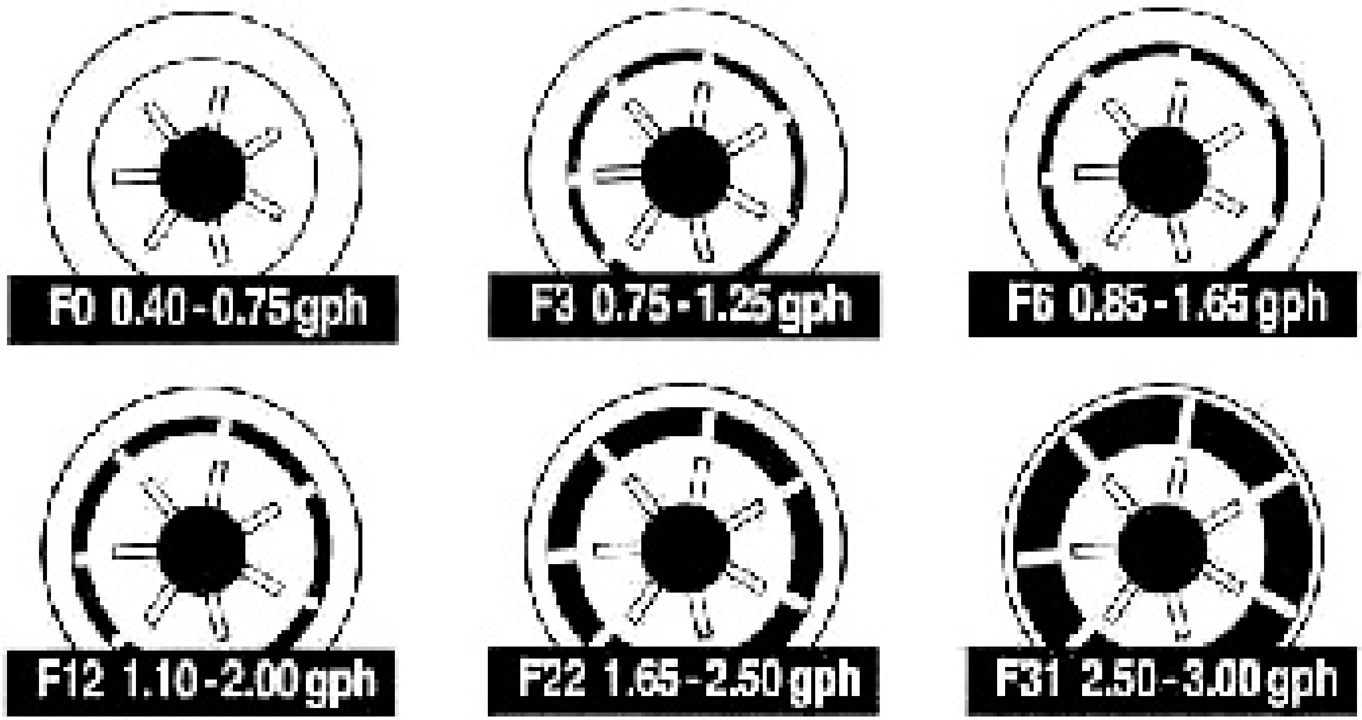
Using a nozzle that is either too large or too small for the burner head and/or combustion area.

*Suggestion – Verify that the nozzle size **AND** fuel unit pressure are correct.*

Improper Air-Fuel Mix (continued)

Inadequate air swirl and turbulence/improper burner head size or mismatched components.

Check air handling components including the retention head size/setting, set burner to manufacturer specs.



Improper Air-Fuel Mix (continued)

Improper adjustment of air handling parts of burner.

Check settings.

Improper Air-Fuel Mix (continued)

The proper settings are included in the manufacturer's guides.

RIELLO

Appliance Model	Burner Model	Air Tube	Insertion Length	Nozzle	Pump PSI	In-put GPH	Head Setting	Air Setting
V-84	F5	VSBT	1 1/2"	1.20 X 80° B	145	1.44	3	6
V-85 S	F5	VSBT	1 1/2"	1.20 X 80° B	145	1.44	2	5.5
V-85 WM	F5	VSBT	1 1/2"	1.20 X 80° B	145	1.44	2	5.5
V-85	F5	VSBT	1 1/2"	1.35 X 80° B	145	1.62	4	6
V-86 S	F10	LBT	10"	1.50 X 45° B	145	1.81	3	3.2
V-86 WM	F10	LBT	10"	1.50 X 45° B	145	1.81	3	3.2
V-86	F10	LBT	10"	1.75 X 45° P	145	2.10	4	3.8
V-87	F10	LBT	10"	2.00 X 45° B	145	2.40	4	4
V-88	F10	LBT	10"	2.00 X 60° B	175	2.65	5	4
V-89	F10	LBT	10"	2.25 X 60° P	145	2.70	5	7

OEM SPECIFICATIONS GUIDE

Improper Air-Fuel Mix (continued)

Dirt or soot accumulation on burner air handling parts including air shutter and fan.

Clean if necessary.

Improper Air-Fuel Mix (continued)

Defective or damaged burner parts.

Check the retention head, air tube, fan-motor coupling and replace if applicable.

Improper Air-Fuel Mix (continued)

Fuel unit pressure set too high or too low.

Check and adjust to specs.

Improper Air-Fuel Mix (continued)

Cold fuel producing larger fuel droplets and increasing the firing rate beyond the air setting.

Consider a nozzle line heater or fuel de-aerator.

Challenge #3 – Flame Impingement

The flame must NOT touch any surface of the burner, retention head; combustion chamber or heat exchanger.

If it does, the flame will be cooled, and the unburned carbon becomes smoke & soot.

Possible causes of impingement are:

- *Overfiring – too large a nozzle or excessive fuel unit pressure*
- *Incorrect nozzle – wrong angle or pattern…*

Flame Impingement (continued)

- Collapse or deterioration or deterioration of combustion chamber, incorrect chamber size or shape, or debris build-up at base of the chamber
- Partially clogged nozzle
- Cold fuel

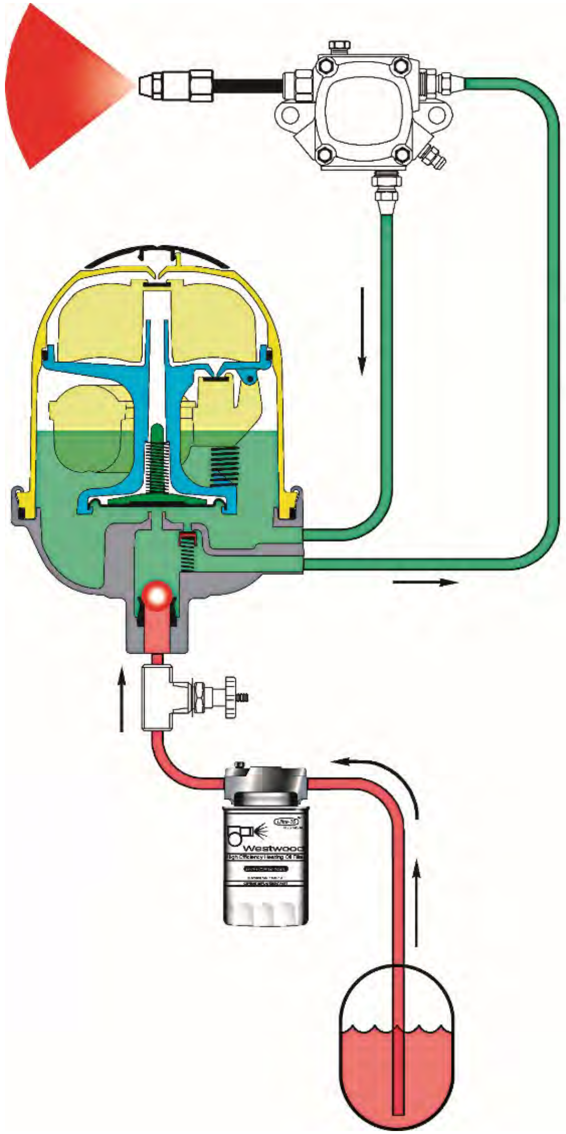
#4 – Shut-down Issues

If the burner rumbles or smokes on shut-down, it is most likely from air accumulation in the nozzle assembly.

- Install a suction analyzer in the suction line close to the burner and observe for any visible bubbles
- Check the vacuum, if it's high clean the fuel line with a push-pull pump

Shut Down Issues (continued)

- If the fuel unit is connected 2-pipe, consider changing to 1 pipe with a de-aerator
- It the vacuum is too low check for a suction leak
- Alternatively, the fuel cutoff may be the cause. Perform a pressure test at cutoff as described in Chapter 4 to check



Review Questions:

- What creates combustion in a burner?
- Why is the ratio of oil to air critical?
- What measurements do you take to test combustion?
- How do you use the manual “wet” kit and the electronic kit to test combustion?
- How do you adjust the burner to get optimal test results?

Review Questions:

Continued…

- What creates insufficient air for combustion and how do you perform a worst-case draft test?
- What causes improper air-fuel mixing and how do you fix it?
- What causes flame impingement and how do you fix it?
- What causes smoky shut-down and how do you fix it?

End of Chapter 7

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 8

Basic Electricity

At the end of this lesson, you will be able to:

- Follow the steps to safely work with electricity
- Explain what controls the flow of electricity in a heating system
- Explain the difference between voltage, current, resistance, and watts
- Name the different types of electrical loads in a heating system
- Explain the difference between series, parallel, and combination circuits
- Explain what happens if circuits are reversed

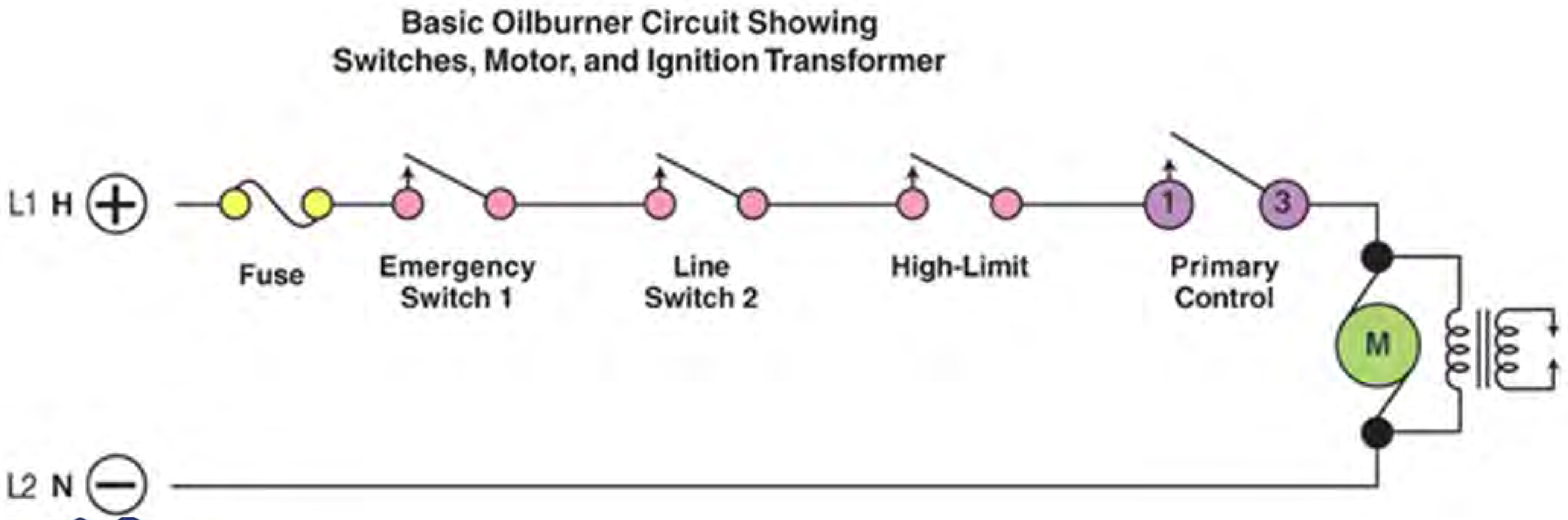
At the end of this lesson, you will be able to:

Continued…

- Identify parallel and series circuits in wiring diagrams
- Explain what the colors mean on different types of wires
- Cut wires using the correct methods
- Splice wires using the correct method
- Read a wiring diagram to decide if a switch is normally closed or normally open
- Find electromagnet switches and transformers on a wiring diagram
- Use a multimeter to measure voltage, current, and resistance

Electrical Control Circuit

In a typical heating system, line voltage flows in a series circuit from the circuit breaker/fuse to the main switch, then to a service switch at the appliance, to the limit controls, to the primary control and then to the oil burner components.



Electrical Safety

Working on a system often requires technicians to perform tasks related to the switches and controls in the system.

It's imperative that techs **fully understand** each component, **follow governing codes** and **ALWAYS** abide by safe work practices.

Electrical Safety

Before attempting to *service* electrical components, take a few minutes to understand the dangers involved and follow ***ALL*** correct safety procedures.

When working with electricity, always:

Avoid working in wet areas

Inspect power tools

& equipment before use……

Electrical Safety

- Use insulated tools & double check insulation
- Use correct size UL listed extension cords
- Make sure equipment being serviced & any electrical tools are properly grounded
- NEVER use a 2-prong, ungrounded adaptor with a 3-prong tool or extension cord
- Avoid overloading circuits

Electrical Safety

- Whenever possible, de-energize equipment before servicing
- Remember, switches can fail! Always test to be sure circuits are de-energized before starting work

Lock Out Tag Out

Place device and tag over the circuit breaker, fuse box, or switch to prevent accidental energizing of circuit.

Alternative - shut power in 2 places (switch & circuit breaker)

Voltage

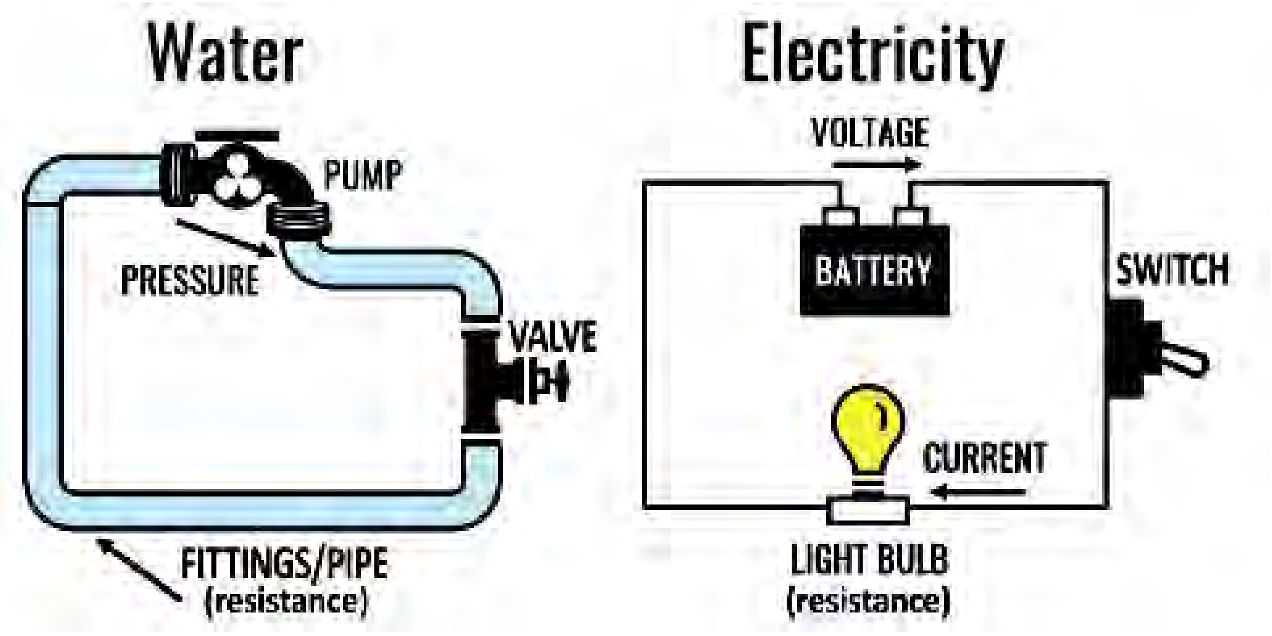
Voltage is electrical potential, like water pressure.

Nothing happens until the tap is opened,
or the switch is turned on.

Electrical Flow is like Water Flow

Electricity is defined as the flow of electrons through a circuit, similar to the way water flows through a piping system.

A comparison of electron flow to water flow is used in the next few slides.



Voltage – Like Water Pressure

Voltage (V or E) is the <u>*potential*</u> to perform work.

Most heating systems include both line voltage (120 VAC) and low voltage (24 VAC) circuits.

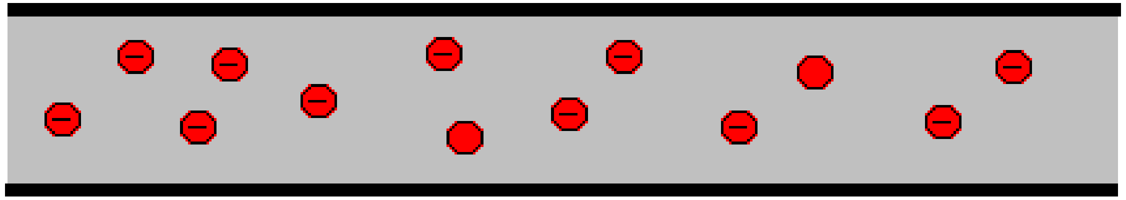
Voltage is the "pressure" to move electrons through a circuit, similar to water pressure pushing water through a pipe.

If a switch is closed, electrons stay idle at the "hot end" of a circuit similar to water pressure being held back by a closed valve.

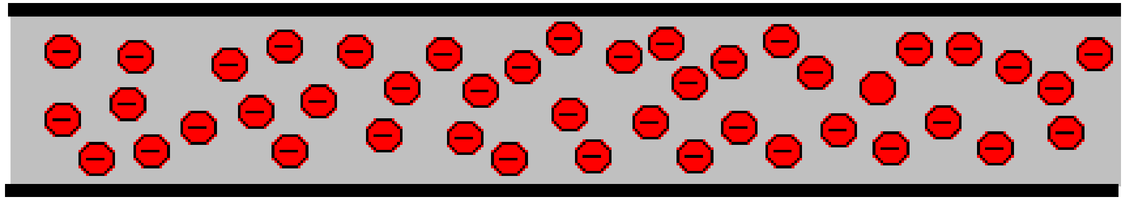
Current – Like Water Flow

Electrical "current" (A or I) is the "rate of flow" of electrons in a circuit, it is measured in **Amperes (Amps).**

Amps are similar to the gallons per minute (gpm) flow of water through a pipe.



Few Electrons Flowing = Low Amps



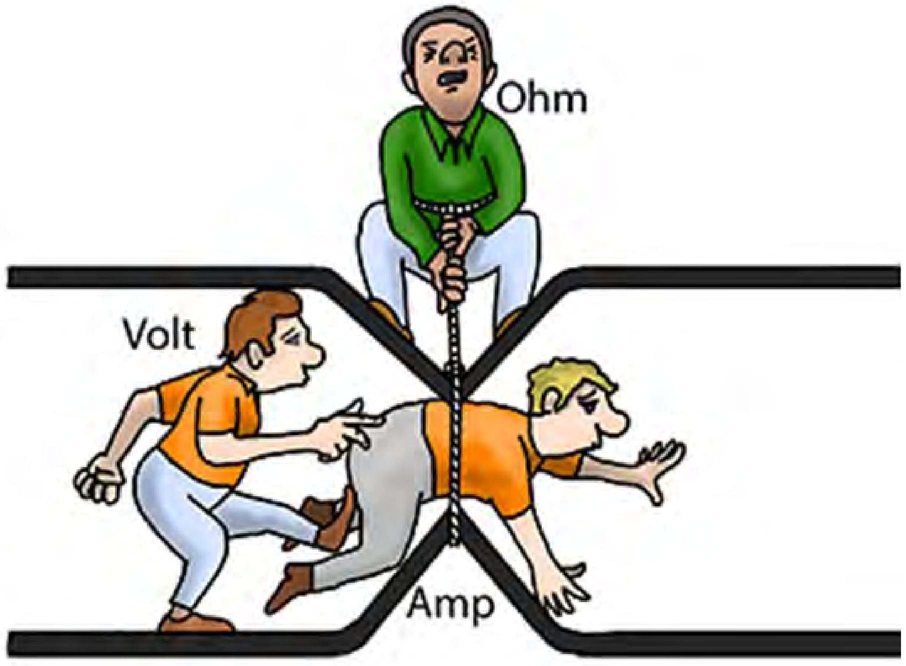
Many Electrons Flowing = High Amps

Ohms – Like Resistance to Flow

Ohms (R) is the resistance to electron flow through the wiring and components of a circuit.

As electrons flow there will be more, or less resistance due to the wiring & components (motors, controls, etc.) of the circuit.

This is similar to the resistance water is exposed to depending on the sizing of the piping & components (valves, meters, etc.) in the plumbing system.

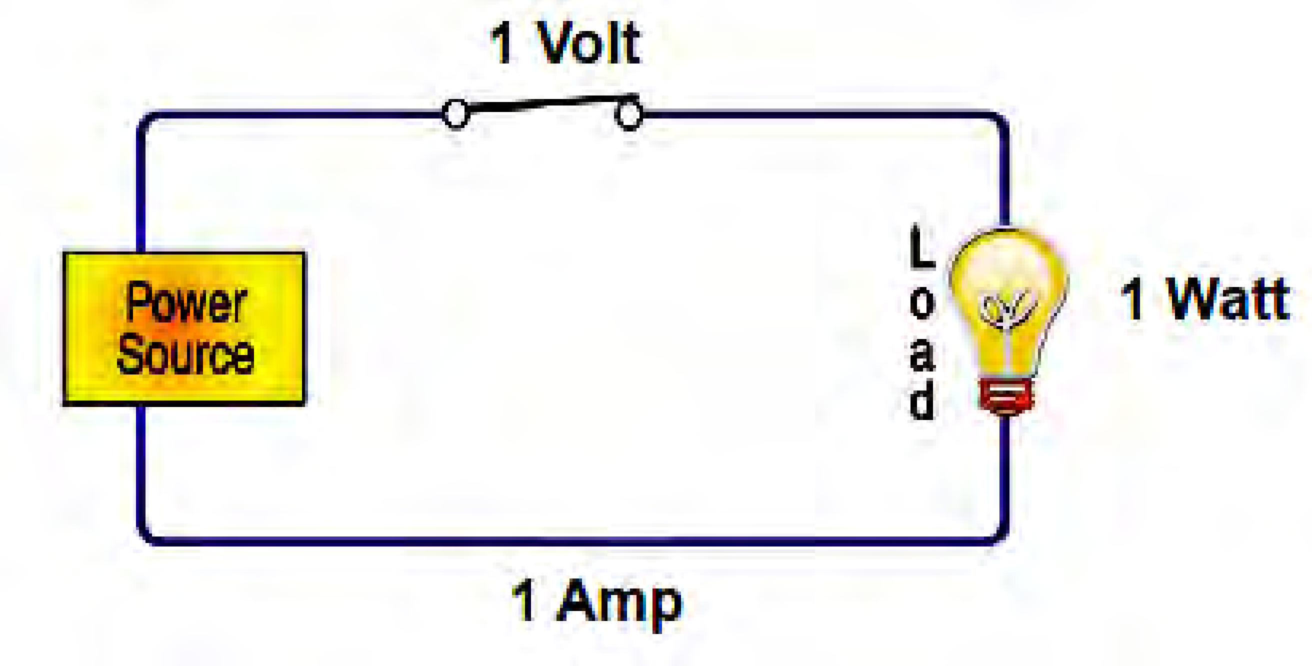


What's a Watt?

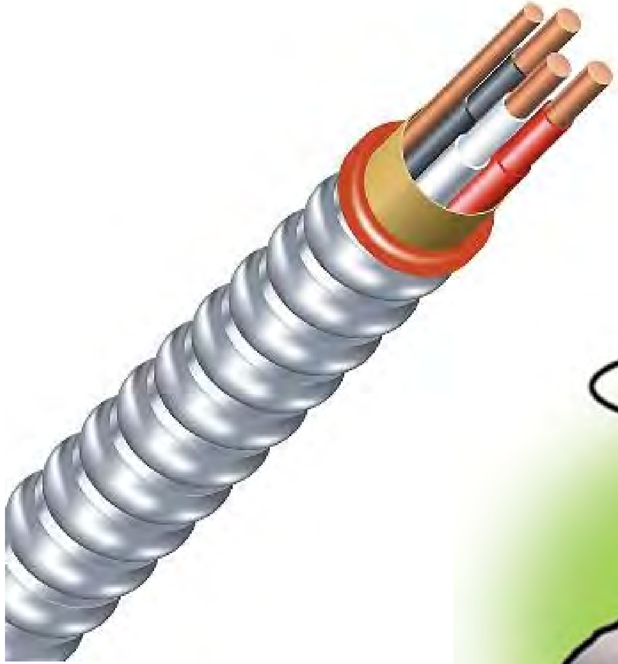
Watts are the power consumed by an electrical circuit.

One amp, driven by one volt through a circuit = 1 Watt.

For reference, a typical a typical burner motor is 1/7 HP (107 watts).



Conductors



Conductors offer little resistance to electrical flow.

Gold, copper & aluminum are good conductors.

Insulators

Insulators resist electrical flow

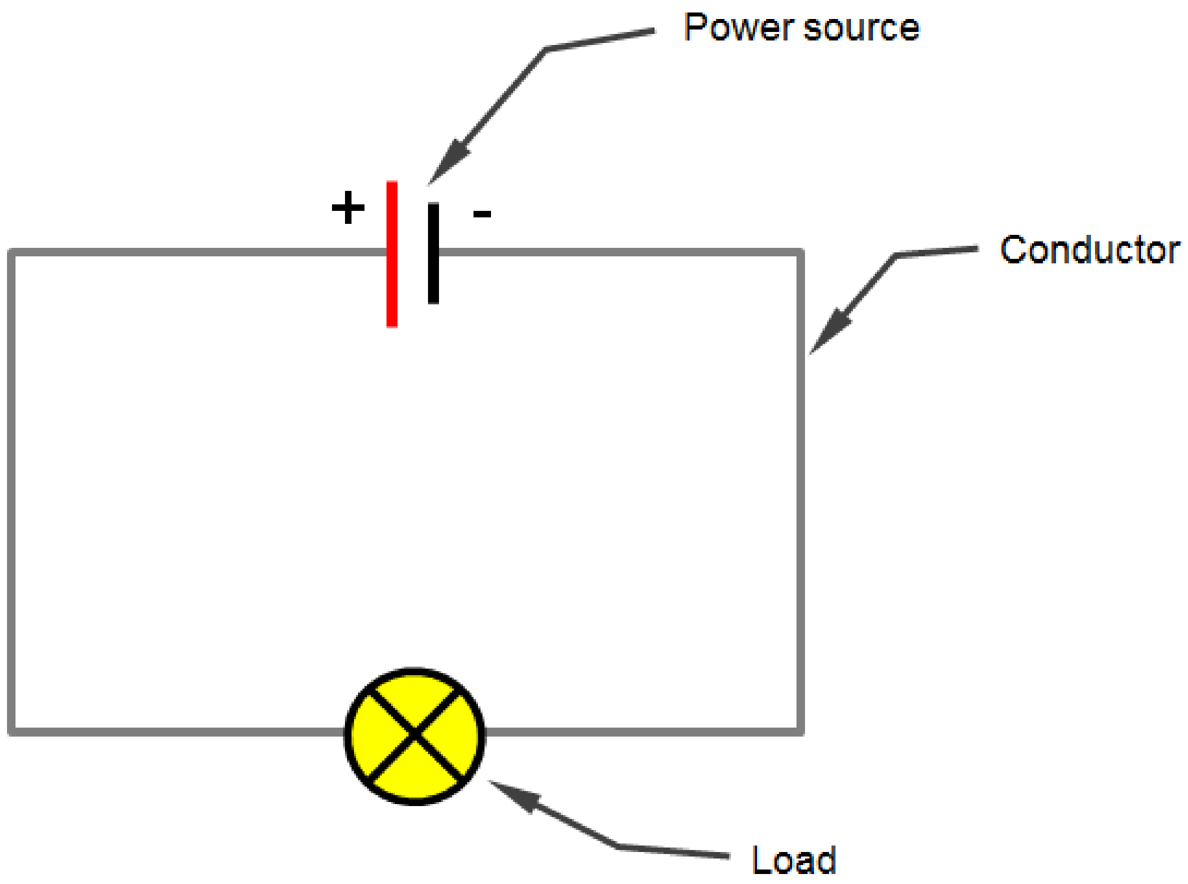
Glass, porcelain, plastic, rubber, air (is it?) and carbon are good insulators.

Loads

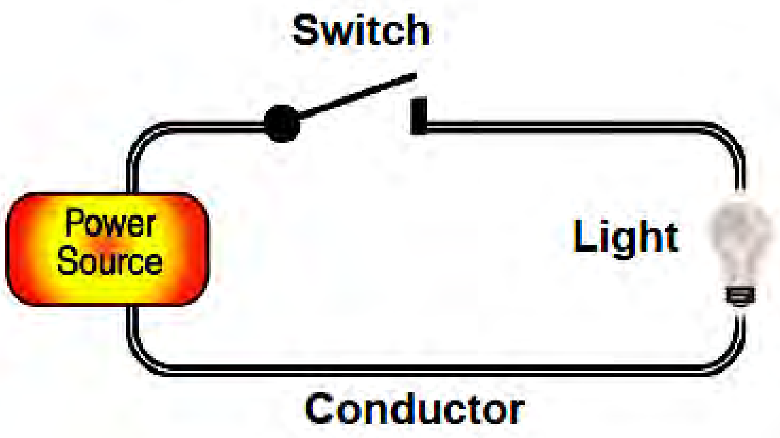
- A load is resistance that uses electricity to perform work
- A load also creates resistance to electrical flow
- In an Oilheat appliance circuit common loads are:
  - Motors – burner, circulator, blower
  - Igniters
  - Electromagnetic coils – solenoid valves and relays
  - Transformers

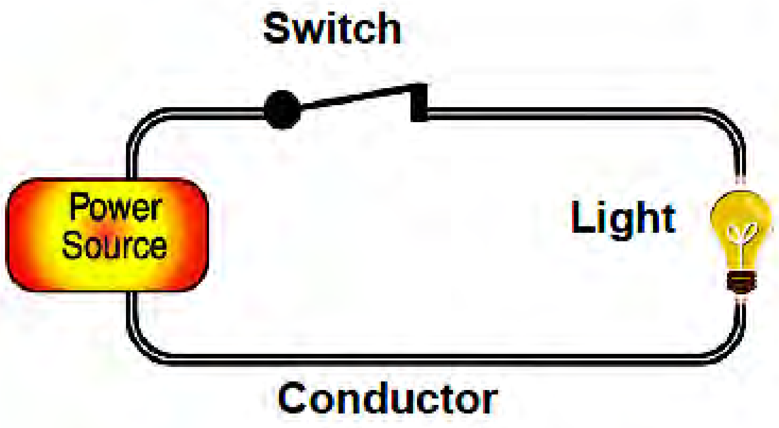
Electrical Circuits

- Electricity flows from a source, out into a circuit and back to the source.
- A typical circuit includes a conductor that carries the current
- from the source, through a switch, to a load and back to the source.



Electrical Circuits - Switches



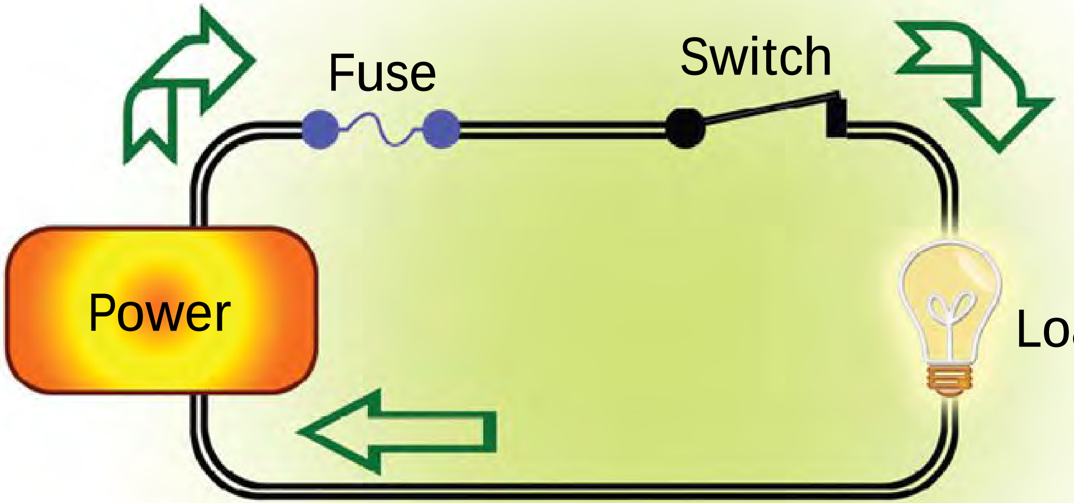


- Switches interrupt the circuit
- When open, electricity can't flow
- When closed, the circuit is complete and electricity flows

Circuit Breakers/Fuses

What if there was no load?

Fuses and circuit breakers are automatic switches that cut off current when it reaches a dangerous level



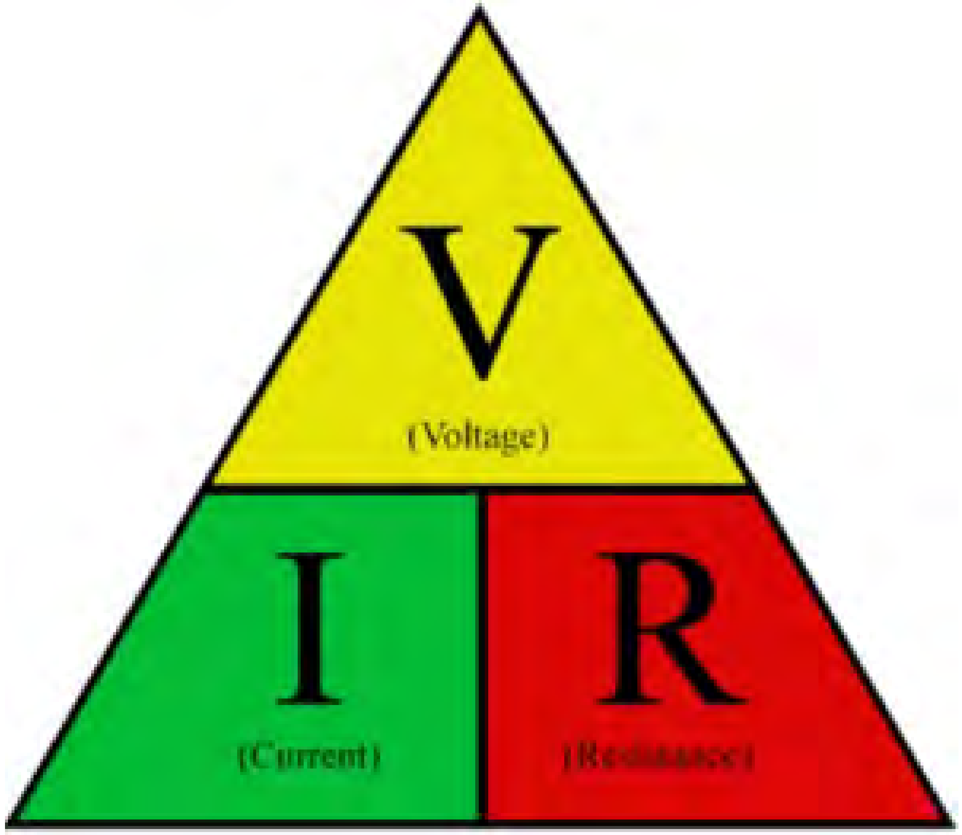
Ohm's Law

There is a relationship among volts, amps and Ohm's in a circuit.

Voltage = Current X Resistance

Current = Voltage / Resistance

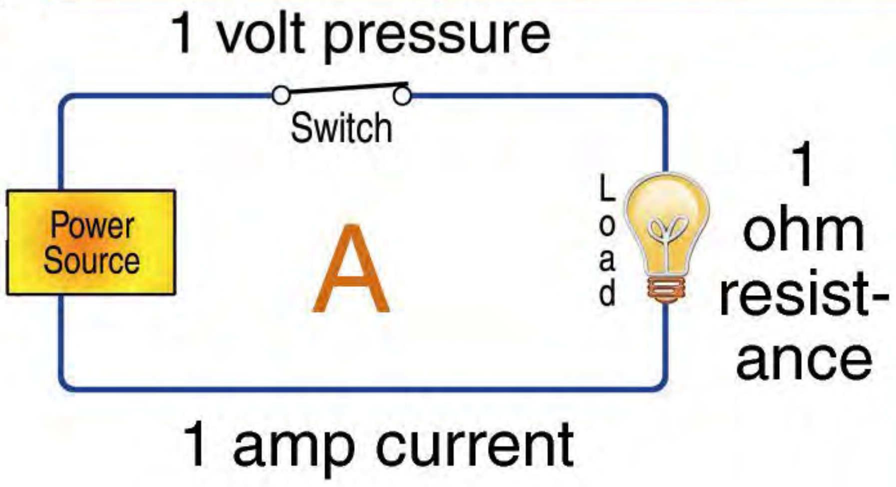
Resistance = Voltage / Current



Ohm's Law

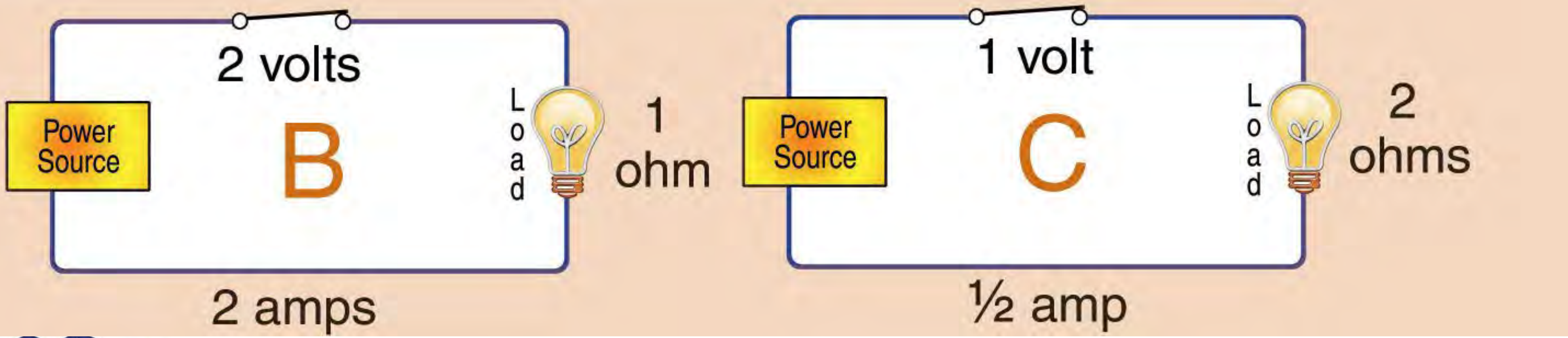
Ohm's Law

Ohm's law: It takes one volt to push one amp through 1 ohm resistance.



If you double the voltage but keep the resistance the same as in this example, you double the current (2 amps), as in Fig. **B** below.

Keeping the voltage the same (one), but doubling the resis-tance (to 2 ohms), results in half the current, or one-half amp, as in Fig. **C**.

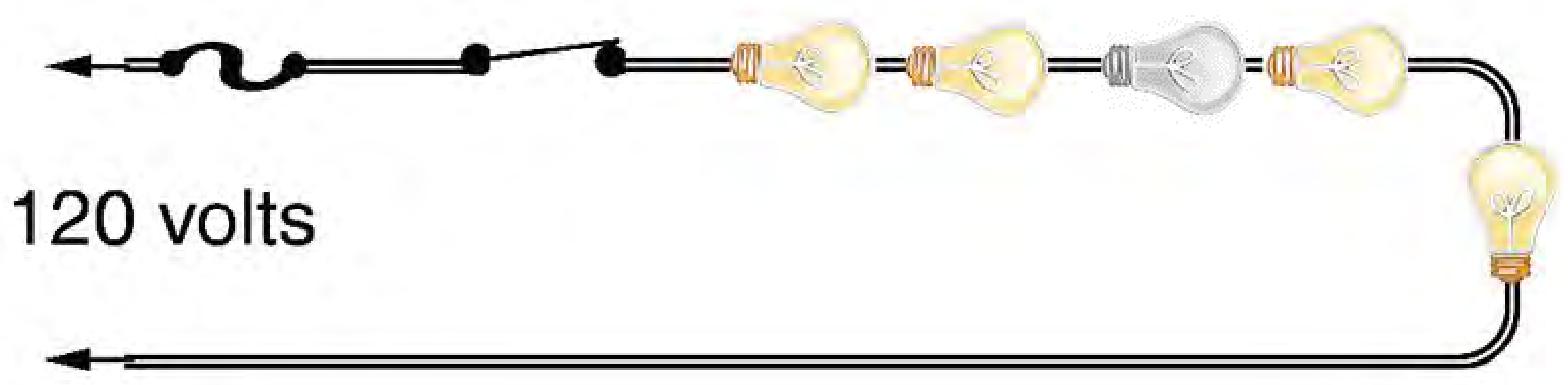


Series Circuit

In a series circuit there is only one path for current to flow.

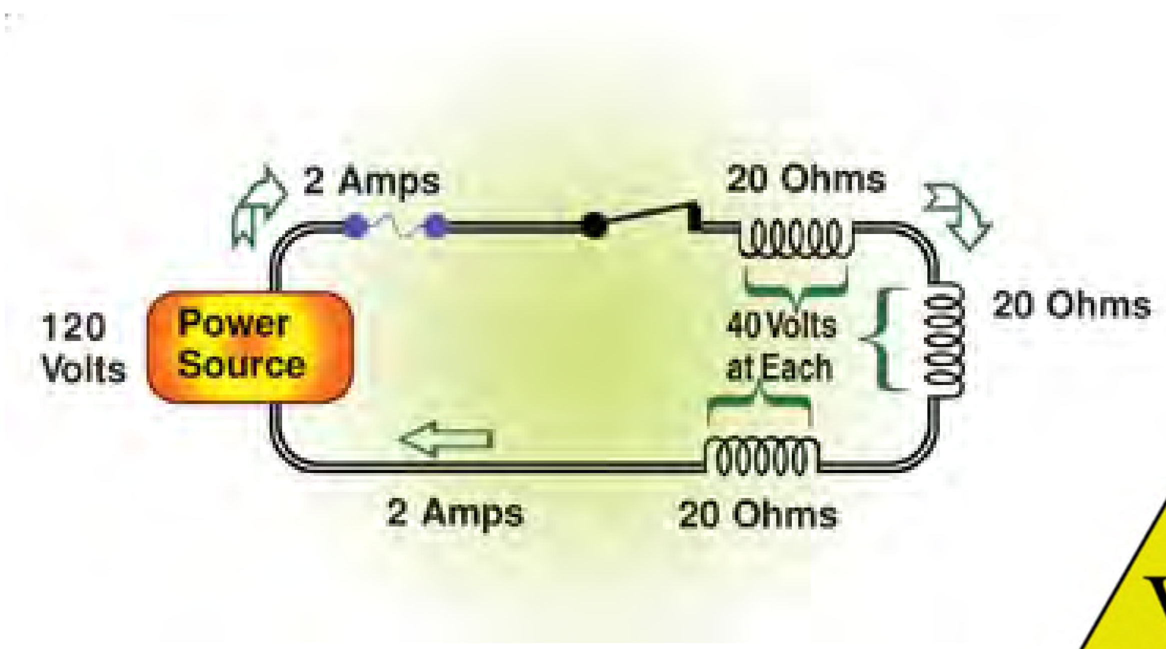
If one load is “lost” all the rest shut off.

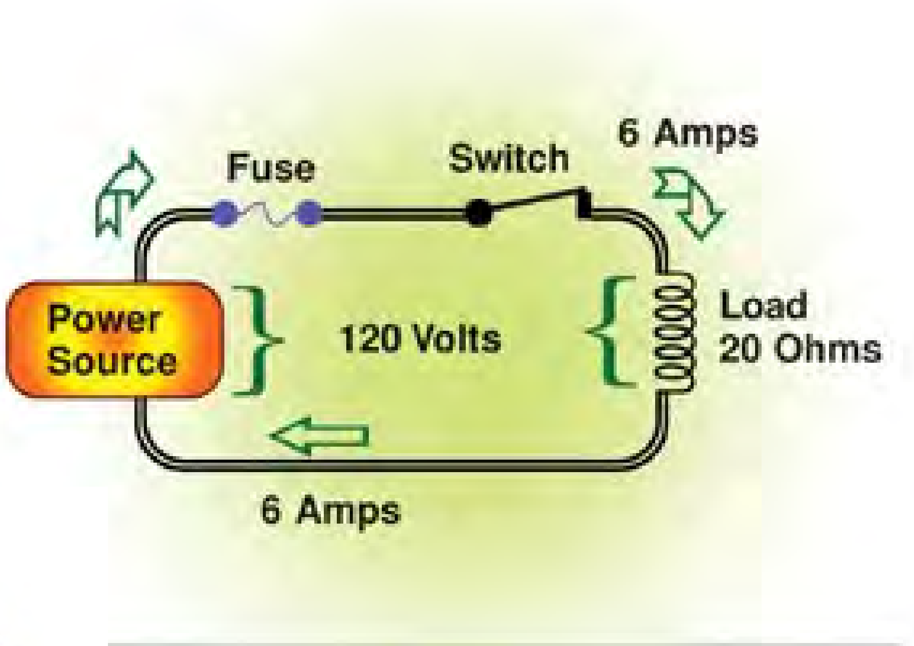
In this figure, if the 3rd light bulb burns out, which ones stay lit?

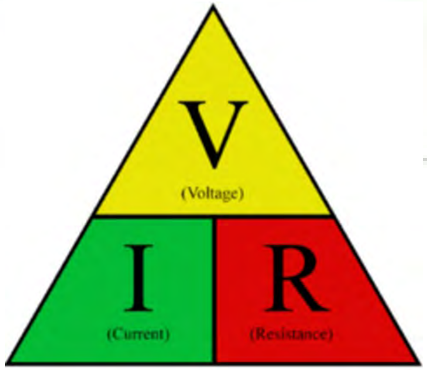


Series Circuit

If there's more than 1 load – voltage is "shared." (reduced)

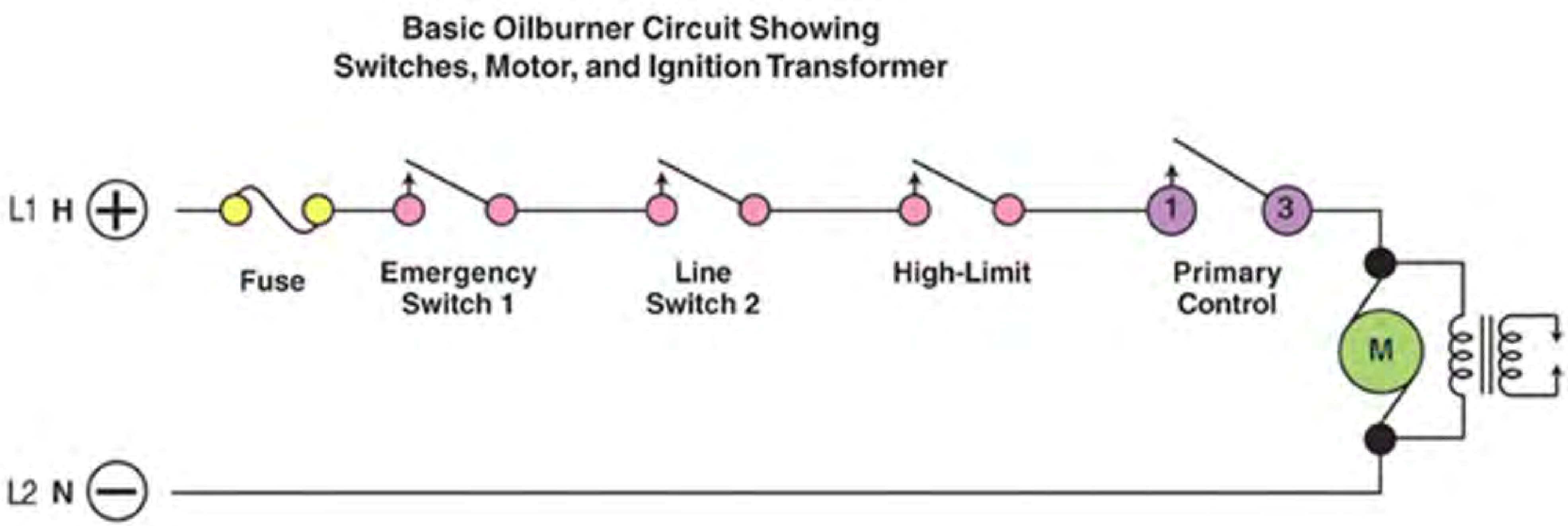






Series Circuit

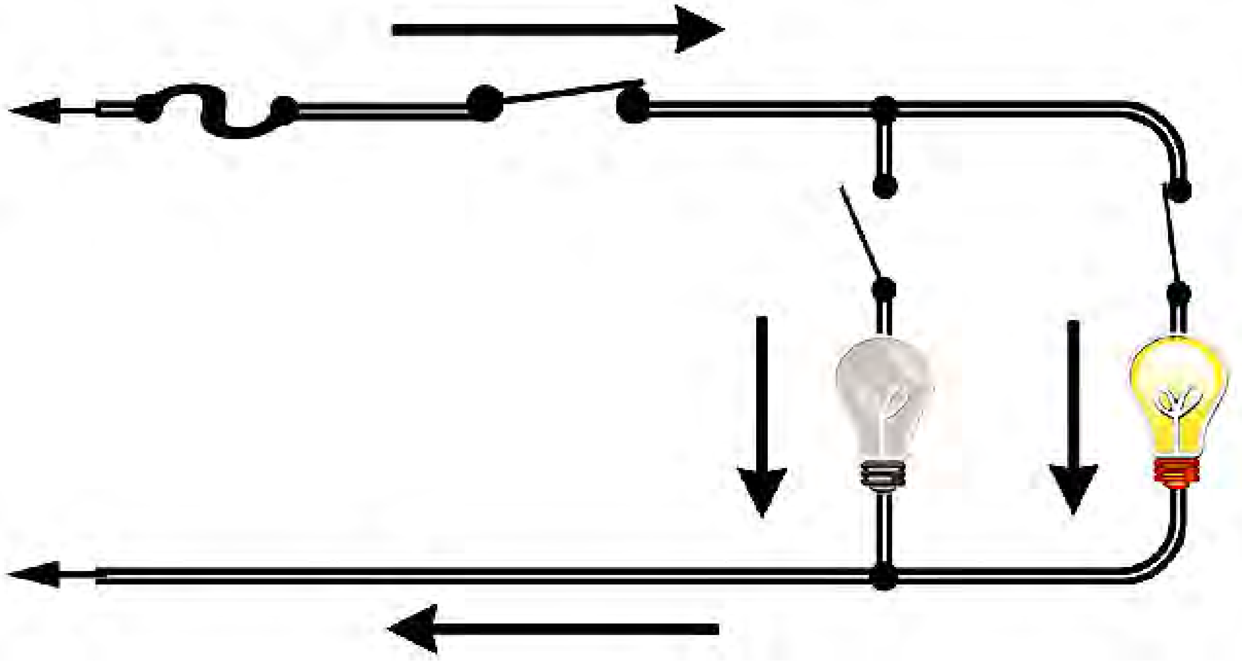
Loads (burner motor, igniter, oil valve, etc.) are ***never*** wired in series and limit controls ***always*** are.



Parallel Circuit

A parallel circuit has separate branch circuits for each load.

All loads receive the same voltage and if one load is shut off or fails, it will not affect the other loads.

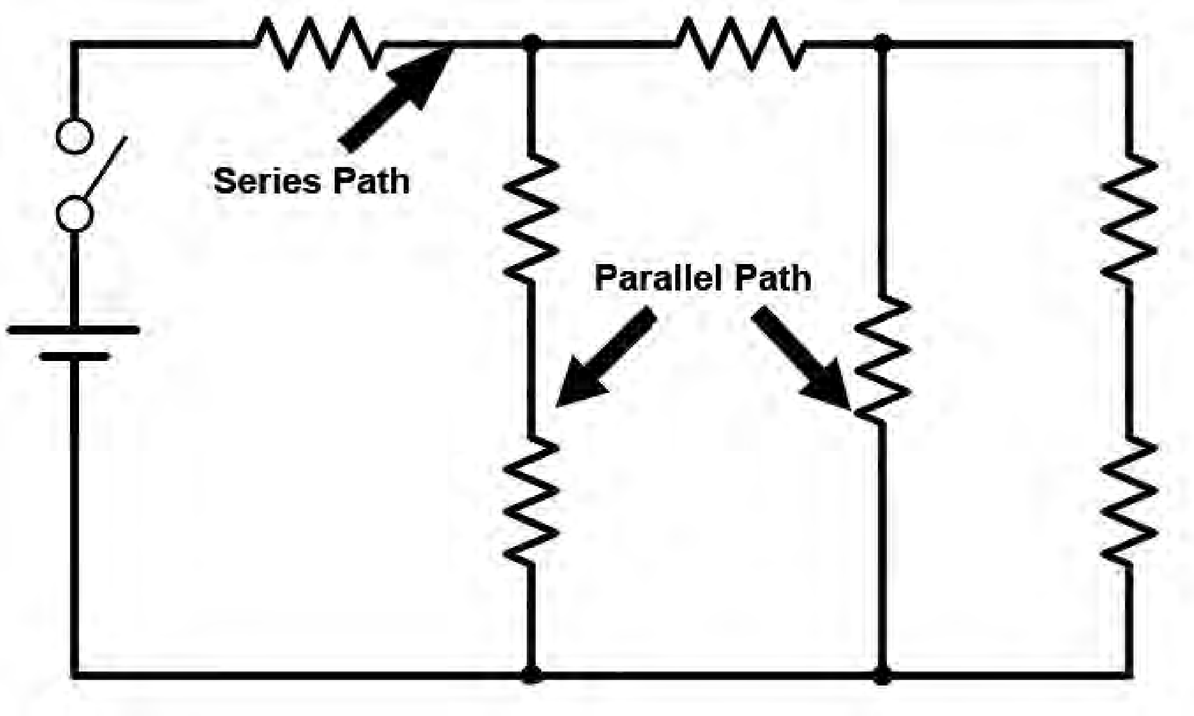


Combination Circuit

Heating systems use a combination circuit, a mixture of both series and parallel connections in the same circuit.

The main switch and all limit controls are wired in series with the primary control, if one of these opens, current to the burner is cut off.

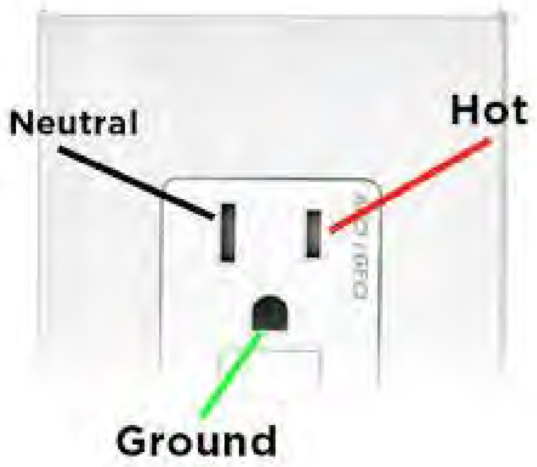
Loads (burner, circulator, blower, etc.) are wired in parallel to allow individual component control & to ensure full voltage is supplied to each load



Polarization

Most appliance plugs have a wide blade and a thin blade so, there's only 1 way to plug them in.

If the outlet is wired correctly, the wide blade connects to neutral and the thin connects to the hot wire, NOT the neutral, allowing for a safe shut off of current.



Polarization

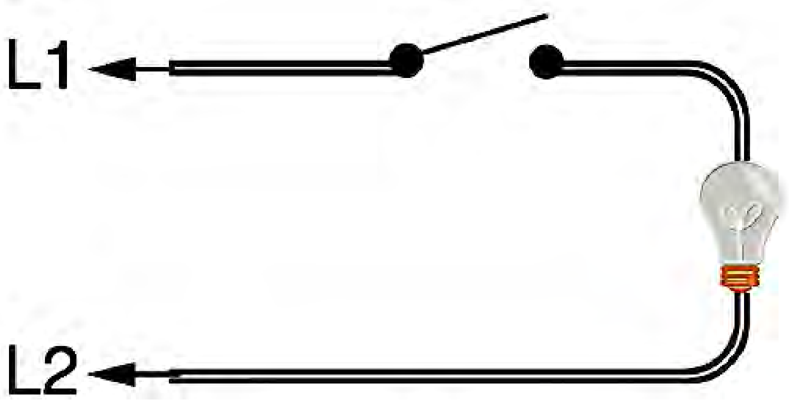
If polarization is reversed in heating systems, some components will function normally

BUT the burner switches and limit controls will interrupt the neutral wire.

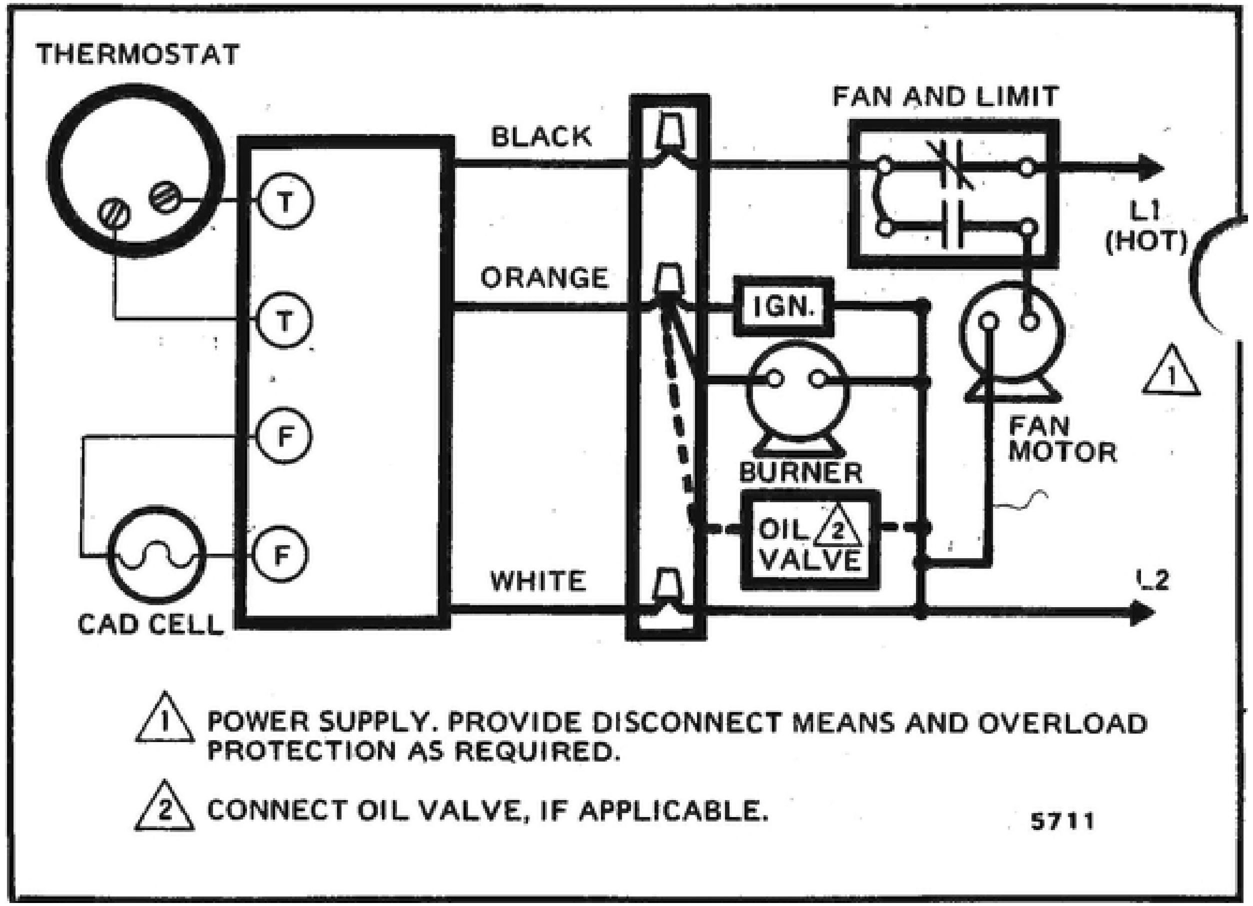
A technician working on the system could receive an electrical shock because the circuit could be completed by flowing through them!

Wiring Diagrams

- Like "road maps" or blueprints



- The arrows on L1 (hot) and L2 (neutral) point at the power source, and represent a complete circuit

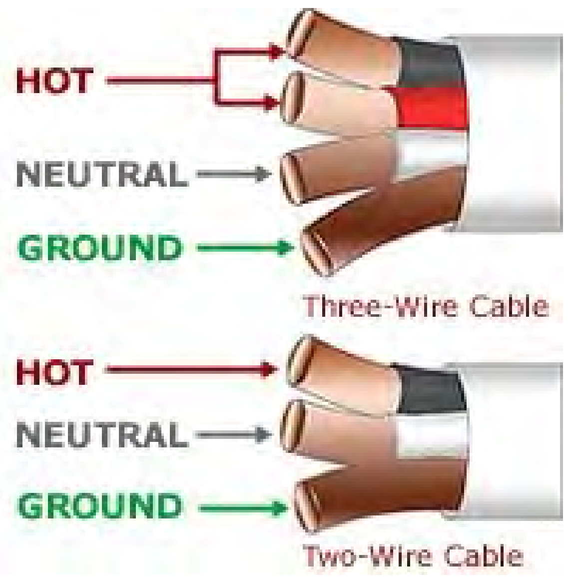


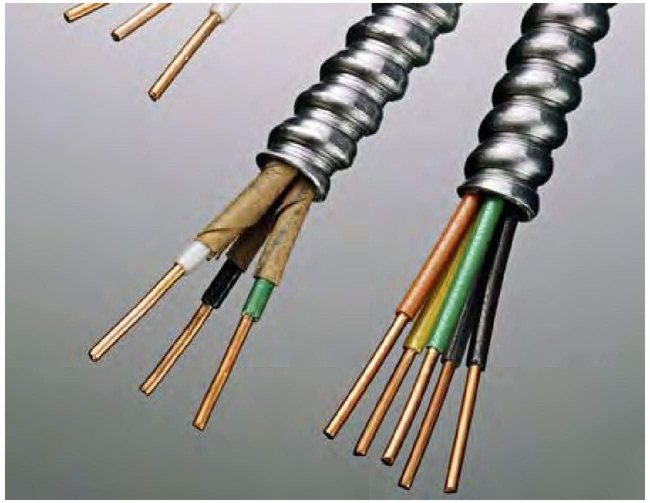
Wires

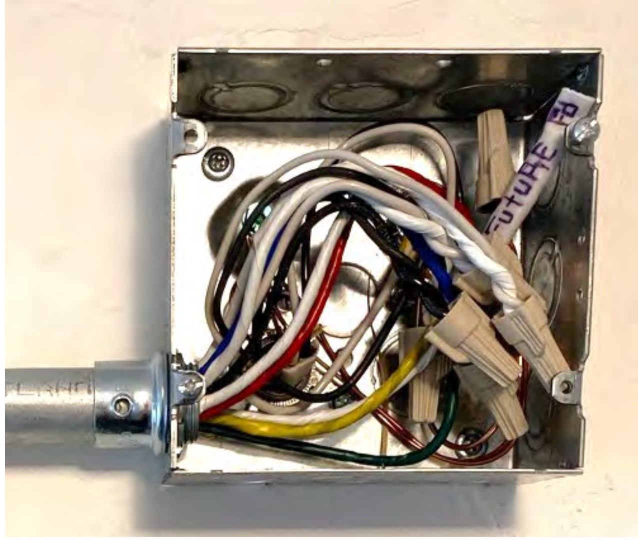
Available in many sizes, typically 12 or 14 gauge for heating systems

- 15 Amp circuit: 14 gauge
- 20 Amp circuit: 12 gauge
  Conduit can also be used

- Thermostat: 18 – 20 gauge



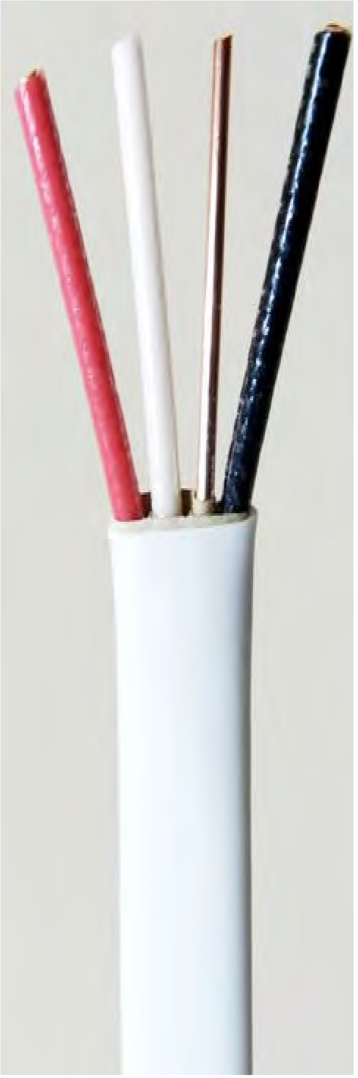




Wires

The number of insulated wires bundled together in the sheathing is how the wire is designated

- **14/2** has black and white insulated wires plus a bare ground wire
- **14/3** has a black, white and red insulated wires plus a bare ground wire



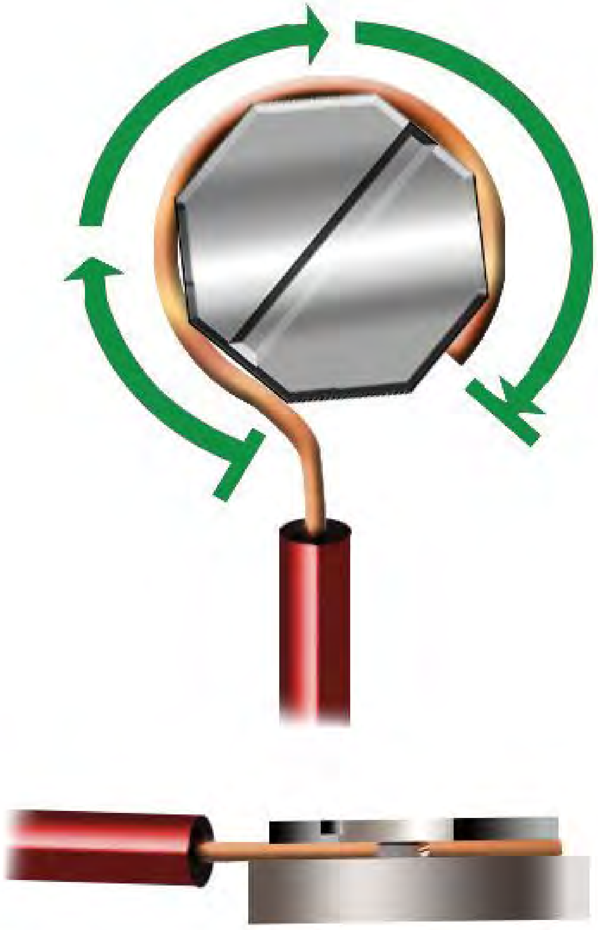
Splicing Wires

- Strip the insulation by inserting the wire into the correct hole in a wire–stripping tool
- Squeeze, twist and pull off the insulation
- Hold the stripped wires together & grab the ends with pliers, twist clockwise into a neat spiral
- Snip off the end leaving about ½" of metal, slip on an appropriate wire nut and turn clockwise until tight
- Wrap electrical tape around the bottom of the nut & wires

Connecting Wires to Terminal Screws

First, tighten any screws not being used, then:

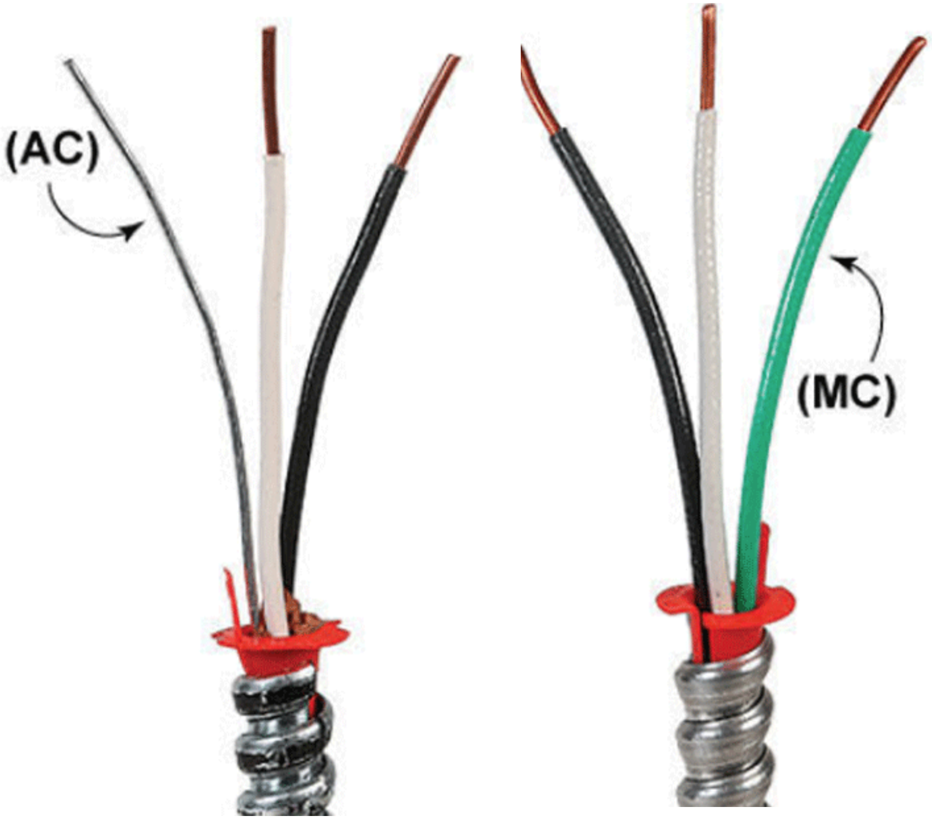
1. Strip ¾” of insulation from each wire being connected.
2. Use needle nose pliers to bend the exposed wire into a “J” shaped hook.
3. Loop the hook around the screw with the opening to the right.
4. Tighten the screw firmly.



Armored Cable

NORA recommends that any line voltage wiring around an appliance be flexible metal conduit (MC) or armored cable (aka BX and AC

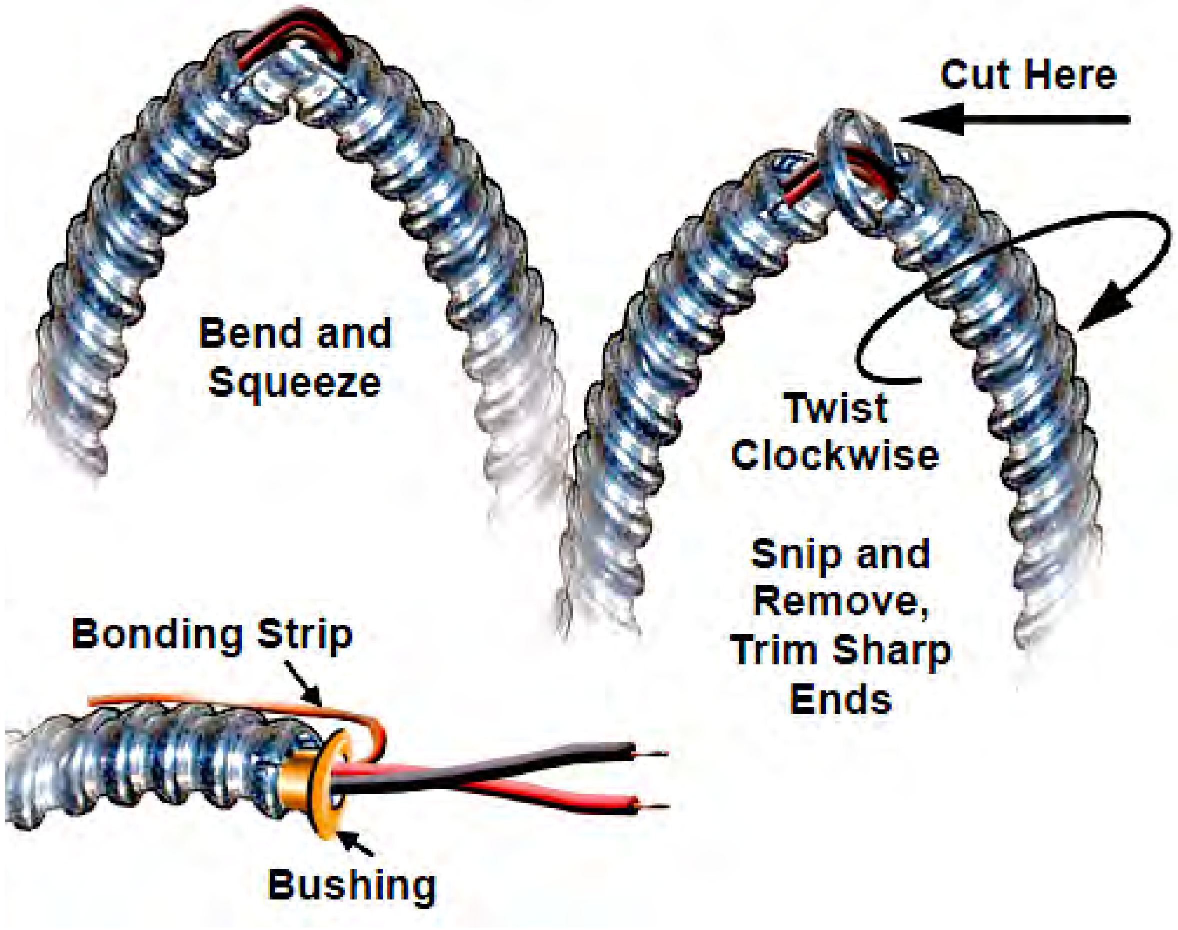
- BX (aka AC) has no ground wire, its metal sheathing as the ground.
- MC is like BX but includes a green insulated grounding wire.



Installing Armored Cable

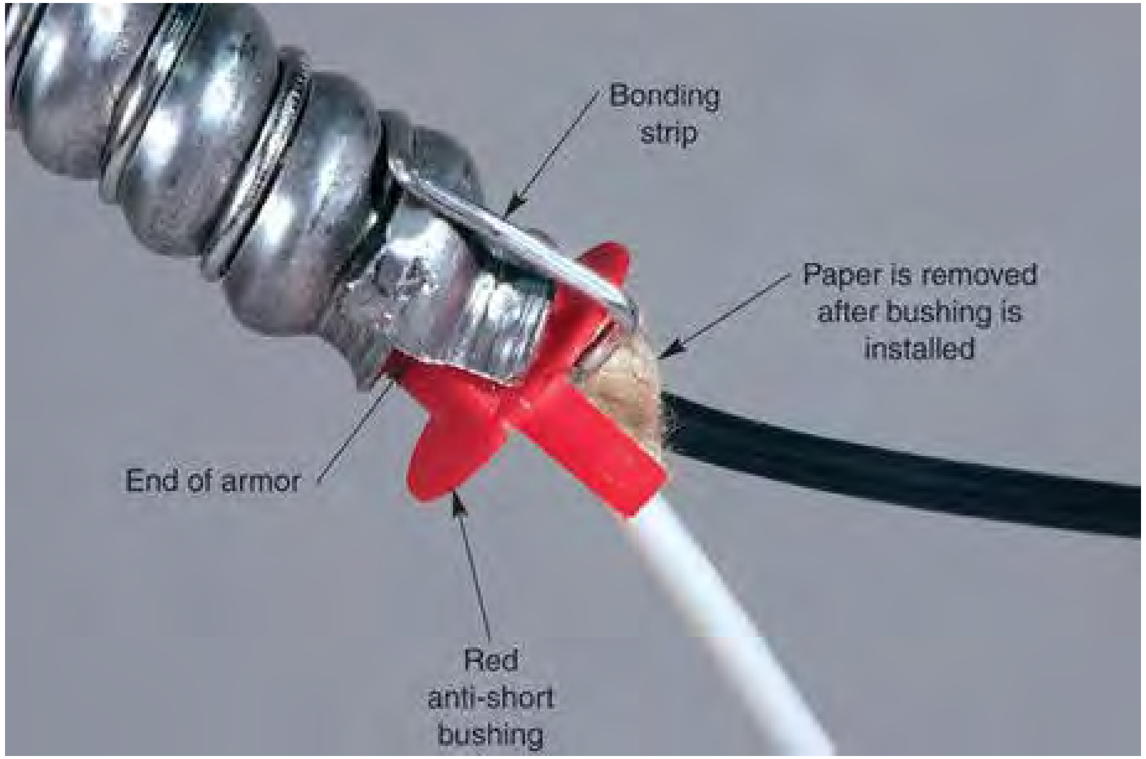
It’s best to use a cable cutter to cut armored cable and follow the manufacturer’s instructions.

If one is not available, bend the cable about 1’ from the end and squeeze until the armor beaks slightly apart & cut through one rib with pliers….



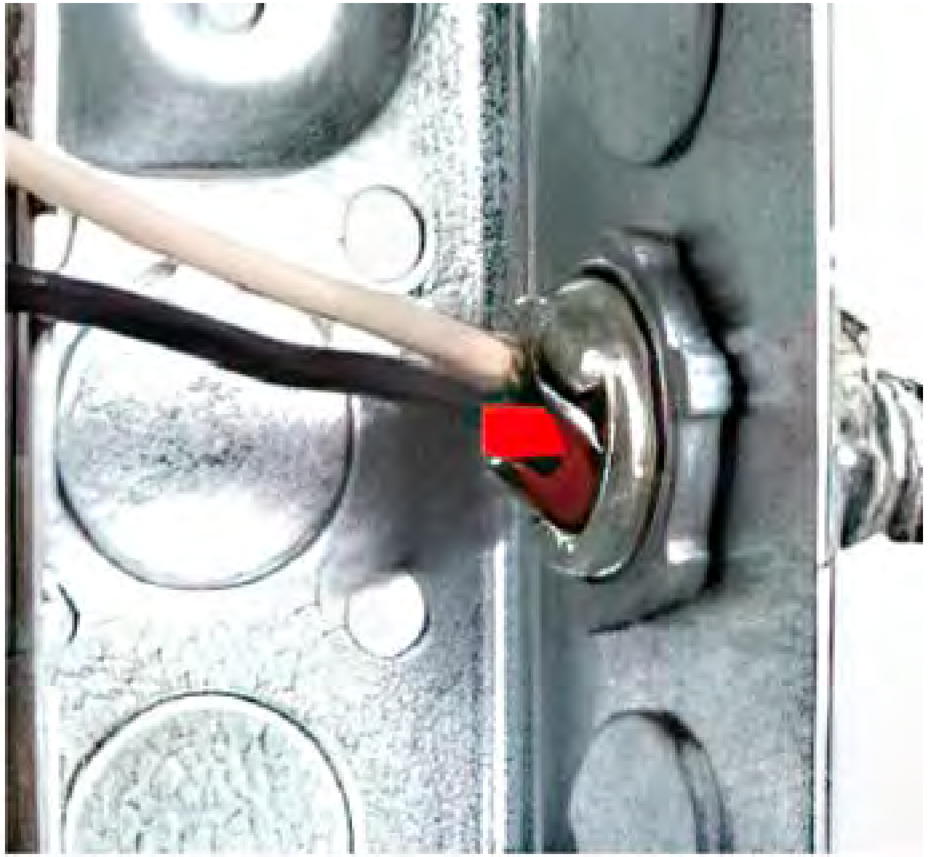
Installing Armored Cable

- Slide the waste armor off the wires
- Leave the thin metal bonding strip alone
- Cut away pointed ends of the sheathing that could nick a wire
- Slip a plastic bushing (redhead) over the wires and slide it down into the armor so it protects the wires from sharp edges……



Installing Armored Cable

- Cut the bonding strip to about 2”, wrap it over the bushing and around the armor to ensure conductive contact
- Attach a connector to the cable and remove the locknut
- Remove a knockout from the junction box, install the cable & connector into the hole, slide the locknut onto the connector and tighten

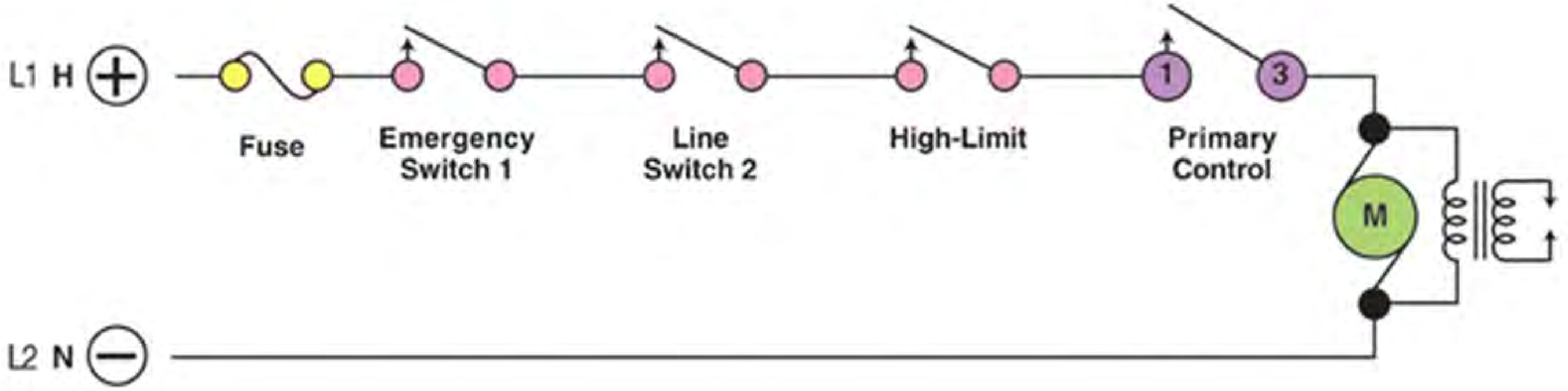


Switches

Switches are electrical components that connect or disconnect the path of an electrical circuit.

They are considered **“open”** when they stop current flow and **“closed”** when the allow the current flow.

They should always be on the “hot” side of all loads.

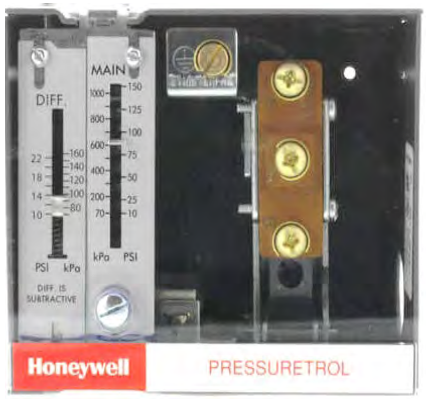


Switches

There are many types of switches in a heating system.

The most common is the "single pole, single throw" (SPST) service switch which turns everything in a single circuit on or off.

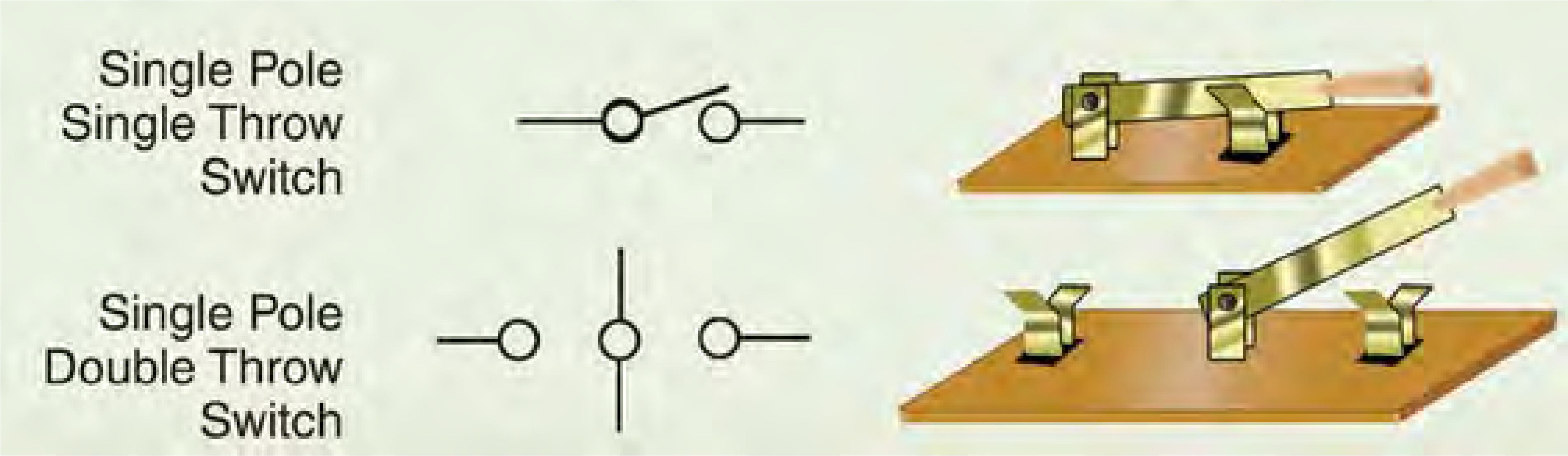
Most other switches in a heating system are "automatic" switches that are operated by temperature, pressure or water level/flow.



Single Pole Switches

Single Pole Single Throw (SPST)
turns everything in a single circuit on or off.

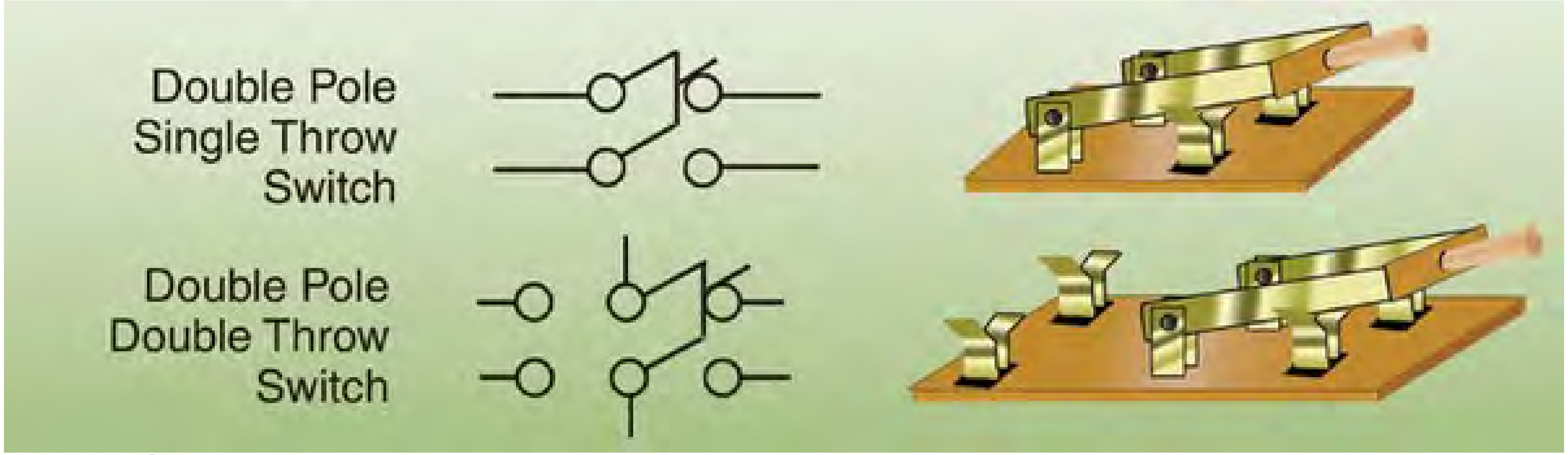
Single Pole Double Throw (SPDT)
turns on/off in either of two circuits.



Double Pole Switches

Double Pole Single Throw (DPST)
make or break 2 separate circuits at same time.

Double Pole Double Throw (DPDT)
redirects the power of 2 separate supply lines to 2 different circuits.

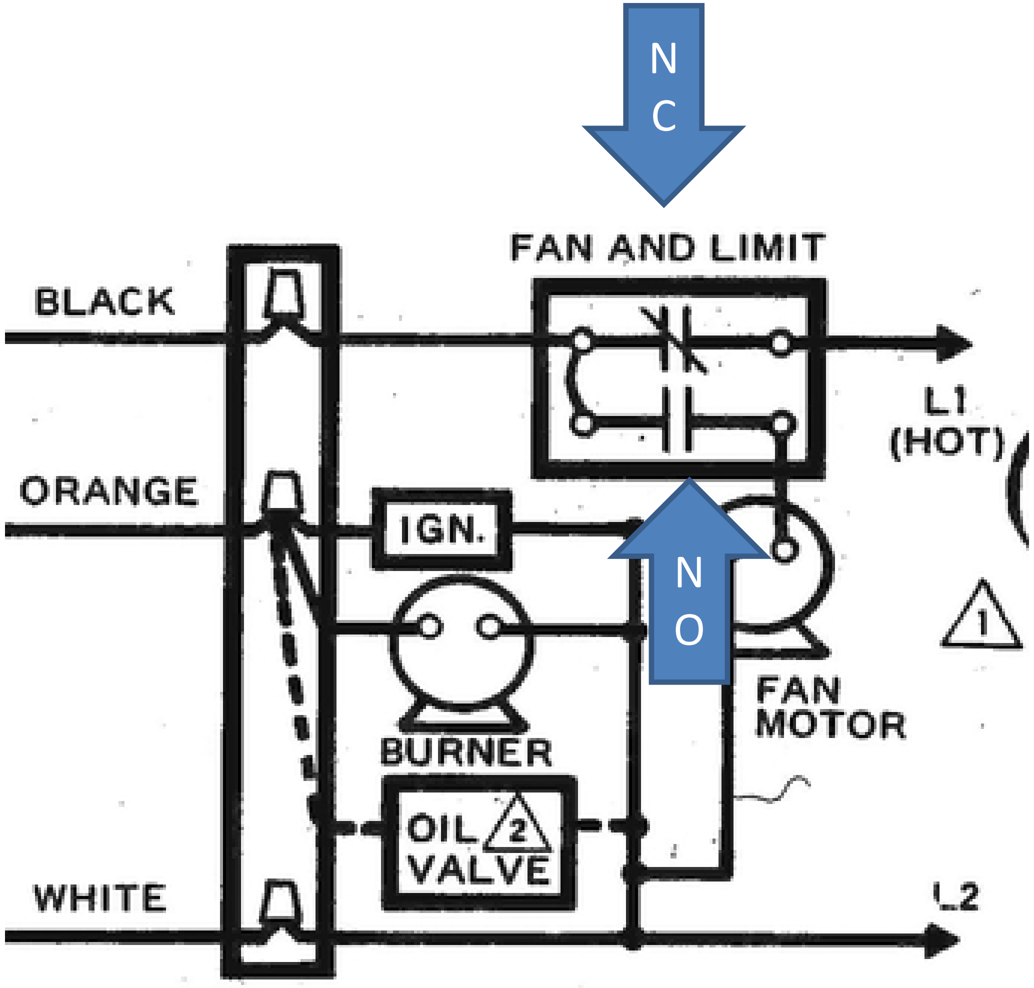


Automatically Operated Switches

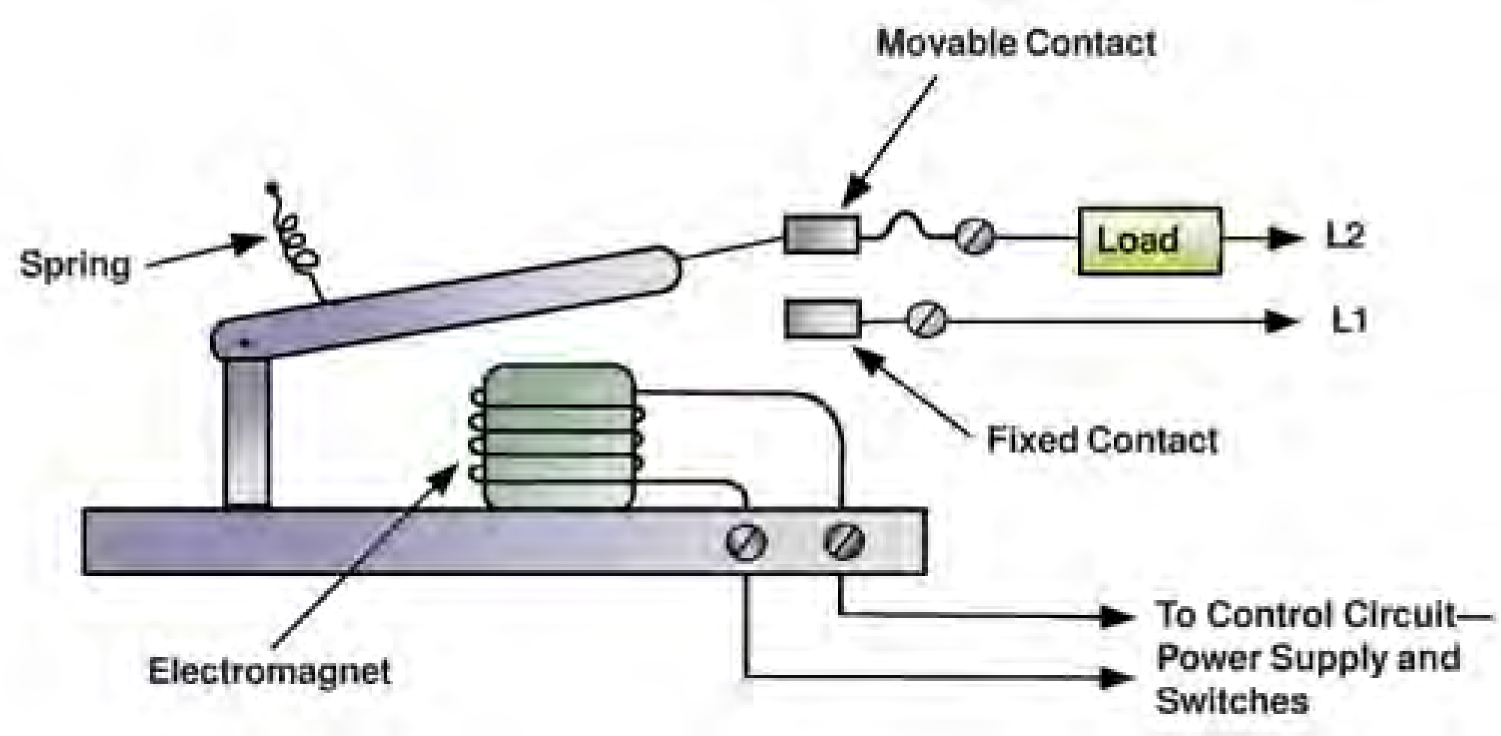
- Respond to a change in temperature, pressure, liquid level, etc.
- Some open on a rise, others open on a fall
- What does this one do?
- Direct acting switches open on a rise in the sensed condition
- Reverse acting switches open on a fall in the sensed condition

Contacts of Automatically Operated Switches

Shown in wiring diagrams in the normal (at rest) position when the unit is *not* operating.



Relay Switches



Some old controls use relays (electromagnetic switches) to open/close.

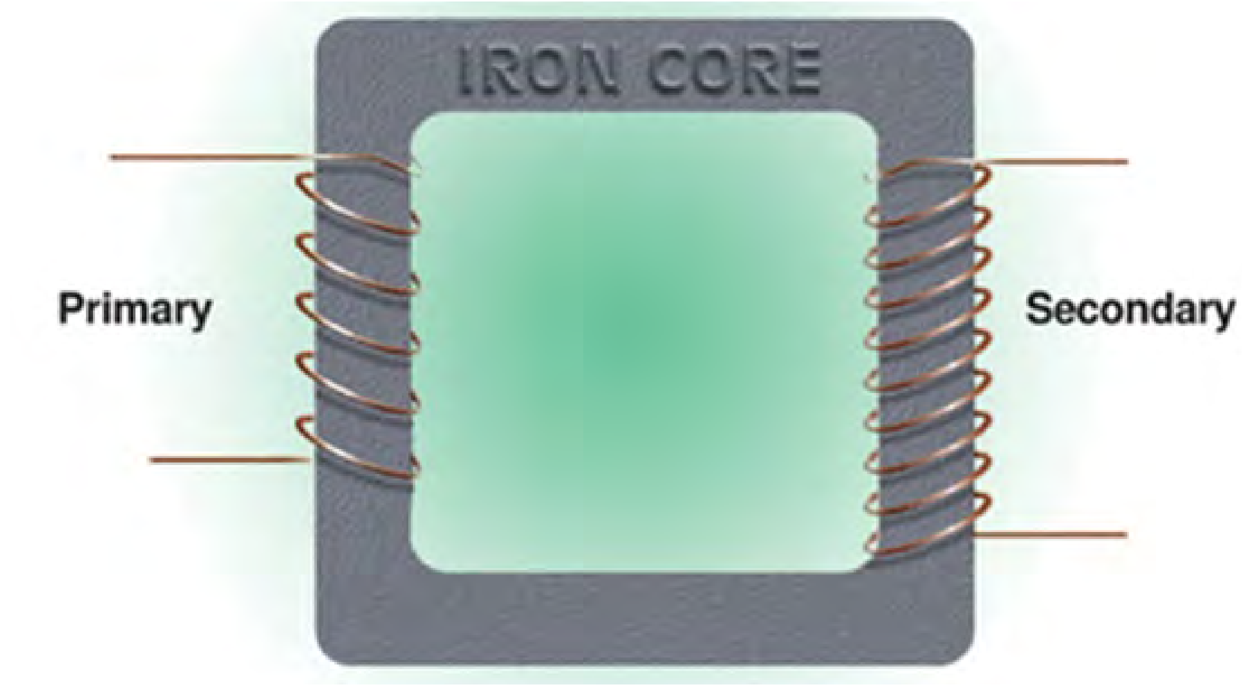
Dirty or corroded contacts are a problem.

Transformers

Transformers are electrical devices that transfer alternating current from one circuit to another with an increase or decrease in voltage.

They have an iron core with 2 separate wire coils wrapped around 2 sides, current enters the primary coil and exits the secondary coil.

When voltage is applied to the primary coil, a magnetic field creates voltage in the secondary



Transformers

- Step down models have more primary than secondary coils
- Step up models have more secondary than primary coils
- Amount of voltage generated in secondary is determined by ratio of coils between primary and secondary

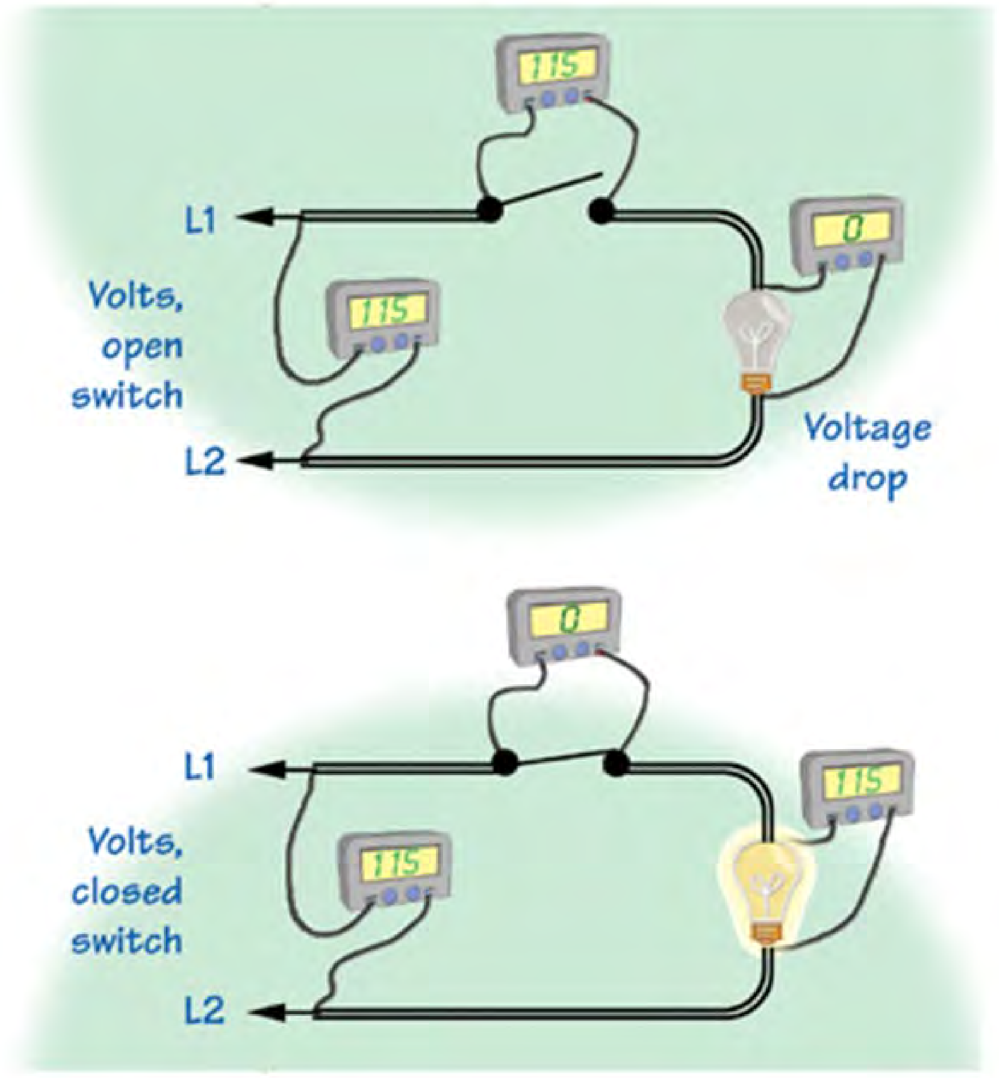
Measuring Electricity

- Multimeters measure voltage, current & resistance
- Must be properly set for what's being measured
- Select range, start high and move down for best accuracy
- Different meters have different features, techs should be thoroughly familiar with the model they're using

Measuring Voltage

- Voltmeters measure a difference in electrical potential (pressure) between 2 points

- Very little current flows through the meter, it can be used on live circuits



Measuring Current

Ammeters measure the rate at which current flows form the source, through the circuit & back to the source.

Clamp on ammeters are commonly used by technicians, to use one:

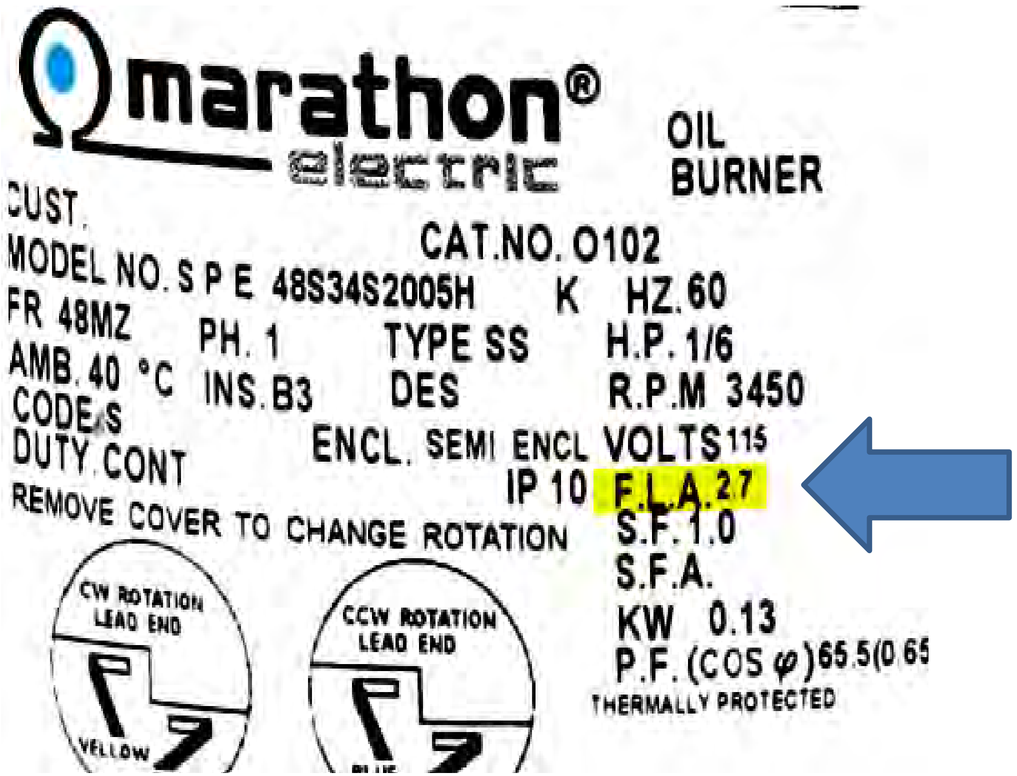
- Choose the correct scale
- Insert one line between jaws
- Take a reading

(Why 1 line? Does it matter which?)

Measuring Current

The design draw of a load is usually listed on the rating plate.

It can be referred to as Amps, Rated Amps, Running Amps or F.L.A which stands for Fully Loaded Amperage.

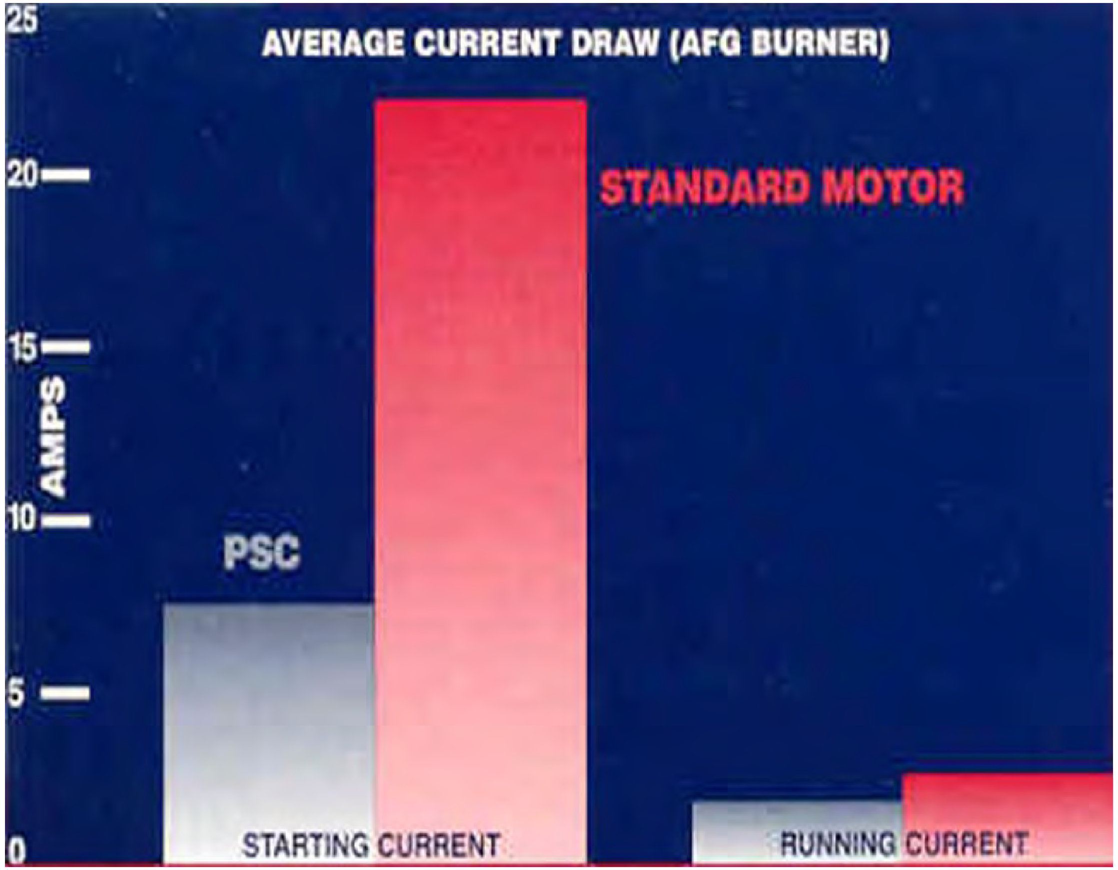


Measuring Current

It’s important to understand that the rating refers to the amperage draw when the component is operating at steady state.

On start up, the amperage draw will be much higher.

This chart shows the relationship between running amps and starting amps for two types of burner motors.

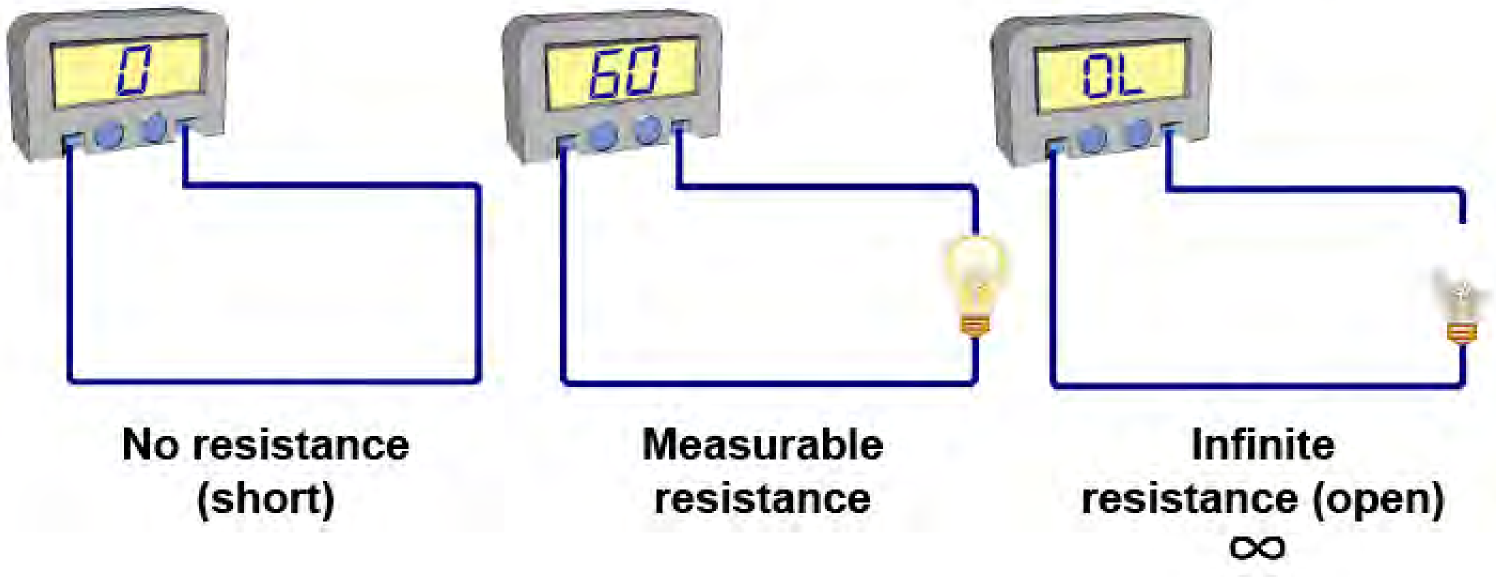


Measuring Resistance

Ohmmeters are used to measure resistance between 2 points.

They can be used to measure an individual load or a whole circuit.

They provide their own power so the circuit or device being tested MUST be isolated from the power source.



Measuring Resistance

In the heating industry, ohmmeters are often used to determine the resistance through a cad cell.

Measuring Resistance

They are also commonly used to check for a break in low voltage thermostat wiring, to check:

- “Zero out” the meter
- Raise the thermostat to its highest setting
- Disconnect the wires from T-T on the control…..

Measuring Resistance

- Touch one lead to each thermostat wire at the same time

- If there’s no continuity, the reading will be OL for open loop which means that there’s a break in the thermostat circuit

Measuring Resistance

To determine if the break is in the wiring or the thermostat:

- Disconnect the correct 2 wires from the thermostat
- Connect them with a wire nut
- Check continuity again

If there's continuity, the problem is with the thermostat.

If not, the problem is with the wiring.

Review Questions…

- What are the steps to safely work with electricity?
- What controls the flow of electricity in a heating system?
- What is the difference between voltage, current, resistance, and watts?
- What are the different types of electrical loads heating system?
- What is the difference between series, parallel, and combination circuits?
- What happens if circuits are reversed?
- How do you find parallel and series circuits in wiring diagrams?

Review Questions:

Continued…

- What do the colors mean on different types of wires?
- How do you cut wires?
- How do you splice wires?
- How do you decide if a switch is normally closed or normally open by reading a wiring diagram?
- How do you find electromagnet switches and transformers on a wiring diagram?
- How do you use a multimeter to measure voltage, current, and resistance?

End of Chapter 8

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 9

Limit Controls & Thermostats

At the end of this lesson, you will be able to:

- Explain how switches work in limits and thermostats
- Draw a basic oil burner circuit with switches, motor, and ignition transformer
- Explain how thermostats are wired for warm air furnaces, steam boilers, hydronic boilers, and zone valve actuators
- Explain what heat anticipators do & how to adjust them
- Describe good locations for thermostats and how to mount them
- Describe how a warm air limit control normally works and what can cause problems
- Describe how an electronic fan timer normally works and what can cause problems

At the end of this lesson, you will be able to:

Continued

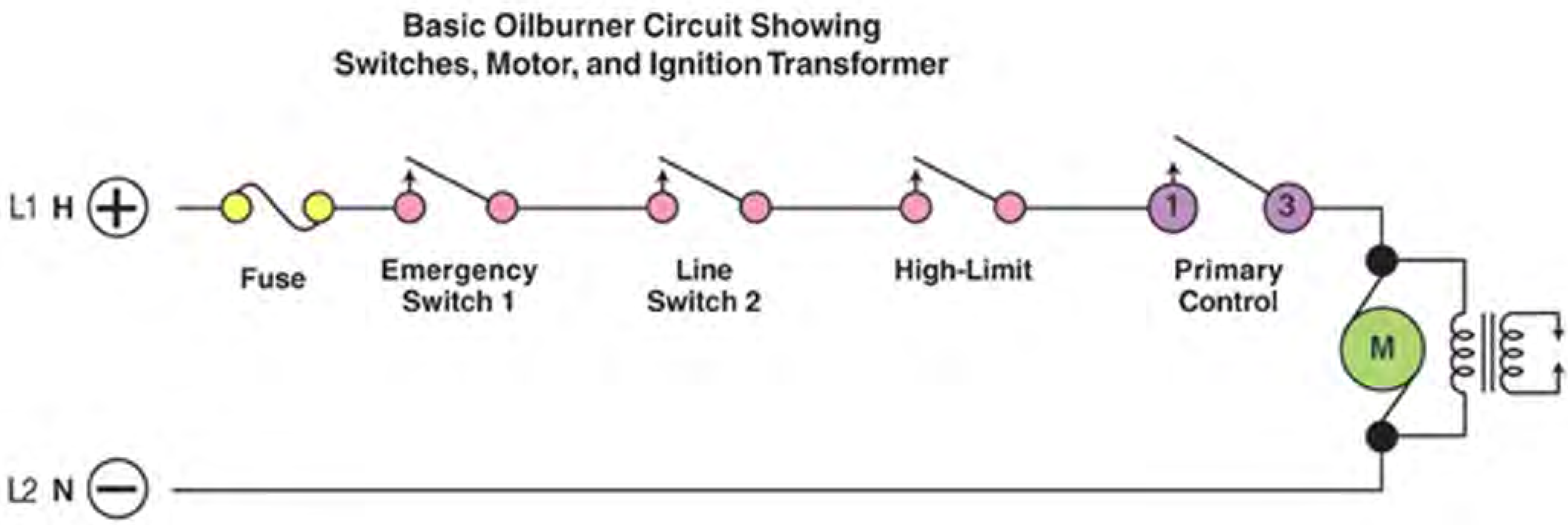
- Explain the difference between a pressuretrol and a vaporstat
- Describe how to correctly install a pressuretrol with a pigtail
- Describe pressuretrol cut-in and cut-out settings and how to adjust the differential
- Explain how switches control a heating circulator
- Explain why low water cut offs are important and how to find them on a wiring diagram
- Explain how boiler temperature controls work and how to find them on a wiring diagram
- Describe the different ways to add zones to a system

Limit Controls and Thermostats

They’re just switches, either line or low voltage,
in the electrical control circuit.

