

Chapter 13

Heating Systems





Chapter 13

Heating Systems

Part 1

Warm air furnaces

Furnaces create warm air that is then distributed throughout the building via ductwork. A warm air furnace utilizes a metal heat exchanger that is designed to absorb heat from the burner flame and transfer that heat to the air that circulates through the furnace and into the house.

It accomplishes this by having the burner fire into a combustion chamber which is inside the heat exchanger. The resulting combustion gases are vented to a chimney via the flue pipe. This heated air is then distributed to the house through supply ducts, while cooler air from the building is brought back to the furnace through return ducts, see Figure 13-1.

The advantage of warm air systems is that air cleaners, humidifiers, and central air conditioning systems can be incorporated into the unit to provide a total comfort indoor air quality climate control system.

Warm air furnaces have an integral blower that moves air through the ducts. The air-flow the blower creates is measured in CFM (Cubic Feet Per Minute). It is important that the blower and ducts be properly sized to move enough air across the heat exchanger to remove the heat from the furnace and deliver it to the house.

The normal operation of a warm air furnace is as follows:

1. Thermostat calls for heat and acti-

vates the burner through the primary control.

2. Burner runs, but the blower does not start until the heat exchanger is warm, preventing the circulation of cool air. This is accomplished with a mechanical fan control or electronic timer.
3. The burner and blower then run together until the thermostat has been satisfied and the burner shuts off.
4. The blower continues to run until the heat in the furnace has been dissipated and the fan control shuts it off. (Usually 100°.) The blower may

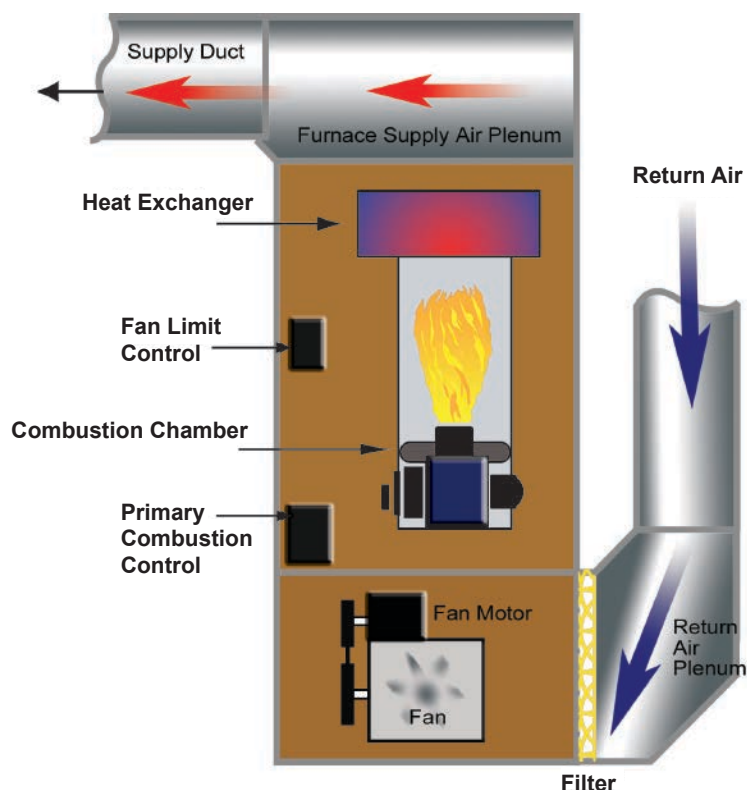


Figure 13-1:
Typical warm air
furnace