Electrical Control Circuit

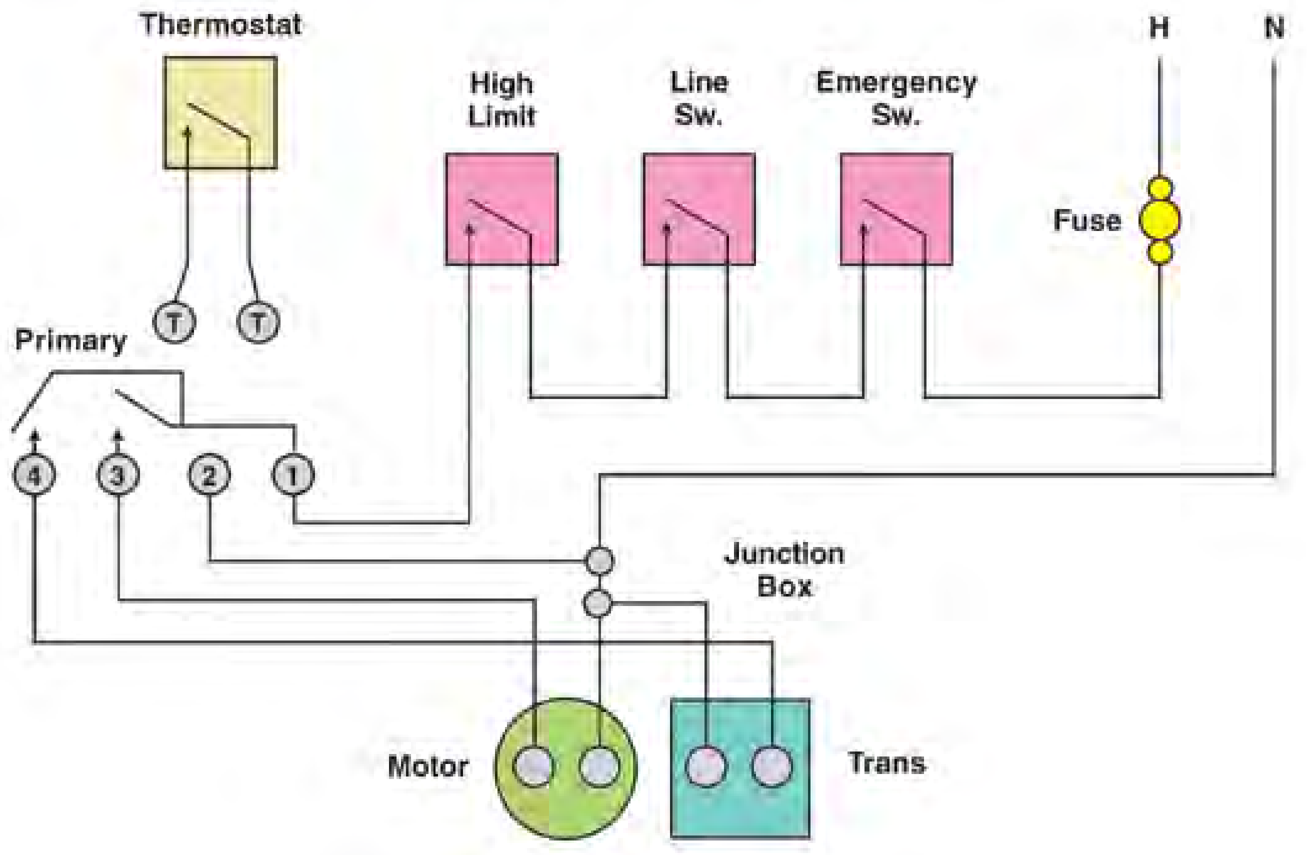
L1 (hot) starts at the electrical panel…travels to the main switch, then to a junction box near the appliance, to a service switch, through the limit(s), to the primary control and then to the burner.



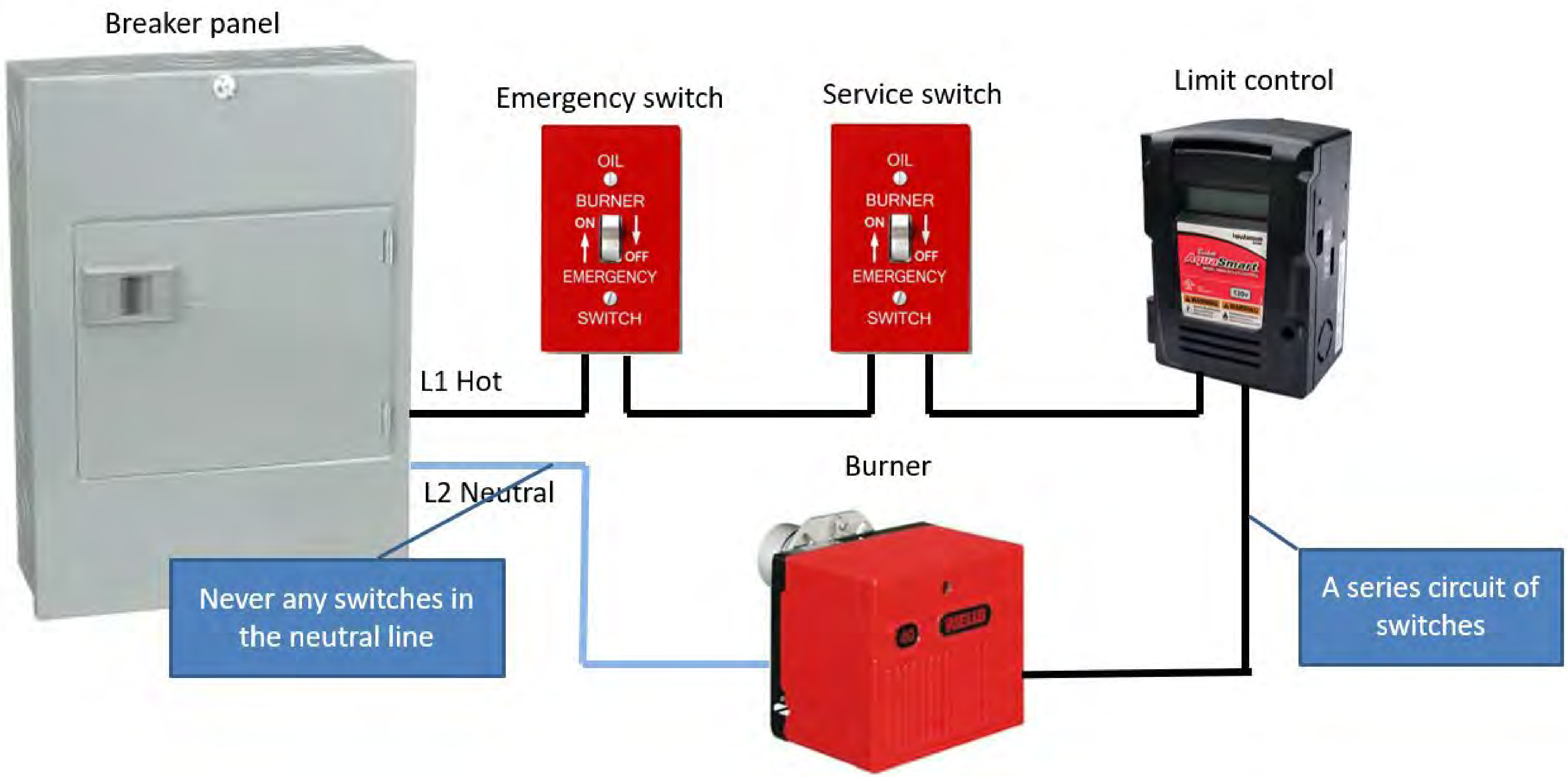
Electrical Control Circuit

L2 (neutral) also starts at the electrical panel and travels to the L2 terminal or the white lead of the primary control.

There should *never* be any switches on the neutral line.



Electrical Control Circuit

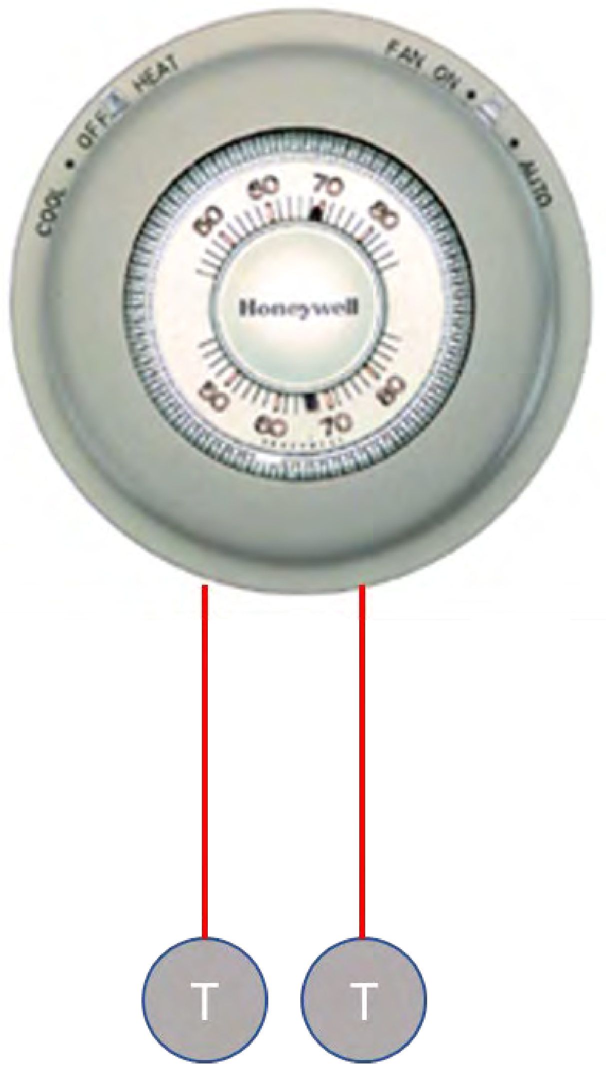


Thermostats

Switch that automatically opens or closes a circuit as room temperature changes.

Starts burner, and/or circulator or blower when the room temperature is below the setting and shuts them off when the heat demand is satisfied.

Low Voltage Thermostats



Low voltage (24 VAC) thermostat circuits typically start at a step-down transformer in a control and are utilized through the T-T terminals to allow the thermostat to control the burner and/or circulator.

Line Voltage Thermostats

Used in some systems to directly control circulators.
They are not as sensitive as low voltage types – leading to wider fluctuations in room temperature.

Differentials

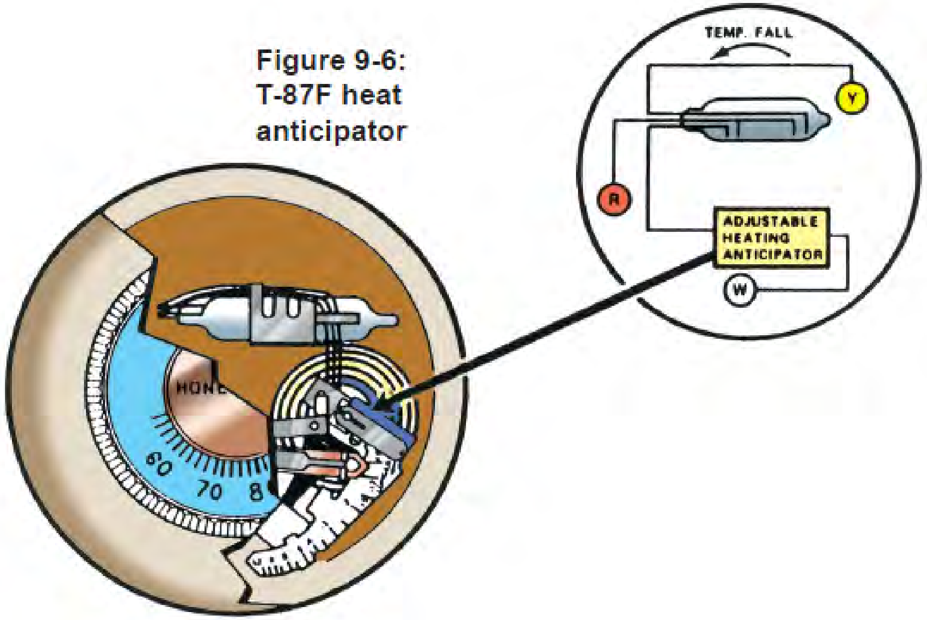
- A differential of a control is the difference between the opening and closing of its contacts. If its contacts open at 70˚F and close at 67˚F, the differential is 3˚F
- Without a differential, systems would "short cycle", turning on and off with minor temperature changes
- Most thermostats have fixed differentials that can't be adjusted

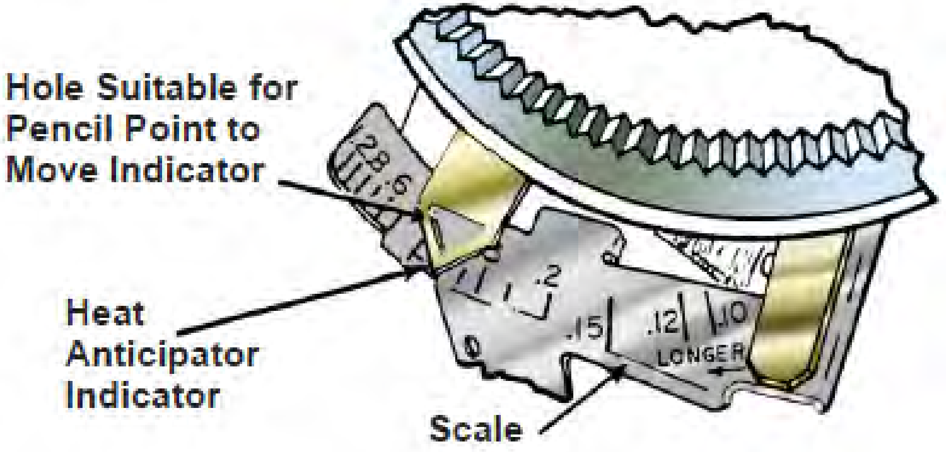
Heat Anticipation

Old thermostats have a heat anticipator (heater) that “fools” the thermostat into thinking it’s warmer than it senses because old, large radiators add a significant amount of heat to the area after the thermostat shuts down.

The anticipator must be adjusted to match the current supplied to the thermostat by the control it is connected to.

Figure 9-6: T-87F heat anticipator





Digital Thermostats

- Operate system plus maintain and store temperature settings, day, date and number of cycles
- Most have multiple settings for each day of the week.

Internet Connected Thermostats

These can be connected through Wi-Fi or communicate through a hub connected to the internet.

Digital and connected thermostat installation and wiring instructions can vary widely between models.

As with all heating equipment, strict adherence to manufacturer's instructions is critical.

Thermostat Location

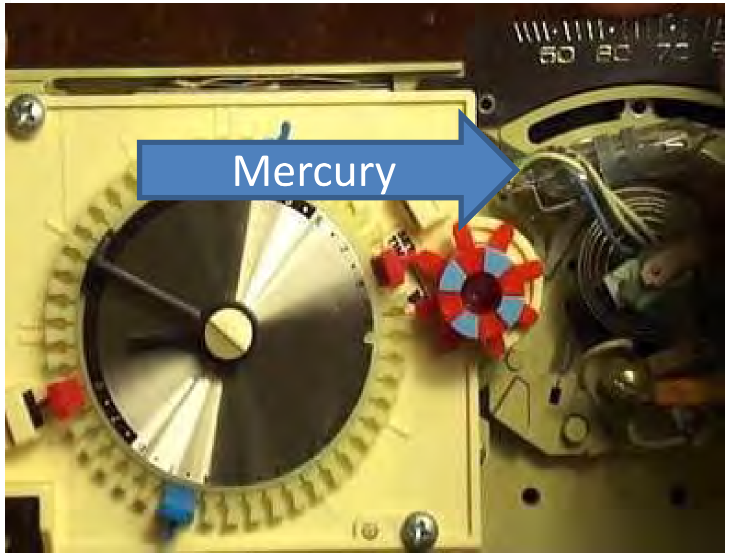
Thermostats should normally be installed about 5’ from floor on an inside wall with good air circulation.

Problem locations:

- On/near an outside wall
- Wall containing heating pipes, warm air risers, chimney, etc.
- In an over or under radiated room
- Near a window or door frequently opened to the outside
- In a room with a refrigerator, stove or fireplace
- Above light, TV, computer, heat emitter, etc.

Mounting Thermostats

- Connect wires to proper terminals – follow color codes
- If thermostat has a mercury switch it MUST be level
- Excess wire should be pushed back into wall and hole should be plugged with putty. WHY?



Limit Controls

Limit controls are automatic temperature, pressure or water level activated switches that control power to the burner.

There are two types of limit controls, “safety limits” and “operating limits.” Most residential controls are listed as both.

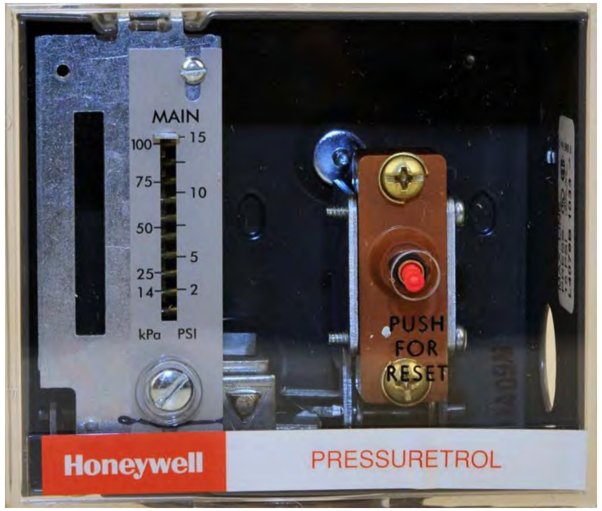
Operating Limits

These automatically prevent a burner from operating if high temperature, high pressure or low water level conditions exist.

Some reset automatically when conditions return to normal, others must be manually reset when the limit is exceeded.

Safety Limits

These automatically prevent a burner from operating if high temperature, high pressure or low water level conditions exist.



Some reset automatically when conditions return to normal, others must be manually reset when the limit is exceeded.

They are normally found in commercial units.

Warm Air System Limit Controls

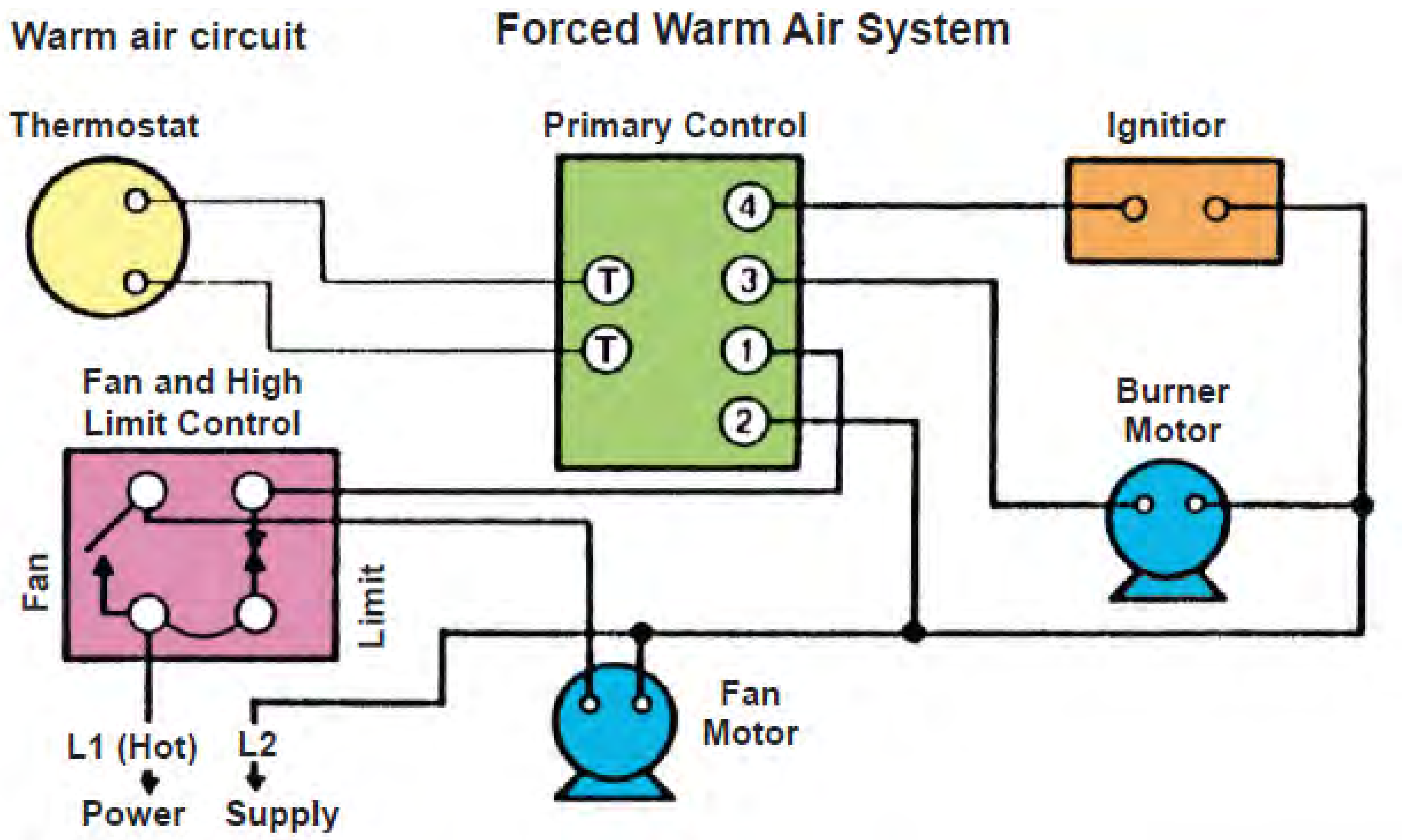
Warm air system limit controls provide on/off operation of the furnace fan motor and high limit control of the burner.

There are two types of warm air limit controls:

- Fan/limit controls
- Electronic furnace control boards

(AKA fan boards, furnace circuit boards or integrated furnace controls)

Fan/Limit Controls

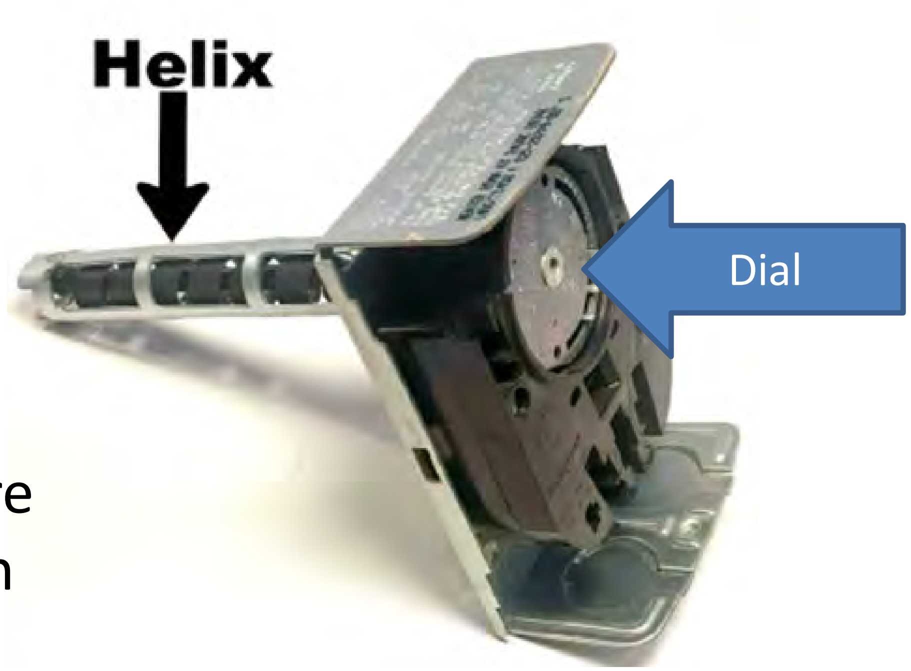


Fan/Limit Controls

Fan/limit controls feature a helix type bimetallic element that operates a fan control switch and a high limit switch.

A single dial is connected to the helix and had indicators for the fan on temperature, fan off temperature and the high limit setting.

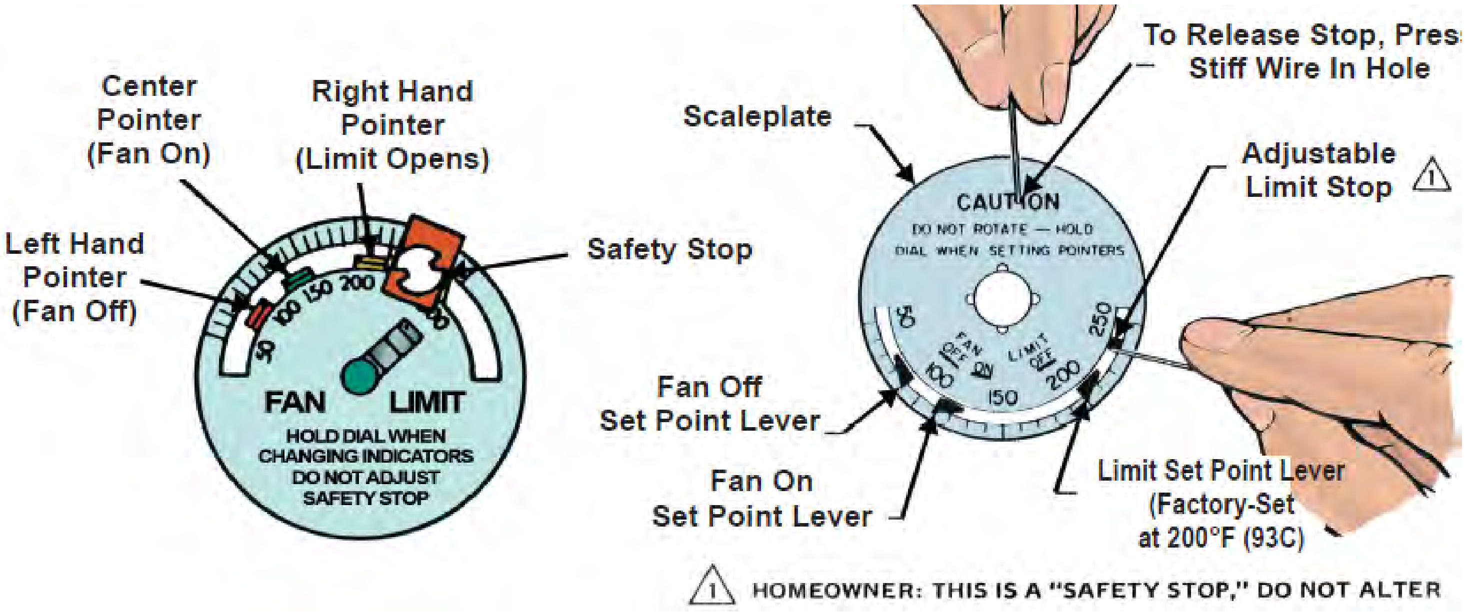
The helix and dial turn in one direction as temperature in the heat exchanger rises and the opposite direction when it decreases.



Fan/Limit Controls

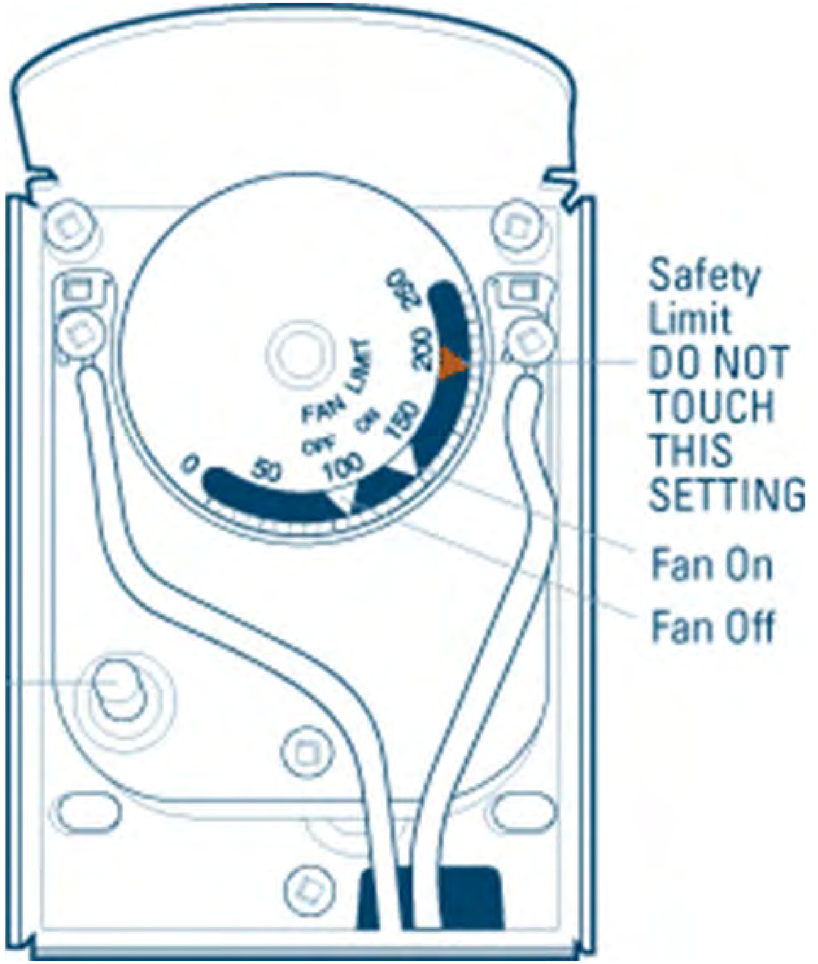
The control operates the system blower when the air temperature in the heat exchanger is within the "fan on" and "fan off" settings.

It prevents blower operation when the temperature in the heat exchanger is below the fan off setting. WHY??



Fan/Limit Operation – Call for Heat

1. The thermostat calls for heat, the burner warms the heat exchanger, the helix senses the temperature rise and turns the dial.
2. When the "fan on" setting is reached the blower moves air through the heat exchanger & the air distribution system.
3. If the temperature in the heat exchanger drops below the "fan off" setting, the blower stops until it rises again to the "fan on" setting…



Fan/Limit Operation – Call for Heat

4. The burner will operate until the thermostat is satisfied, then it will stop and the fan will continue to run until the "fan off" setting is reached (to remove the remaining heat from the heat exchanger.)

Average Warm Air Limit Settings	Limit	Fan = On	Fan = Off
Average furnace, average system	200°F	140°F	110°F

On a properly operating system the burner should NOT shut off on limit.

If the temperature in the heat exchanger exceeds the limit, the limit switch will open and stop the burner. The burner won't start again until the limit temperature (minus the differential of about 25˚F) is reached.

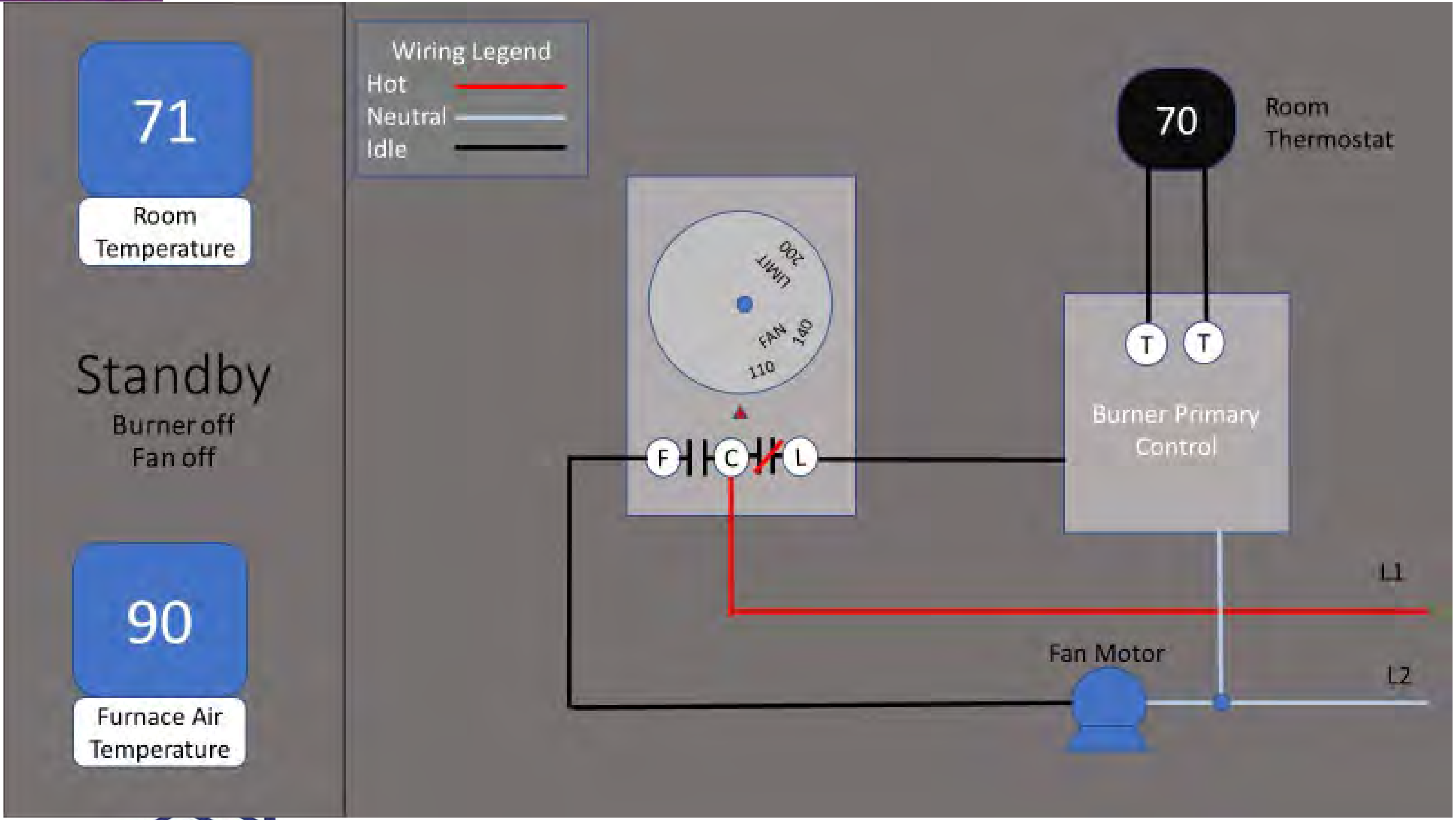
If Burner Shuts Off on High Limit

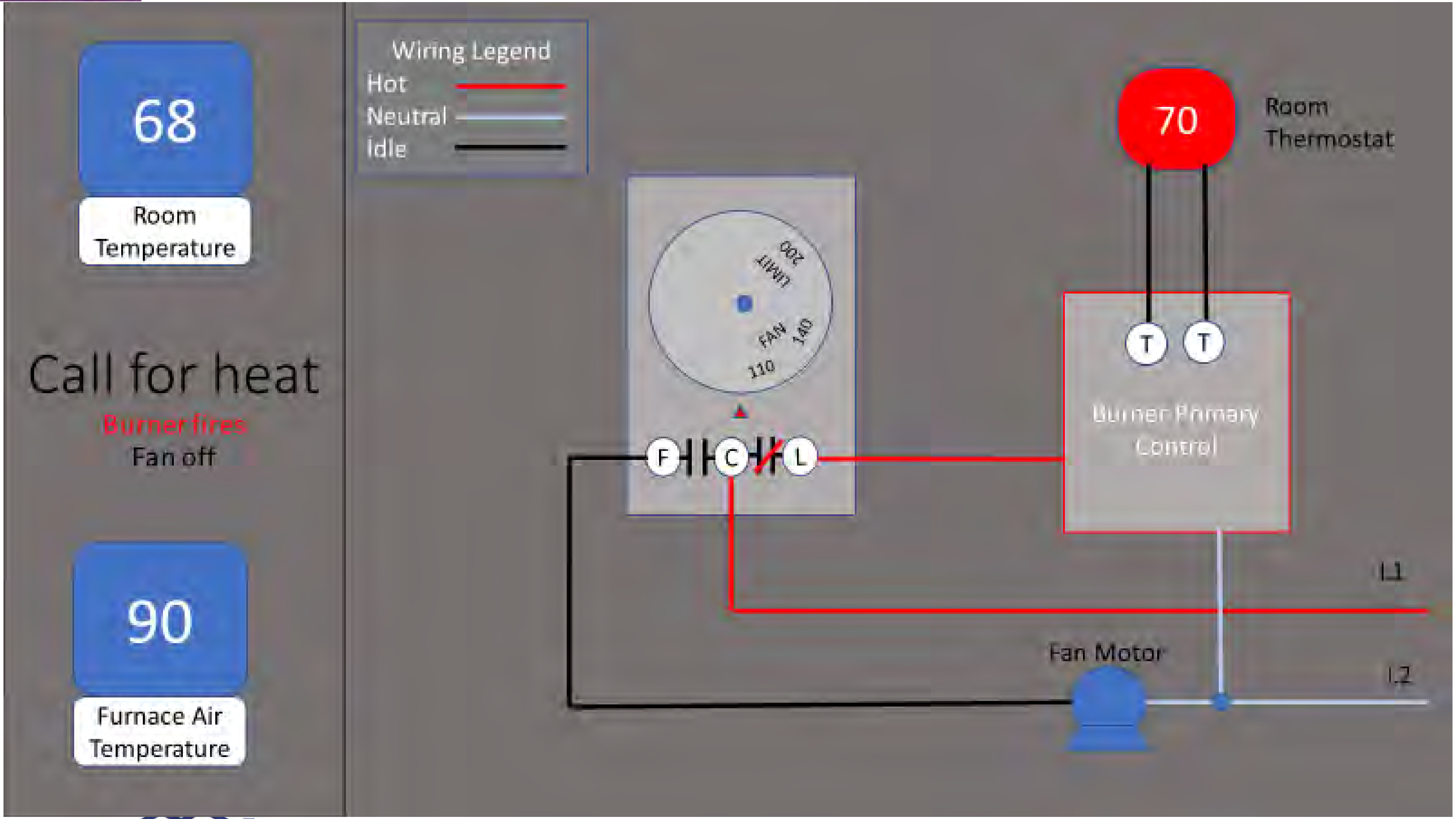
Check for:

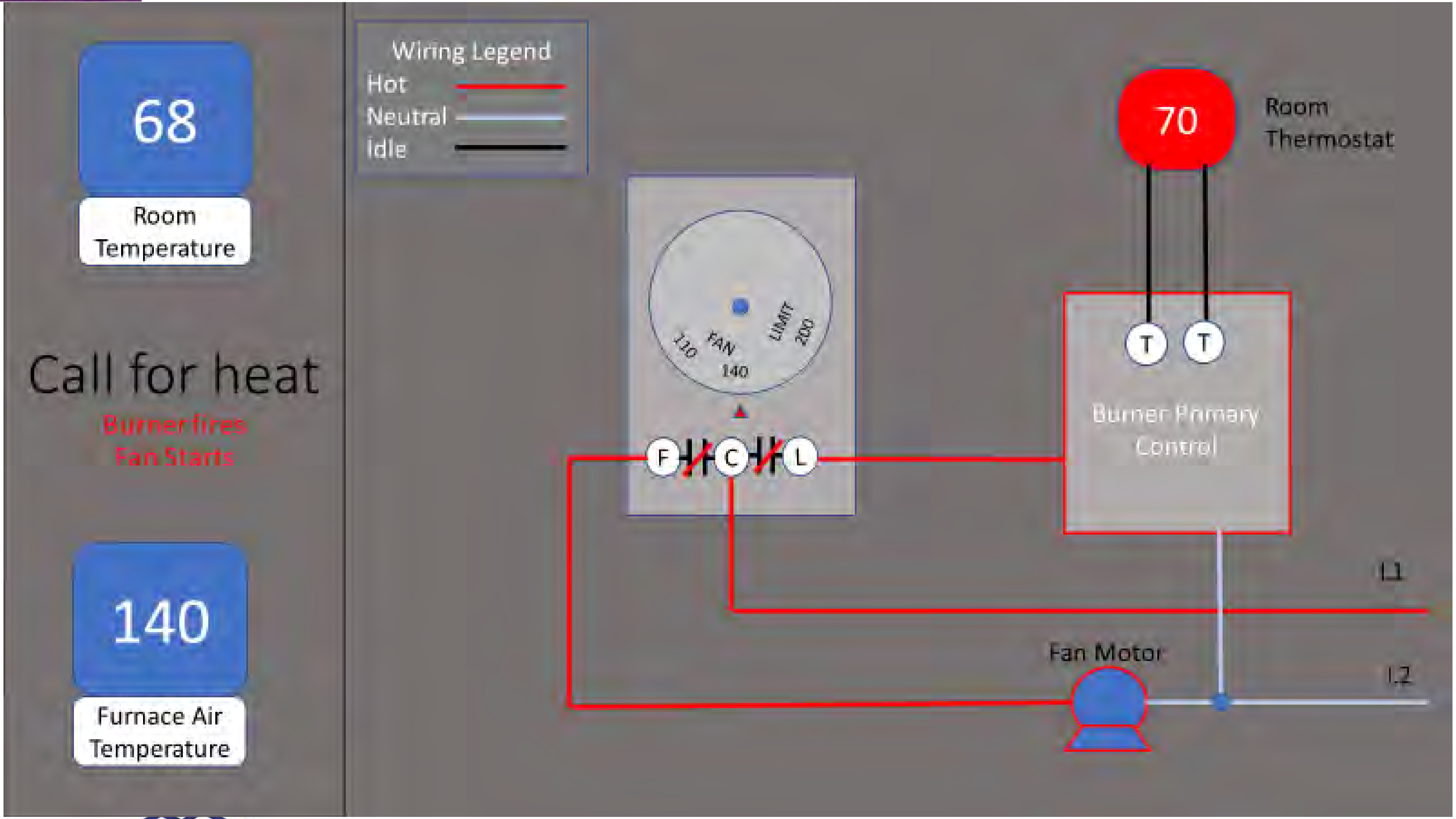
- Limited airflow - dirty filters, damaged ductwork, dirty fan
- Blower belt or motor problem
- Too many dampers closed
- Oversized furnace or undersized ductwork

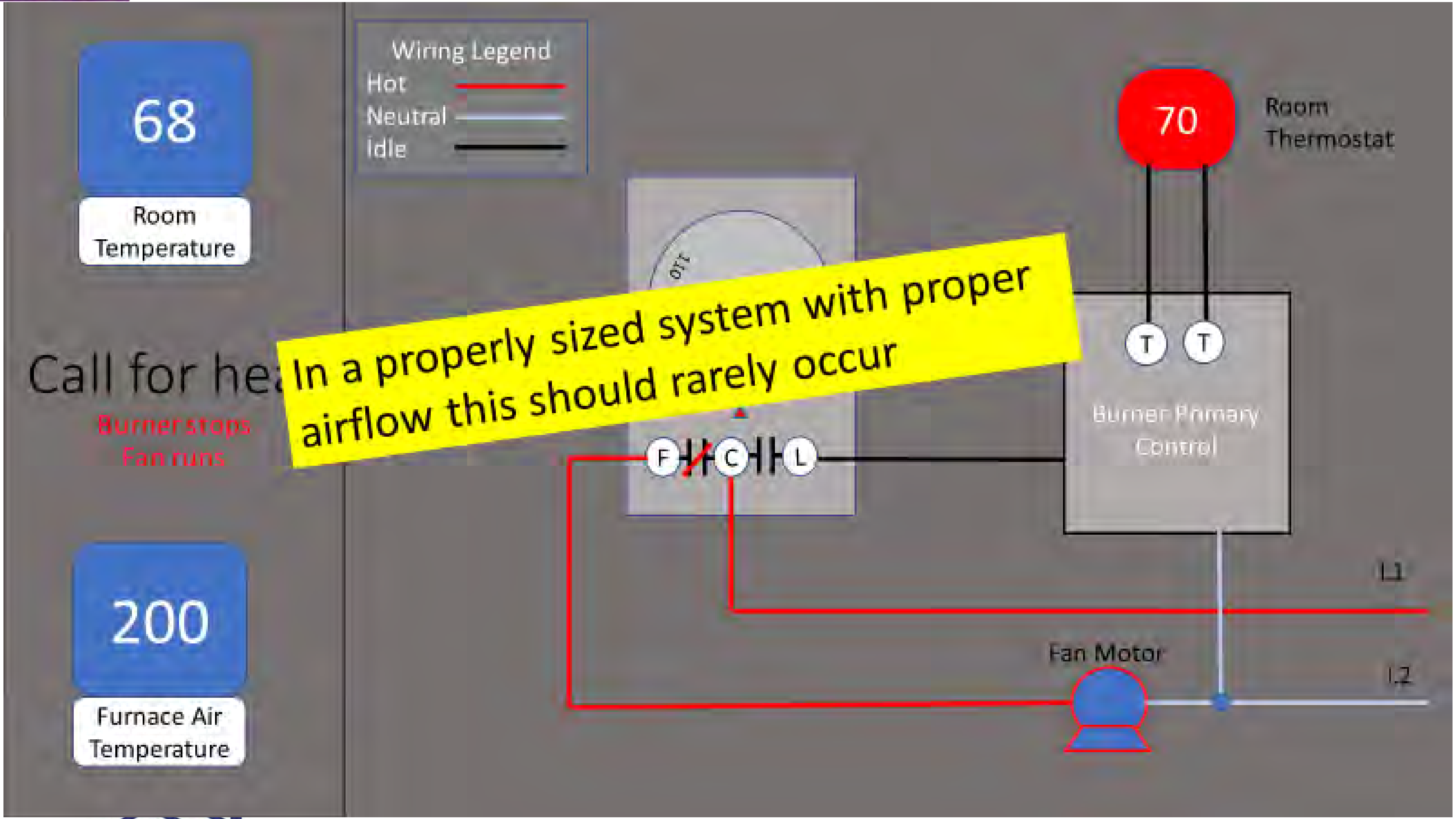
Demonstration

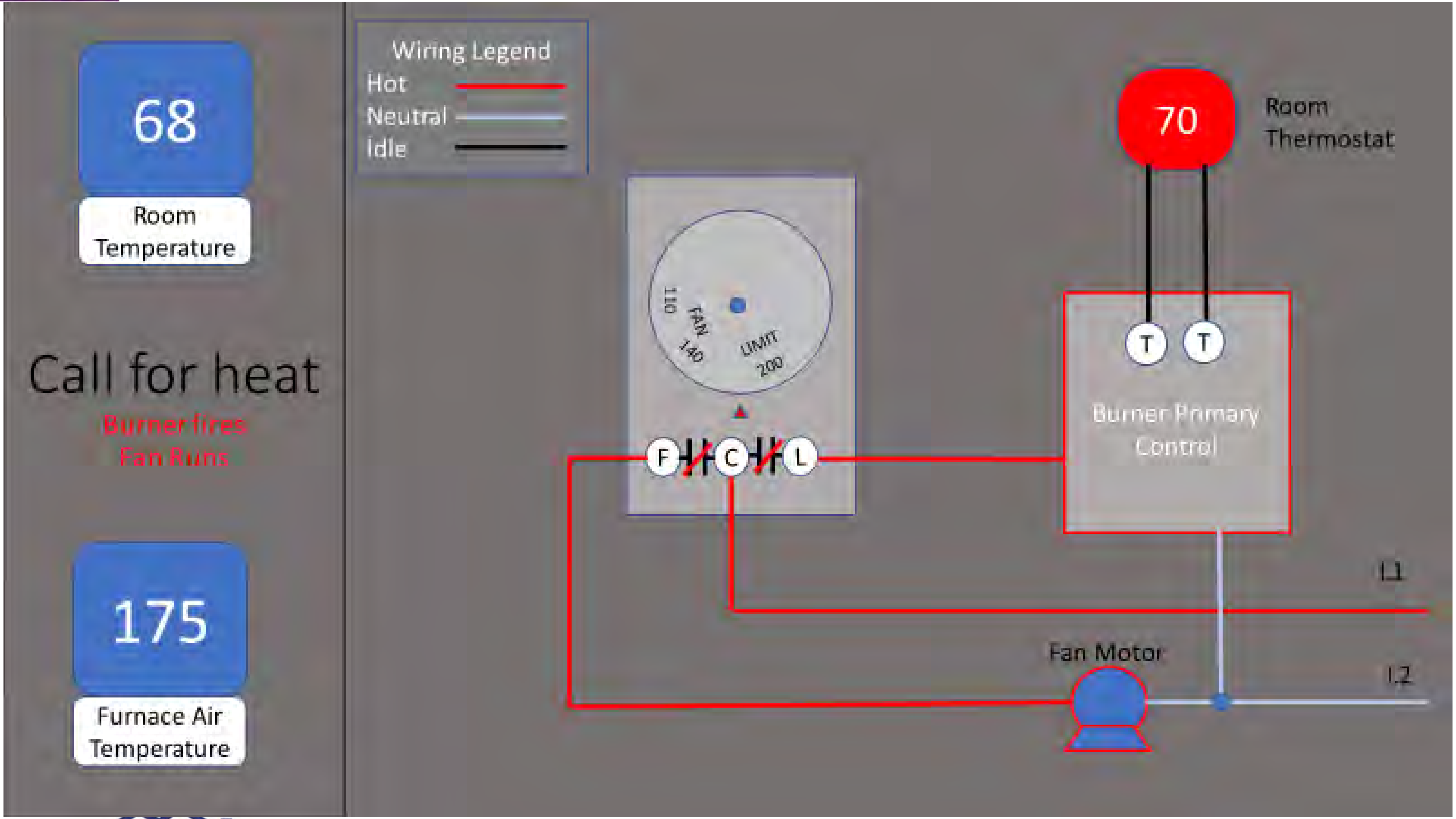
Fan / Limit Control

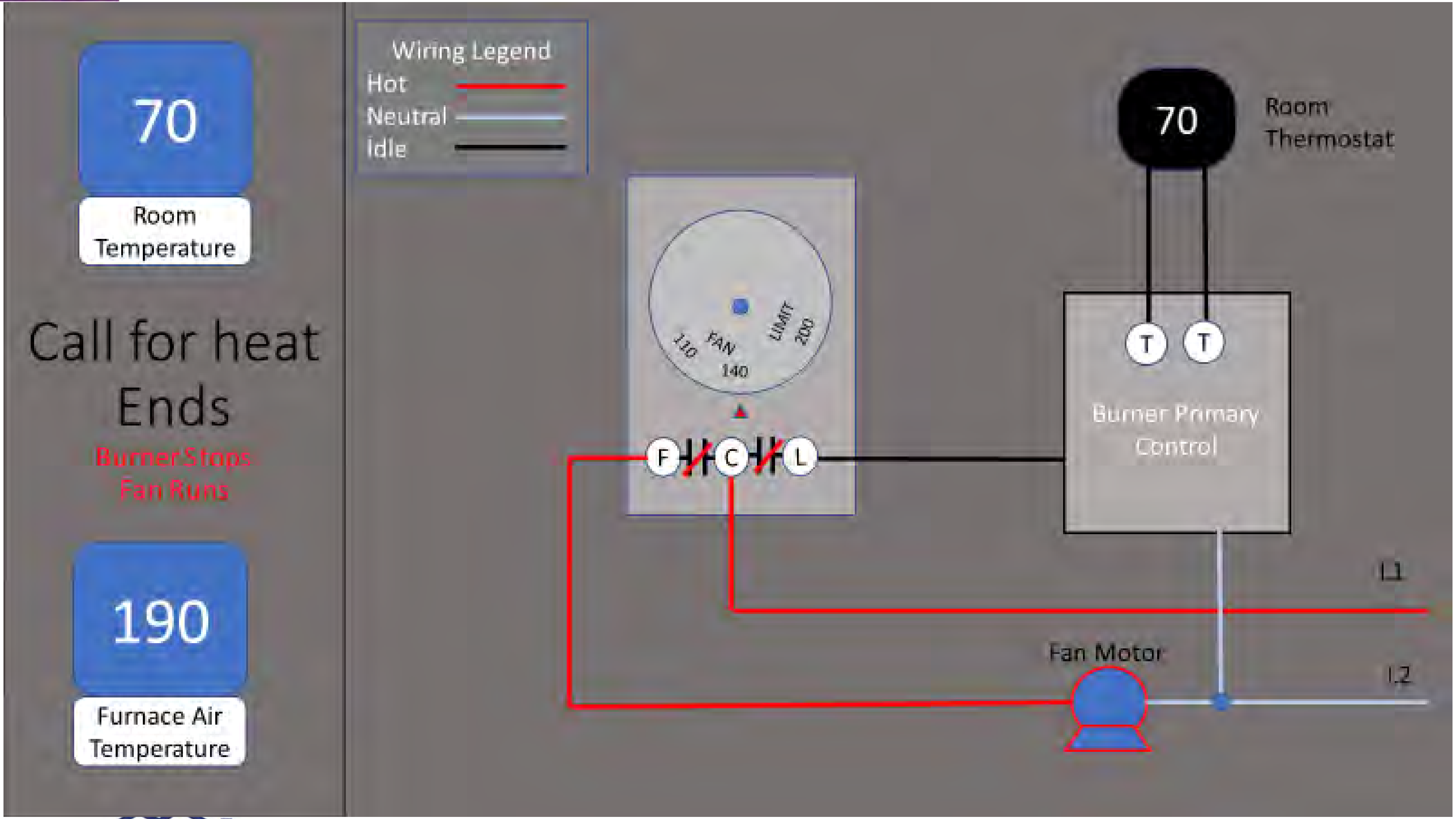

71
Room Temperature
Standby
Burner off
Fan off
90
Furnace Air Temperature
Wiring Legend
Hot
Neutral
Idle
LIMIT
200
FAN
140
110
F
C
L
70
Room Thermostat
T
T
Burner Primary Control
L1
Fan Motor
L2

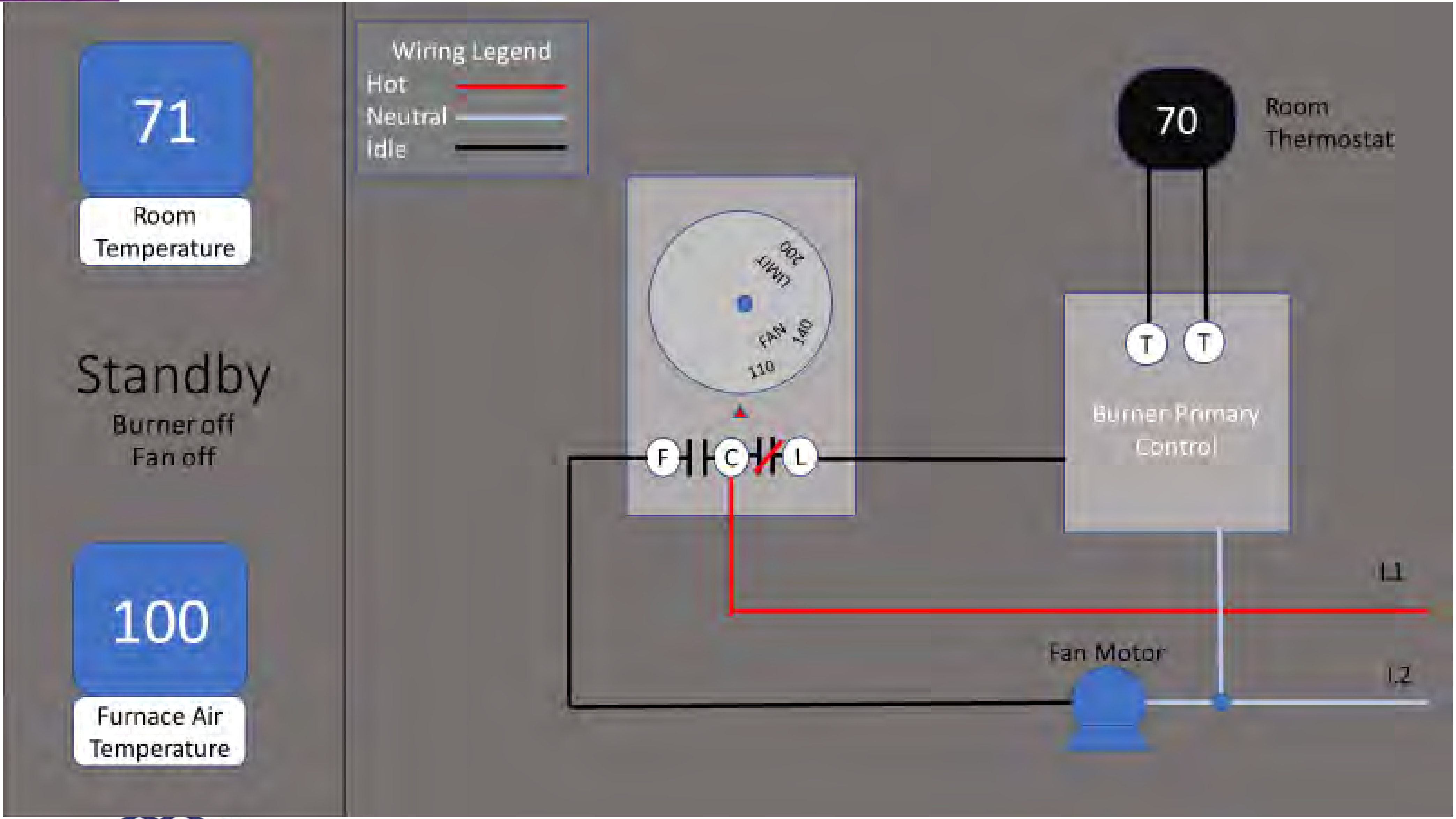

68
Room Temperature
Call for heat
Burner fires
Fan off
90
Furnace Air Temperature
Wiring Legend
Hot
Neutral
Idle
LIMIT 200
FAN 140
110
F
C
L
70
Room Thermostat
T
T
Burner Primary Control
L1
Fan Motor
L2


68
Room
Temperature
Call for heat
Burner fires
Fan Starts
140
Furnace Air
Temperature
Wiring Legend
Hot
Neutral
Idle
110
FAN
140
LIMIT
200
F
C
L
70
Room
Thermostat
T
T
Burner Primary
Control
L1
Fan Motor
L2


68
Room Temperature
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
110
Call for hea
In a properly sized system with proper airflow this should rarely occur
Burner stops
Fan runs
F
C
L
T
T
Burner Primary Control
L1
Fan Motor
L2
200
Furnace Air Temperature

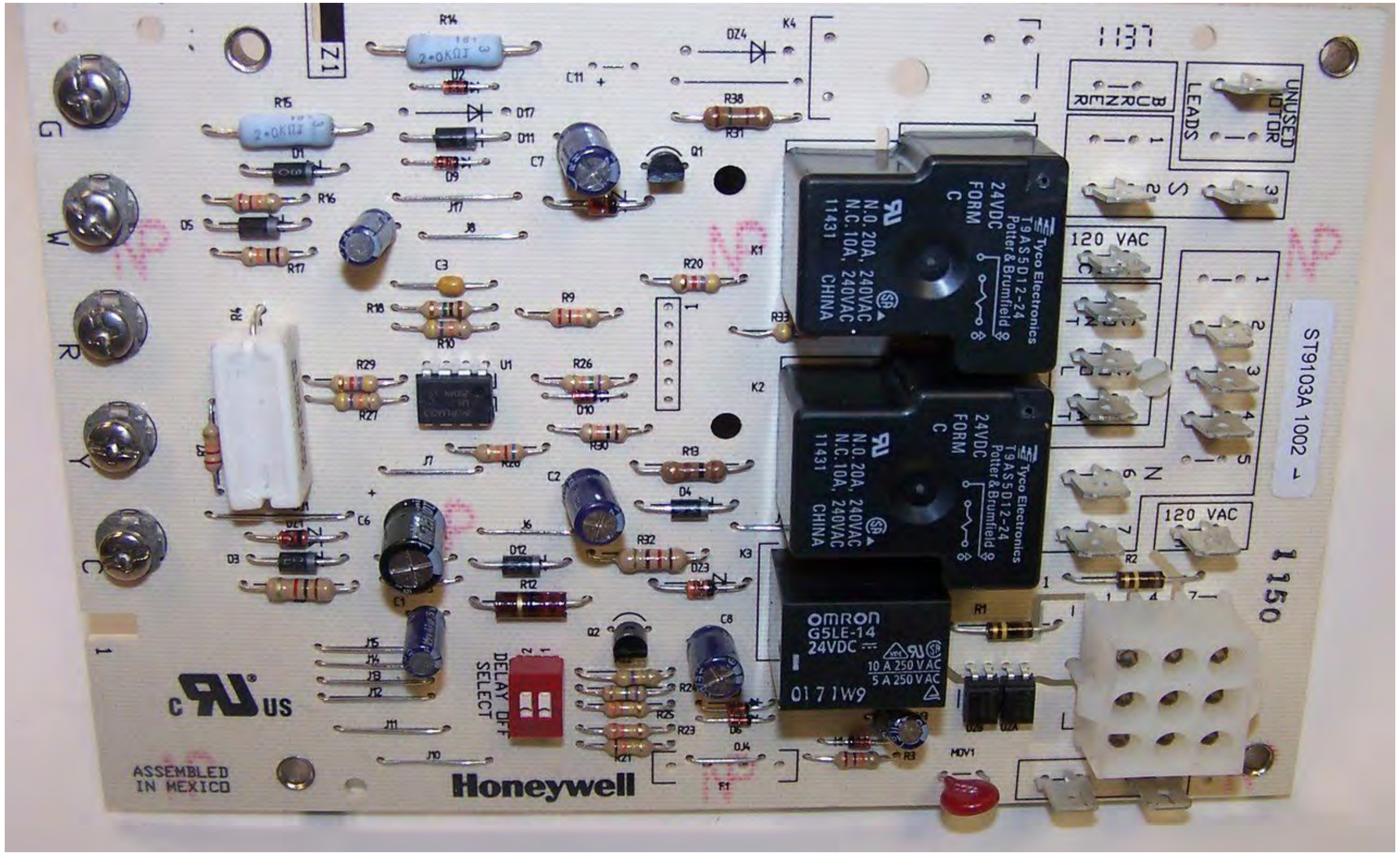

68
Room Temperature
Call for heat
Burner fires
Fan Runs
175
Furnace Air Temperature
Wiring Legend
Hot
Neutral
Idle
110
FAN
140
LIMIT
200
F
C
L
70
Room Thermostat
T
T
Burner Primary Control
L1
Fan Motor
L2


70
Room Temperature
Call for heat Ends
Burner Stops
Fan Runs
190
Furnace Air Temperature
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
LIMIT 200
FAN 140
110
T
T
Burner Primary Control
F
C
L
L1
Fan Motor
L2

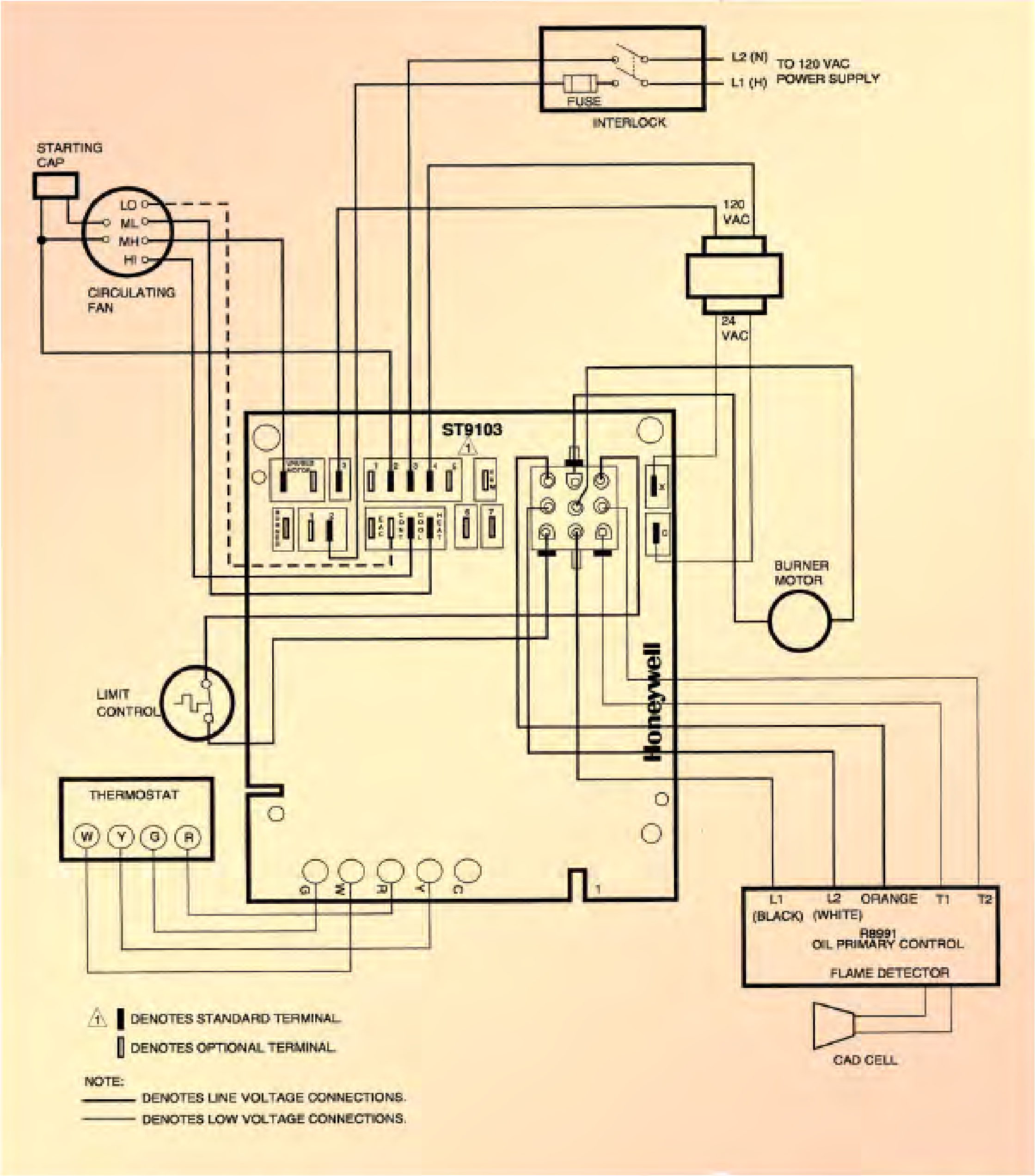

71
Room Temperature
Standby
Burner off
Fan off
100
Furnace Air Temperature
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
LIMIT 200
FAN 140
110
F
C
L
T
T
Burner Primary Control
L1
Fan Motor
L2

Warm Air Limit Controls

Electronic Furnace Control Board



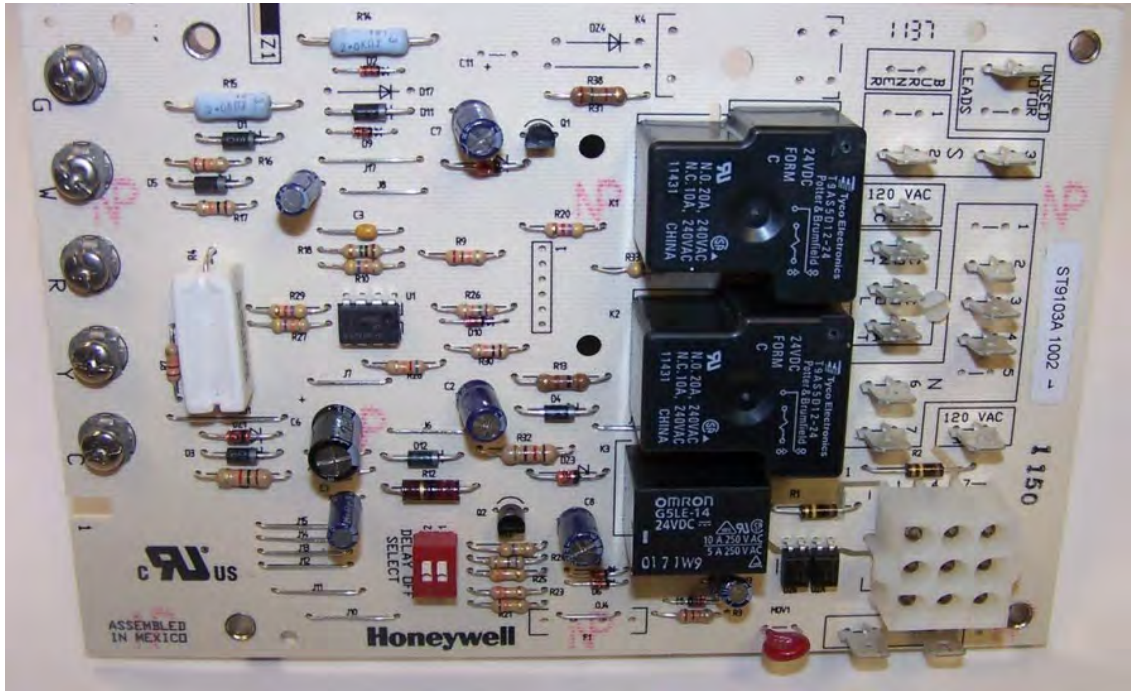
Electronic Furnace Control Board



Electronic Furnace Control Board

- Central wiring point for electronic components of furnace
- Integrates heating, A/C, humidification

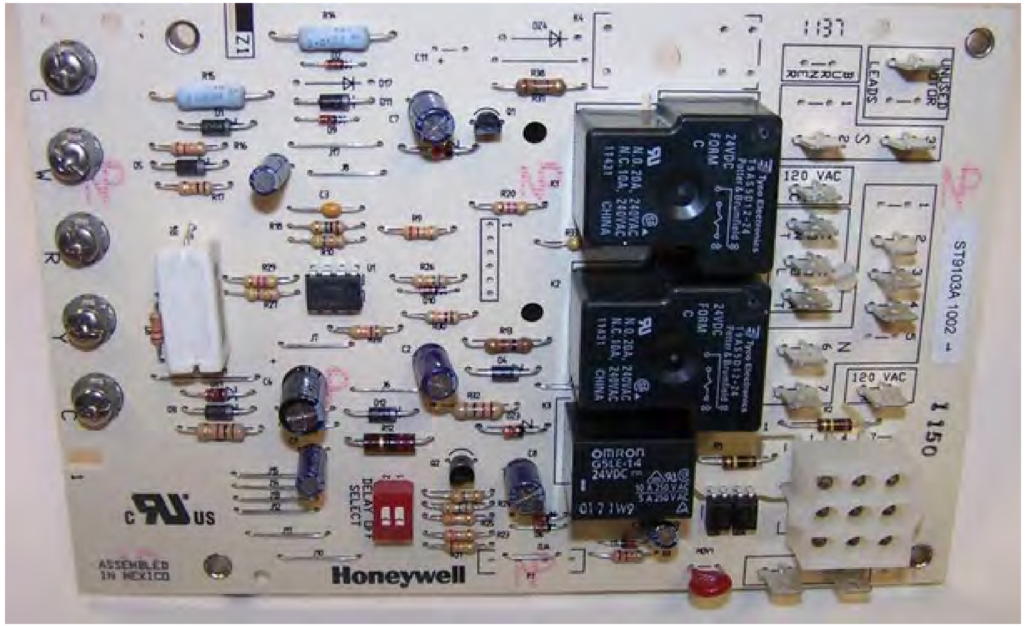
  and air cleaning in one control
- Monitors limit switch & energizes fan whenever limit switch opens……



Normal Operation

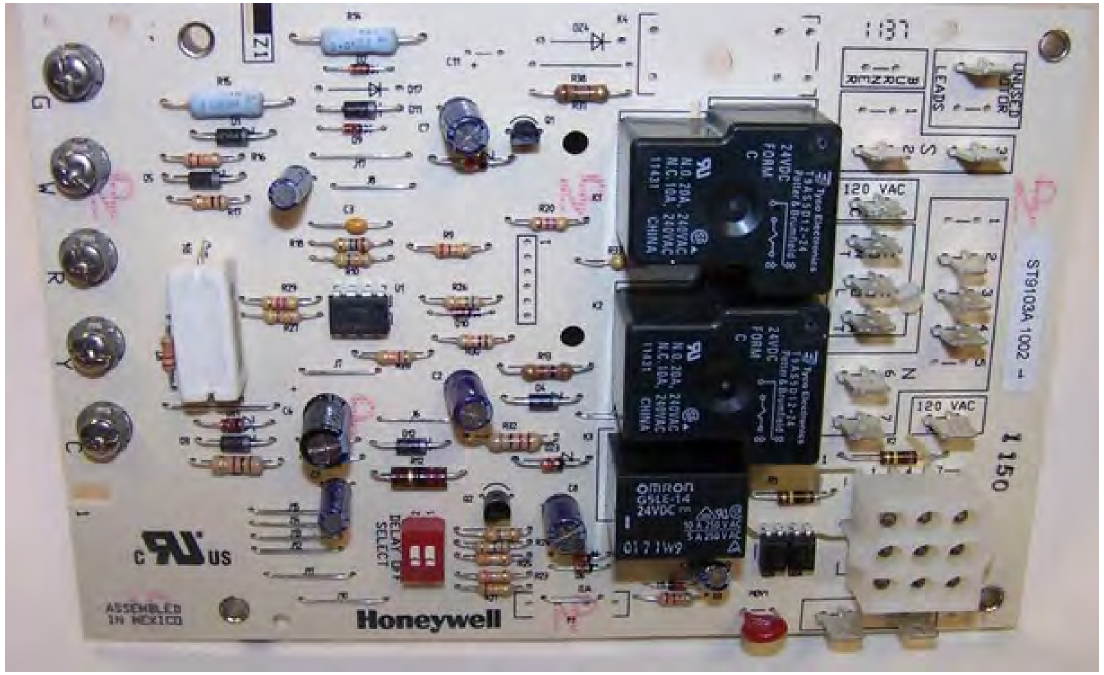
From Standby Mode – Furnace is Cold

1. **Thermostat calls for heat.**
(W terminal energized)
2. Primary control starts the burner.
3. Heat “fan on delay” timing begins.
4. When timing is complete, fan is energized, and warm air is delivered to the controlled space.



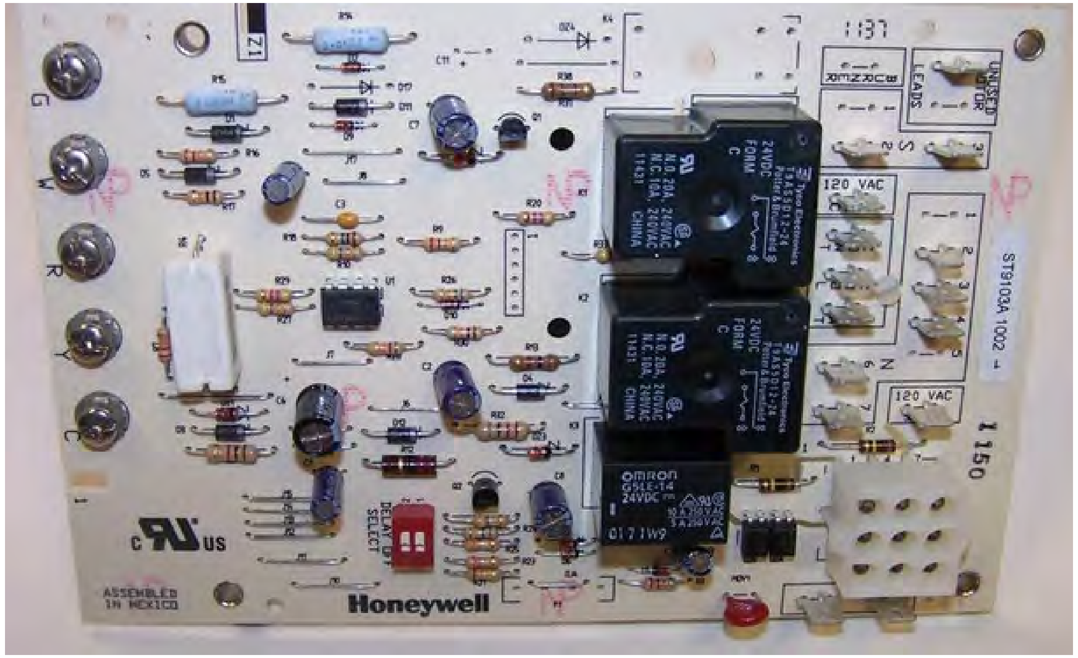
Normal Operation

1. **Thermostat ends calls for heat.** (W terminal de-energized)
2. Primary control stops the burner.
3. Heat “fan off delay” timing begins.
4. When timing is complete, fan is de-energized and control returns to standby mode.



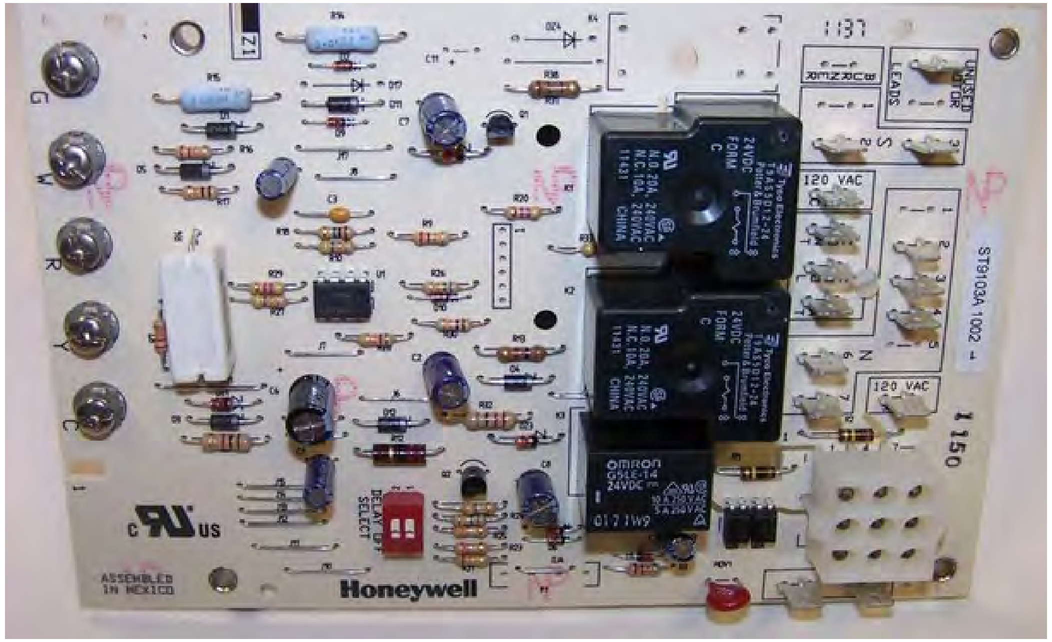
Normal Operation

1. **Limit switch opens.**
2. Primary control stops the burner.
3. Control opens primary controls T-T connection.
4. Fan is energized as long as limit stays open.



Normal Operation

1. **Limit switch closes.**
2. Control begins fan off delay sequence.
3. Fans shuts off after delay timing.
4. Control recloses primary control T-T connections.
5. Primary control restarts burner.



Normal Operation

If electronic air cleaner (EAC) is connected:

- EAC connections are energized when the heat or cool speed of the fan is energized.
- EAC connections are NOT energized when continuous fan terminal is energized.

Normal Operation

If a humidifier is connected:

- Connections are energized when the burner motor is energized.

Steam System Limit Controls

Pressuretrols

Pressuretrols

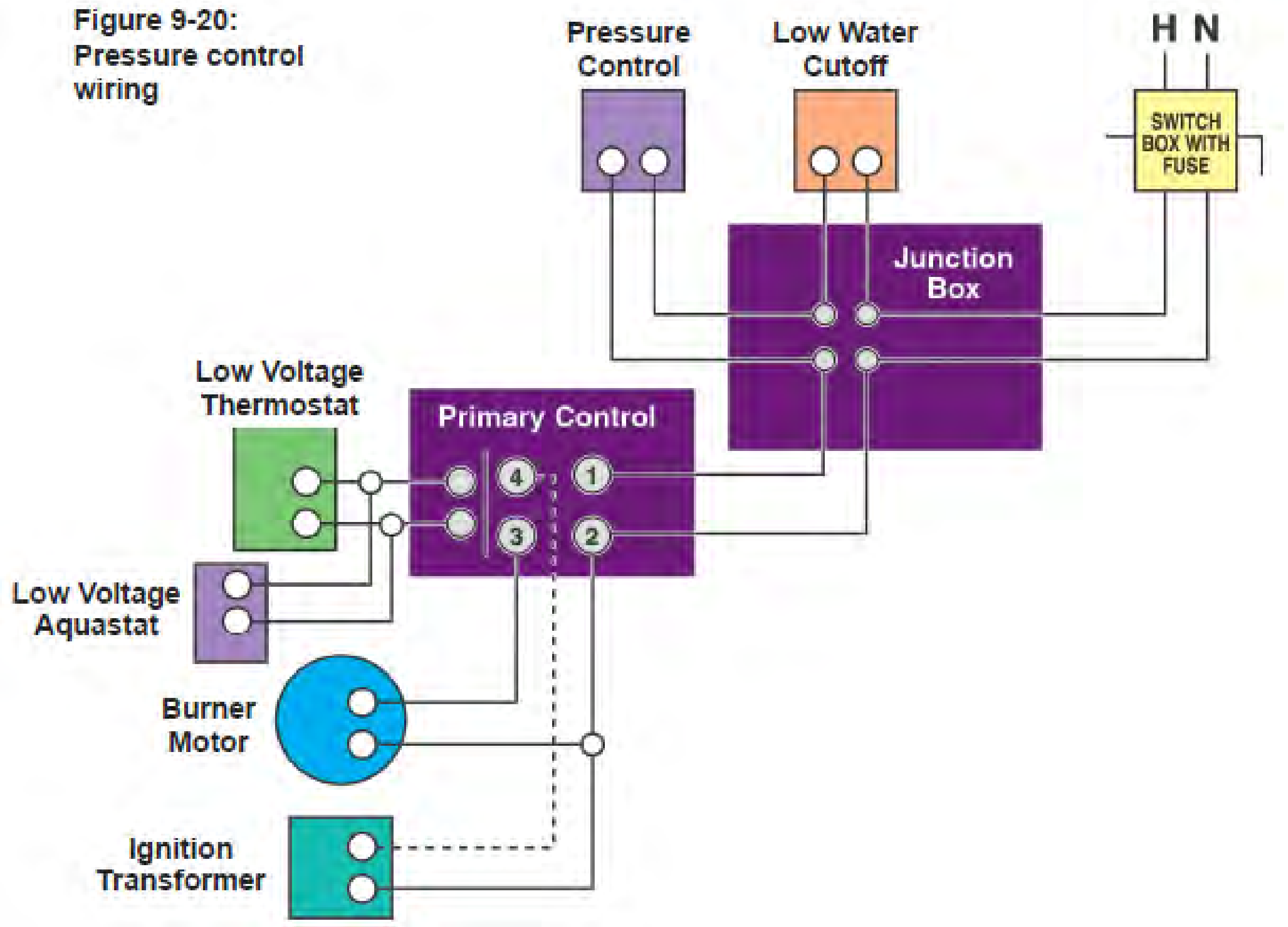
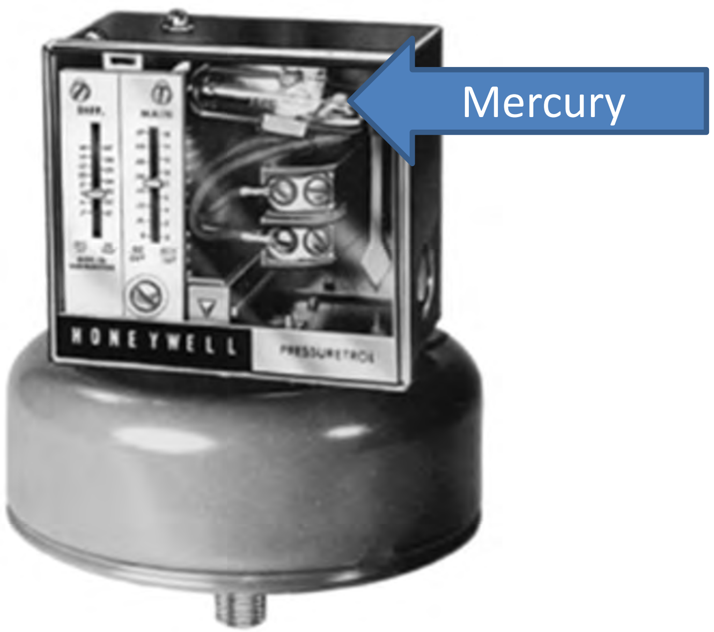


Figure 9-20: Pressure control wiring

Pressuretrols

- Respond to changes in steam pressure
- Contacts can be metal or mercury tubes
- Mercury tube controls MUST be level

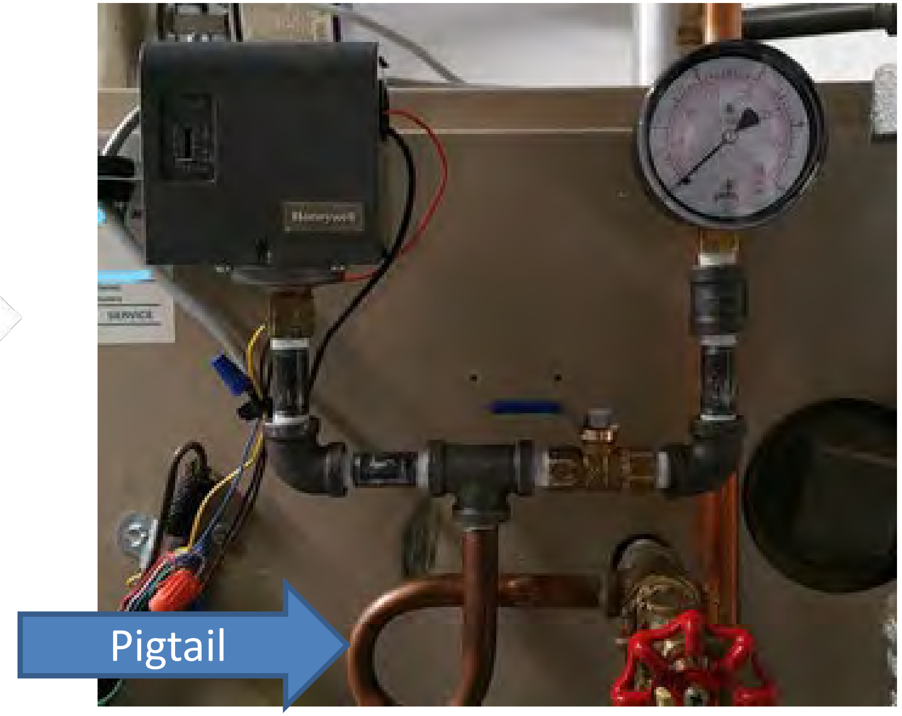


Vaporstats

- Some systems operate on very low pressure
- Vaporstats are more sensitive than pressuretrols
- Operate on ounces instead of pounds

Pressuretrol Installation

ALWAYS installed above the boilers waterline.



A siphon loop (pigtail) MUST be installed between the control and the boiler to prevent steam from damaging the control.

Pressuretrol Installation

ALWAYS installed above the boilers waterline.

A siphon loop (pigtail) MUST be installed between the control and the boiler to prevent steam from damaging the control.

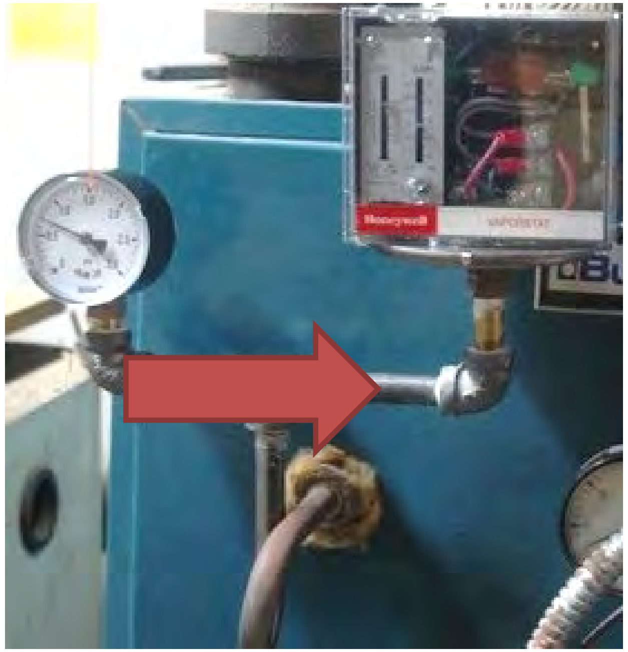
Pressuretrol Installation

Must be installed in either:

- A fitting provided by the boiler manufacturer

Or

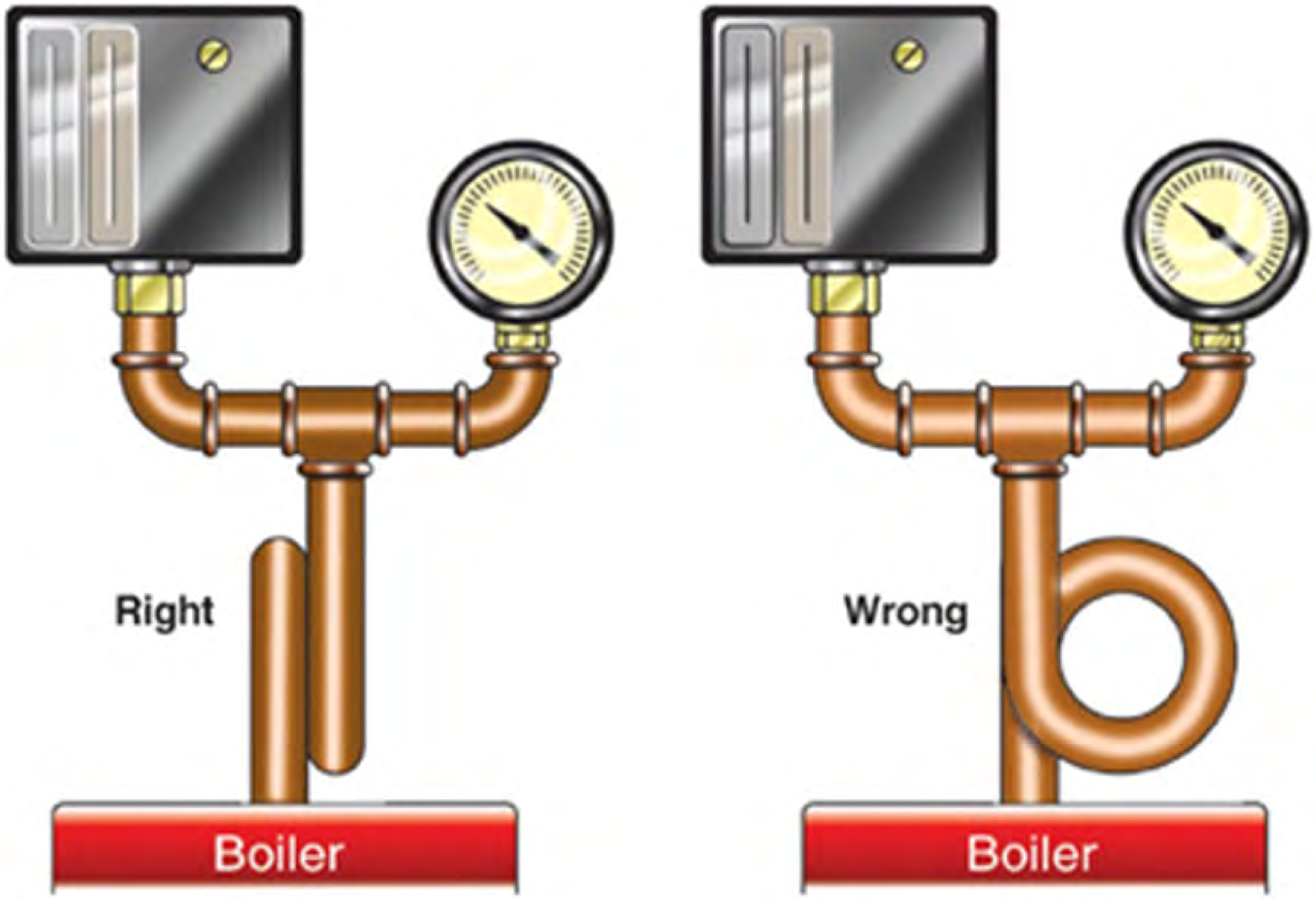
- The mounting provided in the low water cut-off



Mounting

Pigtails tend to expand when heated, so mercury tube pressuretrols MUST be mounted so the face of the control is perpendicular to the pigtail.

Why?



Settings

- The control has a setting and a differential
- Residential systems never require more than 2 psi
- Setting can be "cut-out" or "cut-in"
- Differential can be additive or subtractive

Cut-in VS Cut-out

Cut-in

Pressure at which the burner will start.

Cut-out

Pressure at which the burner will shut off.

Differential

Cut-in

- Additive – cut in set at 1 PSI, differential set at 2 PSI.
- The cut out point is???

Cut-out

- Subtractive – cut out set @ 3 PSI and the differential is set @ 2 PSI.
- The cut in point is???

Differential

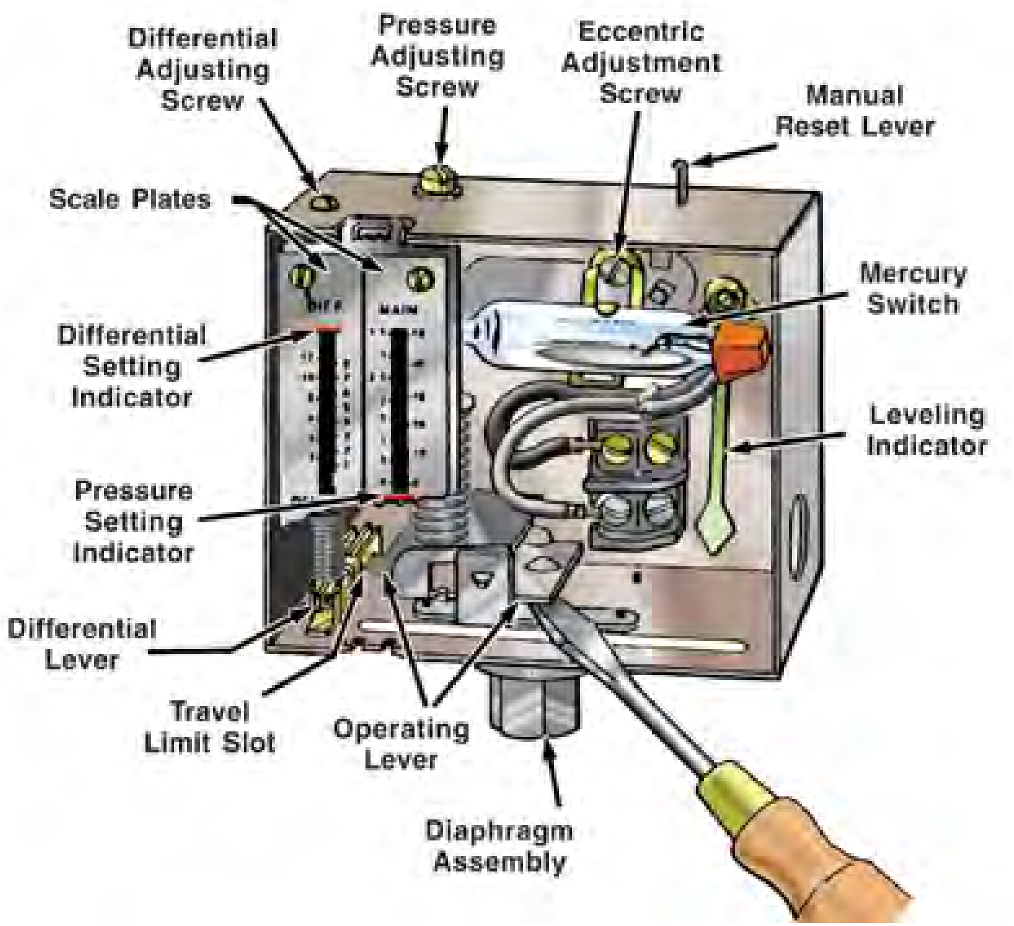
Cut -in

- Additive – cut in set at 1 PSI, differential set at 2 PSI.
- The cut out point is 3 PSI.

Cut-out

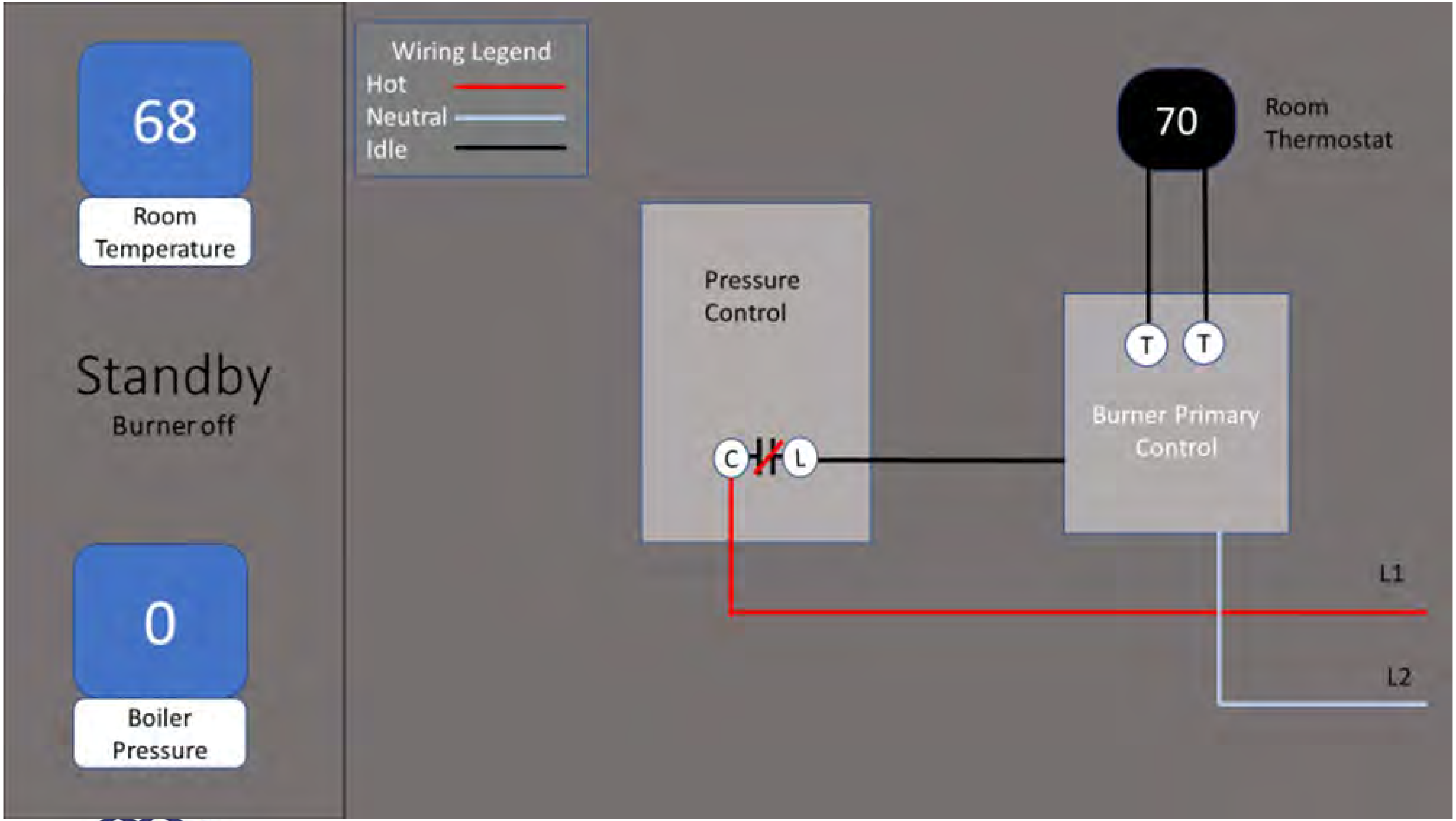
- Subtractive – cut out set @ 3 PSI and the differential is set @ 2 PSI.
- The cut in point is 1 PSI.

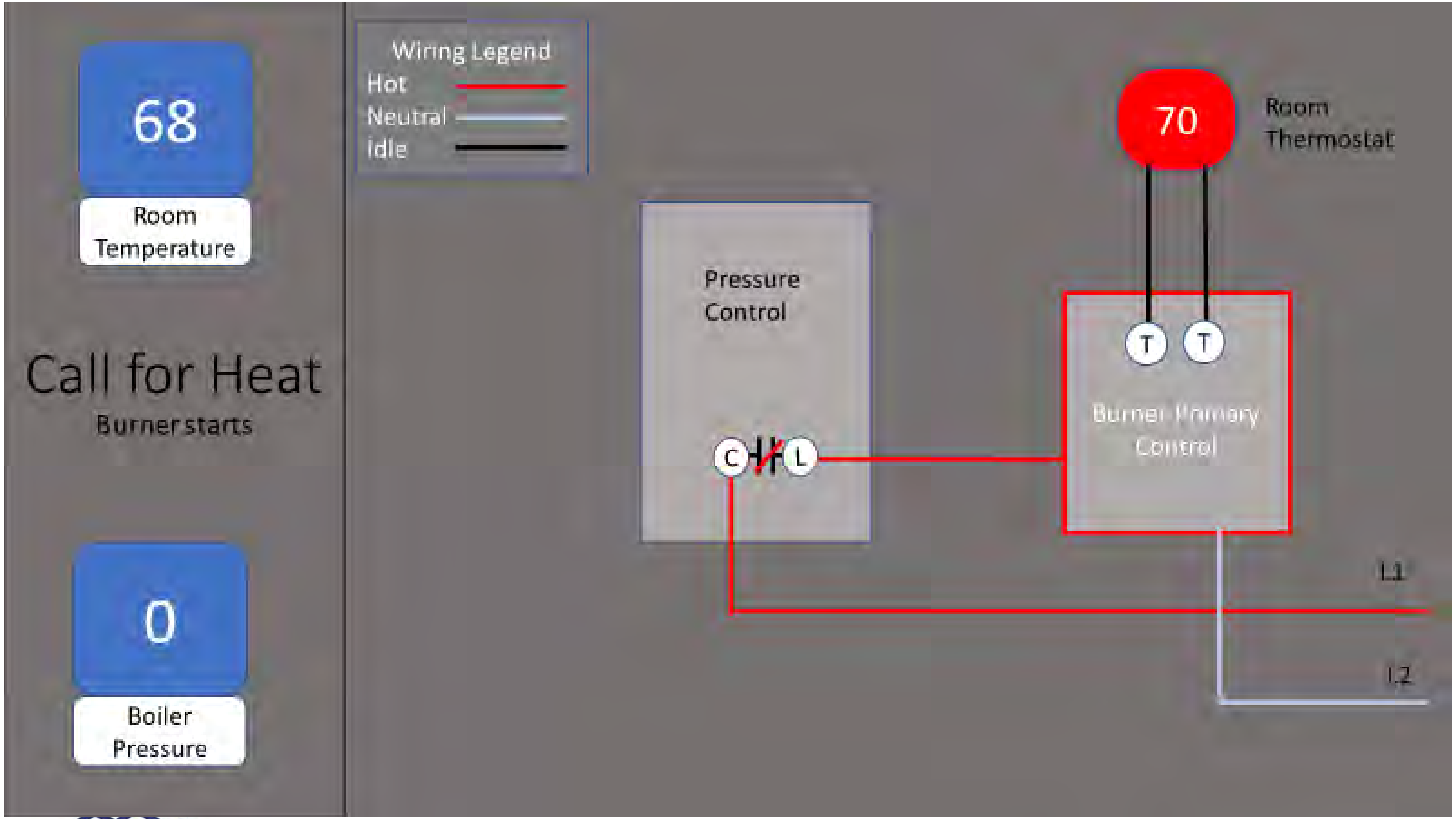
Differential Adjustment

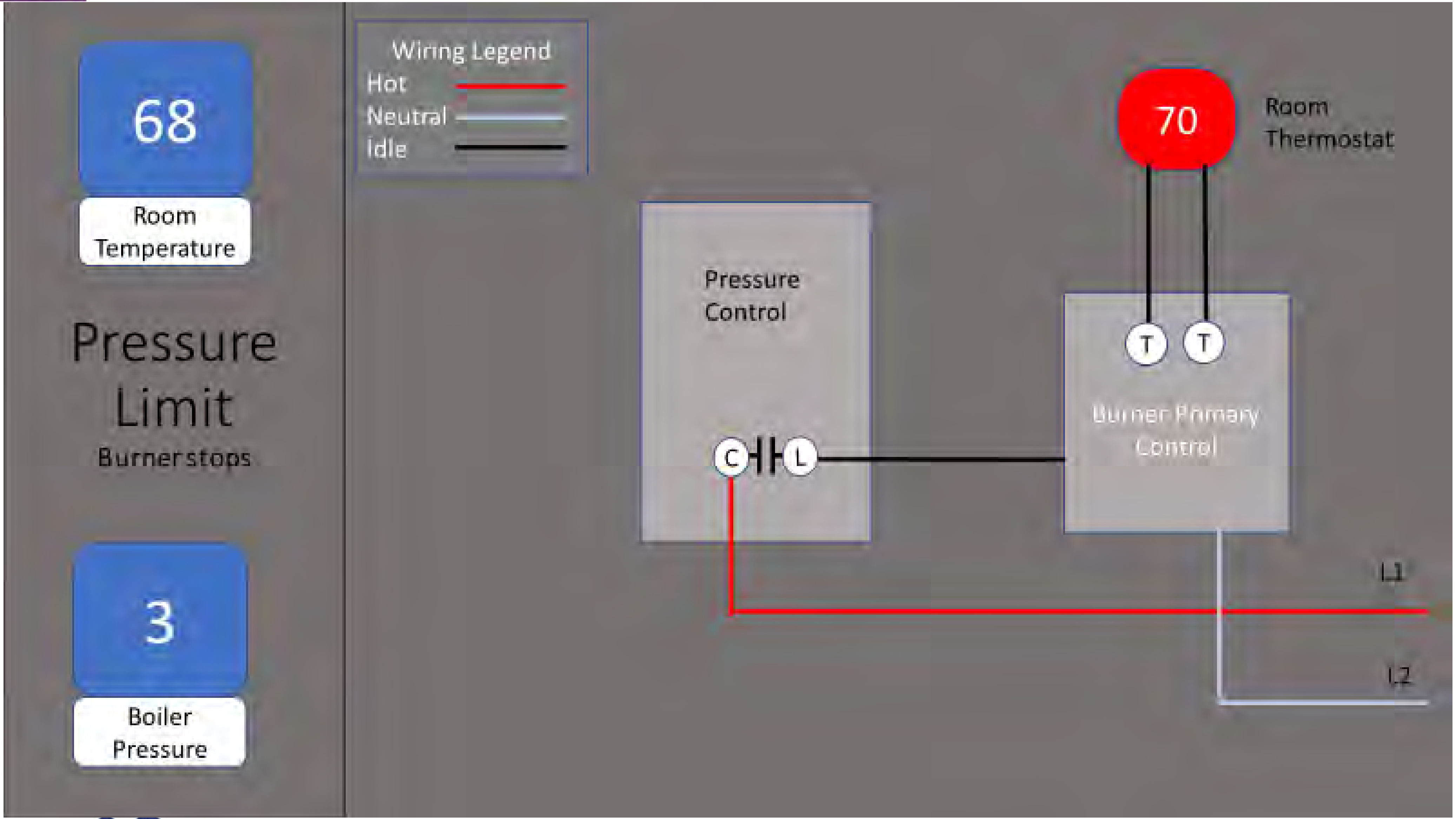


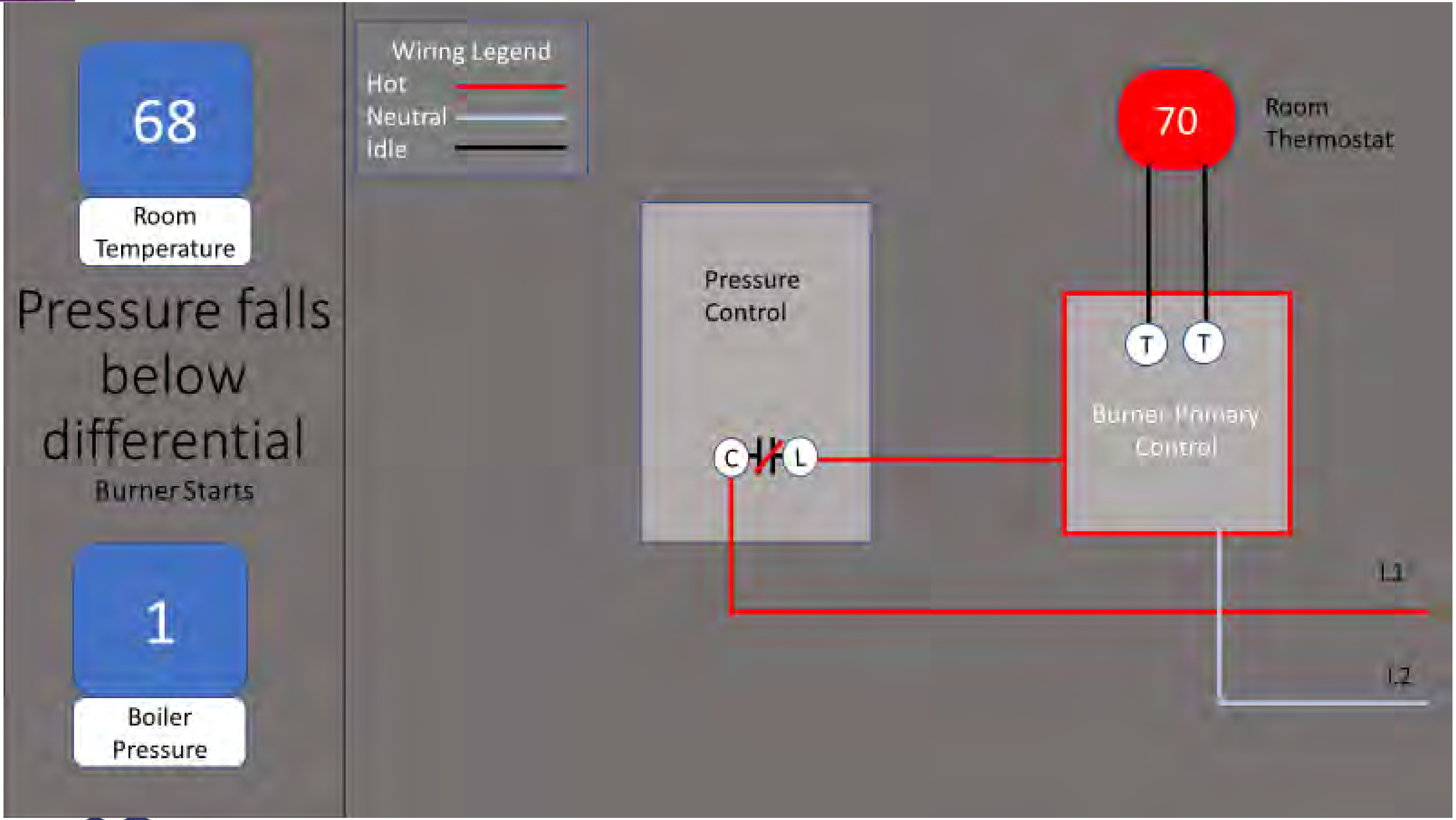
Demonstration

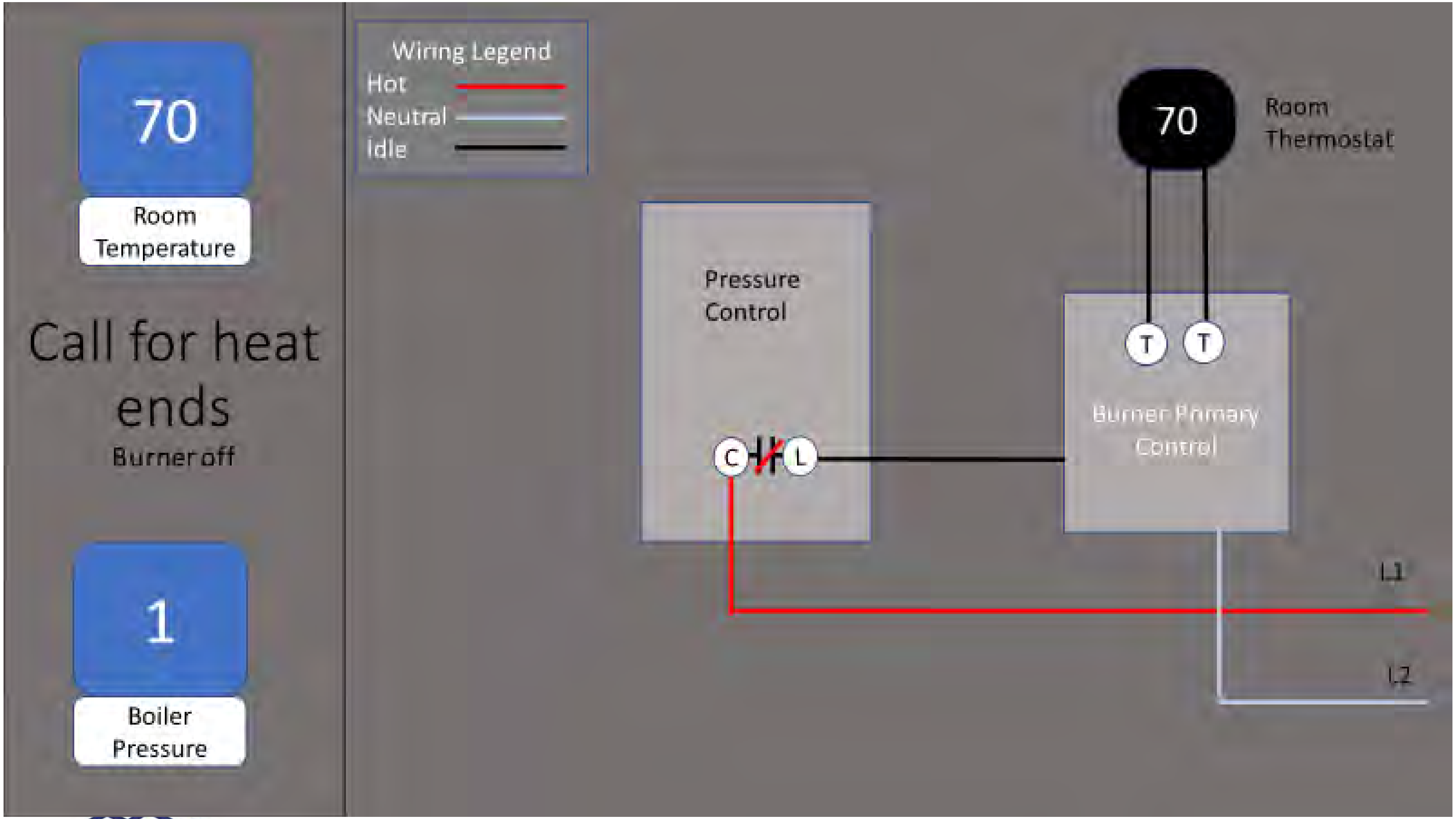
Pressuretrol


68
Room Temperature
Standby
Burner off
0
Boiler Pressure
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
Pressure Control
C
L
T
T
Burner Primary Control
L1
L2


68
Room Temperature
Call for Heat
Burnerstarts
0
Boiler Pressure
Wiring Legend
Hot
Neutral
Idle
Pressure Control
C
L
70
Room Thermostat
T
T
Burner Primary Control
L1
L2

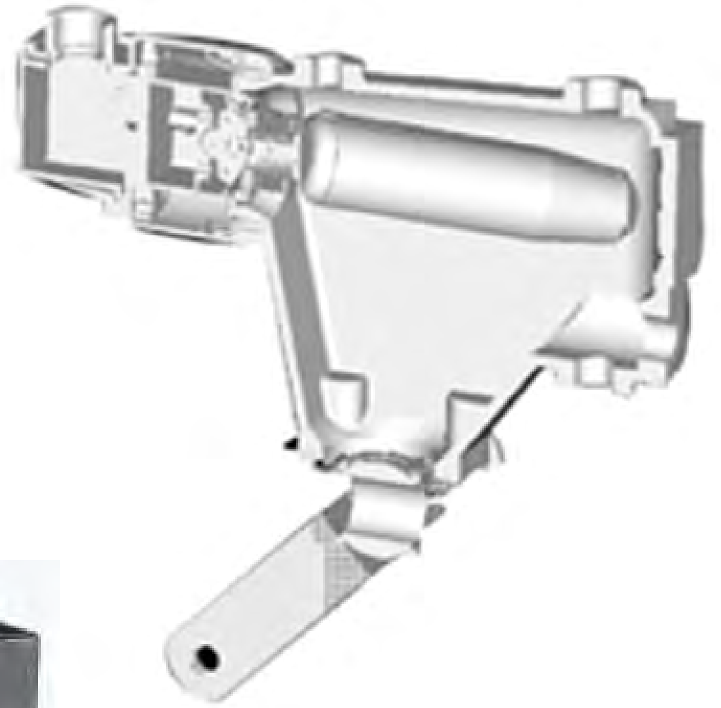

68
Room Temperature
Pressure Limit
Burnerstops
3
Boiler Pressure
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
Pressure Control
C
L
T
T
Burner Primary Control
L1
L2


68
Room Temperature
Pressure falls below differential
Burner Starts
1
Boiler Pressure
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
Pressure Control
C
L
T
T
Burner Primary Control
L1
L2


70
Room Temperature
Call for heat ends
Burner off
1
Boiler Pressure
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
Pressure Control
C
L
T
T
Burner Primary Control
L1
L2

Steam Limit Controls
Low Water Cut-offs (LWCO)

LWCO



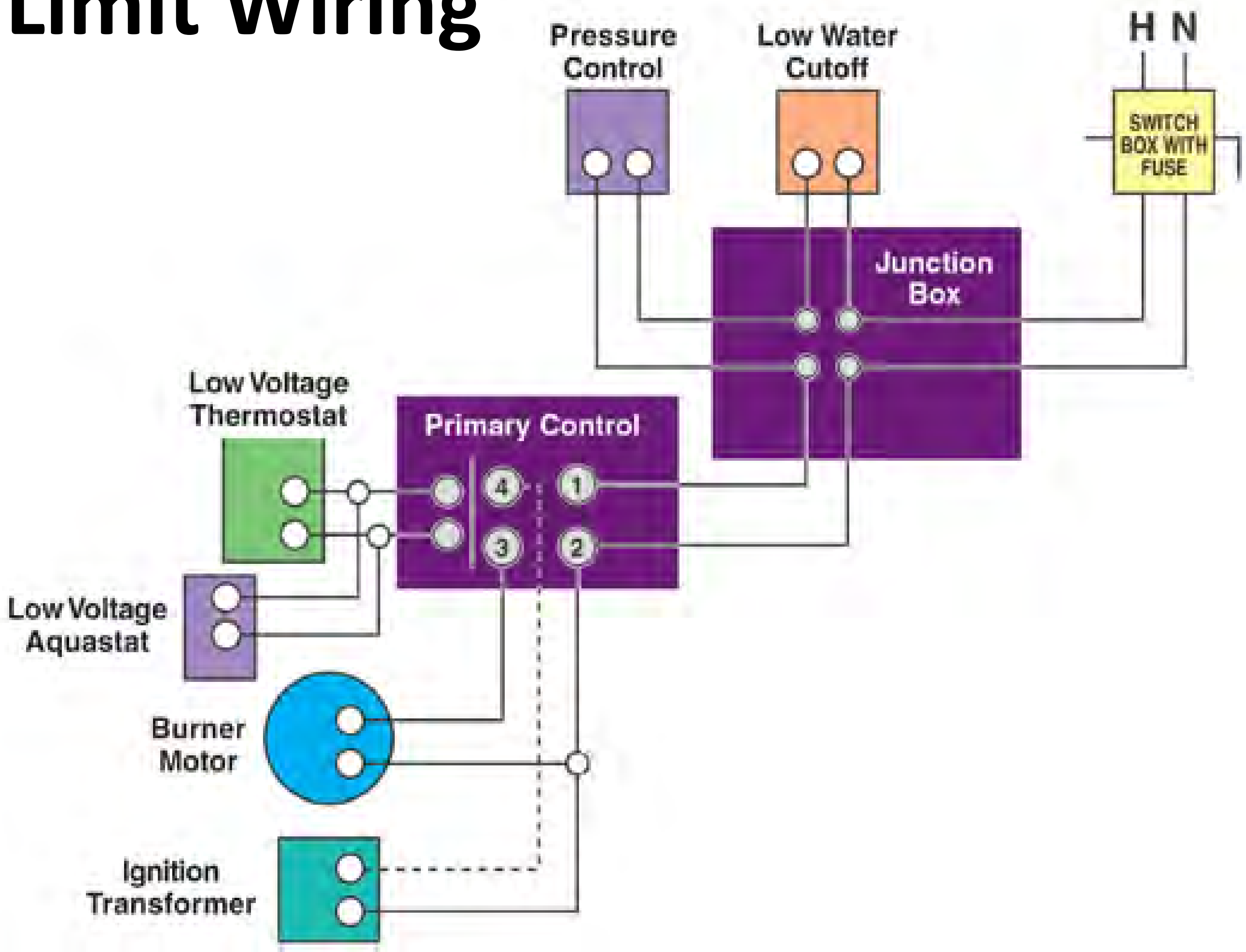
- Prevents the burner from operating if the water level in the boiler is too low
- **<u>Float types</u>** have a spst switch connected to a float, when the water level drops the float also drops and opens the switch

LWCO

<u>Probe types</u> send a low voltage signal through the water to ground on the boiler's metal.

Many have timing devices to prevent nuisance shutdowns due to surging.

Steam Limit Wiring



Automatic Water Feeders

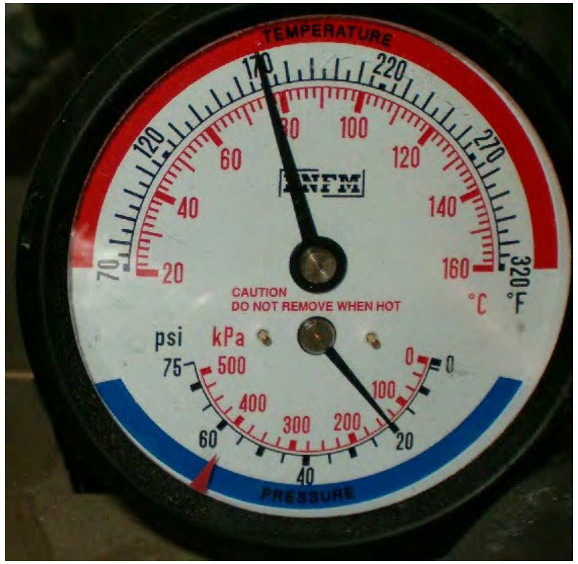
LWCOs can be incorporated with, or wired to, electric water feeders that add water to the system when the LWCO senses a low water condition.

Hydronic Limit Controls: Aquastats

Aquastats

Automatic switches that control the temperature of boiler water & domestic hot water.

Some are “direct acting” others are “reverse acting.”



Direct Acting VS Reverse Acting

Direct Acting Control (A)

- Closes its contacts, completing the circuit, on a drop in temperature
- Opens its contacts on a rise in temperature

Reverse Acting Control (B)

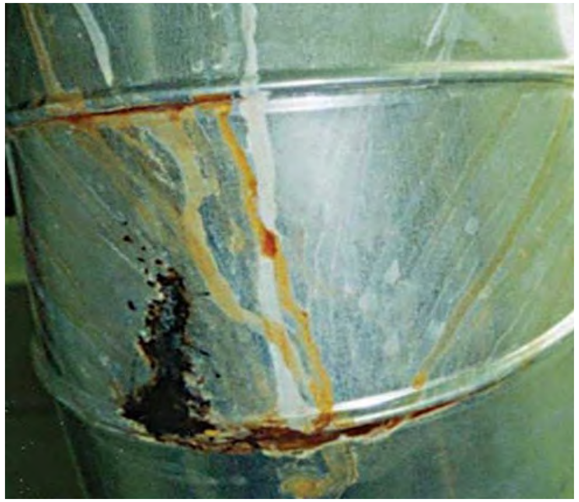
- Closes its contacts on a rise in temperature
- Opens its contacts on a drop in temperature

Reverse Acting Aquastats – Why?

When there's a call for heat while someone is showering, a circulator can send hot water to heat emitters, then cold water returns to the boiler and boiler temperature drops below what's needed for DHW.

They also prevent flue gas condensation in high efficiency boilers.

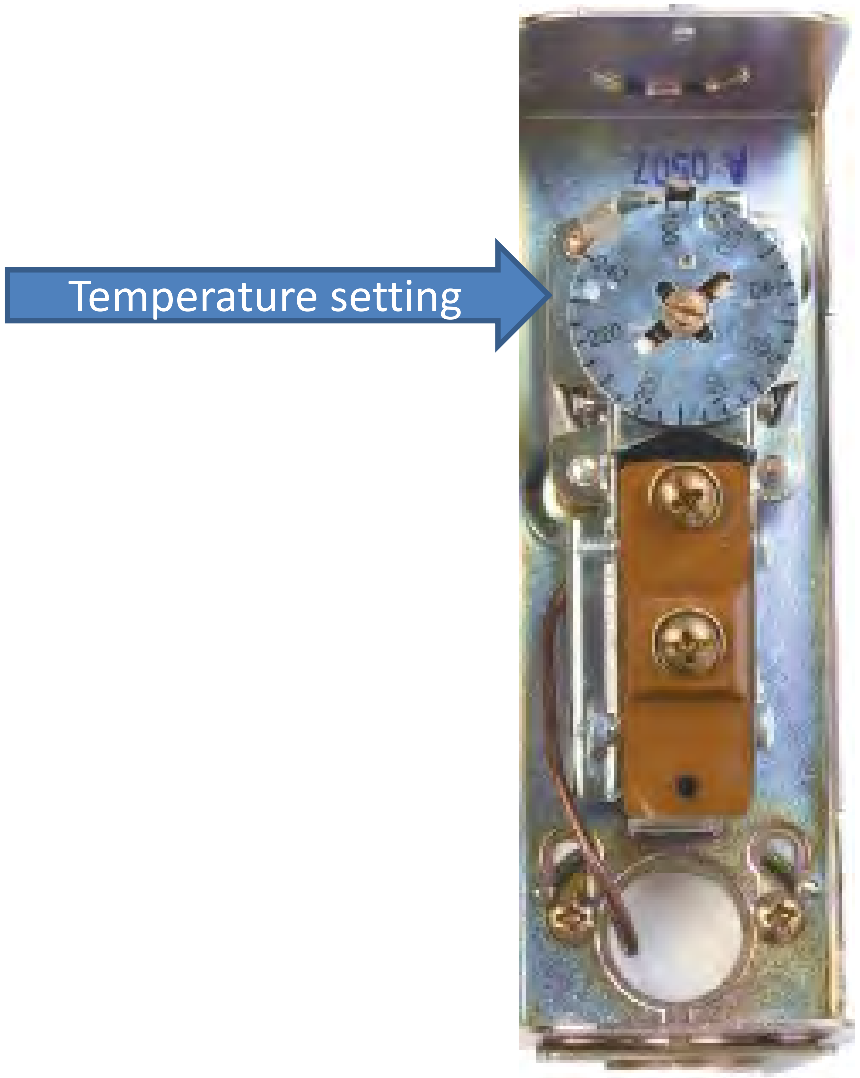
Condensation leads to sulfuric acid & scale buildup in heat exchangers.



Aquastat Functions

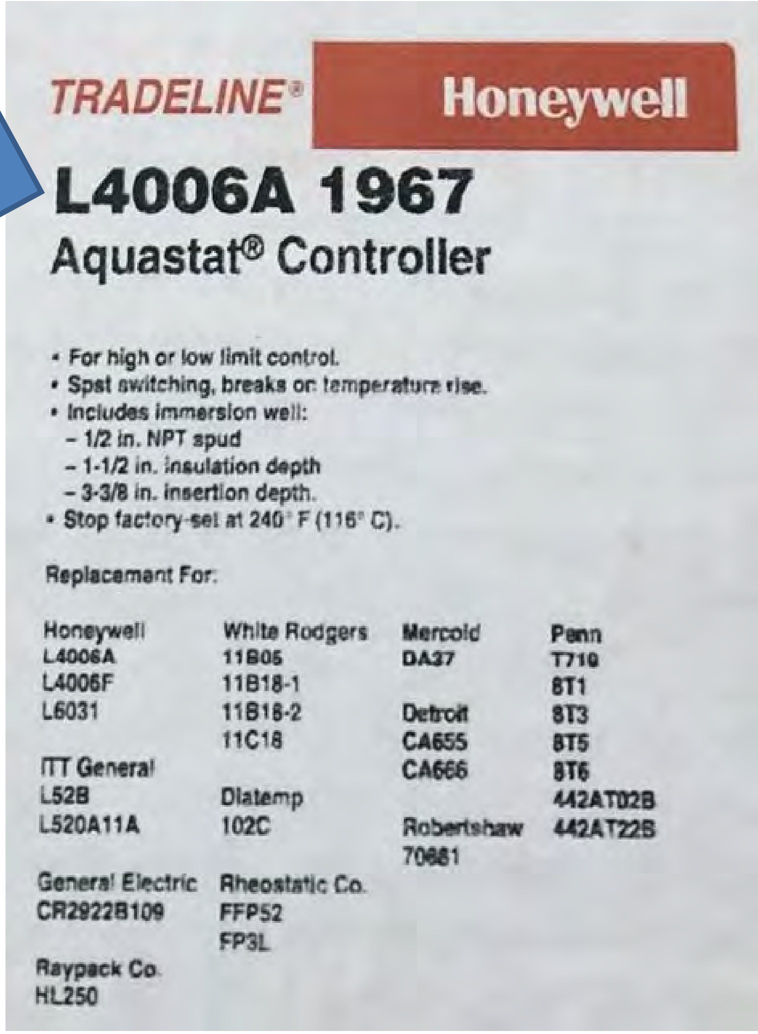
High limit & operating controls (SPST direct acting) break on temperature rise and make on temperature fall.

They cycle the burner on & off based on boiler water temperature.



Aquastat Functions

"A" means high limit, direct acting
"B" means Reverse acting



Reverse acting controls (SPST reverse acting) make on temperature rise and break on fall.

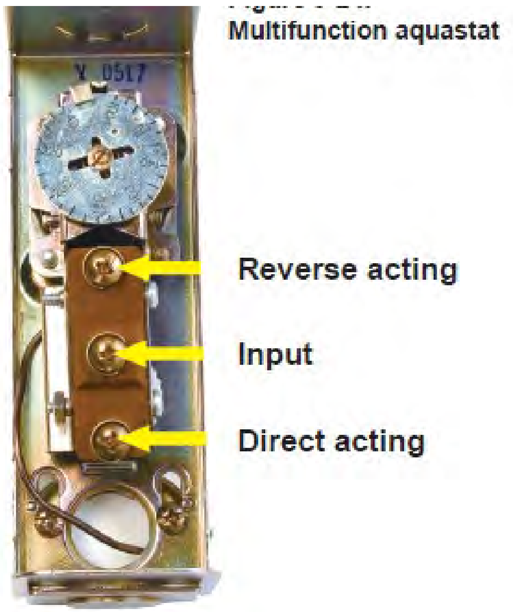
They prevent circulator operation when boiler water temperature is below the setting.

They often look the same as a high limit, the technician MUST verify which control is being used.

Aquastat Functions

And some are SPDT providing either a direct acting ***OR***

reverse acting in a single control.

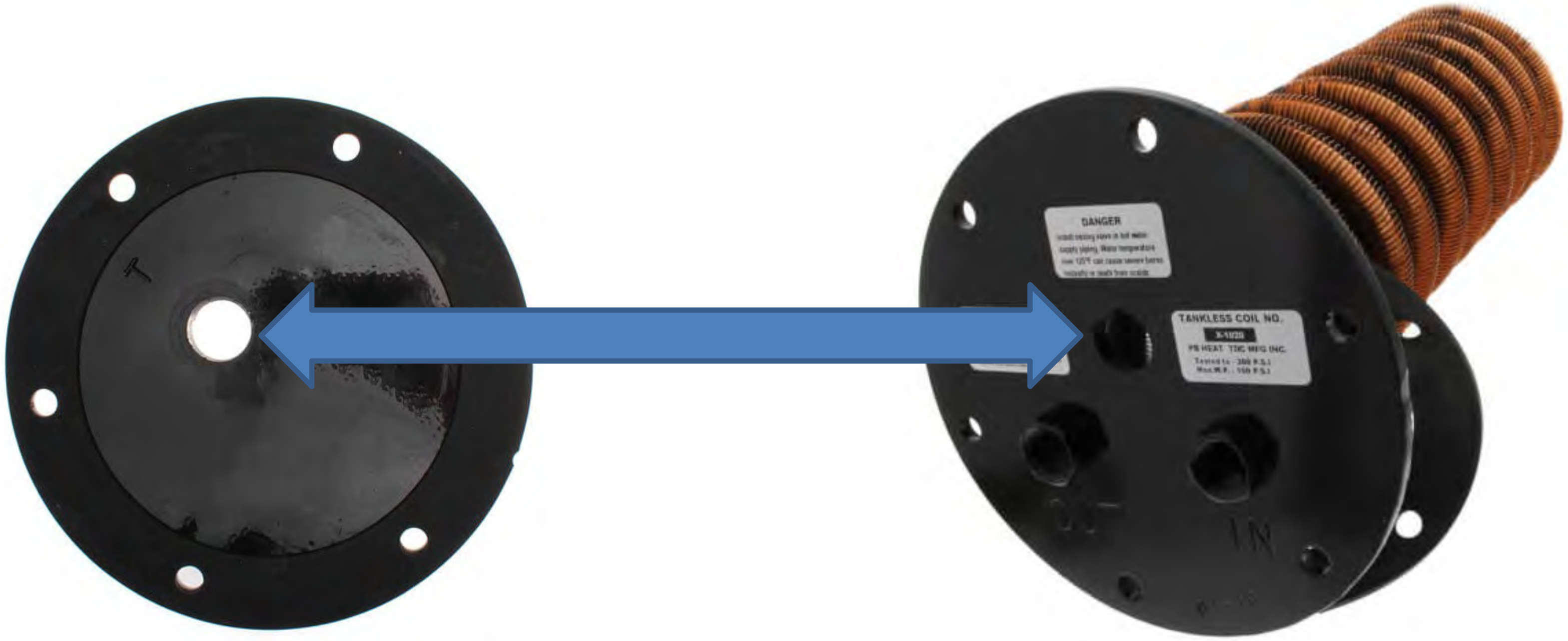


Temperature Sensing Elements

Aquastats are generally of the immersion type, they feature a sensor that's inserted into an immersion well that's installed into a boiler tapping.

Temperature Sensing Elements

Sometimes the tapping is in the domestic hot water coil or a blank plate installed where the coil would be.



Temperature Sensing Elements

Older type sensors are filled with a liquid that expands and contracts due to temperature changes. The sensors are attached to the control with a capillary tube connected to a diaphragm that opens/closes a switch based on the expansion/contraction caused by temperature.

It is advisable to coat the aquastat’s bulb with a heat conductive compound to increase sensitivity

Temperature Sensing Elements

Newer controls utilize thermistors that increase or decrease electrical resistance based on temperature and send that data to the boiler temperature control to open or close switches.

On/Off and Differentials

Once the boiler water temperature reaches the set-point and the control switches off, a small drop in water temperature could cause the control to turn the burner back on quickly.

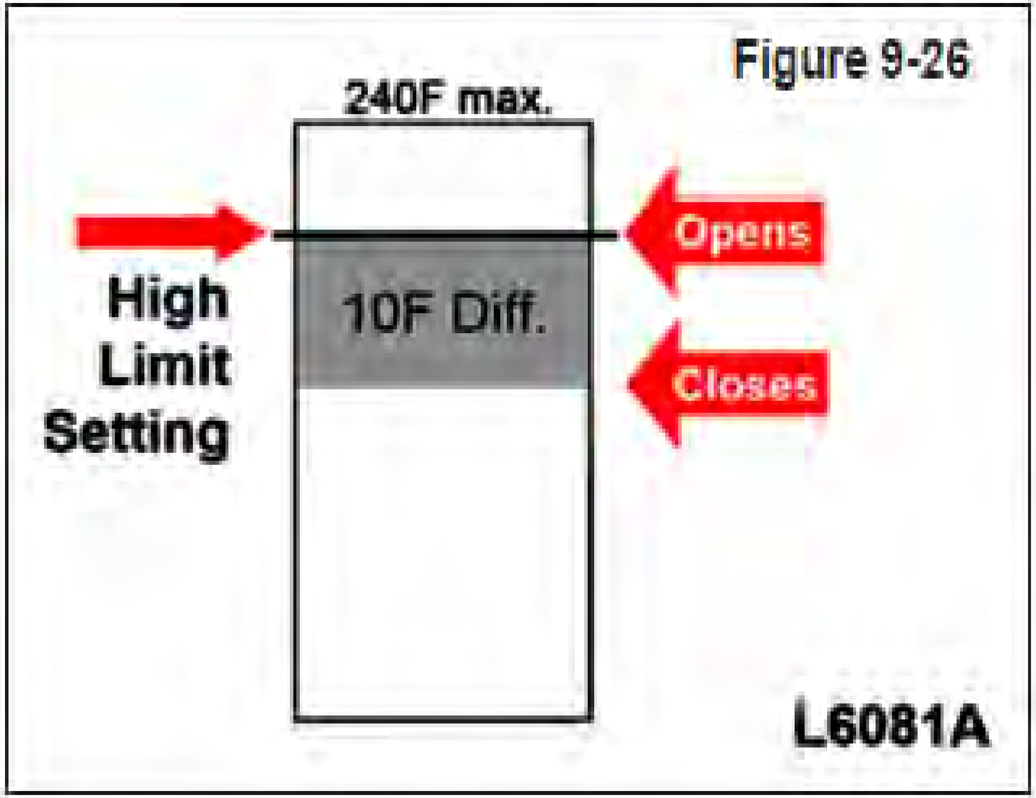
This would cause rapid cycling of the control and
short cycling of the burner.

To prevent this, boiler controls use a “differential function”, which can be fixed or adjustable……

On/Off and Differentials

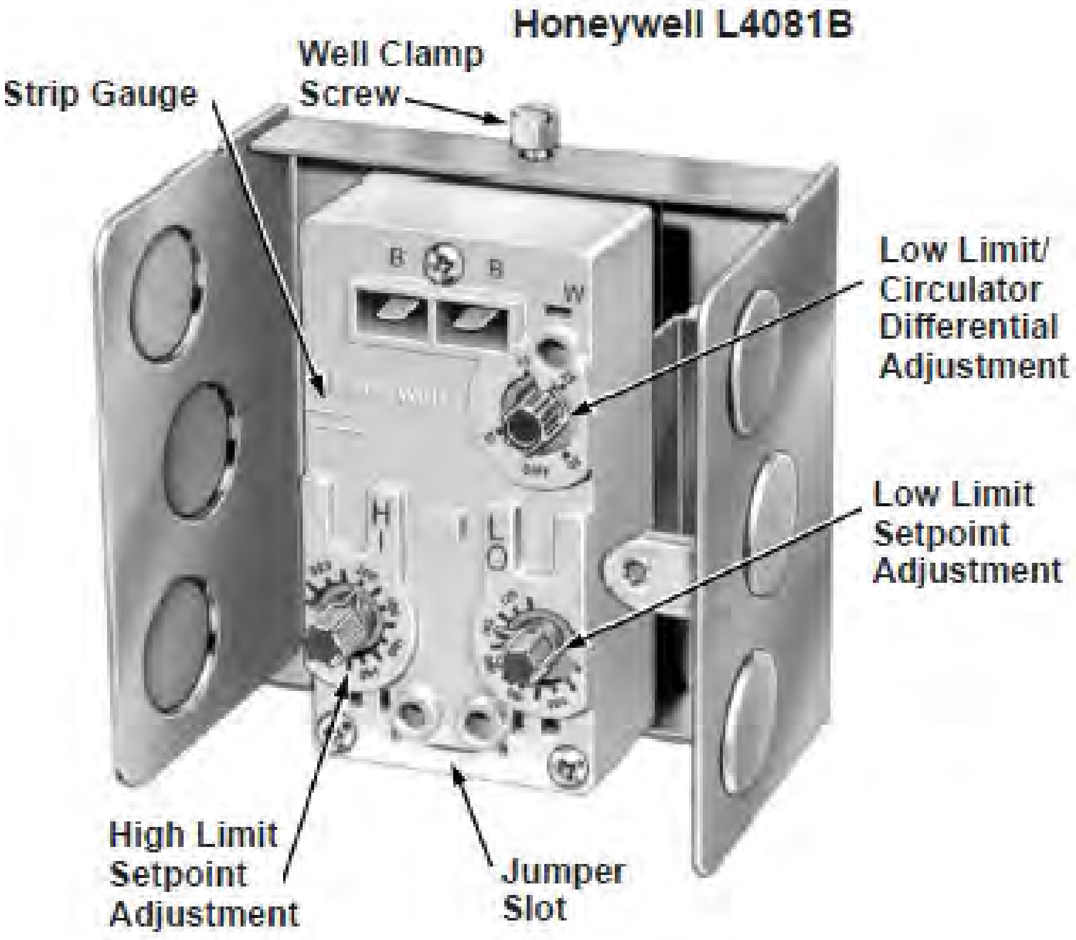
With a differential function, the set point remains where it's set until the boiler water temperature reaches the set point and the burner shuts off.

Then, the set point is altered by subtracting a "differential value." For example, if the set point is 180º & the differential is 10º, the controls contacts will remain open until the boiler water temperature falls below 180º (the set point) minus 10º, or 170º. Then, the contacts will close again and the burner will start.



High Limit and Circulator Aquastats

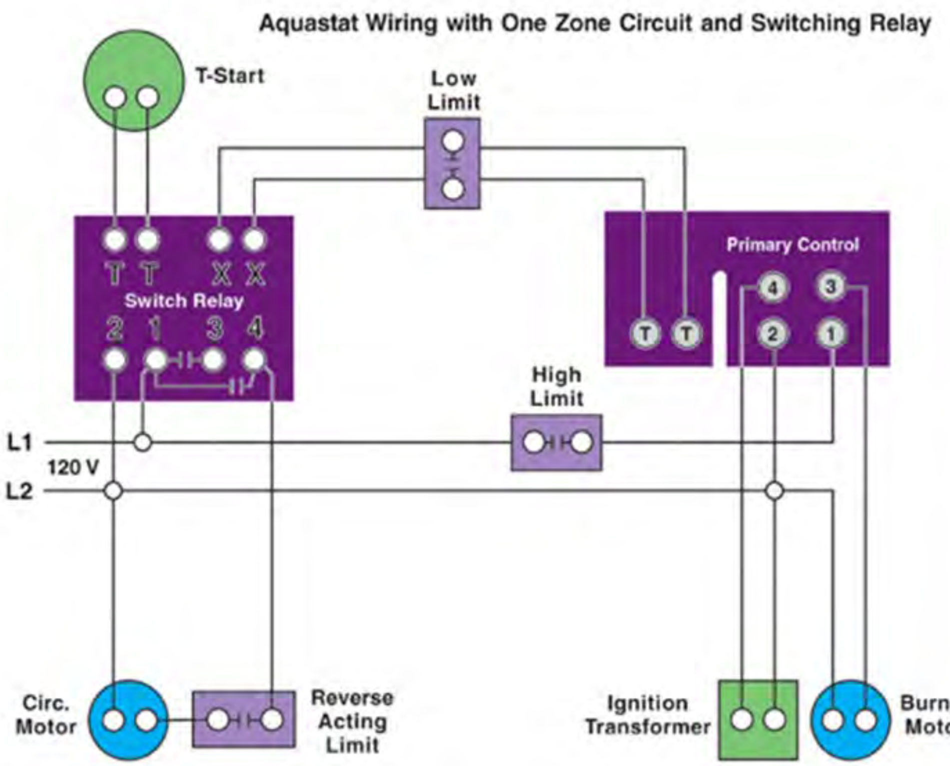
These combine 2 separately functioning single aquastats in the same enclosure, a SPST high limit switch to operate the burner ***AND*** a SPST reverse acting switch to prevent circulator operation when boiler water temperature is below the setting,

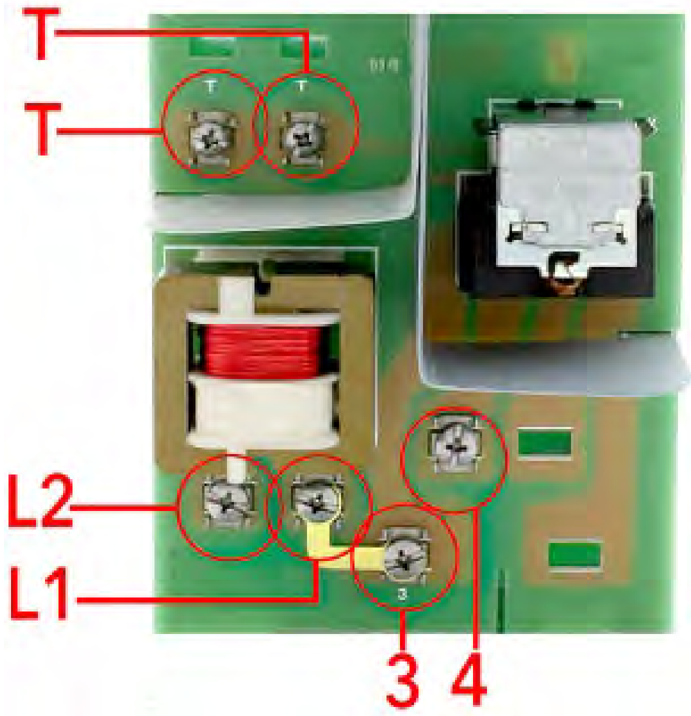


Circulator Switching Relays

These manage a line voltage load with a low voltage thermostat. They are widely used on hot water systems to provide for multiple zones.

This is a SPST type, which is an older design that can only control one load.





Circulator Switching Relays

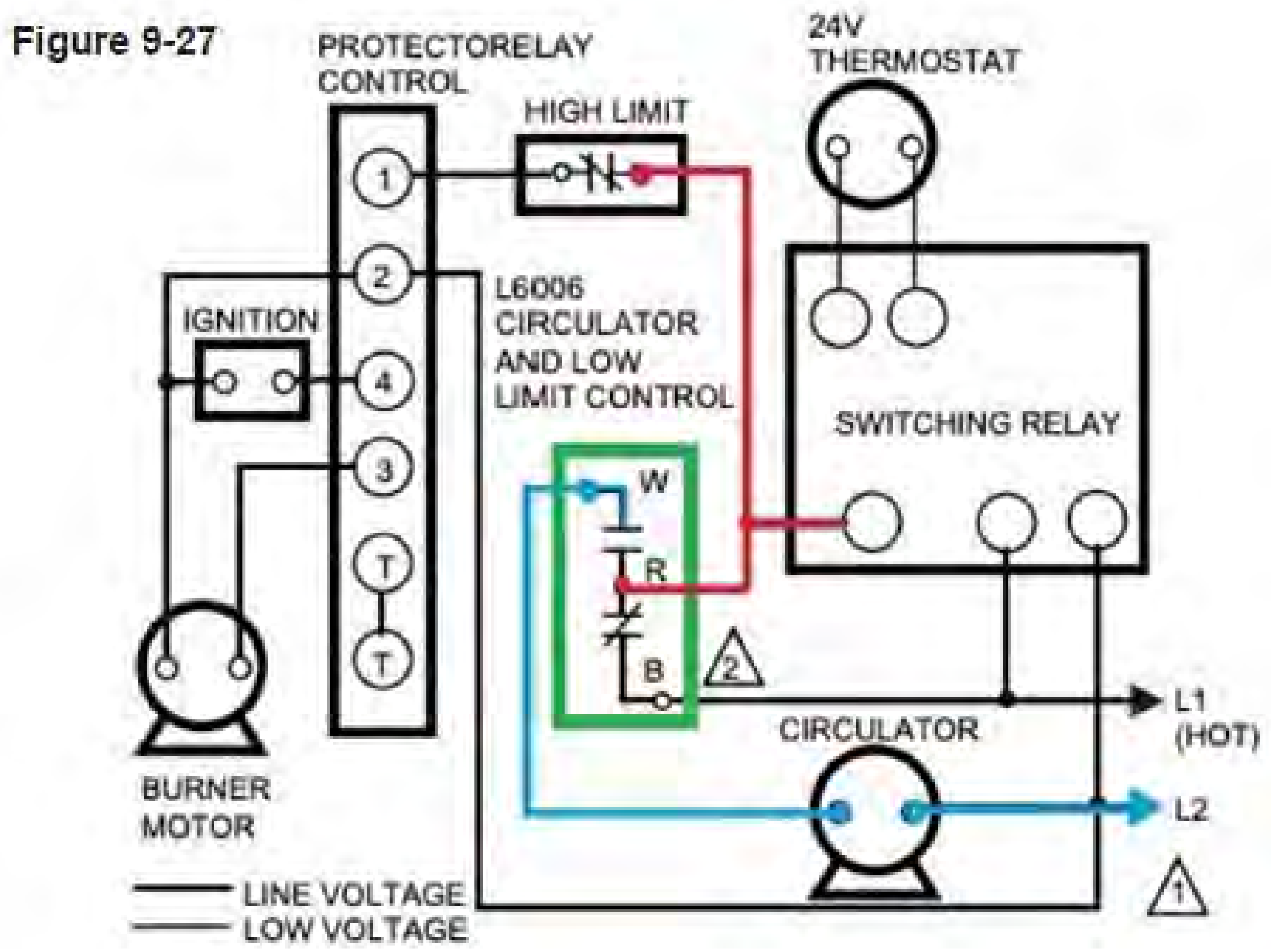
Most current models are DPST or DPDT. This control is a DPST model that allows 2 devices to be switched at the same time.

Typically, they turn on the circulator and activate the primary control.

Single Function Control w/Switching Relay

Operation:

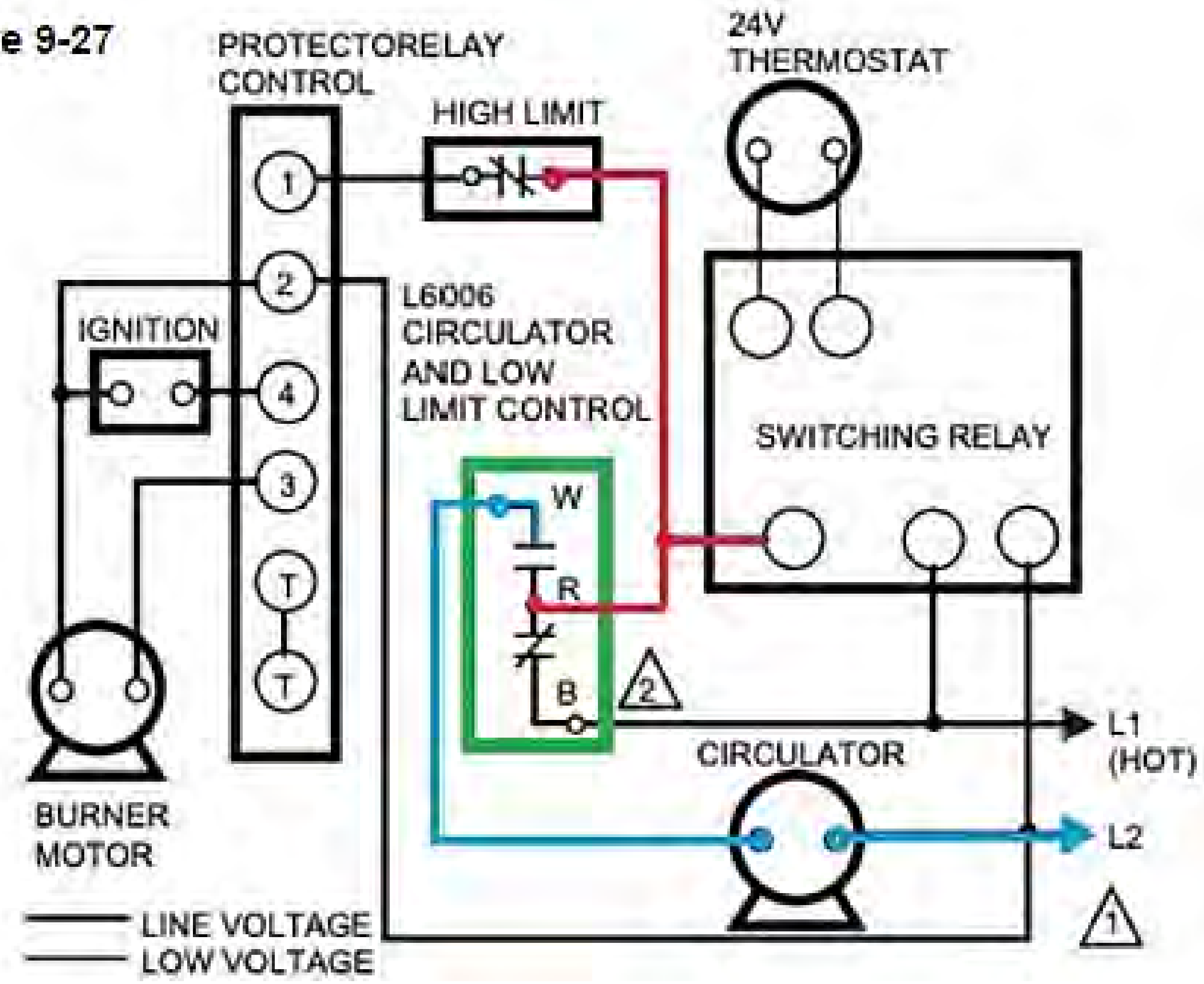
In standby: L1 provides power to the B (NC) terminal on the SPDT low limit control, continuing through the R (common) terminal to the high limit control and then to the burner to maintain low limit temperature.



Single Function Control w/Switching Relay

Call for heat: When the thermostat closes, it completes the T-T circuit which powers the R terminal (bypassing B-R) in the low limit control.

Figure 9-27

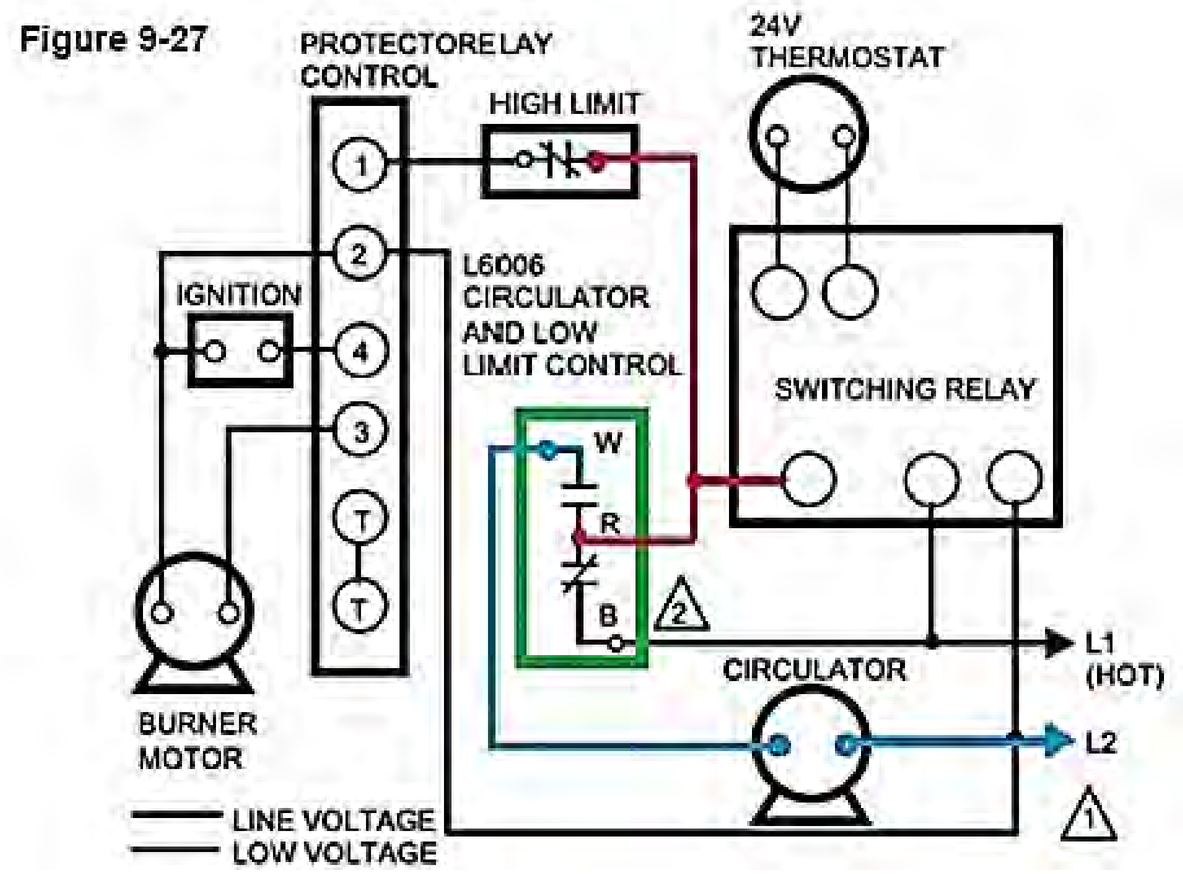


Single Function Control w/Switching Relay

The burner will operate until the high-limit is reached & will cycle between the high-limit & its differential. The circulator will run as long as the boiler water temperature is above the low limit setting.

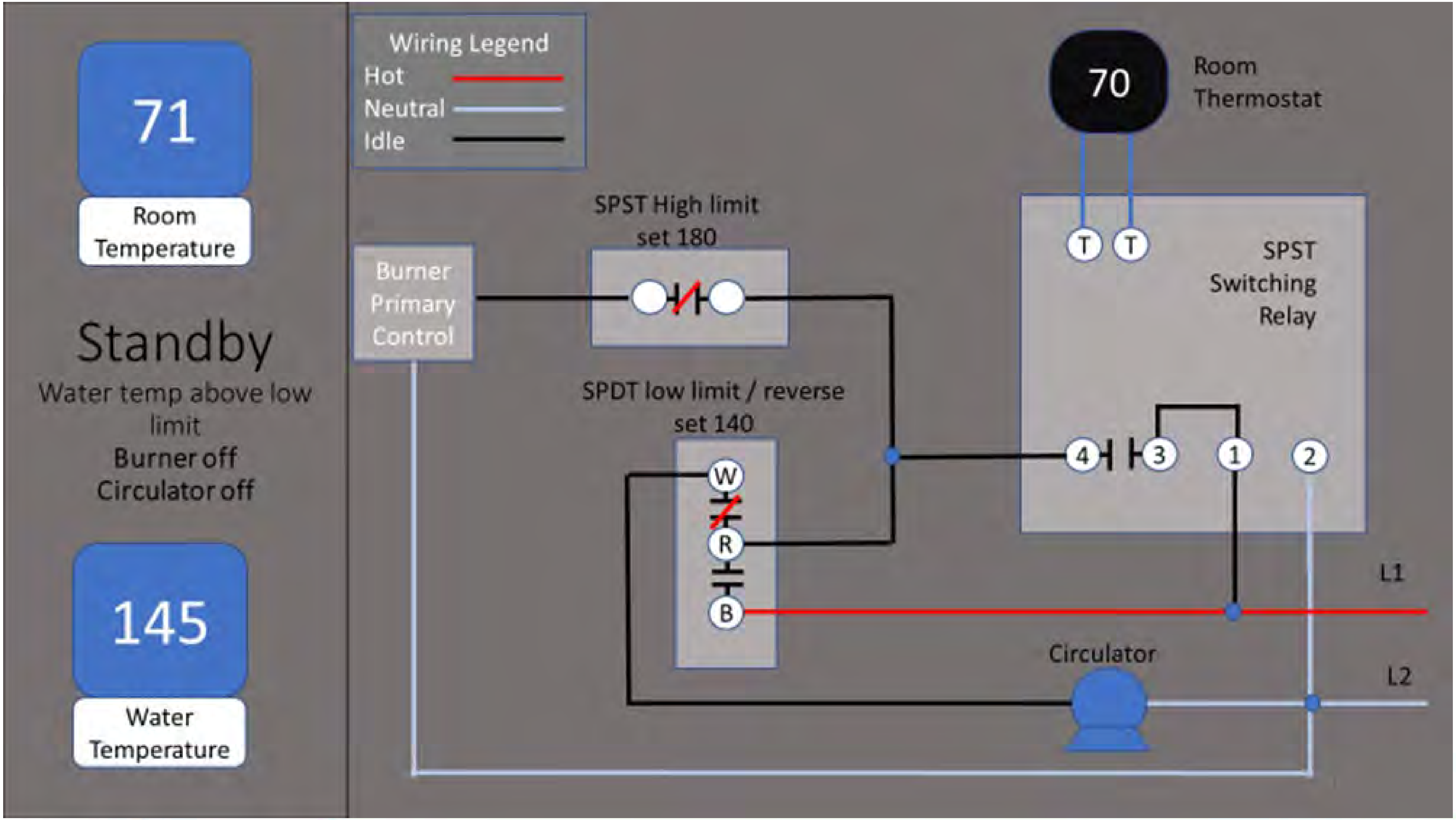
If the water temperature falls **below** the low limit setting, power to the circulator will be cut until the temperature rises above the setting.

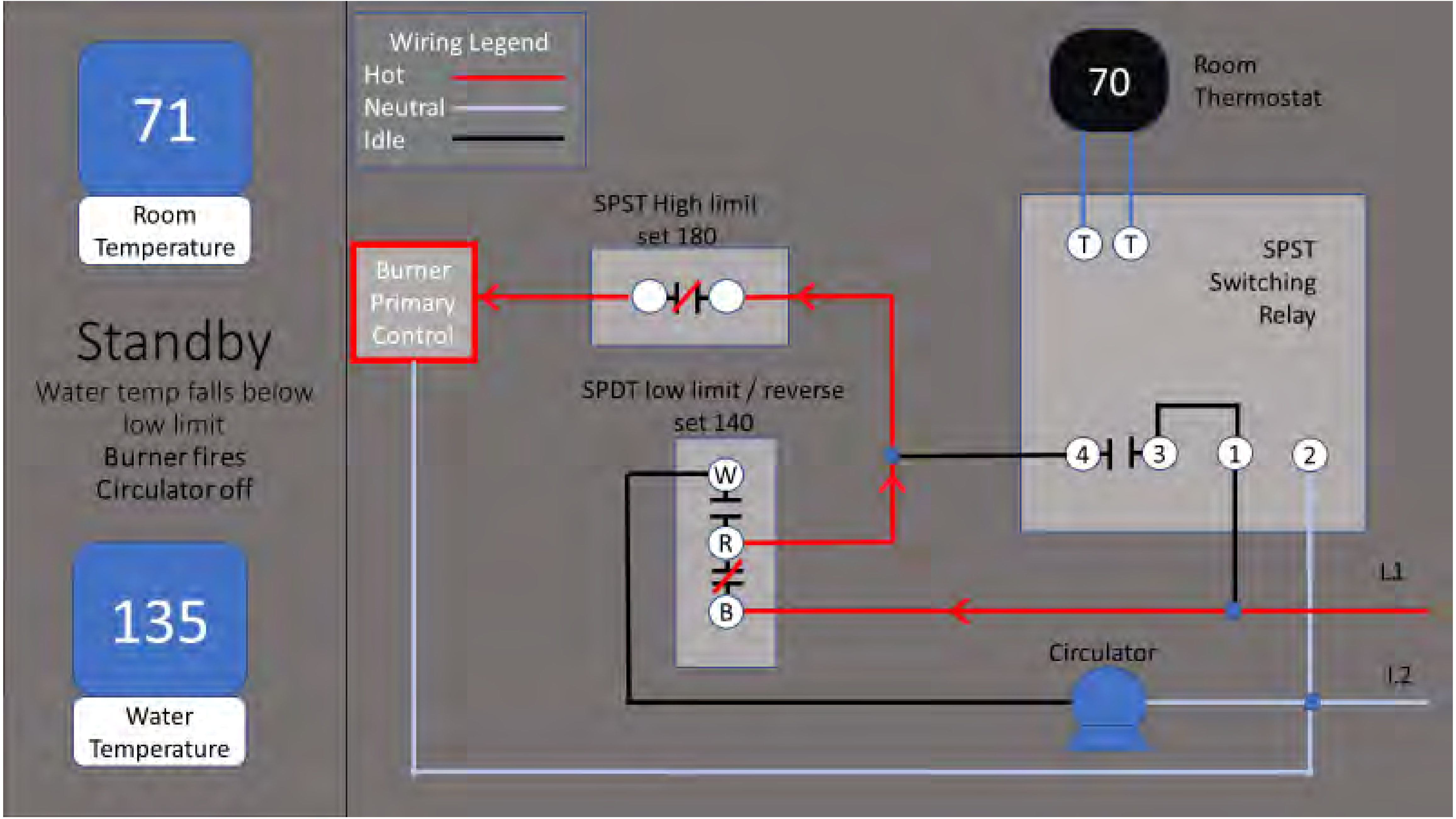
This will continue until the call for heat is satisfied.



Demonstration

Circulator Switching Relay


71
Room Temperature
Standby
Water temp above low limit
Burner off
Circulator off
145
Water Temperature
Wiring Legend
Hot
Neutral
Idle
Burner Primary Control
SPST High limit set 180
SPDT low limit / reverse set 140
W
R
B
70
Room Thermostat
T
T
SPST Switching Relay
4
3
1
2
L1
L2
Circulator


71
Room Temperature
Standby
Water temp falls below low limit
Burner fires
Circulator off
135
Water Temperature
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
SPST High limit set 180
Burner Primary Control
SPDT low limit / reverse set 140
W
R
B
T
T
SPST Switching Relay
4
3
1
2
L1
L2
Circulator

71

Room Temperature

Standby

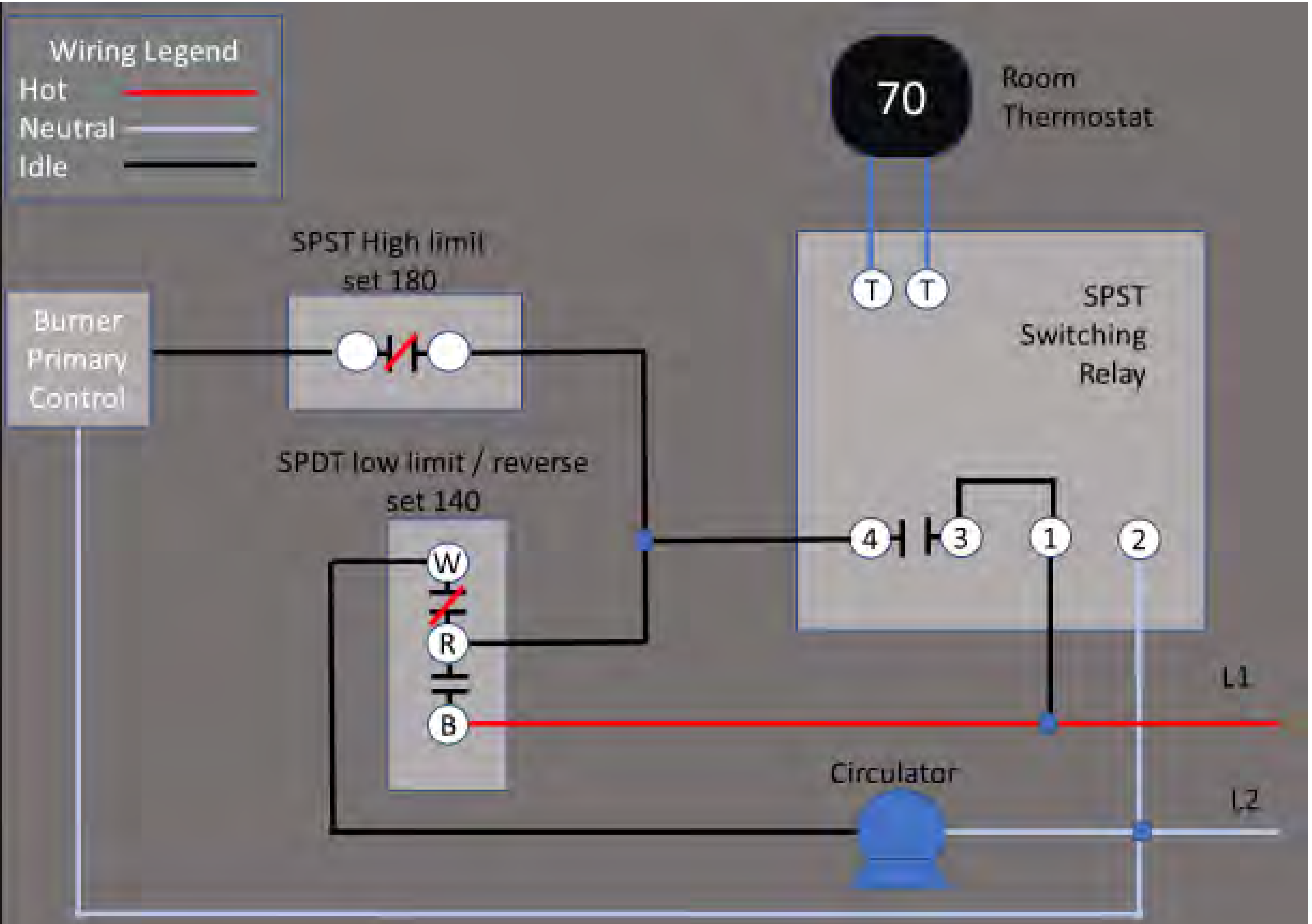
Water temp rises above low limit

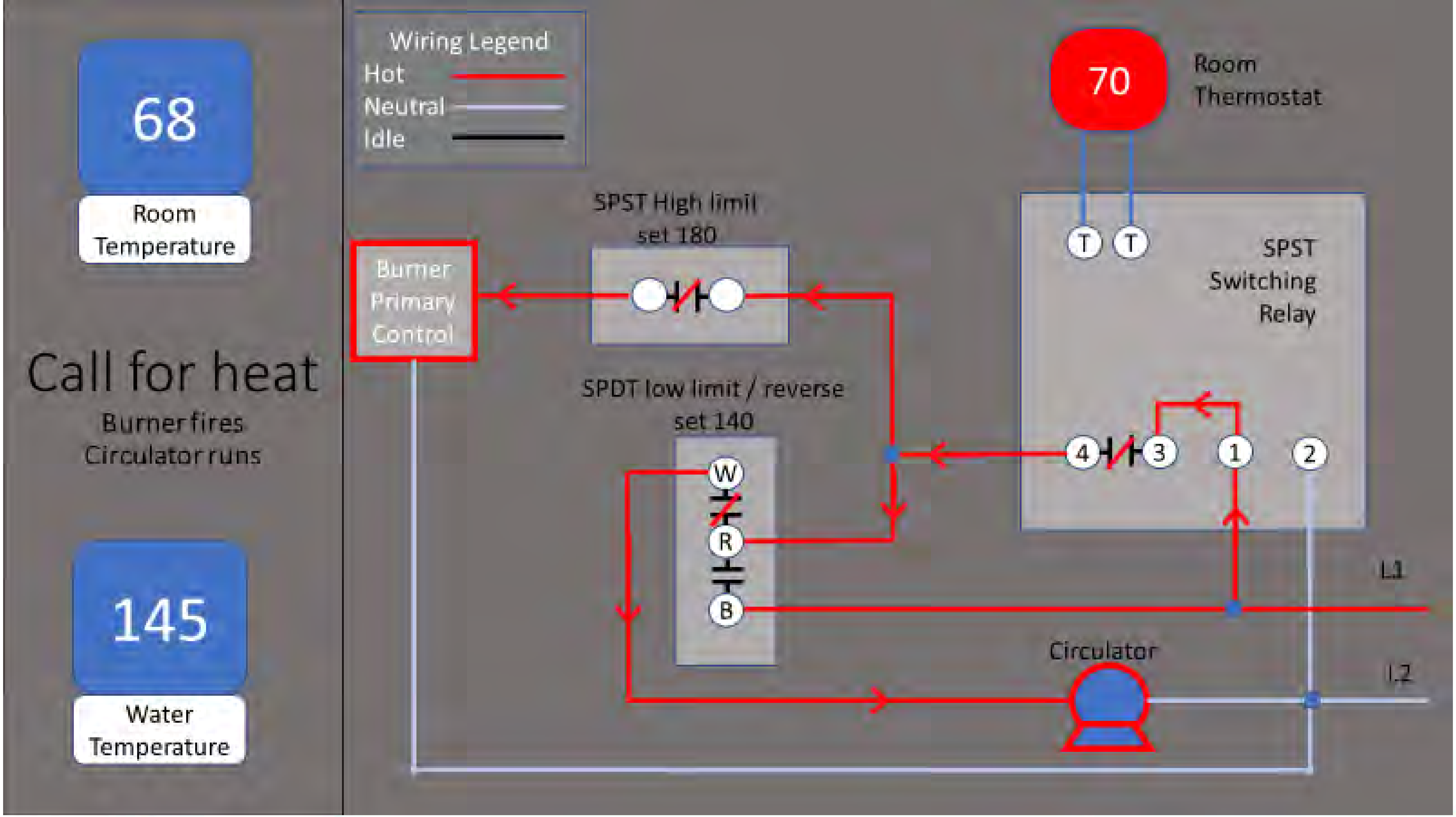
Burner off

Circulator off

145

Water Temperature





68
Room Temperature
Call for heat
Burner fires
Circulator runs
145
Water Temperature
Wiring Legend
Hot
Neutral
Idle
Burner Primary Control
SPST High limit set 180
SPDT low limit / reverse set 140
W
R
B
70
Room Thermostat
T
T
SPST Switching Relay
4
3
1
2
L1
Circulator
L2

68

Room Temperature

Call for heat

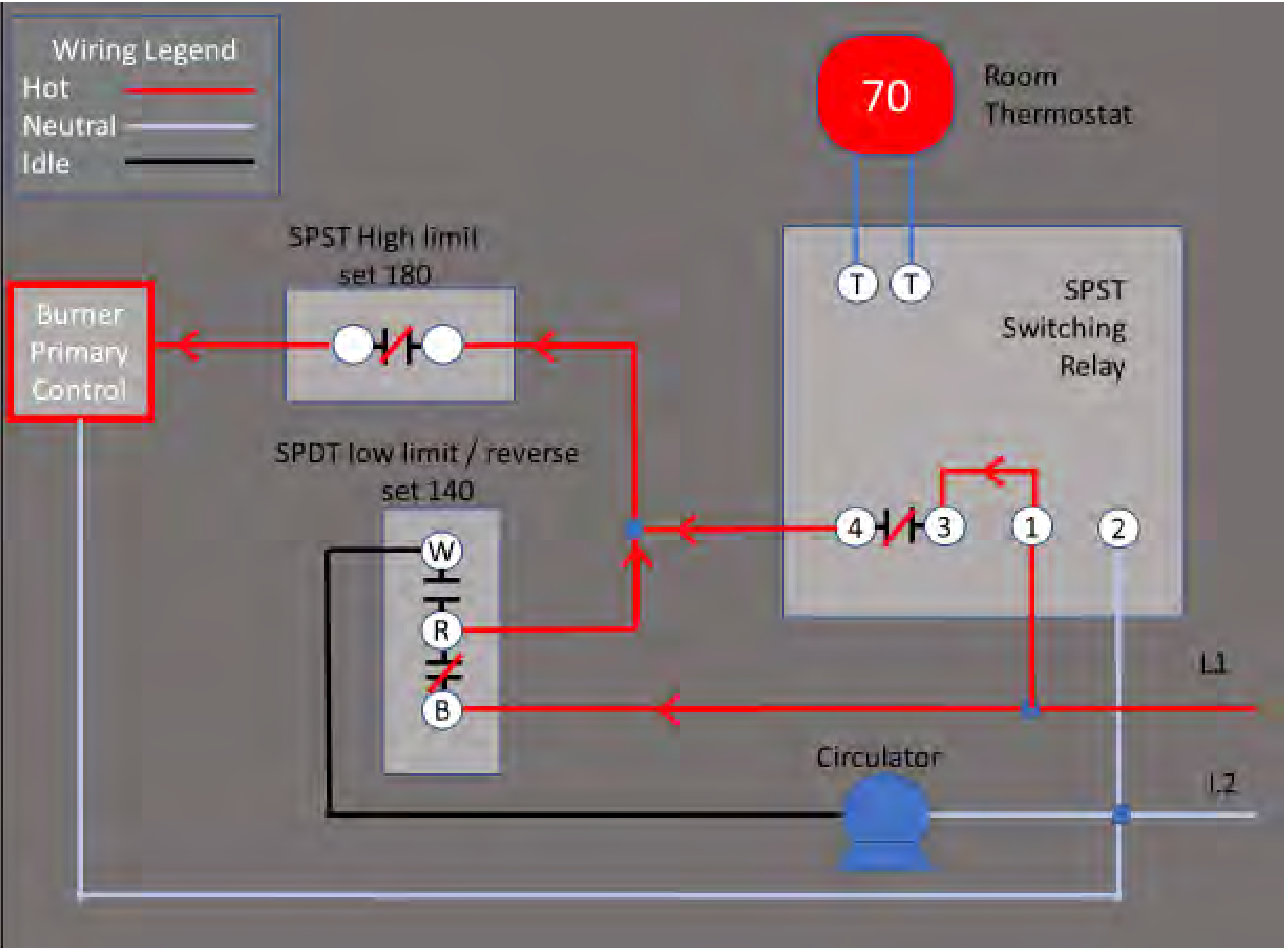
Water temp falls below low limit

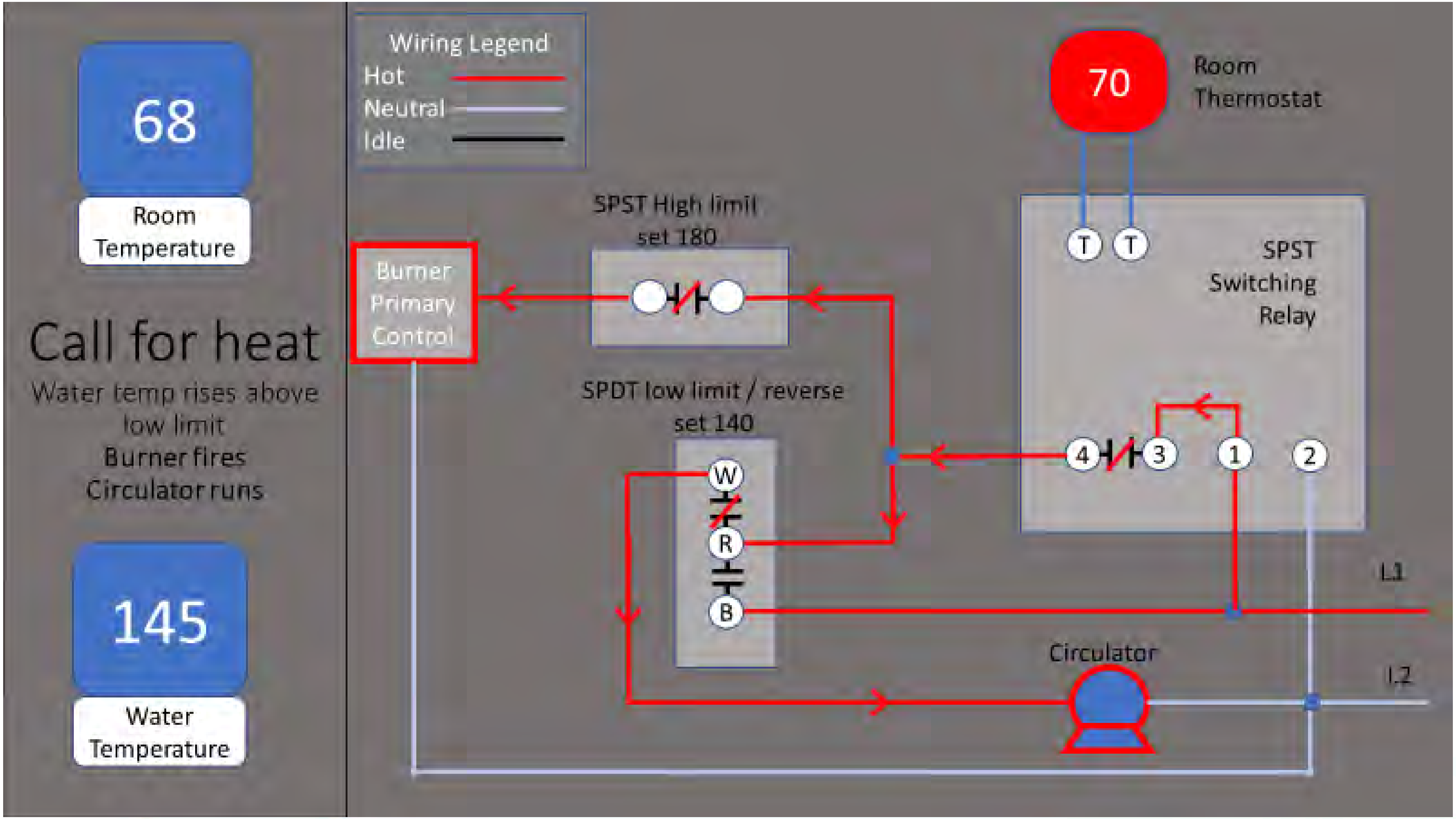
Burner fires

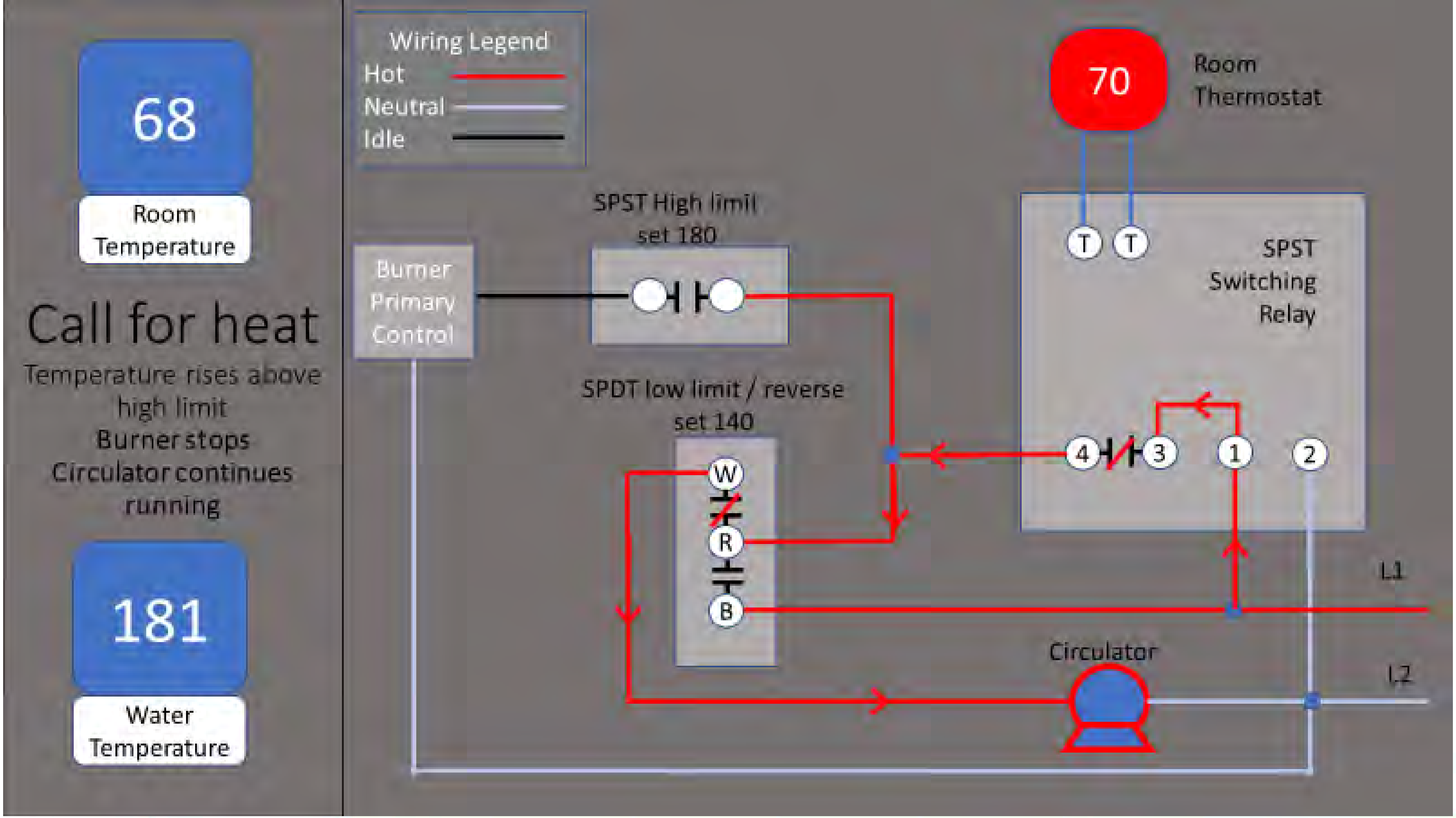
Circulator stops

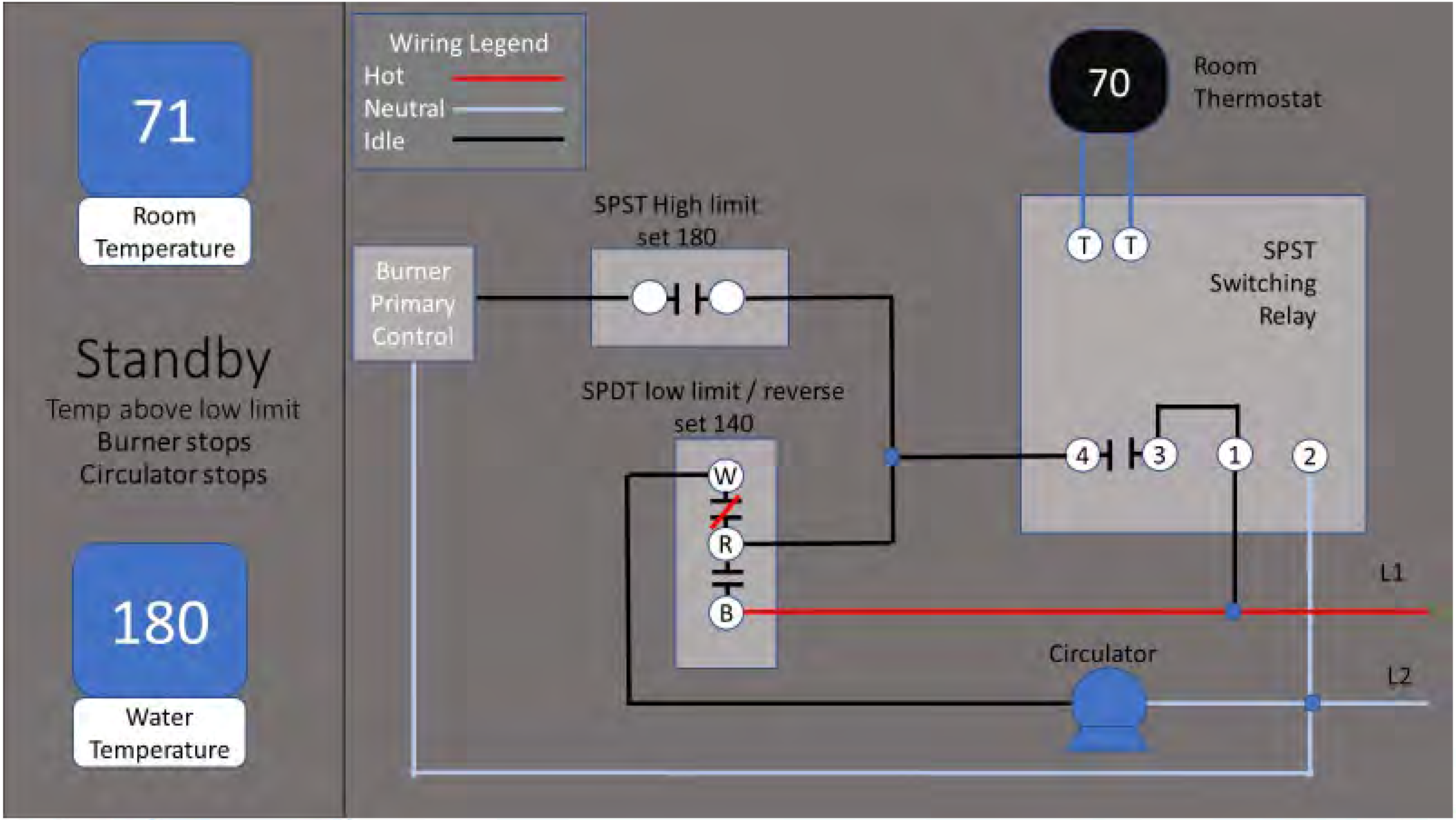
139

Water Temperature




68
Room Temperature
Call for heat
Water temp rises above low limit
Burner fires
Circulator runs
145
Water Temperature
Wiring Legend
Hot
Neutral
Idle
Burner Primary Control
SPST High limit set 180
SPDT low limit / reverse set 140
W
R
B
70
Room Thermostat
T
T
SPST Switching Relay
4
3
1
2
L1
L2
Circulator


68
Room Temperature
Call for heat
Temperature rises above high limit
Burner stops
Circulator continues running
181
Water Temperature
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
SPST High limit set 180
Burner Primary Control
SPST Switching Relay
SPDT low limit / reverse set 140
T
T
4
3
1
2
W
R
B
L1
L2
Circulator


71
Room Temperature
Standby
Temp above low limit
Burner stops
Circulator stops
180
Water Temperature
Wiring Legend
Hot
Neutral
Idle
70
Room Thermostat
SPST High limit set 180
Burner Primary Control
SPDT low limit / reverse set 140
W
R
B
T
T
SPST Switching Relay
4
3
1
2
L1
L2
Circulator

Combination Boiler Temperature Controls

These integrate all major control functions into a single control.

They manage all limit functions and contain input & output terminals to power the burner primary control & circulator.

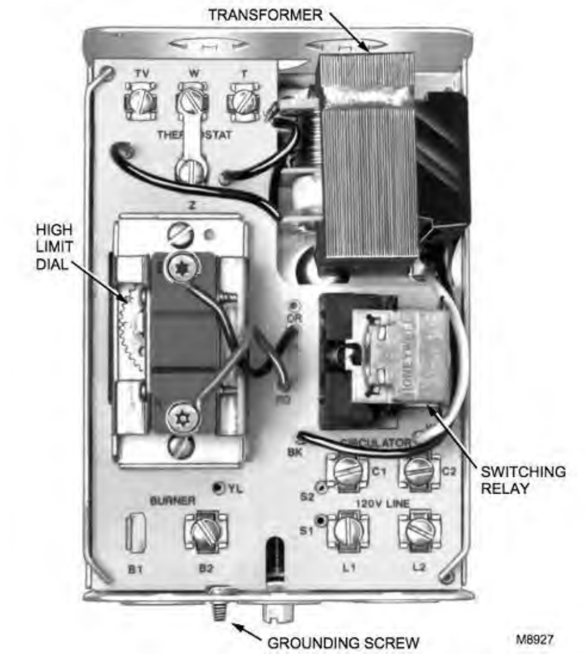
There are 2 types:

- Dual function high limit/relay controls
- Triple function high limit/low limit/relay controls

Dual Function Boiler Temperature Controls

These are manufactured for "cold start" boilers that don't maintain temperature to provide domestic hot water through a tankless coil.

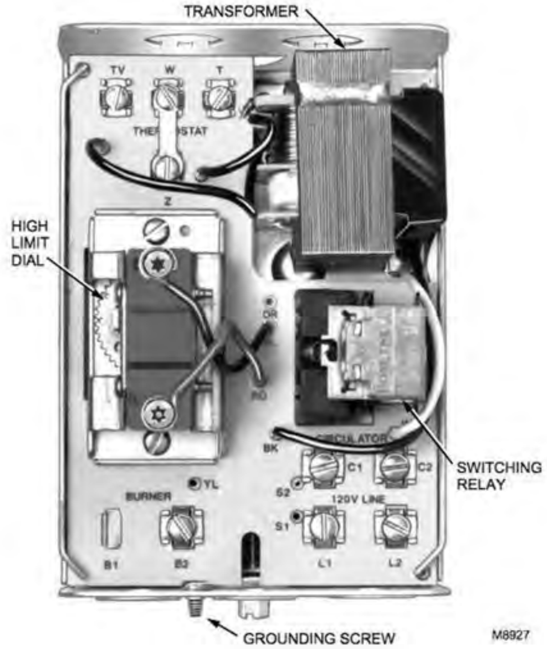
This is how they operate:



When the thermostat closes, it completes the T-T circuit and B1 and C1 are powered, starting both the burner and circulator……

Dual Function Boiler Temperature Controls

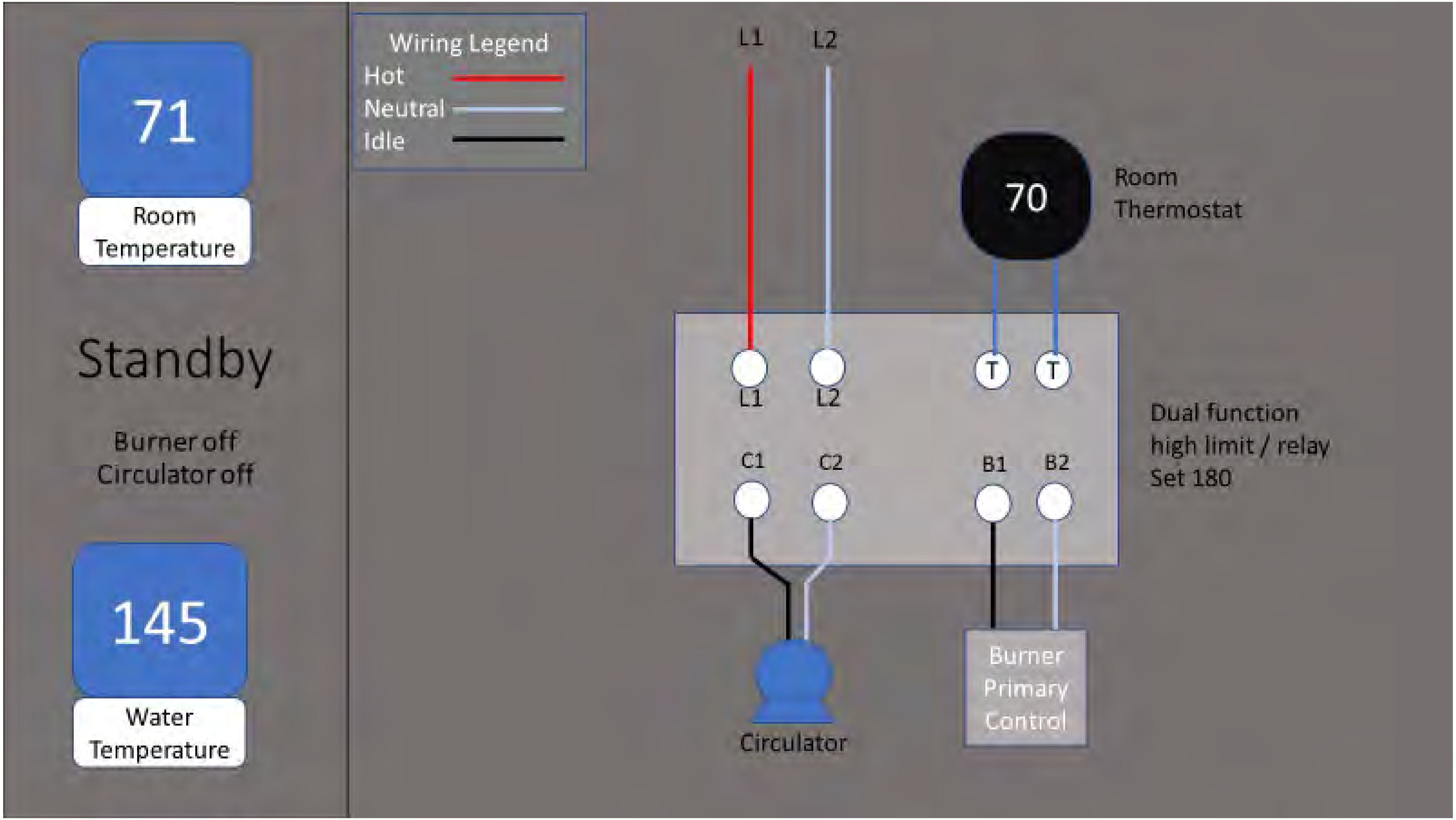
If the high limit is reached the B1 terminal cuts power to the burner which then cycles based on the setting and the differential.



The C1 terminal is powered constantly, and the circulator runs until the call for heat is satisfied and the control returns to standby.

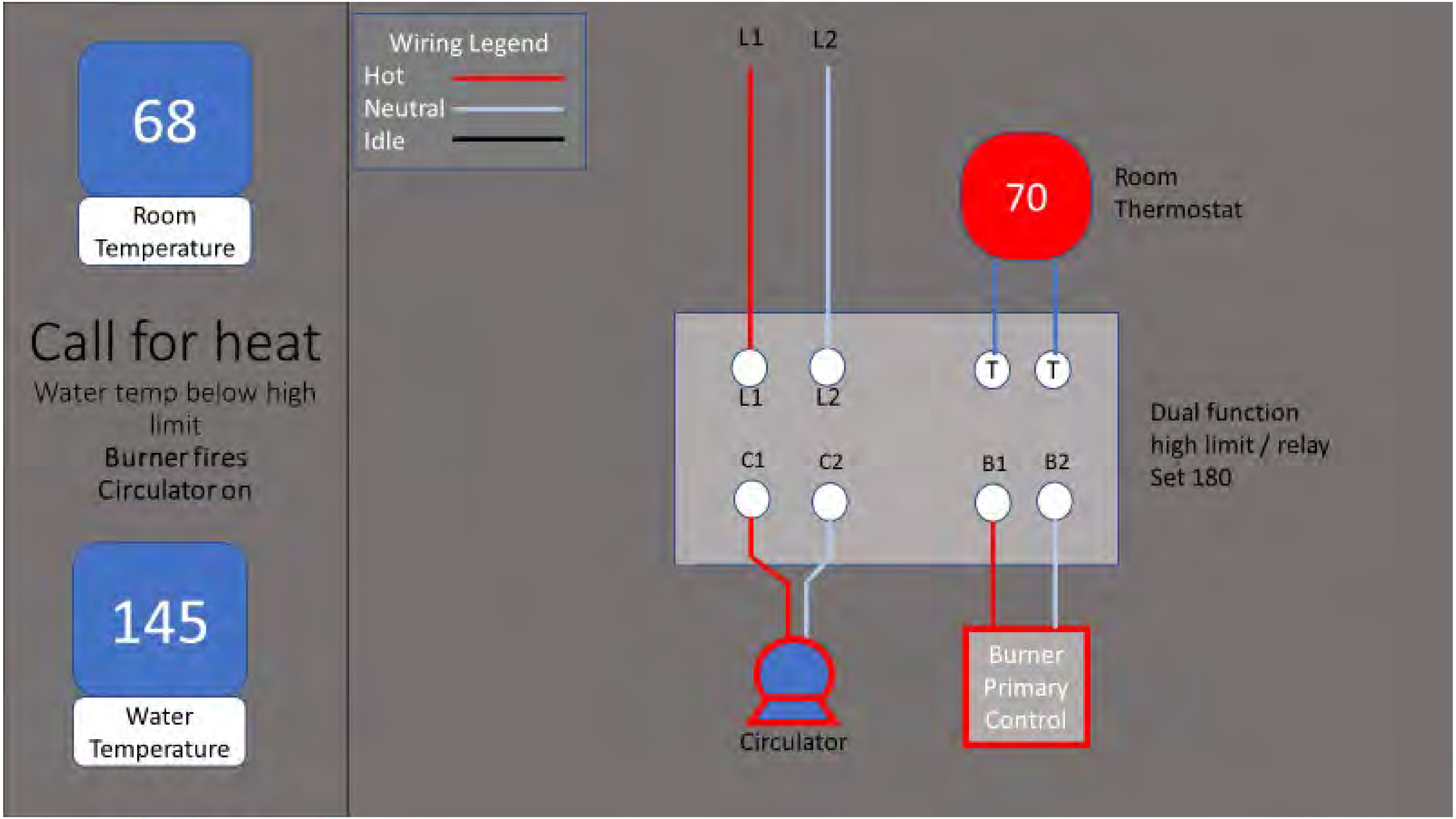
Demonstration

Dual Function Boiler Temperature Controls


71
Room Temperature
Standby
Burner off
Circulator off
145
Water Temperature
Wiring Legend
Hot
Neutral
Idle
L1
L2
70
Room Thermostat
L1
L2
T
T
C1
C2
B1
B2
Dual function high limit / relay Set 180
Circulator
Burner Primary Control

Call for heat

Water temp below high limit
Burner fires
Circulator on



68

Room Temperature

Call for heat

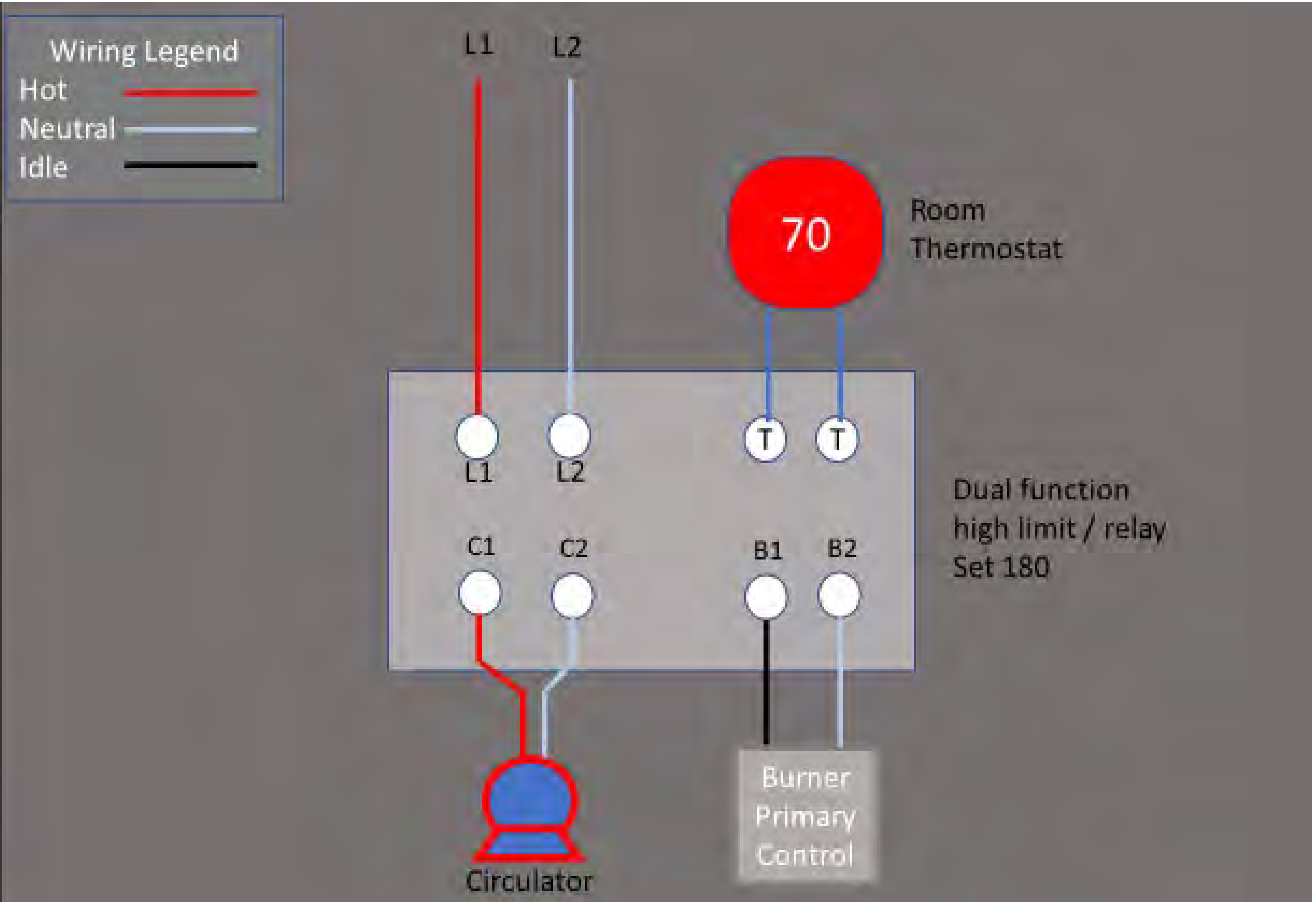
Water temp above high limit

Burner off

Circulator on

181

Water Temperature



68

Room Temperature

Call for heat

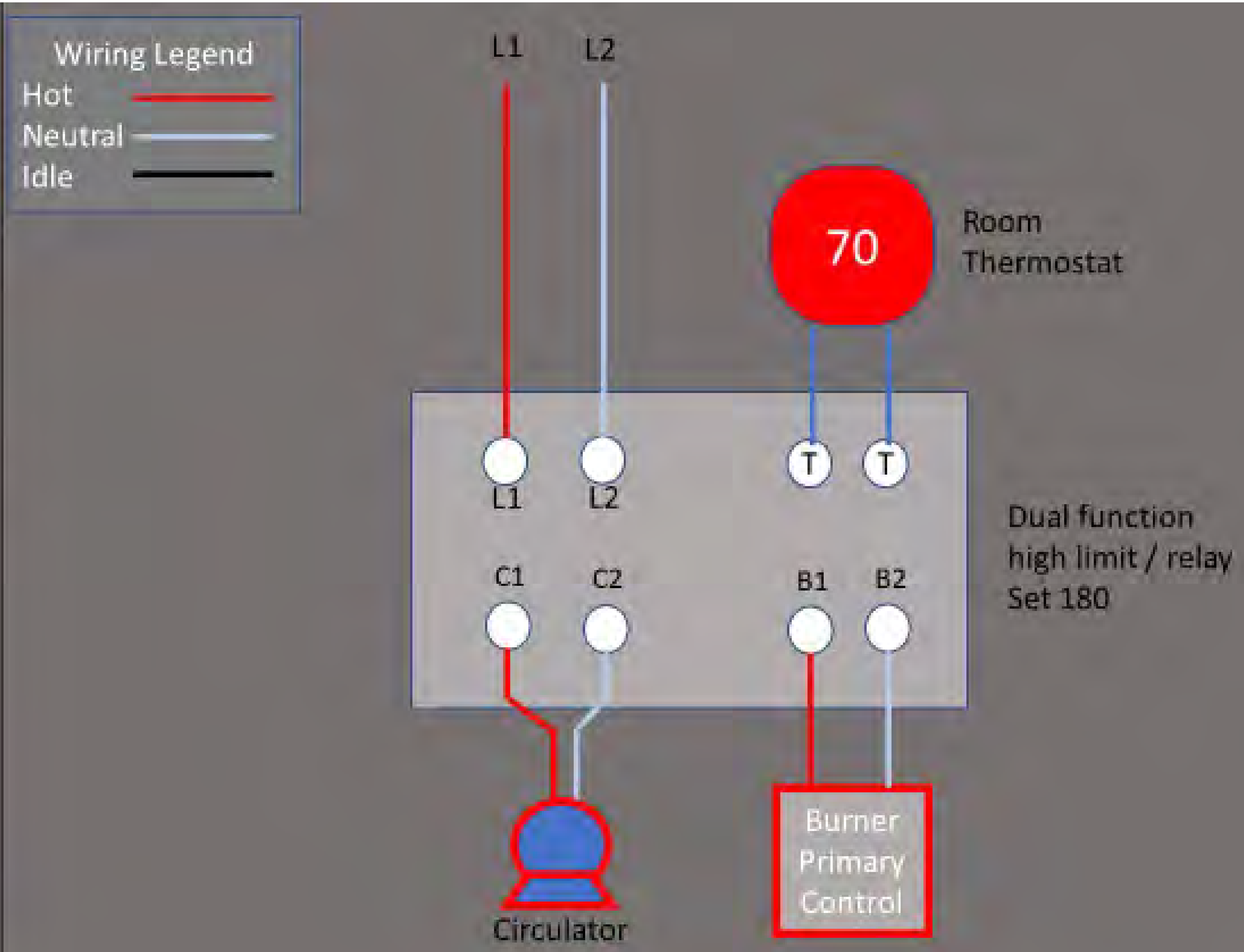
Water temp below high limit

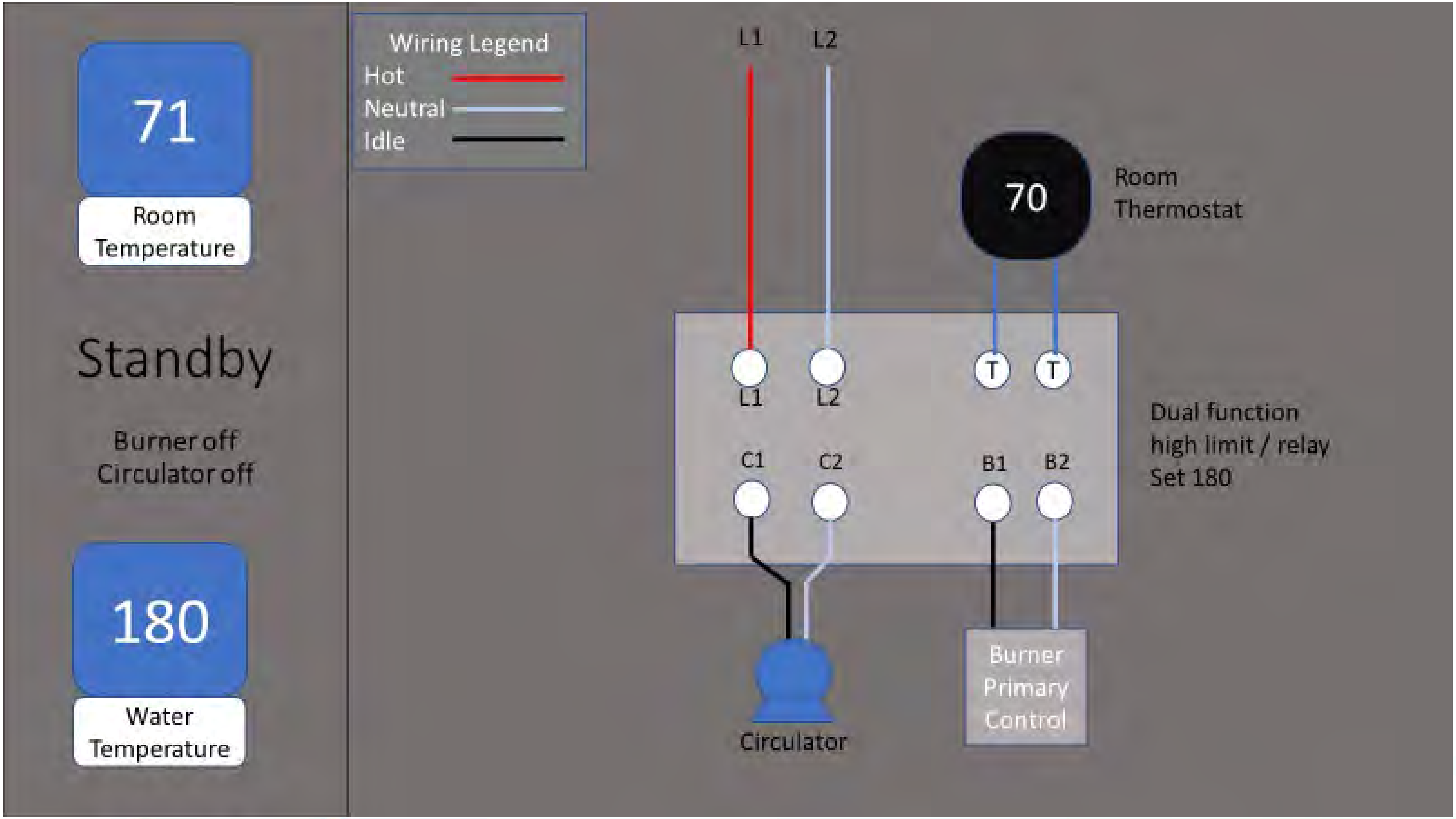
Burner fires

Circulator on

169

Water Temperature




71
Room Temperature
Standby
Burner off
Circulator off
180
Water Temperature
Wiring Legend
Hot
Neutral
Idle
L1
L2
70
Room Thermostat
L1
L2
T
T
C1
C2
B1
B2
Dual function high limit / relay Set 180
Circulator
Burner Primary Control

Triple Function Boiler Temperature Controls

These are manufactured for boilers that maintain temperature to provide domestic hot water through a tankless coil.

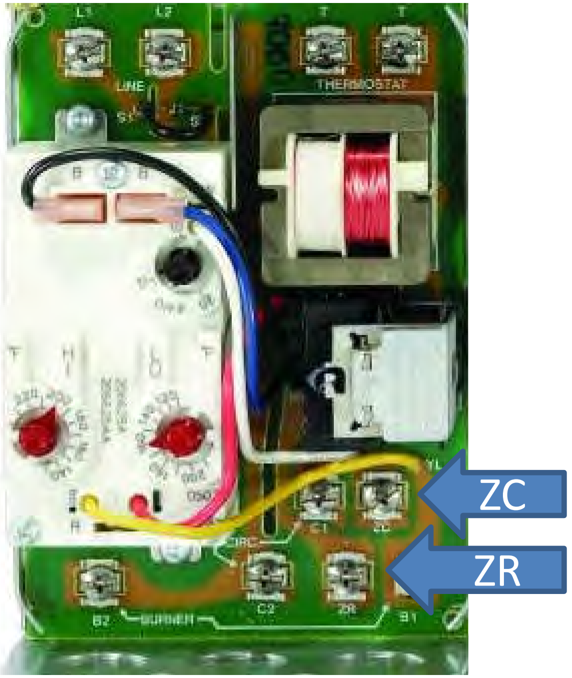
They provide:

- A high limit during calls for heat
- A low limit to maintain temperature during standby to provide dhw
- A reverse limit to prevent circulator operation when boiler temperature is below the low limit setting.

Modern triple function boiler controls can be programmed to operate as dual function controls by disabling the low limit.

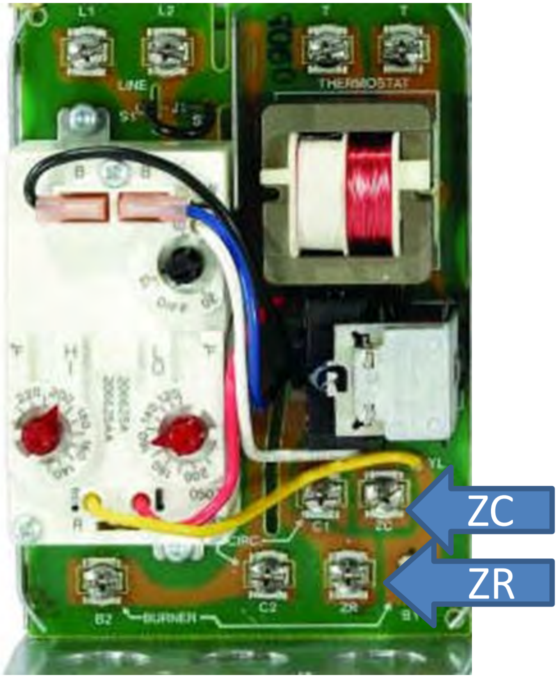
Triple Function Boiler Temperature Controls

These controls have 2 terminals to communicate with zone valve controls to mirror the domestic water protection of the main circulator & provide the control with a signal that there's a call for heat from an external zone.



Triple Function Boiler Temperature Controls

ZC is powered when the boiler temperature is above the low limit setting. This power can be provided to external zone relays to provide reverse limit control of multiple zones.



ZR – when line voltage (typically from an external zone relay) is applied to ZR, the B1 terminal is powered and the burner will start and run until the high limit setting is reached.

Operation Using T-T

In standby: The control provides power to the burner to maintain the low limit temperature, ZC is powered when water temperature is above the low limit setting.

Call for heat: When the thermostat closes, completing the T-T circuit, B1 and C1 are powered, starting both the burner and circulator. If the high limit is reached, B1 stops power to the burner, then cycles based on the high limit & differential.

If water temperature drops below the low limit, power to C1 and ZC is cut until the temperature rises to the low limit setting. These functions continue until the call for heat is satisfied & the control returns to standby.

Operation using ZR

In standby: The control provides power to B1 to maintain the low limit temperature.

Call for heat: A line voltage input to ZR from an external zone relay signals a call for heat. Terminals B1 and ZC are powered, starting the burner and the external zone circulator.

The main circulator, C1 is not powered during a call from ZR, unless there's a call from T-T at the same time.

Operation using ZR (continued)

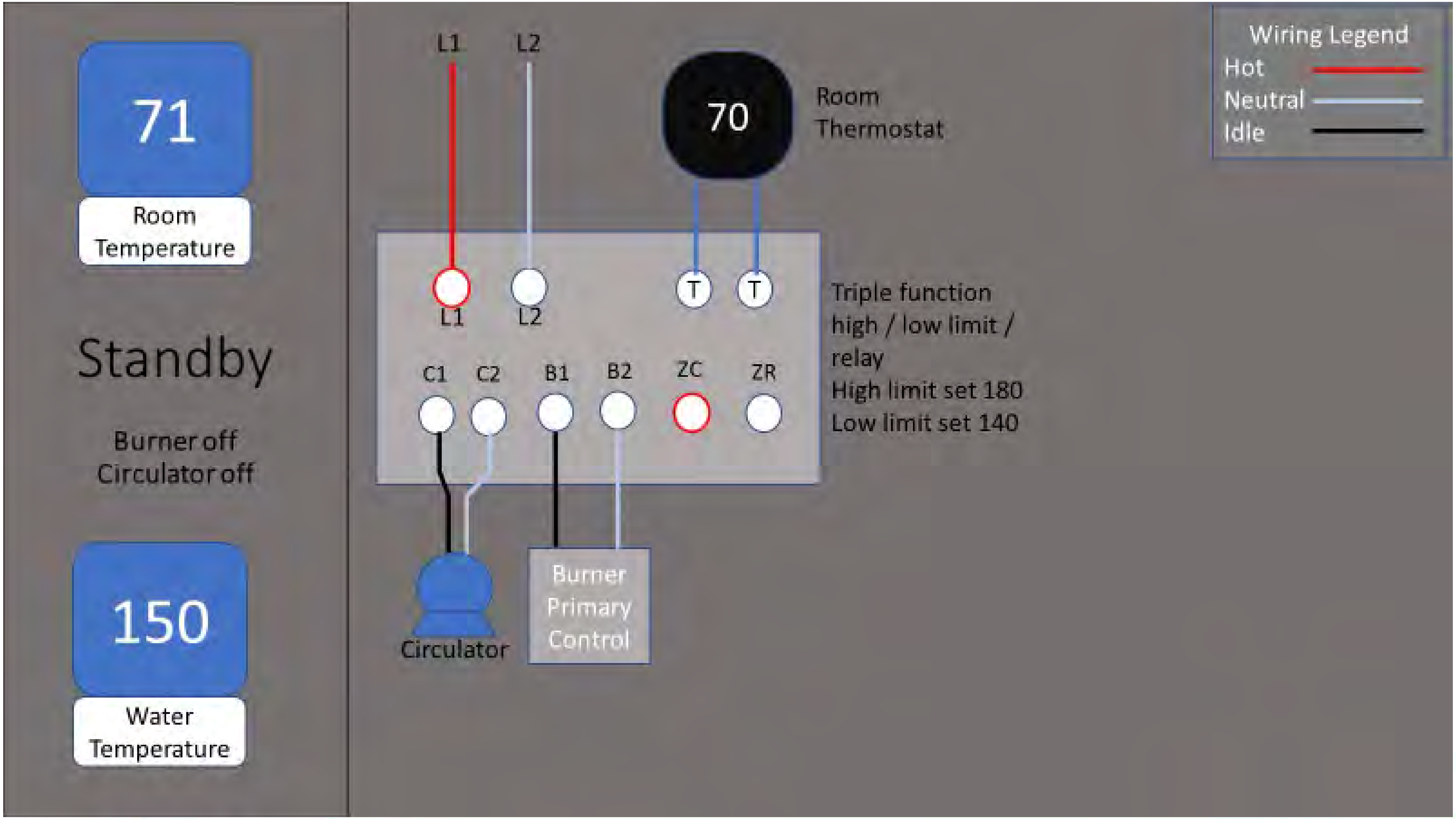
If the high limit is reached during the call for heat, B1 will stop power to the burner which will cycle based on the setting & differential.

If boiler water temperature falls below the low limit setting, power to C1 and ZC will be stopped until the temperature rises above the low limit setting.

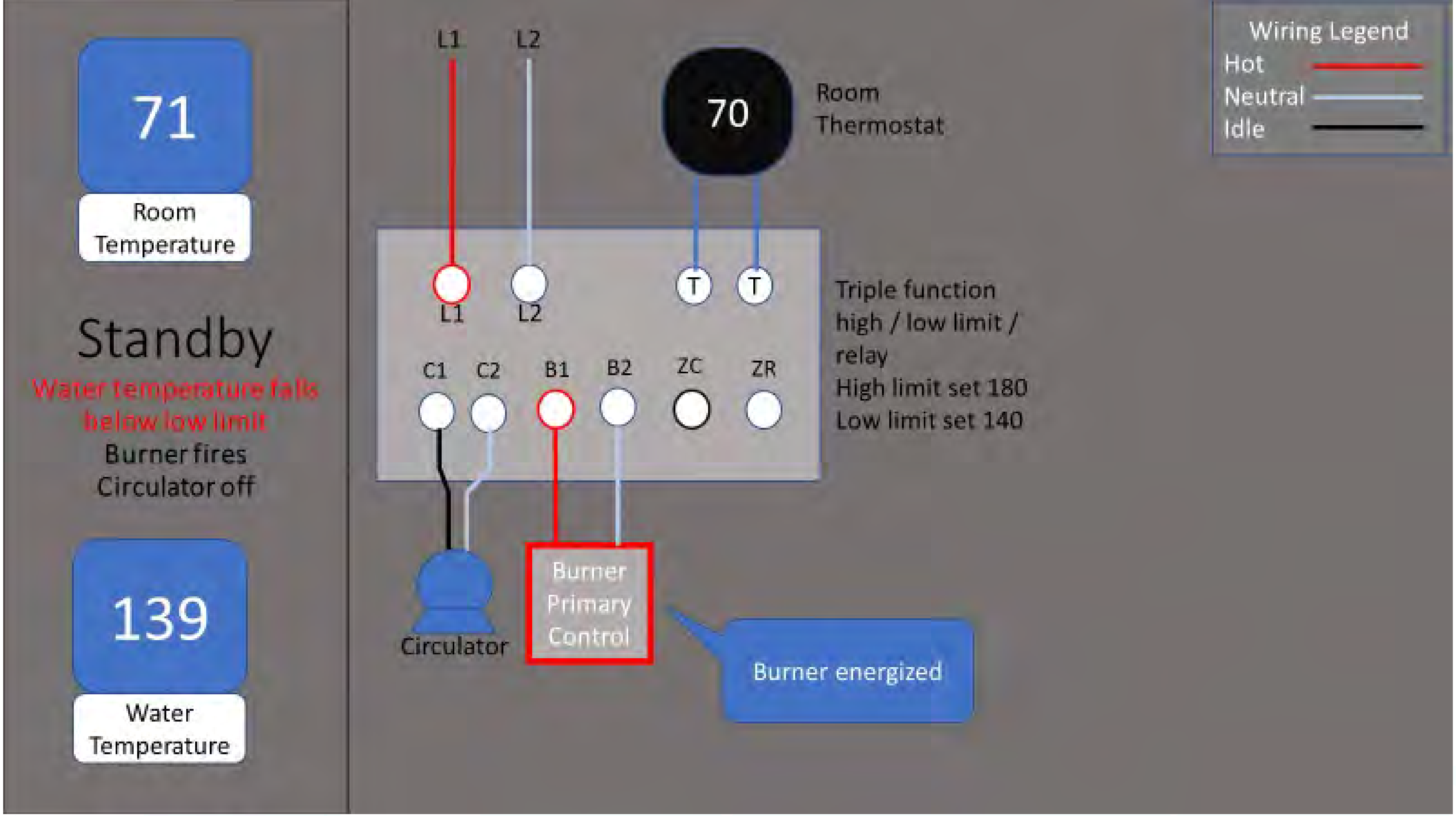
These functions will continue until the call for heat is satisfied & the control returns to standby.

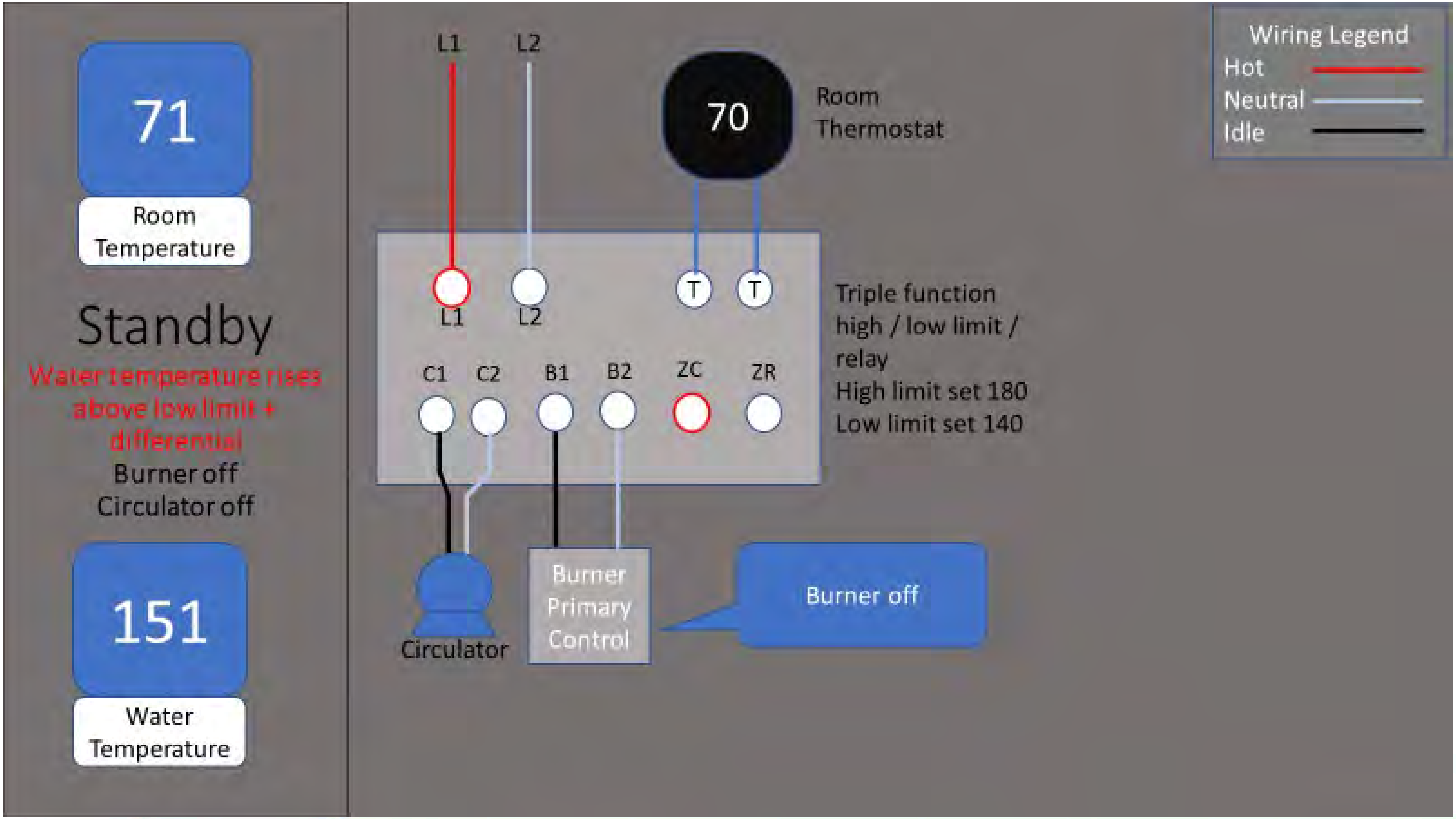
Demonstration

Triple Function Boiler Temperature Controls

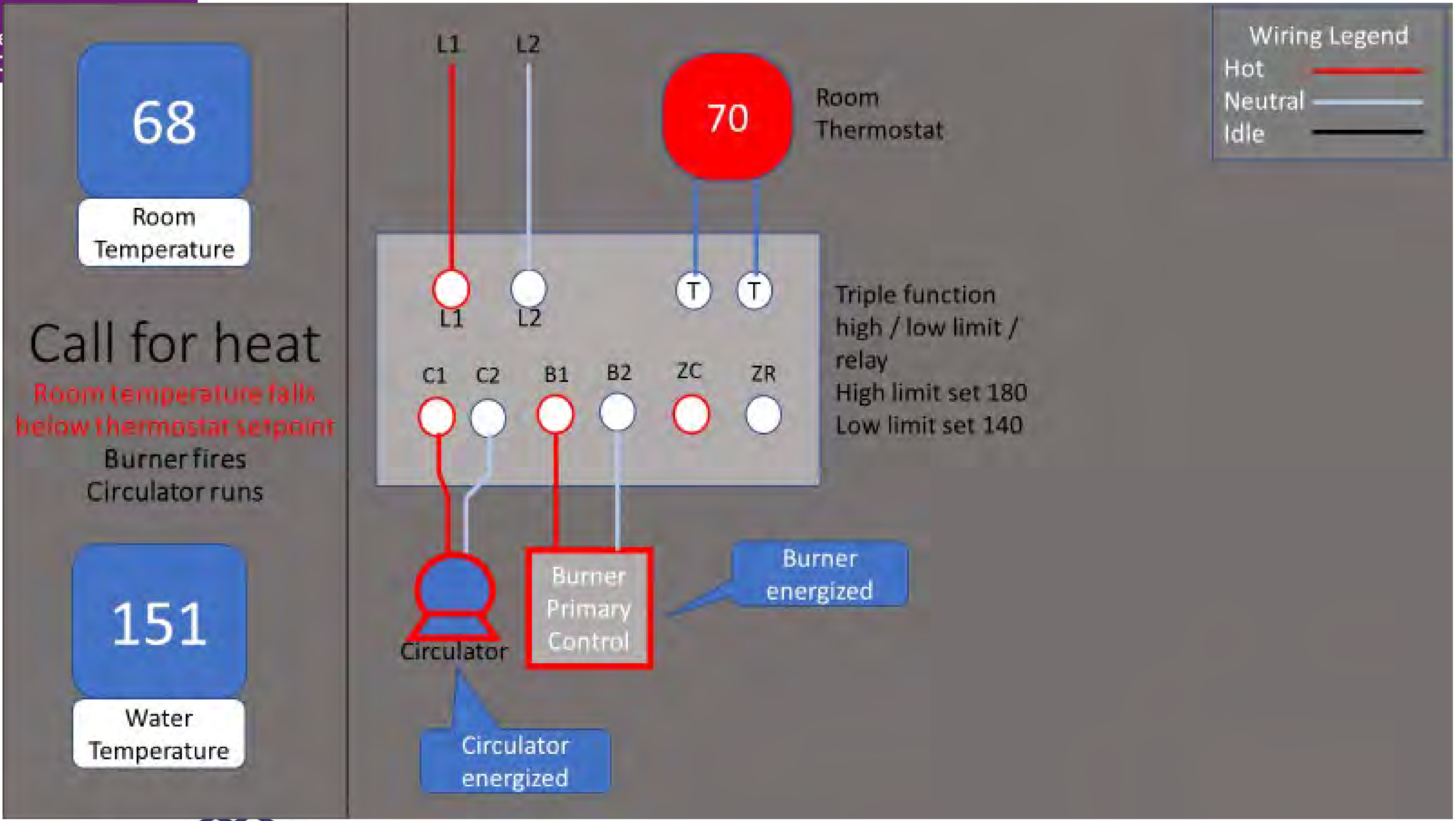


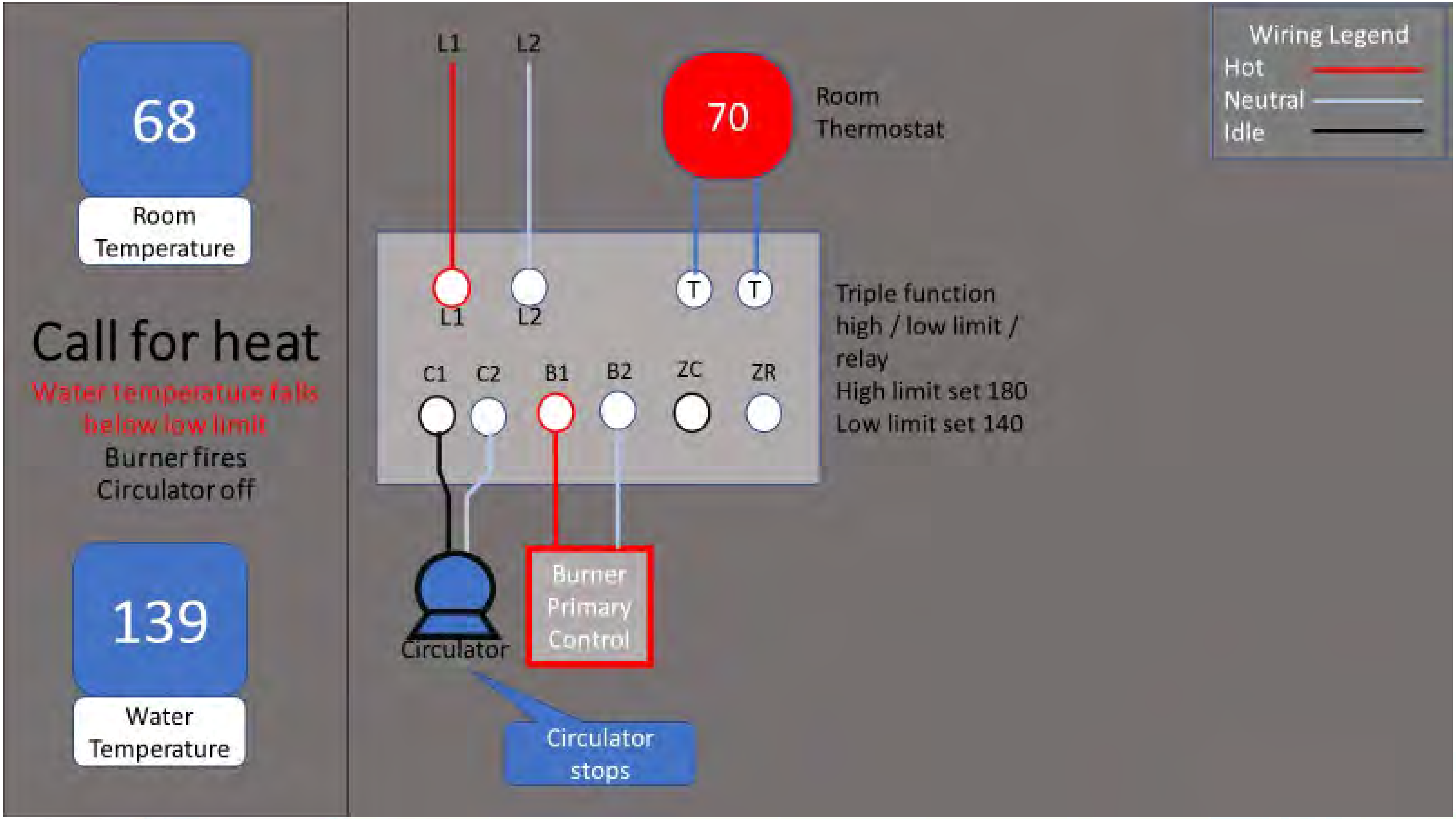
71
Room Temperature
Standby
Burner off
Circulator off
150
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
T
T
L1
L2
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control

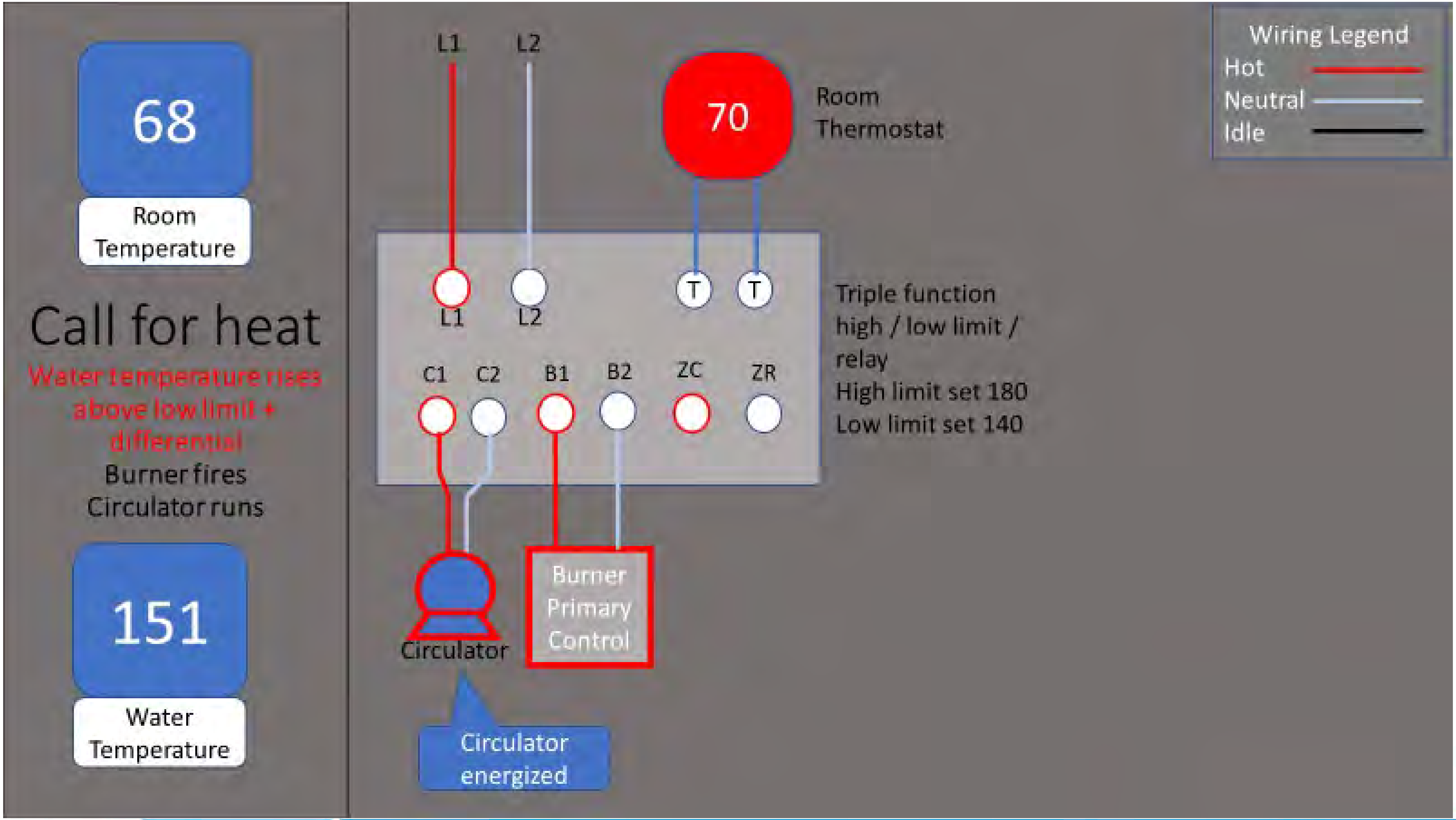

71
Room Temperature
Standby
Water temperature falls below low limit
Burner fires
Circulator off
139
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Burner energized

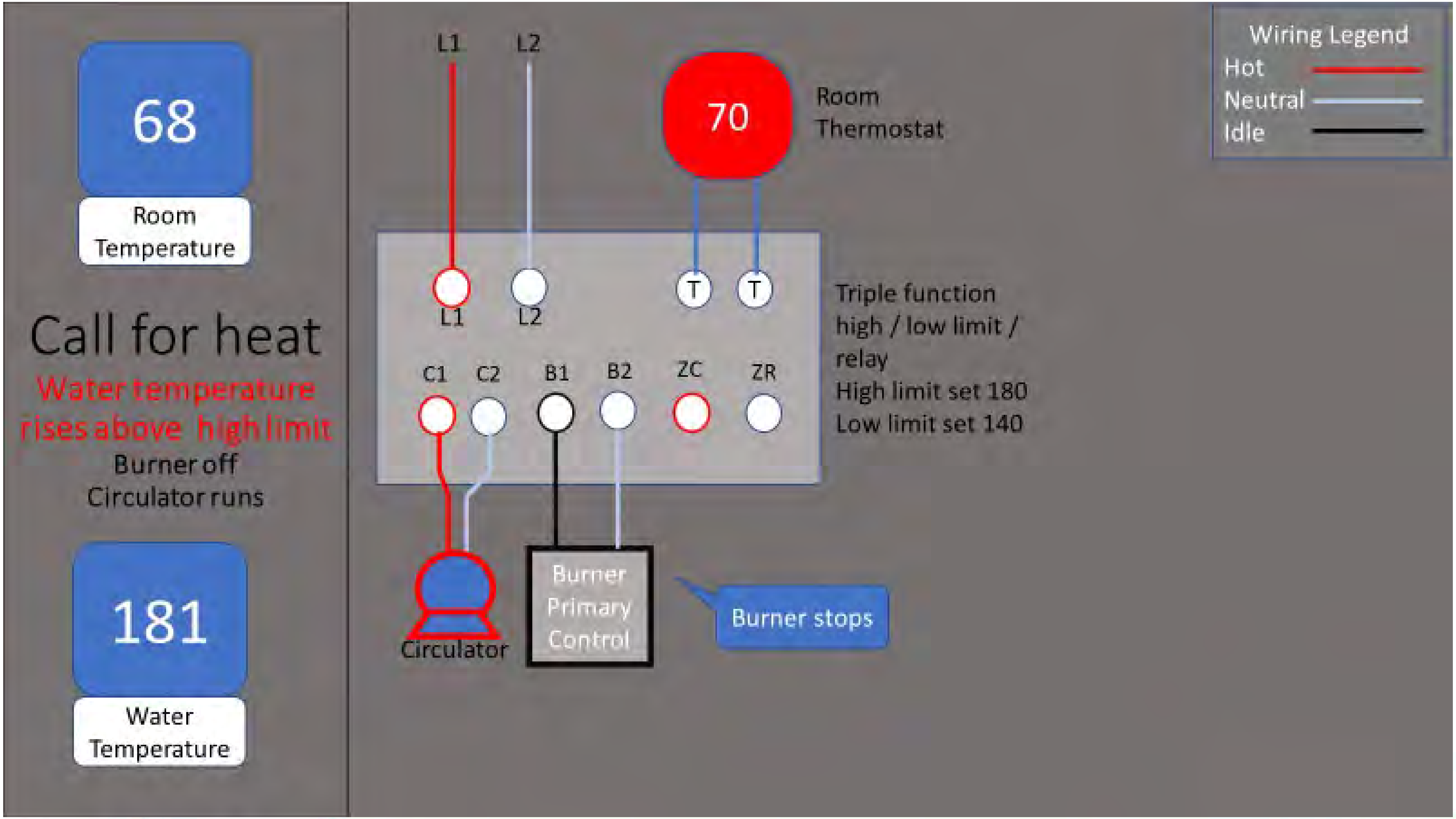


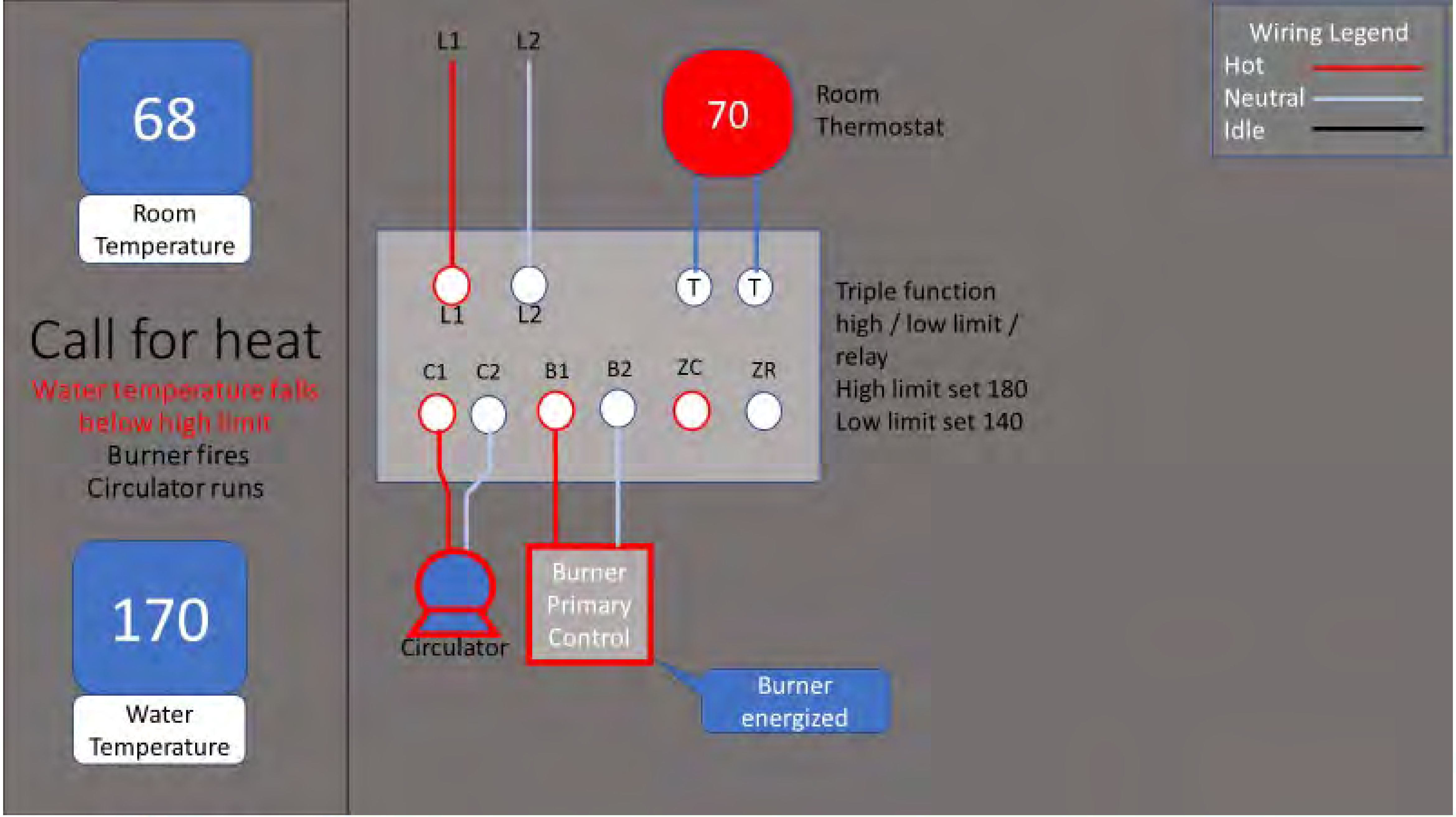
71
Room Temperature
Standby
Water temperature rises above low limit + differential
Burner off
Circulator off
151
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
T
T
L1
L2
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Burner off

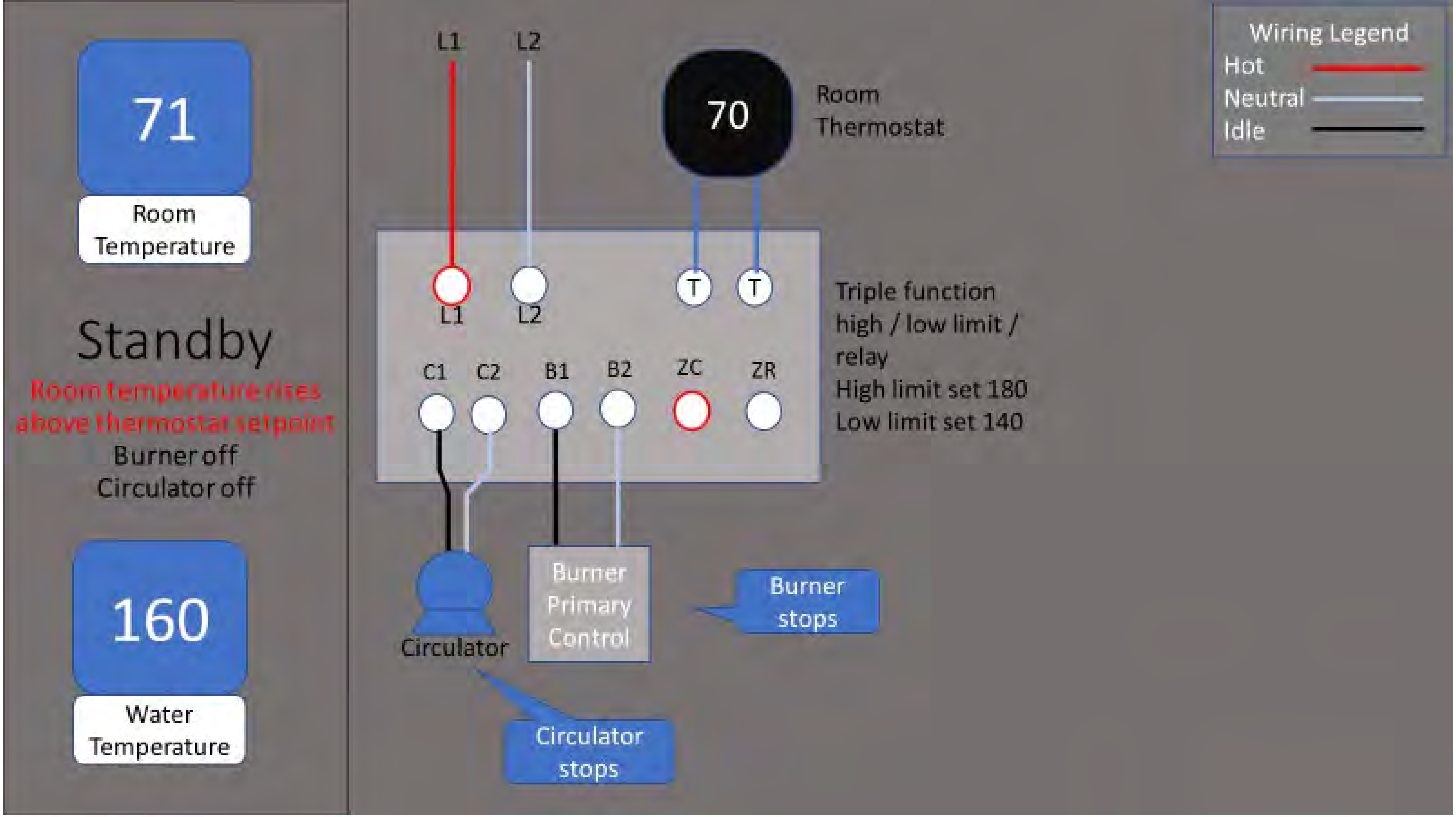

68
Room Temperature
Call for heat
Room temperature falls below thermostat setpoint
Burner fires
Circulator runs
151
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Burner energized
Circulator energized


68
Room Temperature
Call for heat
Water temperature falls below low limit
Burner fires
Circulator off
139
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Circulator stops


68
Room Temperature
Call for heat
Water temperature rises above low limit + differential
Burner fires
Circulator runs
151
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
T
T
L1
L2
C1
C2
B1
B2
ZC
ZR
Triple function high / low limit / relay
High limit set 180
Low limit set 140
Circulator
Burner Primary Control
Circulator energized

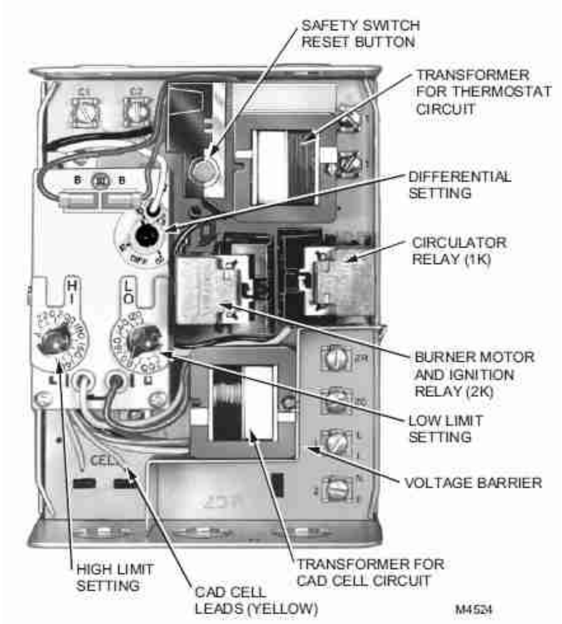

68
Room Temperature
Call for heat
Water temperature rises above high limit
Burner off
Circulator runs
181
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Burner stops


68
Room Temperature
Call for heat
Water temperature falls below high limit
Burner fires
Circulator runs
170
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Burner energized


71
Room Temperature
Standby
Room temperature rises above thermostat setpoint
Burner off
Circulator off
160
Water Temperature
L1
L2
70
Room Thermostat
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
Triple function high / low limit / relay
High limit set 180
Low limit set 140
C1
C2
B1
B2
ZC
ZR
Circulator
Burner Primary Control
Burner stops
Circulator stops

Triple Funct. Cont. w/Integral Primary Control

These are produced to reduce costs for manufacturers. The functionality is identical to other triple combination controls.

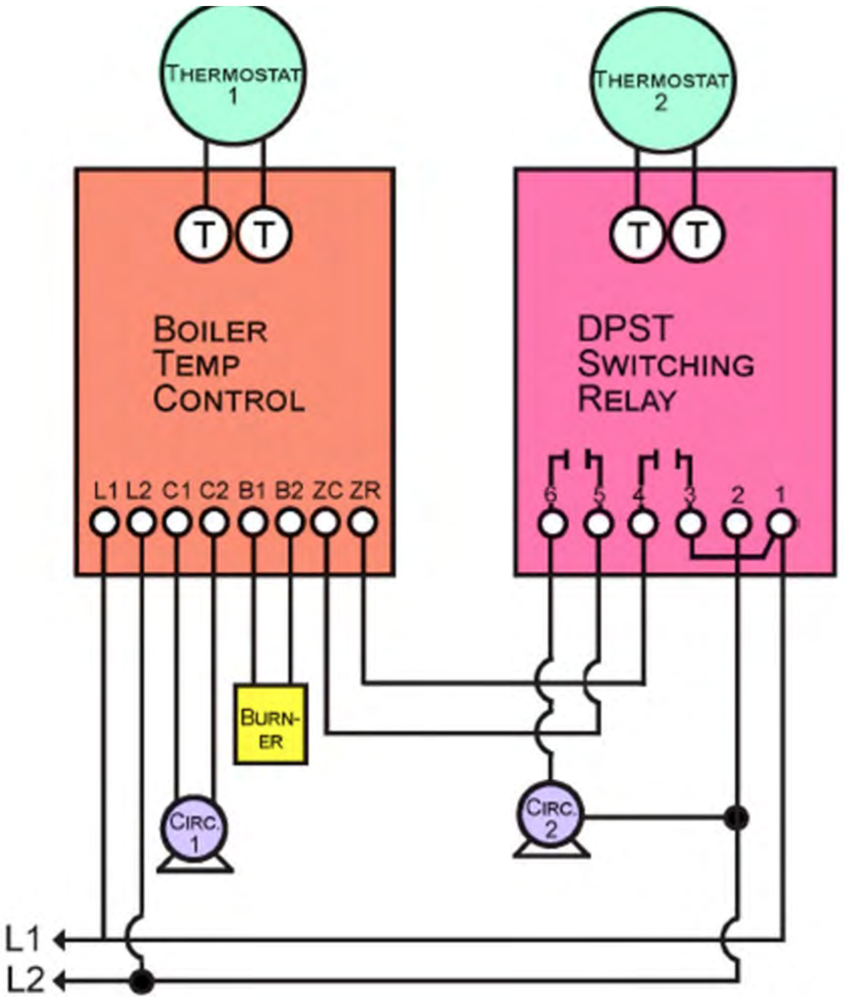


They are expensive to replace & when they fail, they can be replaced with a new boiler temperature control and a separate primary control.

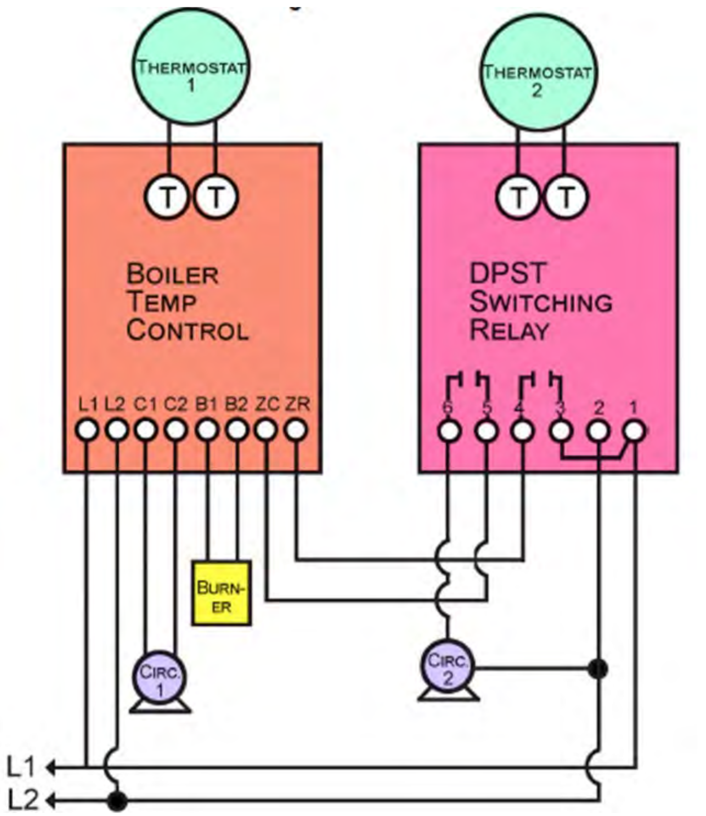
Adding Zones with Circulators

Full zoning control of multiple circulators can be achieved using switching relays.

The relays need to be at least DPST to provide input to the boiler temperature control on the ZR terminal and to provide domestic hot water protection through the ZC terminal.



Call for Heat



When thermostat 2 closes, current flows from terminal 3 to terminal 4, and from terminal 4 to terminal ZR in the boiler temperature control.

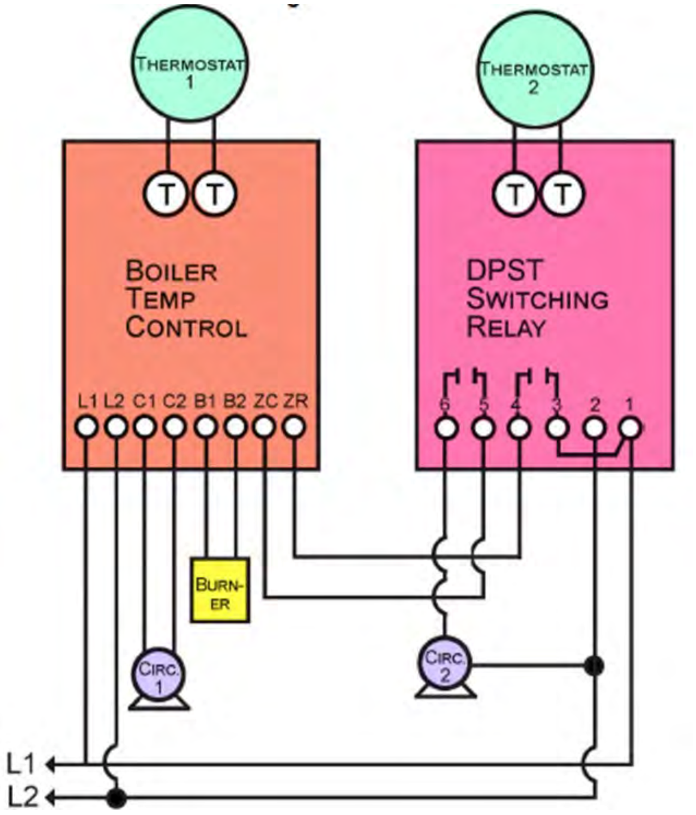
The temperature control recognizes power on ZR as an external zone calling for heat and powers B1 to start the burner.

Terminals 5 and 6 also close allowing current to flow from ZC through terminals 5 & 6 to power the zone 2 circulator.

Call for Heat (continued)

If the water temperature falls below the low limit during the call for heat, power to the ZC terminal will be held off until the temperature rises above the low limit setting.

When thermostat 2 opens, the zone 2 circulator stops and the control returns to standby unless other zones are still calling for heat.



Multiple Zones

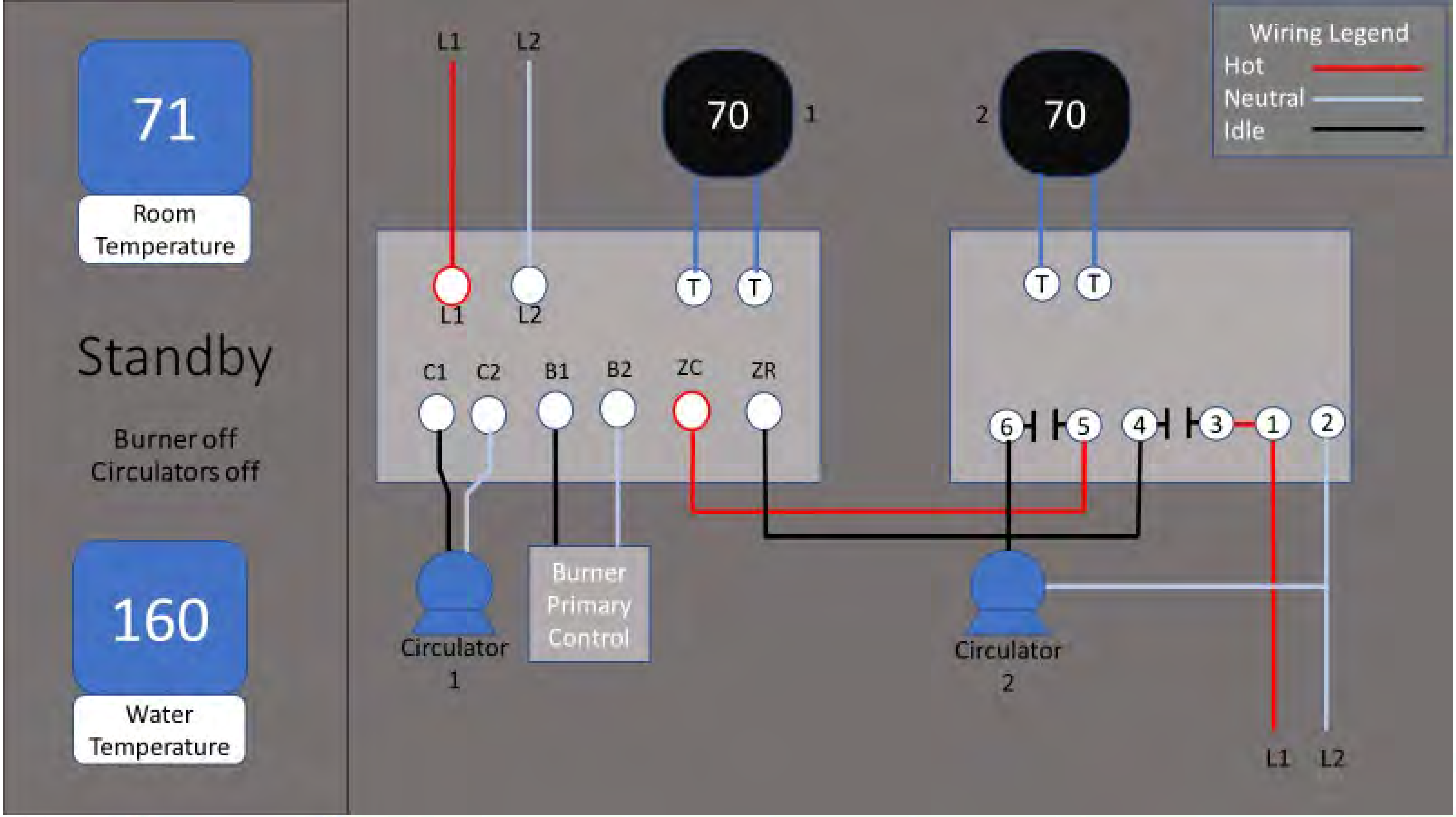
When multiple extra zones are needed, they can be added by using multiple switching relays wired in parallel.

However, “zone panels” that can control multiple thermostats and circulators are available. They provide a cleaner and neater installation and are easier to troubleshoot.

Demonstration

Triple Function Boiler Control

with additional circulator zone


71
Room Temperature
Standby
Burner off
Circulators off
160
Water Temperature
L1
L2
70
1
2
70
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
T
T
C1
C2
B1
B2
ZC
ZR
6
5
4
3
1
2
Circulator 1
Burner Primary Control
Circulator 2
L1
L2

68

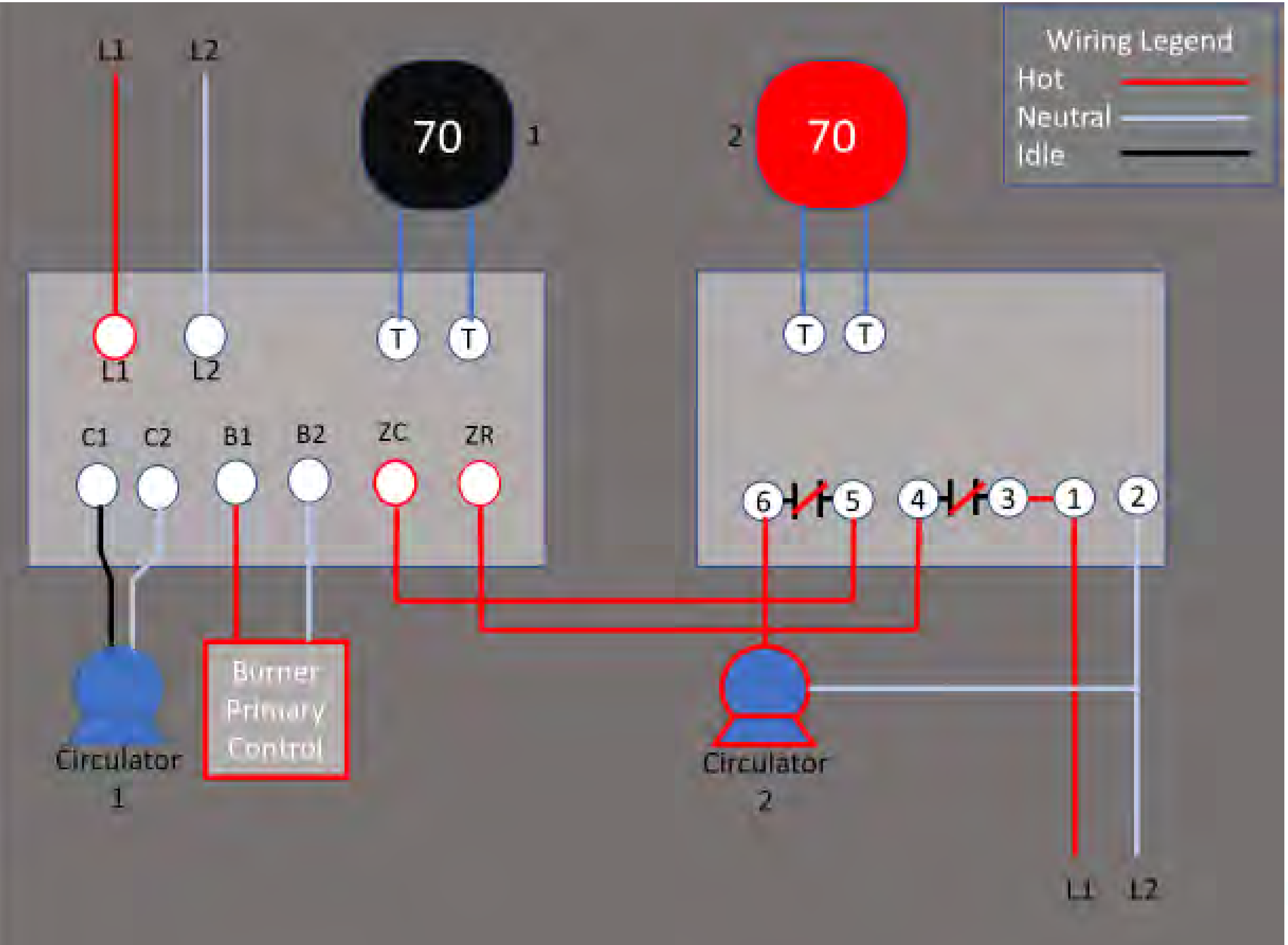
Room Temperature

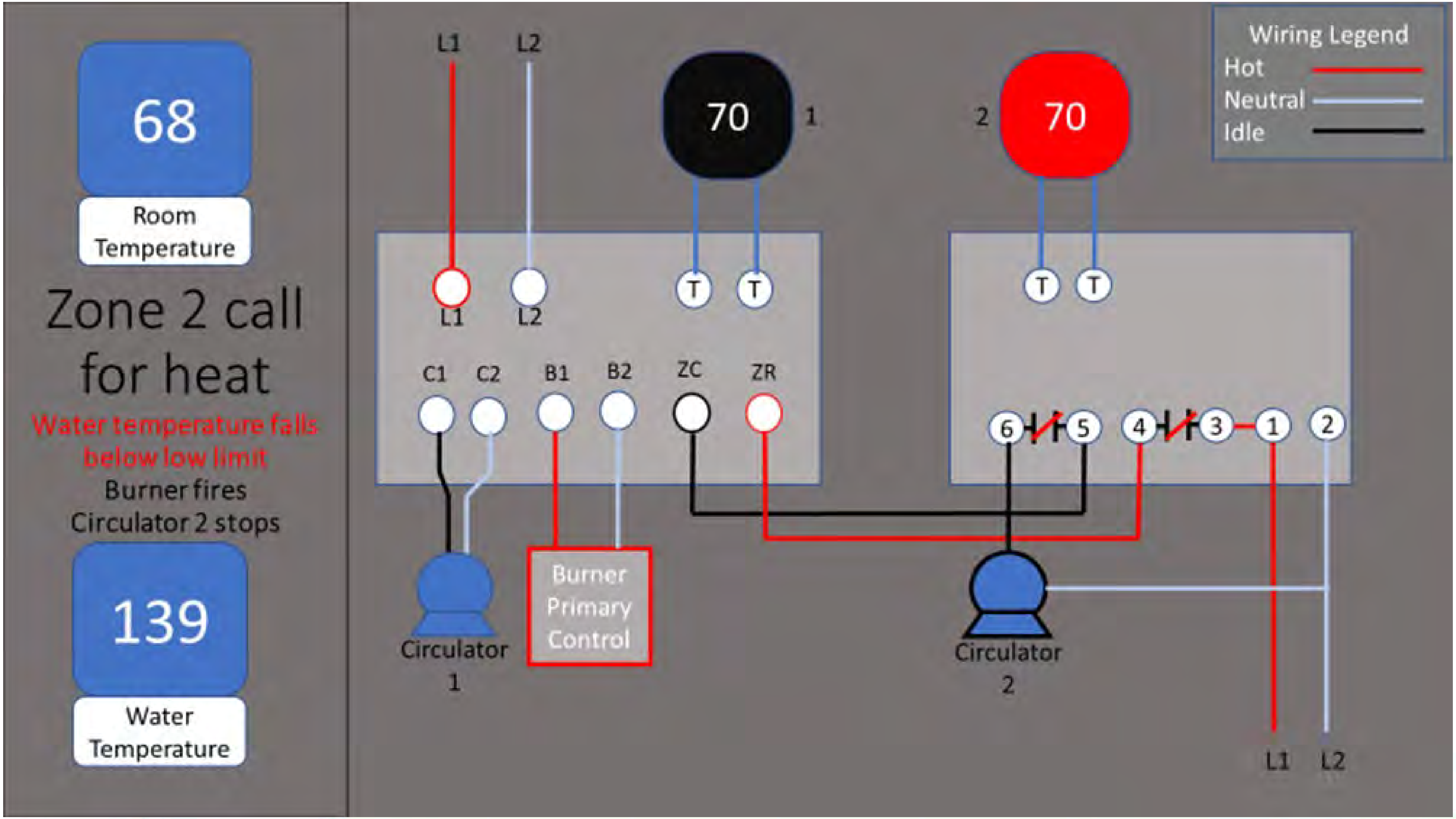
Zone 2 call for heat

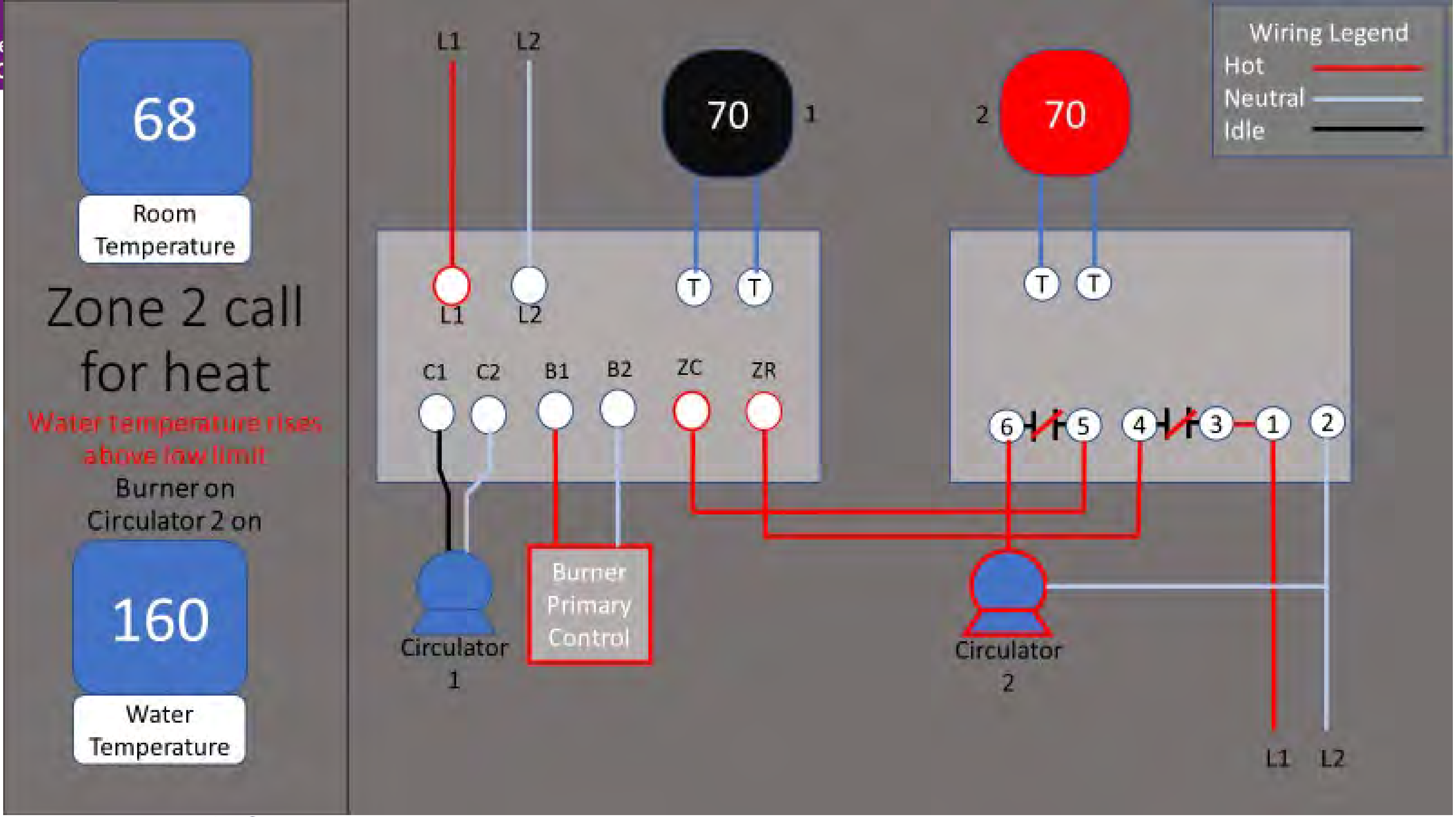
Burner on
Circulator 2 on

160

Water Temperature




68
Room Temperature
Zone 2 call for heat
Water temperature falls below low limit
Burner fires
Circulator 2 stops
139
Water Temperature
L1
L2
70
1
2
70
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
T
T
C1
C2
B1
B2
ZC
ZR
6
5
4
3
1
2
Circulator 1
Burner Primary Control
Circulator 2
L1
L2


68
Room Temperature
Zone 2 call for heat
Water temperature rises above low limit
Burner on
Circulator 2 on
160
Water Temperature
L1
L2
70
1
2
70
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
T
T
C1
C2
B1
B2
ZC
ZR
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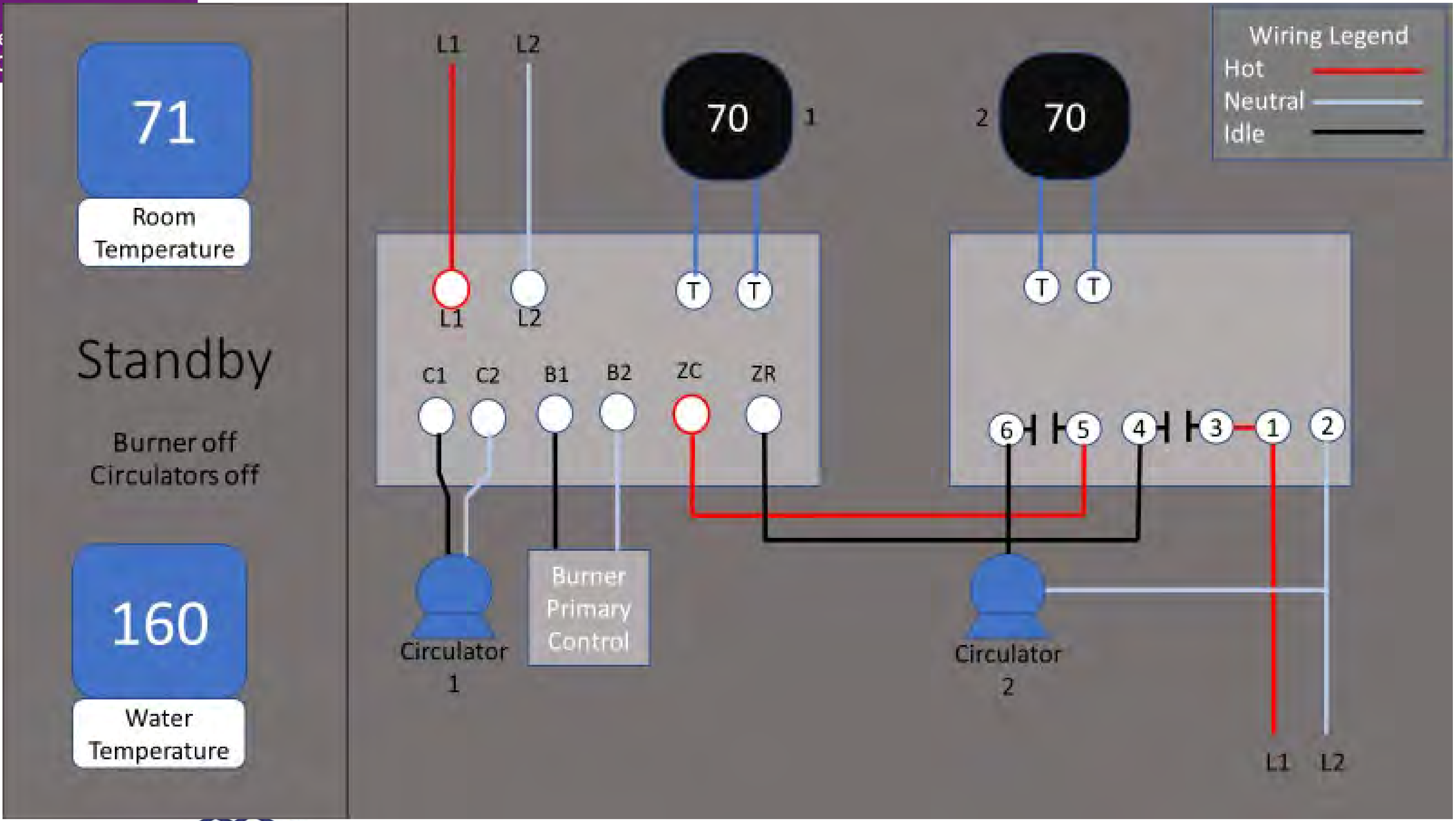
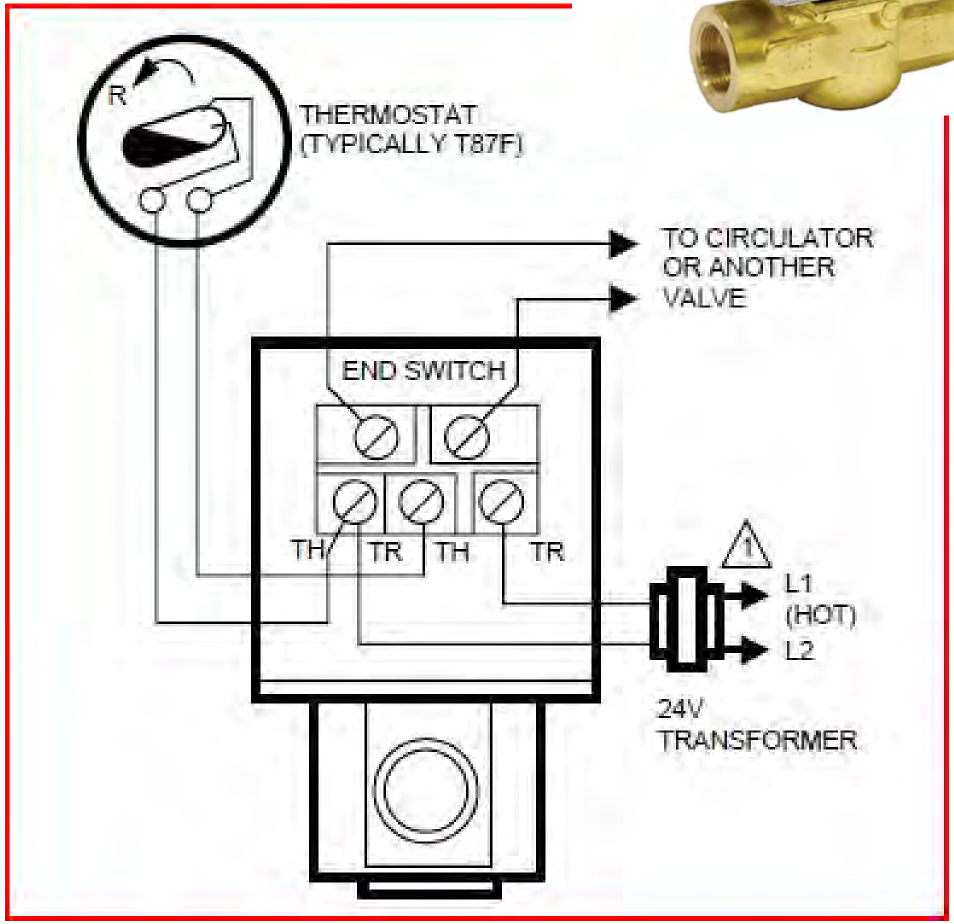
4
3
1
2
Circulator 1
Burner Primary Control
Circulator 2
L1
L2


71
Room Temperature
Standby
Burner off
Circulators off
160
Water Temperature
L1
L2
70
1
2
70
Wiring Legend
Hot
Neutral
Idle
L1
L2
T
T
T
T
C1
C2
B1
B2
ZC
ZR
6
5
4
3
1
2
Circulator 1
Burner Primary Control
Circulator 2
L1
L2

Adding Zones with Zone Valves

Wiring zone valves often seems complicated, BUT it's quite simple. The wiring is divided into two sections:

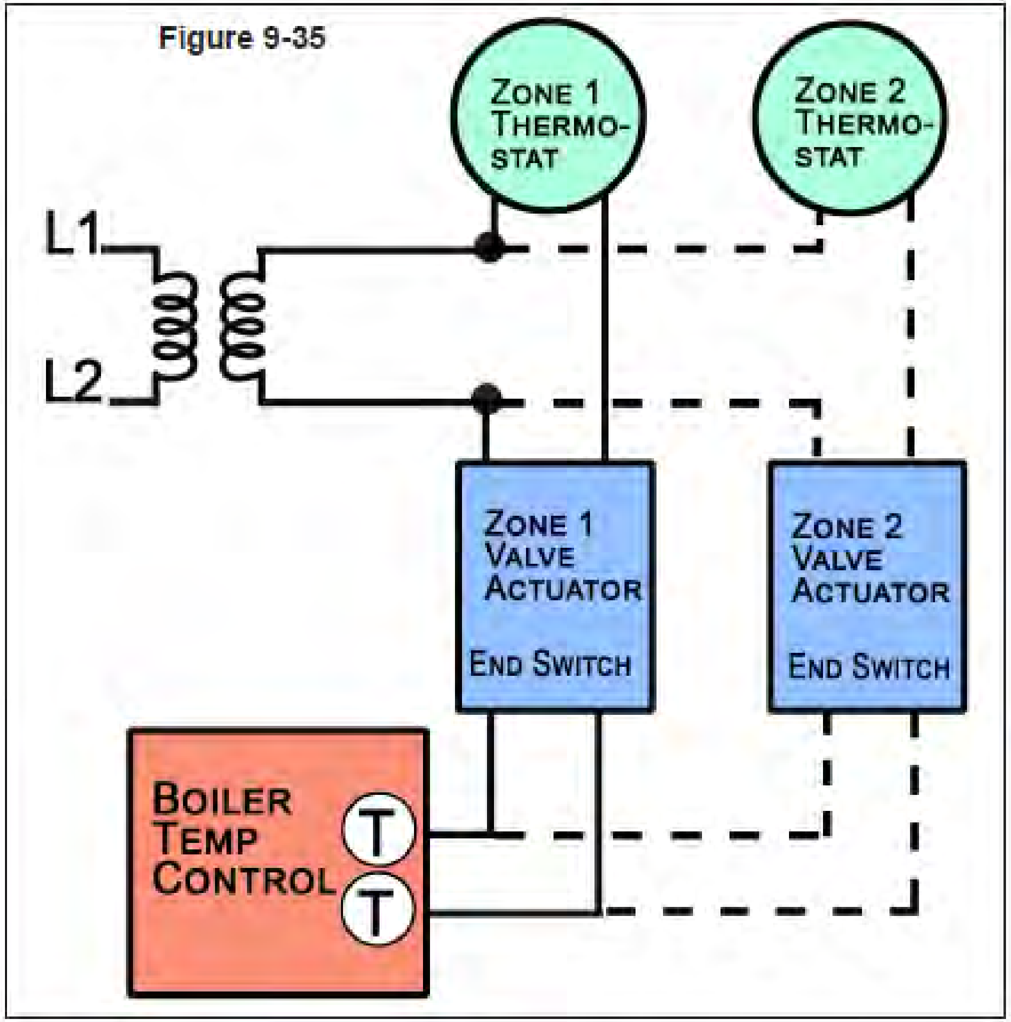
1. An actuator (motor)which opens and closes the valve.
2. An end switch which makes contact when the valve opens to complete a circuit.



Actuator Motor Wiring

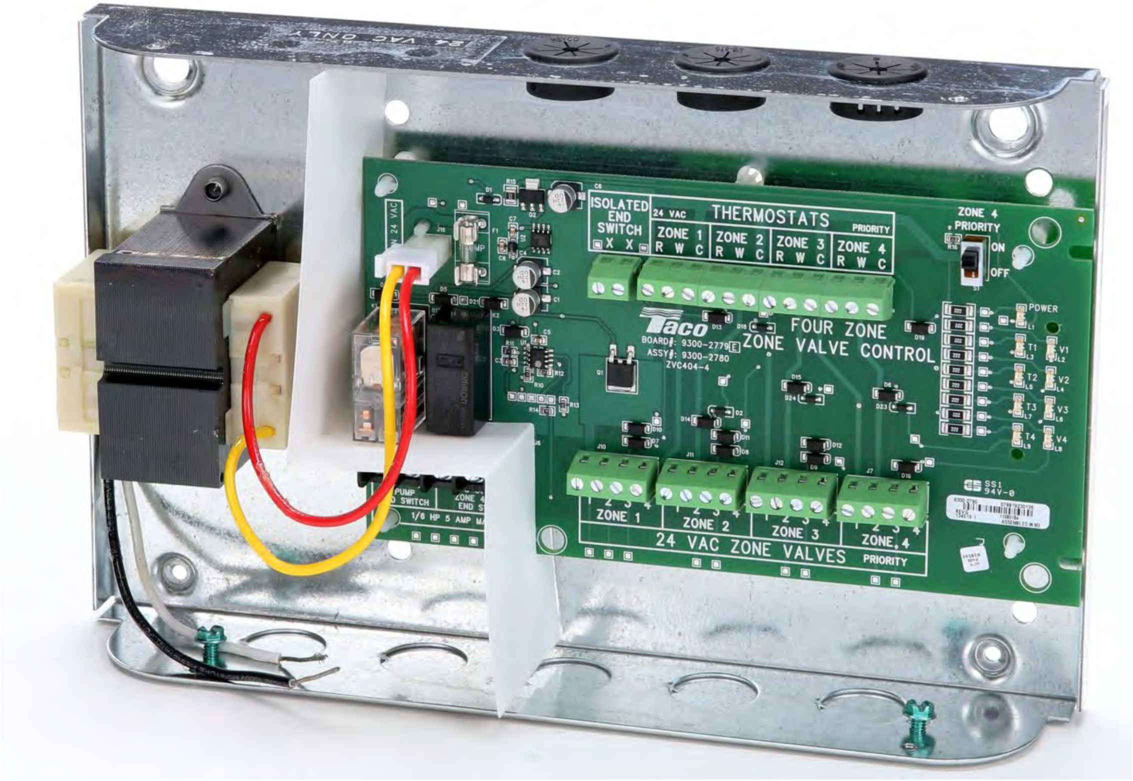
Power flows from the 24V transformer to the thermostat to the zone valve actuator and then returns to the transformer.

Additional zones (dotted lines)can be wired in parallel.



Actuator Motor Wiring

Or, a "zone valve panel" similar to those used for circulator zoning can be used to help organize the wiring and make troubleshooting easier.

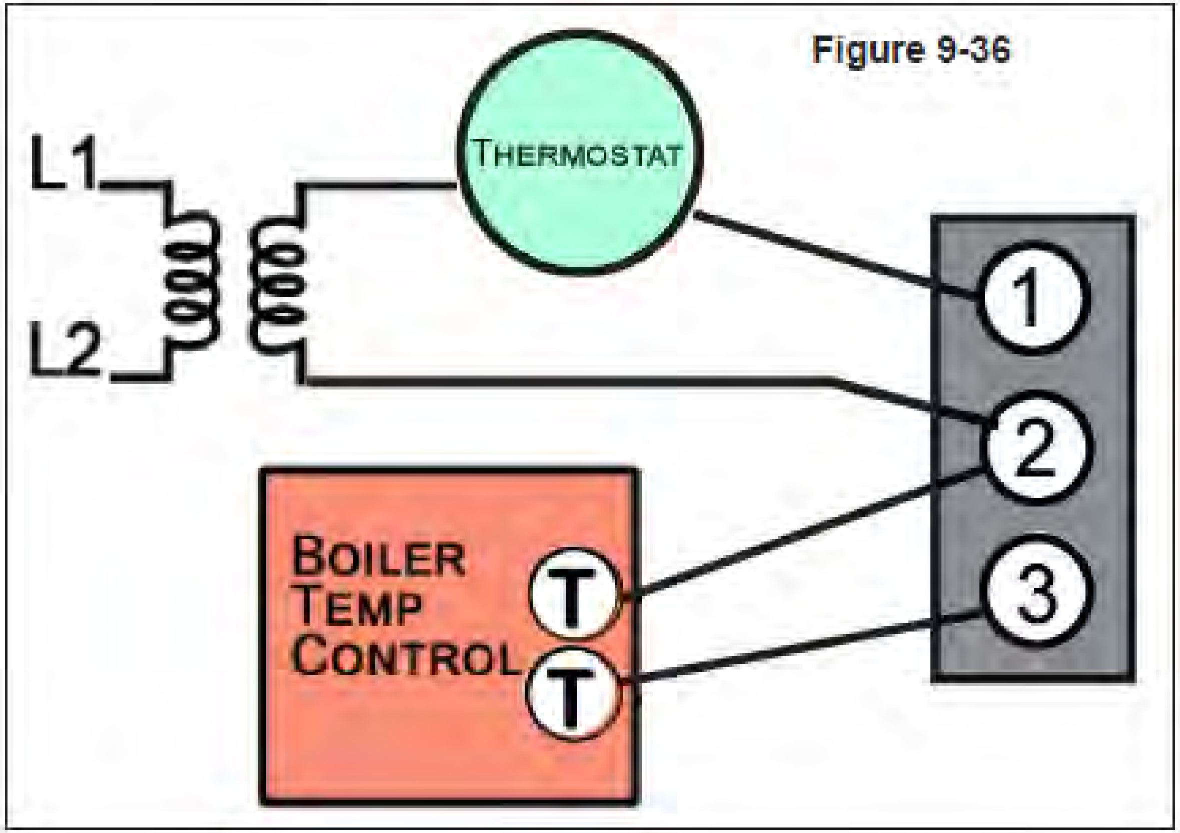


4 Connection VS 3 Connection

Some zone valves have 4 wire connection, and some have 3.

The 3 connection valves are wired the same internally but share a common connection on the terminal board.

With these 3 connection valves, terminals 1-2 control the actuator and terminals 2-3 are connected to the end switch.



Zone Valve Operation

Standby: Valve is closed, and the end switch is open.

Call for heat: When the thermostat closes, it completes the circuit through the actuator, opening the valve.

When the valve opens, the end switch contacts close, completing the circuit between T-T in the temperature control to operate the burner and circulator.

When the thermostat is satisfied, the actuator closes the valve and the end switch contacts open, putting everything back to standby.

Review Questions:

- How do switches work in limits and thermostats?
- How would you draw a basic oil burner circuit with switches, a motor, and an ignition transformer?
- How are thermostats wired for warm air furnaces, steam boilers, hydronic boilers, and zone valve actuators?
- What do heat anticipators do and how do you adjust them?
- What are good locations for thermostats and how do you mount them?
- How does a warm air limit control normally work and what can cause problems?
- How does an electronic fan timer normally work and what can cause problems?

Review Questions:
Continued

- What is the difference between a pressuretrol and a vaporstat?
- How do you correctly install a pressuretrol with a pigtail?
- What are pressuretrol cut-in and cut-out settings and how do you adjust the differential?
- How do switches control a heating circulator?
- Why are low water cut offs important and where do you find them on a wiring diagram?
- How do boiler temperature controls work and where do you find them on a wiring diagram?
- What are the different ways to add zones to a system?

End of Chapter 9

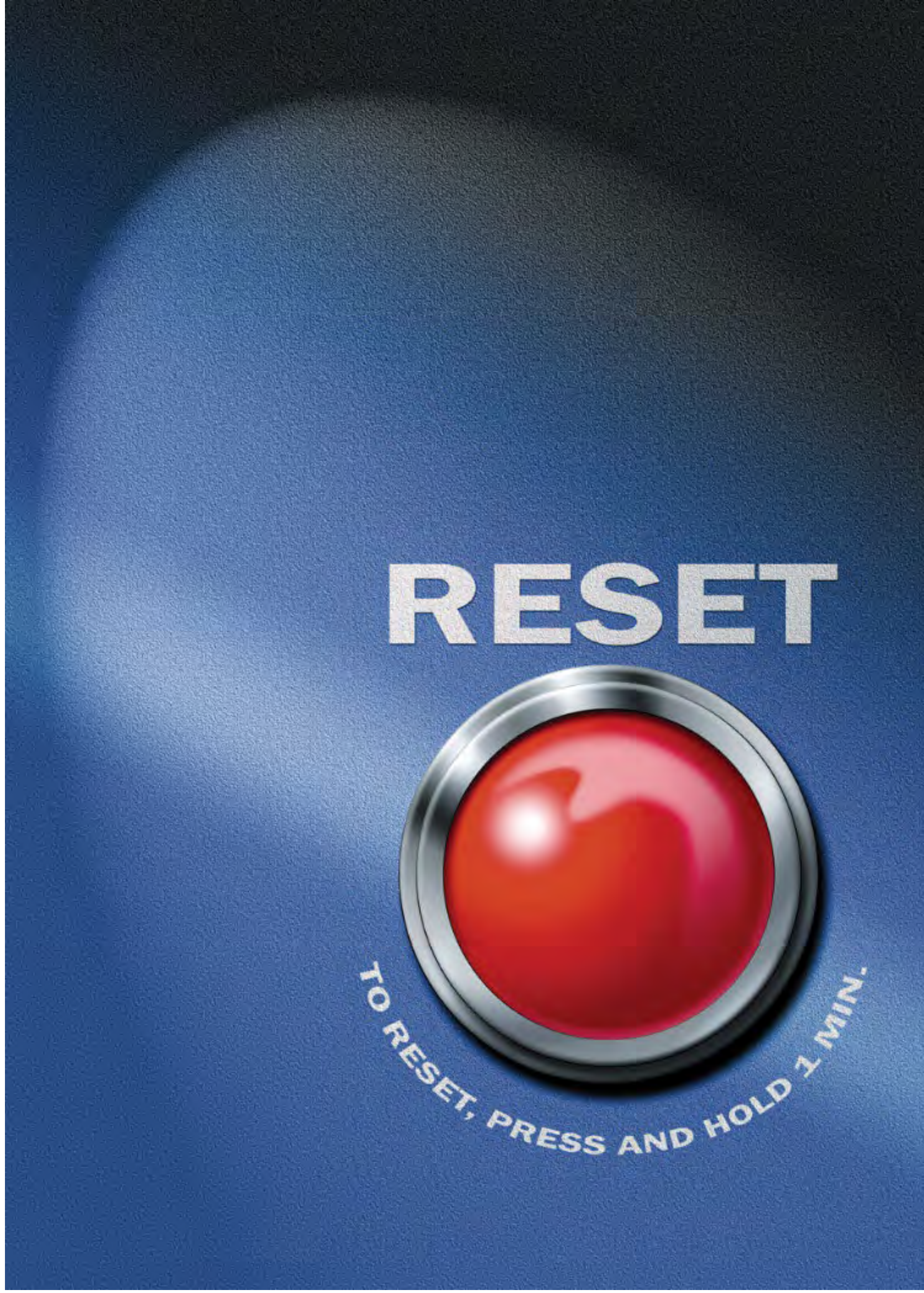
NORA Technician Certification

Review

Bob O’Brien, NORA Director of Education

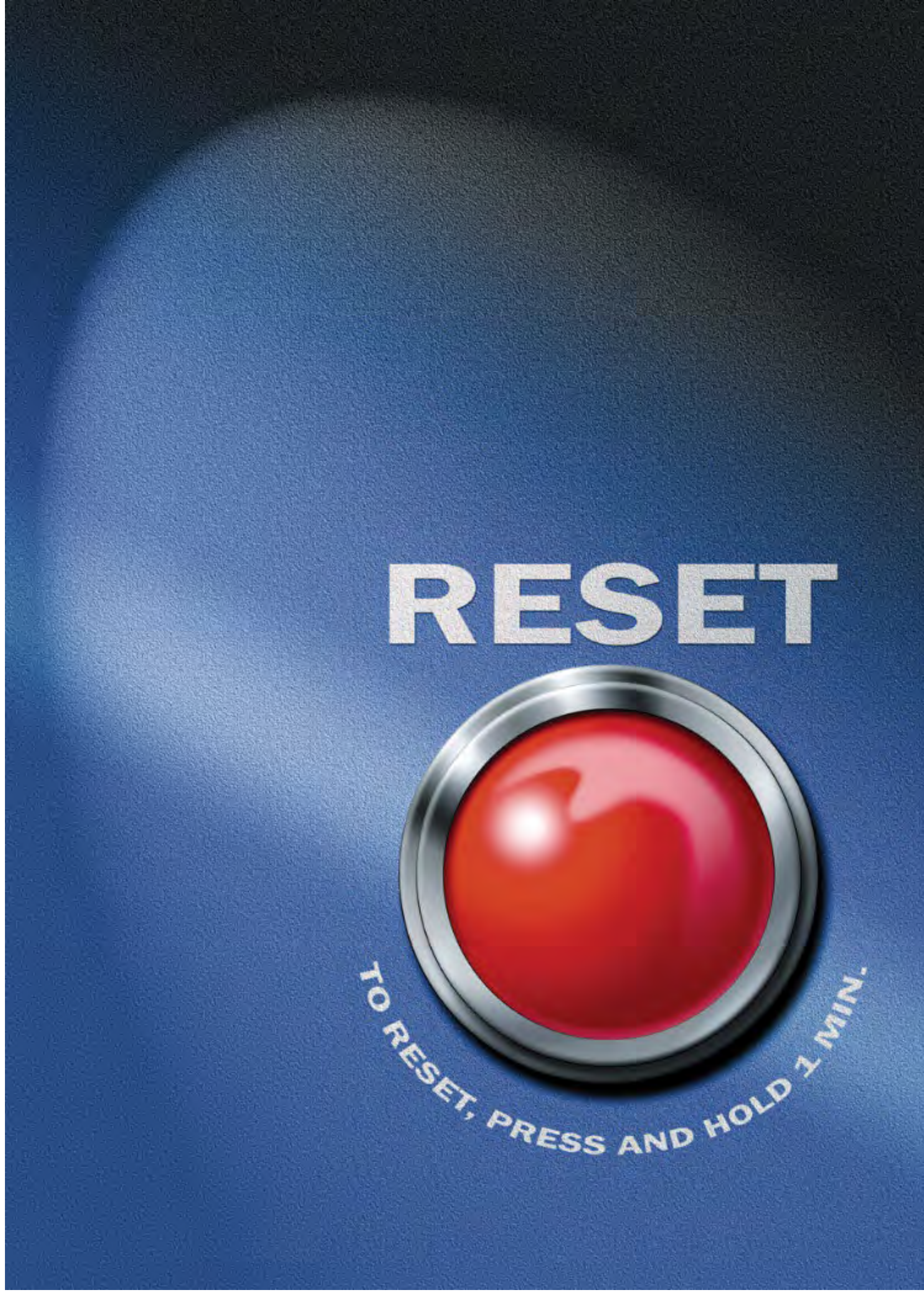
Chapter 10

Primary Controls



At the end of this lesson, you will be able to:

- Explain how a primary control works and how it is connected in warm air, steam, and hydronic systems
- Explain the different flame-sensing devices
- Describe the two ignition modes and why one is preferred
- Troubleshoot a stack relay? Upgrade!
- Describe how a cadmium sulfide (cad cell) primary controls the ignitor, oil solenoid valve, and motor
- Perform a cad cell check
- Explain the differences between a first- and second-generation cad cell
- Explain why obsolete flame-sensing devices should be replaced



Primary Controls

The safe, automatic operation of a heating system is dependent on the interaction between:

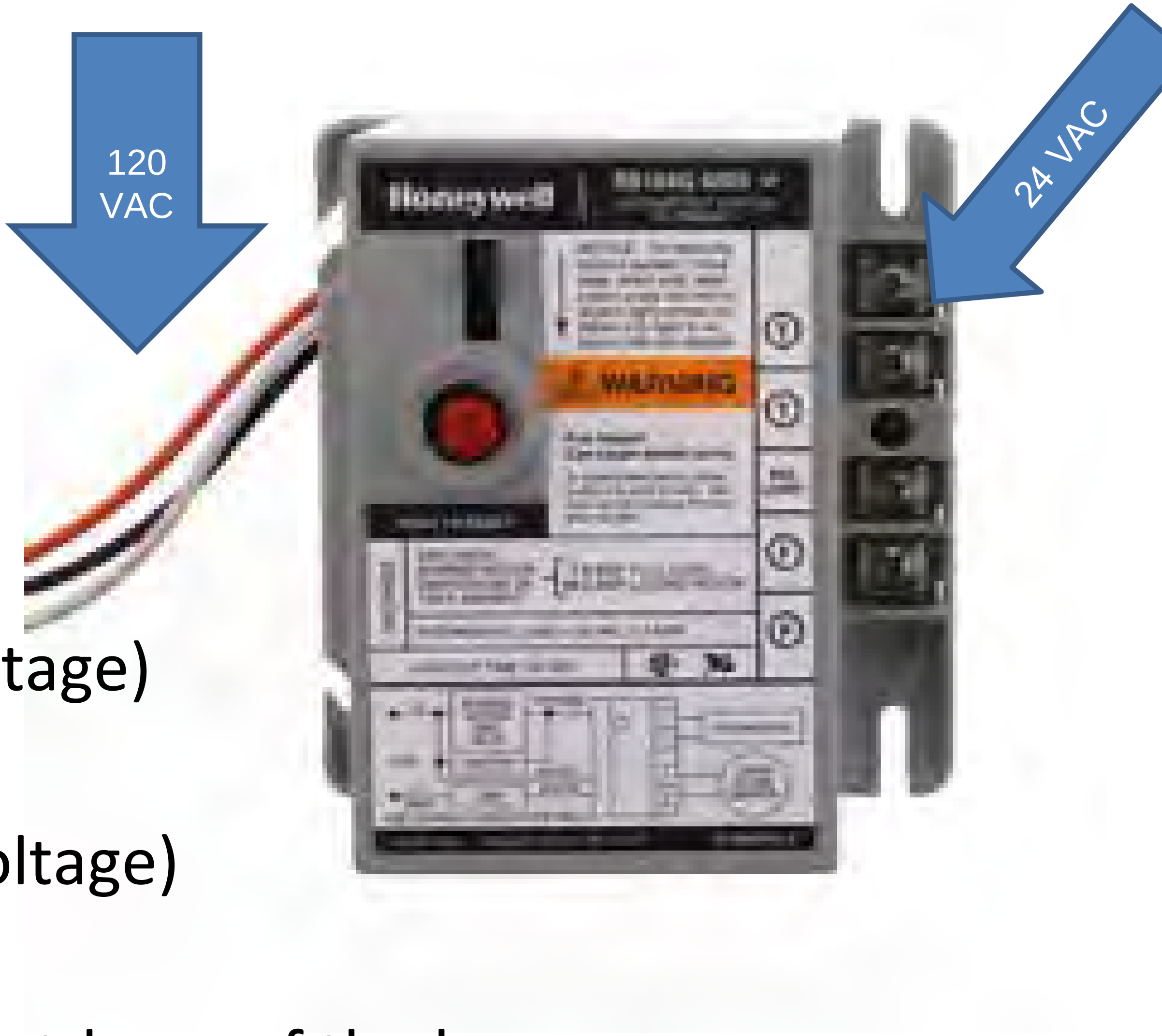
- The thermostat, which opens and closes a circuit based on the temperature in the heated space
- The limit control, which opens and closes a circuit based on the temperature or pressure changes in the appliance
- The primary control, which regulates the operation of the burner

Primary Controls

In a typical Oilheat system, line voltage flows from the electric panel:

1. To a remote switch located away from the appliance,
2. To a service switch at the appliance,
3. To the limit control,
4. To the primary control,
5. To the burner.

Primary Controls



Functions

Primary controls have 3 main functions:

1. To respond to the thermostat. (low voltage)

2. To respond to the limit control. (line voltage)

3. To control the startup, run cycle and shutdown of the burner.

Primary Controls

It Accomplishes these Functions by

- Reacting to the presence or absence of flame
- Managing burner startup by checking for flame before energizing the ignition, motor and oil valve
- Supervising burner shut-down once the thermostat is satisfied or the limit control opens

Line Voltage

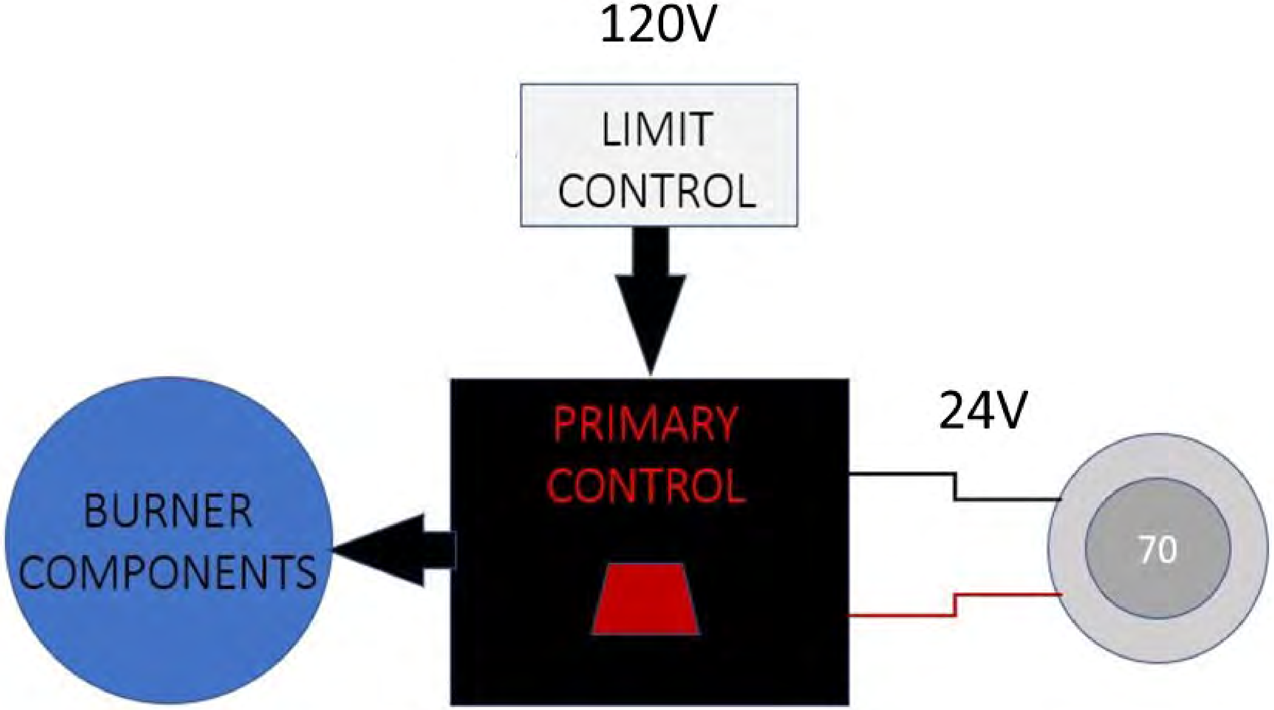
Line voltage is supplied to the PC through the limit control(s) when the temperature (in a water heater, boiler or furnace) or the pressure (in a steam boiler) is below the limit setting.

Note that low water cut-offs are also considered to be limit controls and that the water level in steam and hot water boilers must be at or above the required level for power to reach the burner.

Once the limit control(s) is satisfied, it opens the circuit, de-energizing the primary control and shutting down the burner.

Low Voltage

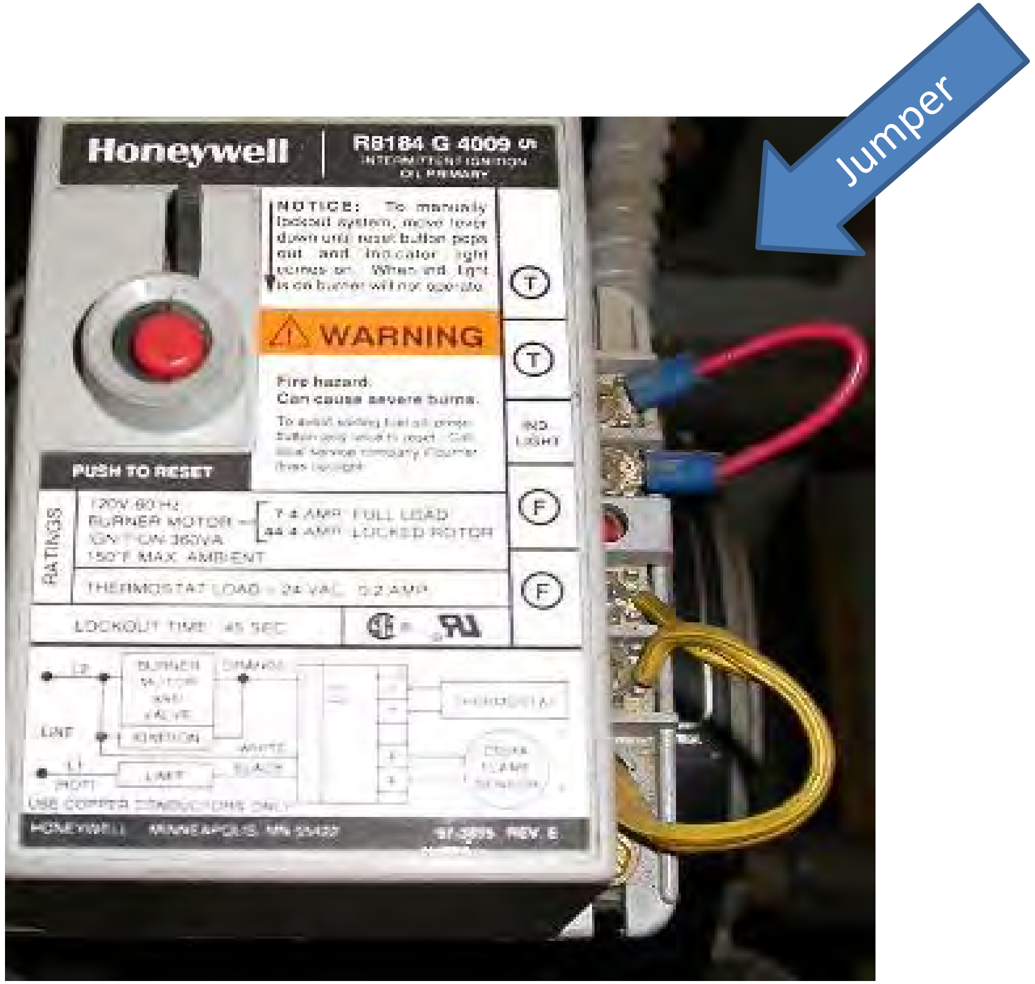
Most PCs have low voltage circuits to accommodate thermostats or other devices. The low voltage circuit is closed when the thermostat senses the need for an increase in room temperature and opens when the thermostat is satisfied.



For the PC to activate the burner, both the line and low voltage circuits must be closed. If either circuit is open , the PC will not activate the burner.

Low Voltage

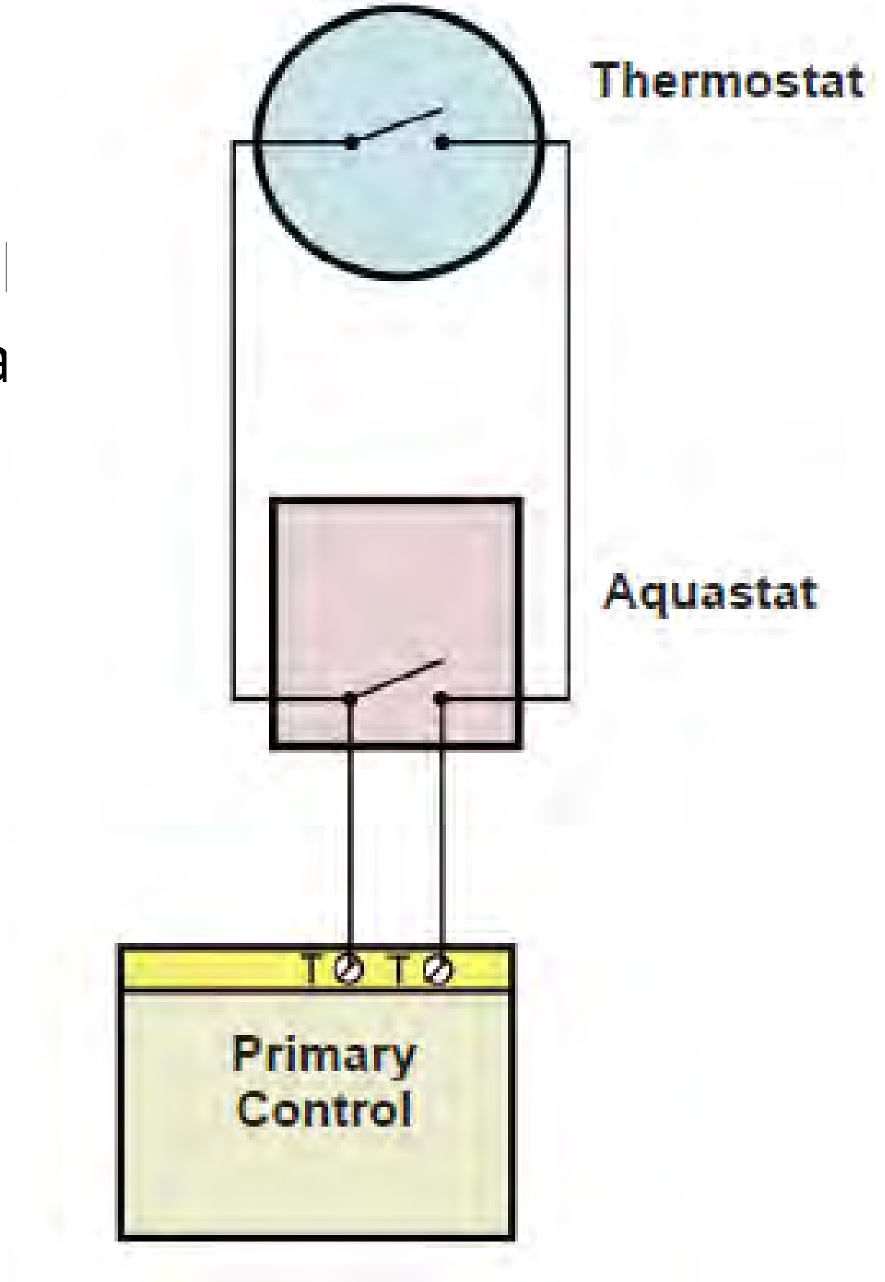
In circuits with line voltage thermostats, or with low voltage thermostats connected to controls other than the PC, a jumper is placed between the thermostat terminals, and the primary control is activated solely by the limit control.



Low Voltage

Some systems have an additional control wired in parallel to the thermostat that ca also complete the primary controls low voltage circuit.

For example, a steam boiler with a domestic hot water coil normally has an aquastat connected to T-T to maintain domestic hot water even when the thermostat is not calling for heat.



Flame Detection

- PCs detect both the presence and absence of flame
- They will NOT allow the burner to start if flame is sensed
- They shut the burner off if no flame is established on startup or if the flame is lost during the run cycle
- When the burner is shut off because no flame is detected it's referred to as "off on safety", "in safety" or "in lock out"……

Flame Detection

When the primary control goes off on safety, it must be manually reset before powering the burner


The amount of time that elapses from the start of a cycle in which flame is not detected to the time the control goes off on safety is referred to as “trial for ignition” (aka “safety timing”)

Ignition Modes

Intermittent Ignition

- Spark on whenever burner runs.
- Used to be called "constant ignition."
- Sometimes referred to as "constant duty ignition"

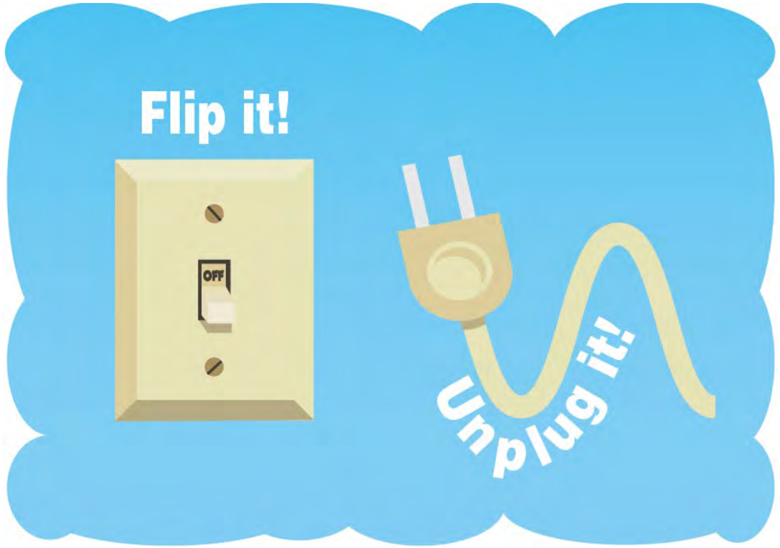
Interrupted Ignition

- Spark remains on for a short time at the beginning of each cycle.
- Turned off once flame is established.

Ignition Modes

Interrupted duty ignition is better because:

1. Combustion is quieter without the noise from the spark.
2. Ignition components last longer.
3. It uses less electricity.



Types of Primary Controls

There are two basic types of primary controls:

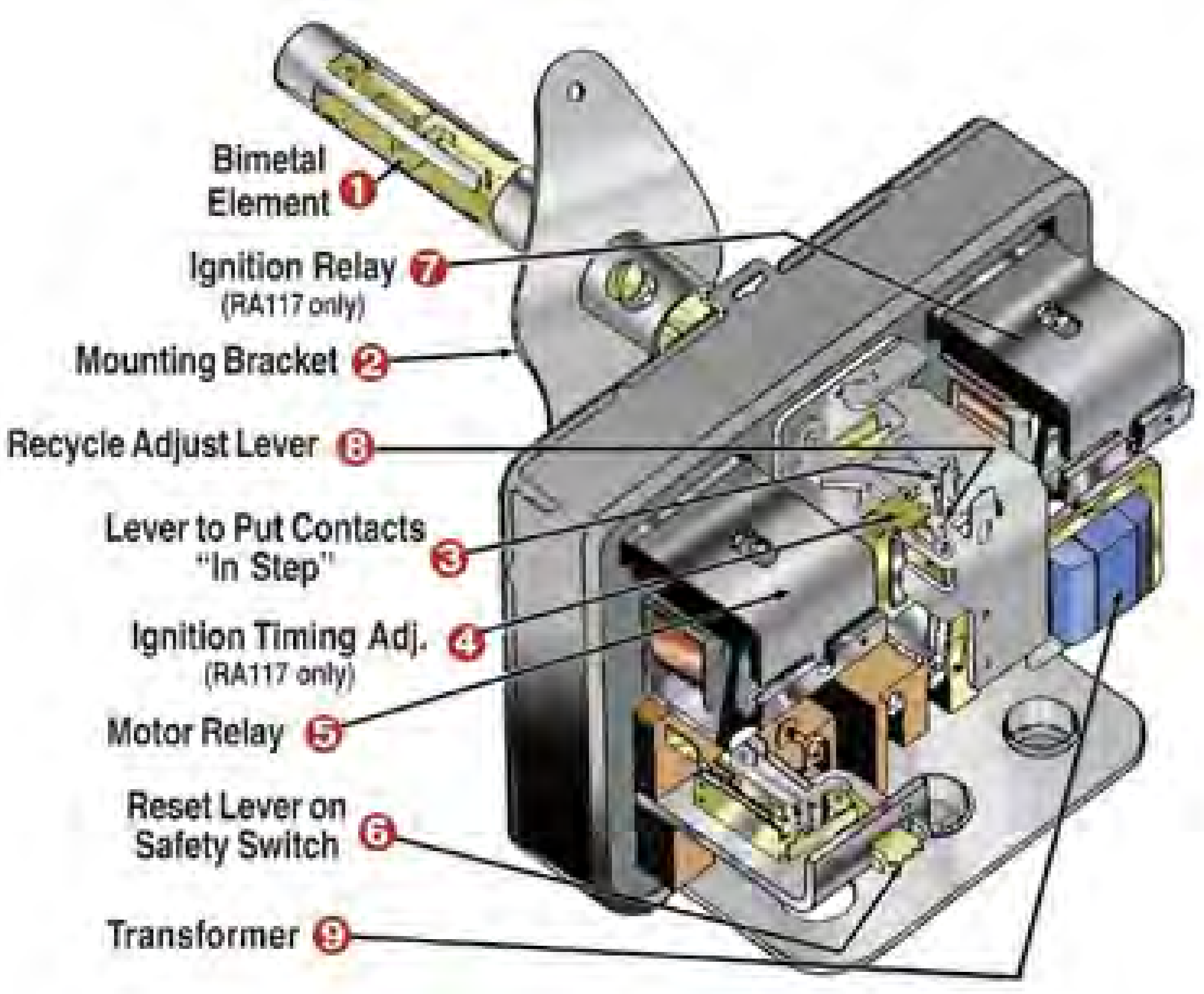
- **Thermo-mechanical**
  controls that have been obsolete for over 50 years although there are still some out there

- **Cad cell controls**
  there are several different types, the older models are also considered to be obsolete

Thermo-mechanical

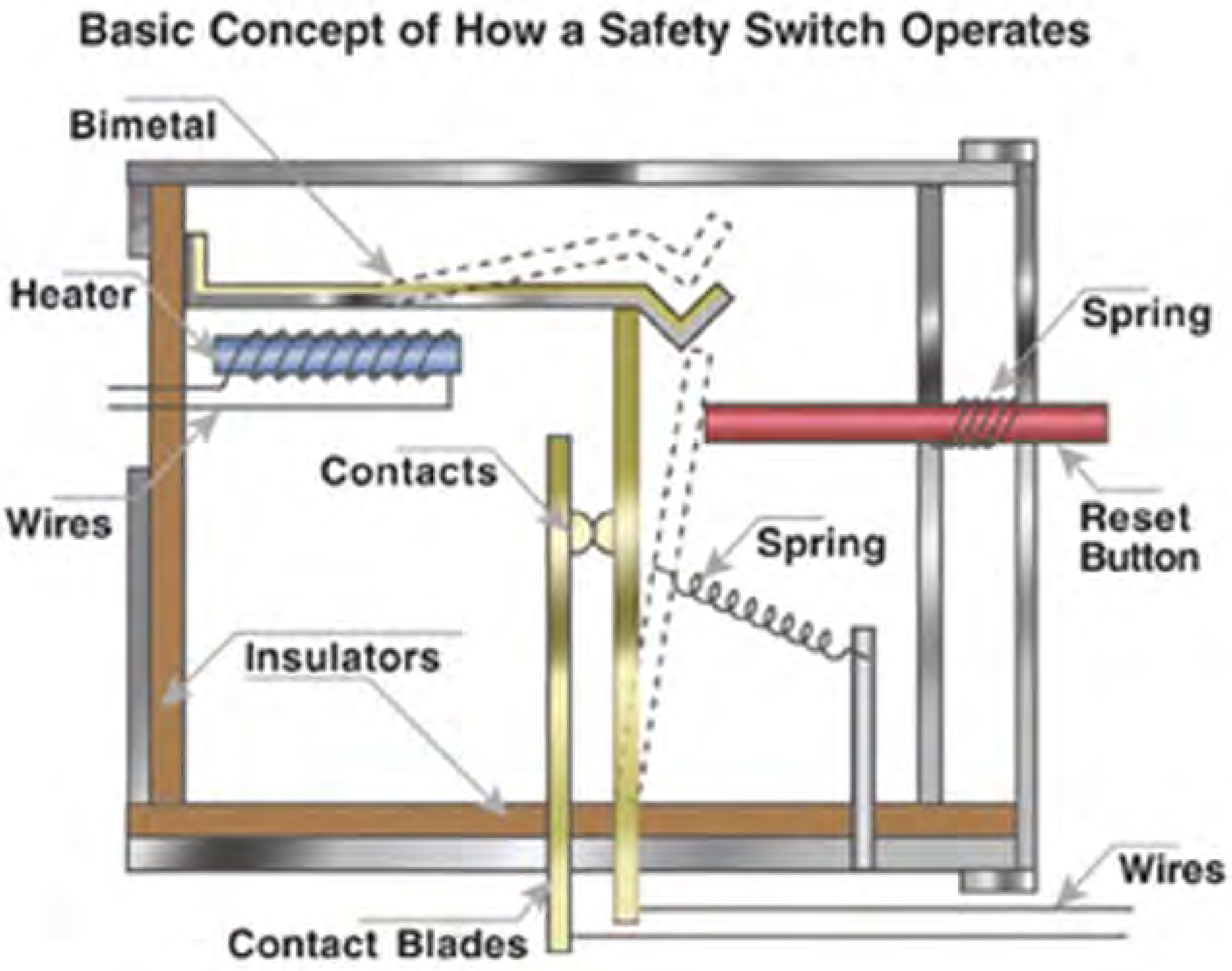
aka Stack Relays

These are typically mounted in the flue pipe, they use bi-metals to detect flame and to mechanically open and close contacts to provide burner control.



Flame Detection

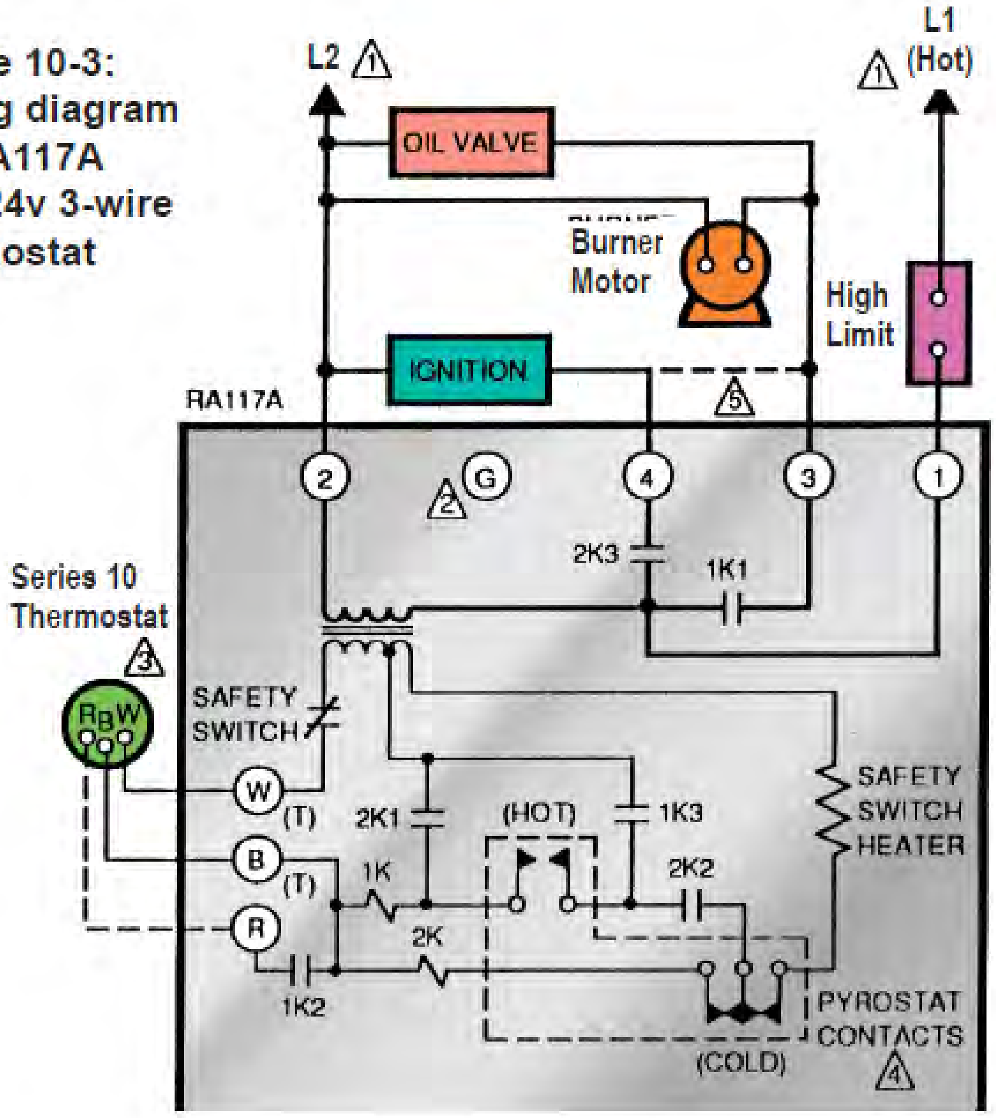
- Heat sensing element in flue pipe exposed to 300º – 1,000º F
- Bi-metal expands & closes contacts
- Safety timing approx. 120 seconds
- Switch needs to cool off before rese



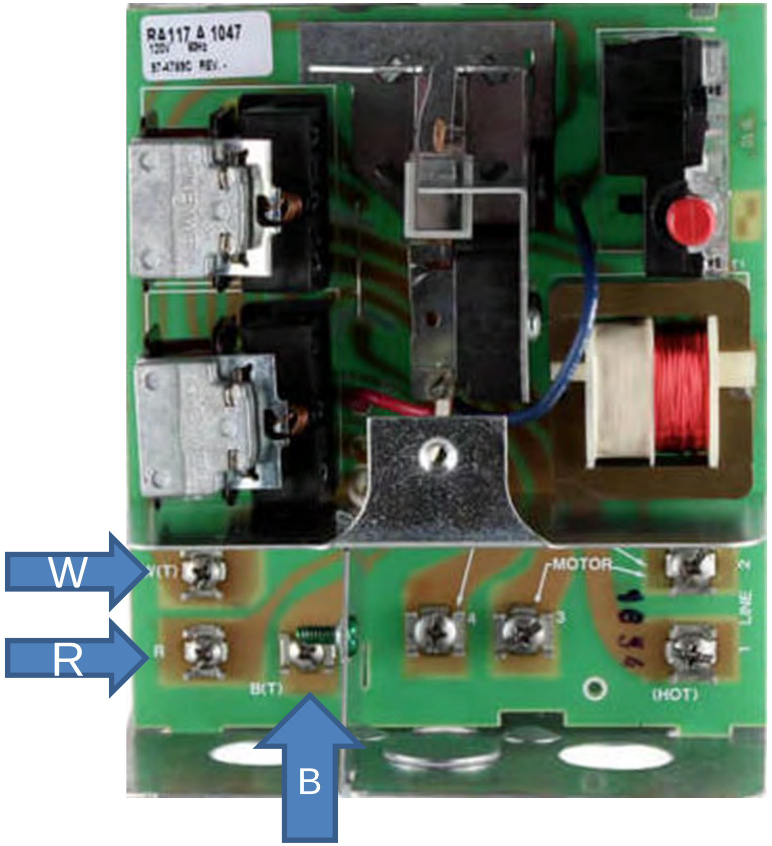
Wiring

1. Hot wire to terminal 1.
2. All neutrals to terminal 2.
3. Burner motor, oil valve and transformer/igniter (intermittent) to 3.
4. Interrupted – trans/ign to 4.
5. Green to ground.

Figure 10-3: Wiring diagram for RA117A with 24v 3-wire thermostat



Wiring – Low Voltage



- 3 wire thermostat – RWB
- 2 wire thermostat – WB
- No thermostat connection – jumper T-T (WB)

Operation

If all components are functioning properly, and the control is NOT sensing flame, control is in standby until:

1. Line voltage is applied through the limit control AND a call for heat completes the T-T circuit.

2. Terminal 4 powered then terminal 3 powered within a second.

3. Transformer/igniter provides ignition, motor turns fan & pump, DOV opens based on delay timing……

Operation (continued)

4. Once flame is established & heated gases expand the bi-metal element, the ignition circuit (terminal 4) is de-energized shutting off the ignition if the burner operates with interrupted ignition

5. Burner runs until limit control (line voltage) or thermostat (low voltage) is satisfied. Either of these cuts power to terminals 3 and 4.

6. The control returns to standby.

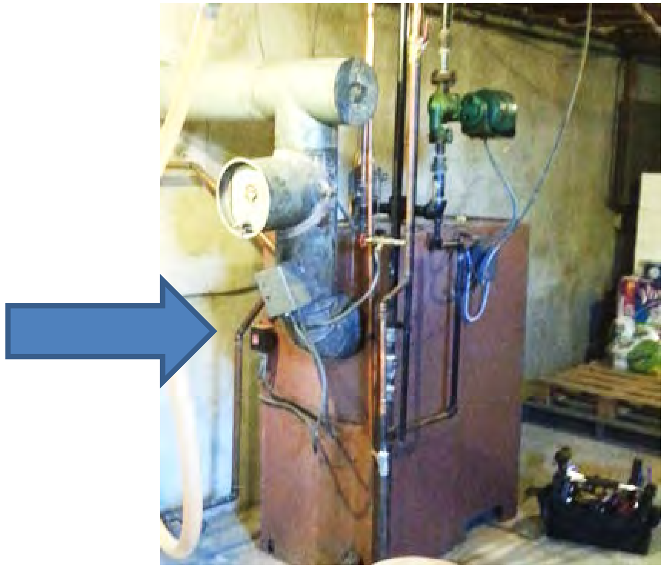
Safety Check

It's important to check the safety timing of primary controls every time a service call is performed.

1. Turn off service switch at the unit.
2. Remove control from flue or block oil flow to nozzle, turn back on.
3. Make sure both line and low voltage circuits are complete.
4. Control should energize & shut off on safety within 120 seconds, if it does, clean the bi-metal & reinstall it……

Safety Check (continued)

5. It the control does NOT go off on safety, replace it and check the safety on the new control.



6. Any system still operating with a stack relay is probably a good candidate for replacement with a high efficiency system.

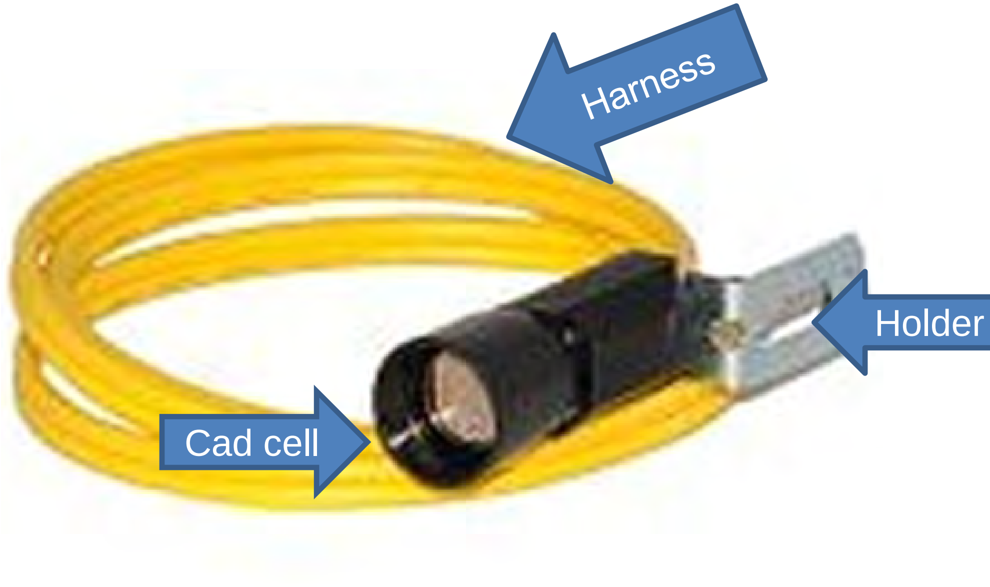
Obsolete 1st Gen Cad Cell Controls

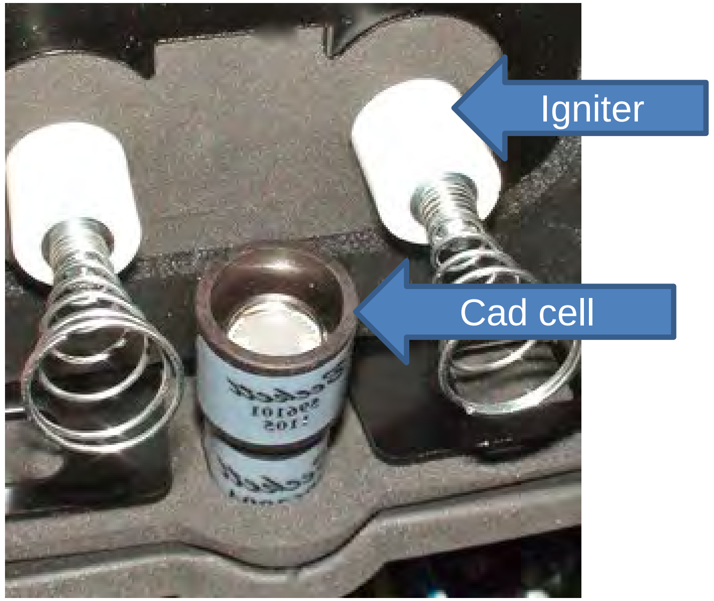
Basic functions are the same as stack relays, they have much quicker reaction time with visual rather than thermal flame detection.

They have two components – flame detector is separate from control.

Flame Detection

- Cad cell, holder and wiring harness
- Cad cell is installed in air tube, senses light from flame
- Safety timing usually 45 seconds
- With older models, the safety switch needs to cool off before reset





Flame Detection (continued)

The cad cell is a ceramic disc coated with cadmium sulfide that transmits an electrical signal to the control.

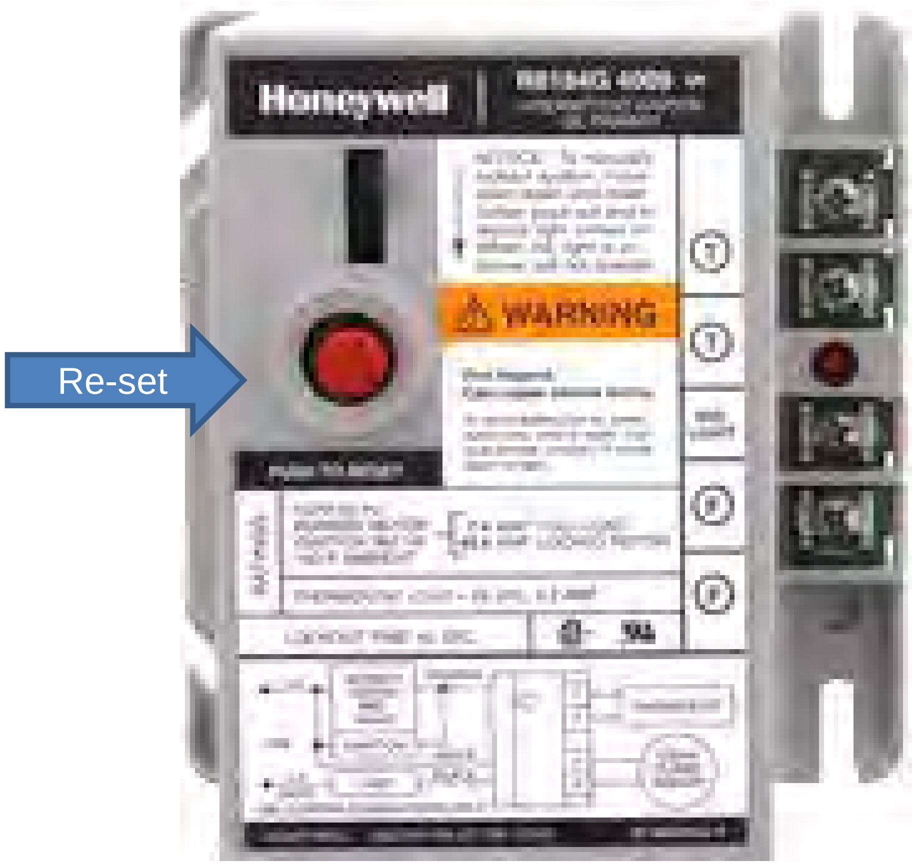
In darkness it has a very high resistance to the passage of current. As it is exposed to light, resistance decreases and current flows.

For the control to start the burner, the cell must sense the ***absence*** of flame……

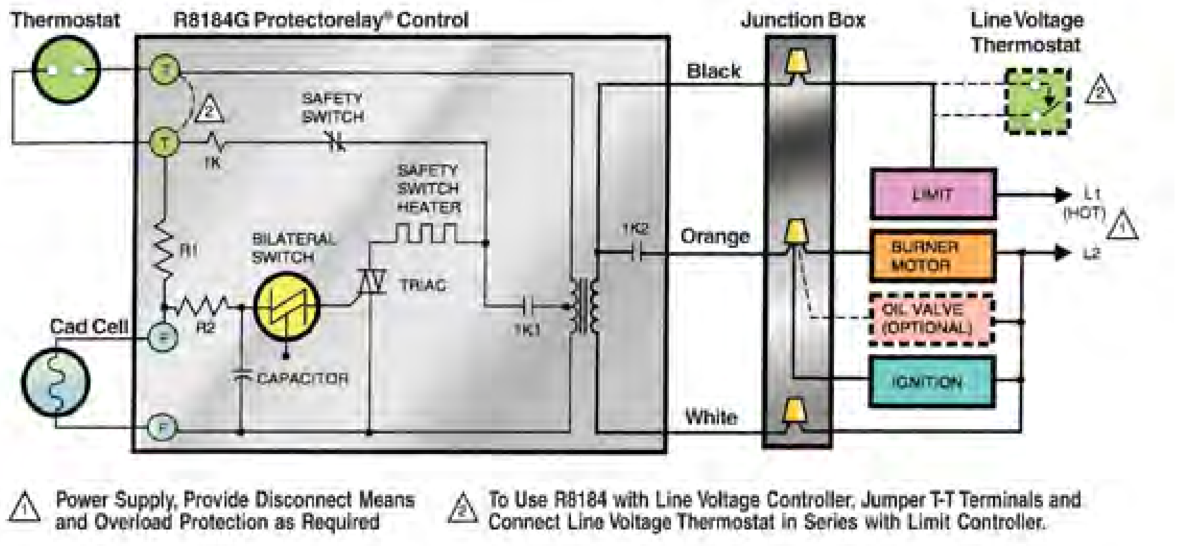
Flame Detection (continued)

Once the burner starts & establishes flame, the cell senses light, resistance drops, current passes through the circuit & the burner continues to run.

If the cell doesn't sense enough light during the run cycle, the control will shut off on safety and won't start again until the reset button is pressed.



Wiring

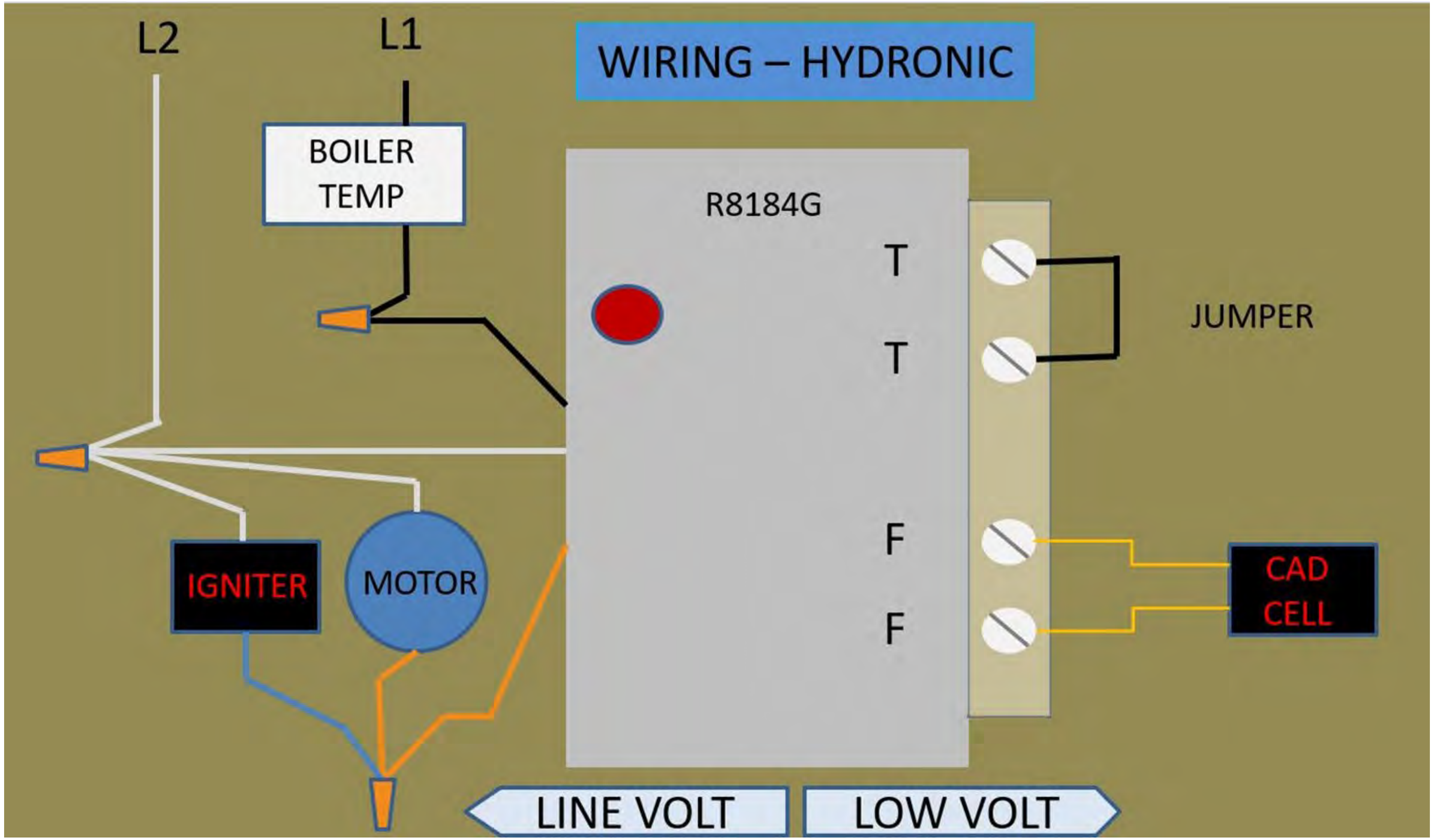


1. Hot to black wire.
2. All neutrals to white wire.
3. Burner motor, oil valve and transformer (intermittent) to orange wire.
4. Interrupted – not on this control.
5. Green to ground in 1900 box.

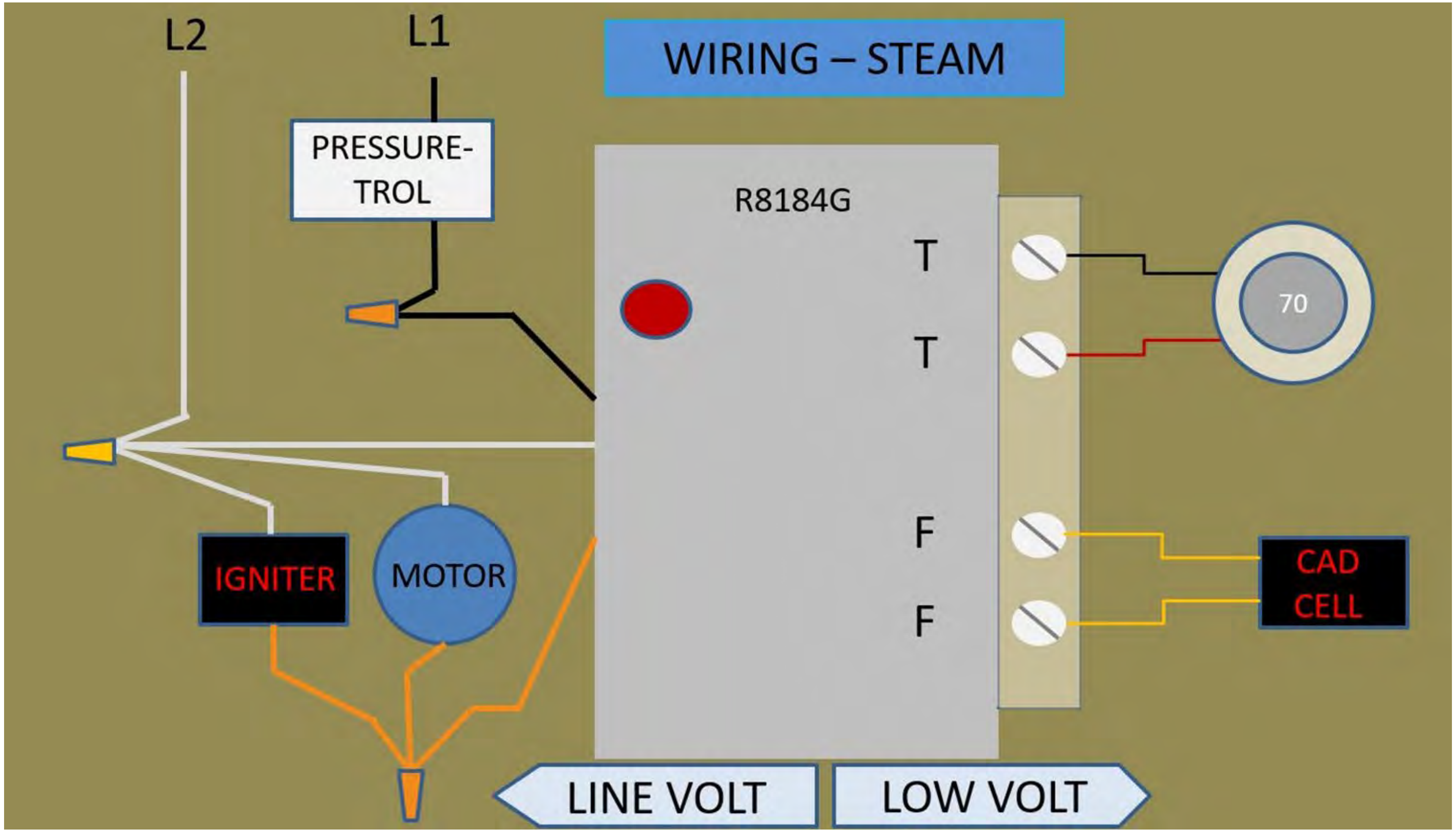
Wiring – Low Voltage & Cad Cell

- 2 wire thermostat – T-T.
- No thermostat connection – jumper TT.
- Cad cell leads to F-F.

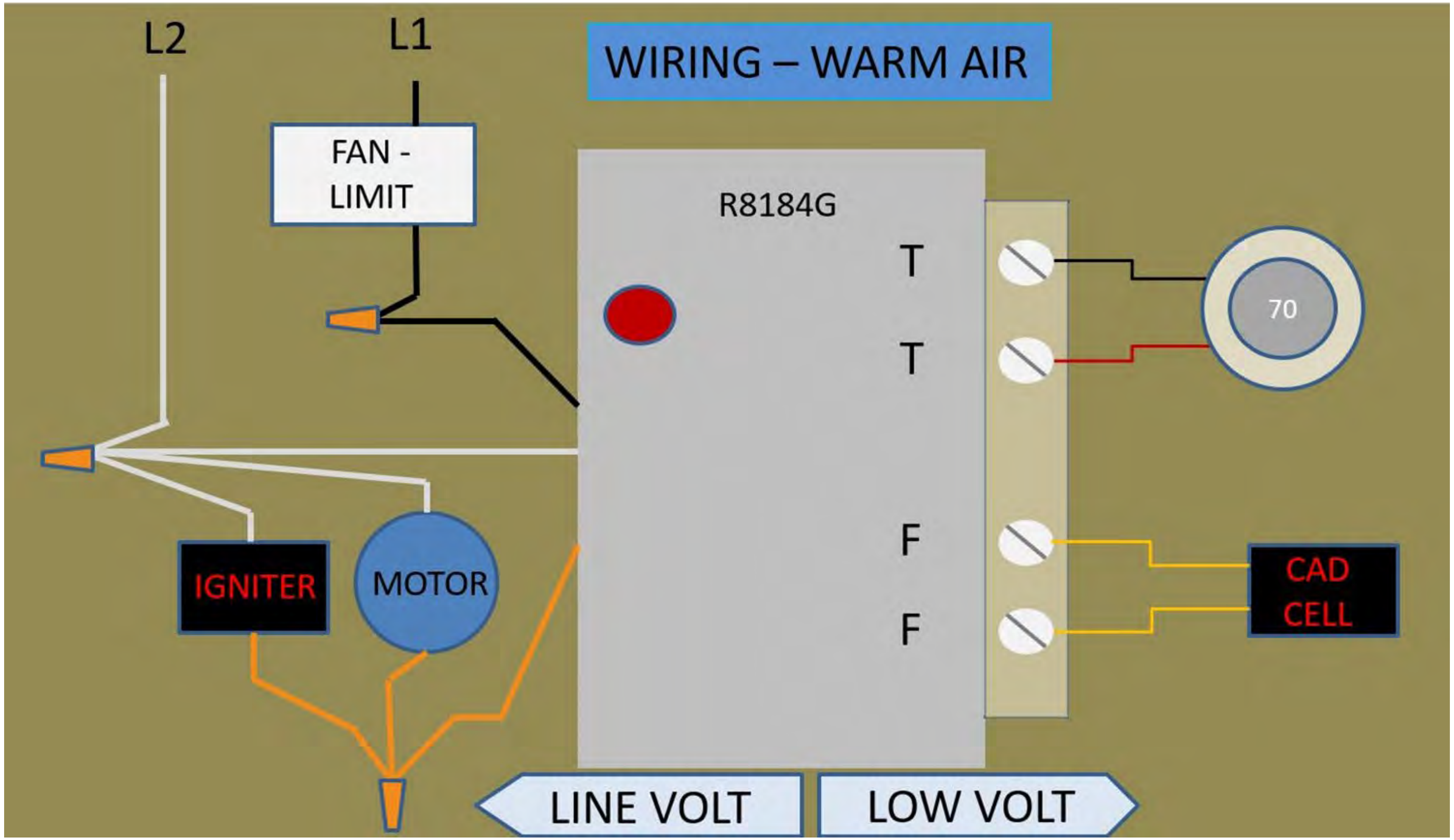
Wiring – 1st Generation



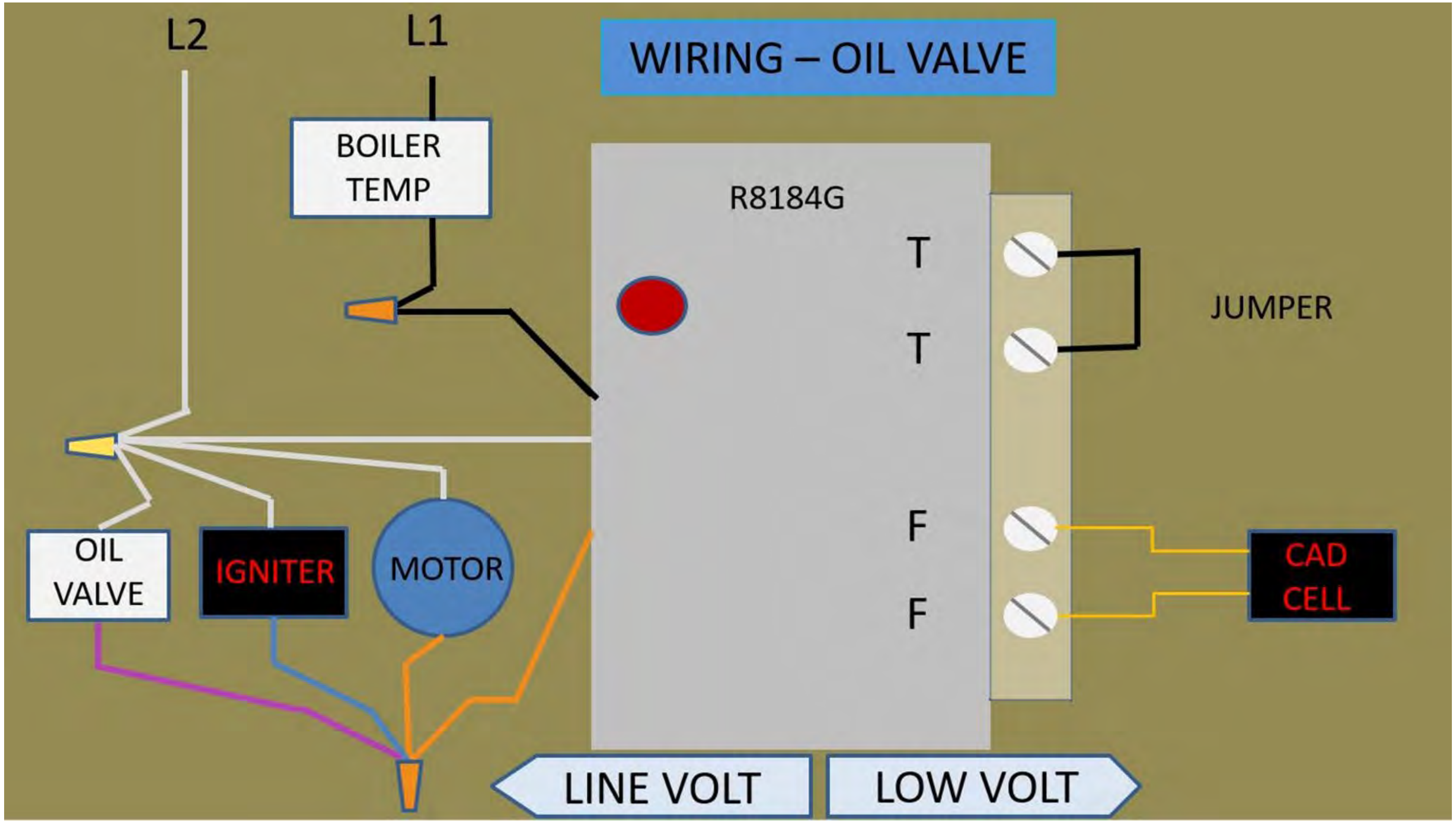
Wiring – 1st Generation



Wiring – 1st Generation



Wiring – 1st Generation



Operation from Standby Mode

If all components are functioning properly, and the control is NOT sensing flame, control is in standby until:

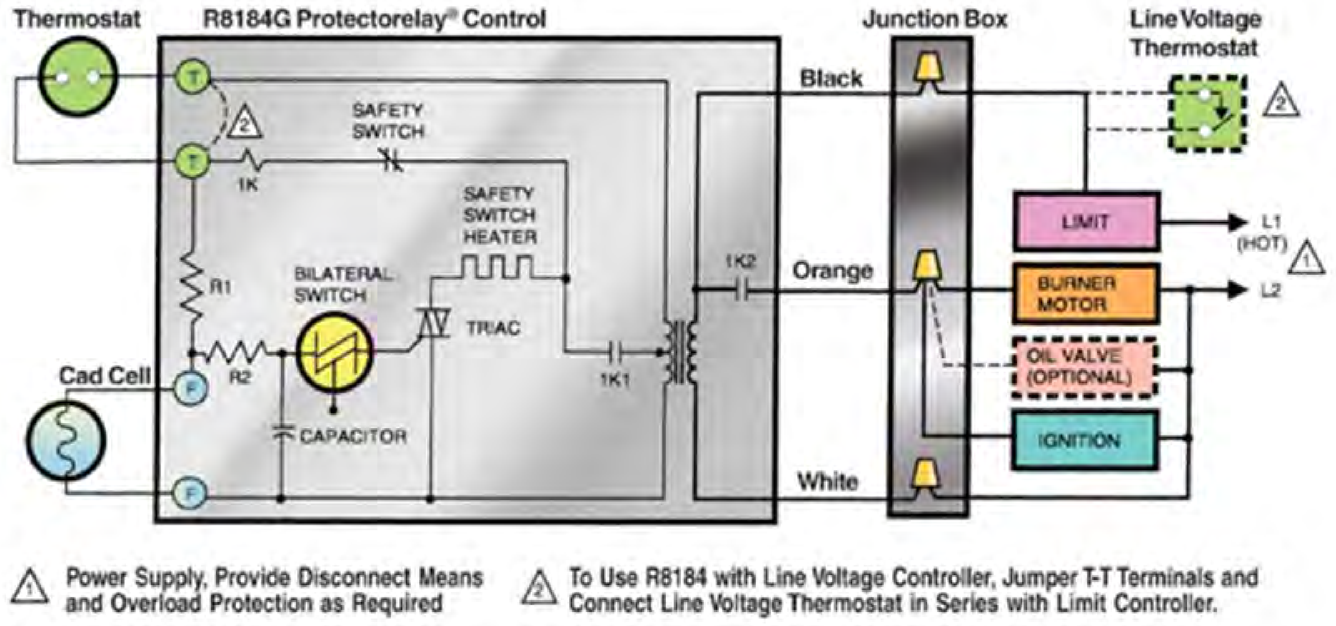
1. Line voltage is applied through the limit control to the black wire AND a call for heat completes the T-T circuit.

2. The orange wire is powered – transformer/igniter provides ignition, motor turns fan & pump, DOV opens based on delay timing……

Operation from Standby Mode (continued)

3. Flame is established, cad cell resistance drops to less than 1600 ohms and the safety switch is de-energized.

4. As long as the cad cell senses flame, the burner runs until either the thermostat or limit control is satisfied.



Safety Check

- Turn off burner
- Leave cad cell leads attached and install a 1,000-ohm resistor across F-F terminals.
- Turn back on
- Make sure both line and low voltage circuits are complete
- Control should not energize because the resistor simulates flame, if it does replace the control
- If it doesn't……

Safety Check (continued)

- Turn off switch and remove resistor
- Disconnect one lead from the F-F terminals.
- Turn burner switch on
- The control should energize and lock out based on its safety timing
- If it does not lock out, replace it and check the safety on the new control
- If it does go off on safety, reconnect the lead to the F terminal and press the reset button. The safety is working properly

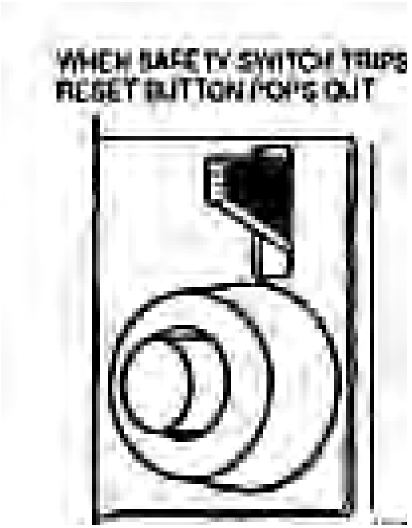
Troubleshooting

If the burner doesn't start:

Be sure electrical switches are in the on position.

Verify that there isn't a fire burning in the appliance…..

Troubleshooting (continued)



Check to see if the control is off on safety

(on some models the reset button pops out)

It it’s not off on safety, check for proper incoming voltage

It there is sufficient voltage, remove 1 lead from the F-F terminals, if the burner starts the problem is in the cad cell sensor or wiring.

If the burner does not start, disconnect the thermostat wires and install a jumper. If the burner starts the problem is in the thermostat or its wiring……

Troubleshooting (continued)

If the primary control is off on safety, check for a fuel saturation in the chamber.

If the chamber contains excess fuel, follow company procedures to eliminate it. **NEVER** attempt to fire a burner into a saturated chamber.

If the chamber is free of excess fuel, press the reset button.

If the primary control energizes but the burner motor does not turn, shut off the switch and check the electrical connections and burner motor reset button (older motors have a reset button, newer ones do not)……

Troubleshooting (continued)

If the burner runs and flame is established but the control shuts off on safety, disconnect the cad cell leads, press the reset and, before the burner shuts off on safety place a 1,000-ohm resistor across the F-F terminals.

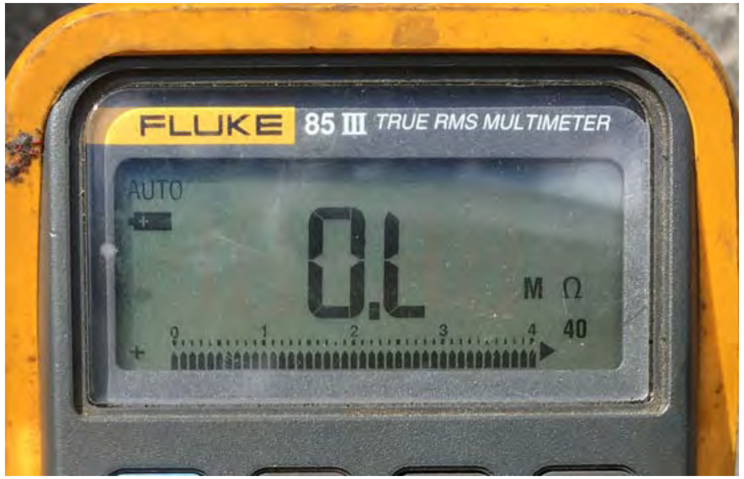
If the burner continues to operate with the resistor in place, the control is working fine & the problem is with the cad cell flame detector……

Troubleshooting (continued)

With the burner operating, connect the cad cell leads to an ohmmeter.

A reading of zero ohms indicates a short circuit, check for shorted cad cell wires.

If the resistance is infinite, check for broken cad cell wires or a loose or defective cell.



Troubleshooting (continued)

Most properly adjusted burners will have a reading of 1600 ohms or less. Some burners with large static plates or small openings in the retention head operate in the 400 – 800-ohm range.

Very few burners operate with resistance over 800 ohms.

If an eye is coated with soot, it will not be able "see" a flame, clean the eye and continue troubleshooting to find out ***why*** the eye is dirty.

Troubleshooting Tips

Figure 10-7

Cad Cell Check List

Ohmmeter Reading	Cause	Action
0 ohms	Short circuit	Check for pinched cad cell leadwires
Less than 160 ohms but not zero	Cad cell and application are working correctly	None
Over 1600 ohms but not infinite	Dirty or defective cell, improper sighting or improper air adjustment	1. Clean cell face, recheck 2. Check flame sighting 3. Replace cell, recheck 4. Adjust air band to get good reading
Infinite resistance	Open circuit	Check for improper wiring, loose cell in holder or defective cell

Obsolete Gen. 2 Cad Cell Controls

2nd generation cad cell controls have the same basic features as 1st generation controls but advances in technology led to major improvements. Typical 2nd generation controls include……

Secondary Monitoring Circuit

- Circuit monitors the contacts of two separate, redundant motor relay
- Safety lockout occurs if the contacts of either motor relay is closed when it should be open

Interrupted Ignition

All second-generation controls include an additional wire for the transformer/igniter. With interrupted ignition:

- Transformers/igniters and electrodes last longer
- Electrical consumption and noise are reduced
- Combustion problems leading to dirty appliances and running saturations are minimized

Recycle on Flame Failure

Instead of shutting off on safety
when flame is lost
during a run cycle,
the burner shuts off in 1-2 seconds,
waits 60 – 90 seconds,
and attempts to restart the burner.

Operation from Standby Mode

If all components are functioning properly, and the control is NOT sensing flame, control is in standby until:

1. Line voltage is applied through the limit control to the black wire ***AND*** a call for heat completes the T-T circuit.
2. The orange and blue wires are powered – transformer/igniter provides ignition, motor turns fan & fuel unit, DOV opens based on delay timing .
3. Ignition stays on for 10 seconds after cad cell senses flame……

Operation from Standby Mode (continued)

4. As long as cad cell senses flame, burner runs until limit or thermostat is satisfied.
5. If the control doesn't sense flame within its safety timing, lockout occurs. Pressing the reset for 3 seconds resets the control.

Gen. 3 Cad Cell Controls

3rd generation controls include a microprocessor in the printed circuit board.

They feature interrupted duty ignition, 15 second safety timing and include several new features such as……

Valve-on-Delay

Using an oil valve, this feature allows the burner motor to get up to speed, delivering full fuel flow from the fuel unit & full air flow from the fan before fuel flows through the nozzle.

This optimizes fuel/air mixing at start resulting in increased efficiency and a significant reduction if soot build-up.

Although many people refer to this as “pre-purge”, it does not fit UL’s definition

Motor-off-Delay aka Burner Valve-on-Delay

This feature allows the motor/fan combination to continue delivering full air flow after fuel flow through the nozzle has been cut off by an oil valve.

This results in cleaner shut-downs.

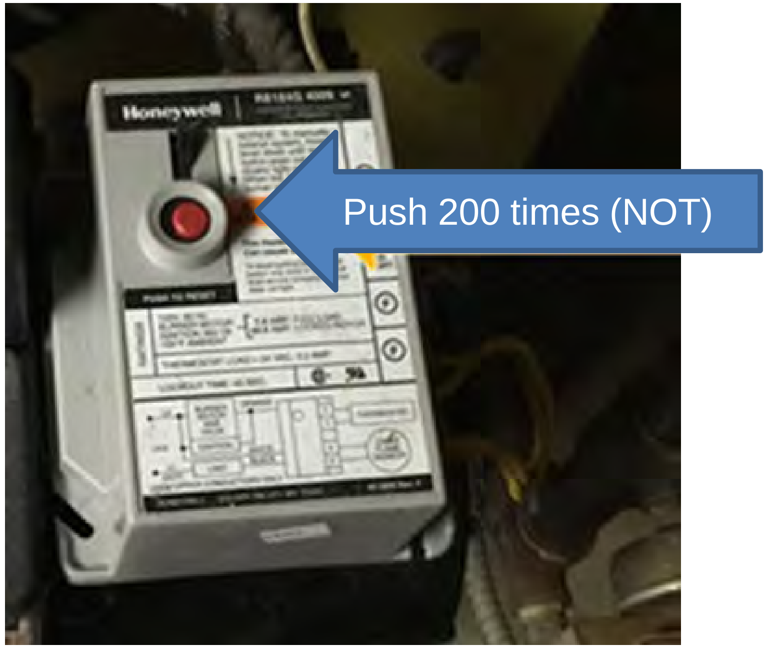
Although many people in our industry refer to this as "post-purge", it does not fit UL's definition

Limited Reset

This protects against repeated pressing of the reset button which floods the appliance with oil.

If the control goes into lockout 3 times during a single call for heat, if goes into a restricted mode called "latch-up."

Instructions for getting the control out of latch up are printed on the underside of the control where the homeowner can't see them.



Dry Alarm Contacts

These contacts close when the control goes into lock-out or latch up.

Through added controls (i.e. an auto dialer) this can alert the homeowner, alarm company or service provider of the situation.

Limited Recycle

This feature limits the number of times a control will attempt to restart if flame is repeatedly established and then lost, preventing excessive sooting from repeated combustion failure.

Diagnostic LEDs

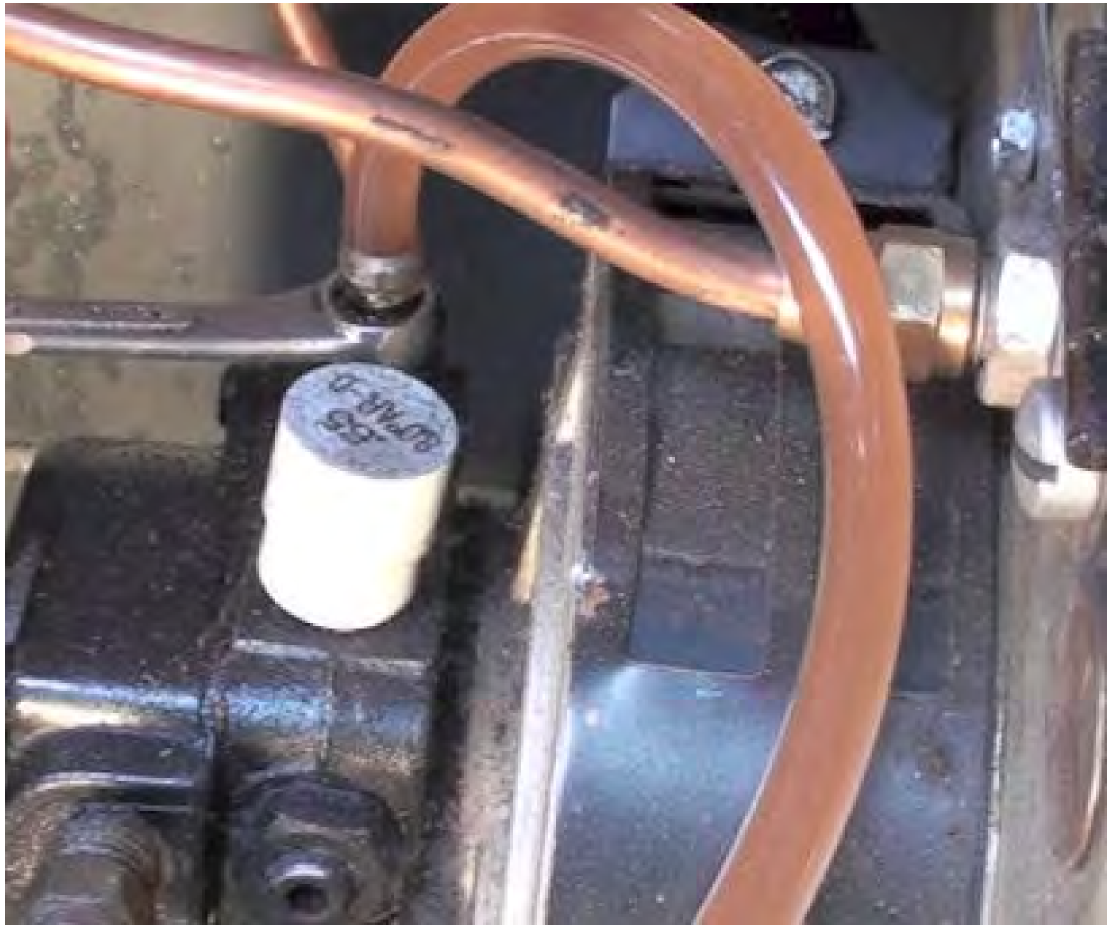
These small, low power lights provide a significant amount of information to help the service technician quickly and accurately diagnose the situation.

Gen. 4 Cad Cell Controls

In addition to all features of 3rd generation controls, depending on the manufacturer they may include several new features such as……

Pump Priming Cycle

These controls can be placed in a purge routine that extends lockout timing for up to 4 minutes to facilitate purging air from the fuel lines and filter.



Adjustable Features

These controls may include adjustable:

- Trial for ignition
- Valve–on-delay
- Motor –ff-delay
- Flame stabilization
- Lock out threshold

User Interfaces & LCD screens

User interfaces allow the tech to program & troubleshoot the control.

LCD screens display burner status & fault history.

Primary Controls

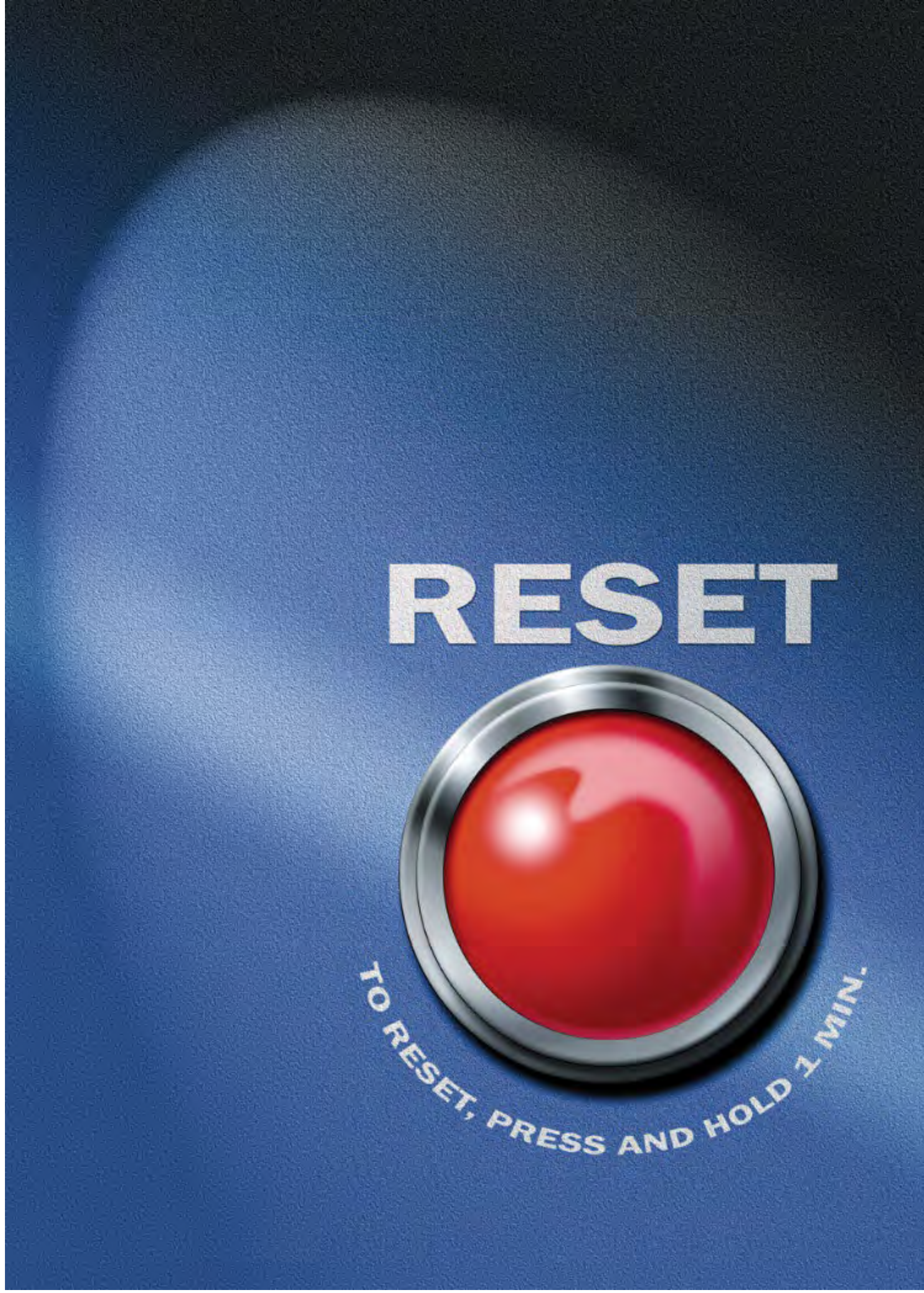
Primary controls have evolved from simple stack switches to microprocessor-based controls that offer greater reliability, safety and efficiency.

Control manufacturers continue to develop new products with advanced features that will make the controls used today seem as obsolete as thermo-mechanical controls are now.

For specific information regarding wiring, operation and troubleshooting refer to manufacturer's instructions.

Review Questions:

- How does a primary control work and how is it connected in warm air, steam, and hydronic systems?
- What is the different flame-sensing devices?
- What are the two ignition modes and why one is preferred?
- How do you troubleshoot a stack relay? Upgrade it!
- How does a Cadmium Sulfide (cad cell) primary control the ignitor, oil solenoid valve, and motor?
- How do you perform a cad cell check?
- What are the differences between a first- and second-generation cad cell?
- Why should obsolete flame-sensing devices be replaced?



End Chapter 11

NORA Technician Certification

Review

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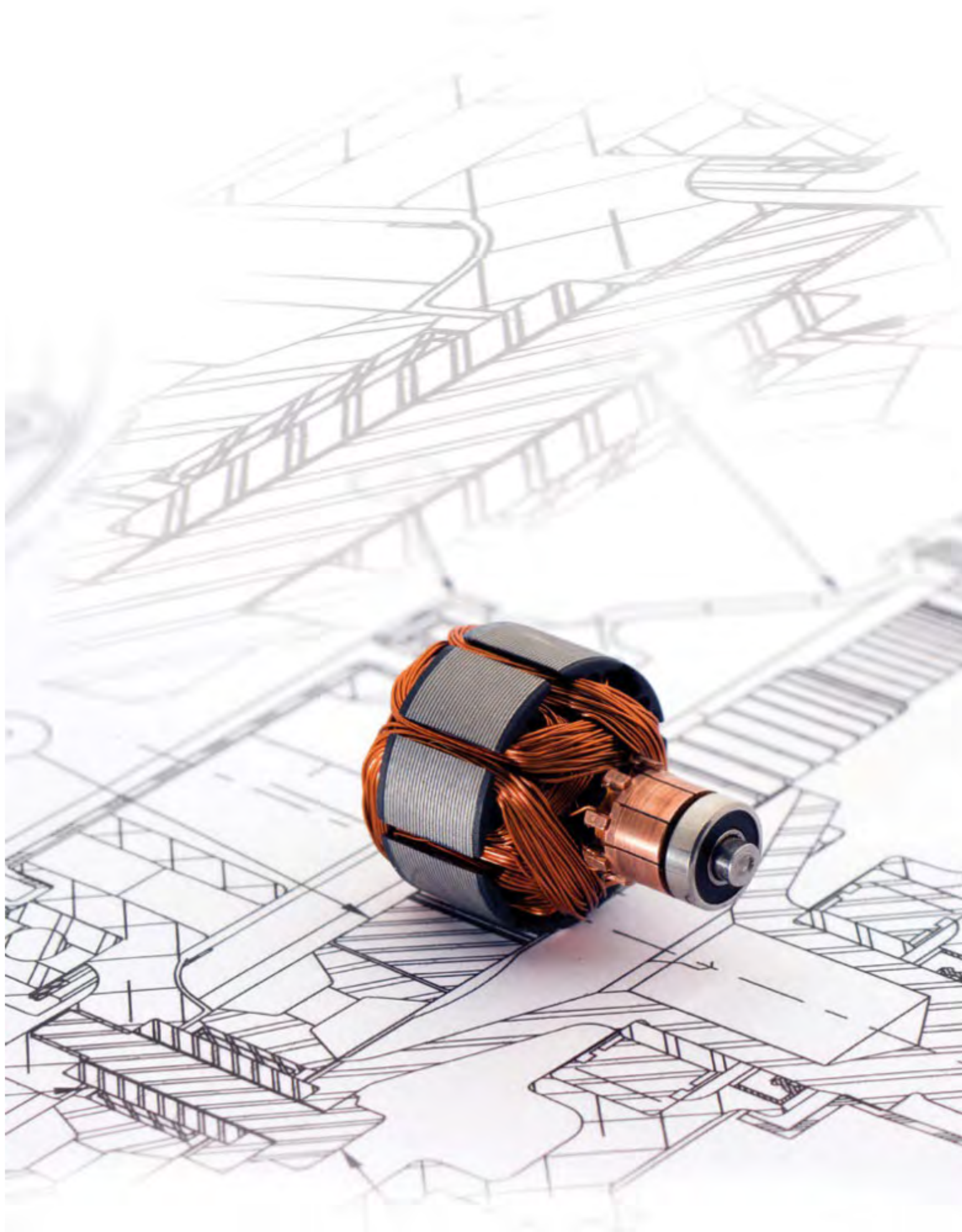
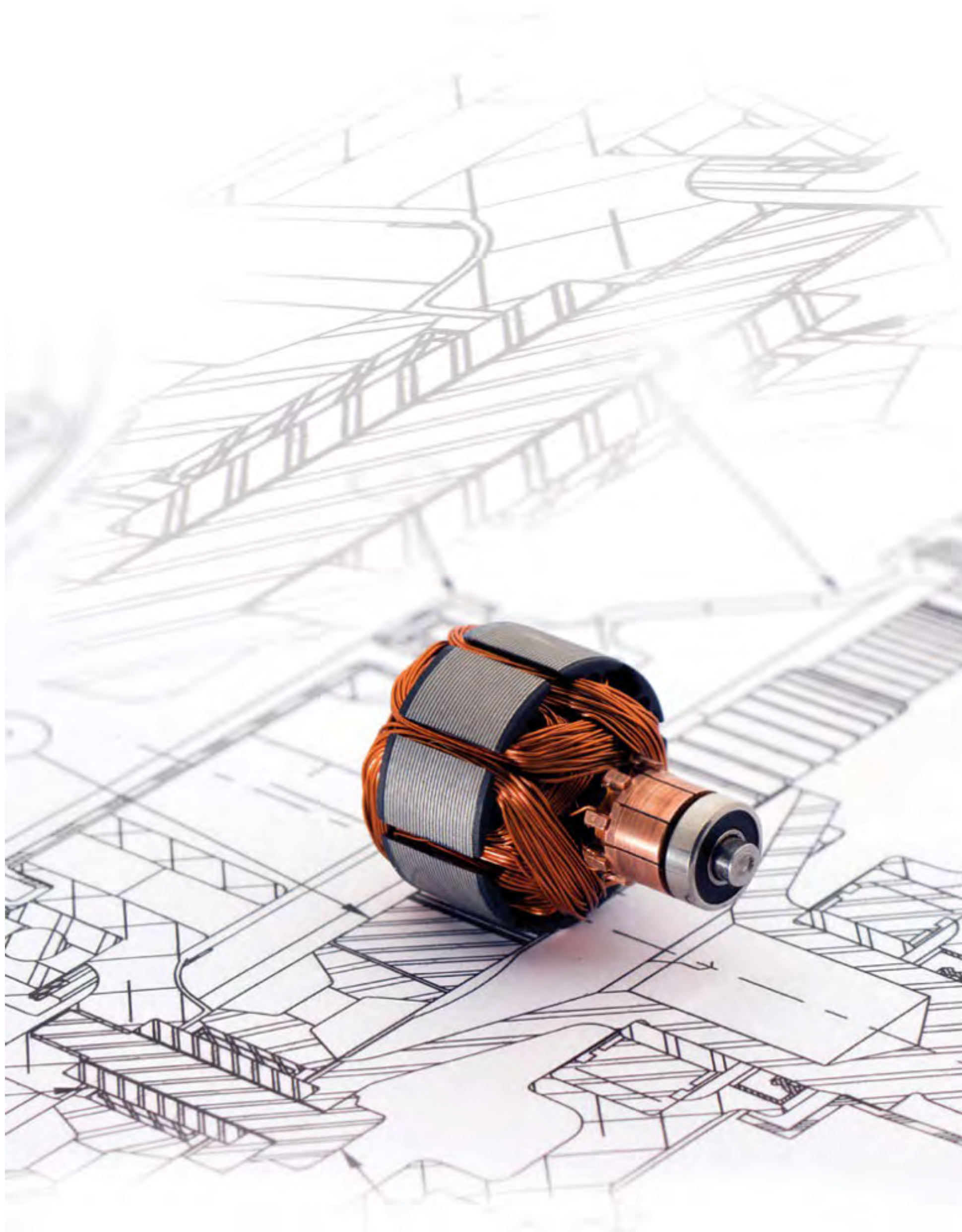
Chapter 11

Motors



At the end of this lesson, you will be able to:

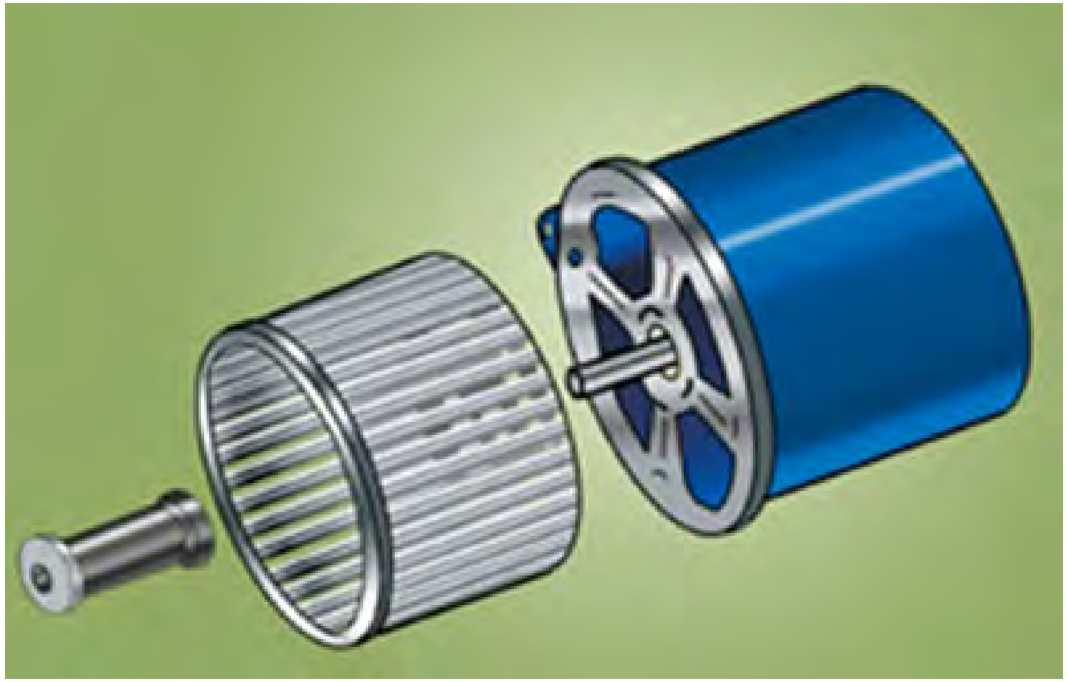
- Describe different types of motors
- List the common reasons for an overload switch to trip
- Use a multimeter to troubleshoot a permanent split capacitor (PSC) motor
- Explain what you need to consider when replacing a motor



Motors

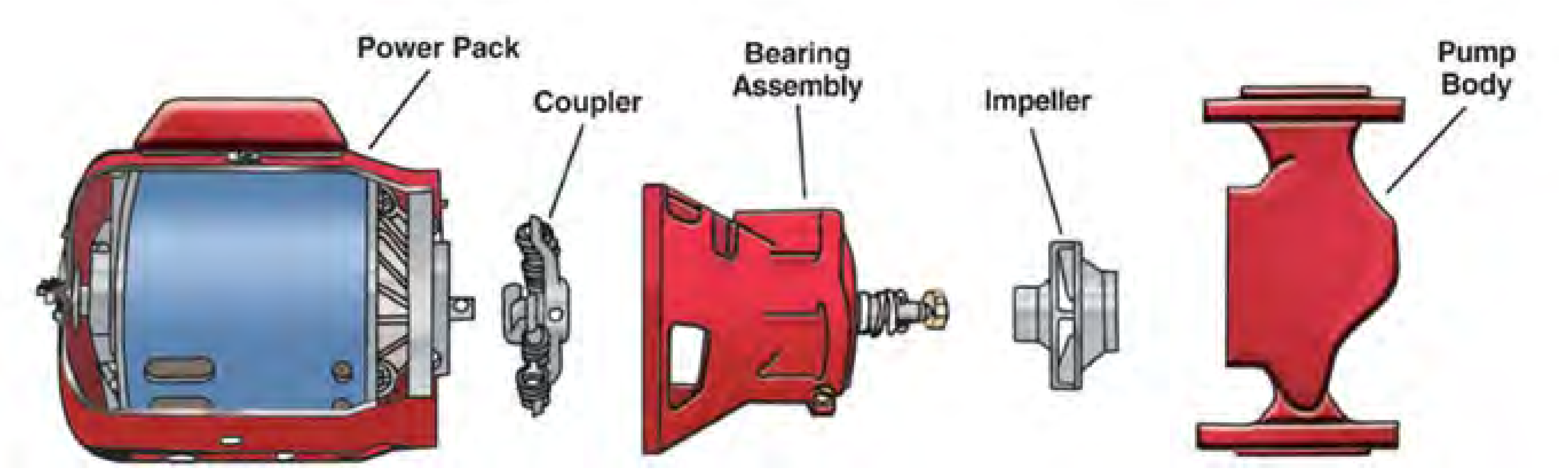
There are a number of line voltage electric motors in an HVAC system.

In burners they drive the fuel unit and burner fan.



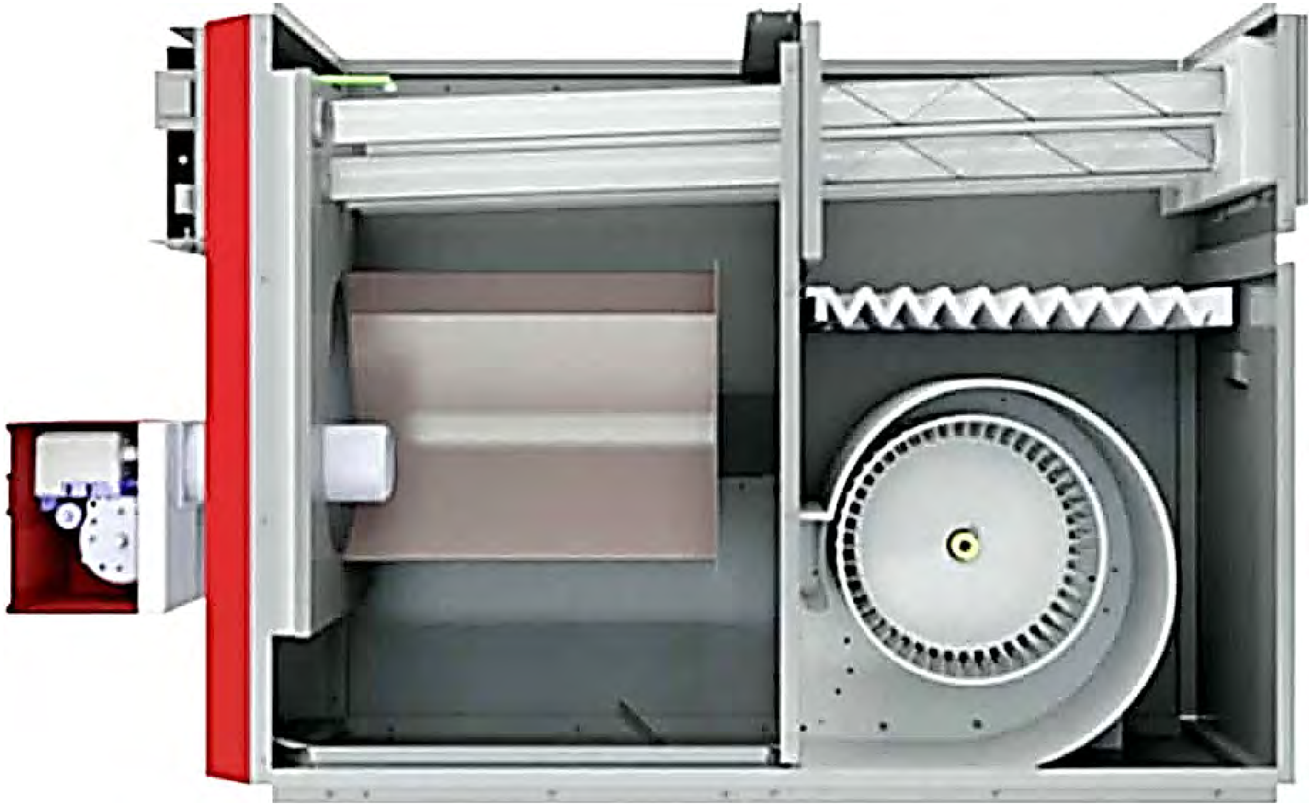
Motors

In hot water systems they power the circulator.



Motors

In warm air systems they turn the blower fan.



Electric Motors

In addition, low voltage motors open & close zone valves and dampers.

Burner Motors

Residential & light commercial burner motors are generally 120 VAC.

Most 3450 RPM motors have an M (6 ¾”) flange.

Older 1725 RPM burners have an N (7 ¼”) flange

Burner Motors

Motors are typically rated by:

- Voltage
- Amp draw
- Frame size
- Horsepower

Burner Motors

The end of the motor around the shaft is the "shaft bell" and the other end is the "end bell."

The type of shaft bell affects air pressure & air flow of the burner.

Shaft bells with fewer air holes provide higher static pressure.

Because of this, a complete combustion analysis MUST be performed when a burner motor is replaced.

Motor Oiling

Most oil burner motors do NOT need to be oiled; they are "permanently lubricated."

However, those require oiling should be lubricated according to manufacturer recommendations, typically with non-detergent SAE 20.

Locked Rotor Amperage

This is the amperage that can be measured for an instant when a motor first starts. Motors draw substantially more amps on start than when running. After starting, they only draw the amount listed on the nameplate.

The locked rotor amperage (not usually on nameplate) is the amount of current present if the motor fails to start after current is delivered

Capacitor Start Motors

Capacitors are used to build up an electric charge and store it until it's needed.

Capacitor start motors are capable of much greater starting torque than standard motors.

They are not used on residential burners, but many commercial burners and circulators use capacitor start motors.

Thermal or Motor Overload Switch

A thermal (overload) switch opens when an unusual increase in temperature occurs inside a motor to protect it from being damaged by overheating.

If the motor overheats, the switch will open & turn it off……

Thermal or Motor Overload Switch

There are two type of overload switches:

Automatic reset is the most common and will reset itself (close) after the motor cools down.

Manual reset switches are found on older motors and must be restored to operation by pressing a reset button.

Motor Overload Switch Tripping

Overload switches trip due to internal failure or external loading conditions.

The following will cause motor overload:

1. Line voltage is too low or too high.
2. The fuel unit has become bound or difficult to rotate.
3. The fuel unit return line is plugged.
4. The motor bearings are bad……

Motor Overload Switch Tripping (cont.)

5. The motor and fuel unit are misaligned.
6. The coupling is too long, putting pressure on the motor shaft and causing it to bind.
7. The burner fan is jammed.
8. Dirt in the motor cooling vents
9. Motor is undersized.

Checking for an Undersized Motor

If the load requirement exceeds the nameplate rating for horsepower, the motor will eventually overheat.

A clamp-around ammeter to make sure the current does not exceed the motor nameplate current.

Permanent Split Capacitor (PSC) Motors

All new burners & most burners in the field have PSC motors.

Old burners used split-phase motors, but most have been replaced PSC motors that offer better efficiency, offer equal or increased power output & have lower starting & running current than split phase motors.

PSC motors are frequently used in air handlers & blowers where a variable speed is desired.

PSC Motors

- Capacitor stores and releases electrical charge
- No start switch
- Second winding stays in circuit the entire time motor runs

PSC vs Split Phase

Test Parameter	Split Phase	PSC	Comments
Average starting current (locked rotor current)	15-25 Amps	7 Amps	PSC has a decreased starting current, which extends primary control relay life.
Average running current	2.0 - 2.4 Amps	1.5 Amps	PSC draws an average 30% less current.
Approximate starting torque	55 - 70 oz-in	49 oz-in	General mini pump starting torque requirement: 13 - 20 oz-in. [1]
Average electrical power	200 Watts	170 Watts	PSC draws an average 15% less power.
Efficiency	40 - 50%	60 - 65%	Efficiency = output power (mechanical) divided by input power (electrical)
AFG full load speed	3375 - 3450 rpm [2]	3440 - 3460 [2]	PSC: Similar or increased output power.

1. Most current fuel units don't require as much starting torque as older ones.
2. CFM is proportional to motor speed, static pressure varies with motor speed squared – if speed increases 2%, static pressure increases 4%.

Troubleshooting PSC Motors

PSC motors have 2 major areas to troubleshoot – the capacitor and the windings.

Both are relatively simple to check & only require a multimeter with a capacitance range.

Checking Capacitors

A failed capacitor will cause a PSC motor to either stop or run more slowly than designed.

The thermal protector will trip if a restart is attempted.

To check a capacitor:

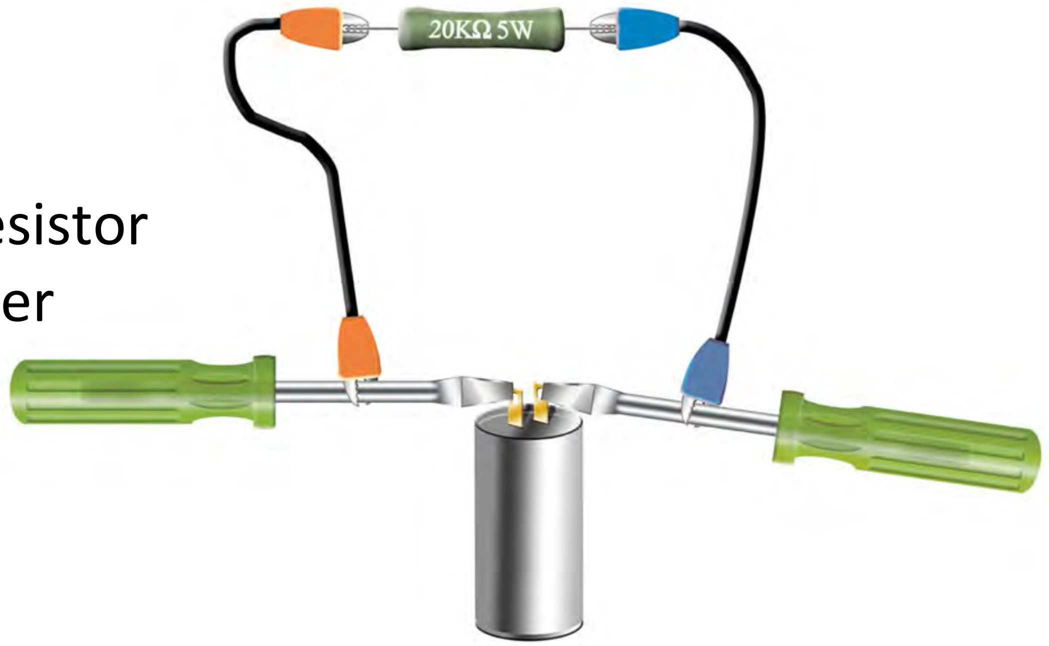
1. Remove power from the burner and carefully disconnect the 2 leads from the capacitor terminals.
2. Discharge the capacitor…..

Safely Discharging a Capacitor

To discharge a capacitor, use a 20,000-ohm 5-Watt resistor, two insulated screwdrivers and two jumper wires with alligator clips on both ends.

Connect one jumper wire clip to each side of the resistor and connect the clips on the other end of the jumper wires to different screwdrivers.

Hold the screwdriver handles and touch the blades to opposite terminals of the capacitor.



Checking Capacitors

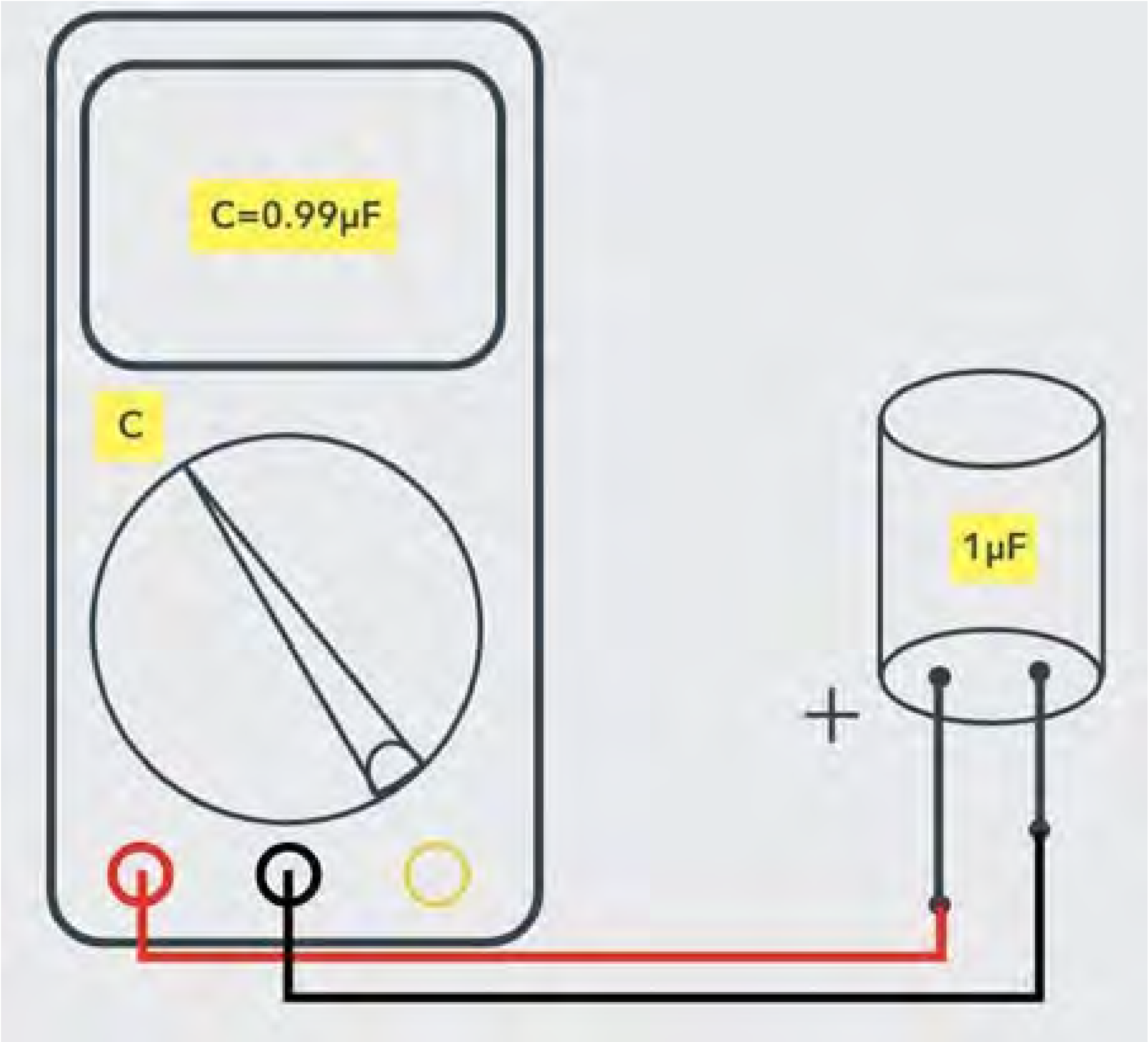
3. Connect an ohmmeter to the capacitor terminals.
   (if repeating the measurement discharge the capacitor again!)
4. The ohmmeter reading should jump immediately to a non-infinite resistance and quickly increase to infinity.

If the meter settles to zero ohms, or is infinite the entire time, change the capacitor.

In most cases, it's best to replace the entire motor.

Checking Capacitors - Alternate

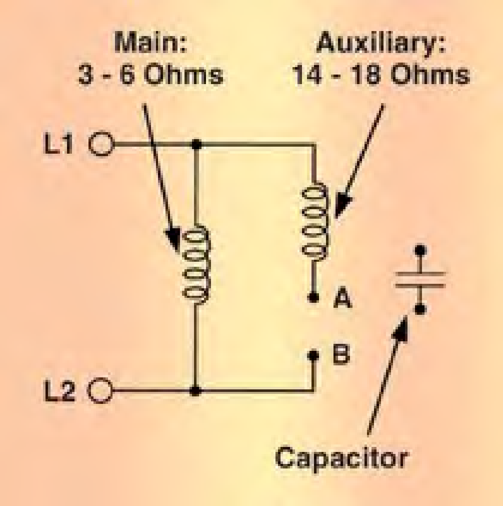
If the meter being used has a capacitance function determine the microfarad output, it should be within 10% of the rating.



Checking PSC Motor Windings

1. Remove power from burner and detach the motor leads.
2. Discharge the capacitor and disconnect its leads.
3. Connect 1 ohmmeter lead to the L1 motor lead and the other to each of the capacitor leads, one at a time.
4. Repeat by measuring the L2 motor lead to each of the capacitor leads……

Checking PSC Motor Windings – change pic



5. Check manufacturer's specs. Generally, from the L1 lead the reading should be 3-6 ohms and from the other it should be 9-18 ohms.
6. L2 should show a short (less than1 ohm) and 15- 25 ohms.

If these readings are not observed, the windings are faulty and the motor should be replaced.

Choosing a New Motor

Generally, burner motors are non-serviceable, they must be replaced when they fail. When replacing a motor:

1. Verify correct voltage, frame, rotation & speed.
2. Horsepower must be at least the same, rated amperage must be at least as high as manufacturer specs.
3. Shaft diameter and length must be the same or at least long enough & the proper diameter to safely couple to the fuel unit.

Choosing a New Motors

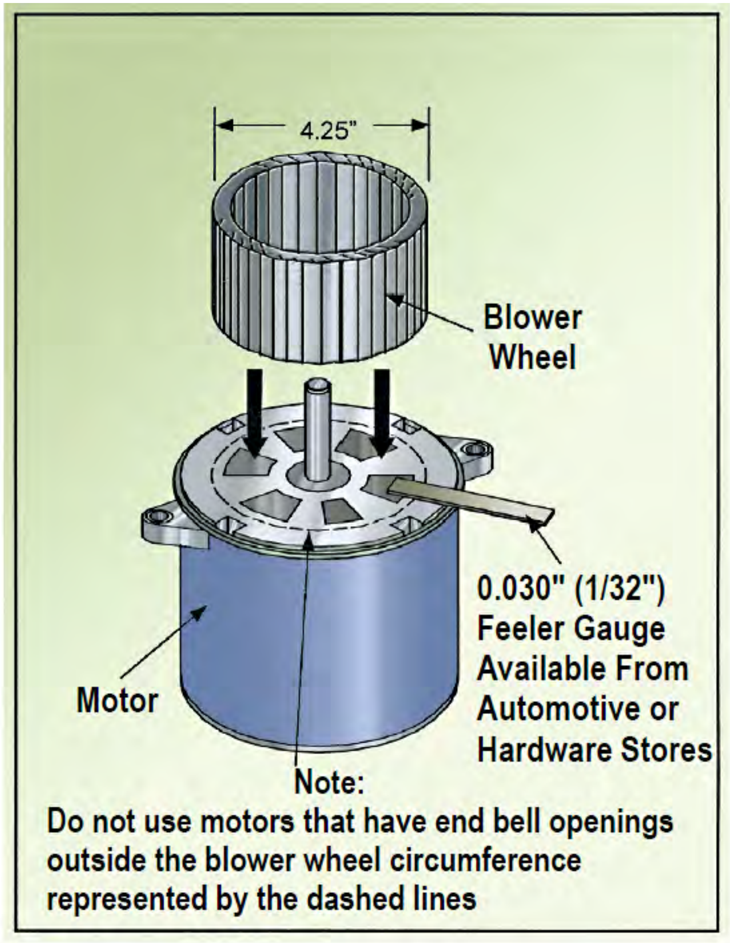
The specified motor for most burners is either the closed end type or models with small cooling openings in the shaft bell.

The small openings are ok as long as they are covered once the fan wheel is installed onto the motor shaft.

The back of the fan wheel must be close to the end bell for maximum efficiency and output.

Use of a motor with cooling openings that are not covered causes a loss of static pressure due to air leakage and turbulence……

Choosing a New Motor



- Use a thickness feeler gauge to measure the gap between the motor and the blower wheel.
- Place the gauge on top of the motor and bottom of the bottom of the blower wheel.
- The setscrew must be centered on the flat of the motor shaft before being tightened.

Burner Couplings

The flexible burner coupling is used to connect the two rotating shafts attached to the burner motor and the fuel unit.

The best coupling to use is the one provided by the burner manufacturer.

Burner Couplings

Many technicians carry a “coupling kit” that has plastic ends and a center piece that can be cut to size to fit most burners.

Be careful cutting the center piece, if it’s too is too long it can put excessive strain on the motor and keep it from starting.

Warm Air Furnace Motors

Four types of motors can be found on warm-air systems

1. Split phase, fractional H.P.,
   used for belt driven blowers.

2. Capacitor start, also used for belt drive……

Warm Air Furnace Motors

3. **<u>Multi-speed, direct drive PSC motor/blower assembly</u>.**

These are ideal for use in systems that also provide A/C because they can run at a slower speed for heating and a faster speed for A/C.

Warm Air Furnace Motors

4. Electronically Commutated Motors (ECMs) feature low power consumption and infinite motor speed capability.
5. They have all the efficiency and speed control advantages of a DC motor with none of the disadvantages, such as carbon brush wear, short life and noise.

They feature 2 main components, the motor and the microprocessor-based control module which is factory programmed for specific manufacturer applications.

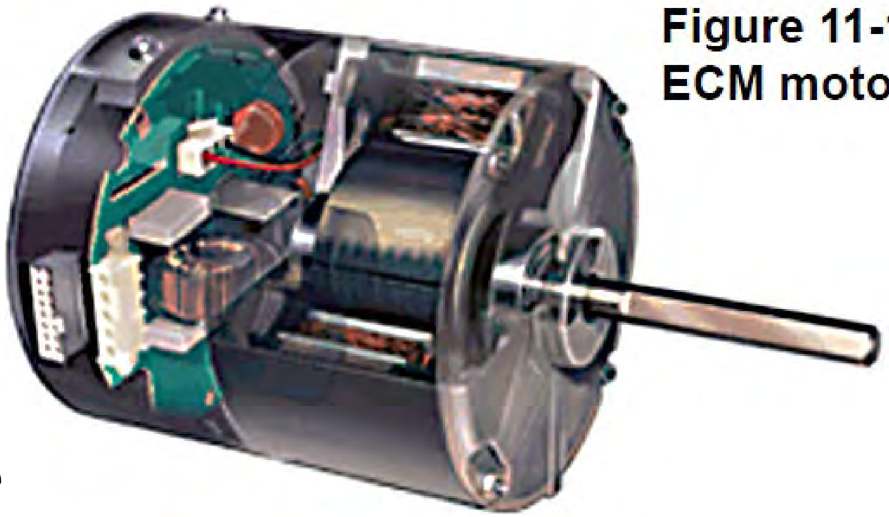


Figure 11-13: ECM motor

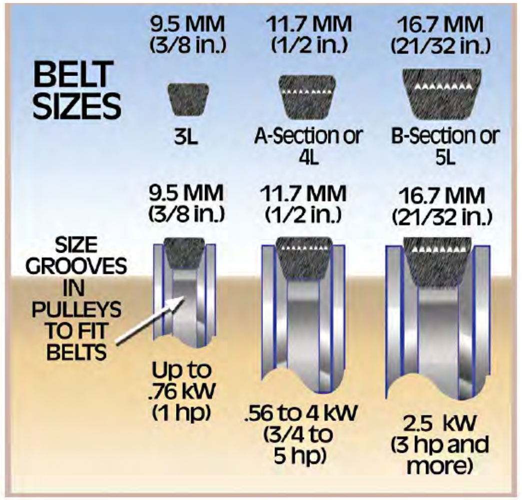
Belt Driven Blowers

Common on older furnaces. The motor is mounted to a blower and drives it through a pulley & "V" belt that requires proper tension without over-tightening.

Belt Driven Blowers

Adjusting the size of the pulleys changes the speed of the blower.

- The larger the pulley on the motor, the faster the fan will turn.
- The larger the pulley on the fan, the slower the fan will turn.
- Width of belts and pulleys varies, must be the same.



Direct Drive Blowers

Motor is mounted inside blower wheel, can be PSC or ECM.

Circulator Motors

One piece – impeller is attached directly to shaft.

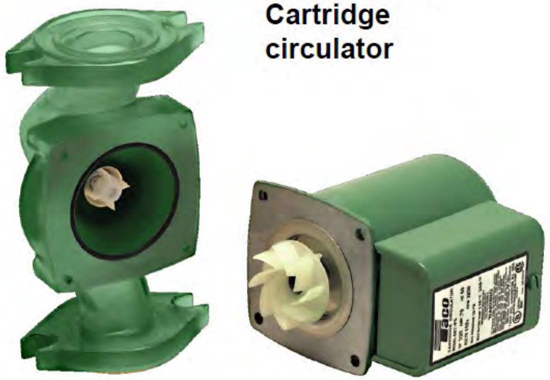
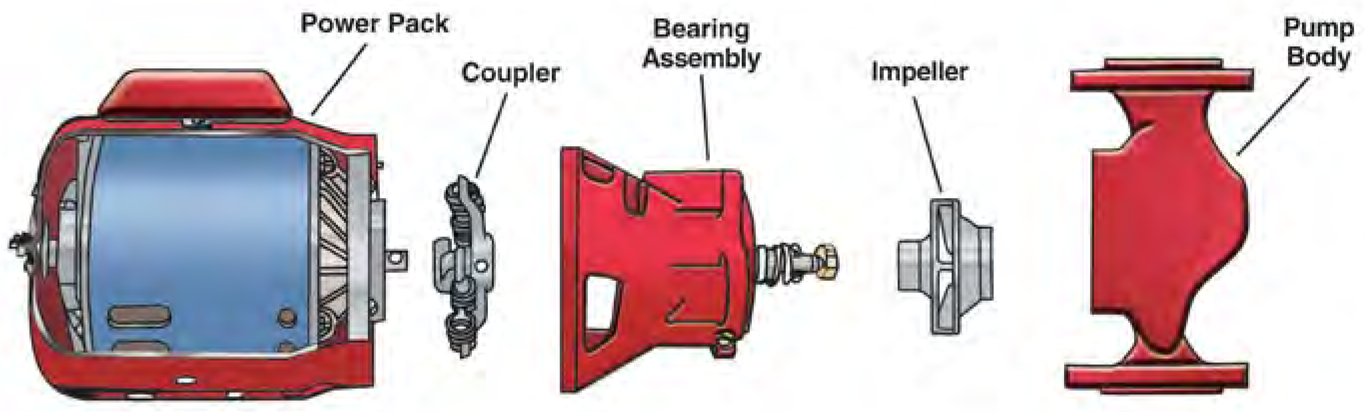


Figure 11-17: Cartridge circulator

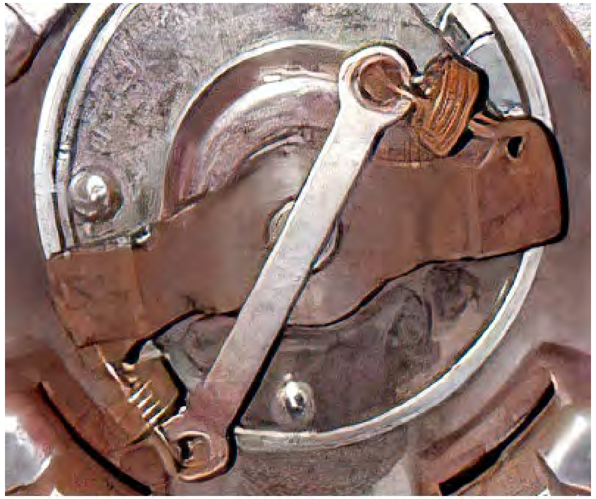
Three piece – coupling connects motor to bearing assembly.



Circulator Couplings

Couplings can wear and break.

When a coupling breaks, check the motor mounts……



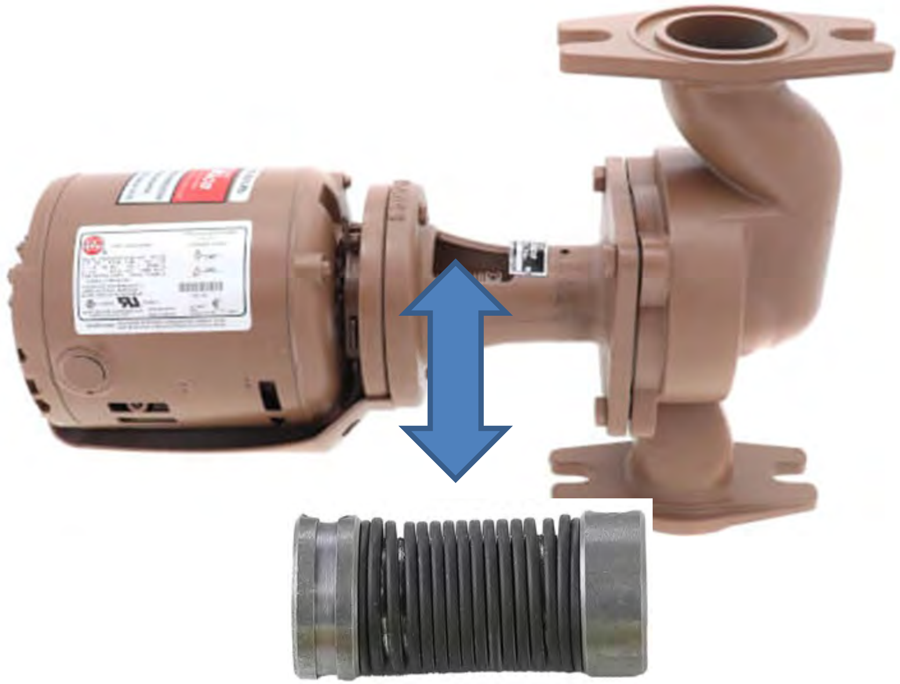
Circulator Coupling

- Excessive circulator oiling can cause motor mounts to sag, causing misalignment of the motor – bearing assembly.
- Sagging mounts lead to broken couplings.

Circulator Couplings

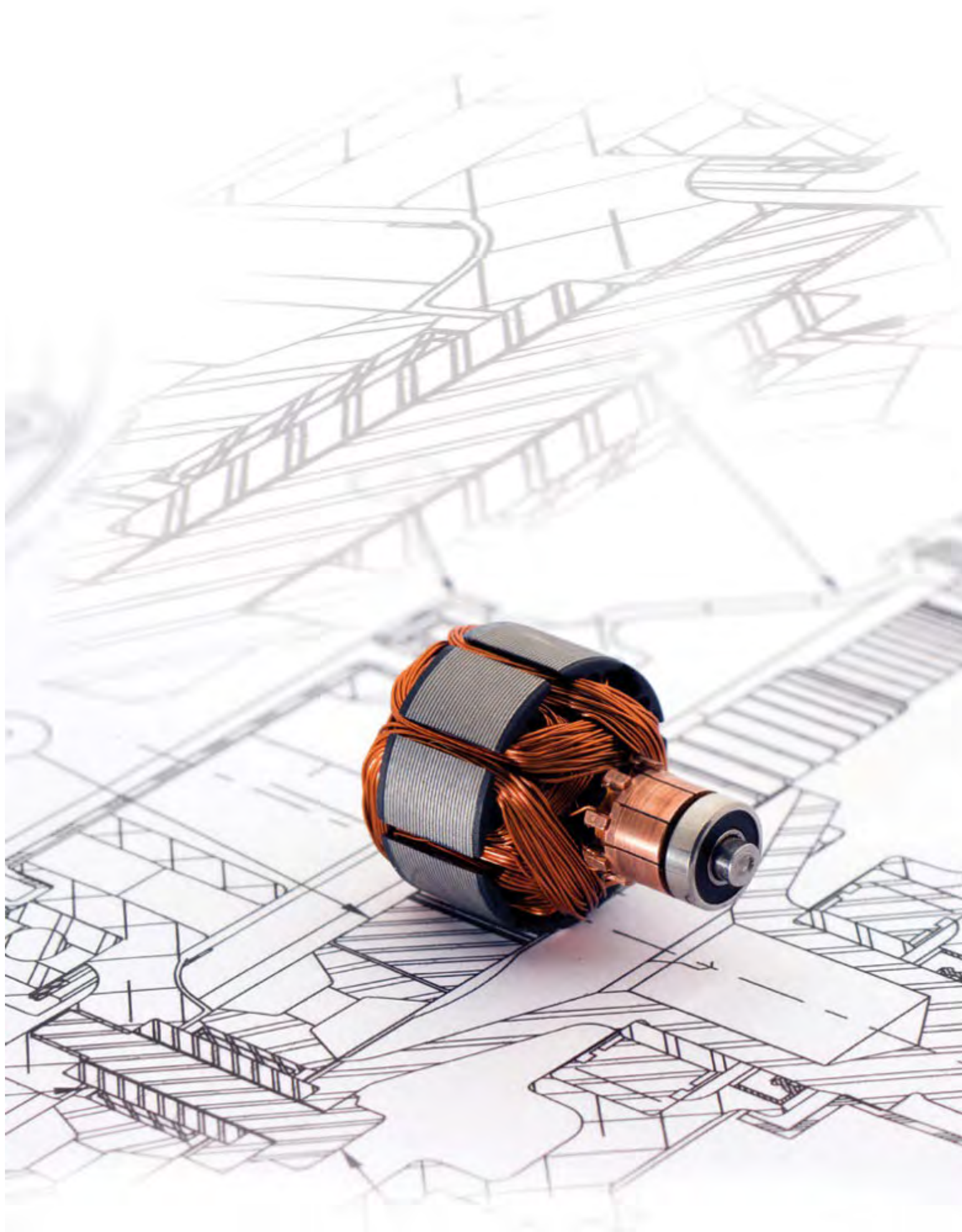
Some 3-piece circulators have a “spring coupling” that pulls the bearing shaft toward the motor to hold a pressure seal in the bearing assembly.

To prevent water from leaking, care must be taken to maintain pressure on the bearing assembly shaft when replacing these couplings.



Review Questions:

- What are the different types of motors?
- What are the common reasons for an overload switch to trip?
- How do you use a multimeter to troubleshoot a permanent split capacitor (PSC) motor?
- What do you need to consider when replacing a motor?



End Chapter 11

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 12

Ignition Systems

At the end of this lesson, you will be able to:

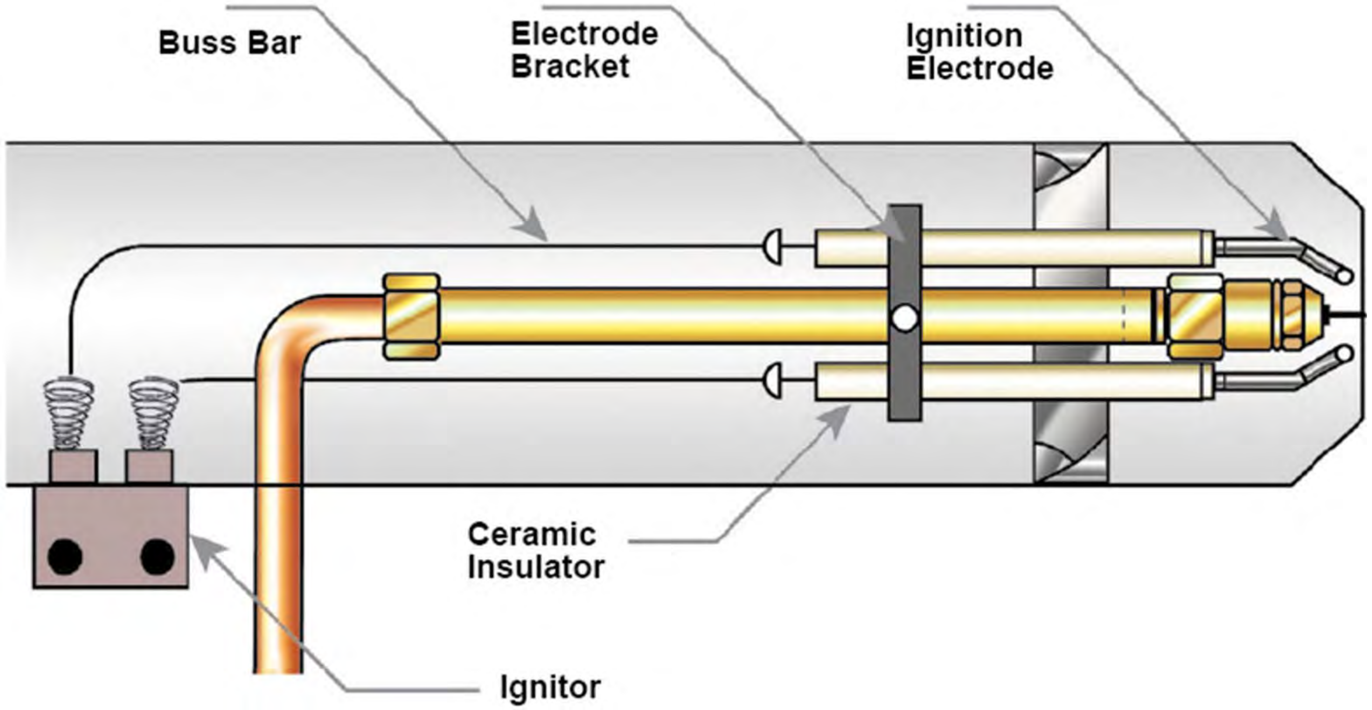
- Explain how an igniter works
- Label the components of an ignition system on a diagram
- Explain what you look for when you inspect and troubleshoot an ignition system
- Test a transformer and an ignitor

Ignition Systems

The main component of the ignition system is a solid-state ignitor that produces 14,000 to 20,000 VAC output. Older burners had ignition transformers that supplied 10,000 to 12,000 VAC, when these fail, they are usually replaced with an ignitor.

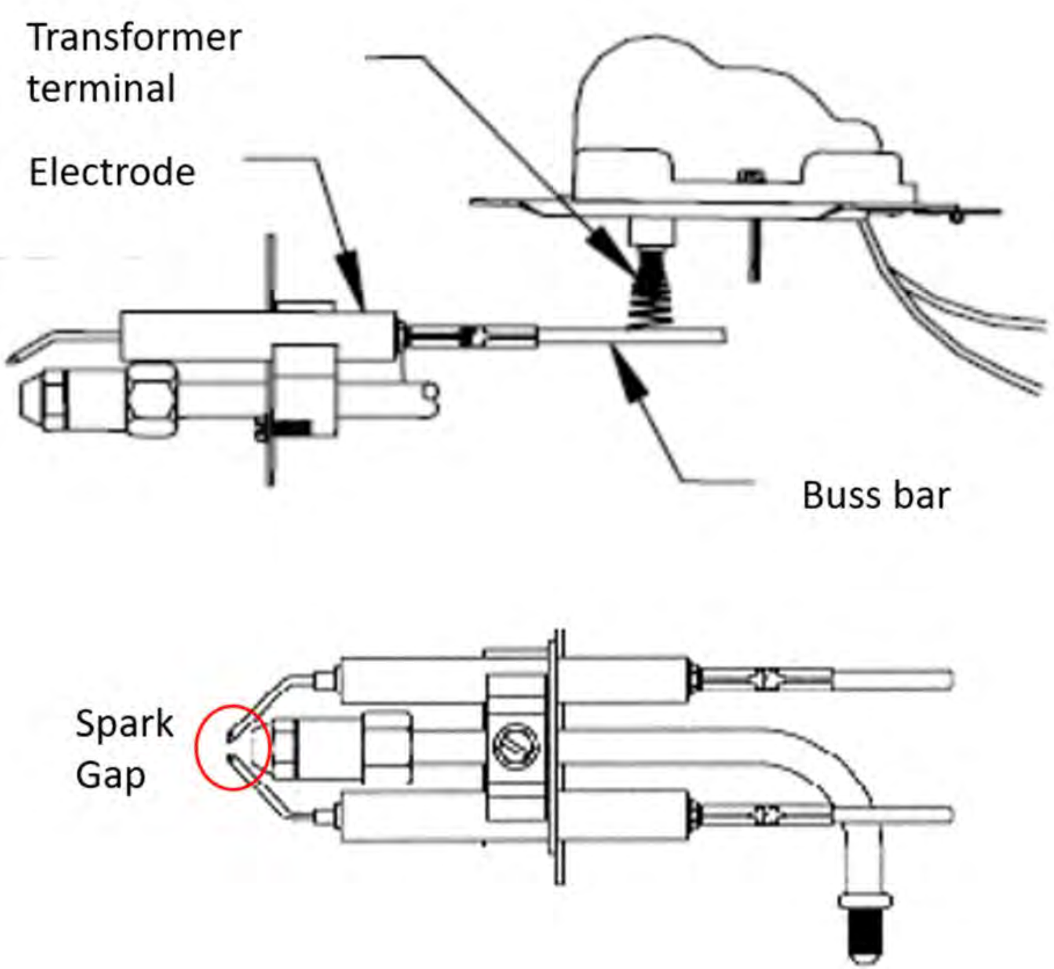
Ignition Systems

The ignitor supplies high voltage to electrodes which carry the voltage to the area just above the nozzle.



Ignition Systems

When a burner starts, a spark jumps from the tip of one electrode to the tip of the other, igniting the atomized fuel.



Two Types of Ignition Control

Interrupted ignition

the spark between the electrodes remains on for only a short time at the beginning of each burner cycle and shuts off after flame is established. (based on the Primary Control TFI timing)

Intermittent ignition

the spark remains on for the entire cycle.

Interrupted Ignition is Better

	Interupted	Intermittent
Electrical Consumtion	less	more
Electrode Life	longer	reduced
Igniter Life	longer	reduced
Flame Noise	less	more
Safety **	greater	less

** Intermittent ignition may hide combustion problems. The constant arc between the electrodes can cause the burners primary control to malfunction and fail to shut the burner when there is a poor flame. This doesn't happen with interrupted ignition because the arc shuts off once flame is established.

A Strong Spark

The air being blown through the air tube forces the ignition spark to form an arc toward the fuel spray.

This arc extends into the spray causing the fuel vapors to ignite and the flame to establish.

Buss Bars & Spring Clips

These devices transport high voltage from the igniter to the electrodes.

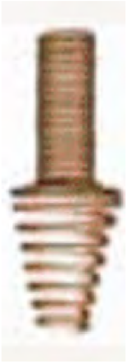
Ignitior Terminals

Attach to ignitor to complete the connection to the buss bars

After some time, these clips can lose their tension and prevent proper contact.

Spring Clips

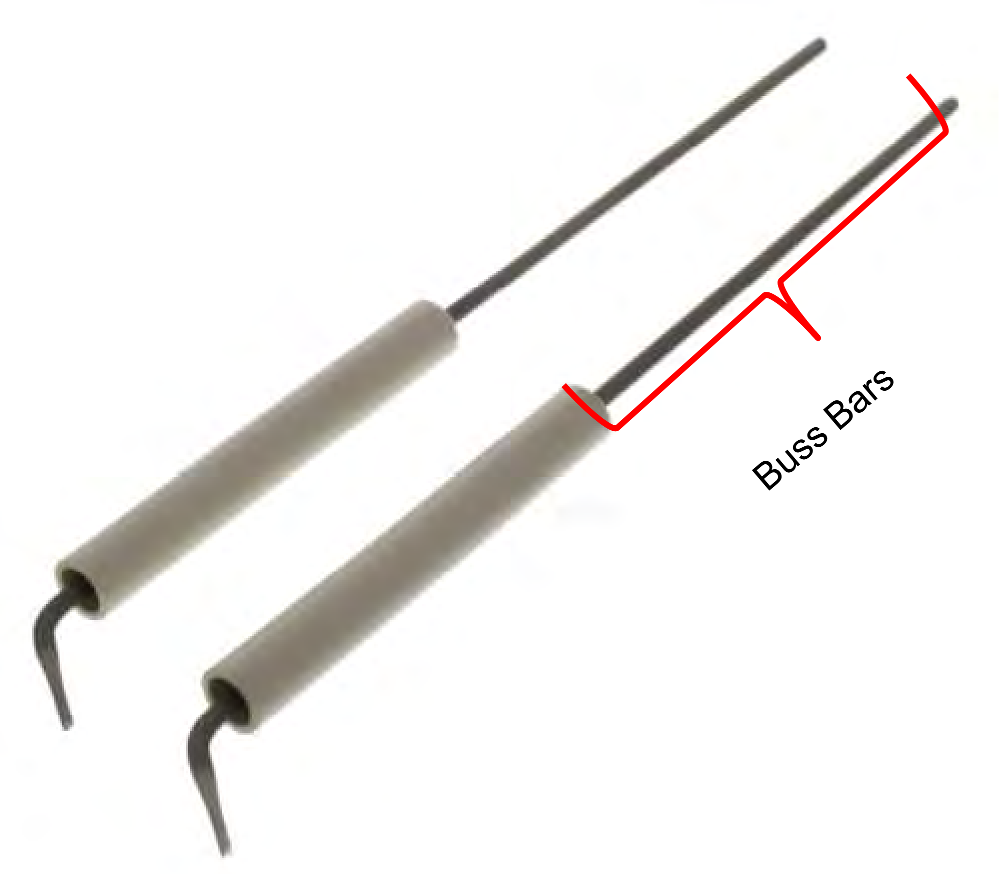
Tension should be checked during servicing.



Buss Bars

Non-insulated heavy gauge strips of metal that are made by the burner manufacturer to the length and shape to fit a certain model of burner.

They are not usually interchangeable with other model burners.

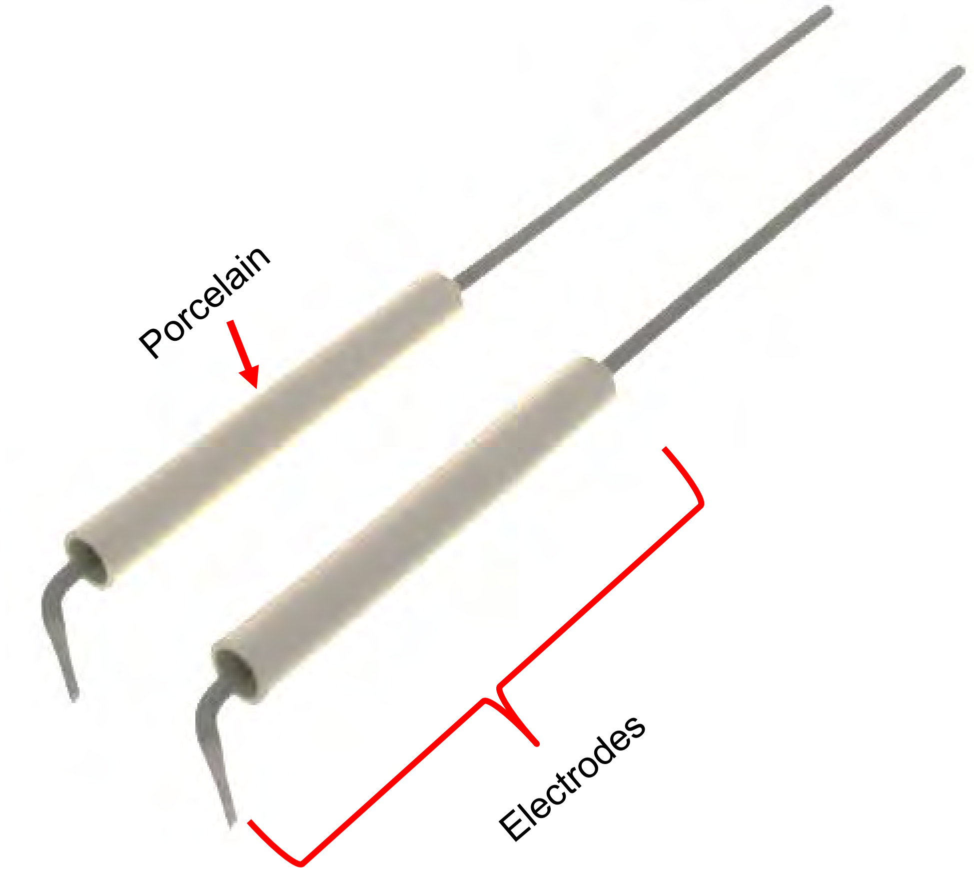


Electrodes

Electrodes are metal rods made of specialized steels, and partially covered with a ceramic (porcelain) insulator.

The porcelains serve two purposes:

- They securely position the electrode rods
- They serve as insulators, protecting the metal rod against shorting out to the nozzle assembly.



Electrodes

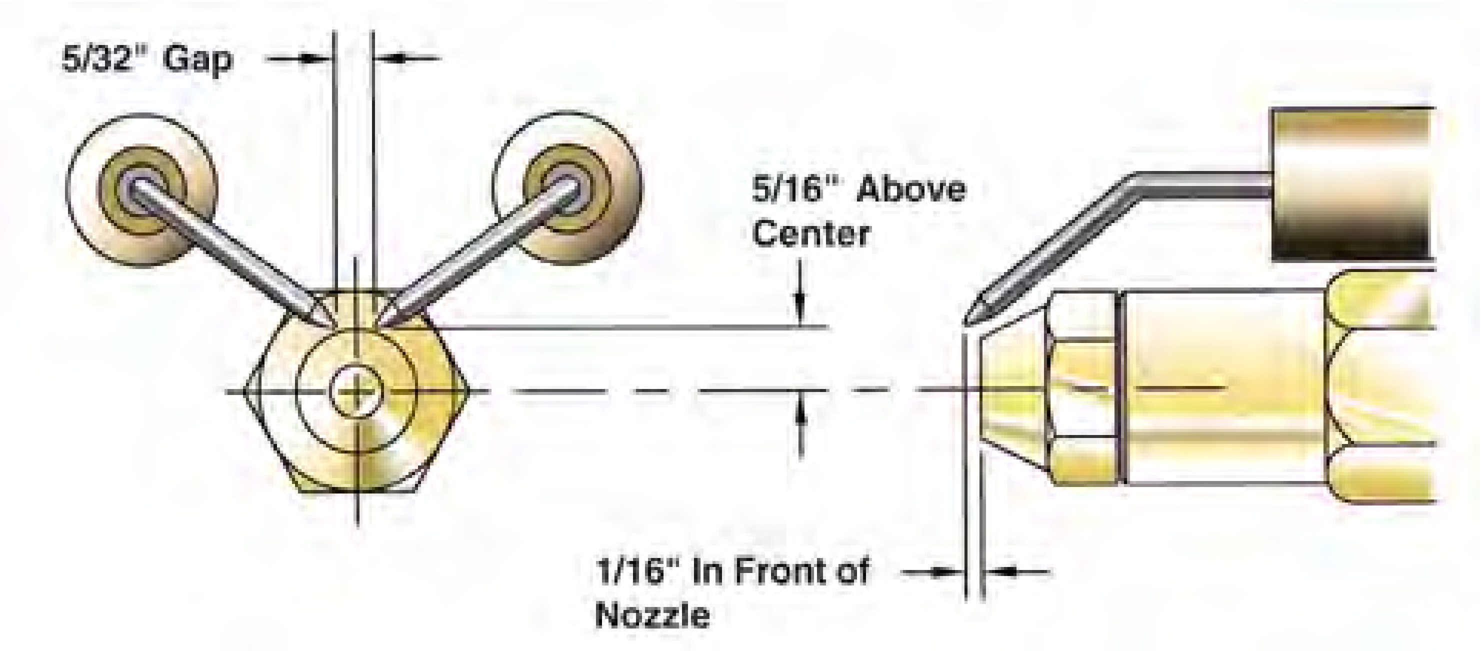
Should be inspected each time the nozzle assembly is removed.

Replace if cracked, broken or have eroded tips.

If a carbon bridge build up between them, they are not properly adjusted.

Electrode Setting

Follow manufacturer's instructions.



Tips shouldn't touch or extend into fuel spray.

Testing Igniters

Do not test igniters or transformers with a screwdriver!

Use the proper tools and

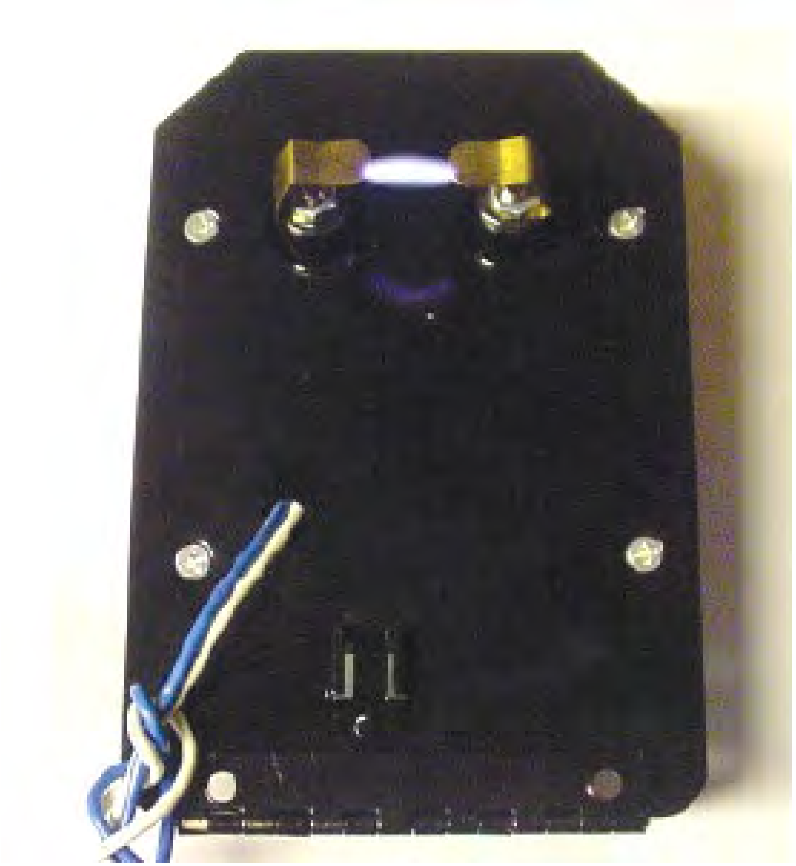
Testing Ignitors and Transformers

There are several tests that a technician can perform onsite:

Test #1

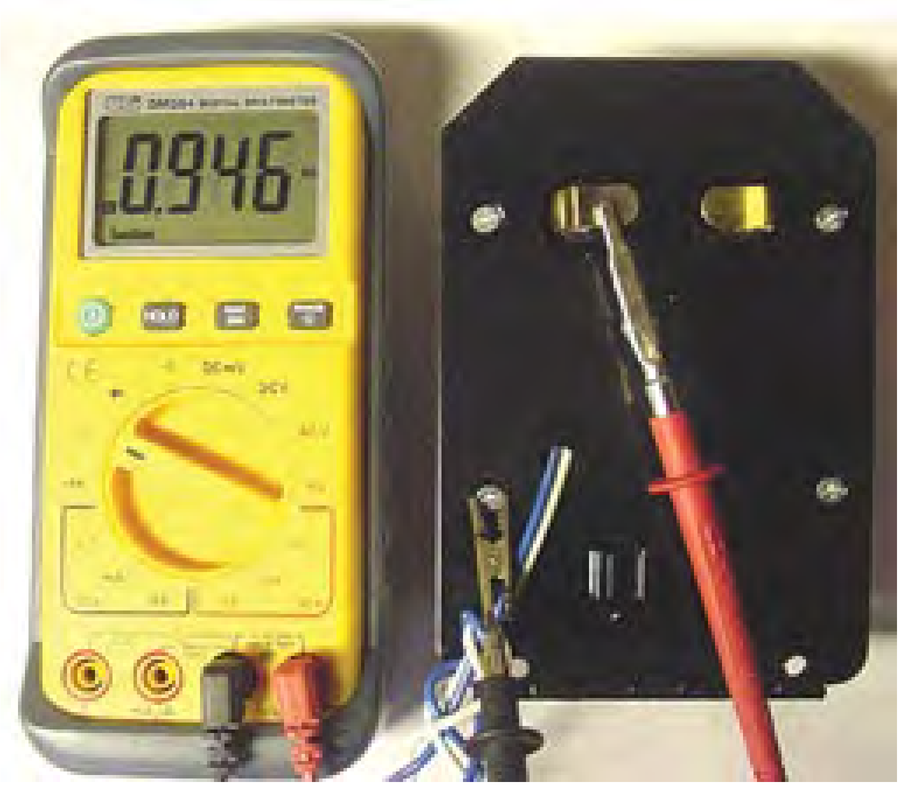
Position the output terminals to within ½” to ¾” apart and then apply power.

A strong spark should jump the gap, if it does not, replace the component.



Testing Igniters and Transformers

Test #2



With the power off, use an ohmmeter to measure the resistance from each igniter post to ground.

Generally, if the difference between the two readings is 10% or less the igniter is considered good.

Testing Igniters

Test #3

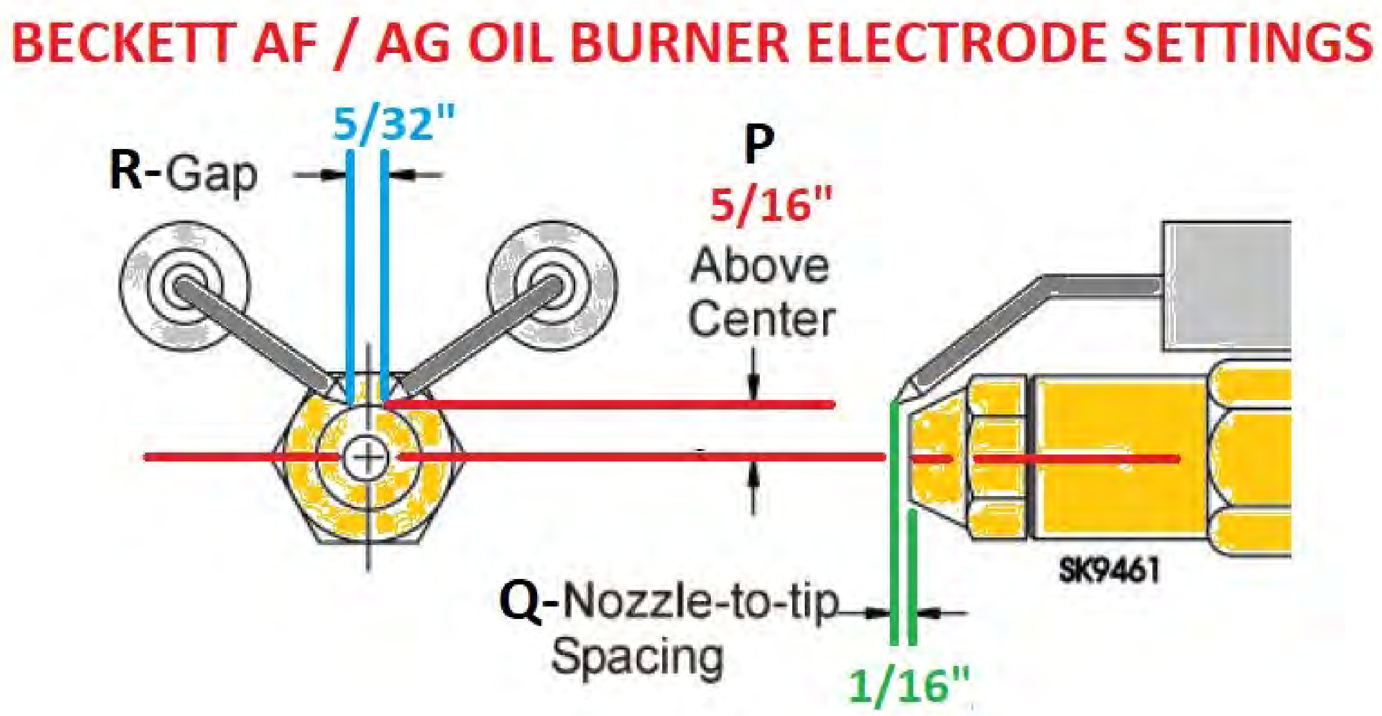
Position the terminals to within ½” to ¾” apart.

Place a milliammeter in series with the hot line going to the igniter and apply power.

The reading should be steady & not vary for 5 minutes. Astrong spark should be maintained while staying within 10% of the rated amperage draw.

Ignition Service Problems

Ignition problems can be the easiest to recognize and solve. Sometimes merely cleaning & adjusting the electrodes to manufacturer specifications is all that's required.



Troubleshooting Ignition Problems

1. Loose electrical connections

Make sure that wire nuts, spade connectors, etc. are tight.

2. Test the ignitor

Replace if defective.

3. Electrodes not making contact with ignitor terminals

Adjust the terminals and/or buss bars.

Troubleshooting

4. Cracked porcelain insulators

Remove the porcelain insulators from the electrode holder to see if they're cracked, replace even if they're functioning properly.

Troubleshooting

5. Carbonized insulator

Carbon on the ceramic insulators will conduct electricity causing the spark to short out.

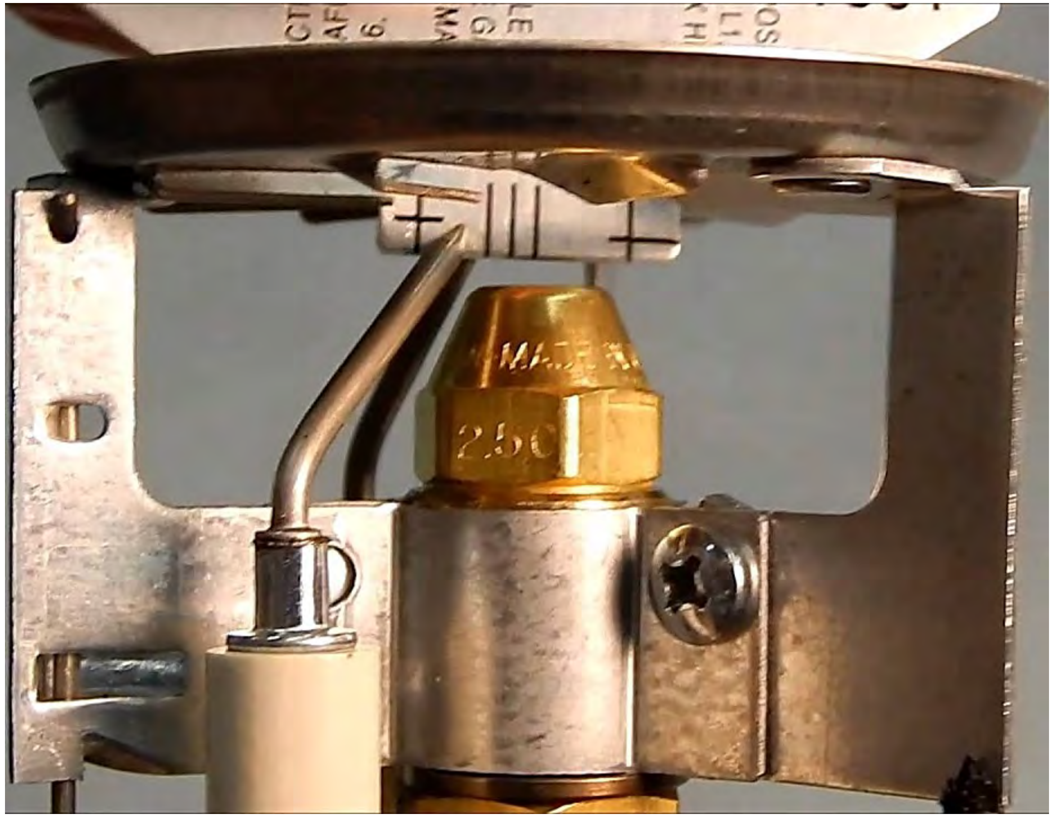
The carbon must be removed with a solvent or cleaner, then the insulators must be dried and checked.

Determine why they're carbonized, typically this is caused by delayed ignition or a draft problem.

Troubleshooting

<u>6. Electrodes in fuel spray</u>
if the electrode tips are extending into the fuel spray, a carbon bridge may for between them, shorting out the spark.

Clean the electrodes and set them to manufacturer specs.



Troubleshooting

7. **<u>Electrodes too close to the nozzle</u>**
If the electrode tips are too close to the nozzle the spark will short from the tip to the nozzle creating delayed or ignition failure.

Always set electrodes to manufacturer's specifications.

Troubleshooting

<u>8. Spark gap too wide</u>

If the spark gap is too wide there will be no spark at all.

Always set electrodes to manufacturer specifications.

Troubleshooting

9. **<u>Insulators not held securely</u>**

If the bracket is loose or the porcelains do not fit properly, the electrodes can move out of position due to vibrations.

Tighten the bracket securely, but do not overtighten because that might crack the ceramic insulators.

Troubleshooting

<u>10. Delayed ignition may be caused by a lack of draft</u>

If the ceramic insulators are heavily carbonized and the electrode tips are set properly, a lack of overfire draft might be the problem.

Check both breech and overfire draft to determine if the appliance needs to be cleaned or if there's a problem with the venting system.

Review Questions:

- How does an igniter work?
- What are the components of an ignition system?
- What do you look for when you inspect and troubleshoot an ignition system?
- How do you test a transformer and an ignitor?

End Chapter 12

NORA Technician Certification

Review

Bob O’Brien, NORA Director of Education

Chapter 13

Heating Systems

Part 1 – Warm Air

At the end of this lesson, you will be able to:

- Describe the different configurations of warm air furnaces
- Label the parts of a distribution system on a diagram
- Troubleshoot a warm air system
- Describe the different types of hydronic (hot water) systems
- Explain how a series loop, 1-pipe, and 2-pipe systems are different
- Describe what the components of a hydronic system do
- Explain what is used to eliminate or control air in a hydronic system
- Explain what is used to control zones in a hydronic system

At the end of this lesson, you will be able to:

Continued

- Explain how steam boilers use pressure to move heat
- Explain what happens if the pressure is too low or too high in a steam system
- Explain the important things to remember when installing a steam boiler
- Describe what the different steam boiler components do
- Explain how air, steam, and water move in a one-pipe steam system
- Explain the difference between a direct and indirect hot water system
- Explain what components in direct hot water systems do
- Explain what components in an indirect hot water system do

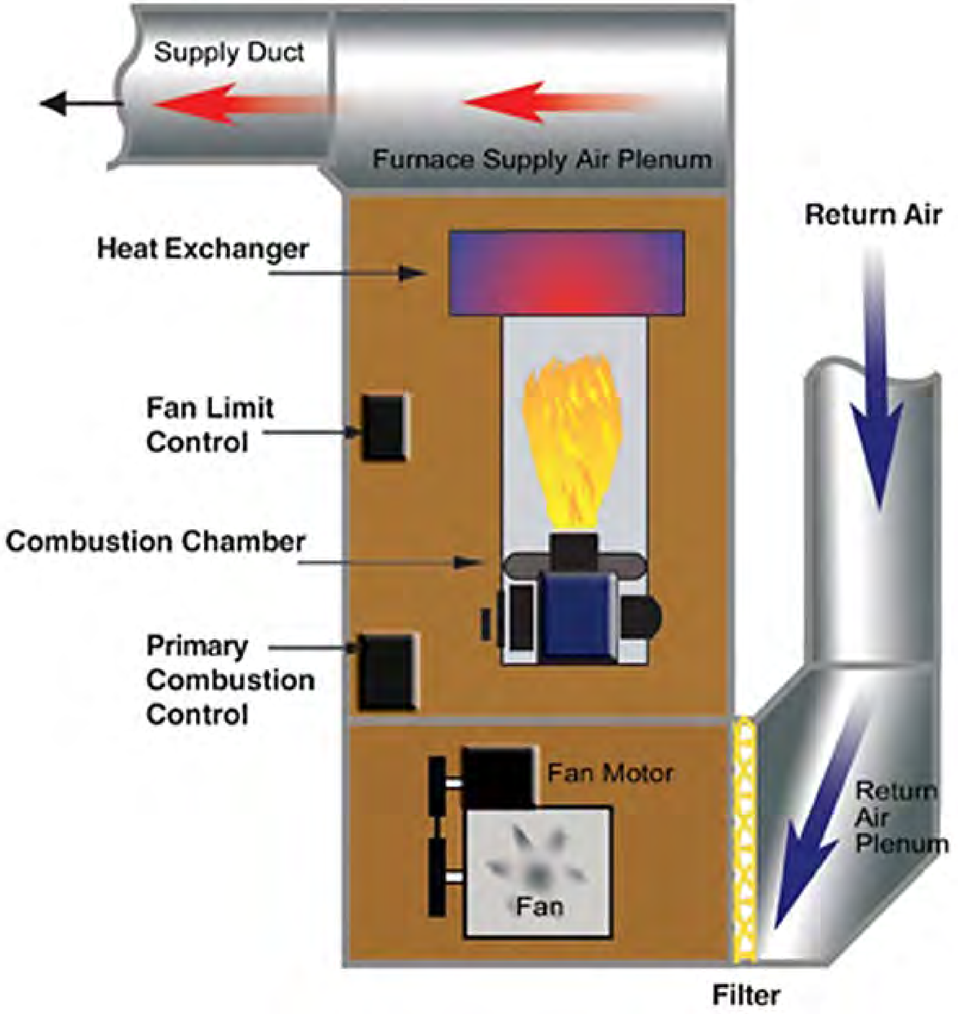
Warm Air Furnaces

Furnaces create warm air that is distributed through ductwork.

They utilize a heat exchanger that absorbs heat from the flame and transfers it to the air that circulates through the furnace and into the building.

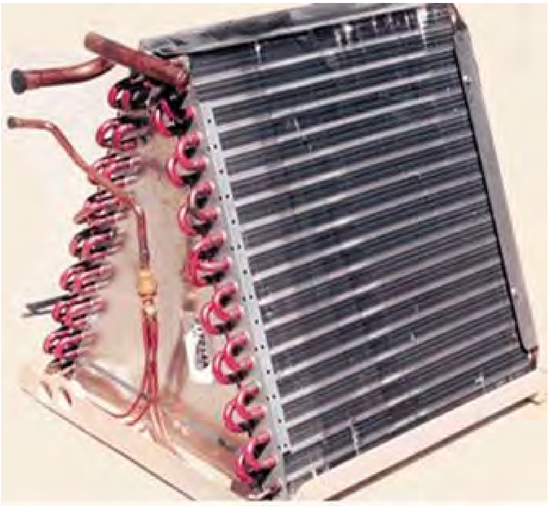
Warm Air Furnaces

- Heated air is distributed through supply ducts
- Cold air is brought back through return ducts

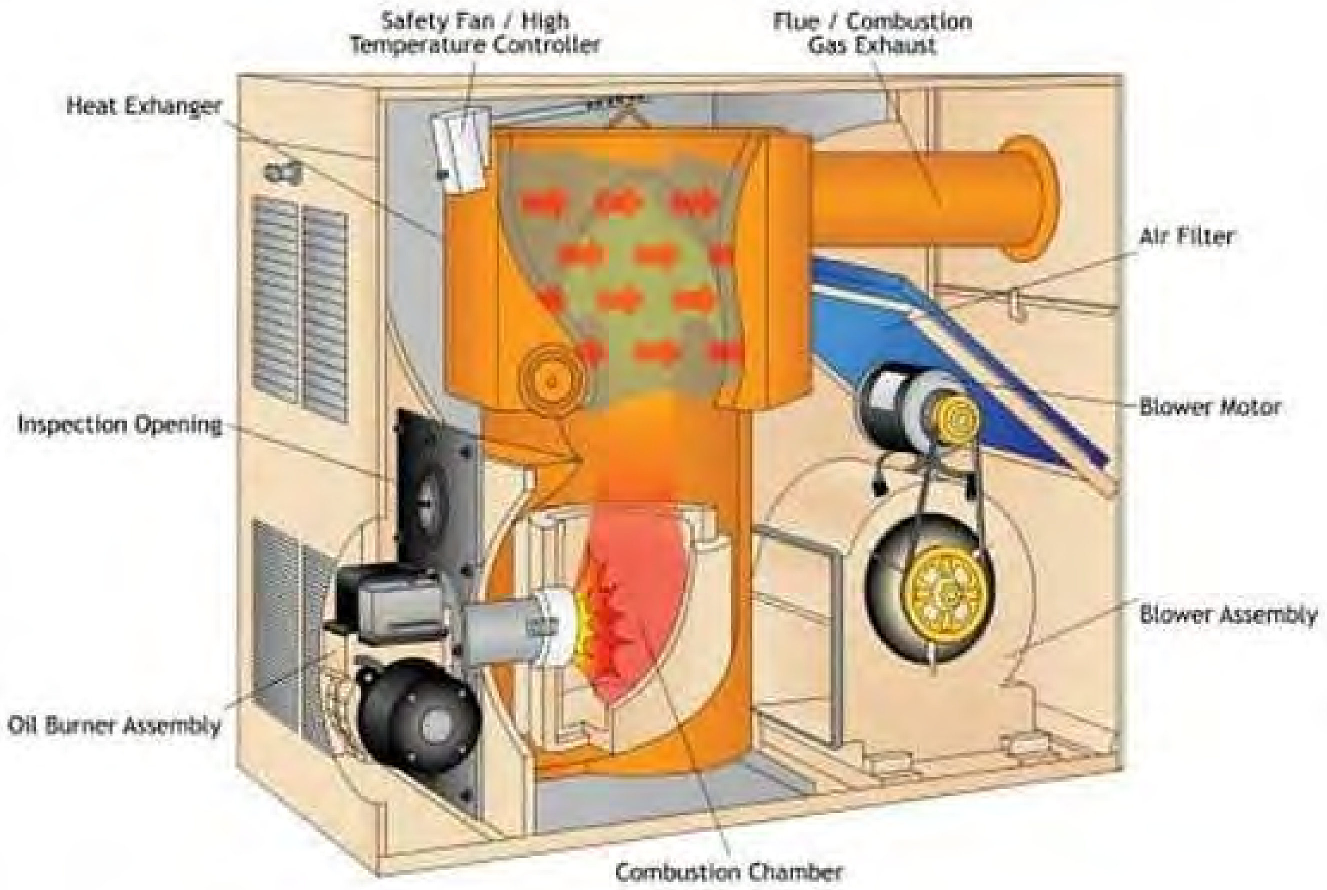


Warm Air Advantages

Air cleaners, humidifiers and central air conditioning can be incorporated into the unit to a total comfort indoor air quality climate control system.



Blower



- Blower is attached to ducts
- Airflow is measured in CFM
- Ducts MUST be properly sized to move enough air across the heat exchanger to remove heat and deliver it to building

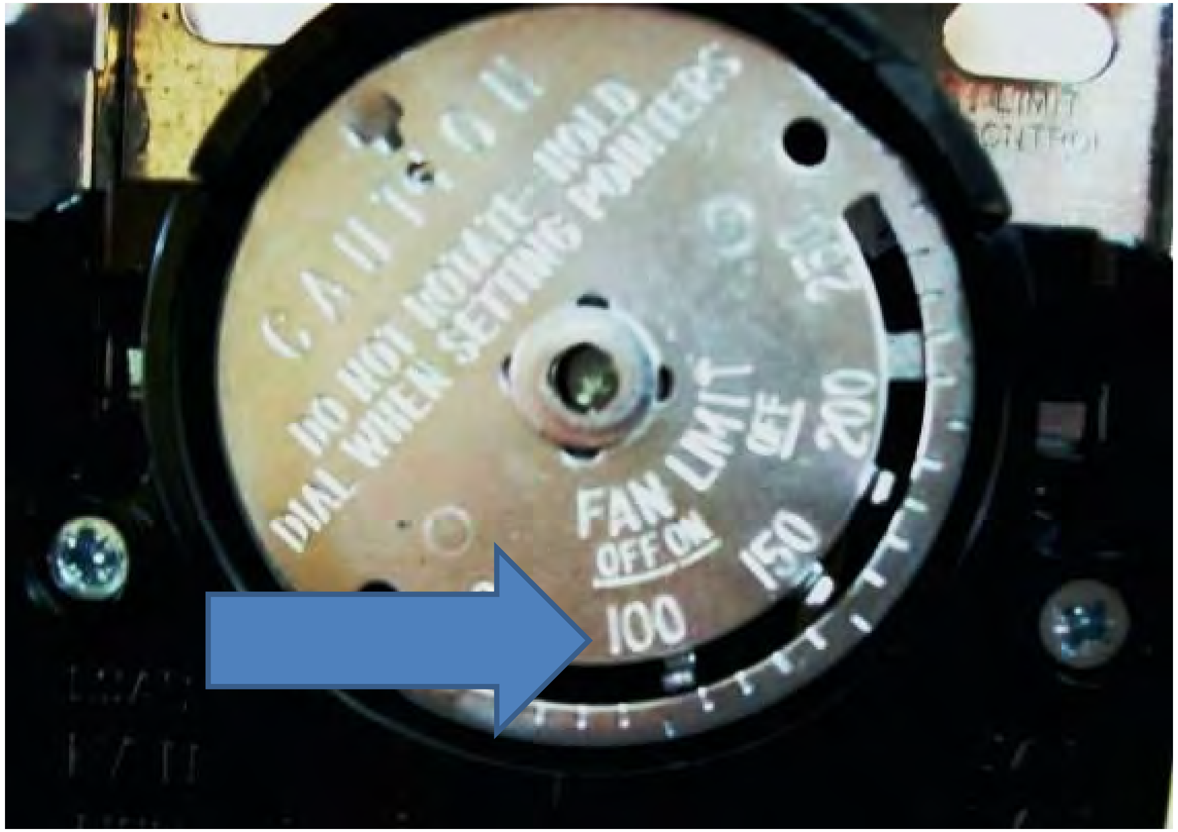
Normal Operation

1. Thermostat calls for heat and activates burner through the primary control.
2. Burner runs until sufficient heat builds up to activate fan control and start blower.
3. Burner & blower run together until the thermostat is satisfied and burner turns off.

Normal Operation (continued)

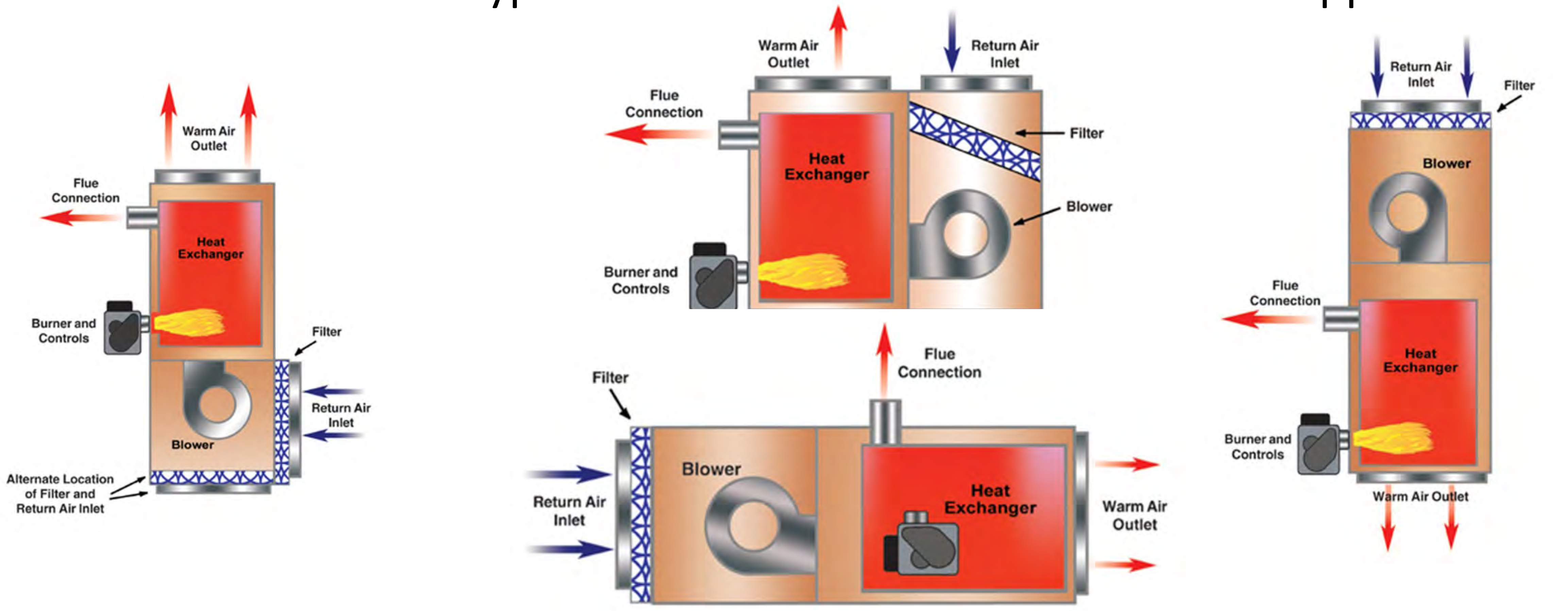
1. Blower continues to run until heat in furnace is dissipated and fan shuts off. (usually around 100° F)

The blower may come back on after a few minutes due to residual heat from the heat exchanger rising and reactivating the fan-limit control. (if there is one.)



Types of Furnaces

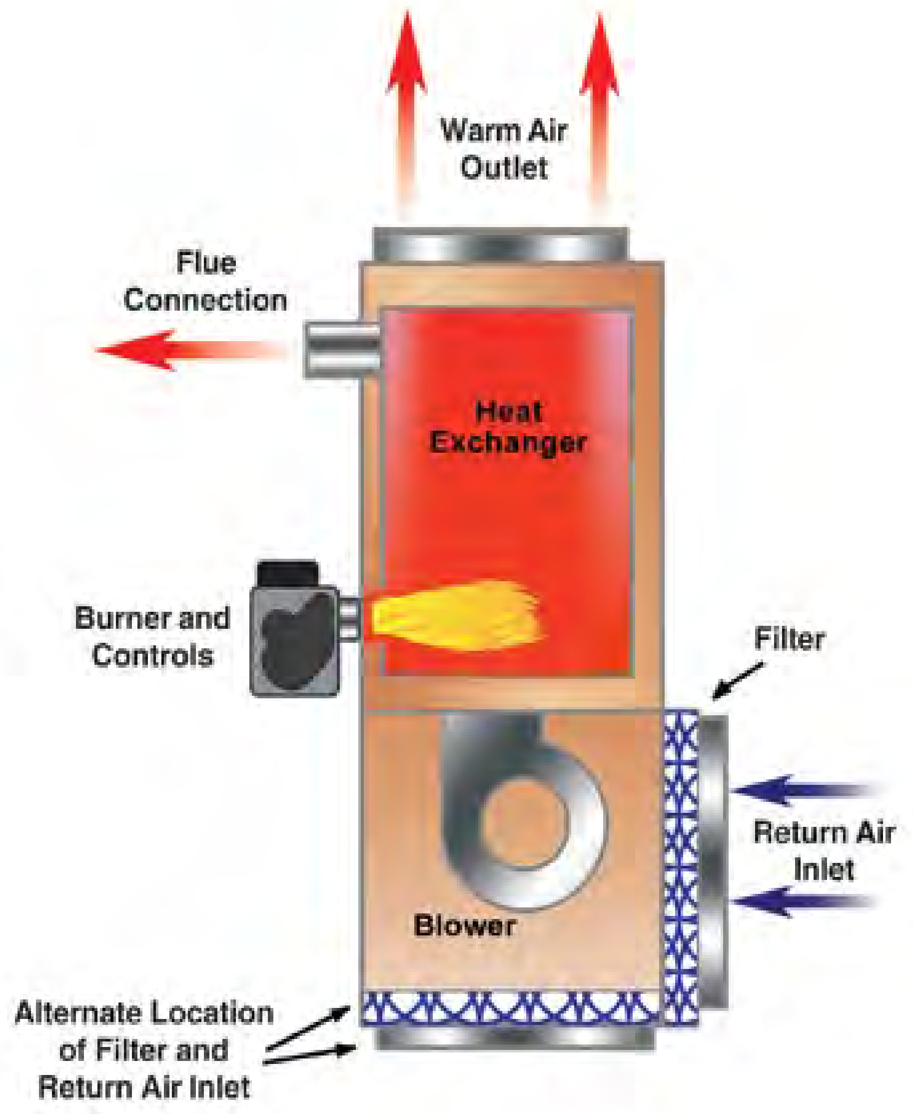
There are different types of warm air furnaces for different applications.



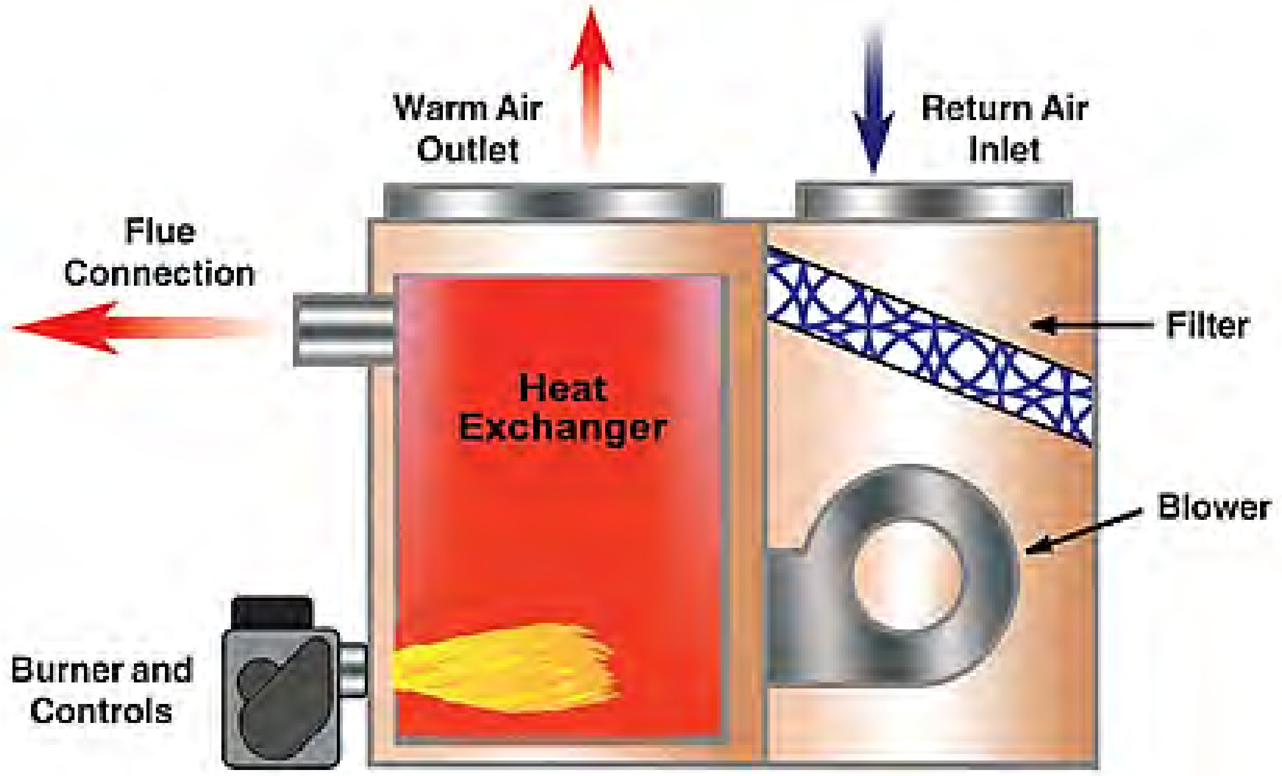
The basic operation of these is similar, but the configurations vary……

Highboy

- Most common type in the field
- Heat exchanger sits on top of the blower
- Return air is pulled through the bottom of the appliance, across the heat exchanger anc out through the top



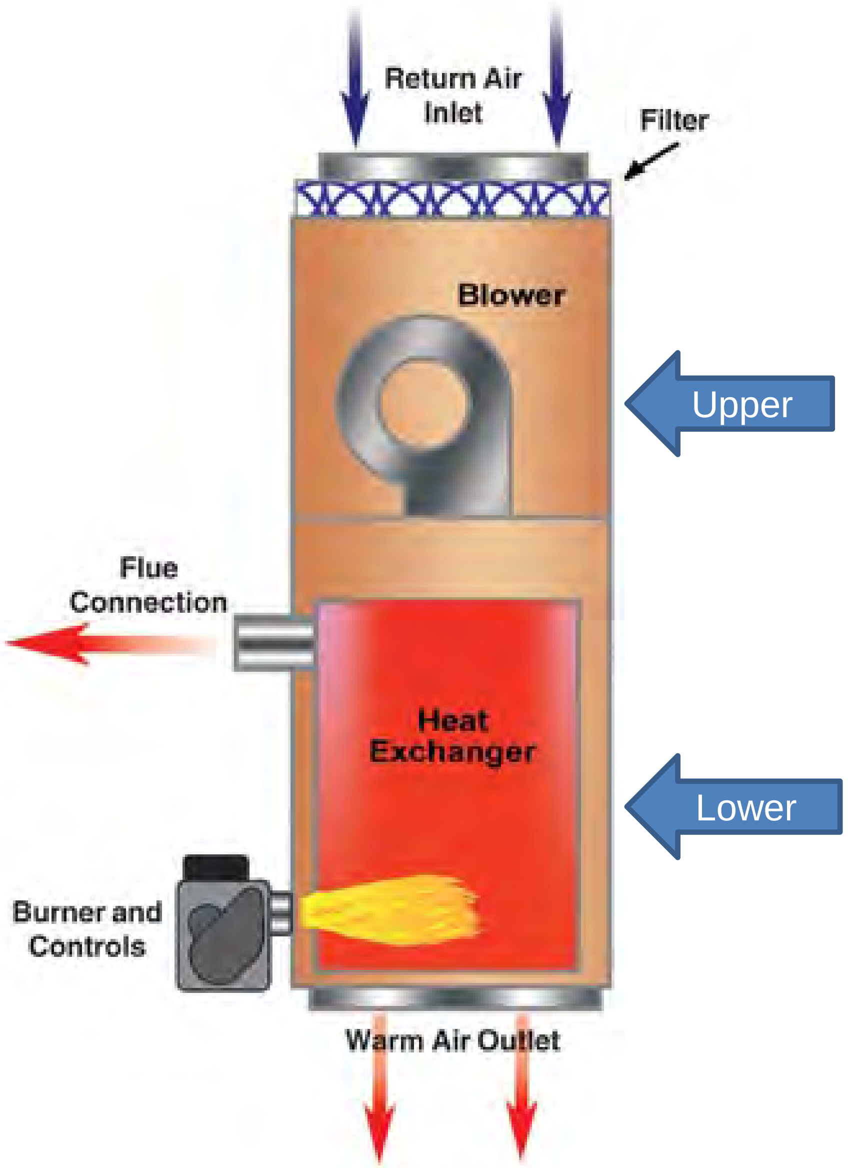
Lowboy



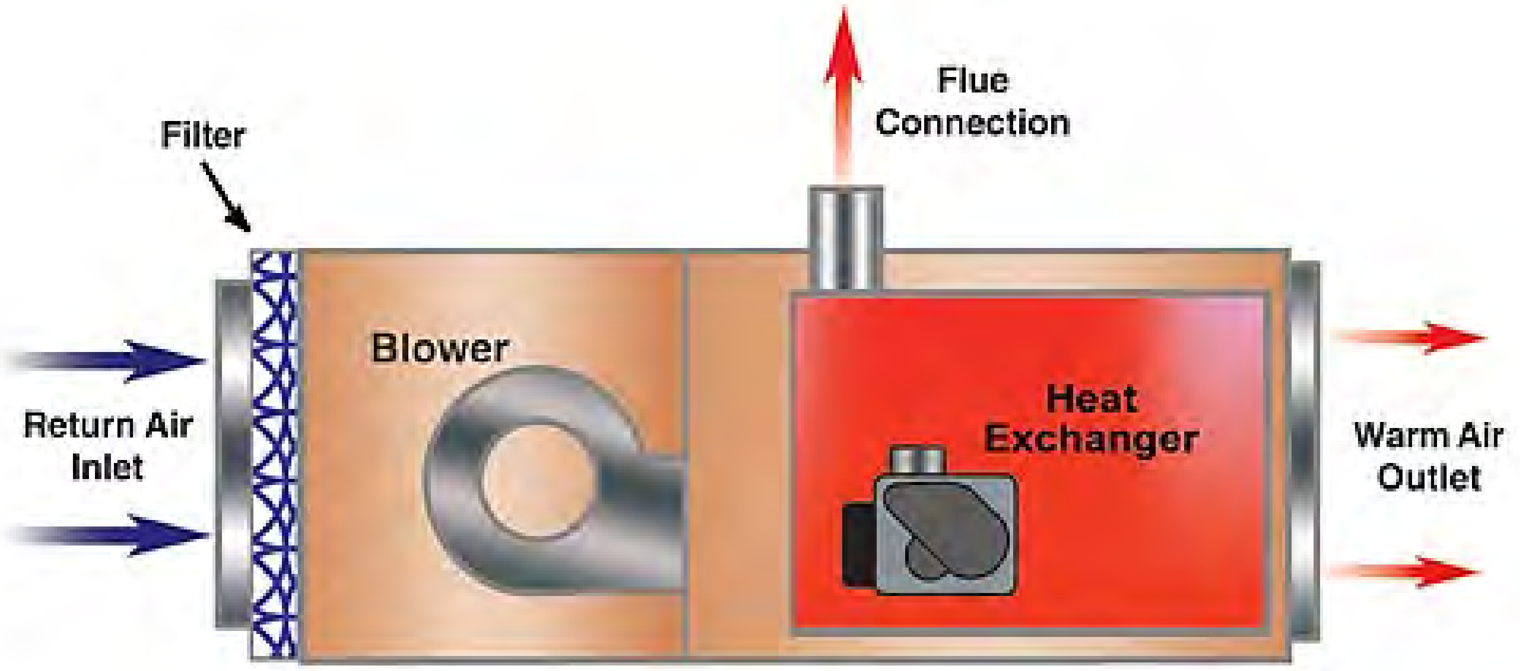
- Used when height constraints are present
- Blower is next to the heat exchanger

Counterflow

- Look like highboy but blower is above the heat exchanger
- Used in slab houses
- Additional control is installed below the heat exchanger
- Upper control turns on blower on temp. rise, lower control turns off blower on temp. fall



Horizontal



- “Highboy on its side”
- Used in crawl spaces or suspended from ceiling

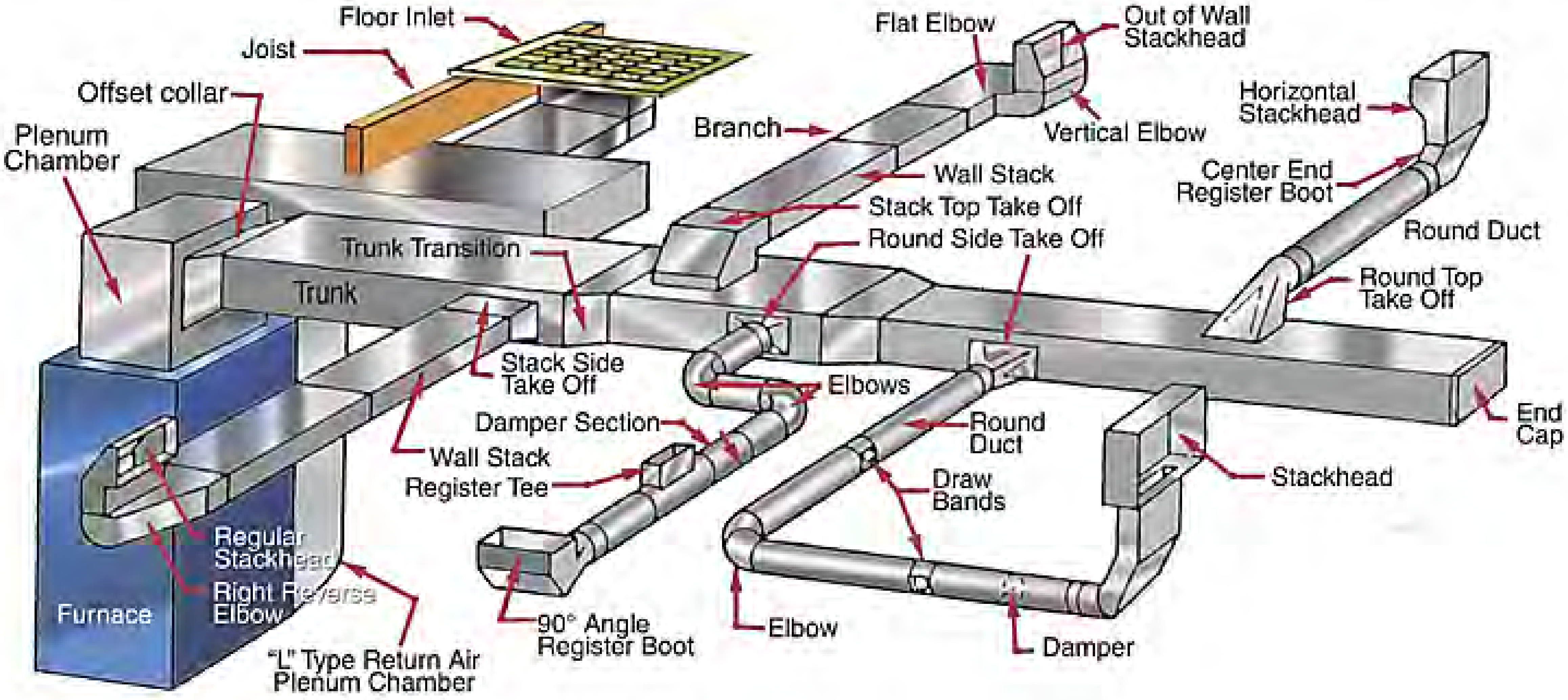
Distribution System

Three main components:

Plenum – boxlike chambers connected to furnace, one on supply, one on return. Should be same size as furnace opening.

Trunks – Usually rectangular ducts that connect to the plenums and run through central areas of building.

Branches – smaller ducts, round or rectangular, connect trunks to individual registers.


Floor Inlet
Joist
Offset collar
Plenum Chamber
Trunk Transition
Trunk
Furnace
Regular Stackhead
Right Reverse Elbow
"L" Type Return Air Plenum Chamber
Stack Side Take Off
Damper Section
Wall Stack
Register Tee
90° Angle Register Boot
Flat Elbow
Out of Wall Stackhead
Vertical Elbow
Branch
Wall Stack
Stack Top Take Off
Round Side Take Off
Elbows
Round Duct
Draw Bands
Elbow
Damper
Horizontal Stackhead
Center End Register Boot
Round Duct
Round Top Take Off
End Cap
Stackhead

Dampers

It's a good practice to install dampers on each branch to allow for system balancing.

Troubleshooting

When responding to a service call for “not enough heat” or certain rooms “not heating”, first see if the burner, controls and blower are set and operating correctly, then look to the distribution system.

Most issues of this type are air flow related.

Check the following……

Troubleshooting

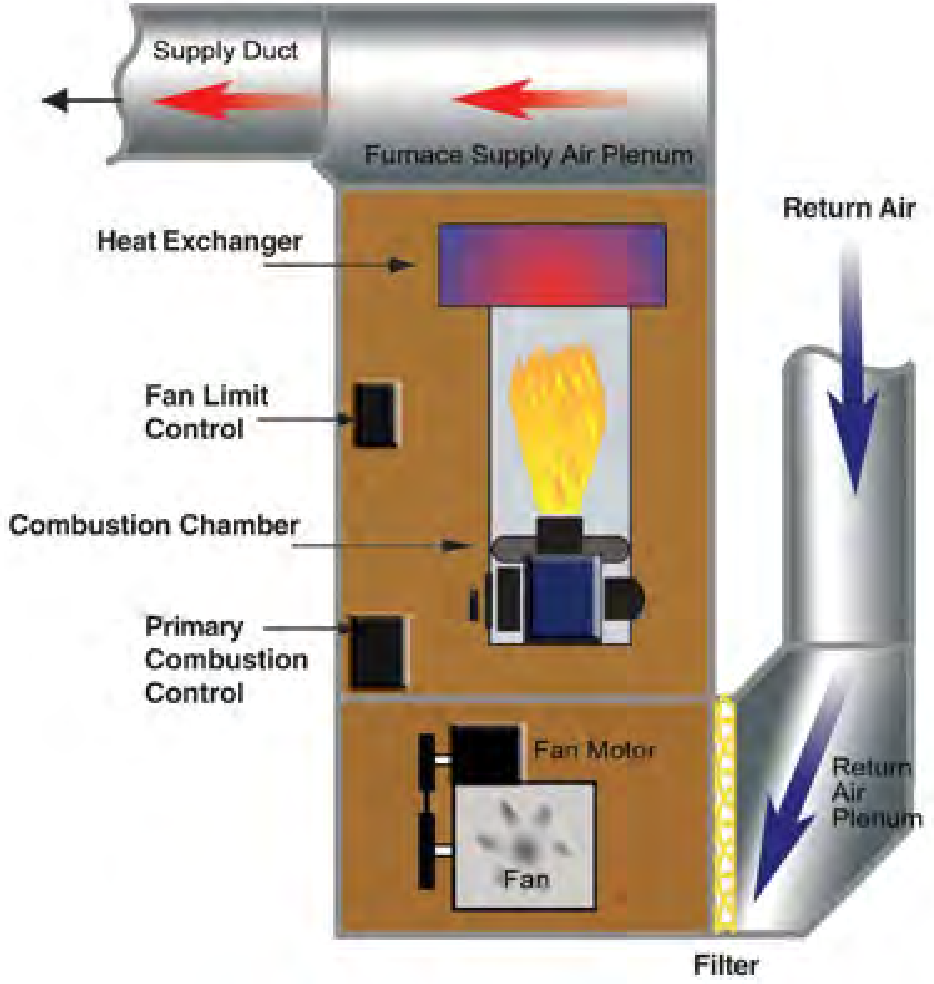
Not enough heat, check for:

1. Temperature rise
2. Adequate return air
3. System balance
4. Missing duct insulation

1. Temperature Rise

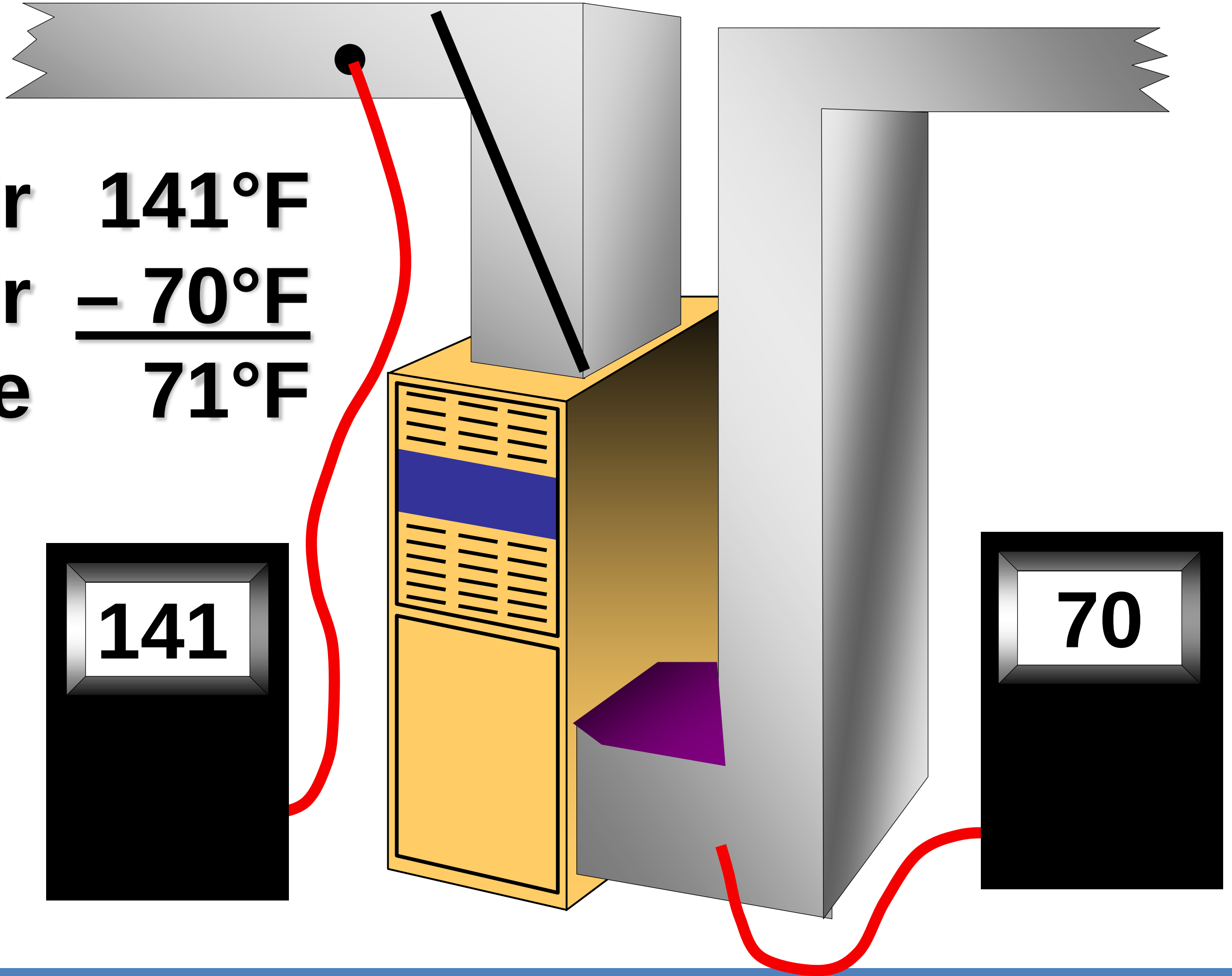
(an indirect way of measuring airflow)

Also called Heat Rise, it is the delivery air temperature minus the return air temperature after 5 minutes of continuous operation.

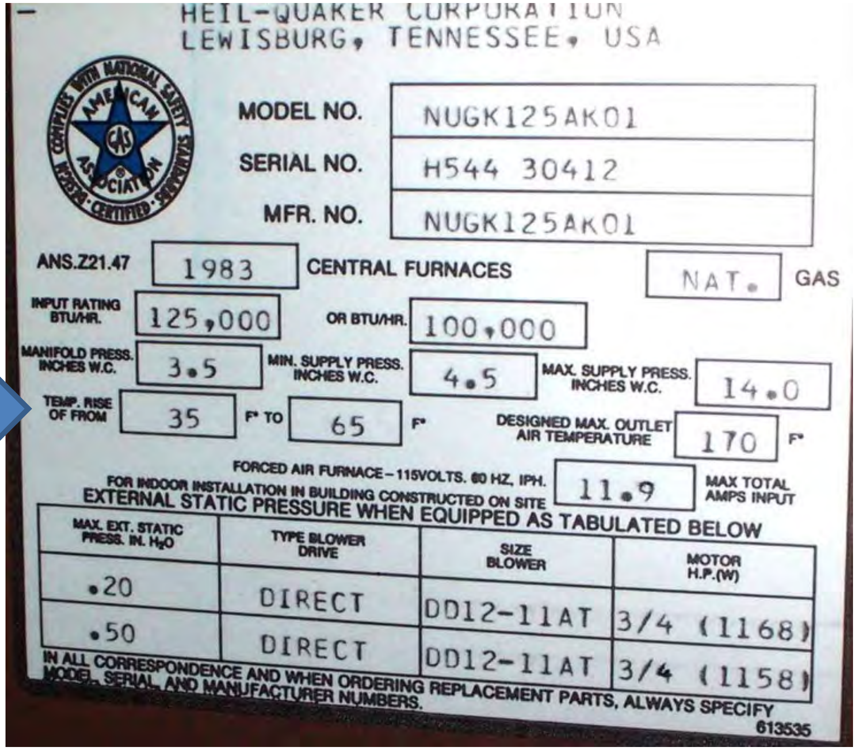


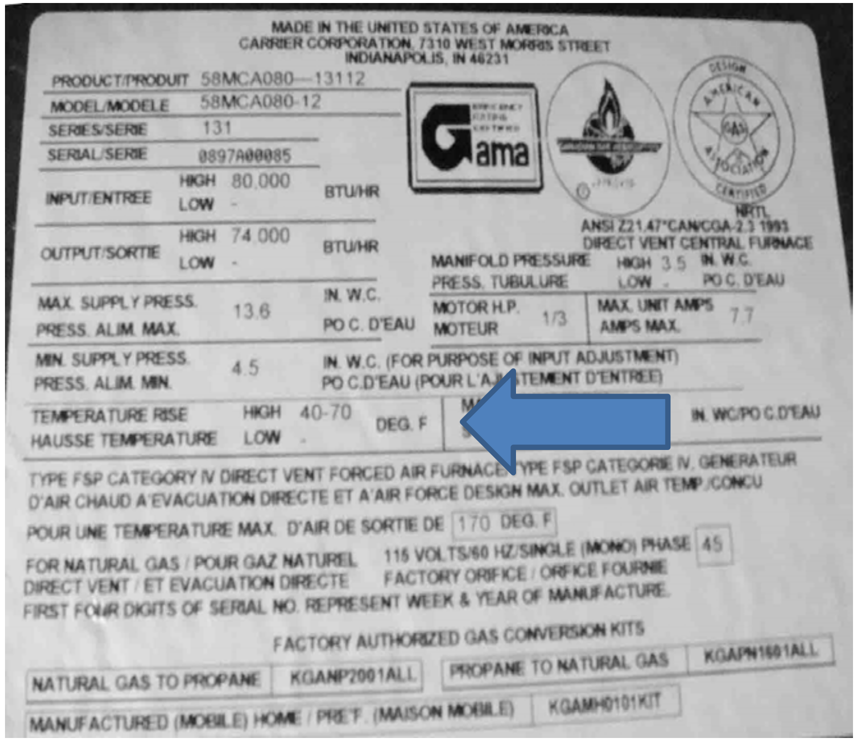
Temperature Rise

Supply Air	141°F
Return Air	– 70°F
Rise	71°F



Check Manufacturer Specifications





Temperature Rise

(an indirect way of measuring airflow)

Too high:

- Too little airflow
- Filters (short cycling)
- Check blower speed
- Duct restrictions?

Too low:

- Too much airflow
- Check blower speed
- Open return

2. Is there Adequate Return Air?

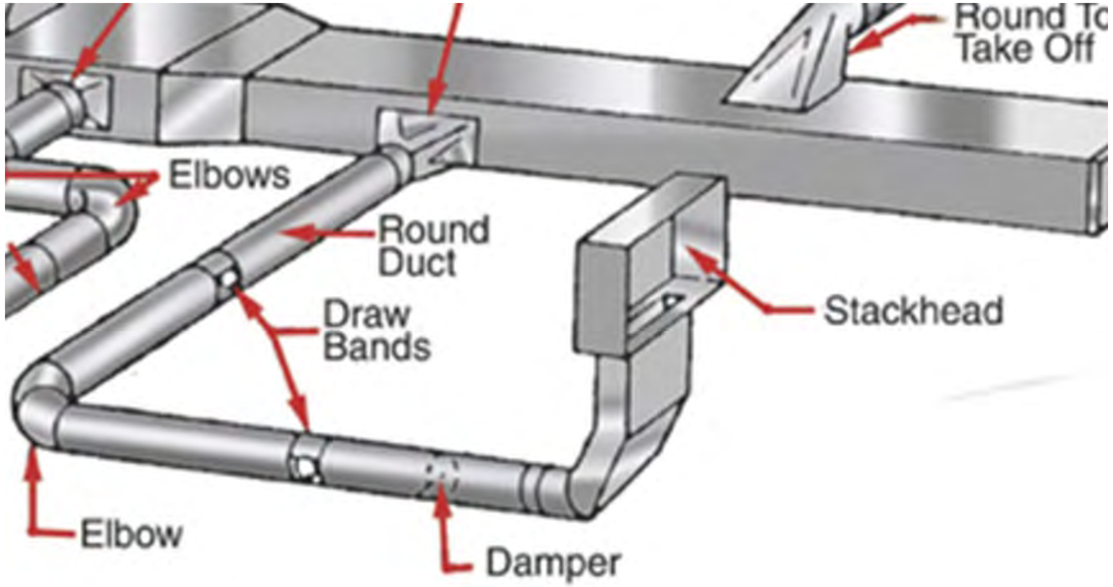
Ideally, there should be the same amount of return & supply air.

At a minimum, the return should never be less than 80% of supply.

It the ducts seem to be adequate, check to see if any supply or return grills are blocked by furniture or rugs.

3. Is the System Balanced?

Check to be sure that dampers are properly adjusted.



4. Do Ducts Run Through "Cold" Areas?

The heat loss from bare ducts running through unheated areas cools the air coming from the registers.

Ducts should be insulated to prevent heat loss!

Short Cycling or Going Off on High Limit

Check:

1. Control settings.
2. Blower operation.
3. Fan belt/pulleys.
4. Filter…..

Short Cycling or Going Off on High Limit

5. Return air grills and ducts - free of obstruction?

6. Supply registers and ducts free of obstruction?

7. Firing rate – overfired?

8. Is duct system designed to meet furnace requirements?

Testing for a Leaking Heat Exchanger

A combustion analyzer can be used to find leaks, cracks or holes in a furnace heat exchanger.

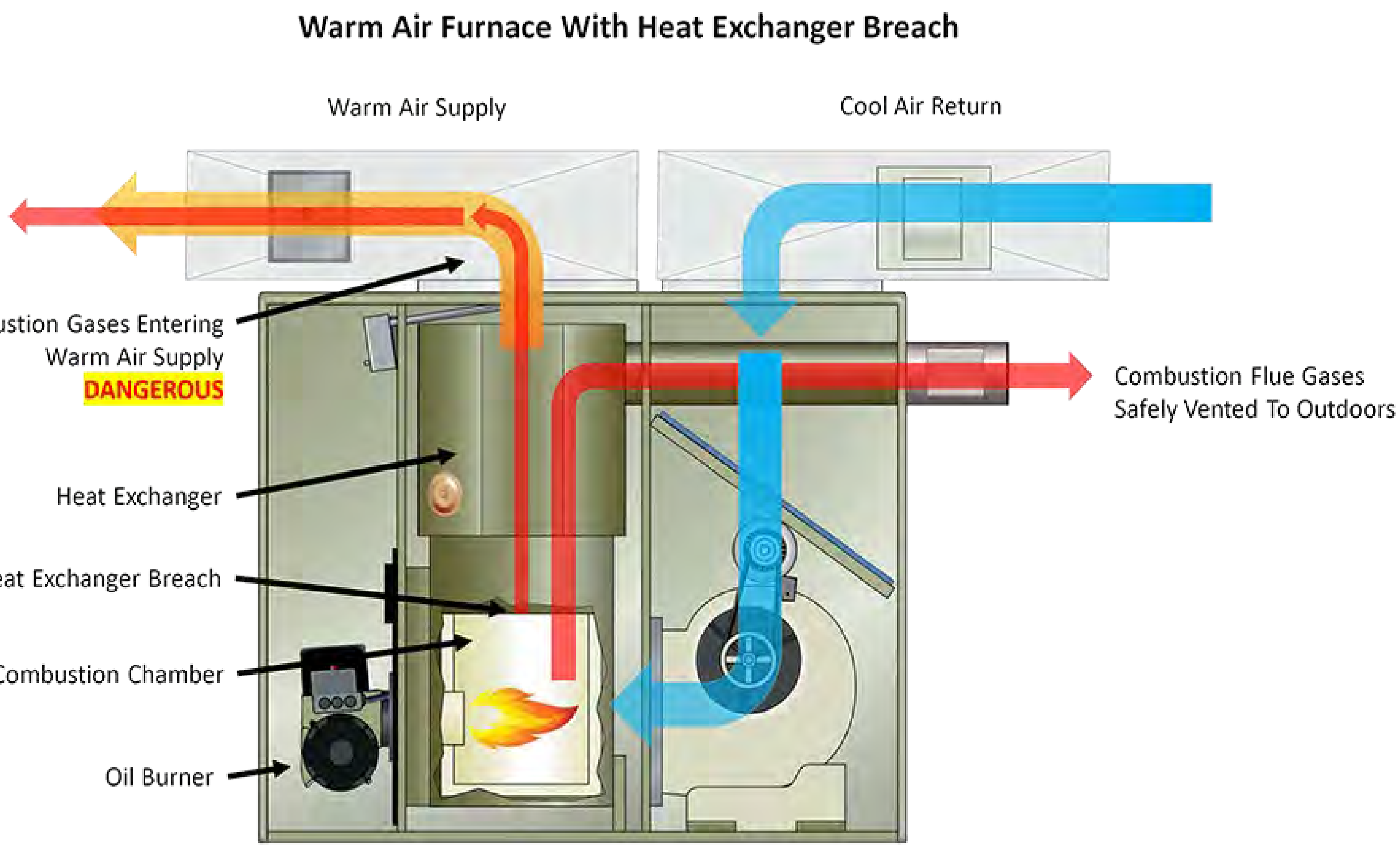
High static pressure created by the blower can pressurize the heat exchanger and force air to leak into the combustion chamber.

And

High positive pressure in the combustion chamber can allow combustion gases to leak into the space heating side of the furnace & allow CO to be carried into the conditioned space……

Testing for a Leaking Heat Exchanger

$O2/CO_2$ or draft readings that change when the blower comes on indicate a combustion air, venting or mechanical problem such as a cracked heat exchanger.



Procedure for Checking using the O_2 reading

Follow the manufacturers instructions to zero the analyzer. Insert the analyzer's probe into the flue pipe.

Start the furnace & observe the O_2 reading for stability for 1-3 minutes.

When the blower starts, watch the reading, if it changes there is a leak.

Corrective Action: Try to Find the Leak

1. Sometimes a cleanout or inspection door can leak air, this requires that new gaskets be installed and/or the leak sealed.
   This is NOT a heat exchanger failure.

2. If a visible defect can be seen, show it to the customer.

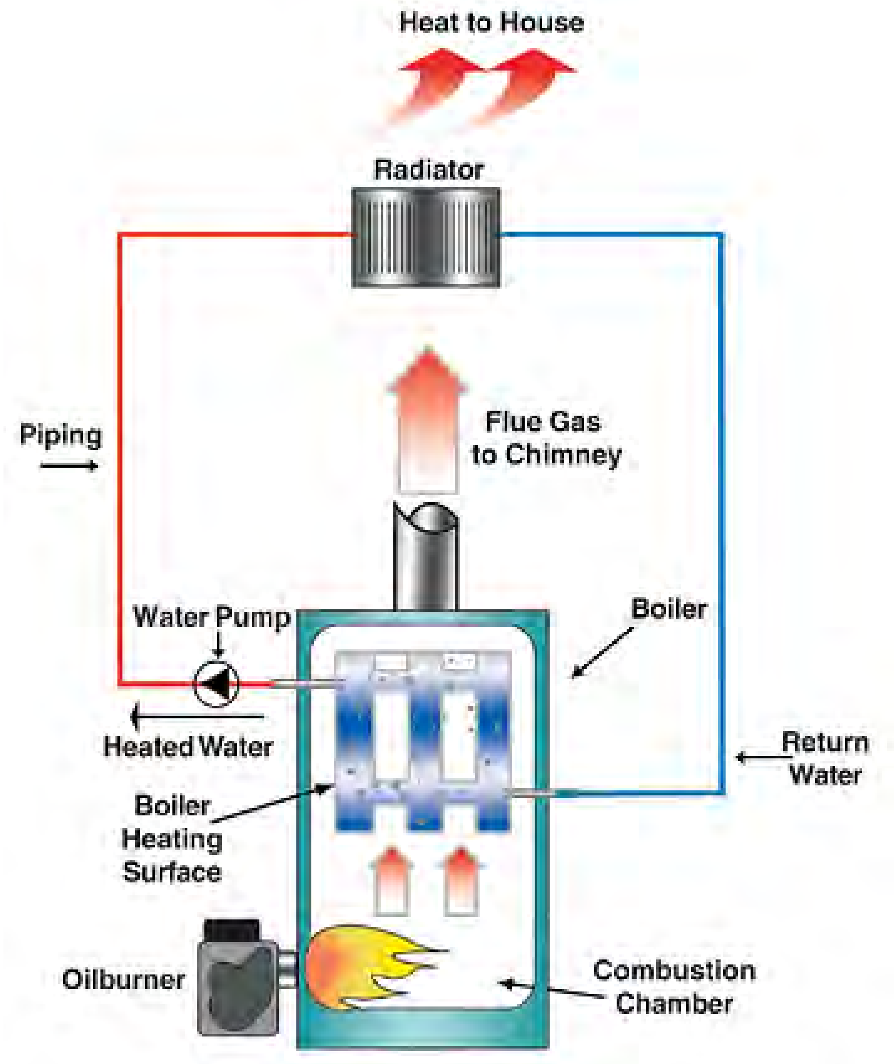
Corrective Action: Try to Find the Leak

3. On the service invoice write that the testing indicates a leak in the heat exchanger (even if you don't find the leak.)
4. Inform the customer, in writing, that the heat exchanger has a defect and the furnace should NOT be operated.

Part 2 - Hydronics

Hot Water Boilers & Heating Systems

- A hot water boiler is a heat exchanger that uses heat from the burner's flame to heat water
- Heated water (160Fº-180Fºish) is piped to heat emitters to supply space heating
- Cool water (140Fº-160Fºish) returns to the boiler to be reheated



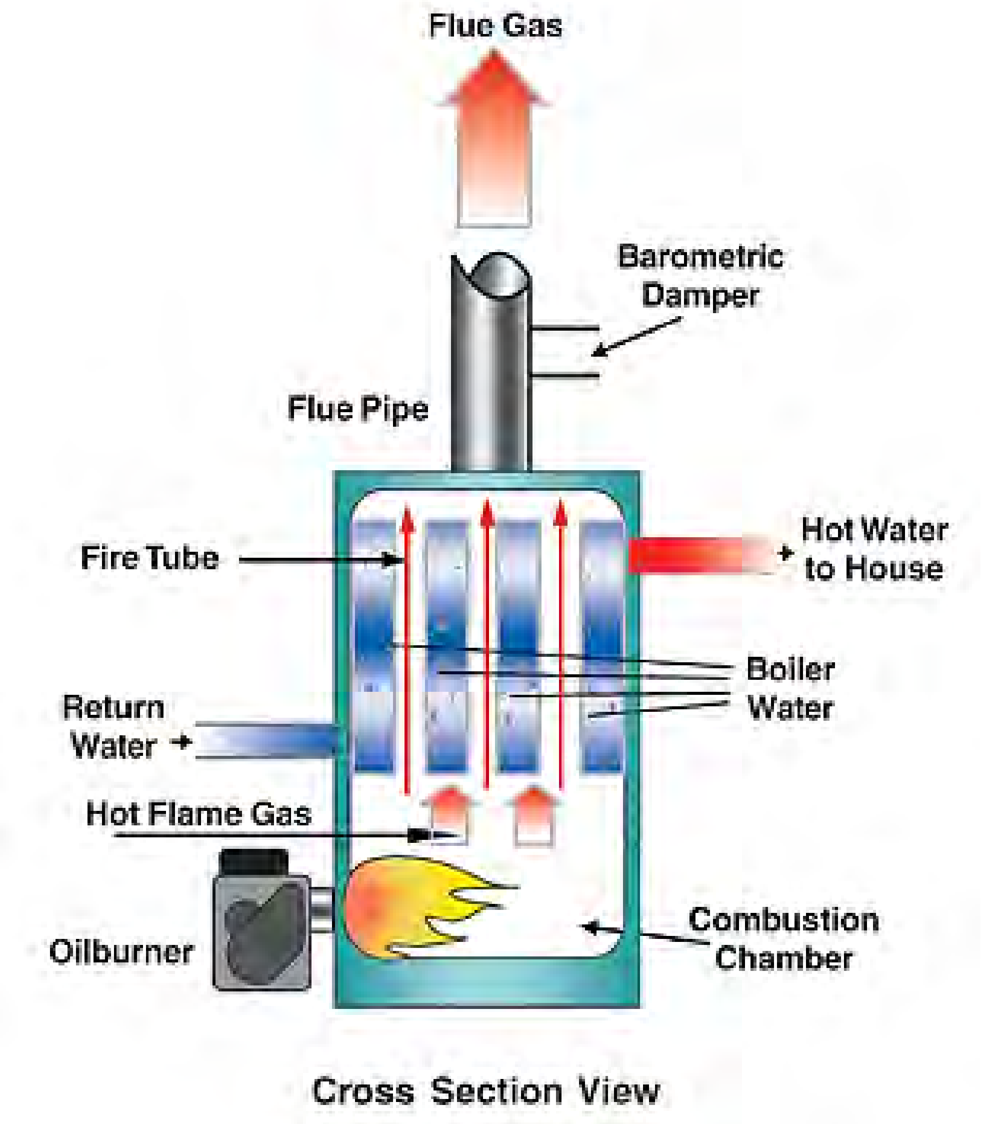
Boiler Designs

Boilers are made of cast-iron or steel and can be either "wet base" or "dry base".

A wet base boiler has water surrounding the combustion area while a dry base boiler does not.

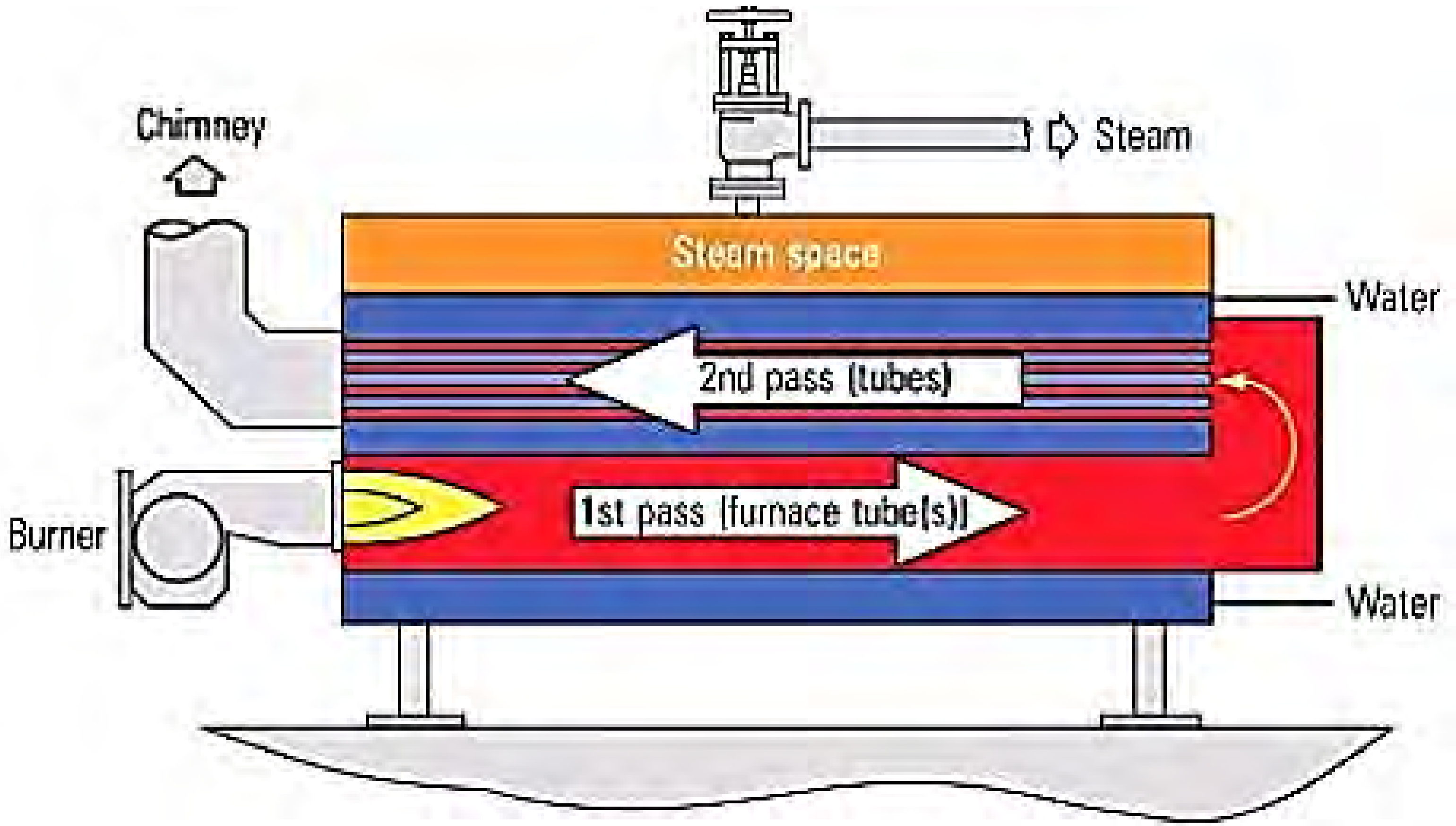
Vertical Fire Tube Boiler

- Most common steel boiler
- Gases flow inside tubes surrounded by water
- Heat passes through wall of tube to water

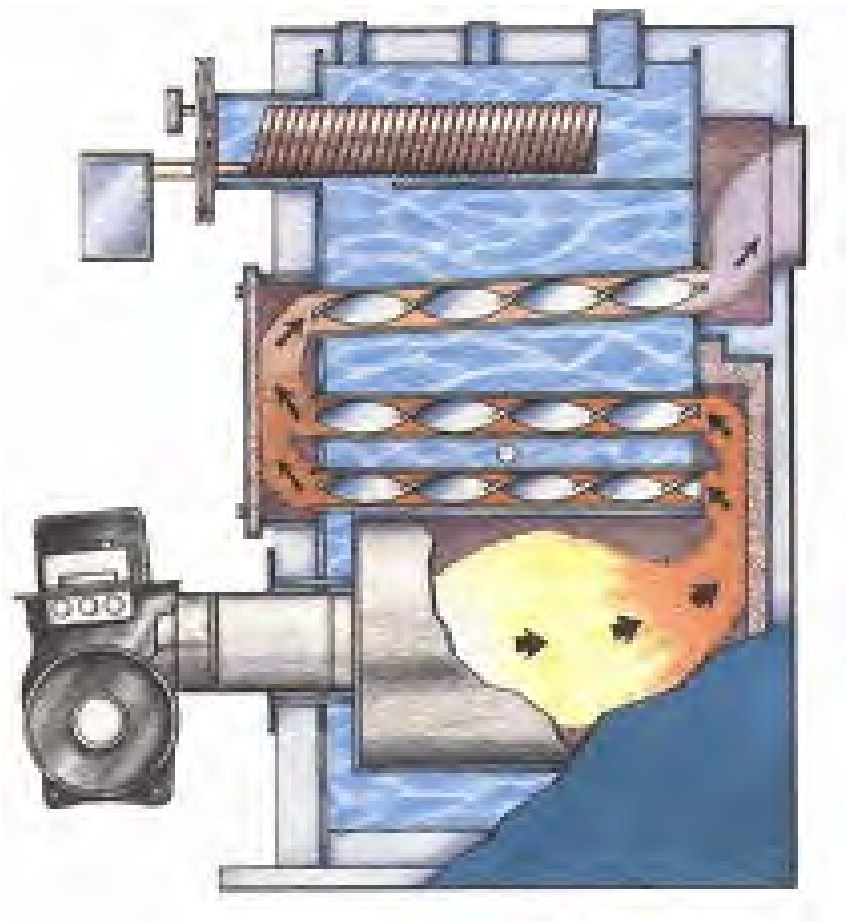


Horizontal Fire Tube Boiler

- Gases travel to back of boiler
- Then pass into horizontal tubes
- Also called "2 pass" boiler……

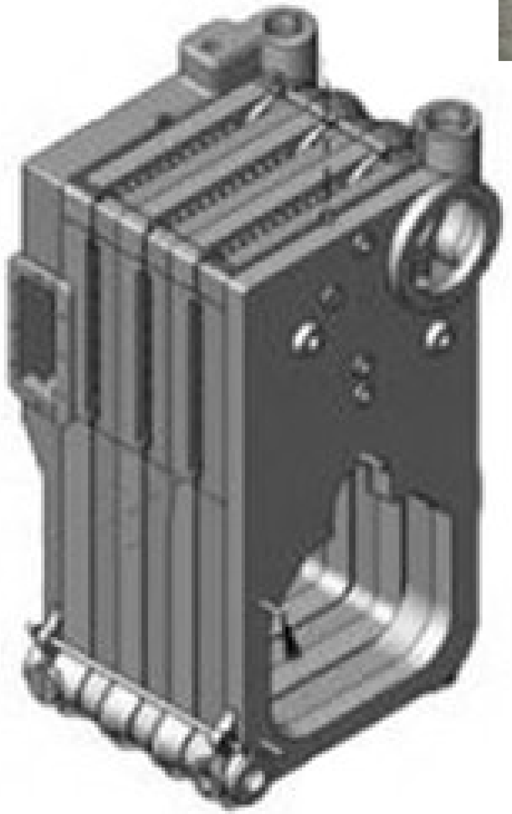


Three Pass Boiler



- Increased efficiency
- Typically, “low mass”
- Reduced water content
- Lower heat loss

Cast Iron Boilers



- Sections of cast iron joined together
- Each section contains water
- Hot gases pass between sections

Cast Iron Boilers

Sections are joined together with metal push nipples or non-metallic “O” rings (elastomer seals)……

Cast Iron Boilers

Water is supplied to each section through a common header at the top & bottom of each section.

It flows upward & is heated by the inner surface of the iron.

Firebox & Combustion Chambers

Burners fire into a combustion area that may be lined with a refractory material that reflects heat back to the flame.

Dry base boilers require a combustion chamber made of insulating material to reduce heat loss and prevent burning out the base.

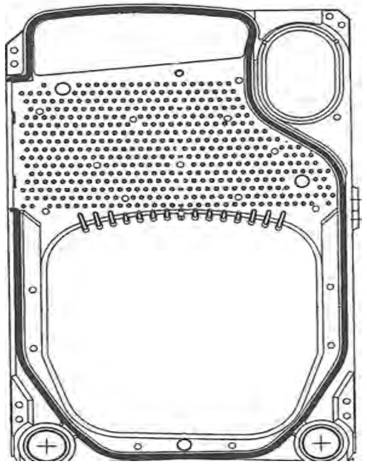
In wet base boilers the insulating properties are not as important because the surrounding water recovers the heat.

Heating Surface

Exposed to heat on one side and boiler water on the other.

Cast iron boilers are designed with contours, fins, pins or projections to increase outer area and improve gas-side contact.

They must be kept clean for good heat transfer. Soot acts as an insulator.



Baffles - Turbulators

- Placed in heating passages to redirect gas flow for better heat transfer

- Often narrow strips of metal twisted to spin the gases & prevent the flow of gases through the center of the fire tube

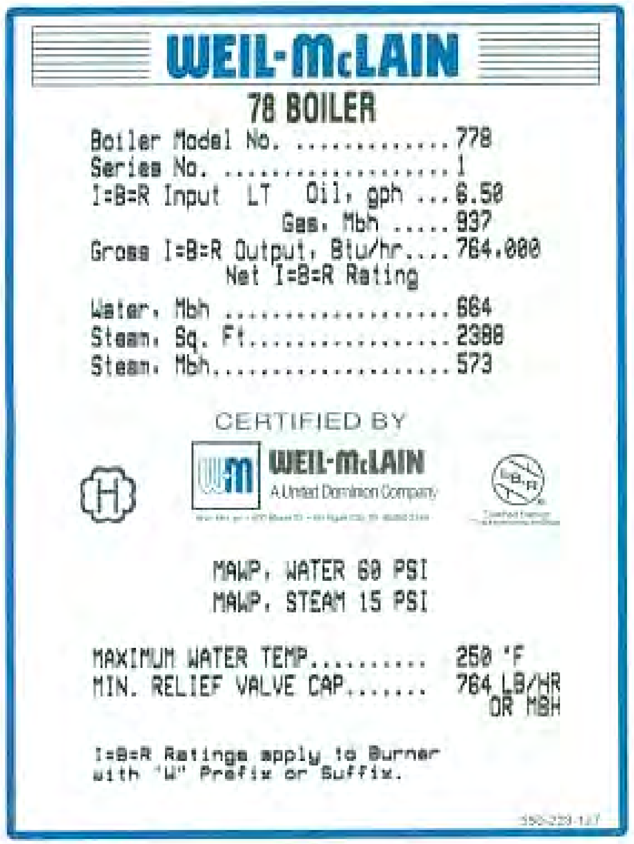
- Should always be put back in tubes after cleaning & replaced id damaged or badly corroded

Insulation

- Boilers (and furnaces) have thermal insulation on the outside of the heat exchanger to reduce heat loss.
- The outer jacket MUST be securely fastened to minimize heat loss.

Boiler Ratings

- Boilers are tested to verify heating capacity and efficiency
- Gross output = total heat delivery in BTUH
- Net rating deducts 15% for piping & distribution losses
- Use net for sizing – FSA calculator……



FSA Calculator

NORA's FSA calculator provides a simple way for consumers to see various upgrade options & their estimated return on investment when considering replacement of their boiler or furnace.

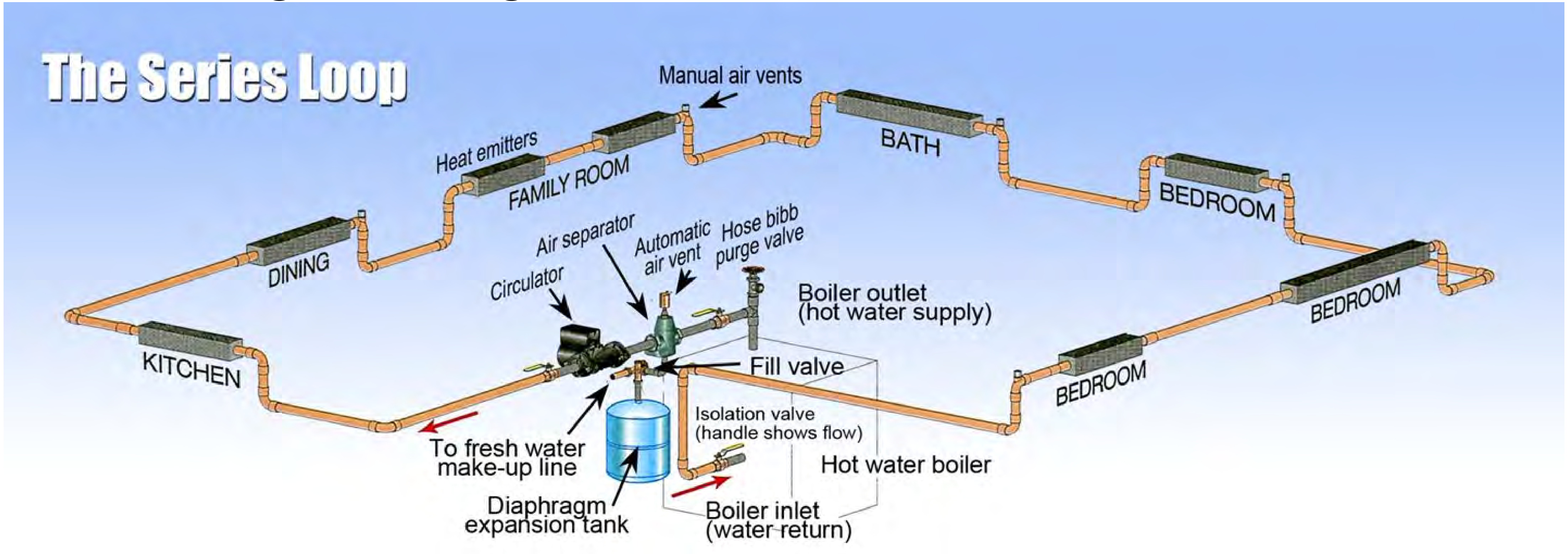
Piping Systems

There are three basic types:

- Series loop.
- One pipe.
- Two pipe.

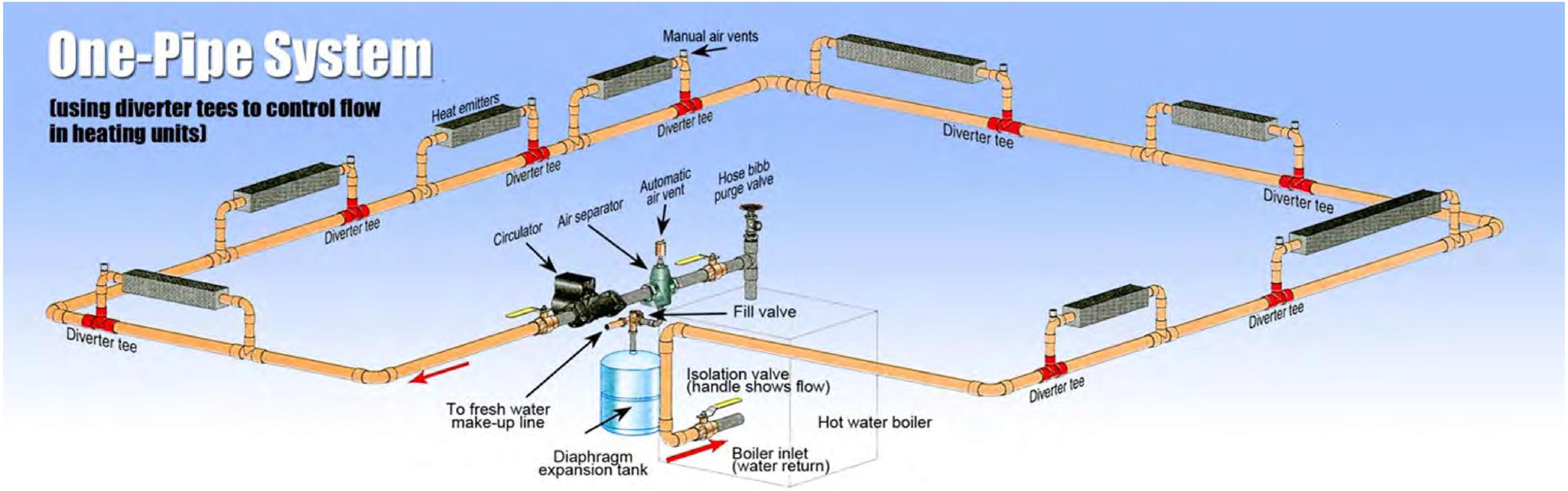
Series Loop

Most common, easiest to install, least expensive. Single pipe from the boiler goes through each heat emitter and back to the boiler.



Disadvantage – heat delivered to end of loop is less than at beginning.

One Pipe

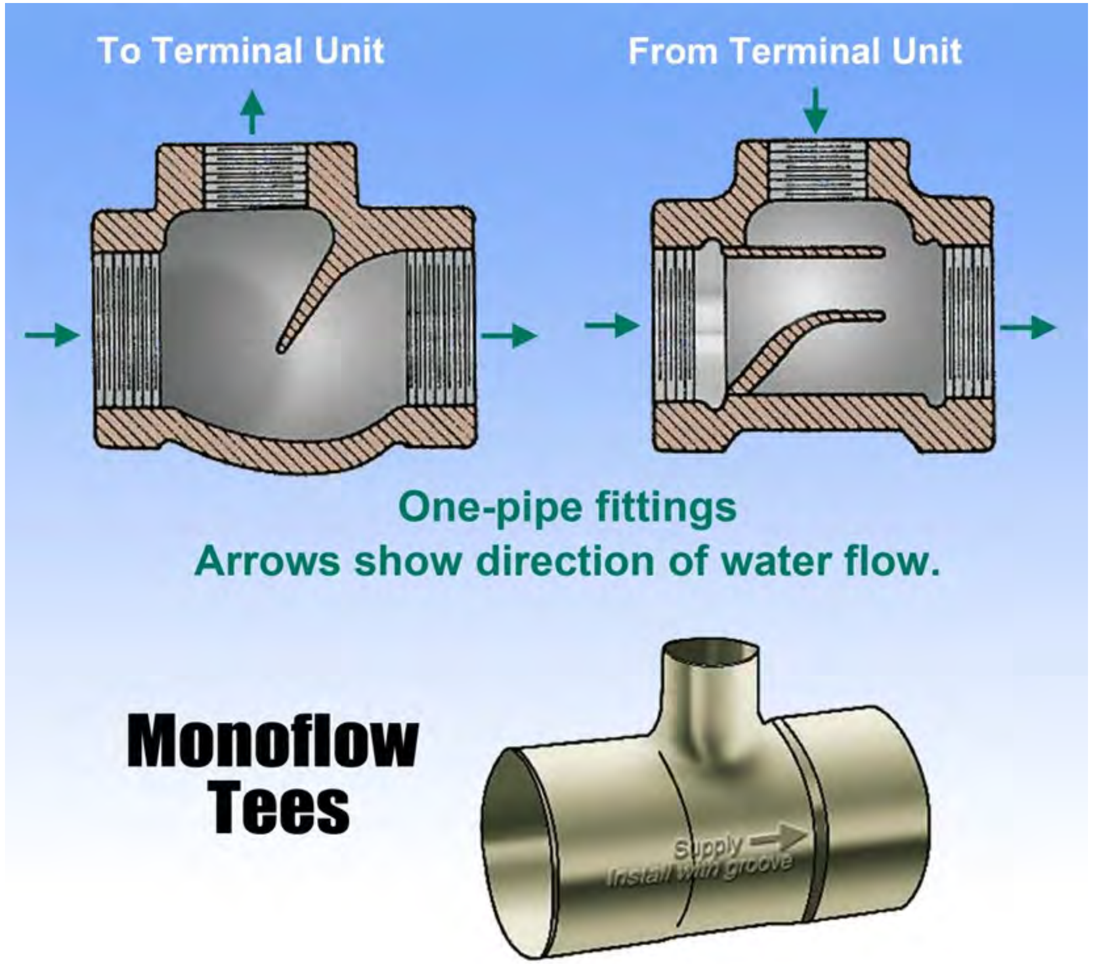


Single pipe connects supply to return while supplying heat emitters. These systems require the use of a special “tee”……

One Pipe (continued)

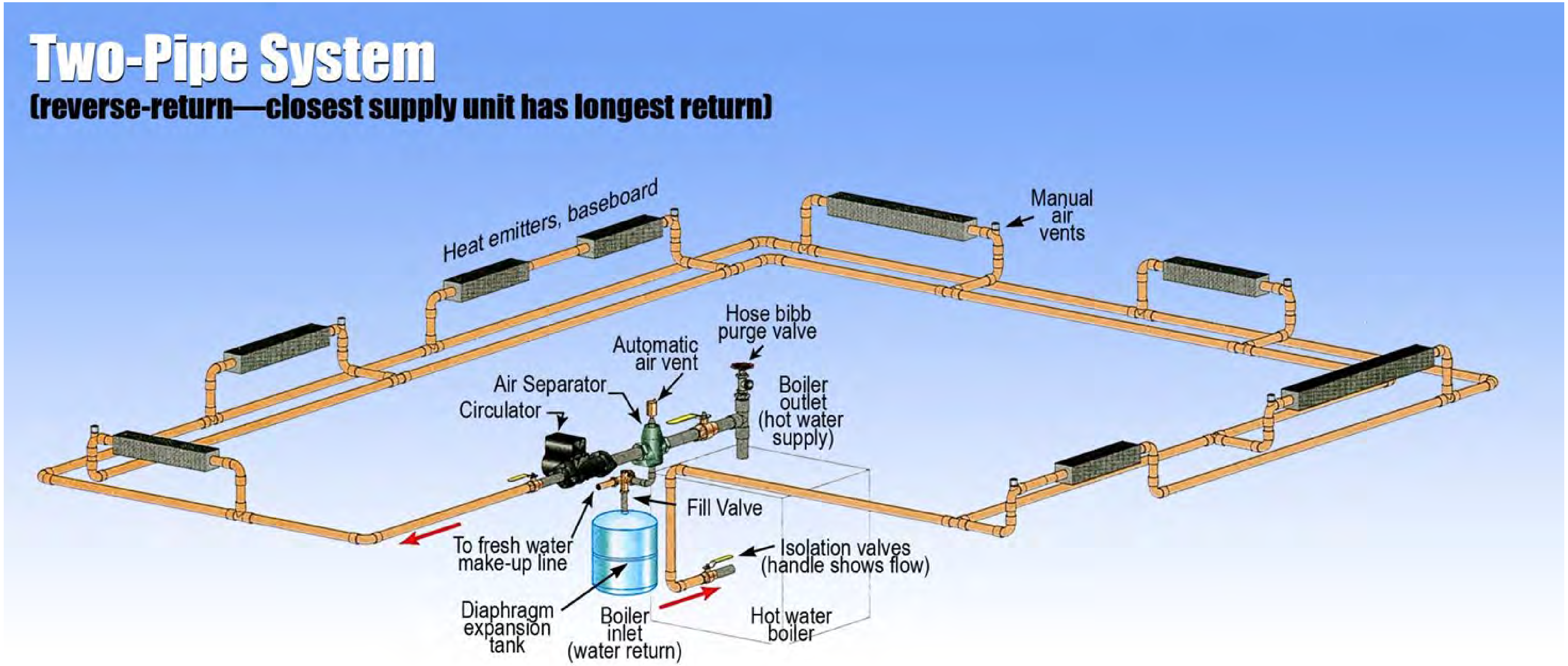
These tees are referred to as "**diver tees**", "**mono-flo tees**" and "**jet tees**."

They direct the water flow so that each emitter is supplied with water at approximately the same temperature.



Two Pipe

Separate supply and return pipes, no special fittings required.



"First fed, last returned and last fed, first returned"

Components of Hot Water Systems

Heat Emitters aka Radiation

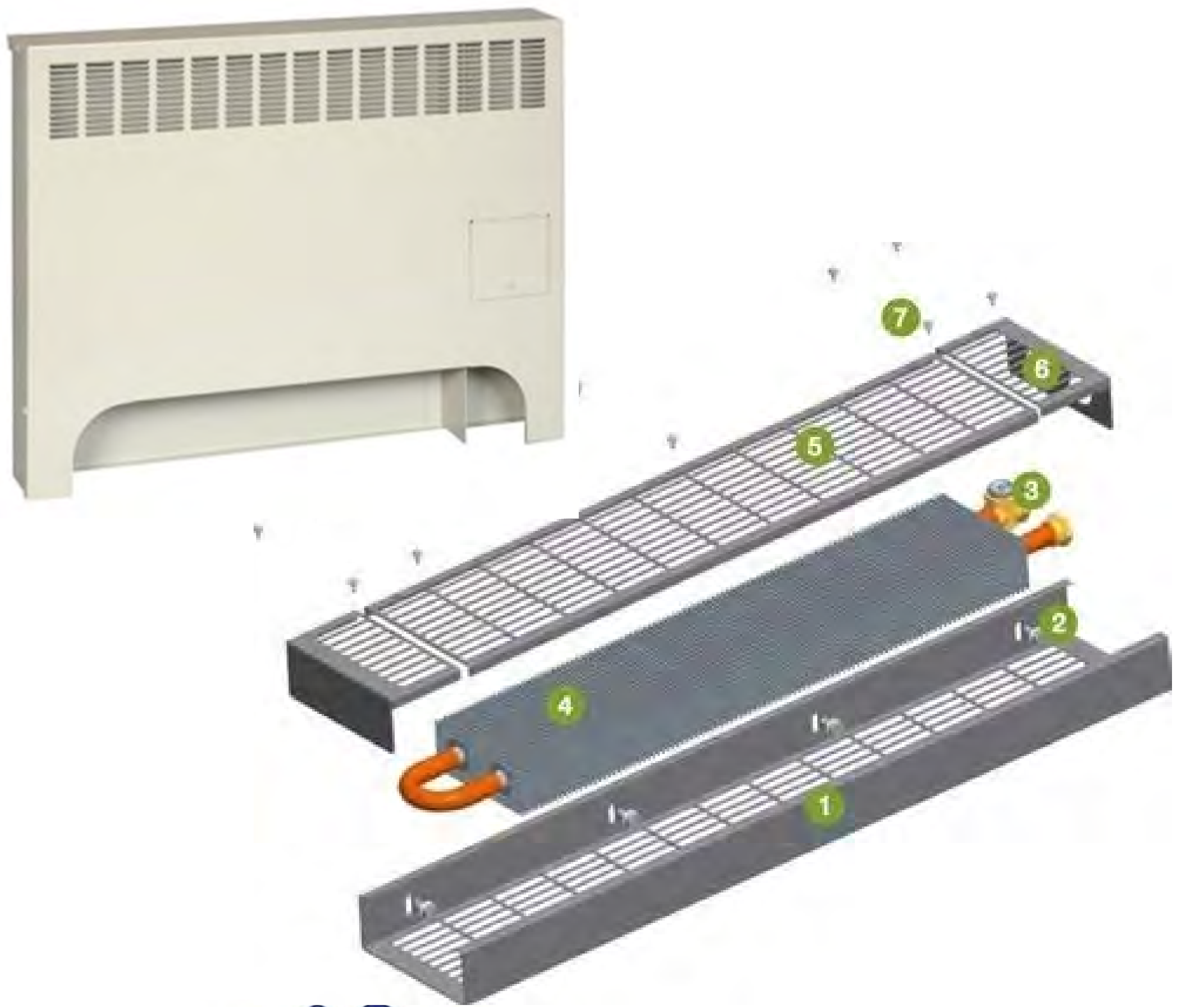
Five most common types of hot water radiation:

- Conventional Radiator
- Convector
- Baseboard
- Fan coil/unit heaters
- Radiant/panel

Conventional Radiator

- Typically made of cast iron
- Normally found in older systems
- Rest on floor or mount on wall.

Convector



- Series of finned tube sections enclosed in a cabinet.
- Sections can be cast iron or steel.

Baseboard Radiation

Cast iron panels or copper pipe covered with aluminum fins.

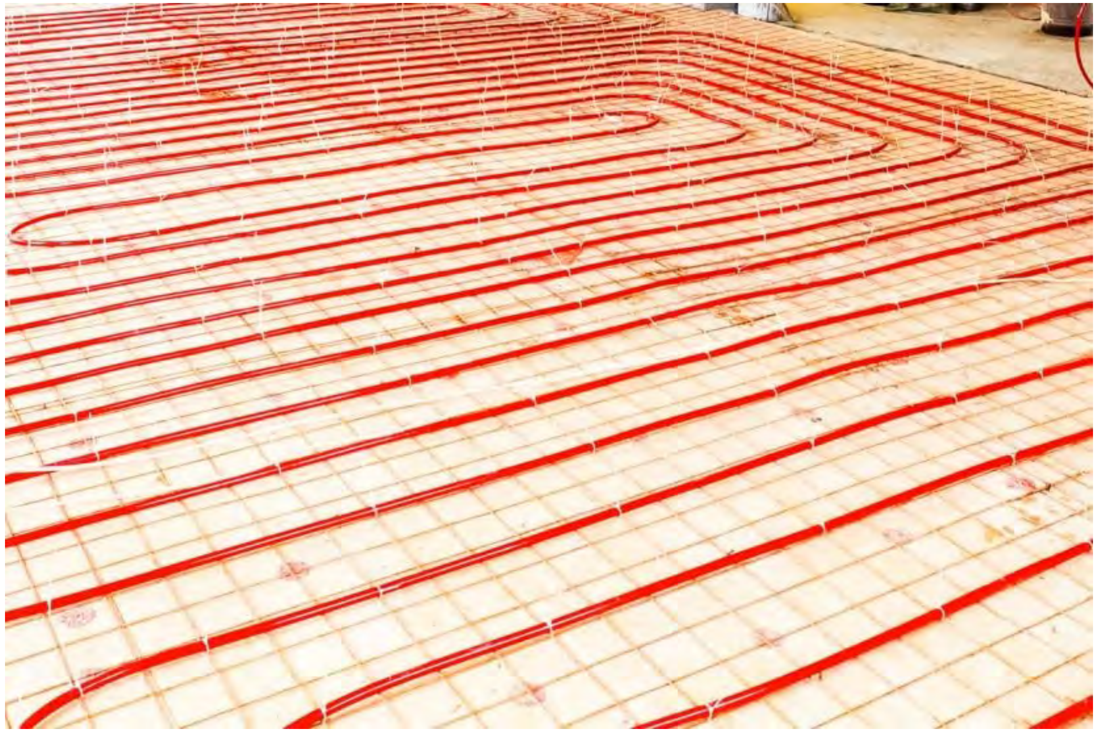
Larger systems can use steel pipe & fins.

Fan Coil/Unit Heaters

- Coils of fin tube with a fan that blows air over the coils
- Well suited for rooms with little wall space available
- Popular in garages & commercial applications

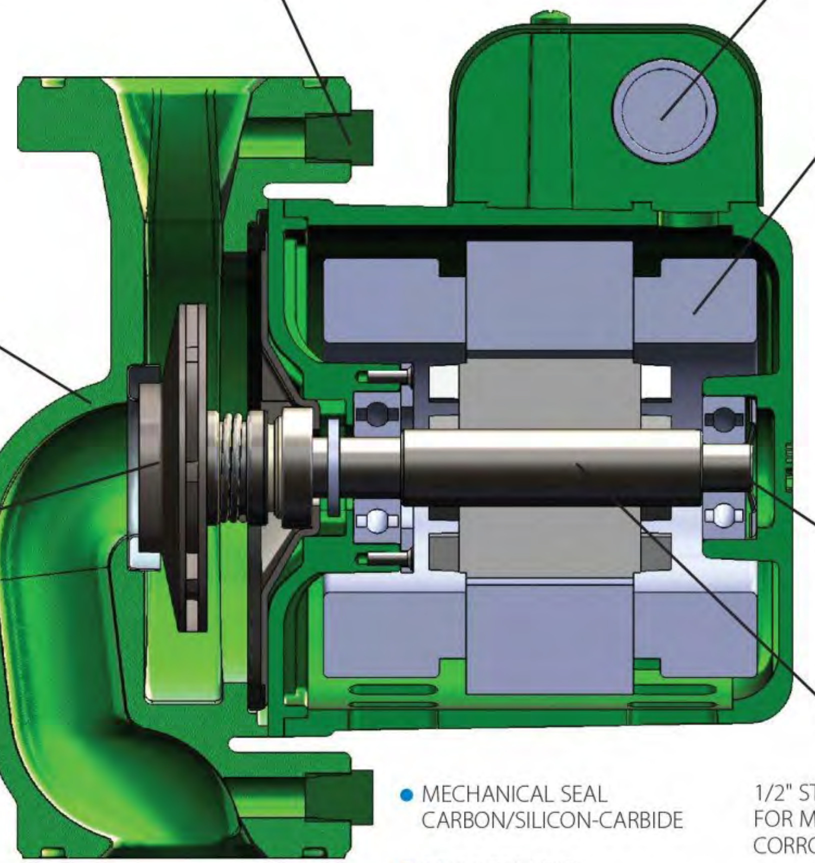
Radiant/Panel Heating Systems

- Serpentine loops of non-finned pipe in floor, walls, ceilings etc. that circulate low temperature water.
- Also used for heating driveways, sidewalks, pools, etc.



Circulators

- Create a pressure difference to produce flow in a system.
- The motor rotates an impeller that pushes water away from the pump, pulling water from the system into the impeller.



Always "Pump Away"

Systems work best when the circulator is located on the supply line and pumps away from the expansion tank.

Figure 13-20: Circulator located on return line

Typical Hot Water Heating System
with Cast Iron Wet Base Boiler

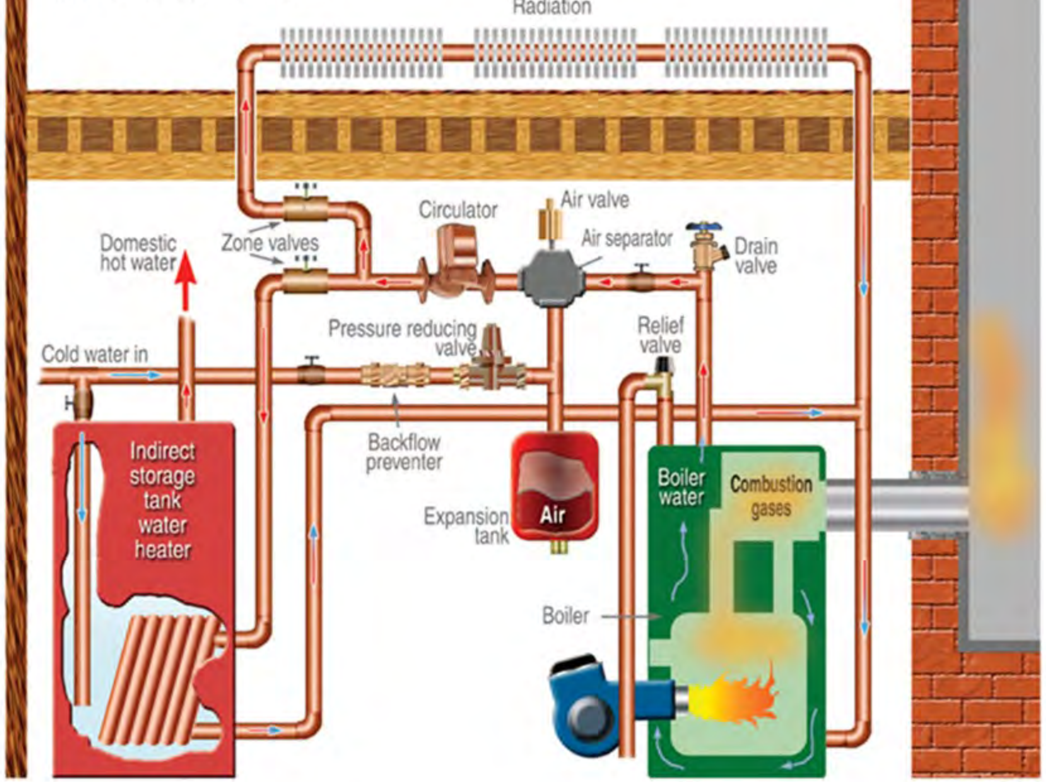


Figure 13-19: Circulator located on supply line

Expansion Tanks

All hot water heating systems need an expansion tank because water expands as it's heated.

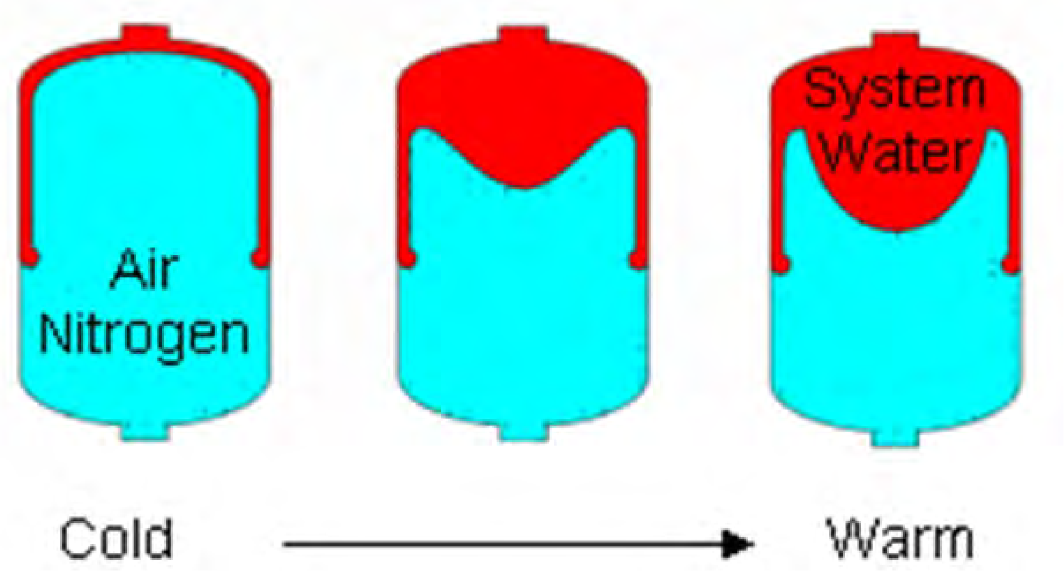
Without a place for the expanded water to go, pressure would increase and the relief valve would open.

Expansion Tanks

Expansion tanks have a flexible diaphragm that separates the water from the air.

When the burner fires, the water expands, pushes against the diaphragm and compresses the air.

When the burner shuts off, the water cools and the compressed air pushes the water back into the system.



Expansion Tanks

- Must be set to system pressure, typically 12 psi.
- Never pump in air while the tank is connected to system.

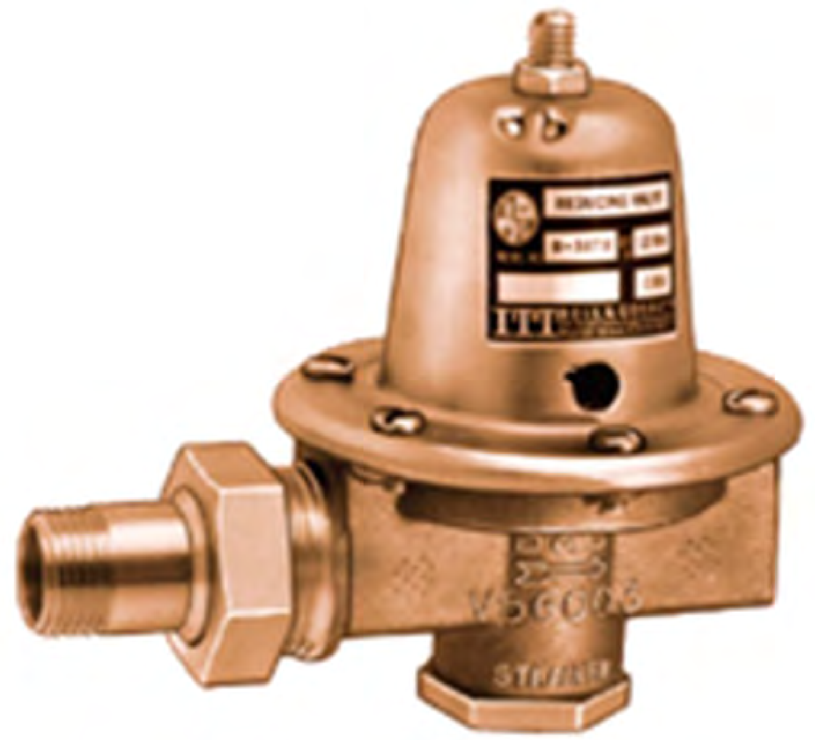
Expansion Tanks

Some older systems still contain non-diaphragm tanks. These must be drained when they become full.

When they fail, they are typically replaced with diaphragm tanks.

Pressure Reducing Valve

- Allow for the automatic filling and maintenance of system water pressure
- Reduces incoming pressure and reduces it to an adjustable pressure
- 1 psi pushes water 2.3 feet up a pipe
- Typical residential systems operate at 12 psi

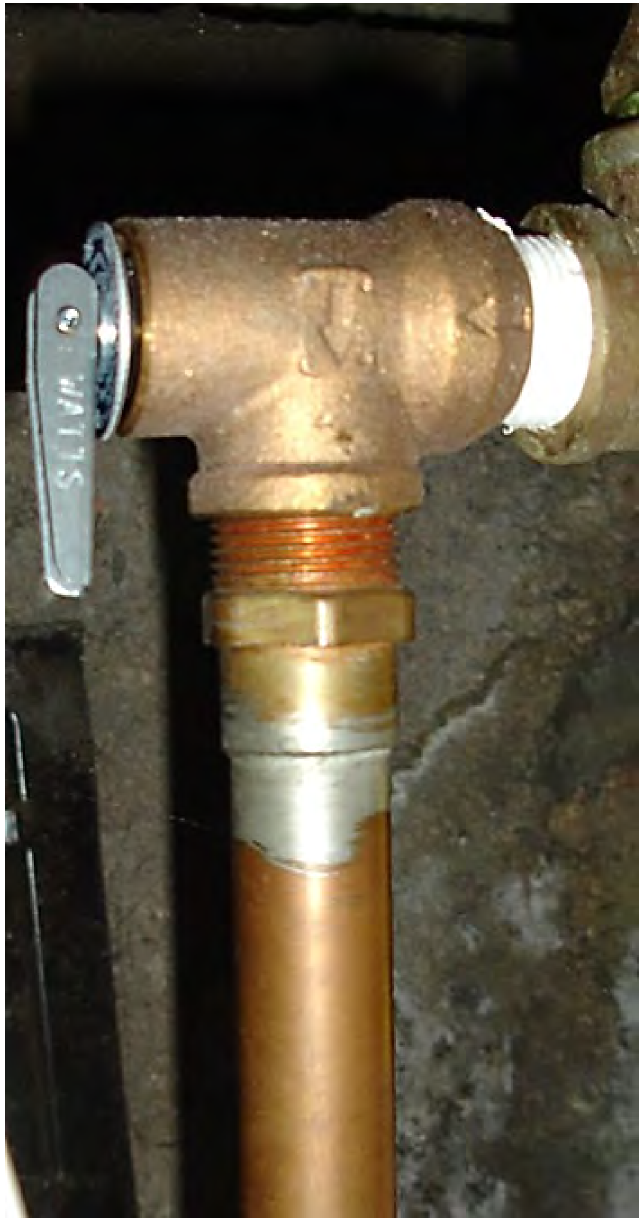


Pressure Relief Valve

- Protects the boiler & system from high pressure conditions.
- Sized to boiler manufacturers' specifications.
- Residential RV's open at 30 psi….

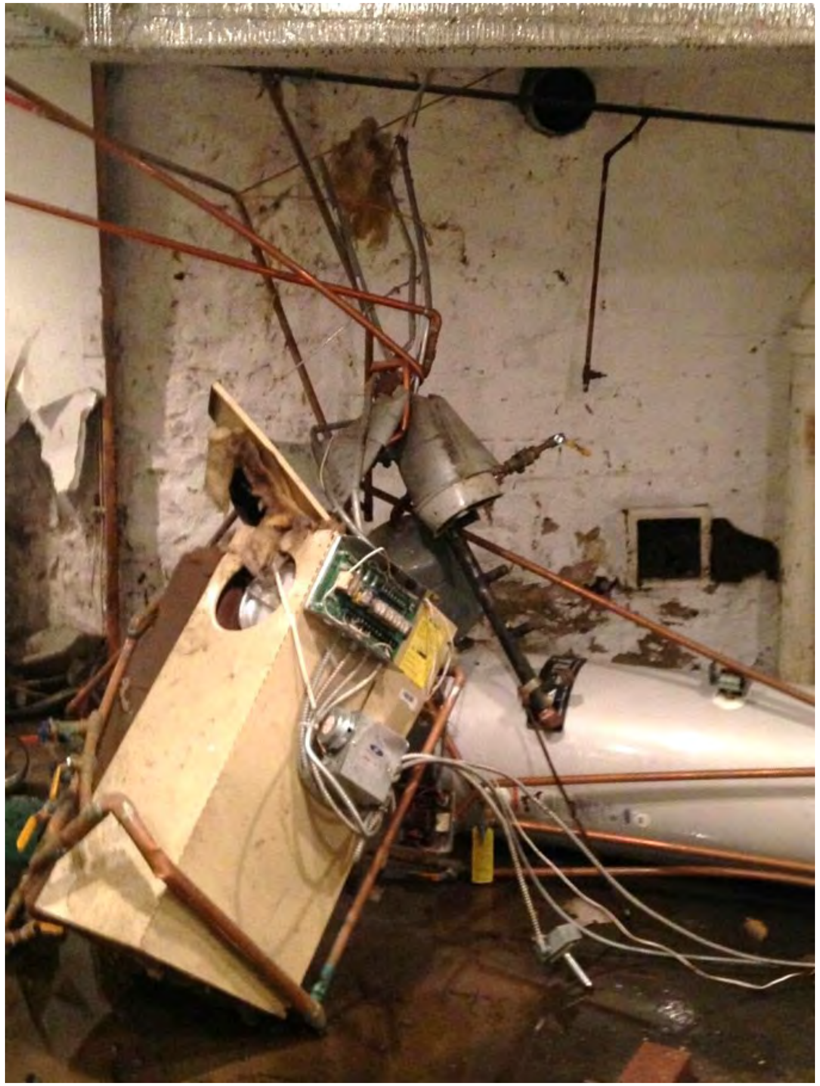
Pressure Relief Valve

- Discharge must be piped to an area where released water will not scald occupants, pets, etc. Typically, 6” off floor
- Discharge pipe must not be black pipe
- No shutoff valves between valve & appliance
- Position shown is acceptable for a water heater but not for a boiler

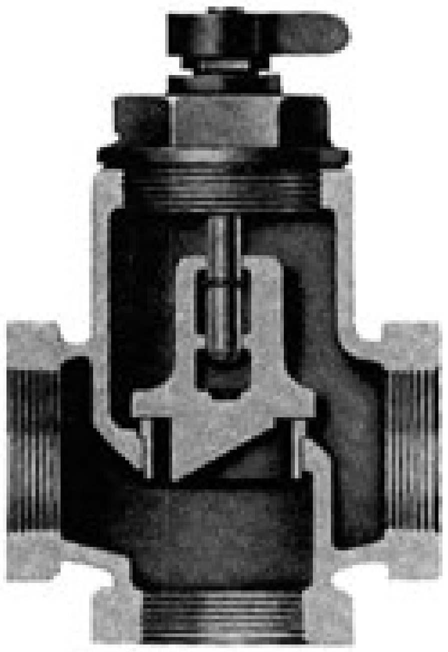


Pressure Relief Valve NO-Nos!

Pressure Relief Valve NO-Nos!



Flow Control Valve



- Prevents gravity circulation
- Basically, a check valve opened by the circulators force so water can travel through the system

Air Elimination or Control

Water holds a lot of air in suspension

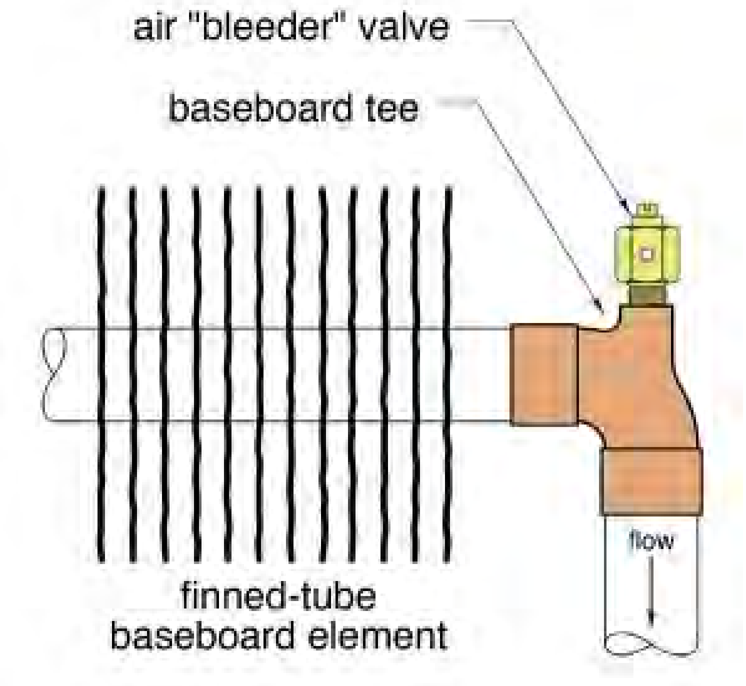
As water is heated air is released

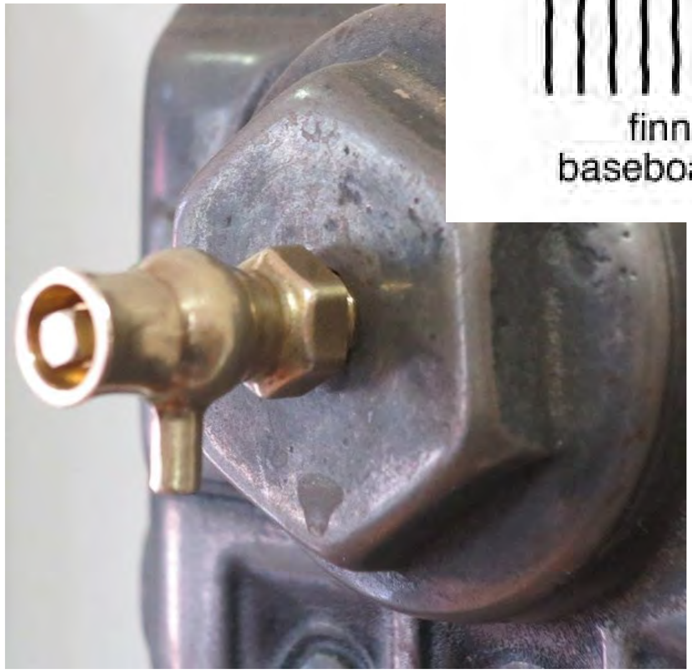
If air gets trapped in the system, it can stop the flow of water and cause a no-heat call……

Air Elimination or Control

- Air vents release air from the system and are often installed at the highest point.

- Most systems, except series loops, have air vents installed in each piece of radiation.



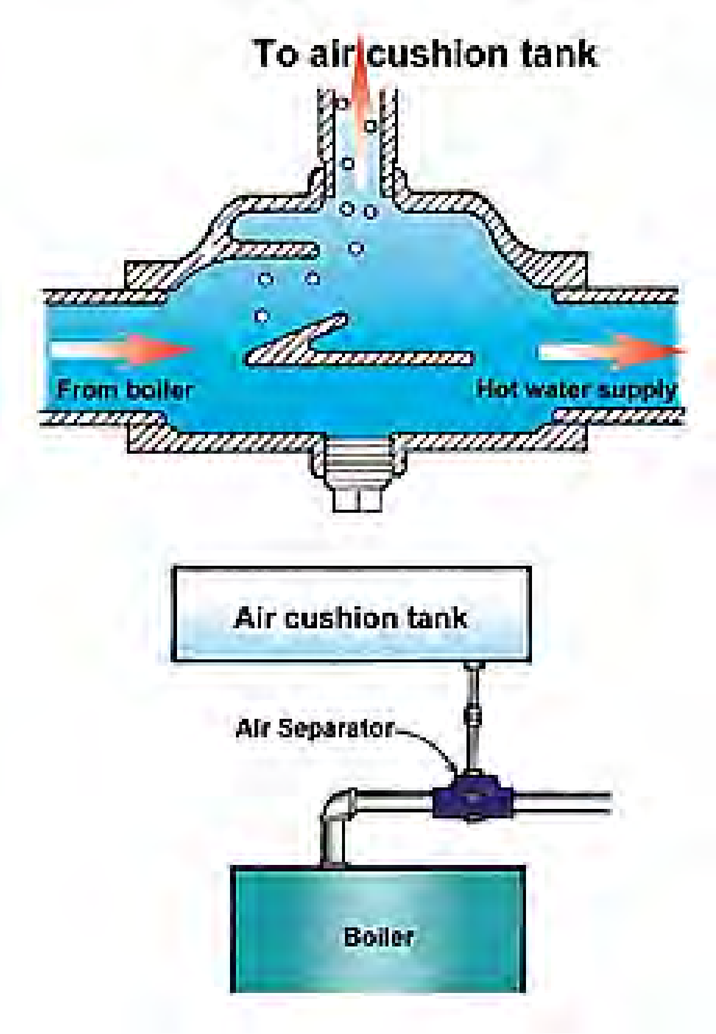


Air Elimination or Control

Series loop systems typically have "purge valves" installed to remove air.

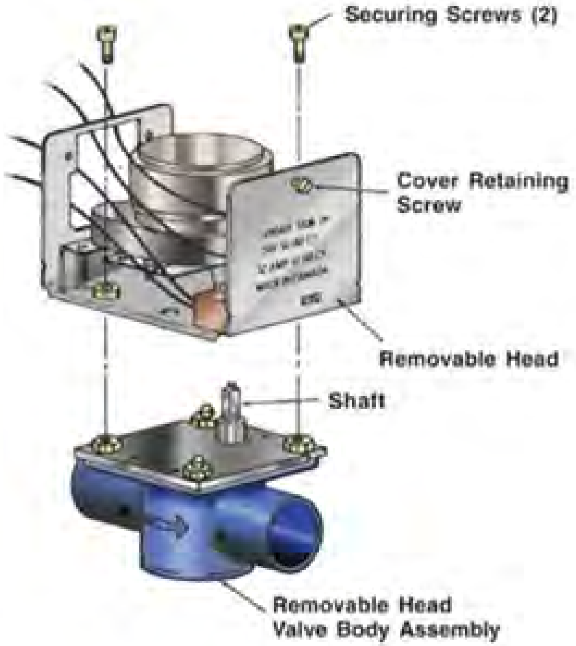
Air Separators

- Located in supply piping
- Remove air from water as it leaves the boiler



System Zones

The two primary ways to provide zone control are (1) with individual circulators and (2) with a circulator and multiple zone valves.



Zone valves are 24-volt devices that provide control to either a circuit or an individual section of radiation.

End Chapter 13 Part 2

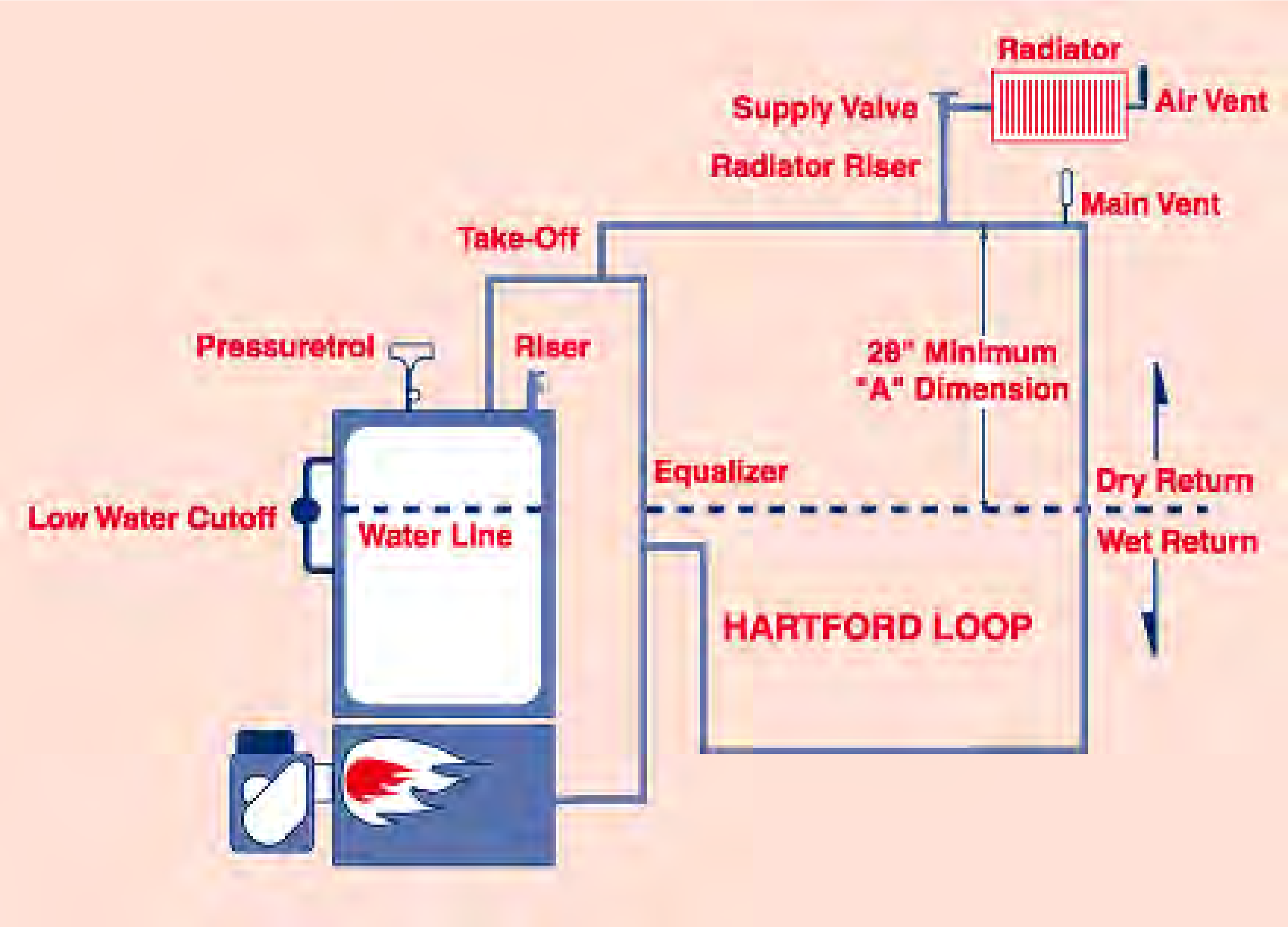
Heating Systems - Hydronics

Part 3 - Steam Systems

Steam Boilers

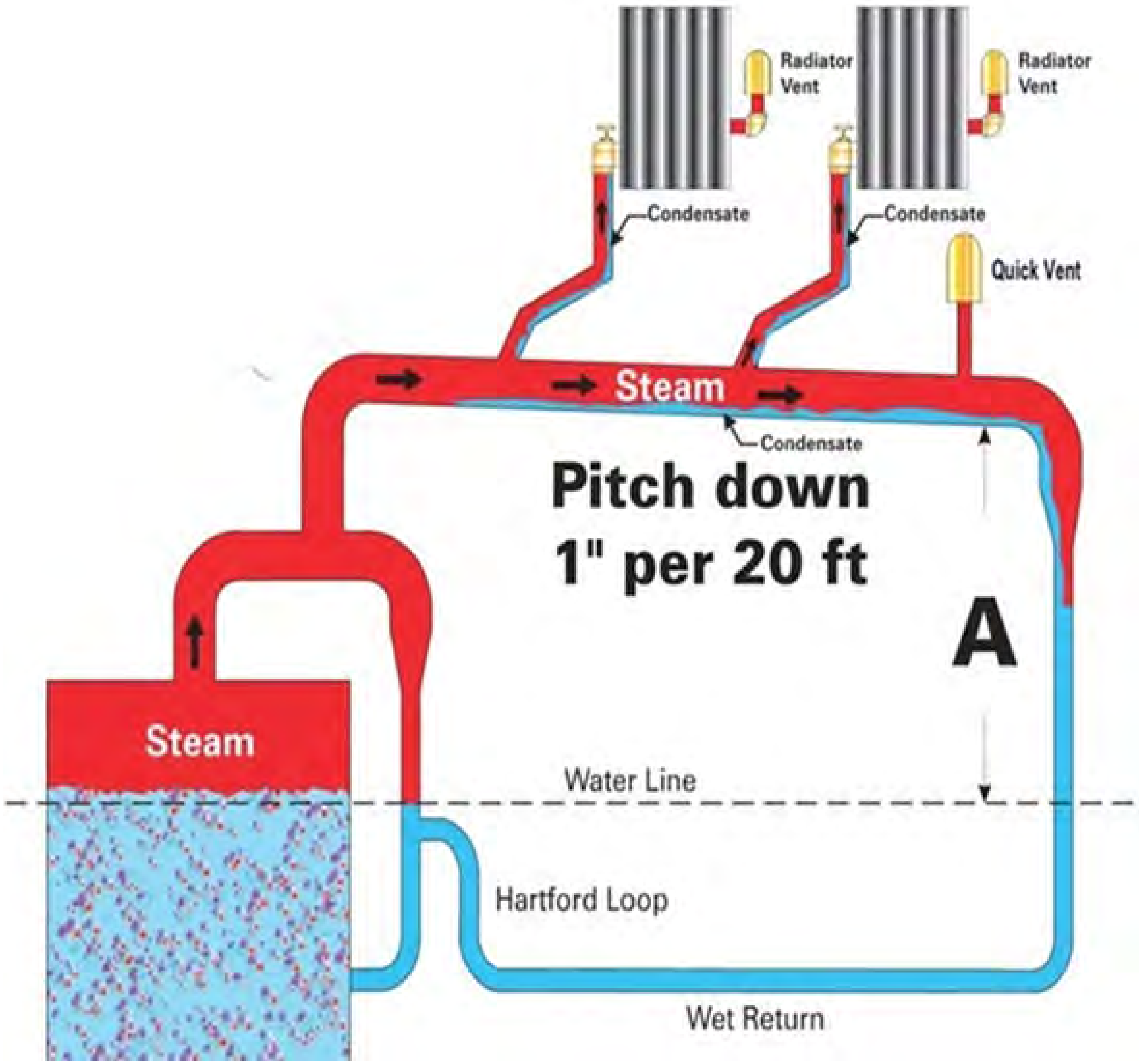
Like hot water boilers, steam boilers use heat from the flame to heat water.

A key difference is that steam boilers are only partially full of water.



Steam Boilers

- As the water in the boiler is heated and turns to steam, it expands by 1,700 times
- The expansion forces steam into the heating system
- Then, once the air is vented from the system, steam rushes in



Steam Pressure

- Pressure, typically 2 psi or less in a typical residential system, is needed to overcome friction in the system
- Raising pressure causes problems and slows the steam flow
- As steam flows it begins to condense into water and shrinks to 1/1,700 of the space it occupied, creating a slight vacuum that helps move the steam to the heat emitters

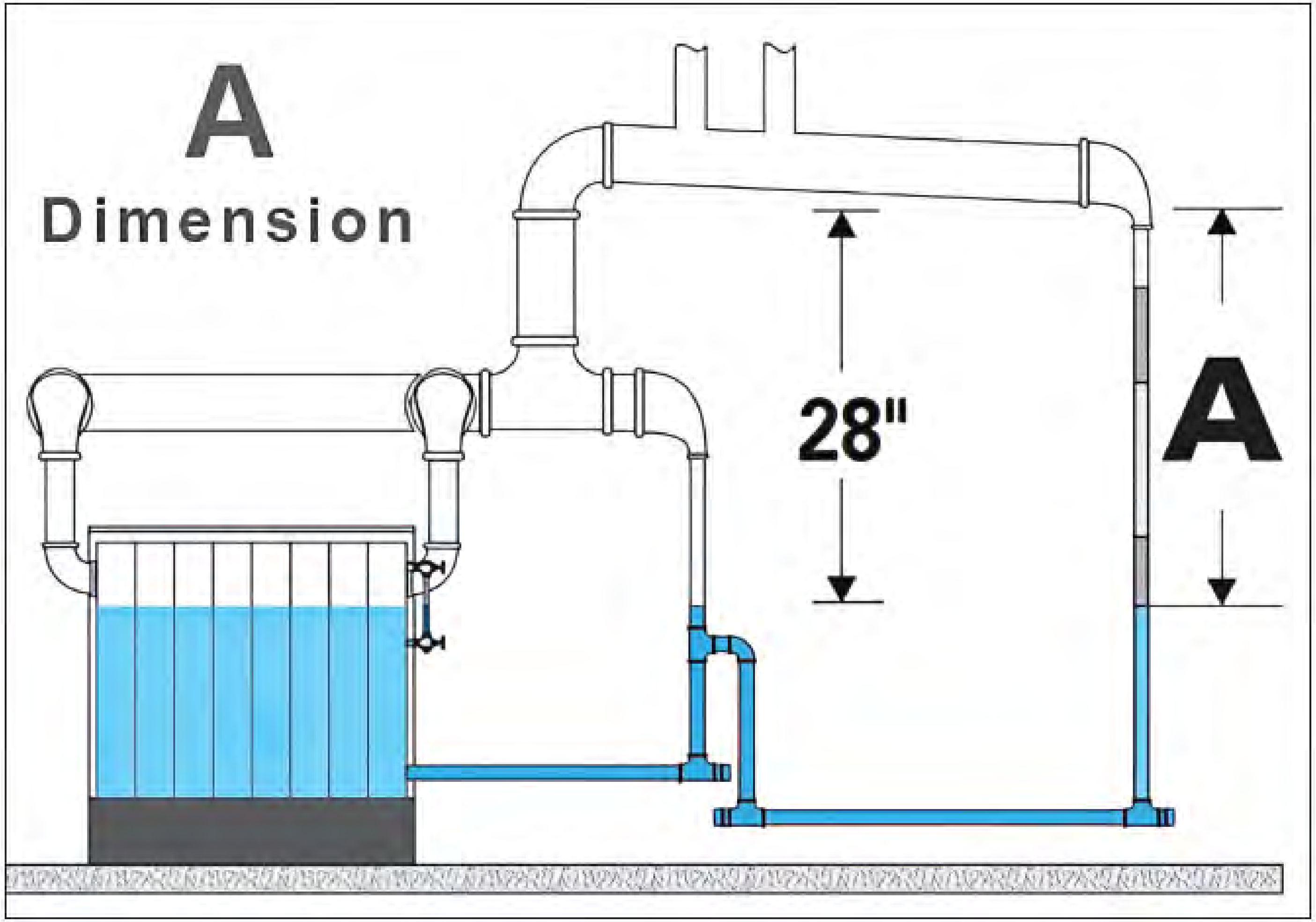
Piping

Today's boilers hold MUCH less water.

Near boiler piping is critically important!

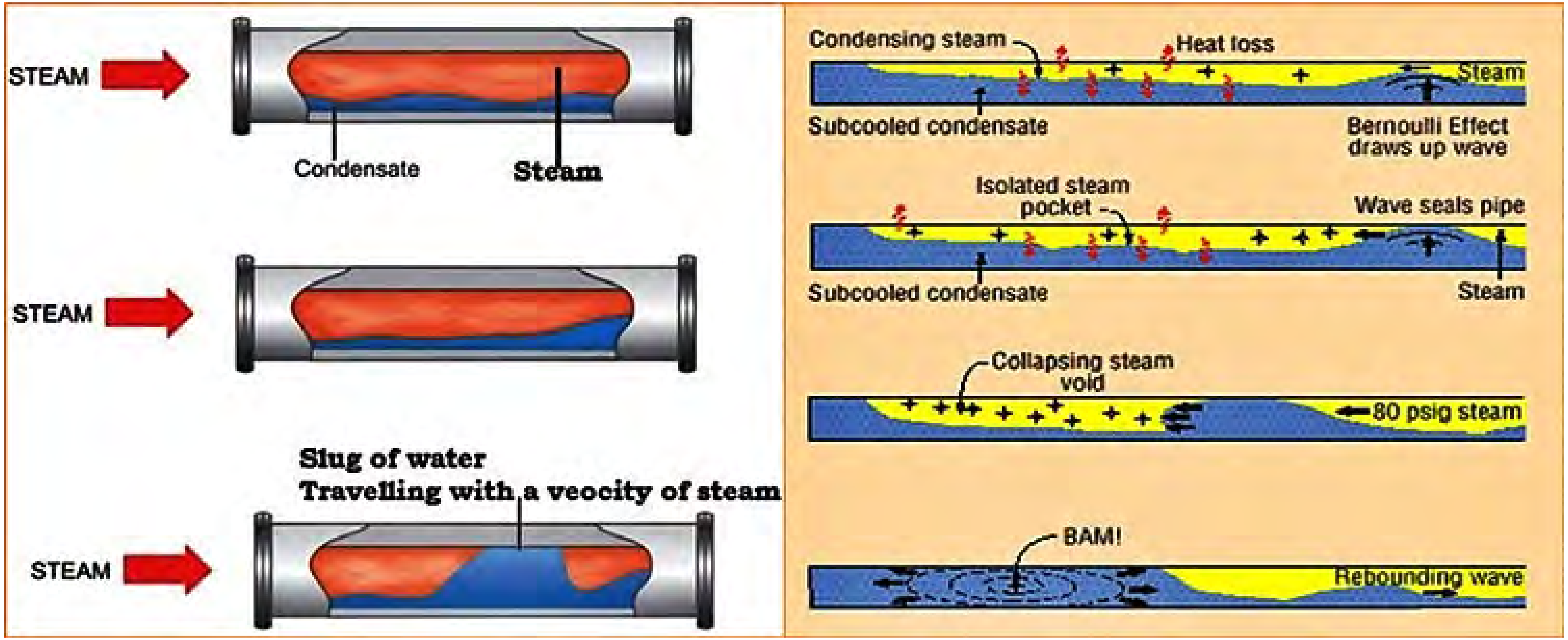
Piping - Follow Manufacturer's Instructions

In 1 pipe systems dimension "A" (the distance from the center of the gauge glass to the bottom of the header) must be at least 28", to provide the force to put condensate back in boiler.



Piping - Follow Manufacturer's Instruction

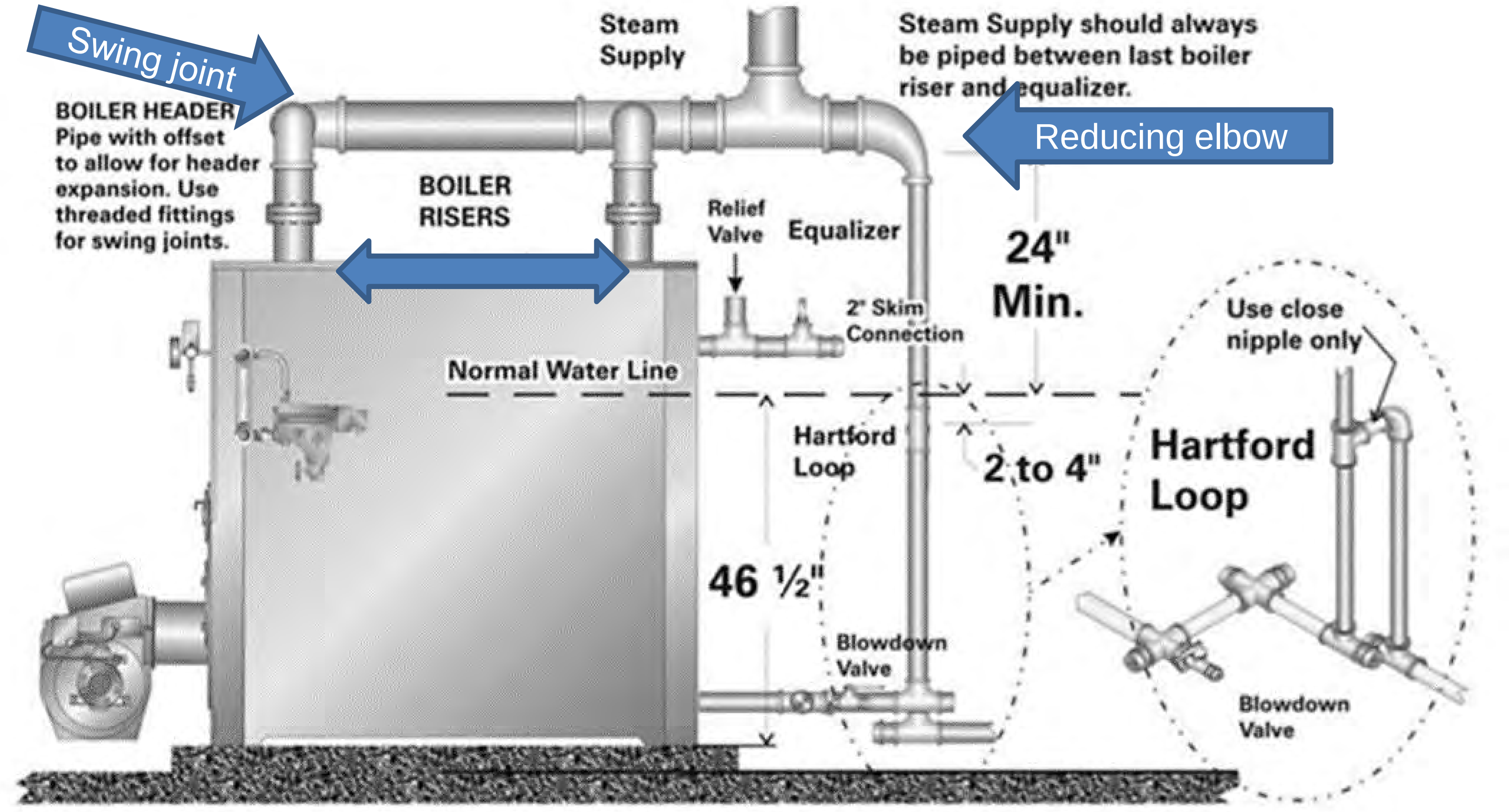
If the A dimension is less, water will back-up in the horizontal piping and block the take-offs to the heat emitters.



The house will heat unevenly and water hammer is likely.

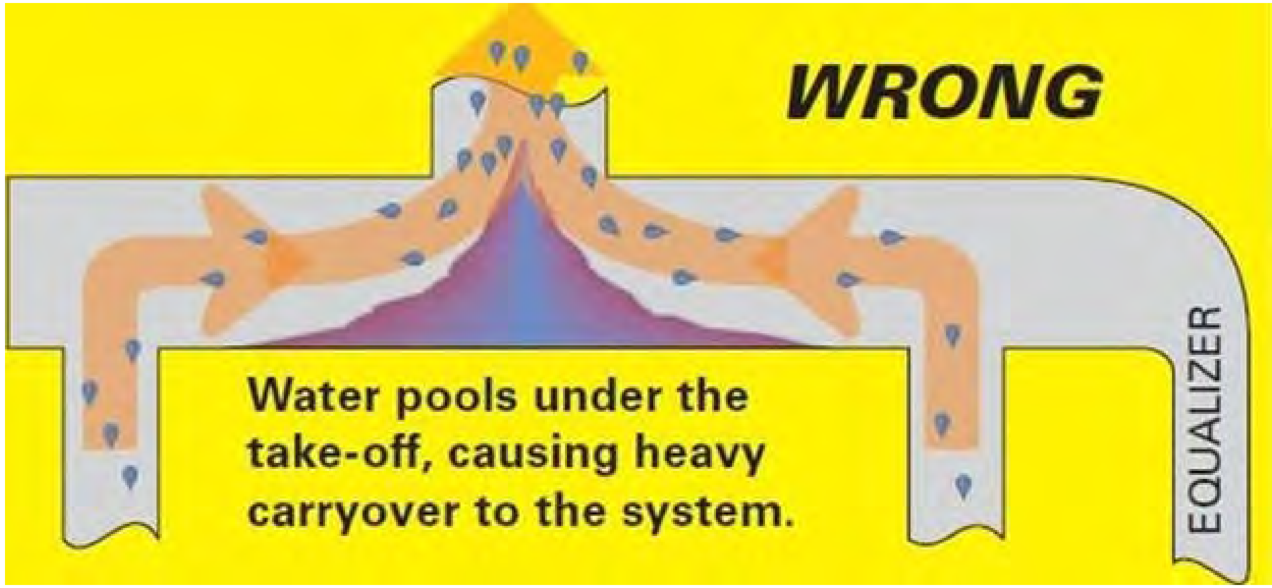
Manufacturer's Instructions

Use full size risers to the header & pipe swing joints into the header.



Use a reducing elbow to connect the header to the equalizer.

Manufacturer's Instructions



Pipe the system take offs at a point between the last riser to the header and the equalizer.

Skimming the Boiler

- The waterside of all steam boilers must be cleaned after the installation to remove substances that cause foaming and surging
- Skimming removes cutting oil, grease, sludge, etc. from the system
- Follow manufacturer's instructions, if they are not available.

Check Manufacturers Skimming Instructions

Typically, they include:

Using a 1 ¼” or larger nipple in a horizontal tapping above the waterline.

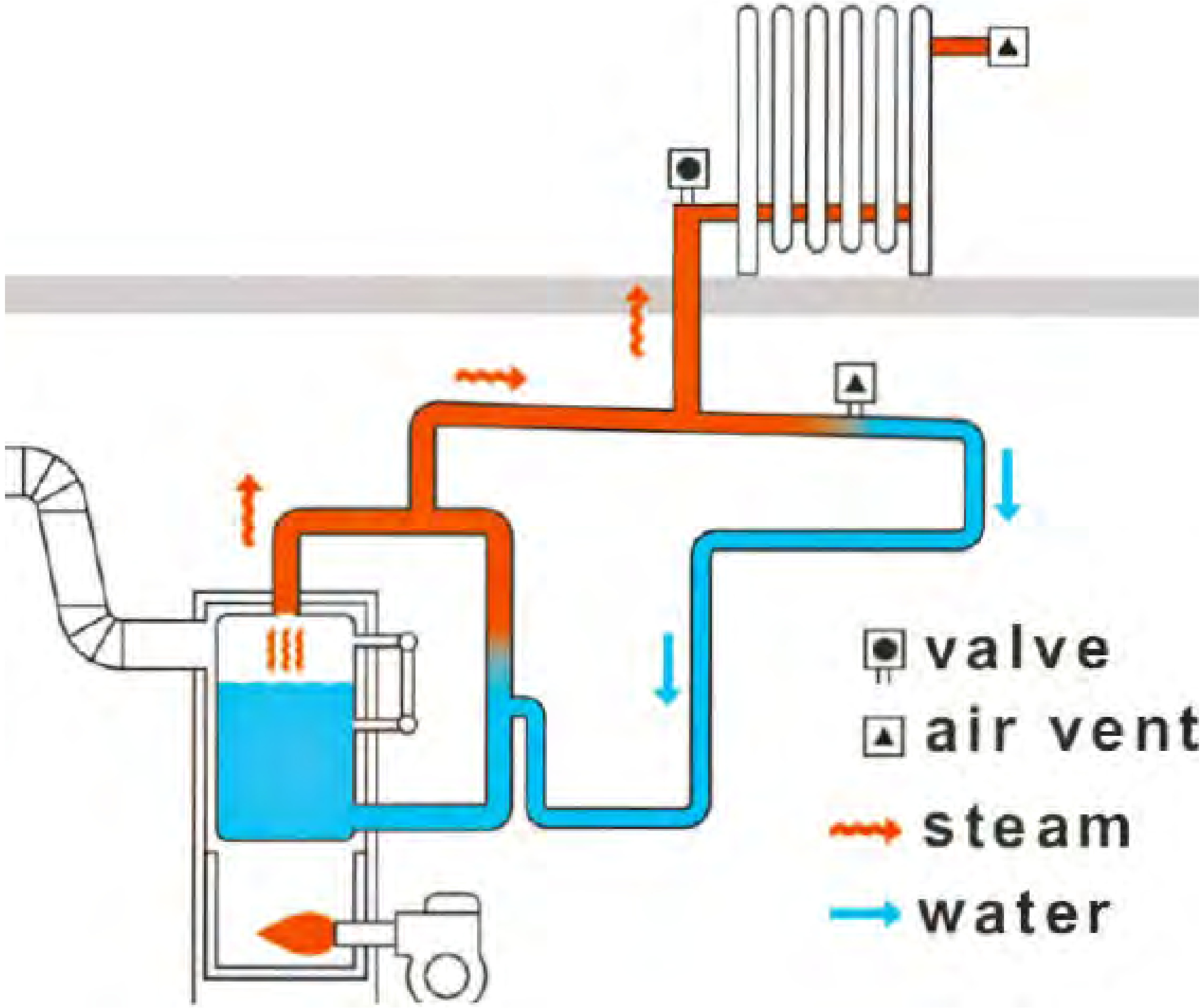
Raising the waterline to the level of the nipple.

Draining water until it runs clear and clean.

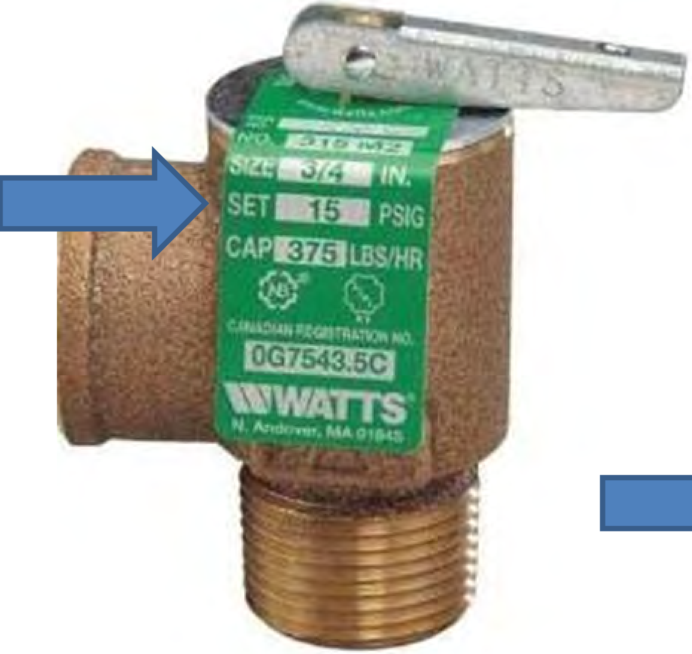
One-Pipe Steam Svstem

These have a single pipe that connects each heat emitter to the steam main, both steam and condensate travel in this pipe, but in opposite directions.

The mains downward pitch must be at least 1” for every 20’.



Pressure Relief Valve

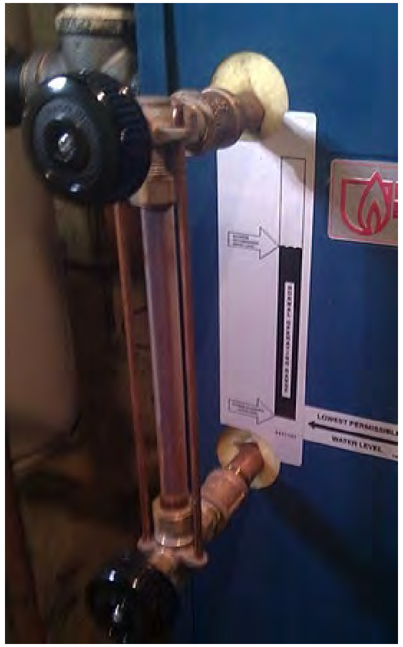


- Protects boiler from excessive pressure.
- Typically, 15 psi, but may weep @ 13 psi.
- MUST match DOE heating capacity.

Is this one OK?

Gauge Glass

Shows boiler's water level.



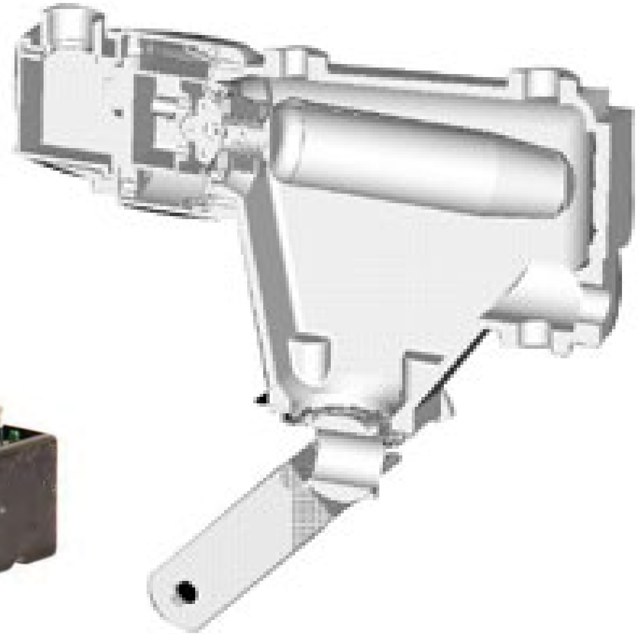
Expect minor (3/4") movement in waterline.

Low Water Cutoff

Prevents the burner from operating if the water level in the boiler is too low.

Low Water Cutoff

<u>Float types</u> have a spst switch connected to a float, when the water level drops the float also drops and opens the switch in the line voltage control circuit to keep the burner from operating……



LWCO

<u>Probe types</u> send a low voltage signal through the water to ground on the boiler's metal. If the water level is too low the switch opens.

Many have timing devices to prevent nuisance shutdowns due to surging.

Automatic Water Feeders

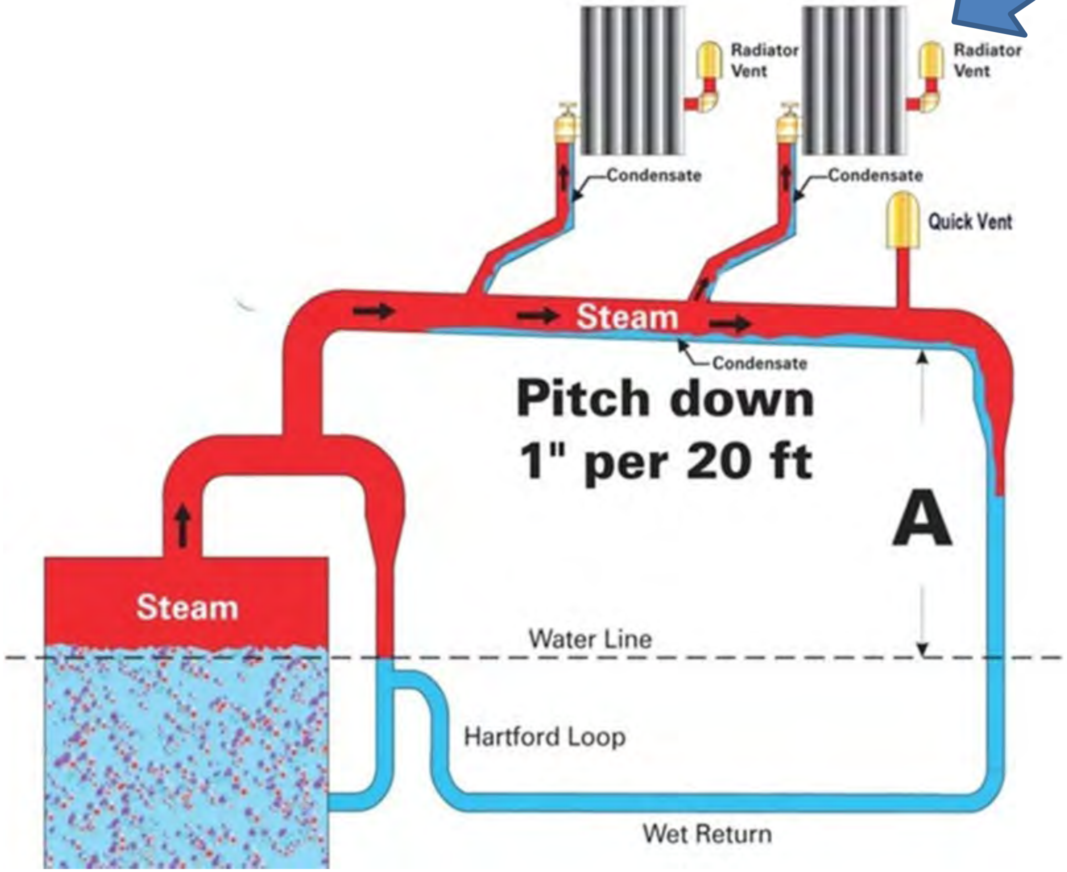
LWCOs can be incorporated with, or connected to, electric water feeders to maintain a safe minimum water level.

Main Vents

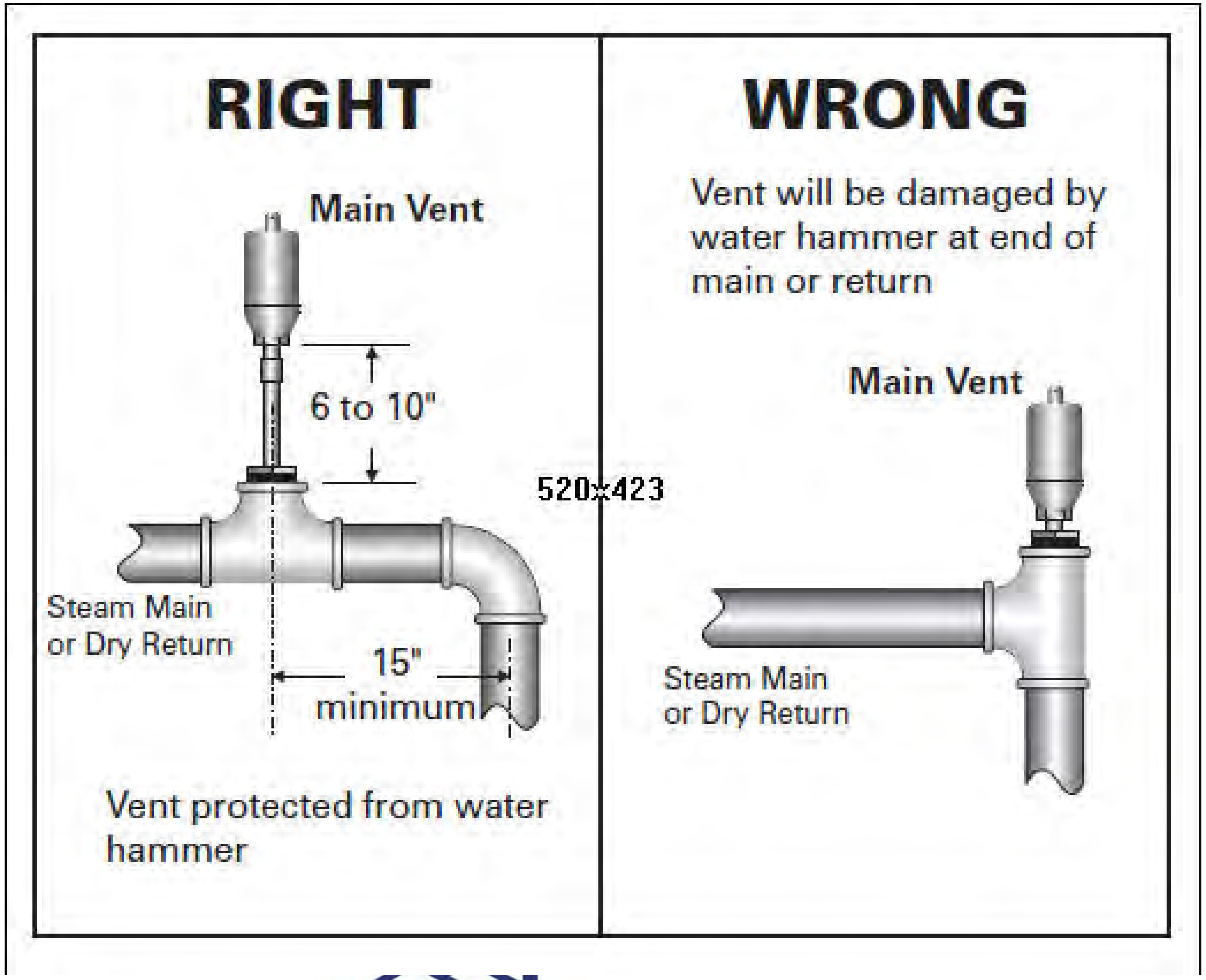
Main (aka "quick") vents are installed near the ends of each main so steam will travel quickly to each heat emitter.

They provide uniform heat by removing air from the main and closing when steam reaches them.

When they work properly, all heat emitters receive heat at about the same time.

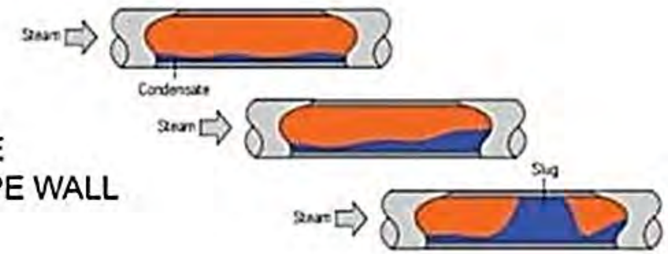


Main Vents



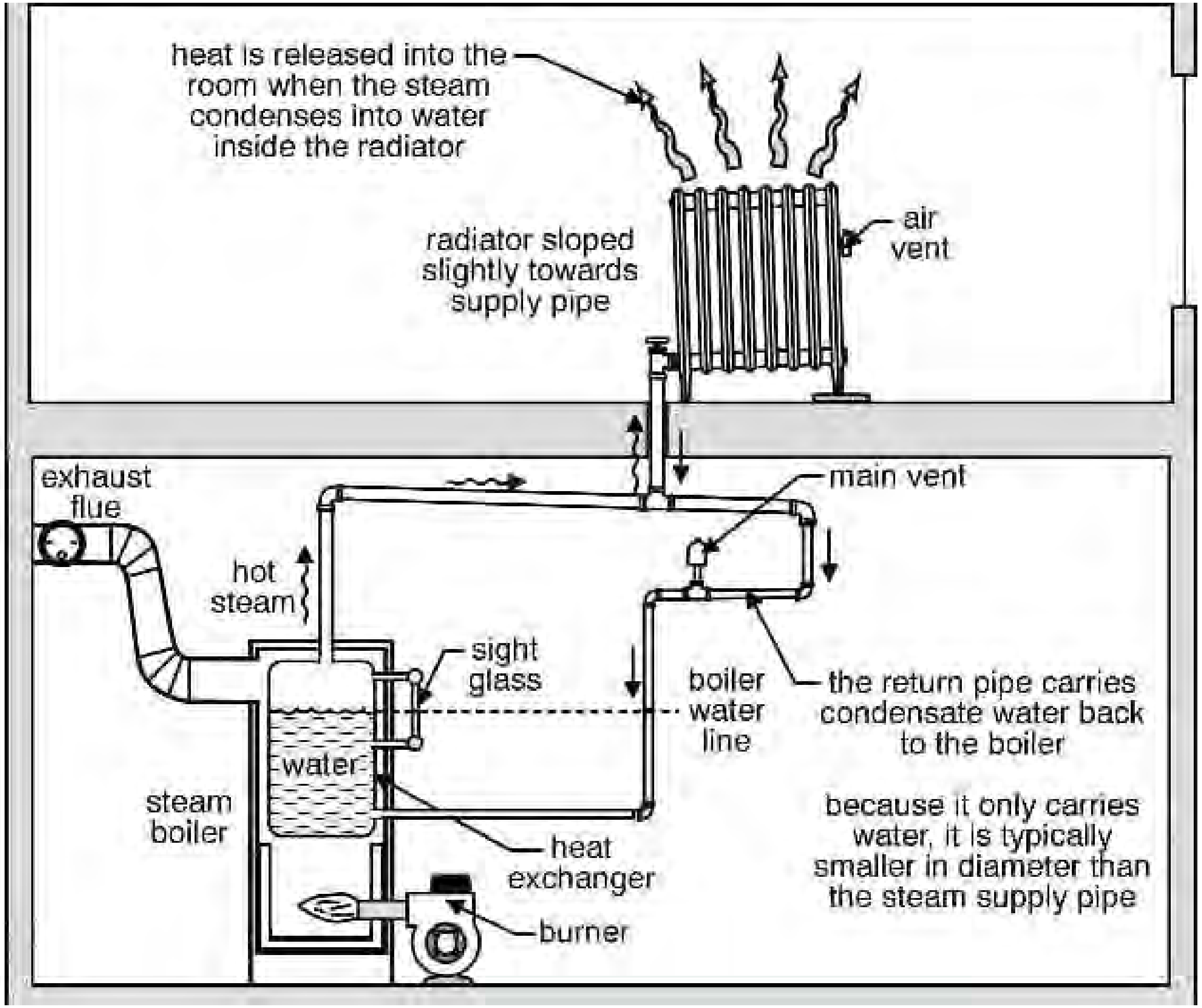
WATER HAMMER

OCCURS WHEN CONDENSATE MOVES FAST AND HIT THE PIPE WALL



Steam Air Vents

Air vents are installed on each heat emitter to let the air escape as steam enters.



Steam Air Vents

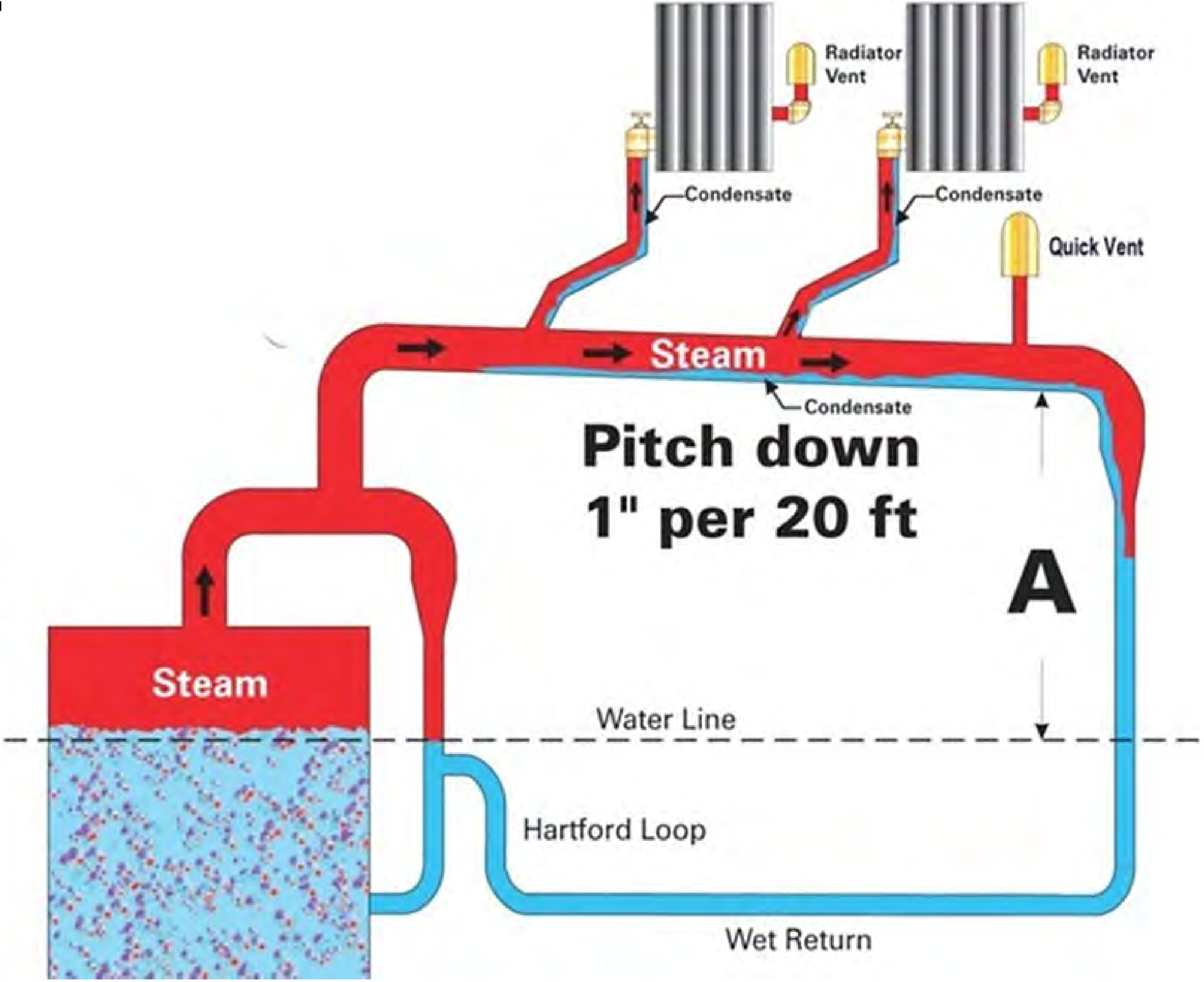
These vents can have non- adjustable openings to allow air to escape at a fixed rate or they can be adjustable.

Normal Operation of One Pipe Steam Systems

One Pipe Steam

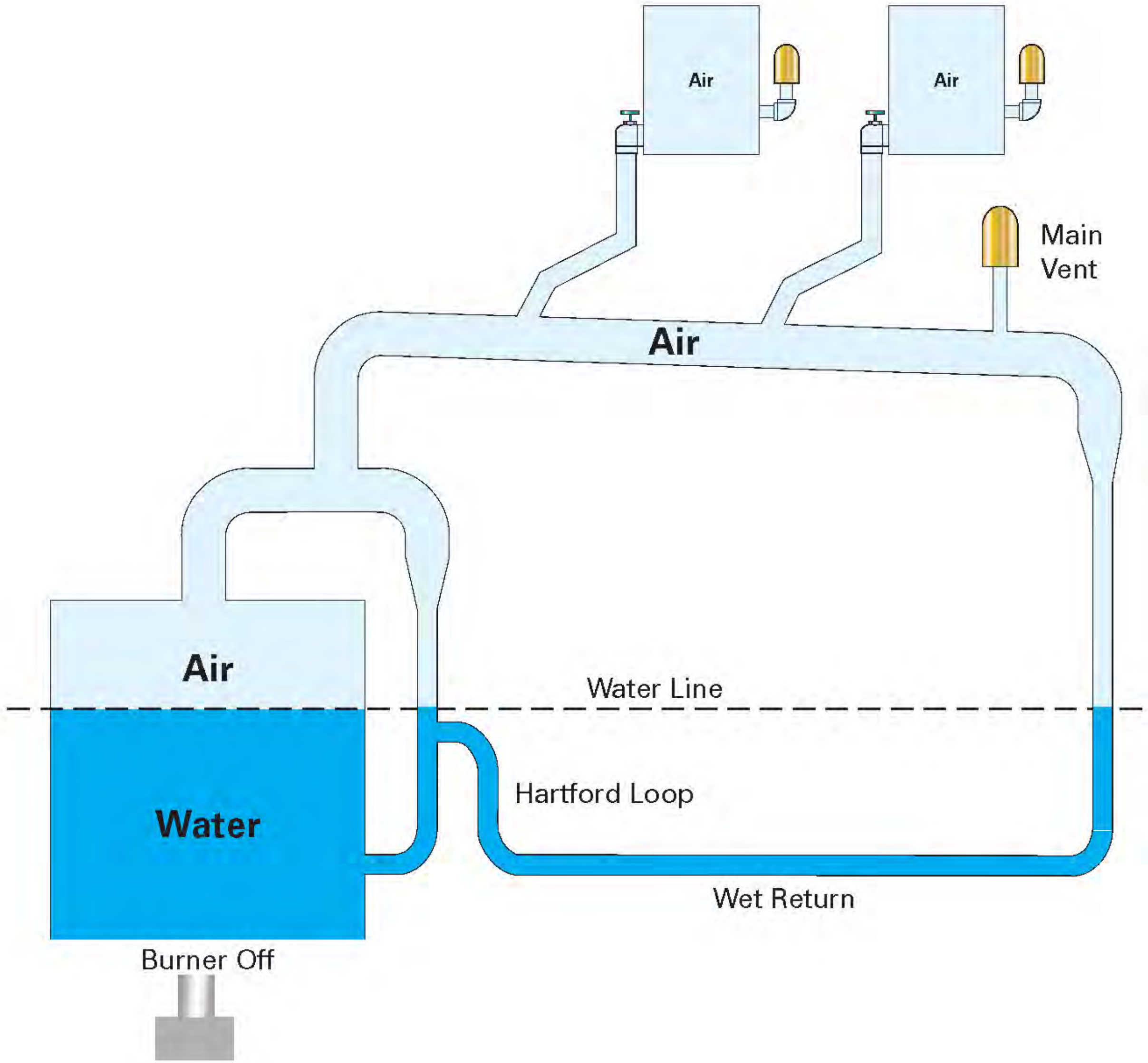
- Main - carries steam from supply header and condensate to return

- Riser – carries steam up from supply main to heat emitters.



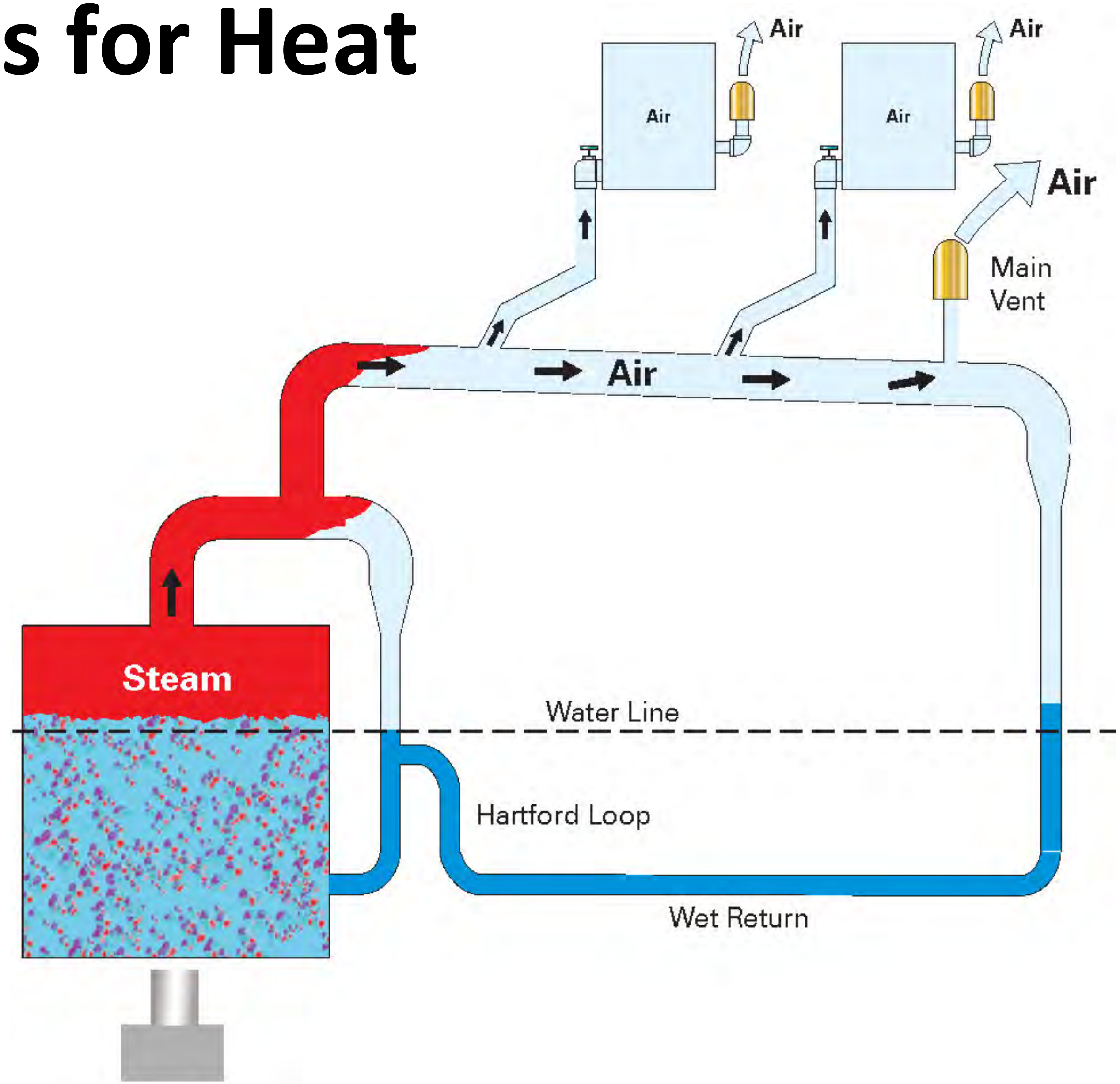
Standby Mode

- Same water level in boiler & return
- Piping & heat emitters full of air.



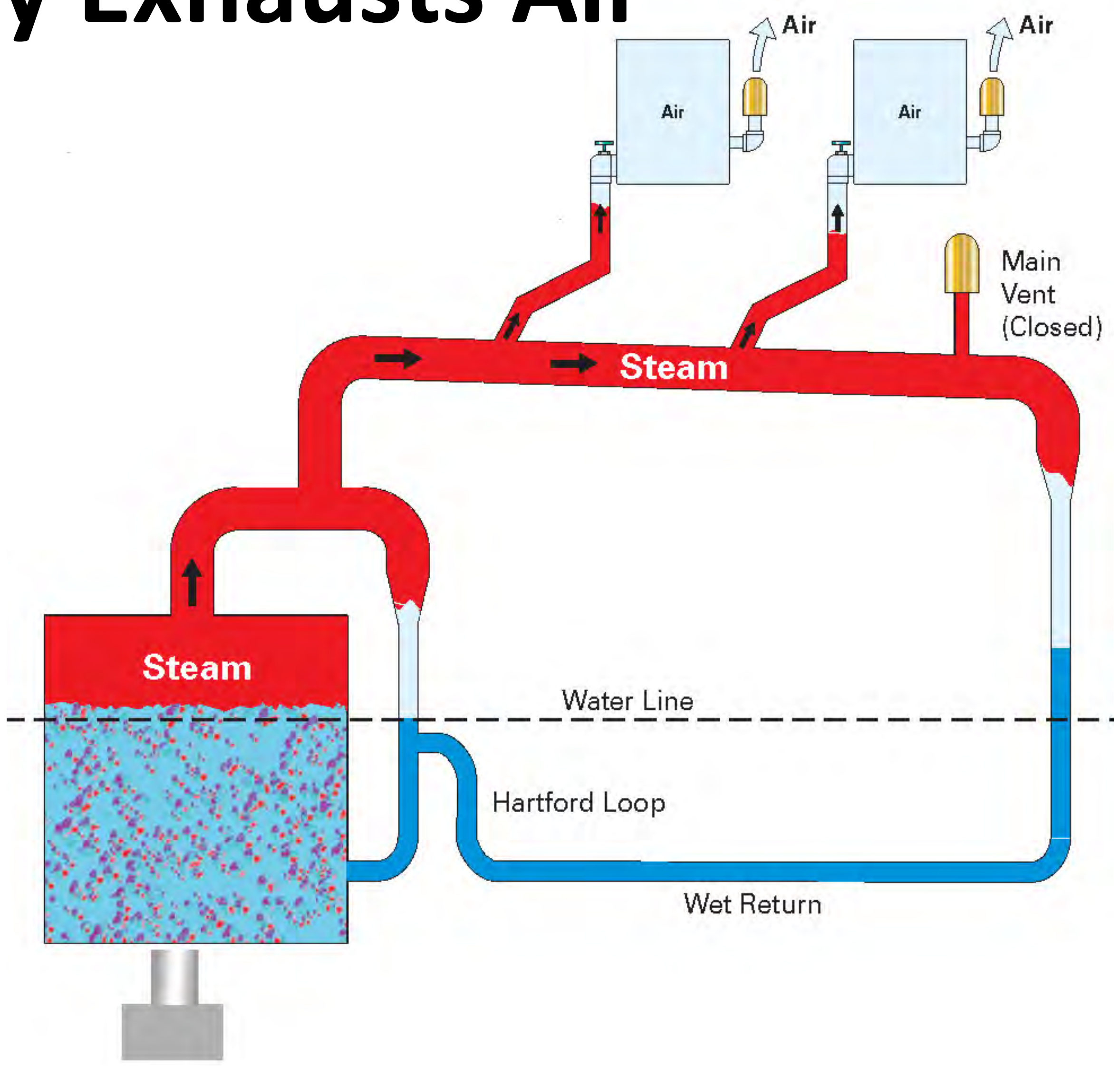
Thermostat Calls for Heat

- Burner fires, water boils, creating steam
- Water rises as bubbles displace water
- Pressure pushes air out
- Pressure drop causes water to rise in return riser



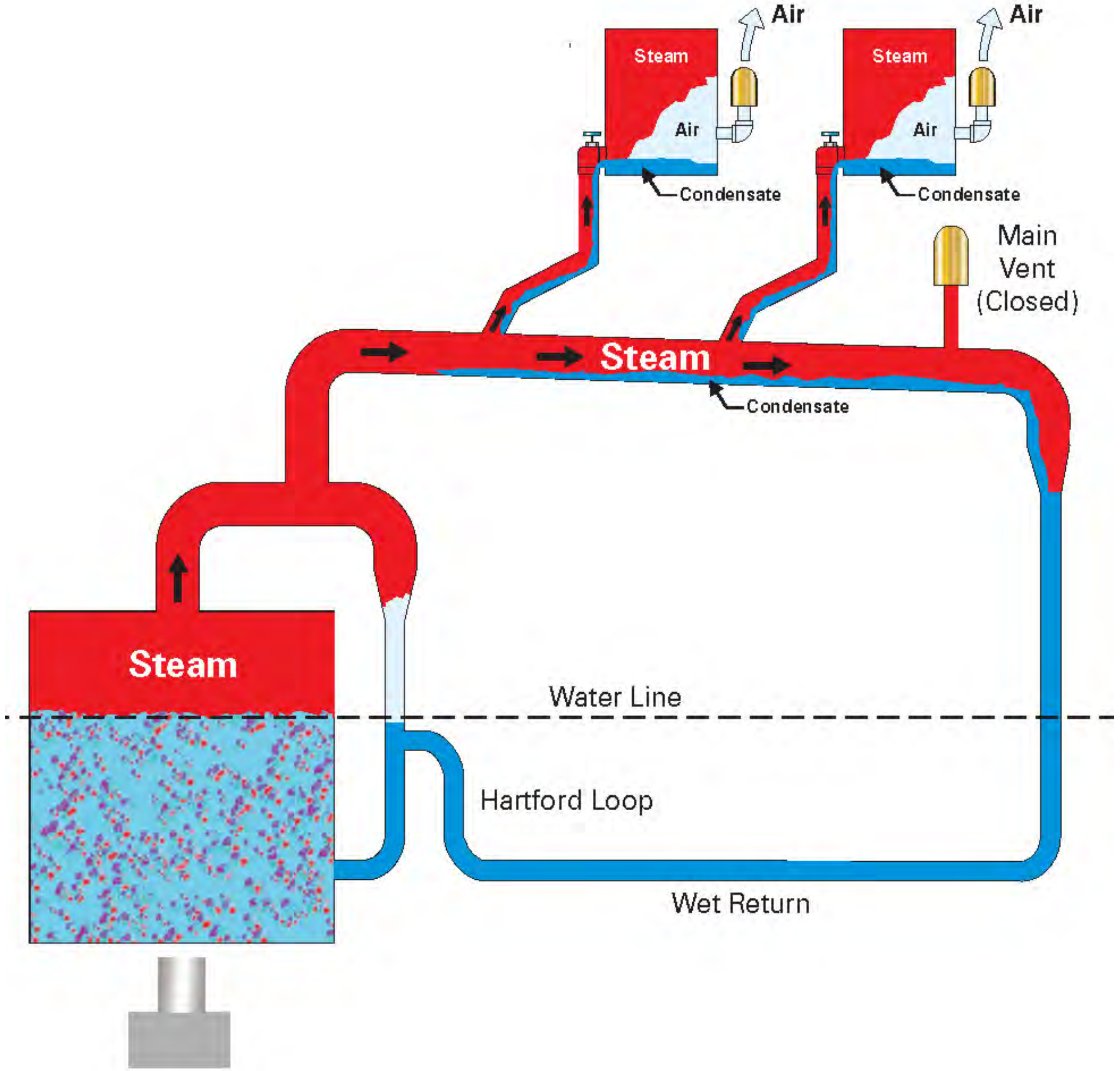
Main Vent Quickly Exhausts Air

- All branches receive steam at about the same time
- Air is slowly vented by radiator vents
- Water rises higher in return
- Condensate begins to form.



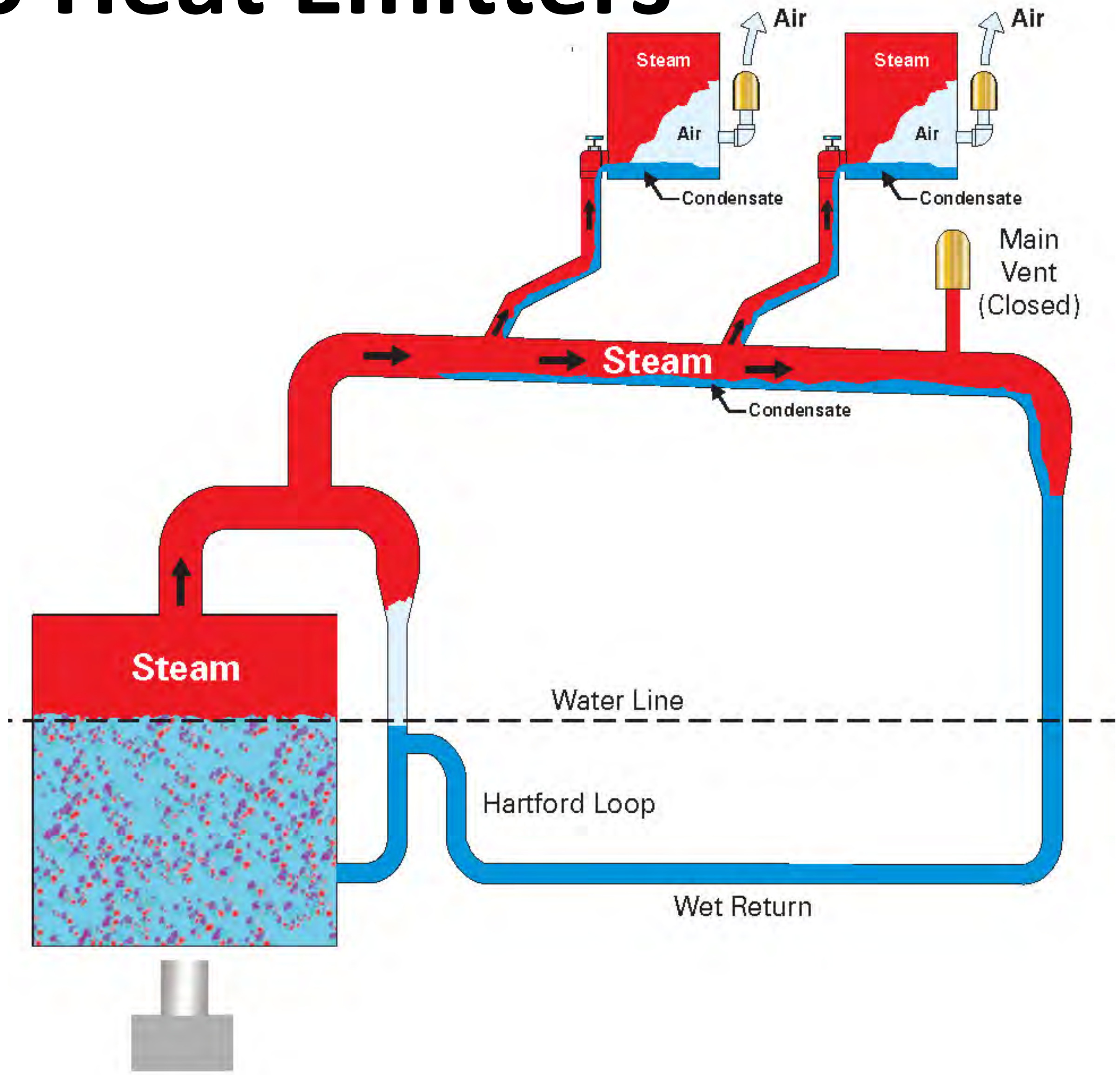
Steam Pushes into Heat Emitters

- Emitters heat up and cool steam
- Steam begins to condense
- Condensate begins to flow back into piping through radiator valves
- Condensate runs down branch piping – against flow of steam.



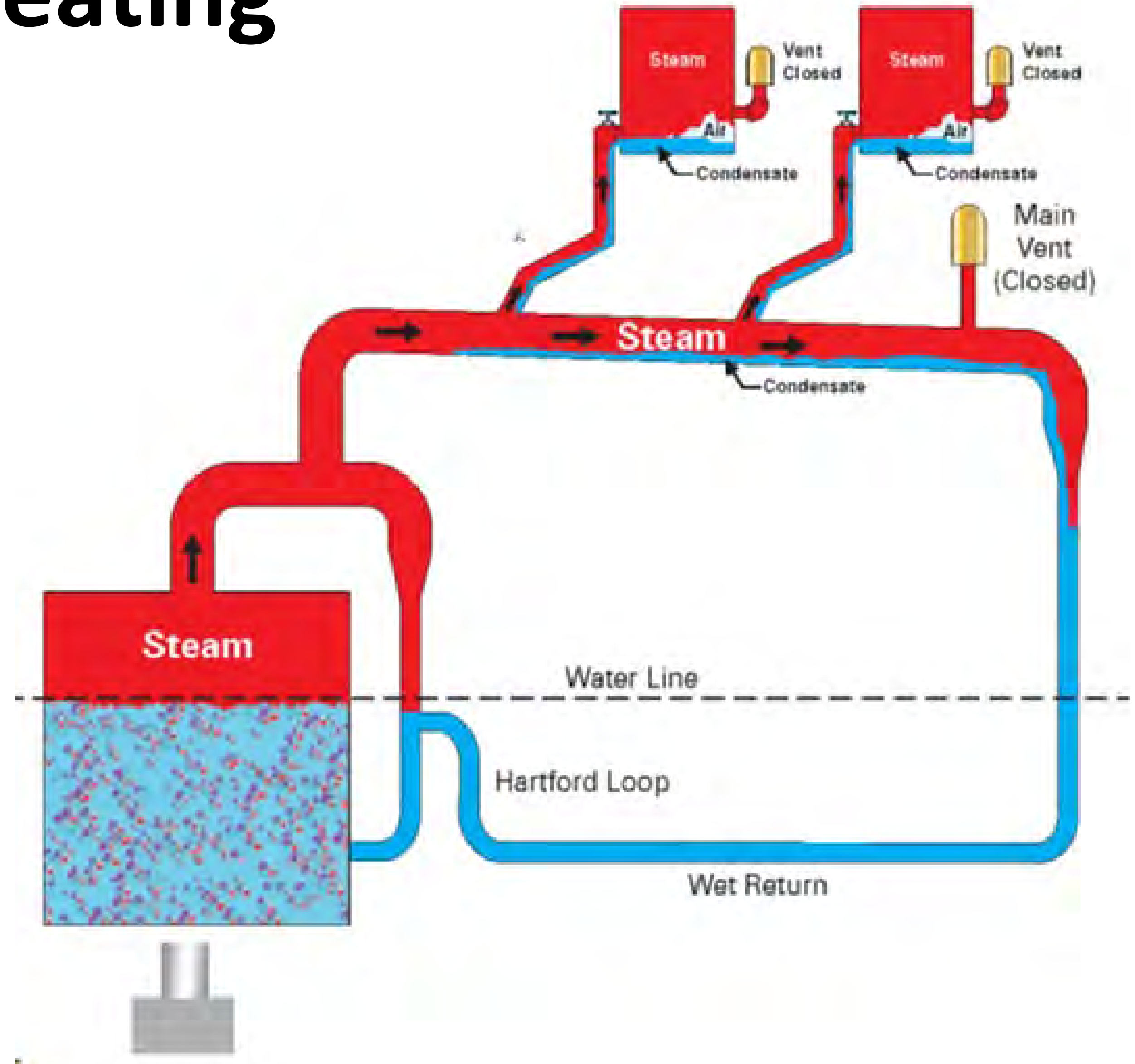
Steam Pushes into Heat Emitters

- Condensate load increases pressure difference in piping, raising water level in return
- Boiler water drops slightly – water has been "steamed off" and condensate has not returned.



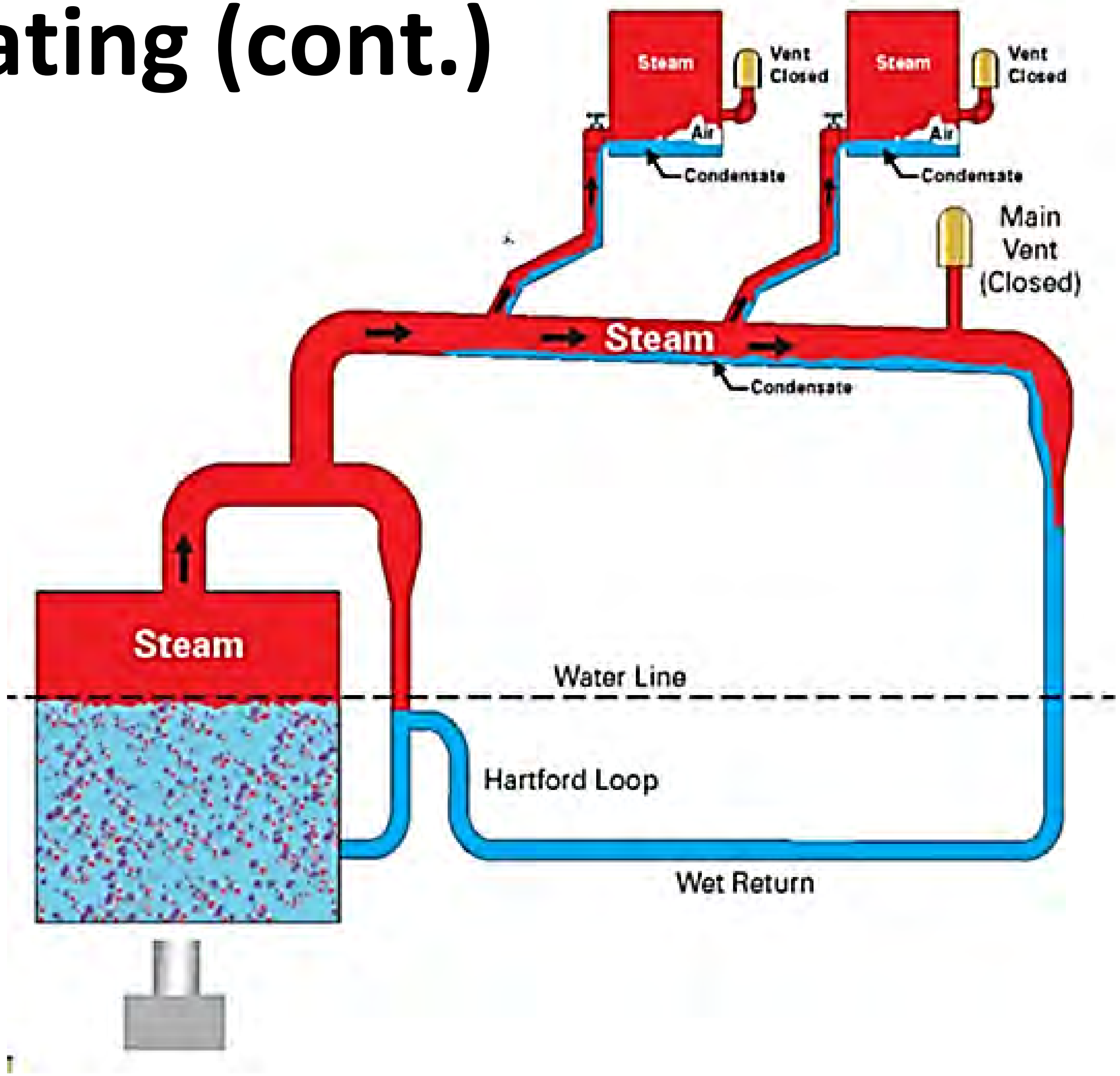
Steady State Heating

- Steam fills emitters until it reaches the vents
- Vents close when exposed to steam temperature
- Boiler fires until thermostat is satisfied or limit is reached.



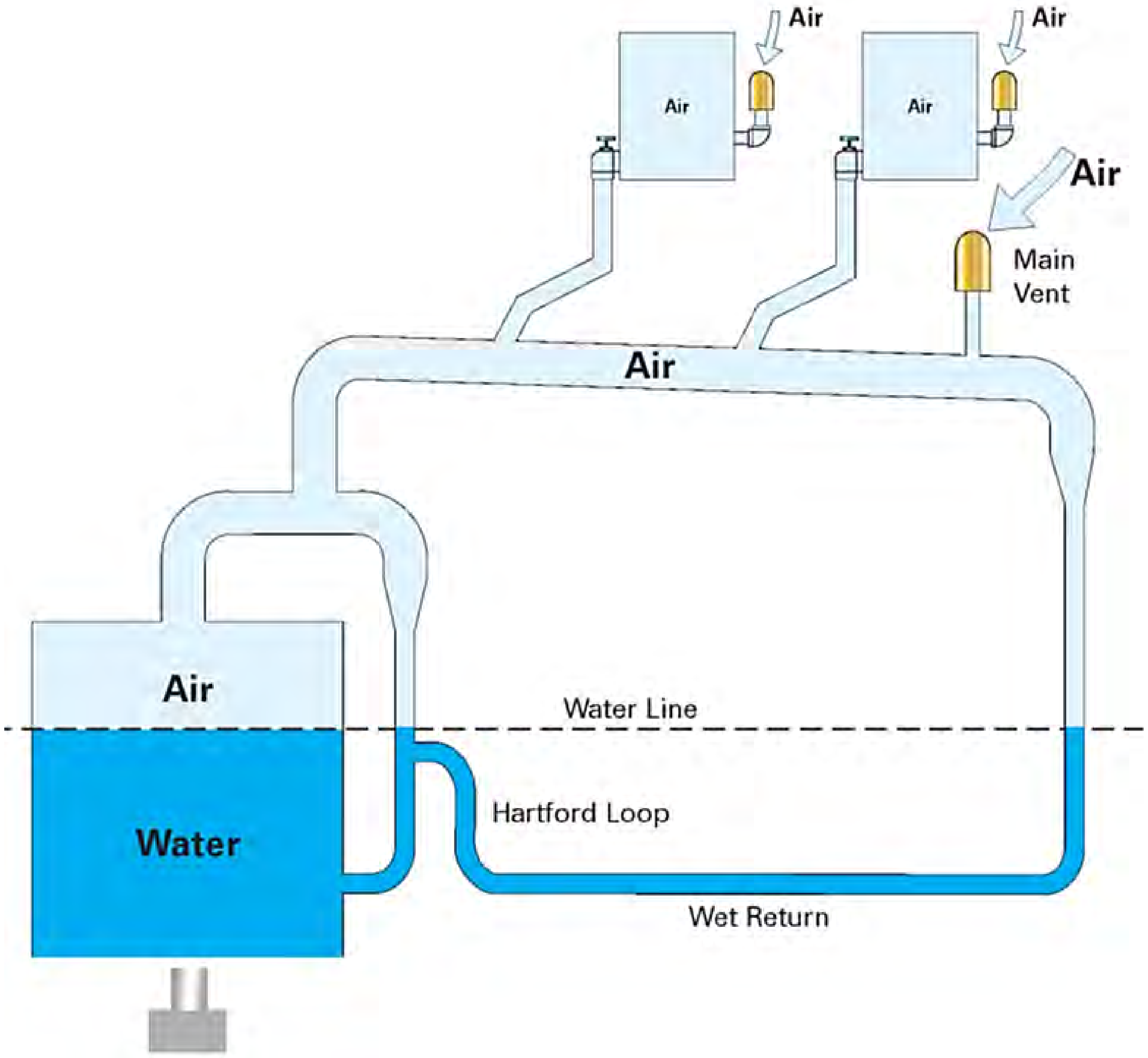
Steady State Heating (cont.)

- Water level in return drops as condensate flows back to boiler
- Boiler water level is lower because of condensate out in the system



Off Cycle

- Burner shuts off
- Steam condenses and creates a vacuum
- Vents let air back into system
- Water level in return and boiler is the same – no pressure difference in piping.



Off Cycle

The water level may drop out of glass on shutdown because the steam bubbles

collapse and the condensate has not yet returned.

Part 4 - Domestic Hot Water

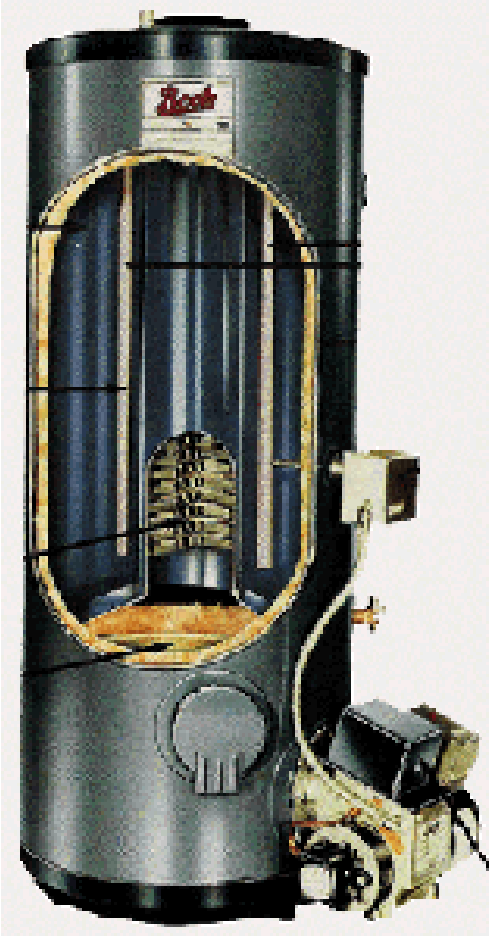
Domestic Hot Water

Domestic hot water systems fall into two major groups:

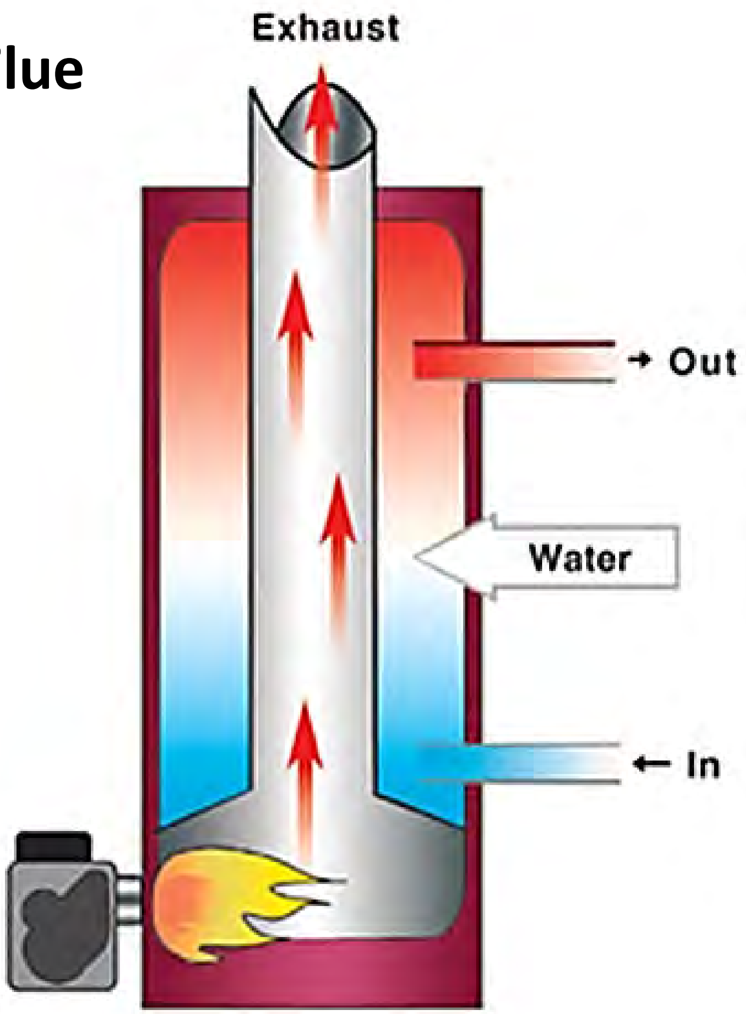
- **Direct** – water is heated directly by heat from the flame
- **Indirect** – boiler water is used to heat domestic water

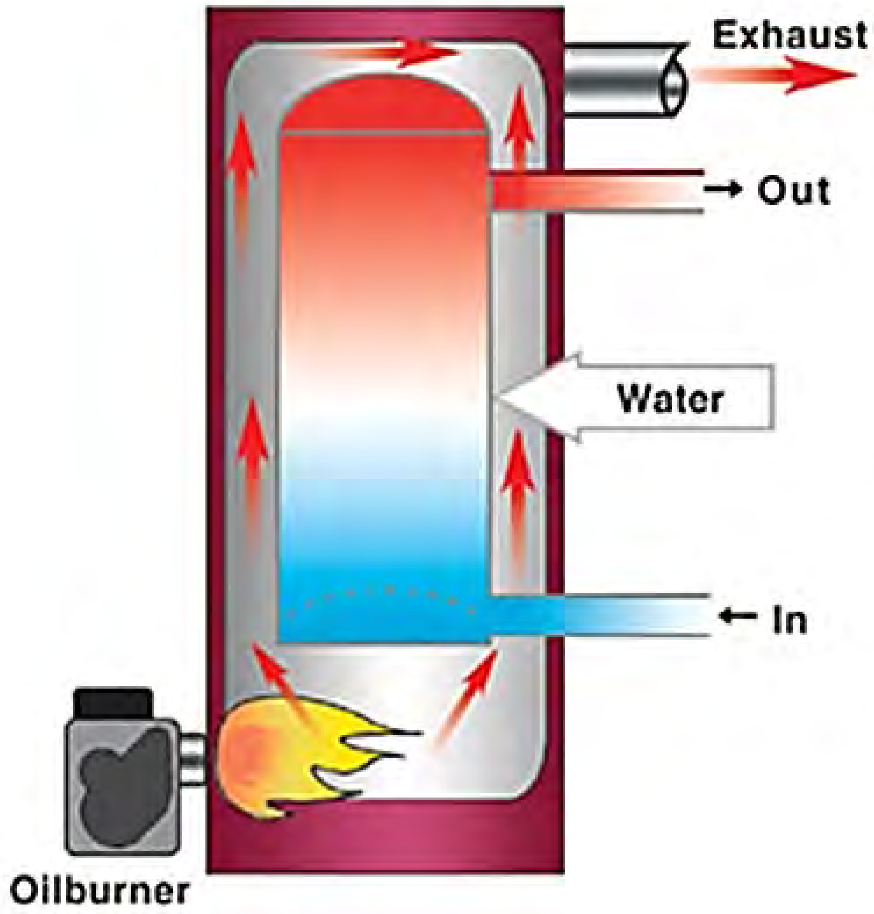
Direct Fired Water Heaters

- Tank, sitting over a combustion chamber, surrounded by an insulated jacket
- Burner fires into the chamber and the combustion gases heat the water as they pass through the tank
- Typically glass lined steel tanks made of steel and internally coated with ceramic to help prevent corrosion



Direct Fired Water Heaters





Anodes

- Sacrificial magnesium anode rods are immersed in the the water

- Anodes break down to protect the tank from corrosive properties of air & chemicals in the water

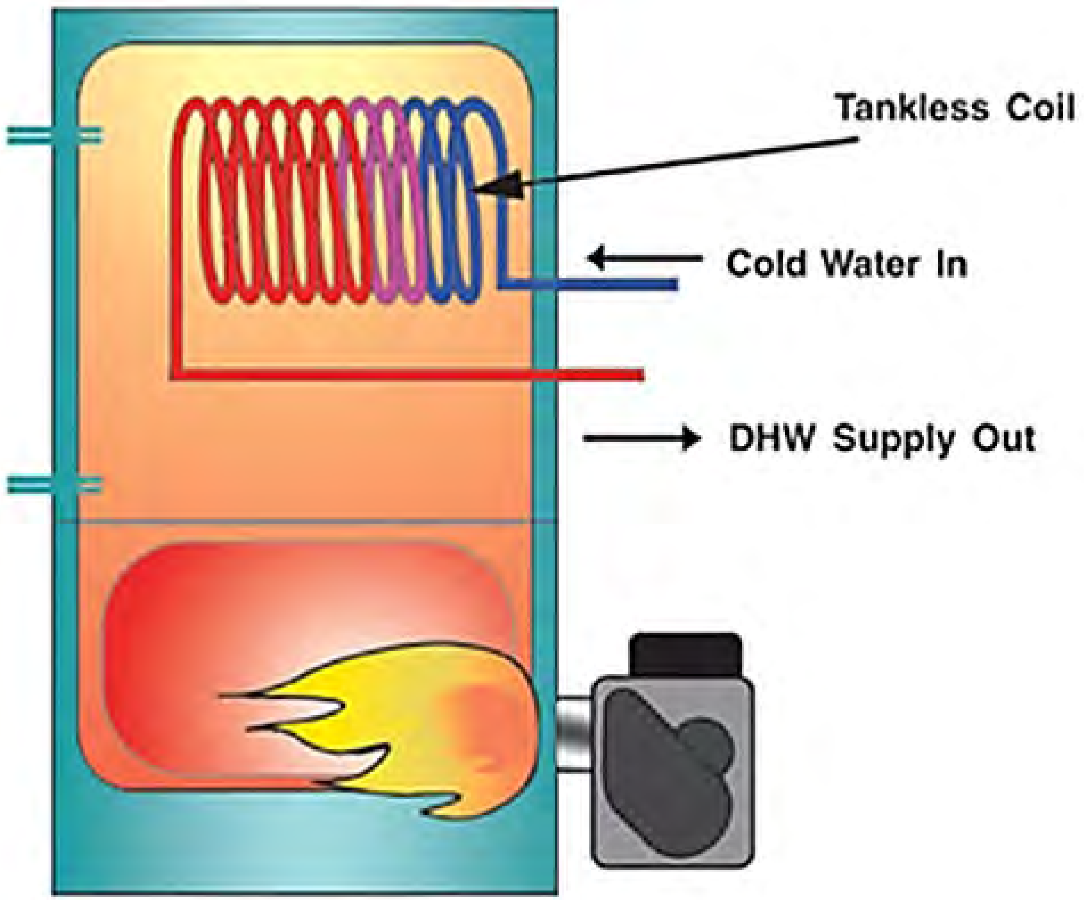
- They should be checked periodically and replaced when necessary

Indirect Water Heating

There are four common types of indirect water heating:

- Internal tankless coil
- External tankless coil
- Tankless coil with a storage tank
- Indirect storage type water heater

Internal Tankless Coil



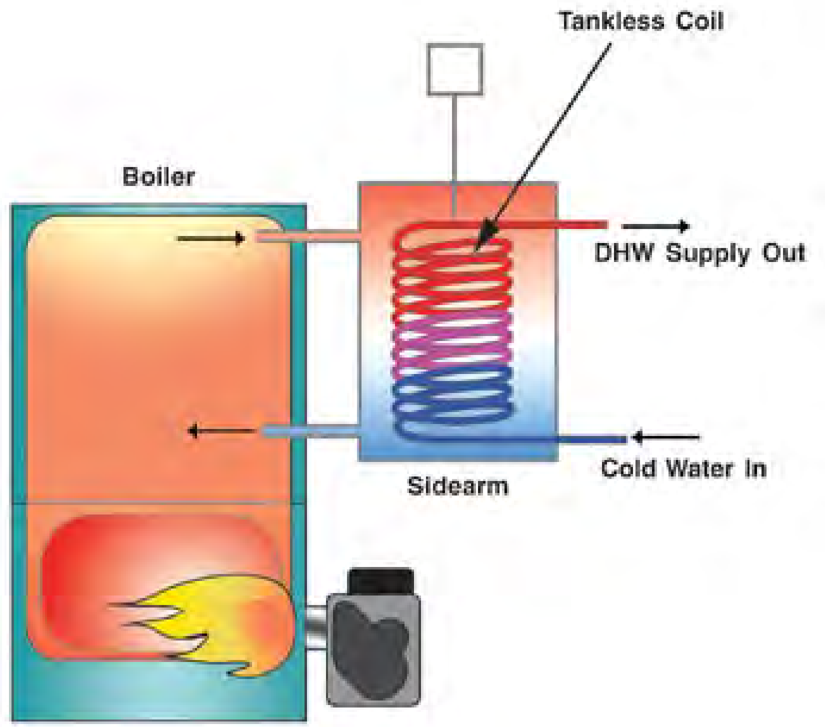
- Copper coil placed in boiler water, attached to a mounting plate

- Requires boiler temperature to be maintained

- No storage capacity

External Tankless Coil

- Copper coil installed inside a copper, cast-iron or steel tank
- Boiler water is piped to tank, circulates on gravity or forced flow
- New versions – plate heat exchangers – a series of plates with internal porting, alternate between boiler water & domestic water

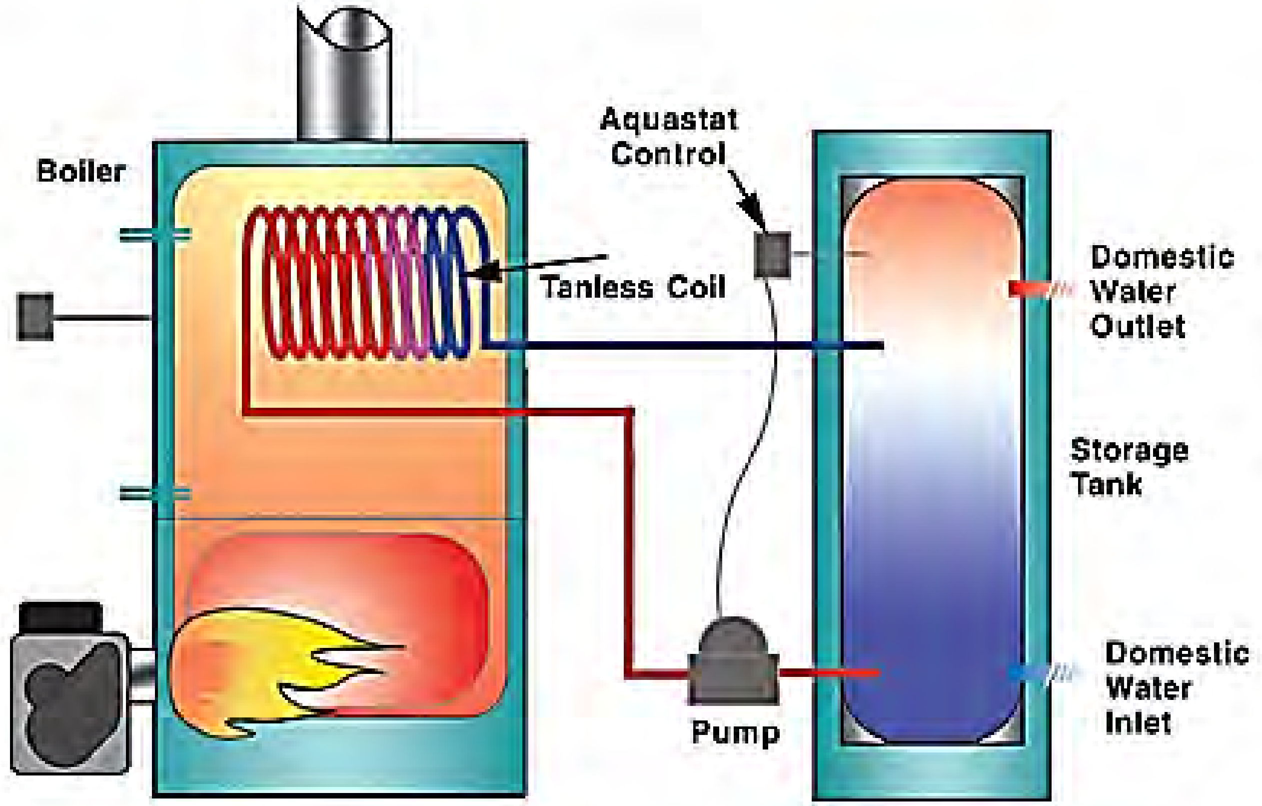


Tankless Coil with a Storage Tank

AKA "Aquabooster"

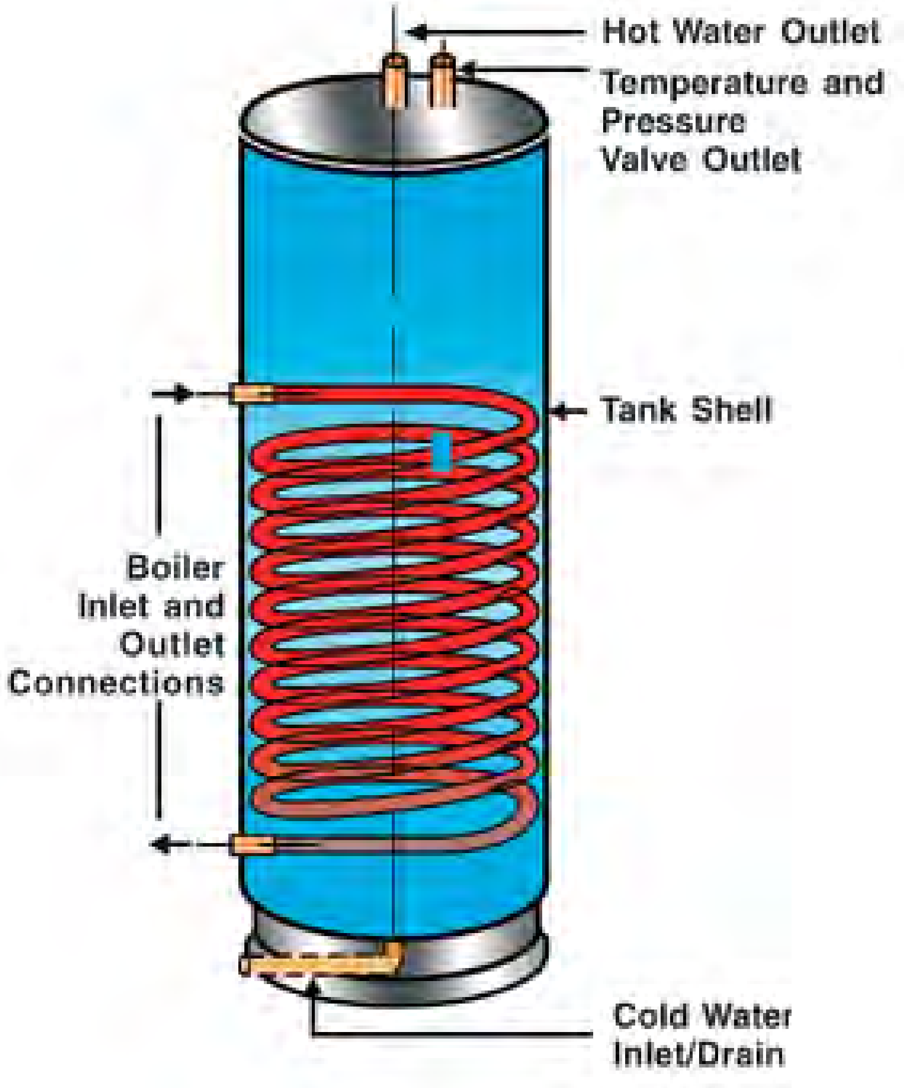
Water heated by coil & stored in tank.

Tank temperature controlled by an aquastat and maintained by recirculation loop with non-corrosive circulator.



Indirect Storage Type Water Heaters

- Storage tank with a coil inside
- Boiler water circulates inside the coil
- Domestic water around coil is heated by circulating boiler water
- Piped like a zone – used with hot water or steam boilers
- Temp controlled by aquastat that controls circulator & burner



Components

Temperature & Pressure Relief Valve (T&P)

- Discharges water if temp or press becomes too high
- Drain line from valve protects against scalding
- No shutoff devices on inlet or outlet side

Pressure Relief Valve

With a domestic coil application, where no water is being stored, a pressure only relief valve is used to protect against excess pressure.

Vacuum Relief Valve (VRV)

If vacuum occurs, the valve automatically vents the closed system to the atmosphere to prevent damage to the water heater.

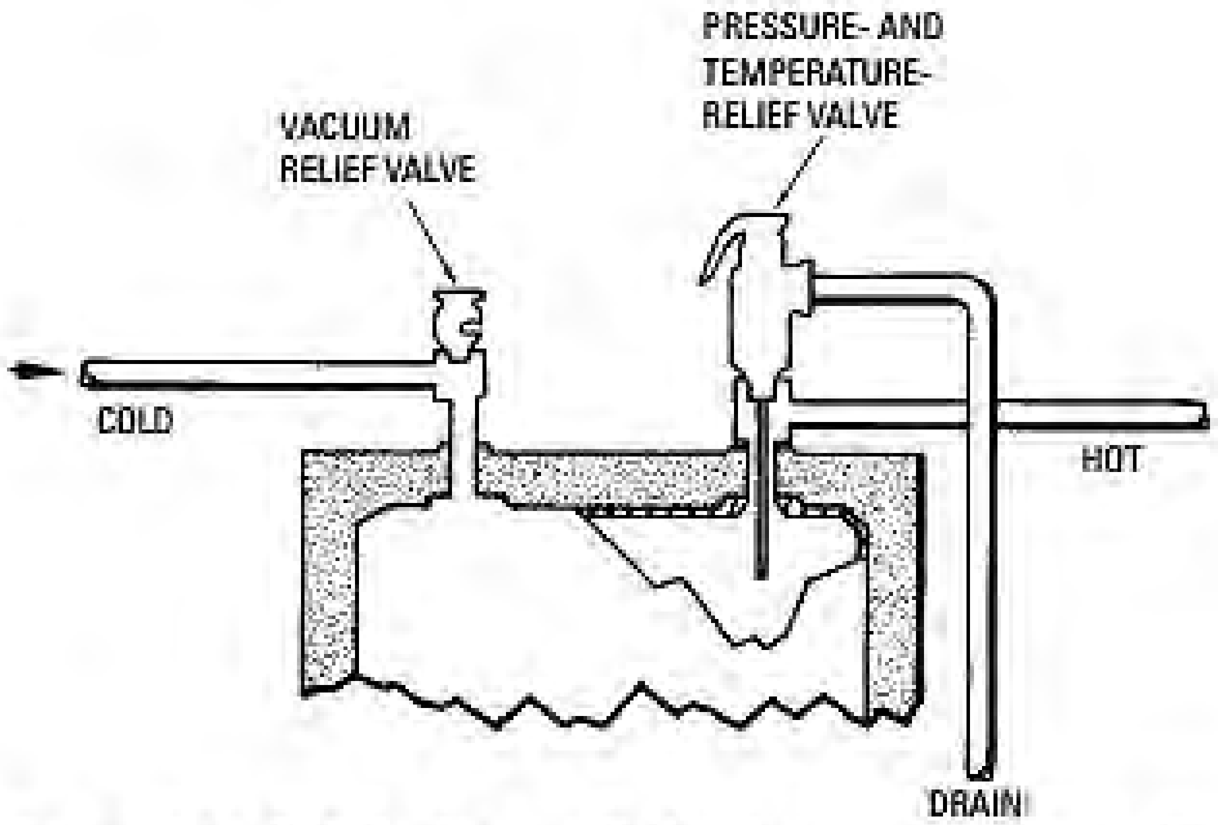


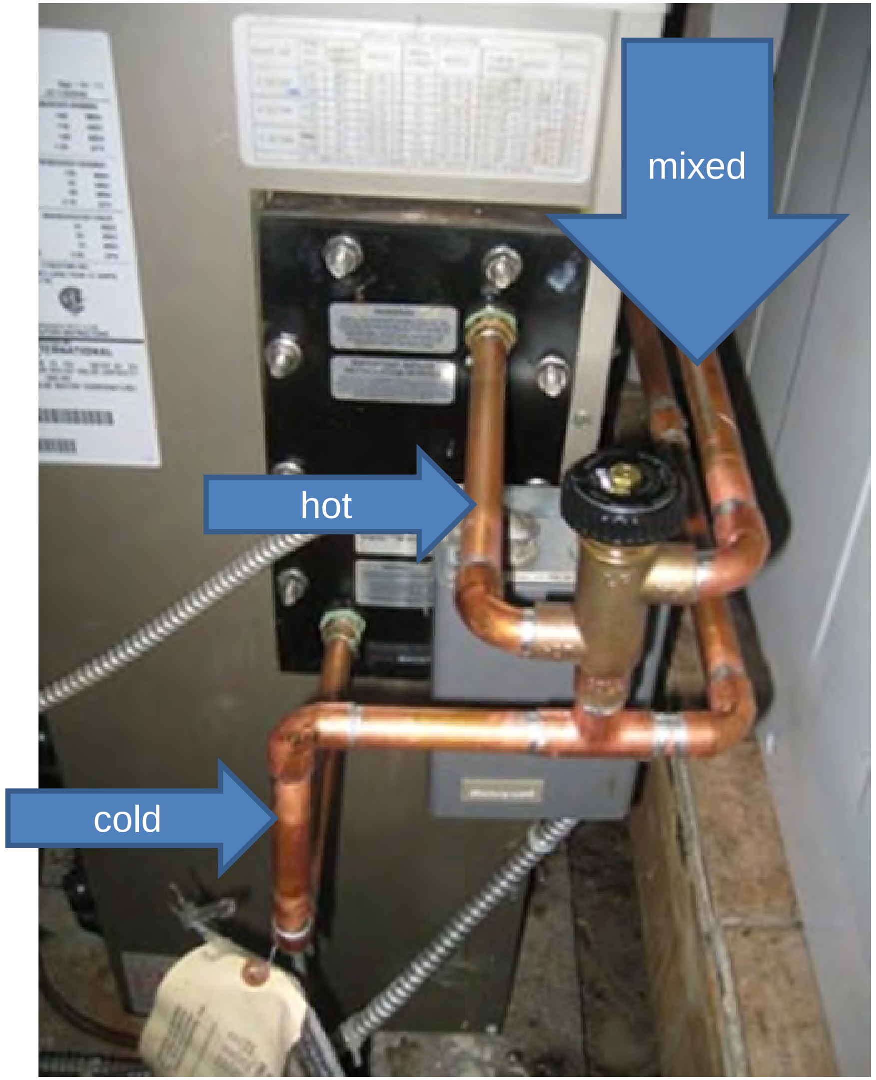
Figure 4-24 Relief valve installed in hot-water discharge line.
(Courtesy Watts Regulator Co.)

Back Flow Preventer

- Like a VRV, it opens a vent to the atmosphere if it senses a vacuum
- Also prevents cross contamination of domestic water

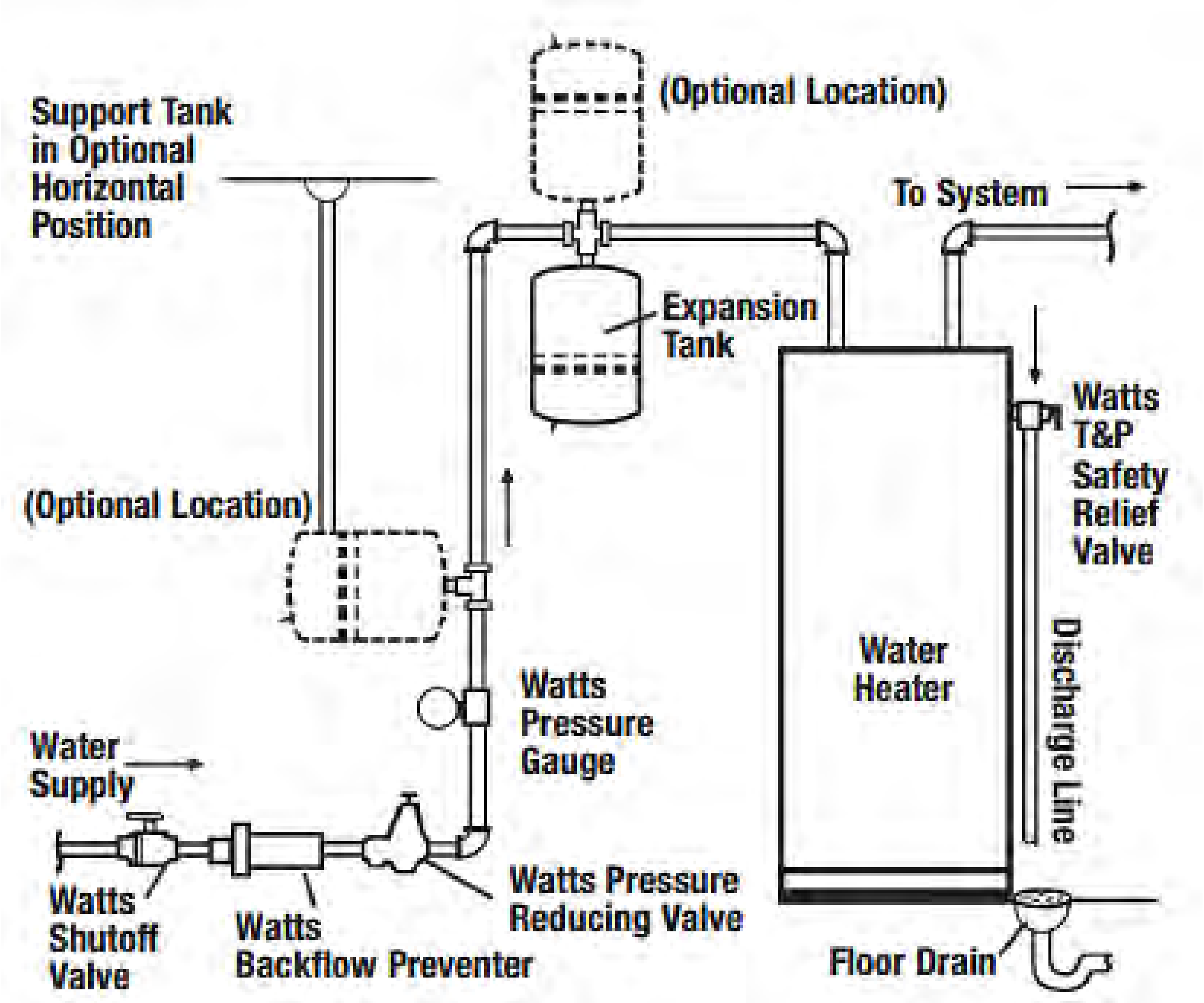
Tempering/Mixing Valve

- Controls the temperature of water delivered to fixtures
- 3 ports – cold, hot from heater or coil, mixed
- Avoids scalding



Pressure Reducing Valve & Expansion Tank

- Prevents nuisance R/V discharge and premature tank failure
- NOT a standard expansion tank
- Need for expansion tank became common after backflow valvein stallation



Review Questions:

- What are the different configurations of warm air furnaces?
- What are the parts of a distribution system?
- How do to troubleshoot a warm air system?
- What are the different types of hydronic (hot water) systems?
- How are a series loop, 1-pipe, and 2-pipe systems different?
- What do the components of a hydronic system do?
- What is used to eliminate or control air in a hydronic system?
- What is used to control zones in a hydronic system?
- How do steam boilers use pressure to move heat?

Review Questions:

Continued

- What happens if the pressure is too low or too high?
- What are the important things to remember when installing a steam boiler?
- What do the different steam boiler components do?
- How do air, steam, and water move in a 1-pipe steam system?
- What is the difference between a direct and indirect hot water system?
- What do the components in direct hot water systems do?
- What do the components in an indirect hot water system do?

End Chapter 13

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 14

Annual Maintenance

At the end of this lesson, you will be able to:

- Explain why preventative annual maintenance is important
- List the items you should have in your “tune up” kit
- Explain what you should do before you begin your inspection
- Follow the procedures for inspecting the oil tank, oil line, valves, and filters
- Follow the procedures for inspecting the fuel unit
- Follow the procedures for inspecting the flue pipe, heat exchanger, and chamber

At the end of this lesson, you will be able to:

Continued

- Follow the procedures for testing the operation of the fuel unit
- Describe appropriate combustion analysis readings
- Describe the procedures to maintain a hot water system
- Describe the procedures to maintain a warm air system
- Describe the procedures to maintain a steam system
- Explain what you should do after you have completed your inspection and maintenance

Annual Maintenance

The annual preventive maintenance is one of the most important services this industry provides.

A properly performed tune-up assures the customer that their heating system is operating at peak safety, reliability and efficiency.

Key Factors for a Proper Tune-up

1. Safety
2. Efficiency
3. Reliability
4. Cleanliness

Safety

Service & adjust the system to minimize the possibility of a problem.

Check the controls to be sure they work properly and shut off the burner if a problem develops.

Efficiency

When a combustion analyzer is used to adjust the system for maximum efficiency, the customer can conserve fuel and save money.

The tune-up also presents an opportunity for the technician to recommend new equipment to those customers whose systems are not as reliable or as efficient as today's equipment.

Reliability

Typically, certain parts (nozzles, fuel filters & strainers) are replaced before they fail to keep the system operating efficiently throughout the year.

The technician also checks components, looks for & corrects potential problems and advises the customer regarding necessary repairs.

Cleanliness

There are 2 critical aspects to cleanliness:

1. The technician should focus on assuring the system is operating at peak performance, with as little effect on the environment as possible.

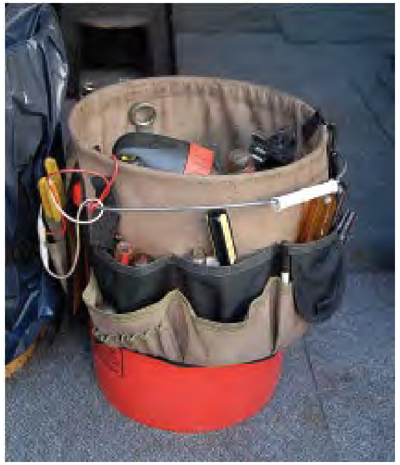
Cleanliness

2. Most of the work performed during a tune-up is not visible to the customer.

Every effort must be made to make sure that what the customer does see—the outside of the unit and the area around it—are neat and clean when the job has been completed.

Tools of the Trade

To successfully perform a tune-up, technicians must have certain hand tools, testing instruments, parts, and supplies, including:



A complete set of hand tools, test equipment and a vacuum cleaner.
A comprehensive list can be found on page 228 of the
NORA Technicians Manual.

Tune-Up Procedure

The following slides present typical tune-up procedures.

Individual companies often develop tune-up procedures that vary from these.

It is important to follow company policies and procedures.

Step 1 – Customer Interview

Give the customer a friendly and professional greeting.

Listen carefully and address their concerns.

Operate the remote switch to be sure it works properly and leave it in the “off” position

Step 2 – Visually Inspect the Unit

While spreading material to protect the work area, then:

1. Verify that limit controls are properly set with the correct differential. Note what nozzle, filter and fuel unit are installed so the correct parts can be brought in from your service vehicle.

2. If the unit is cold, fire the burner on for about 5 minutes to dry the heat exchanger surfaces.

Step 2 – Visually Inspect the Unit (cont.)

3. Check the draft drop by testing at the breech and over-the-fire. If the drop is greater than -.04 inches, there is probably a buildup of soot and scale or there may be air leaks in the unit.
4. Note any problems so they can be repaired during the tune-up and turn off the unit before proceeding.

Step 3 - Inspect the Fuel Tank

- Perform the NORA Routine Inspection procedure
- If water is found remove and properly dispose of it. If a significant amount is found, contact your supervisor
- Reinstall any fittings removed for tank access

Step 4 – Fuel lines, Valves and Filters

- Inspect the fuel line for leaks, kinks or dents
- If bare copper is contacting concrete or dirt, notify the customer & follow company procedures.
- If compression fittings are found, NORA recommends that they be replaced with flare fittings.

Step 4 – Fuel lines, Valves and Filters

- Shut off the oil valve, place a pan under the filter to protect the area & collect any fuel drippings and replace the fuel filter.

- Follow the manufacturers instructions regarding filter replacement. If they are not available, the following procedures are recommended.

Step 4 – Cartridge Filters

1. Loosen the center bolt, remove the bowl, remove & discard the old cartridge and gaskets.

2. Clean the filter bowl and head.

3. If you find leaks, corrosion, scratches, missing coating or any other damage replace the filter assembly.

Step 4 – Cartridge Filters

4. Install the new cartridge first, and then the gaskets for the bowl, center bolt and vent screw.

5. Re-assemble the bowl to the filter head and tighten the center bolt.

Step 4 – Spin On Filters

1. Using a filter wrench, loosen and spin off the old cartridge.

2. Cut and remove the old O-ring.

3. Inspect the threads for signs of wear or damage and replace head if required.

Step 4 – Spin On Filters

4. Apply a thin coat of petroleum jelly or motor oil to the gasket. ***(Do NOT use heating fuel!)***

5. Spin on the new cartridge.

Step 5 - Fuel Unit

1. Clean or replace the strainer, carefully scrape of the old gasket before installing a new one.

2. Open the valve, turn the switch on and bleed the unit. Run fuel through a clear tube into a container until there are no bubbles.

Check for fuel leaks in the line, the valve, the filter and the fuel unit.

Step 5 - Fuel Unit

3. Disconnect the nozzle line from the nozzle assembly and install a pressure gauge on it.
4. Operate the unit until the pressure holds steady, then increase it 40-50 PSI above the recommended setting. Check that the pressure reading changes smoothly as the adjustment screw is turned.
   A pulsating needle could indicate a leaking fuel line or defective fuel unit.
5. Operate the unit until the pressure holds steady, then increase it 40-50 PSI above the recommended setting. Check that the pressure reading changes smoothly as the adjustment screw is turned.

Step 5 - Fuel Unit (cont.)

5. After adjusting the fuel unit back to its proper setting, allow the unit to shut off on safety to verify the primary control's safety timing.

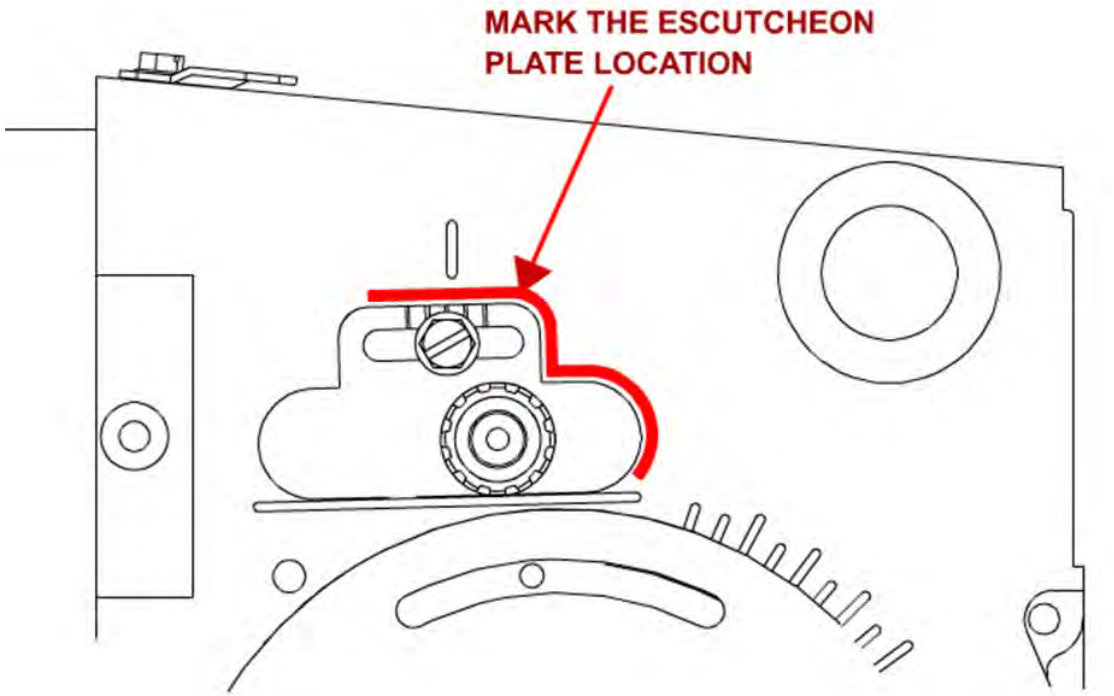
6. When the unit shuts off, the pressure should drop no more than 15 to 20% and then hold steady. If the pressure continues to drop, the fuel unit has a bad cut-off and requires replacement.

Step 6 – Nozzle/Drawer/Firing Assembly

Mark the position of the assembly on the burner housing before removing it.

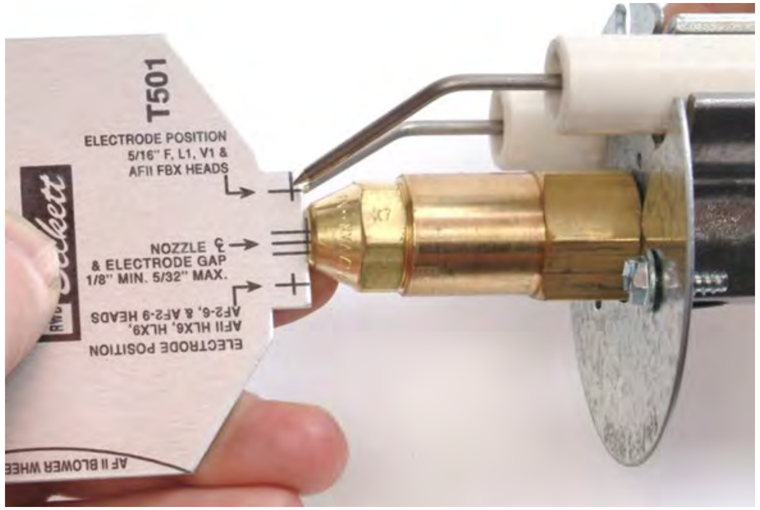
1. Remove the nozzle & drain the fuel into a container.

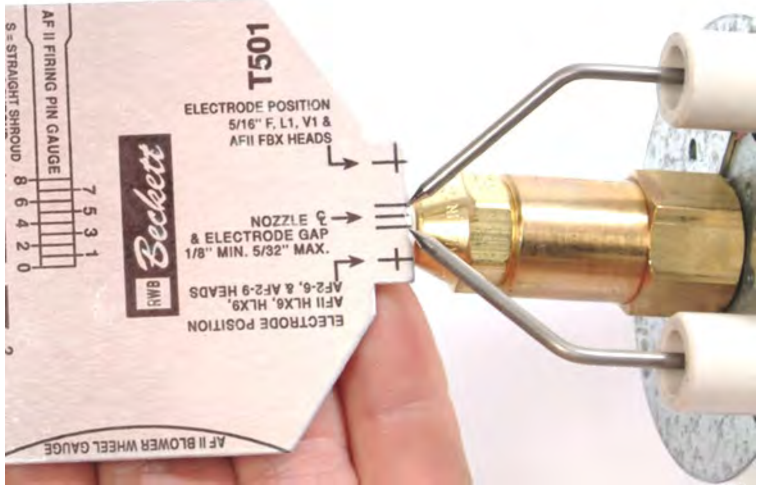
   Inspect the nozzle adaptor and replace if stripped, cracked or if the seat is worn. Flush the assembly, fill it with clean fuel and install a new nozzle.



Step 6 – Nozzle/Drawer/Firing Assy

2. Clean, inspect and adjust the electrodes using the appropriate gauge.





Replace them if the porcelains are damaged or the electrode tips are worn beyond the ability to set them properly.

Step 6 – Nozzle/Drawer/Firing Assy

3. Clean & inspect the air tube, including the end cone slots & holes.
4. Reinsert the assembly into the air tube & secure it in place, making sure it's in the same position as marked. Verify the position using the manufacturers gauge if appropriate.

Step 7 – Burner Motor, Housing & Fan

1. Remove the burner motor & check for fuel in the burner housing which could indicate a loose fitting, cracked flare or leaking fuel unit seal.

2. If there are oiling points, lubricate with 3-4 drops of SAE20 non-detergent oil.

   If there are cooling slots, clear off dust/blockages.

Step 7 – Burner Motor, Housing & Fan

3. Check the motor shaft end play, if it's excessive, replace the motor.

4. Inspect the coupling to be sure it isn't worn or stripped.

5. Clean the air inlets & fan using a small brush.

Step 7 – Burner Motor, Housing & Fan

6. Reinstall the motor & spin the fan to be sure the motor, fan & fuel unit are moving freely & everything is properly connected.
7. Check all wires & connections at the burner.

Step 8 – Ignitor and Cad Cell

1. Clean & check ignitor bushings & springs. Verify the electrode rods make solid contact with the ignitor connections.
2. Clean the cad cell eye & wires. Make sure the bracket is positioned correctly for good flame sighting.
3. As the ignitor is being closed, be sure the electrodes are making solid contact with the ignitor springs and that no wires are pinched.

Step 9 – Flue Pipe

1. Verify that the flue pipe is properly screwed together and supported, correct any deficiencies.
2. Remove the pipe, brush it out, inspect its condition, replace if necessary.
3. Check the draft regulator to be sure it swings freely.

Step 9 – Flue Pipe

4. Clean the chimney base and check the chimney for blockages. If there's an accumulation of broken brick or liner, advise the customer to contact a chimney professional and note this info on the service ticket.

Step 9 – Flue Pipe

If the unit uses power venting, follow the manufacturer's maintenance instructions, which usually include the following:

- Clean & check the fan blower wheel
- Oil the motor
- Check the draft-proving switch
- Clean/check the outside hood & exterior mechanism

Step 10 – Clean the Heat Exchanger & Chamber

1. Remove any baffles & brush the flue passages, keeping the vacuum close to the brush to avoid spreading soot. Look for signs of air or water leaks & reinsert the baffles.

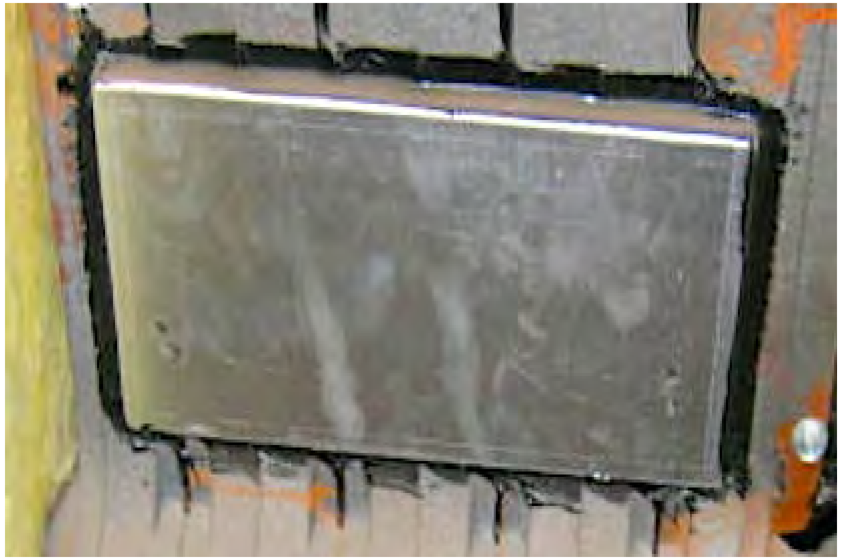
Step 10 – Clean the Heat Exch & Chamber

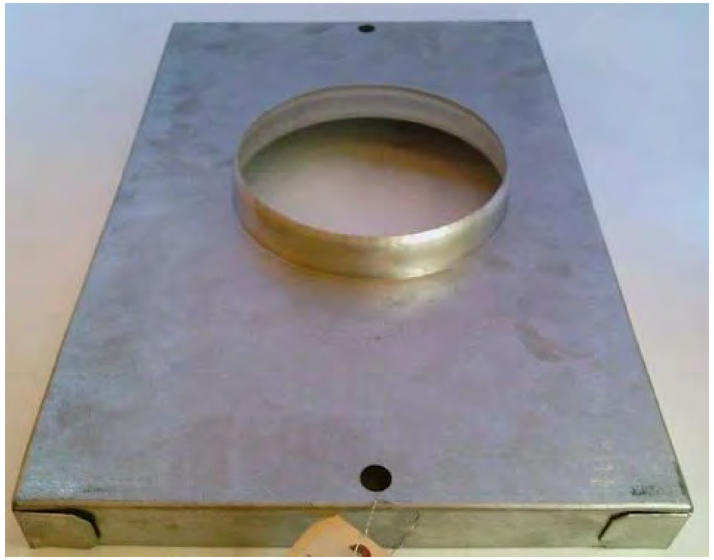
2. Clean the combustion area, being careful not to damage the chamber or target wall.

3. Inspect the condition of the refractory material, repair or replace as necessary.

Step 11 – Replace, Seal & Fasten

Reassemble the unit using furnace cement if necessary to seal any leaks.





Step 12 - Fire the Unit and Check Operation

1. Start the burner, if possible, check the appearance of the flame & make sure there's no impingement.

2. Cycle the burner to check for prompt ignition, smooth operation & clean cut-off.

3. If appropriate, disconnect the thermostat & install a jumper across T-T to keep the burner running. Check the operation of the high limit.

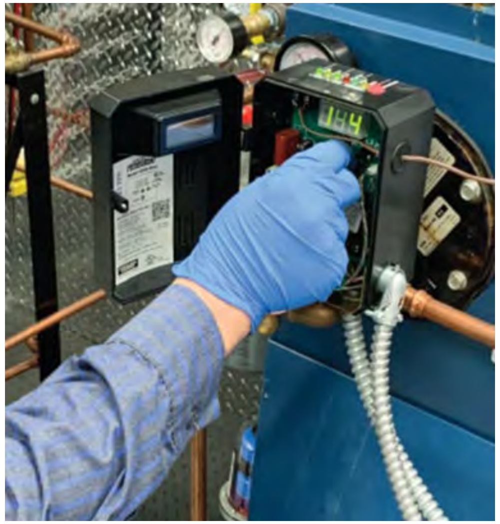
Step 13 – Combustion Analysis & Adjustment

1. Perform a complete combustion analysis, make adjustments & record final readings which should be in line with manufacturer recommendations, typically:

Smoke: zero
Draft: -.02 over fire
(unless positive pressure unit)
CO_2: 10.5 – 12%
Net stack temp: 350ºF +

Step 13 – Combustion Analysis

2. After final adjustments are made, remember to return all controls to proper settings and remove any jumpers installed to facilitate testing.



Some companies routinely seal the test hole after tests are completed to prevent customer concerns.

Step 14 – The Heating System

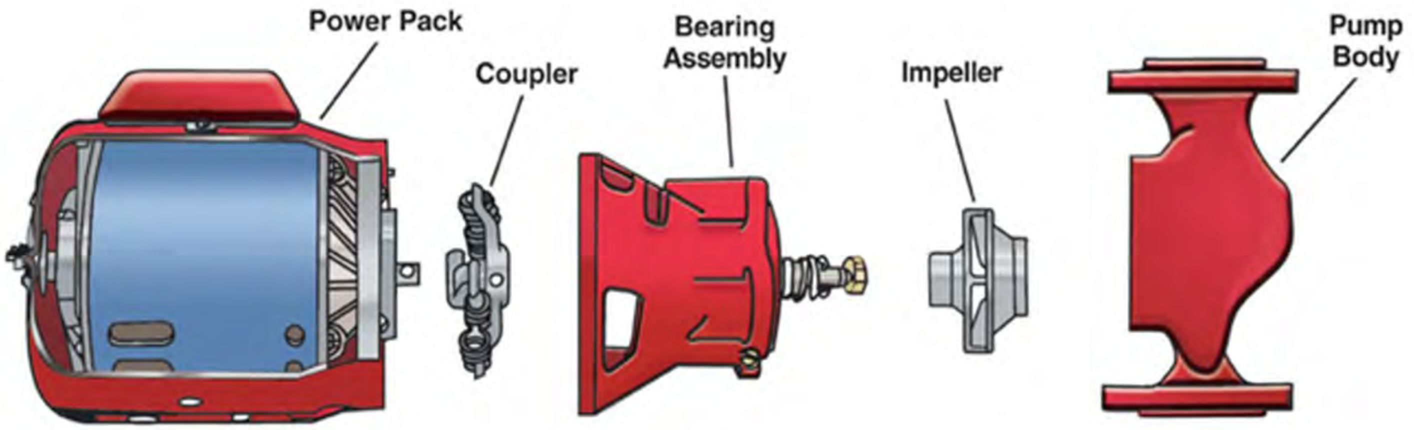
The following steps vary depending on the type of heating that's being worked on

Regardless of the system type, follow manufacturers instructions & verify that all limit controls are functioning properly

Ask the customer to set each thermostat 10^{o}F above room temperature

Hot Water Systems

1. Check zone valves and/or circulators to be sure each operates properly. If applicable, lubricate each circulator and bearing assembly.



2. Check circulator couplings & motor mounts, replace if worn.

Hot Water Systems (cont)

3. Check that control settings are correct for proper heating, hot water and circulator operation.

4. Check system pressure & the expansion tank.

5. If there’s an indirect water heater, check its circulator and control.

Warm Air Systems

1. Check heat exchanger for cracks, missing or loose cleanouts & anything else that could allow flue gases to escape.

2. Check the blower settings.

3. Inspect & clean the blower compartment.

4. Check the air filters, clean/replace, as necessary.

Warm Air Systems (cont)

If appropriate:

5. Check & lubricate the blower.

6. Check fan belt condition & tension. Replace/adjust as necessary.

7. Check blower mountings & bearings for excessive wear.


8. Check humidifier for proper operation, water leaks & mineral build up.

Steam Systems

1. Check the LWCO by draining water until the burner shuts off.

2. Check the automatic water feeder.

3. Clean the sight glass, replace it & washers if necessary.

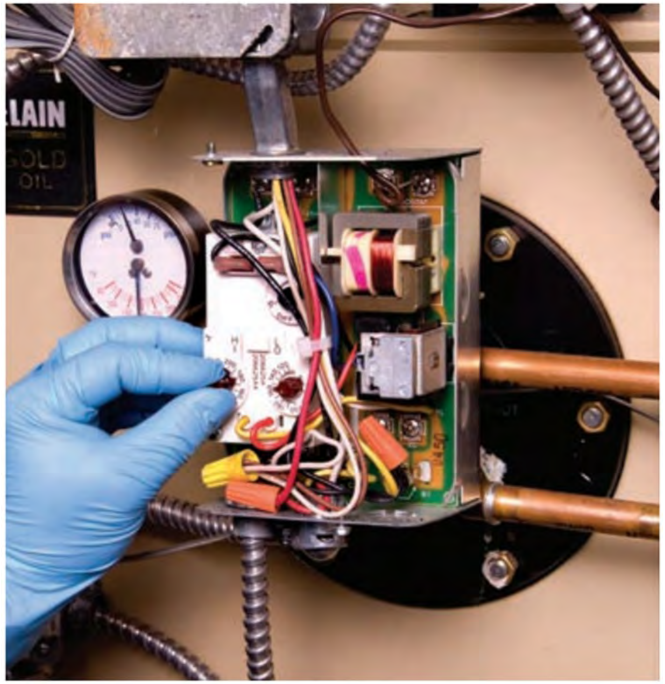
4. Check the main vents – look for evidence of leaks.

Steam Systems

1. Check the LWCO by draining water until the burner shuts off.
2. Check the automatic water feeder.
3. Clean the sight glass, replace it & washers, if necessary. Skim boiler if full of dirty water.
4. Check the main vents – look for evidence of leaks.

Step 14 – The Heating System

After completing these steps, be sure to return all controls to their proper settings and double check to be sure that all jumpers have been removed.



Ask the customer to return all thermostats to their normal settings.

Step 15 – Cleanup the Work Area

1. Wipe and clean all external surfaces of the appliance and work area. Use only clean rags to avoid leaving an odor behind.

2. Collect all used parts and debris and place them in the service vehicle, avoid using the customers garbage cans.

Step 15 – Cleanup the Work Area

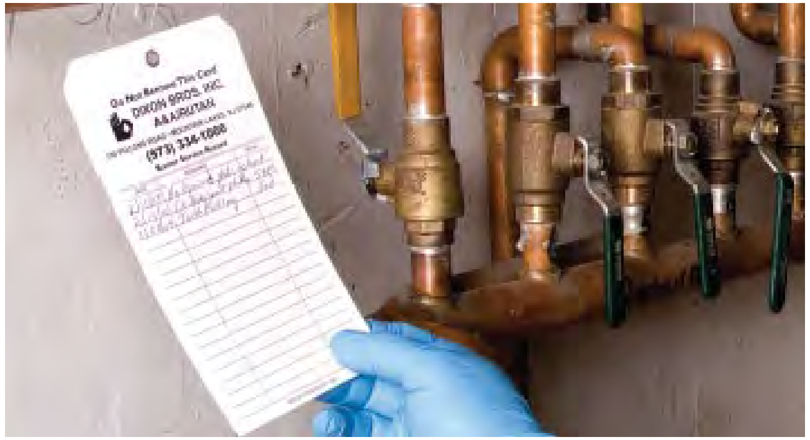
3. Use a vacuum cleaner to clean the area around the system.

Before leaving, check the work area one last time. Pay particular attention to potential sources of fuel leaks, such as the filter cannister, fuel unit, burner housing and oil valve.

Step 16 - Reset and Record

1. Verify that thermostats and controls have been returned to their proper settings.

2. Fill out the service card.



3. Fill out company paperwork and note and follow-ups needed.

Step 17 – Report to the Customer

Before leaving, explain what was done, including steps taken to address concerns expressed during the customer interview.

Explain the combustion analysis results & advise the customer of potential energy saving improvements.

If follow up work is required, explain what and why.

Have the customer sign the work order, give them the appropriate copy and **THANK THEM** for their business.

Review Questions:

- Why is preventative annual maintenance important?
- What are the items you should have in your “tune up” kit?
- What should you do before you begin your inspection?
- What are the procedures for inspecting the oil tank, oil line, valves, and filters?
- What are the procedures for inspecting the fuel unit?
- What are the procedures for inspecting the flue pipe, heat exchanger, and chamber?

At the end of this lesson, you will be able to:

Continued

- Follow the procedures for testing the operation of the fuel unit
- Describe appropriate combustion analysis readings
- Describe the procedures to maintain a hot water system
- Describe the procedures to maintain a warm air system
- Describe the procedures to maintain a steam system
- Explain what you should do after you have completed your inspection and maintenance

End Chapter 14

NORA Technician Certification

Review

Bob O'Brien, NORA Director of Education

Chapter 6

Service Procedures

At the end of this lesson, you will be able to:

- Explain what you should consider before you troubleshoot a heating system
- Explain how to work carefully and systematically
- Explain what information you need to gather before you start work
- Perform an investigation
- Describe the steps to determine the problem
- Explain how to use the “Five Whys” to help you figure out how to prevent a problem from happening again

Service Procedures

The most interesting and challenging part of a Service Technician's job is troubleshooting.

Many parts must work together for a system to function properly; if any one of them becomes defective, the system will malfunction.

Service Procedures

A technician is like a detective, they must figure out:

- What happened
- Why it happened
- How to fix it
- How to keep it from happening again

Check the Basics First

- Are all the switches on?
- Is the fuse blown or circuit breaker tripped?
- Is the thermostat set above the room temperature?
- Is there fuel in the tank?
- Is there enough water in the steam or hot water system?
- Is the blower door closed properly?
- Are the air filters clean?

Why are you there?

There are many reasons for a customer to call, including:

- No heat
- Insufficient heat
- Too much heat
- No hot water

- Water leak
- Fuel leak
- Odors, smoke or soot
- And…?

Why are you there?

Once the technician understands why the customer requires their expertise, they should approach the situation

Carefully **and** ***Systematically***

Safety First

Never do anything that can put people or property in danger.

- Wear appropriate Personal Protective Equipment and protect the work area with drop cloths, newspaper or builder's paper

- Use insulated screwdrivers and avoid working on live electrical circuits

- Do not press reset buttons without first making sure that there isn't a fire or a fuel buildup in the combustion chamber

A systematic approach starts with logic—looking for the obvious solution and then trying to narrow down the problem.

Start with the easy—if the heating system is not working, check that all electrical switches are turned on and that there is enough fuel in the tank before starting to disassemble the heating system.

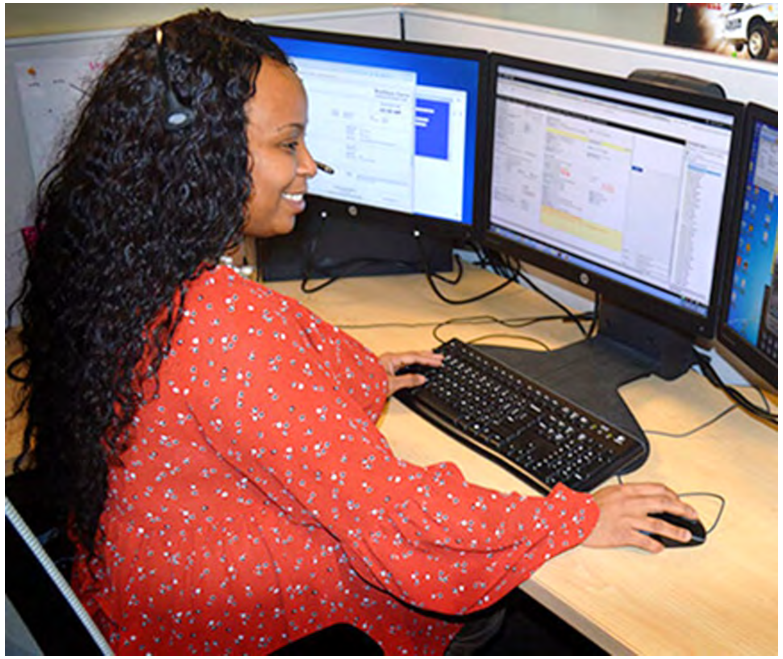
NEVER make assumptions

- Don’t assume that the reset was only pressed once
- Don’t assume that the last technician installed the correct nozzle
- Don’t assume that the dispatcher gave the correct reason for the call
- Don’t assume that because a customer says they have plenty of fuel that their tank is not empty

Step 1. Information Gathering

Effective troubleshooting starts before arriving at the customer's home.
When the dispatcher assigns the call, try to get data such as:

- What problem did the customer report?
- When was the last fuel delivery?
- When was the last tune-up?
- When was the last service call and what was done?



Step 1. Information Gathering

After arriving listen to the customer & ask clarifying questions

Has any work been done recently that might have caused the situation?

If the customer has no heat, have pressed the reset button, how many times? What happened after it was pressed.

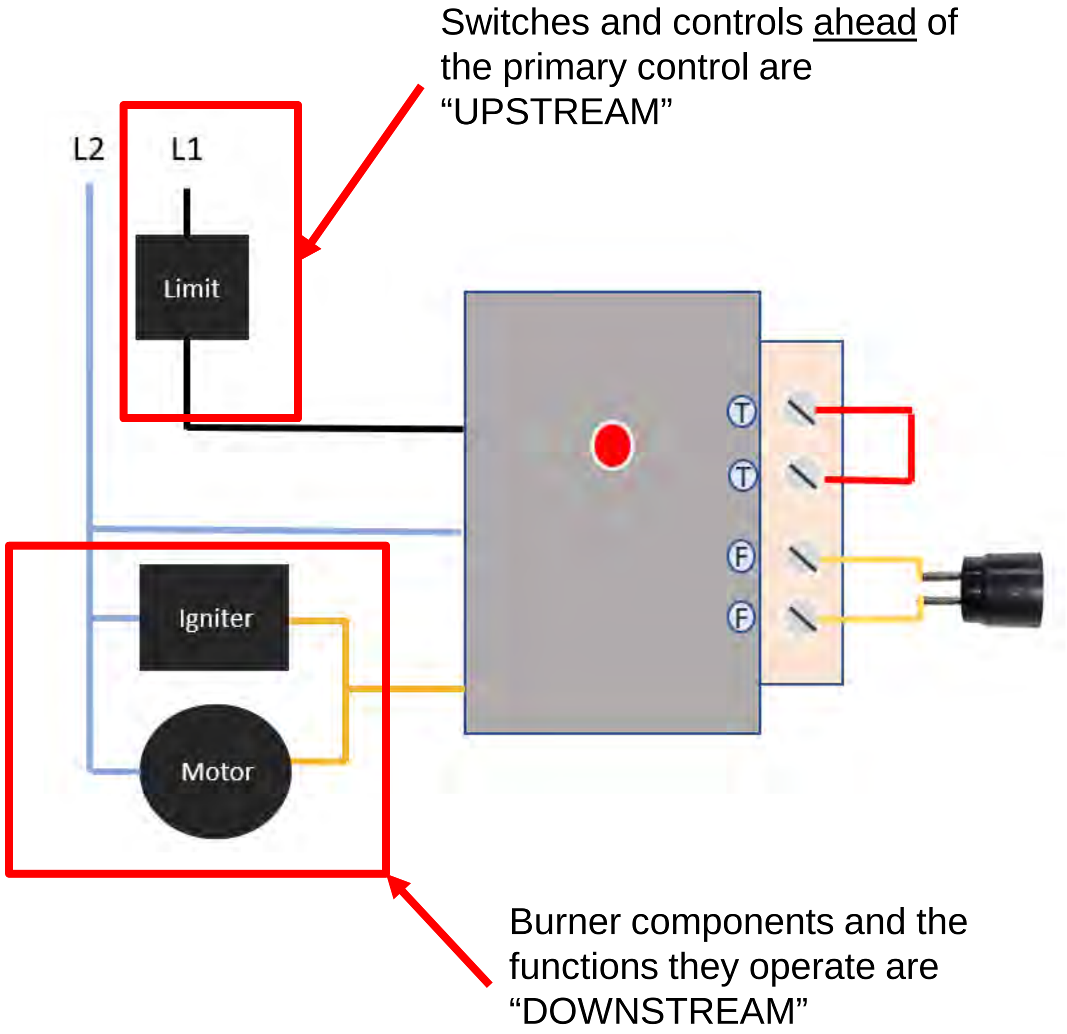
When arriving at the appliance, read the service card to see what work previous technicians have performed.

Step 2. The investigation

At this point the problem is clear (no heat) so narrow it down:

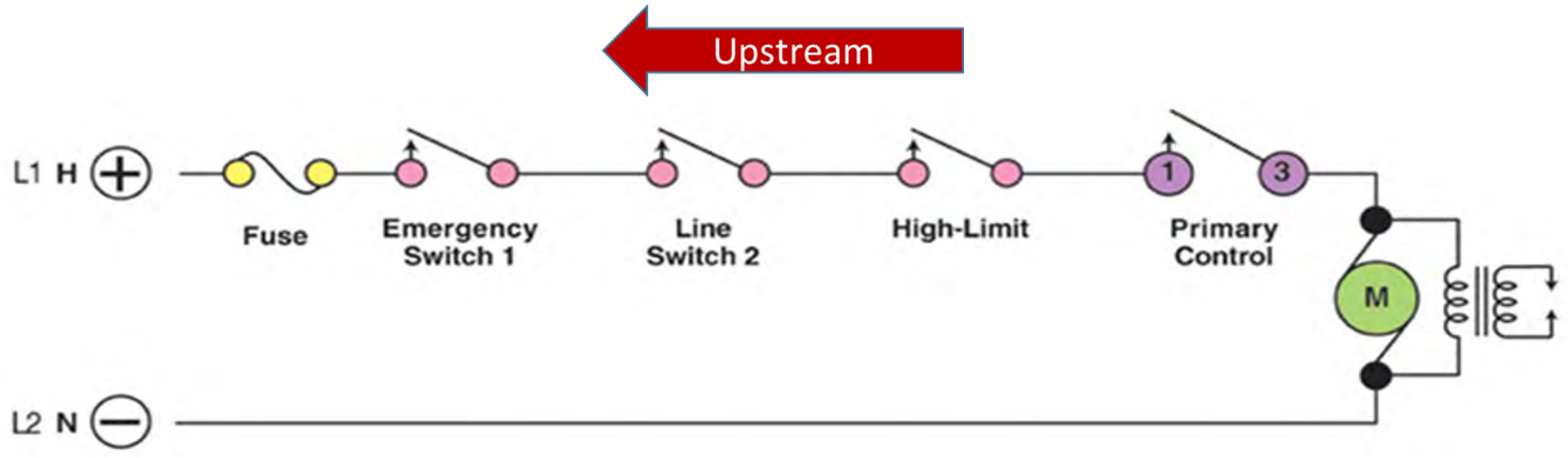
- If the primary control is in lockout, everything electrically upstream from it cannot have caused the problem.

- The problem is probably with the fuel supply or the burner components. Move to the next step……



Step 2. The investigation

If the burner is **not** in lockout check the incoming voltage, if it's not correct then check the output voltage for each switch and control in the limit string until the problem is located.



If the incoming voltage is not correct at Switch 1, the services of a licensed electrician are normally required.

Step 3 – Determine the Problem

- Protect the work area
- Remove the thermostat wires or jumper from the T-T terminals of the primary control
- Install a temporary jumper between the terminals to simulate the thermostat calling for heat
- Open the observation door &check for flame/excess fuel in the chamber
- Leave the door open to allow any excess pressure to escape in the event of a delayed ignition when the burner starts

Step 3 – Determine the Problem

Press the reset button and observe what happens:

Step 3 – Determine the Problem

Burner ignites & runs properly but shuts off on safety

If the burner ignites and runs properly but shuts off on safety, visually check the cad-cell eye & leads. Also check the retention head for carbon build up.

If the eye and/or head are dirty, clean them & determine why they got that way

Step 3 – Determine the Problem

If the eye & head are clean, disconnect the cad cell leads from the control, start the burner & put a jumper across the FF terminals to simulate a flame.

Then connect an ohmmeter to the leads to check the resistance through the cad cell.

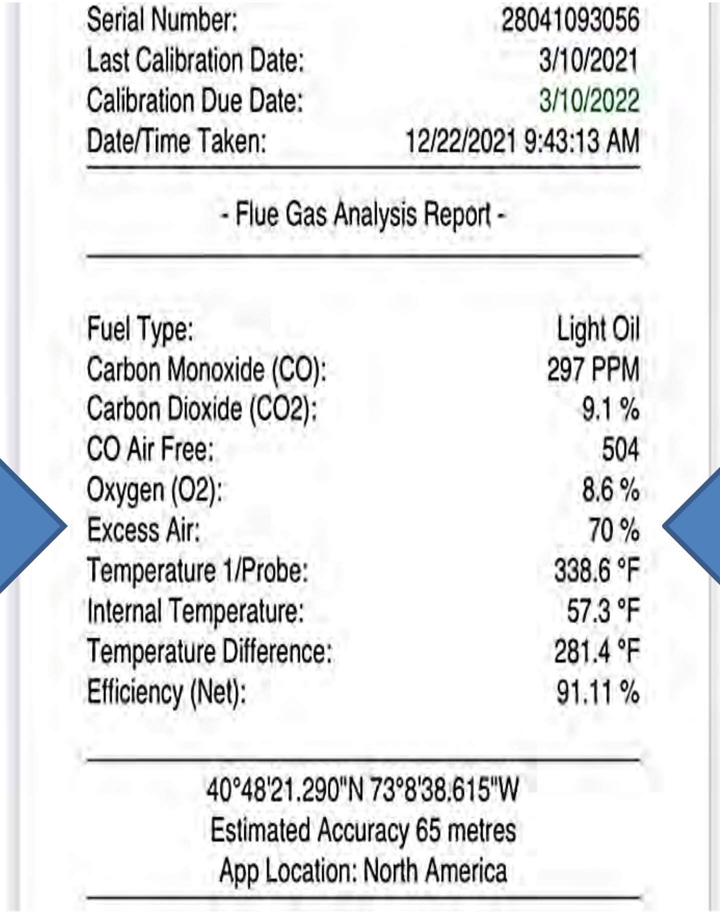
Step 3 – Determine the Problem

Burner ignites & runs properly but shuts off on safety

If the resistance is high, there are several possibilities including:

The cell (or leads) is either defective or isn't sighting the fire correctly

There could be issues such as too much excess combustion air or air in the fuel supply



Serial Number:	28041093056
Last Calibration Date:	3/10/2021
Calibration Due Date:	3/10/2022
Date/Time Taken:	12/22/2021 9:43:13 AM

- Flue Gas Analysis Report -

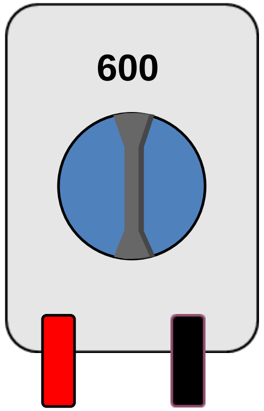
Fuel Type:	Light Oil
Carbon Monoxide (CO):	297 PPM
Carbon Dioxide (CO2):	9.1 %
CO Air Free:	504
Oxygen (O2):	8.6 %
Excess Air:	70 %
Temperature 1/Probe:	338.6 °F
Internal Temperature:	57.3 °F
Temperature Difference:	281.4 °F
Efficiency (Net):	91.11 %

40°48'21.290"N 73°8'38.615"W
Estimated Accuracy 65 metres
App Location: North America

Step 3 – Determine the Problem

Burner ignites & runs properly but shuts off on safety

If the resistance below 1,500 Ohms, check the cad cell & leads again, either they or the control are defective.



Step 3 – Determine the Problem

After reset, burner starts but does not ignite

The problem is related to the combustion process it, could be:

- An ignition problem
- A fuel problem
- A broken or slipping coupling
- Too much excess air

Go over the burner checking ignition and fuel delivery to the nozzle.

Step 3 – Determine the Problem

After reset, nothing happens.

The primary control may not be in lockout but may be sensing flame.

The cad cell leads might be crimped together, or the FF terminals might be shorted.

Step 3 – Determine the Problem

After reset, burner hums but does not start.

The burner motor defective, or the fuel unit might be bound, causing the motor to shut off on overload. might be

Try spinning the burner fan by hand. If it won't turn freely the pump may be stuck.

Step 4 – The 5 “Why’s”

Professional technicians look beyond the symptoms to find the cause of a problem

If the reset is pressed & the burner starts, nothing has been fixed

The technician must find out WHY the control locked out and take corrective action to keep it from happening again

Step 4 – The 5 “Why’s”

When the cause of a problem has been determined ask “why did this happen”.
Continue to ask the same question at least 5 times & eventually the underlying cause will be found.

The chart on the right shows an example of a rotted vent tank and how the 5 Whys can help troubleshoot a “no heat” call.

Step 5 – The How's

Once the "Whys" are known, it's time to correct the immediate problem and keep it from happening again

How is that done? In the rotted vent pipe example, where water was in the tank due to a corroded vent pipe, the following steps are required:

Note: In some situations, a technician might not have the time, equipment or experience to perform all the "How's". In that case, they should troubleshoot the situation to the best of their ability & contact their supervisor for instructions on how to proceed.

Step 5 – The How's

1. Replace the vent pipe
2. Remove the water from the tank.
3. Clean the fuel lines
4. Replace the fuel unit
5. Replace the nozzle
6. Replace the fuel filter
7. Reset the primary control (and burner motor if applicable)
8. Fire the unit
9. Adjust the burner and perform a combustion analysis

Step 6 – Paperwork and Exit

Once the "Hows," have been completed:

- Make sure that tools have been returned to their proper place, all jumpers have been removed and all controls and thermostats have been returned to their proper settings.
- Clean up the work area & remove all debris to a receptacle in the service vehicle.

Step 6 – Paperwork and Exit

Complete all company paperwork and fill in the service card at the unit.

Give the customer the invoice, explain what was done and the efficiency test results and answer any questions.

Thank them for their business.

Serial Number:	28041093056
Last Calibration Date:	3/10/2021
Calibration Due Date:	3/10/2022
Date/Time Taken:	11/22/2021 1:36:05 PM

- Flue Gas Analysis Report -

Fuel Type:	Light Oil
Carbon Monoxide (CO):	0 PPM
Carbon Dioxide (CO2):	12.4 %
CO Air Free:	Incalculable
Oxygen (O2):	4.2 %
Excess Air:	25 %
Temperature 1/Probe:	543.3 °F
Internal Temperature:	67.8 °F
Temperature Difference:	475.5 °F
Efficiency (Net):	89.13 %

40°43'54.299"N 73°12'14.304"W
Estimated Accuracy 65 metres
App Location: North America

Troubleshooting Suggestions

The following slides are intended to help technicians troubleshoot typical situations they are likely to encounter.

It is NOT a list of all possible situations or every step that should be taken.

1. No Heat – Unit Cold & Burner not Operating

A.) Primary control has no power:

1. Check the limit controls. If any component in the string is not allowing current to pass, determine why.

For example, if the LWCO has current coming in but isn't allowing it to pass through, make sure the water level is correct before condemning the control

1. No Heat – Unit Cold & Burner not Operating

A.) Primary control has no power: (cont)

2. If the limit control string has no power coming to it, check the switch. If there is no power to the switch, check the circuit breaker.

3. If the circuit breaker is reset and the unit runs, the technician must find what caused the breaker to trip.

Measure the amperage of components such as burner motors, circulator motors, and blower motors to determine the cause.

1. No Heat – Unit Cold & Burner not Operating

B.) PC has correct input voltage but isn’t powering burner components:

1. Check to be sure that there isn’t a fire in the chamber.

2. Make sure the thermostat is set well above room temperature.

3. If the burner still doesn’t start disconnect the thermostat wires from TT & install a jumper.

If the burner starts, there’s a problem with the thermostat or its wiring.

1. No Heat – Unit Cold & Burner not Operating

B.) PC has correct voltage but isn't powering burner (cont)

4. If the burner still doesn't start, disconnect the cad cell leads from FF.

If the burner starts, there's a problem with the cad cell or its leads

If the burner doesn't start, check to be sure there's not a piece of wire or something else shorting out thew FF terminals

If there's nothing shorting the terminals, the control is malfunctioning

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but: Motor doesn't start

1. The motor might be off on overload. If it has a reset press it. If it doesn't, check if it feels hot, if it does, give it a few minutes to cool down.

2. If it still doesn't start, the trouble is in the motor or the motor circuit.

3. If the motor has a capacitor, check it before condemning the motor.

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but: Runs but no flame

1. Disconnect the nozzle line & check the fuel flow. If water is found in the fuel, drain it from the tank.

2. If flow is good & water free check the nozzle & ignition system.

3. If there is no flow, check the solenoid valve & prime the fuel unit.

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but:
Runs but no flame (cont)

4. If the fuel unit can't be primed make sure all valves are open& check the fuel level – stick the tank, gauges can be wrong.

5. If there's sufficient fuel, check the filter & perform a vacuum test (chapter 4), the fuel line or tank vent may be clogged.

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but: Runs but no flame (cont)

6. If the vacuum is high, clean the line with a push-pull pump.

7. If the vacuum is low, check the coupling.

8. If the coupling is good, check the fuel unit strainer.

9. If everything checks ok, perform a complete a complete fuel unit test. (Chapter 4)

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but: Motor runs with fuel flow & ignition but no flame

1. Check the nozzle & replace if defective.

2. Check the fuel pressure, set to manufacturer specs.

3. Check the air settings – adjust, as necessary. Too much excess air can “blow out” the flame.

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but: Motor runs with fuel flow but no ignition

1. Check the ignitor/electrodes/porcelains/ignition cable for defects.

2. Check the electrode setting and nozzle position.

3. Check it ignitor connections.

4. Verify the correct voltage is supplied to the ignitor/transformer.

1 –Unit Cold & Burner not Operating (cont)

C.) PC is powering burner components but: Burner fires, but shuts off on safety

1. If a stack relay is in use check the helix & clean or reposition if necessary. Verify that there is sufficient temperature in the flue.

2. If a cad cell control is installed check the cell, clean & reposition, as necessary.

Check the air tube & end cone, clean/replace as necessary.

1. No Heat – Unit Cold & Burner not Operating

C.) PC is powering burner components but: Burner fires, but shuts off on safety (cont)

3. Check for water or air in the nozzle line:

If water is found, drain it from the tank & lines

If air is found, perform fuel unit tests to determine why (Ch. 4)

4. Check air settings, adjust, as necessary.

1. No Heat – Unit Cold & Burner not Operating

If the burner operates properly, but no heat come from the radiation or ductwork, the problem is with the delivery system.

Make sure all thermostats are set to call for heat and follow the steps outlines on the following slides.

2. Unit Warm, but No Heat

Hot Water System

1. Check for closed hand or motorized valves.

2. Check that there is sufficient pressure in the system.

3. Check that the circulator is operating properly.

4. Check the flow control valve.

5. Check that the system is not air-bound.

2. Unit Warm, but No Heat

Hot Water System (cont)

6. Check that the high limit is set properly.

7. Check that the reverse aquastat is set properly.

2. Unit Warm, but No Heat

Warm Air System

1. Check that the fan-limit control is set properly.

2. Check that all dampers are open.

3. Check that air filters are clean.

2. Unit Warm, but No Heat

Warm Air System (cont)

4. Check to see if the blower is operating: If it is, check the drive belt.

If it isn’t, check for correct voltage from the fan control, if that’s acceptable check the motor and capacitor.

2. Unit Warm, but No Heat

Steam System

1. Check the water level, too much water in the system will prevent steam from rising.

2. Check for closed hand or motorized valves.

3. Check the main vents.

Check the pressuretrol setting.

3. Insufficient Heat: Burner is operating, but house is much cooler than thermostat setting

Sometimes this occurs because it's much colder than normal & the house can't "keep up" with the outside temperature and/or the system (boiler, furnace, piping, radiation, ductwork) might be undersized.

3. Insufficient Heat: Other Causes

A. Burner trouble

The burner might be under-fired.

Make sure that the burner's firing rate is properly set for the appliance.

3. Insufficient Heat: Other Causes

B. Control circuit

1. Check the heat anticipator settings if appropriate.

2. Check that the thermostat is properly located. They are affected by lamps, appliances & fireplaces & should not be located by any heat source.

3. Check that limit controls and reverse aquastats are properly set.

3. Insufficient Heat: Other Causes

C. Heating Systems

1. Check to be sure steam vents are operating properly.

2. Check that pipes and/or ductwork are properly insulated.

3. Check that airflow through filters and heat emitters is not obstructed by dust, carpet, furniture, curtains or closed air dampers.

3. Insufficient Heat: Other Causes

C. Heating Systems (cont)

4. Check that the water level is adequate in steam systems

5. Check that hot water systems are not airbound.

6. Check that blowers and their pulleys and belts are functioning properly.

4. Too Much Heat: Likely Causes

1. Thermostat stuck, set too high, improperly located or defective.

2. Limit control set too high or defective.

3. Flo control valve stuck.

4. Motorized valve stuck.

5. No Hot Water

Troubleshooting this with a liquid fuel-fired heater is basically the same as troubleshooting a “no heat” call, check the burner and the limit control.

When the hot water comes from a domestic hot water coil or storage tank then……

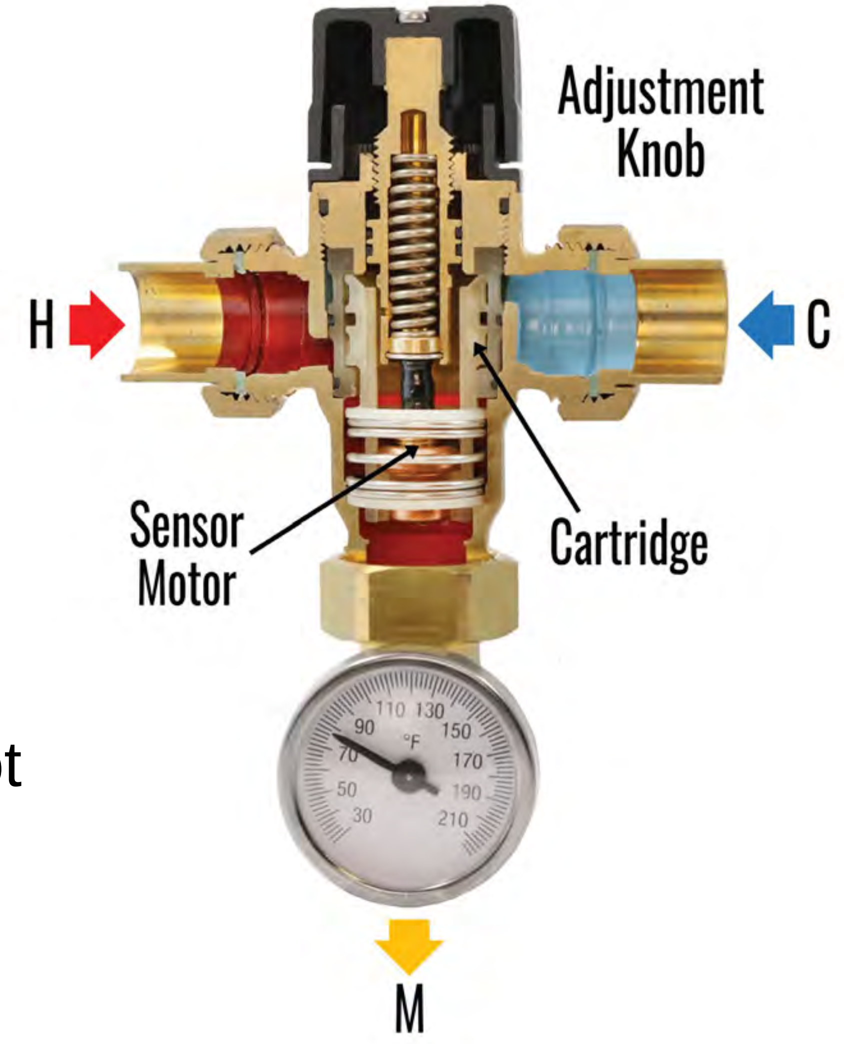
5. No Hot Water

1. Check the aquastat settings.

2. Check that the water level in the boiler is above the coil.

3. Check the mixing valve.

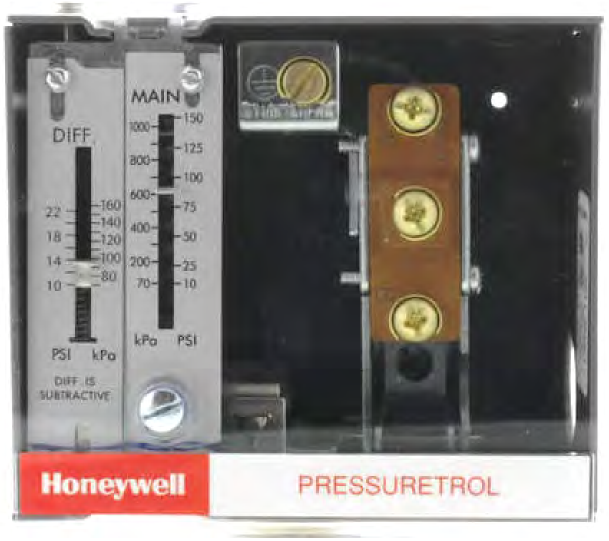
4. If there's a storage tank installed check the circulator, control settings and, if the tank seems hot but the water coming from the faucet is cool, check the dip tube on the tank inlet.



6. Water Leak

Depending on the severity of the leak, this can be a minor inconvenience or a major problem.

6. Water Leak: Relief Valve Leaking



Steam system – check the steam gauge and the pressuretrol. Remember that residential systems typically operate at 2 PSI and their relief valves open at 15 PSI.

If the relief valve opens, it's likely that either the valve or the pressuretrol is malfunctioning.

6. Water Leak: Relief Valve Leaking

Hot water system – several things can cause the valve to open:

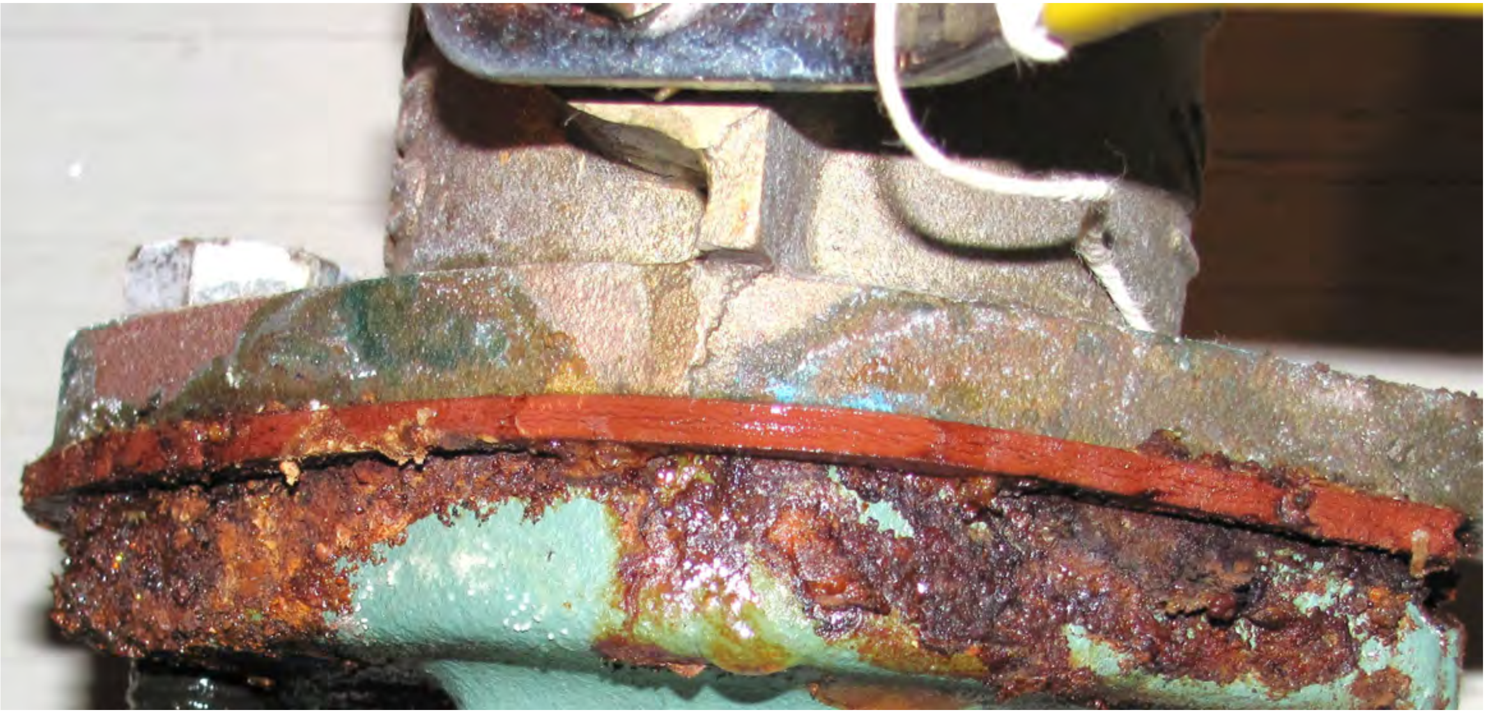
- A full expansion tank
- A bad diaphragm in a pressurized expansion tank
- A malfunctioning or improperly set aquastat
- A misadjusted or malfunctioning pressure relief valve
- A leaking domestic hot water coil
- A malfunctioning relief valve

Water heater – check the aquastat and the domestic hot water pressure.

6. Water Leak: Circulator Flange

Tightening the flange may stop the leak.

However, it's usually better to replace the gaskets once they start leaking.



6. Water Leak: Bearing Assembly

3-piece circulators have a separate bearing assembly that leaks water from a weep hole when they become defective.

With this type of leak, either change the bearing assembly or replace the entire circulator with a 1-piece model

6. Water Leak: Boiler

It is usually beyond repair.

- Turn off the power and water supply to the unit
- Drain the remaining water from the system
- Contact management for instructions.

7. Fuel Leaks

Fuel leaks are a serious concern because they can lead to significant damage.

The approach to these calls depends on the severity of the leak.

Minor leaks typically occur at:……

7. Fuel Leaks: Brass Fittings

If the system has compression fittings, replace them with flare fittings.

If a flare fitting is leaking, disassemble & inspect it. If there’s any evidence of a leak, cut-out the flare, re-flare the copper & reconnect it.

After several minutes recheck to verify that the leak has been stopped.

7. Fuel Leaks: Malleable Fittings

If the leak appears to be coming from the area of the threads, disassemble the fitting, clean it, apply pipe joint compound and reconnect it.

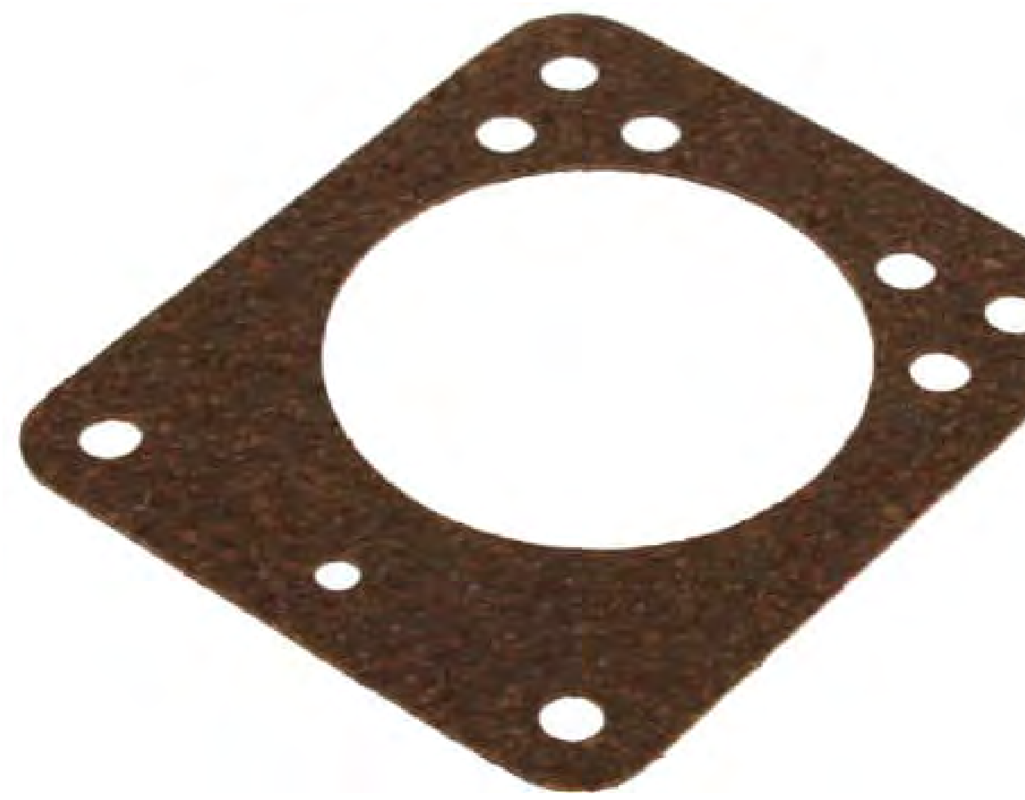
If the leak appears to be coming from a crack or sand hole, replace the fitting.

7. Fuel Leaks: Fuel Unit

Verify that all fittings, plugs and cover bolts are tight.

If the leak persists, check the gasket & replace if appropriate.

If the fuel unit is still leaking, replace it.



7 – Fuel Leaks (cont)

Burner

Most burners have a “weep hole” in the bottom to allow fuel to drain from the housing. If such a leak is found check:

The fuel unit seal

The nozzle adaptor

For an after-drip from the nozzle

7. Fuel Leaks: Fuel Storage Tanks

Minor tank leaks often appear as drips or wet spots.

If a tank has a leak, contact the service manager for instructions

Some companies use magnet patches for temporary containment of minor leaks until a new tank can be installed

7. Fuel Leaks: Fuel Lines

DO NOT cut out the leaking section and replace it.

When a leak develops, replace the line from the tank to the burner.

If the line is buried in, or contacts dirt or concrete, install coated tubing or install the line is secondary containment.

7. Fuel Leaks: Serious Leaks

Try to stop the flow of fuel, turn off any sump pumps, close off floor drains and any access to groundwater.

Contact the office immediately and spread absorbent materials while waiting for help to arrive.

8. Odors, Smoke & Soot: Causes

- Delayed ignition
- Combustion problems
- Dirty/defective chimney/flue
- Insufficient air in combustion zone
- Air leaks in the appliance
- Defective heat exchanger
- House fan sucking air down the chimney

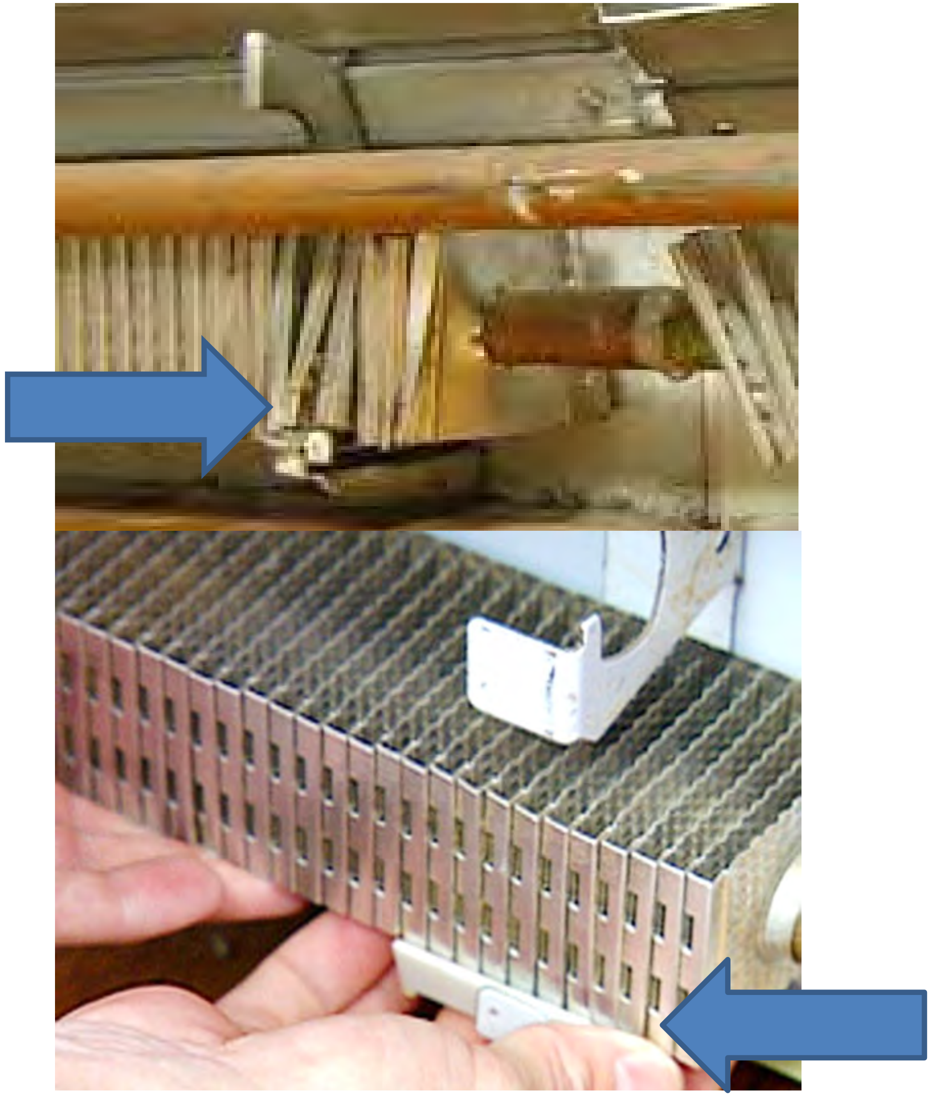
9. Noise

These calls can be frustrating because the noises are often intermittent. Noise can come from:

- Worn fuel unit gears
- High vacuum
- Air in the fuel line
- Fuels line in contact with each other, appliance jacket, beams, etc.
- Improper control settings (too much temperature or pressure)
- Circulators.

9. Noise

- Blowers
- Zone valves
- Loose control covers
- Water pipes, heating pipes & baseboard
- Chimneys



Troubleshooting Advice

- Remember the “5 Whys” and always look beyond the symptoms and for the cause.
- Look, think & listen before starting to Rip, Tear & Destroy.

Review Questions:

- What are the questions to answer before you begin troubleshooting a heating system?
- What are the basics for working carefully and systematically?
- What information do you need to gather before you start work?
- How do you perform an investigation?
- What are the steps to determine the problem?
- How do you use the “Five Whys” to help you figure out how to prevent a problem from happening again?

End Chapter 15

NORA Technician Certification

Review

Bob O’Brien, NORA Director of Education

Chapter 16
Energy Conservation

At the end of this lesson, you will be able to:

- Describe where heat can be lost in the system
- Explain how to stop air from leaking into the heat exchanger
- Explain why and when to adjust firing rates
- Explain why insulating pipes and ducts and sealing the envelope of the house can save energy
- Explain the steps customers can take to conserve energy

The Technician as an Energy Expert

A service technician must ensure that the customer's heating system is operating as efficiently as possible.

Customers with efficient heating equipment are more satisfied with their fuel supplier and their system.

As an Energy Expert, the Technician Must

- Keep track of new technology – stay up-to-date on current advances
- Inform customers of technology advances - customers trust technicians to offer them valuable advice about heating system improvements
- Install and adjust equipment for peak efficiency – properly adjusted equipment provides safe, reliable, efficient, clean, environmentally friendly and comfortable heat,……

As an Energy Expert, the Technician Must

- Service the equipment
  take responsibility for the operation of the customer's system

- Measure and record combustion efficiency
  Use test instruments to ensure customer's equipment is operating at its peak potential and cleanliness, while producing minimal emissions & CO

Combustion Efficiency Testing

- Using instruments to adjust burners improves efficiency, ensures minimal smoke and soot, lowers air pollution emissions and ensures safe operation
- It also reduces call backs, improves our image and increases customer satisfaction
- NORA recommends the use of electronic analyzers over “wet kits” because they provide excess air readings, CO measurements & a clearer picture of what’s happening in the combustion process

Steady State vs Heating System Efficiency

Combustion analysis measures the efficiency of the appliance when the burner is running.

Heating system efficiency is the actual heating efficiency of the home for the year.

Unfortunately, technicians can’t measure it. It involves the amount of fuel consumed, the total degree days, the temperature the customer heats the home to and the amount of hot water consumed.

Heat Losses

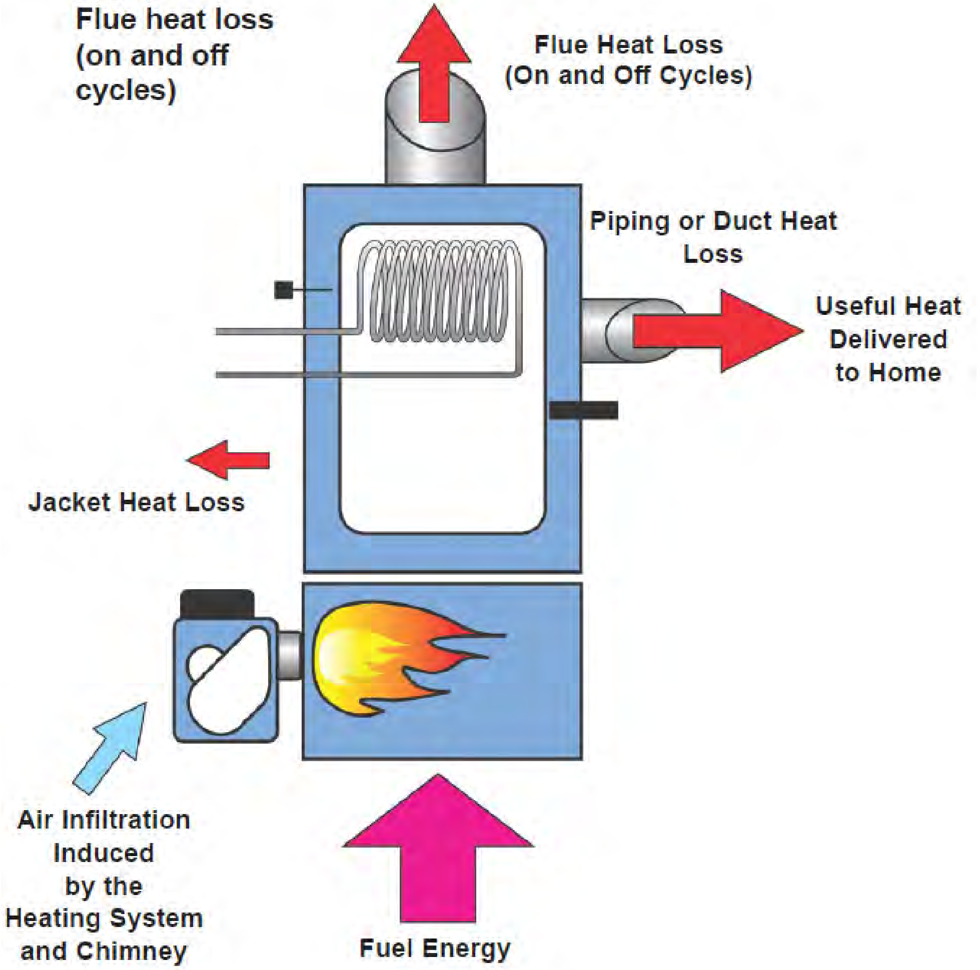
The purpose of a heating system is to transfer heat from the burner flame to the home.

No heating system operates at 100% efficiency.

Some energy is lost before it reaches the heat emitters reducing effectiveness & increasing fuel use, they include:

- Burner on cycle loss
- Piping loss
- Burner off cycle loss
- Ductwork loss
- Jacket loss
- Air infiltration loss

Figure 16-1:
Flue heat loss
(on and off
cycles)



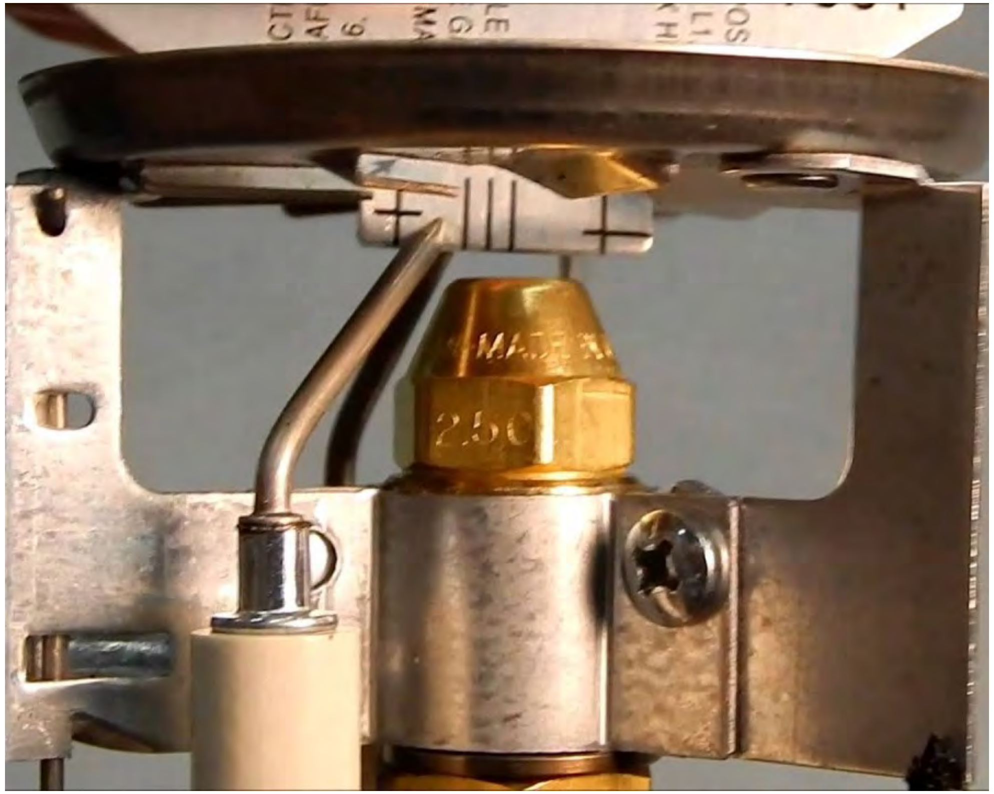
System Efficiency is Affected by Many Factors

Installation factors

- Selection & sizing of appliance
- Control strategies
- How domestic hot water is produced
- Chimney – height, materials, construction
- Appliance operating temperatures
- Piping/ducting design
- Burner adjustment, including barometric damper setting
- Combustion air source

System Efficiency is Affected by Many Factors

Service factors



- Burner adjustments
- Checking for & sealing air leaks
- Cleaning the heat exchanger
- Proper firing rates

System Efficiency is Affected by Many Factors

Service factors

Even the most efficient heating appliance will waste fuel if it's not adjusted properly.

Routine service, using standardized procedures, vacuum cleaning when appropriate & precise burner adjustment is a vital part of good service.

System Efficiency is Affected by Many Factors

Other factors

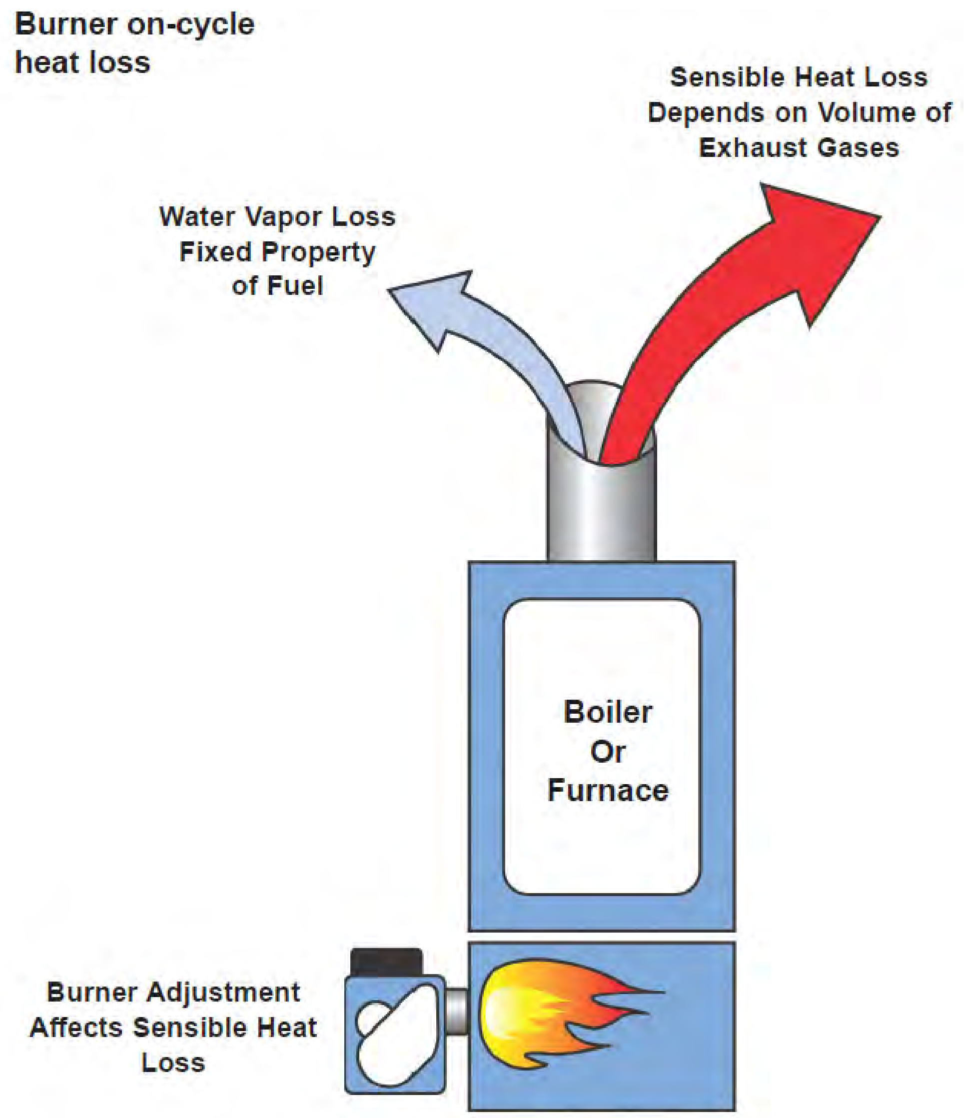
- Location of unit
- Source of combustion air
- Burner design
- Zoning of distribution system

Burner On-Cycle Heat Loss

The venting of exhaust gases while the burner is operating results in a significant heat loss.

This loss can be reduced by:

- Proper burner adjustment
- Clean heat exchanger surfaces
- Upgrading to more efficient appliances

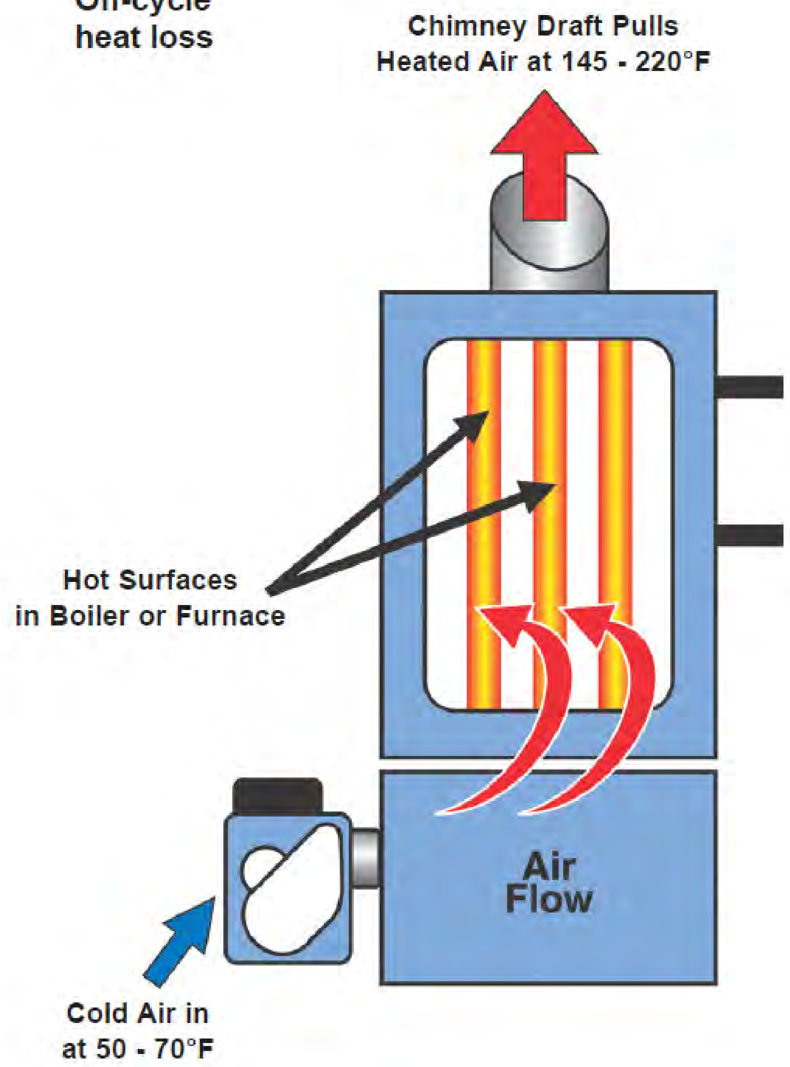


Burner Off-Cycle Heat Loss

Burners cycle on and off, they do not operate continuously. A typical burner will run approximately 15-20% of the time during the heating season.

During the off cycle, chimney draft pulls cold air in through the burner air inlet & air leaks in the appliance. This air is heated as it passes through the unit & carries heat out of the appliance.

Figure 16-3: Off-cycle heat loss



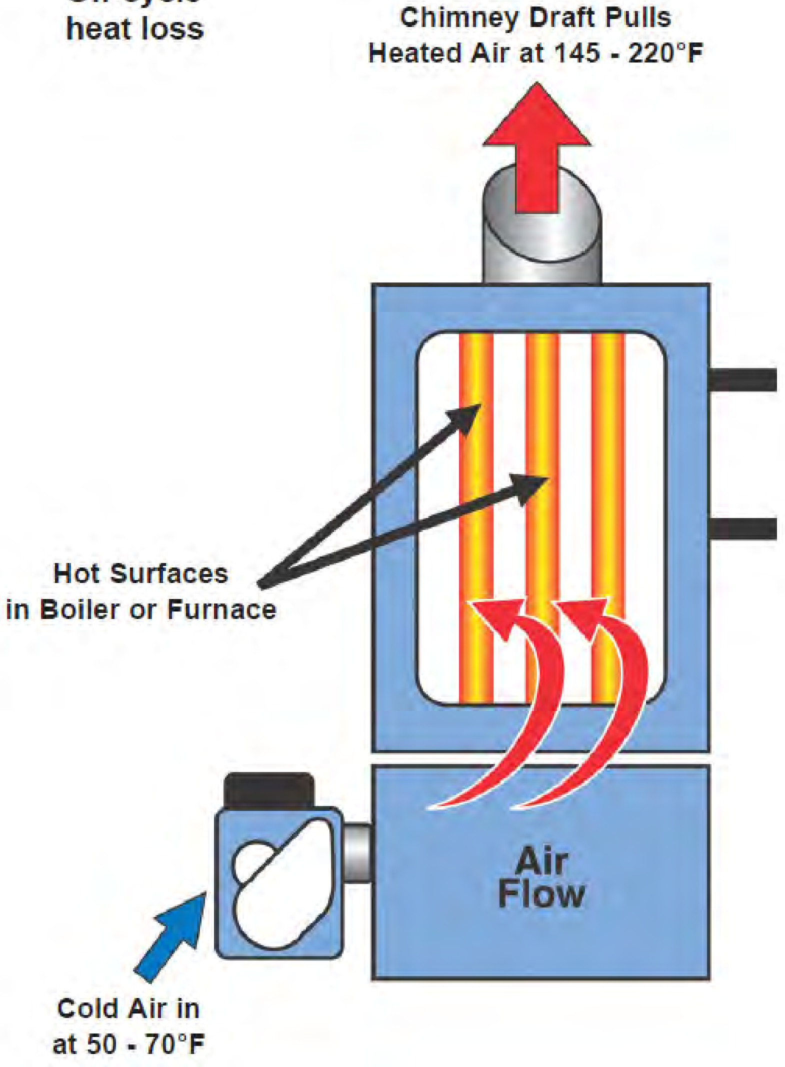
Burner Off-Cycle Heat Loss

The size of this loss depends on appliance design, control strategy, chimney draft and the operating temperature of the unit.

Oversized appliances and boilers with domestic hot water coils have high off cycle losses.

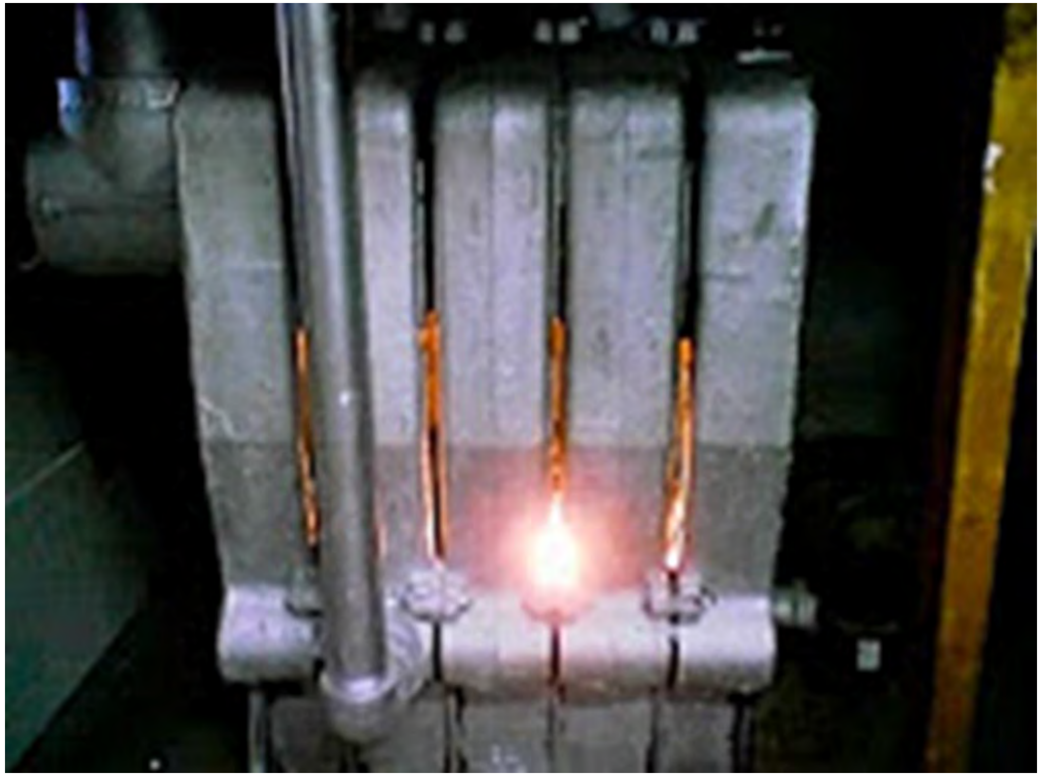
Furnaces have lower losses than boilers because the fan control lowers the appliance temperature before stopping the fan.

Figure 16-3:
Off-cycle
heat loss



Off-Cycle Losses - Air Leaks

Air leaks into the heat exchanger provide a path for off-cycle airflow, they should be sealed during annual servicing.



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Off-Cycle Losses - Air Leaks

Common air leak locations

- Between air tube & combustion chamber opening
- Between combustion chamber & heat exchanger
- Loose fitting clean outs
- Loose flame inspection doors
- Space between sections

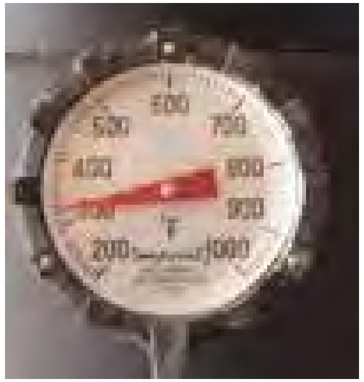
Off-Cycle Losses - Temperature Settings

- Water & air temperature controls affect heat loss
- Furnace blowers operate until the low temperature setting is reached, but heat that remains in the furnace is lost during the off-cycle
- Boiler water temperature settings have the same effect & maintaining excessive boiler temperatures increases off-cycle losses

Off-Cycle Losses –Excessive Firing Rates

- Firing rates that exceed what's required to heat the house increase both on and off-cycle losses
- Large firing rates produce long burner-off cycles and larger off-cycle losses
- Reducing firing rates solves these problems as long as the system performs well with the lower firing rate
- Remember that fixed heads may need to be changed when changing firing rates

Off-Cycle Losses –Older Units



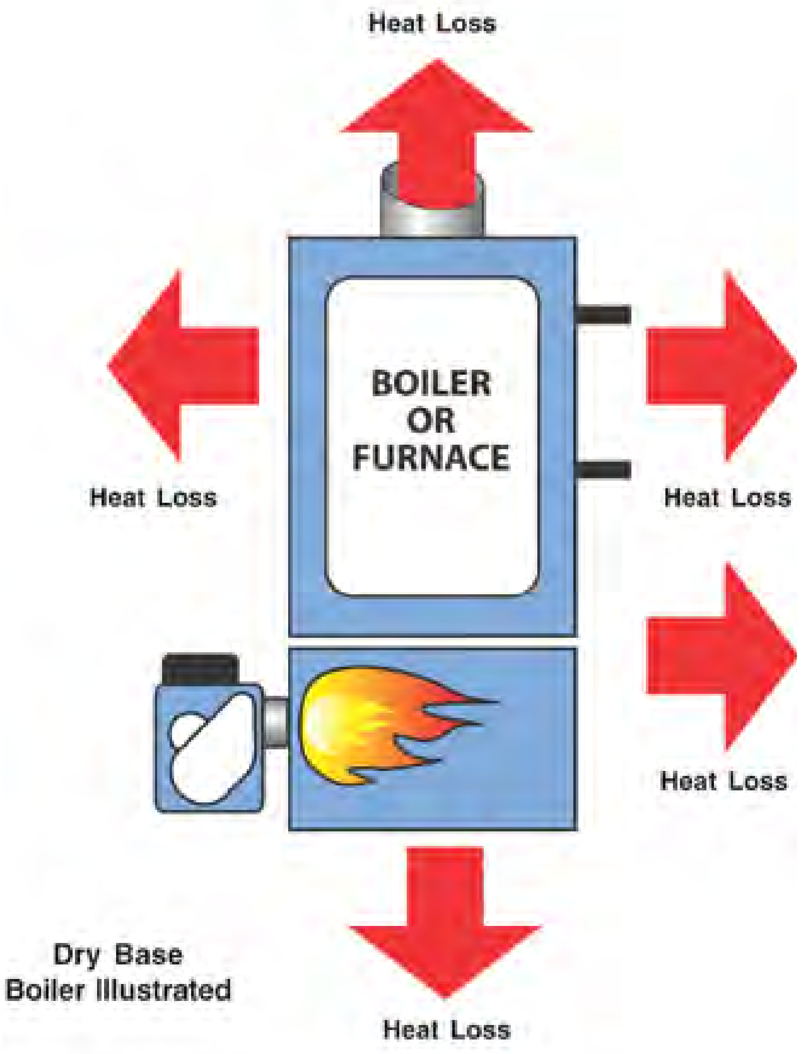
- New units that are properly sized should be fired to the manufacturer's recommendations

- Reducing firing rates on very old units works well because most of them are oversized

Three exceptions

- Steam boilers,
- Boilers with DHW coils
- Any appliance with less than 350^{o}F net stack temperature

Jacket Heat Loss



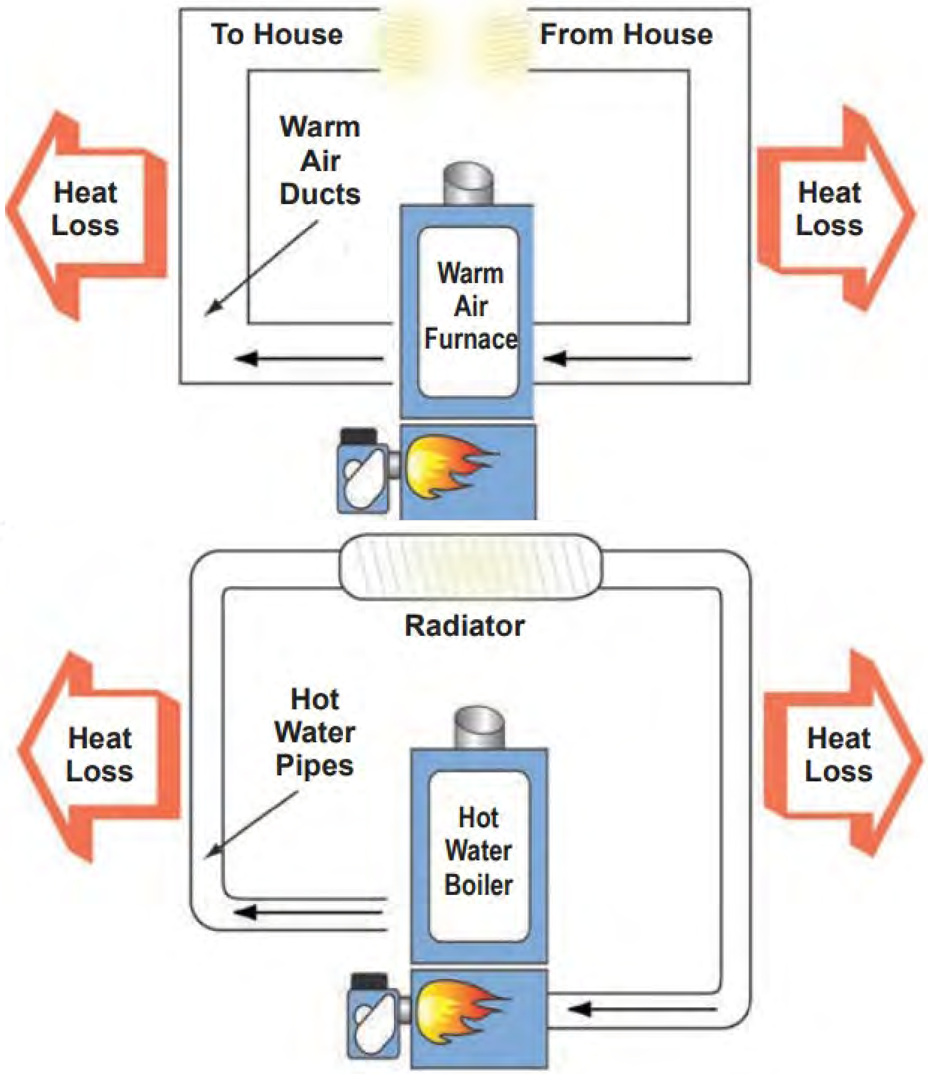
- Jacket loss is the heat is lost through the walls of the appliance
- The size of this loss depends on the appliance design and its location in the home
- It is largest when the burner is operating and heat escapes through the jacket to the surrounding area

Distribution (Pipe & Duct) Heat Loss

Heat from an appliance is transported through-out the home through pipes or warm air ducts.

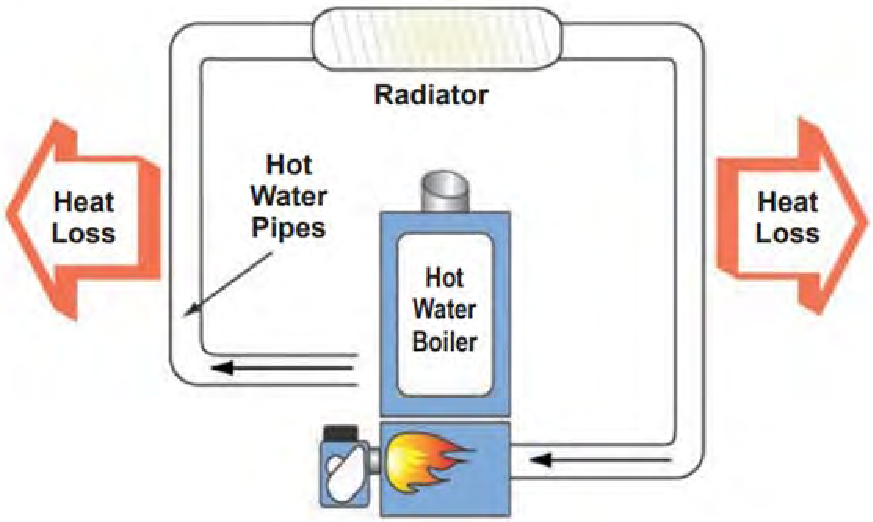
Heat loss that occurs between the appliance and the living space causes system inefficiency.

The level of efficiency depends on the size of the distribution system, the amount of insulation & the location of the pipes and ducts.



Distribution Heat Loss

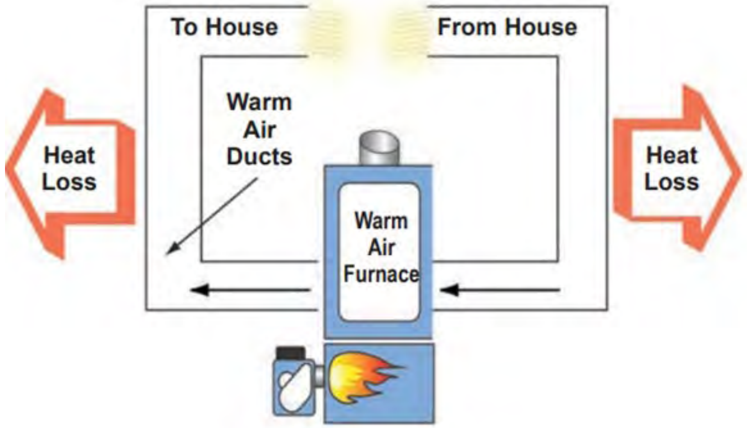
Piping that is not insulated adequately causes additional heat loss.



More fuel must be consumed to compensate for these losses.

Distribution Heat Loss (cont)

Heat loss from uninsulated ducts typically wastes more heat (up to 40%) than piping losses for 2 reasons:



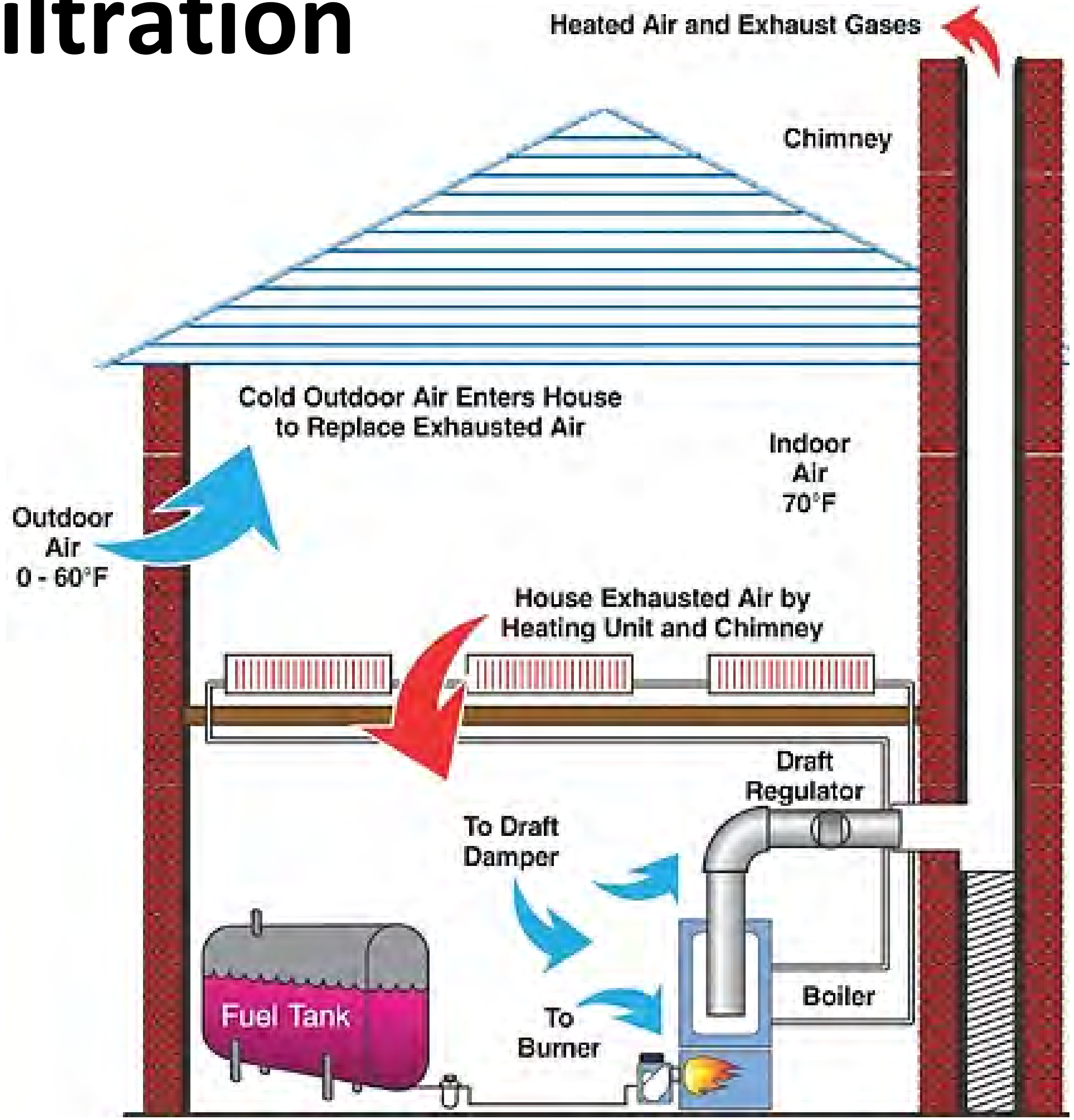
- Ducts have a larger surface area
- Warm air can leak from leaky joints

Outdoor Air Infiltration

Air that goes up the chimney (combustion air & dilution air) must be replaced by outdoor air drawn into the building.

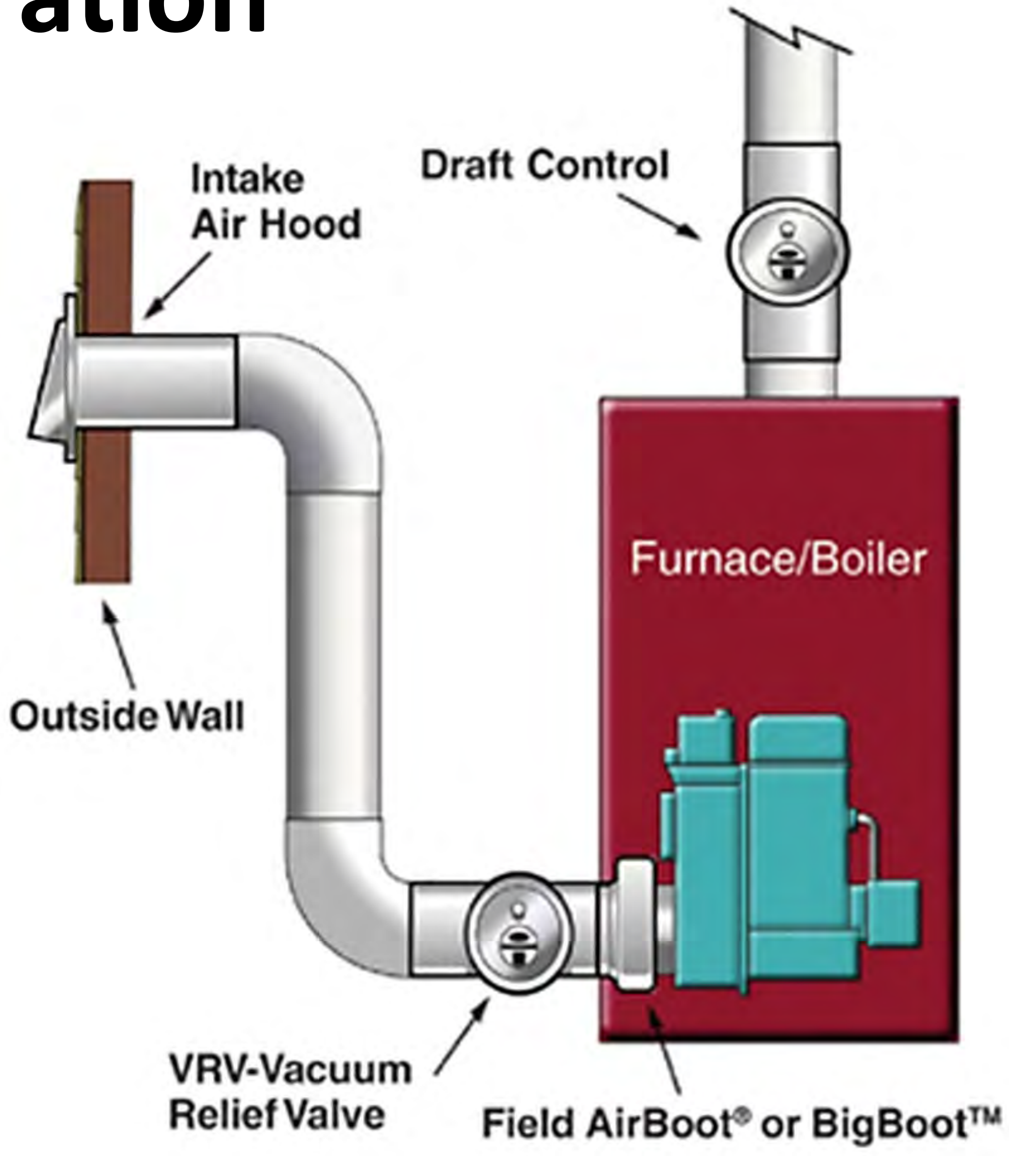
During the heating season this cold air is heated to indoor temperature before going up the chimney.

This loss is usually about 2% of the total fuel use, but can be as high as 12%.



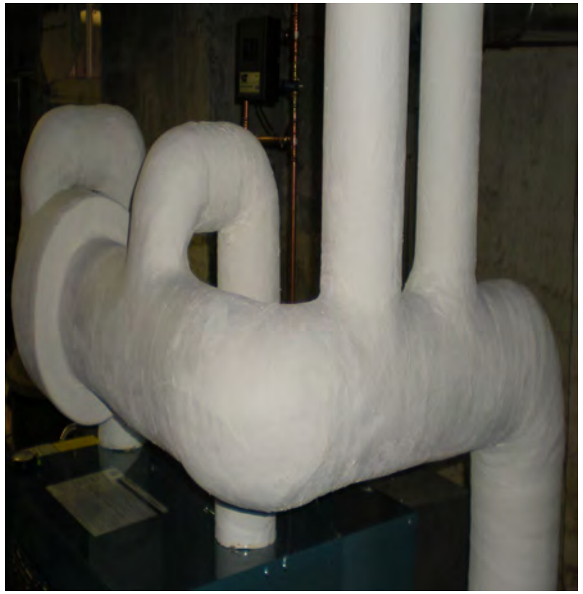
Outdoor Air Infiltration

The best solution for air infiltration losses is isolated combustion air, whereby outdoor air is piped directly to the burner air intake.



Equipment Modifications to Improve Efficiency

There are ways to invest in improved efficiency, including:



- ✓ Replacement appliances
- ✓ Pipe and duct insulation
- ✓ Heating system tune-up
- ✓ Thermostat set-back
- ✓ Combining the above

Equipment Modifications to Improve Efficiency

Appliance replacement

Many older units are inefficient and oversized & replacement of the appliance with a new, high efficiency model can reduce fuel consumption more than any other option.

Field studies show that boiler or furnace replacement will often save 18-30% with a typical payback period of 3 – 6 years.

Equipment Modifications to Improve Efficiency

Pipe & duct insulation

All heating system distribution systems that run through unheated spaces (attics, crawl spaces, etc.) should be protected against heat loss.

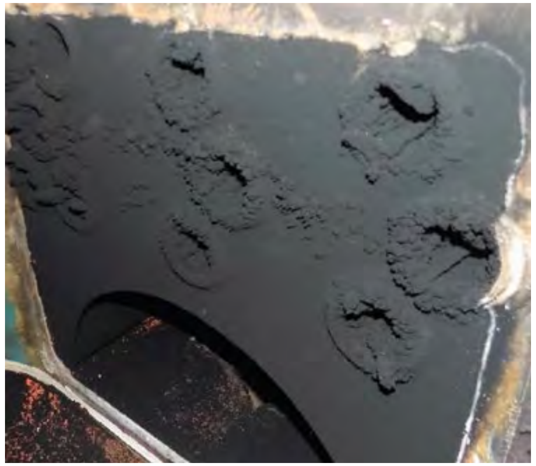
Expected energy savings:

- Steam/hot water systems – insulating piping may save 5 – 15%
- Warm air ducts – insulation and sealing leaks may save up to 40%

Equipment Modifications to Improve Efficiency

Proper Service

Periodic tune-ups assure the highest levels of efficiency and cleanliness.



Expected energy savings:

- About 3% for systems that are regularly serviced & adjusted.
- 10% or more for infrequently tuned or out of adjustment appliances.

Equipment Modifications to Improve Efficiency

Thermostat Set-Back

It's possible to save energy by lowering the thermostat when the home is unoccupied and/or when occupants are sleeping.

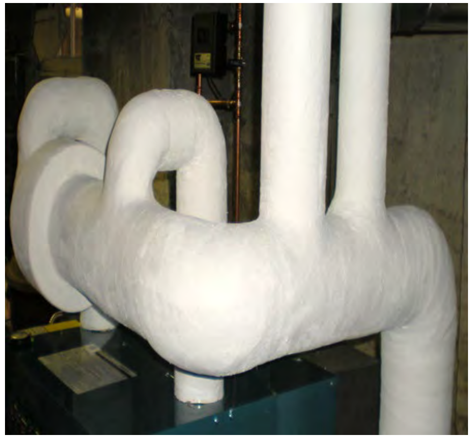
Expected energy savings:

According to the US Department of Energy, turning the thermostat back 7-10 degrees F for 8 hours a day can save as much as 10% a year on heating and cooling costs.

Equipment Modifications to Improve Efficiency

Combining equipment modifications.

It’s difficult to estimate fuel savings when more than one modification is applied to the same heating system.



The savings can’t be determined by adding the savings for each individual modification because some may address the same heat losses.

Steps for Advising the Customer

1. Measure combustion efficiency
2. Inspect the heating system
3. Evaluate upgrade options
4. Present recommendations

Steps for Advising the Customer

Replacing an old, inefficient, oversized appliance is one of the best investments a customer can make.

Review Questions:

- Where can heat be lost in an oilheat system?
- How do you stop air from leaking into the heat exchanger?
- Why and when would you adjust firing rates?
- Why can insulating pipes and ducts and sealing the envelope of the house save energy?
- What are steps customers can take to conserve energy?

End Chapter 16

NORA Technician Certification

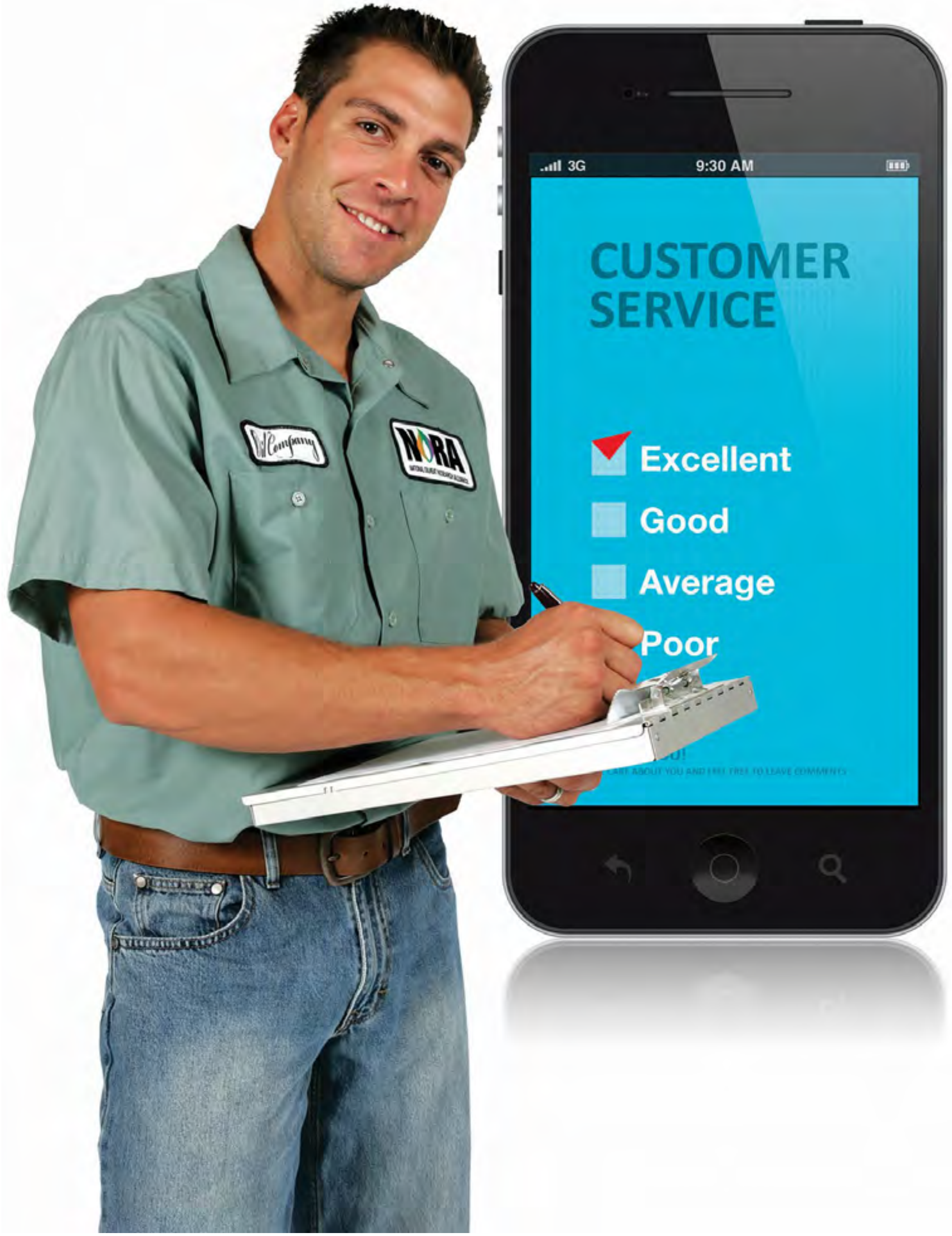
Review

Bob O'Brien, NORA Director of Education

Chapter 17
Customer Service

At the end of this lesson, you will be able to:

- Explain the technician's role in providing excellent customer service
- List the steps to problem solving
- Explain what to do if a customer becomes abusive or brings up controversial topics



Service Technicians: Industry Ambassadors

Service techs have more face-to face time with customers than anyone else in the industry, making them our industry's most important ambassadors.

Service Technicians – Industry Ambassadors

- What they say
- How they say it
- What they do
- How they act
- How they look

All determine how customers feel about them, their company and our industry.

What's in it for the Technician

When a customer requests a certain Tech, writes a complementary letter or tells their friends about a company, it's because of the tech's technical skills, attitude and people skills.

Raises and promotions are often based on people skills too, managers know which of their techs deliver good service.

Why Extraordinary Service is so Important

Most unhappy customers don’t complain, they vote with their feet
by quitting & going to a different company.

vote with your feet

Meaning: If you vote with your feet,
you show your opinion of something
by acting in a certain way, such as by buying
something if you like it,
or by not buying it if you don't like it

Why Extraordinary Service is so Important

The key to successful customer relations is to put yourself in the customers place – treat them the way you'd like to be treated, or better yet, the way they want to be treated.

Do the job right the first time, be helpful, friendly, thoughtful, tactful and polite.

Keep Promises

Breaking promises is the fastest way to lose a customer.

A service techs job usually requires keeping promises made by their company – appointment times for example.
Customers want to know when some one will be at their home.

Techs must communicate with their dispatcher if they're going to be late for a scheduled call so the customer can be notified or another can be given the job.

Moments of Truth

Think of customer relations as "moments of truth."

During every customer interaction a technician has the opportunity to make either a good or a bad impression. They can make all of them good by being patient, understanding & professional.

If there's a problem, acknowledge it & apologize for the inconvenience. Use the customers name, confirm that they're being listened to and, if authorized, give the customer a choice in the resolution.

What Customers want when Things Go Wrong

They want their heating system to function properly and when there's a problem, they want it fixed quickly.

When something goes wrong, they want action, NOT excuses.

They want respect for themselves, their property and their time.

The don't expect perfection but they do expect the company to care enough to correct the problem with a minimal amount of inconvenience.

Steps to Problem Solving

1. Listen to the complaint: remain calm & let them vent.
2. Calm them, reassure them, apologize if appropriate & get the facts.
3. Enlist their help: ask what can be done to satisfy them.
4. Investigate: troubleshoot to find the cause of the problem.
5. Explain the cause of the problem & offer a solution.

Abusive Customers – When to Leave

Sometimes a customer can push too hard & make it difficult to respond professionally. If a tech becomes angry, they should tell the customer they need to go to their vehicle.

If a short break doesn't give enough time to calm down, contact a supervisor or service manager for advice & assistance.

Do NOT say or do anything to make the situation worse.

Never Criticize the Work of Others

Don't throw anyone "under the bus" by criticizing their work, regardless of whether they work for your company or a competitor.

Never criticize the customers equipment – if it's obsolete suggest an upgrade, they might be pleased to hear that can save money and avoid more service calls.

Image is Everything

A techs appearance is important, cleanliness implies a higher level of quality in the service performed.

Focus on clean trucks, neat uniforms, clean shoes, clean toolboxes and leaving the customers home cleaner than it was before you arrived.

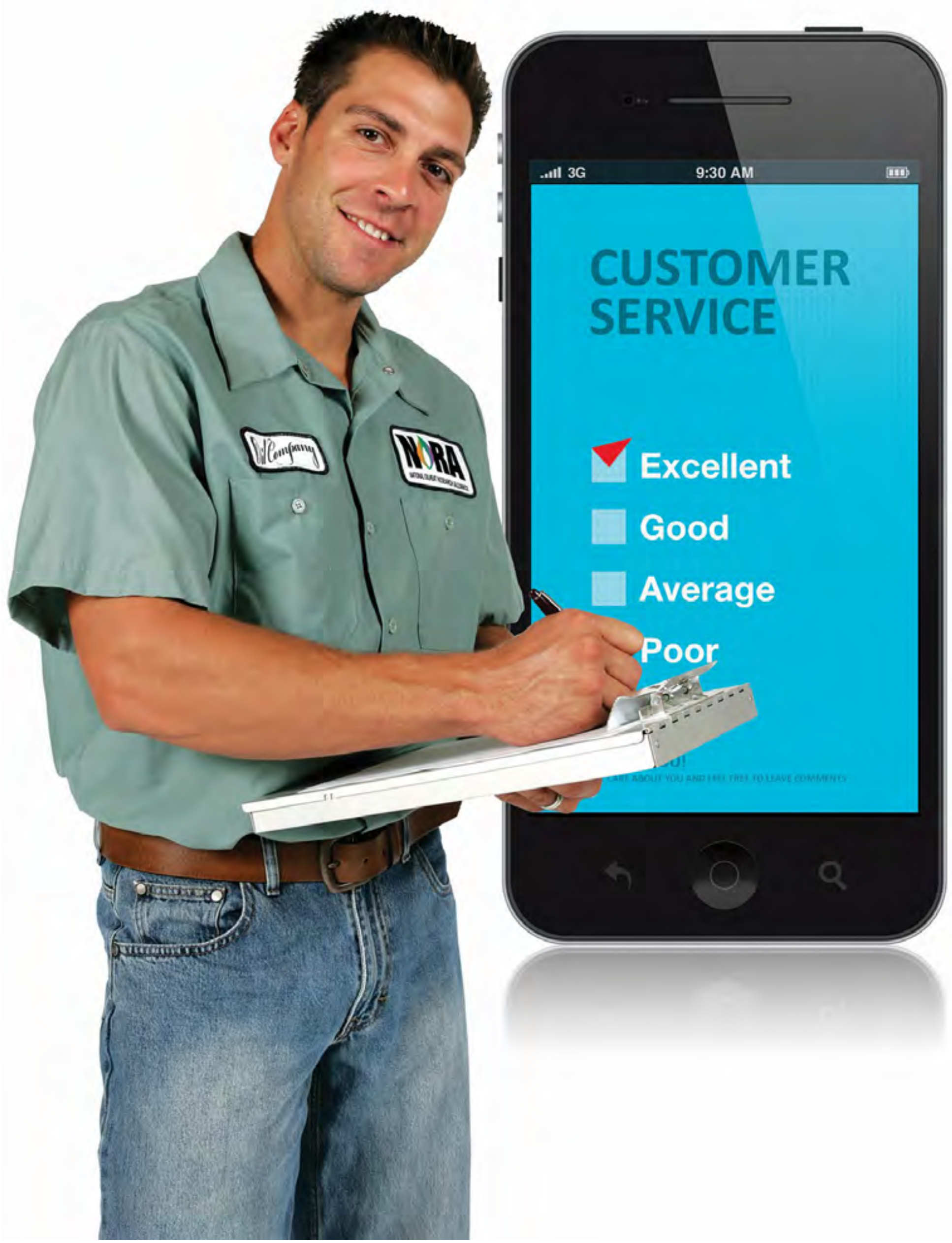
Focus on the Heating System

Unfortunately, the condition of the heating system, and the area around it is why many people think that liquid fuels are dirty.

Make cleaning up the heating system & area around it a priority. Customers often judge the quality of work performed by the appearance of their heating equipment after the job has been completed.

Review Questions:

- What is the technician's role in providing excellent customer service?
- What are the steps to problem solving?
- What do you do if a customer becomes abusive or brings up controversial topics?



End Chapter 17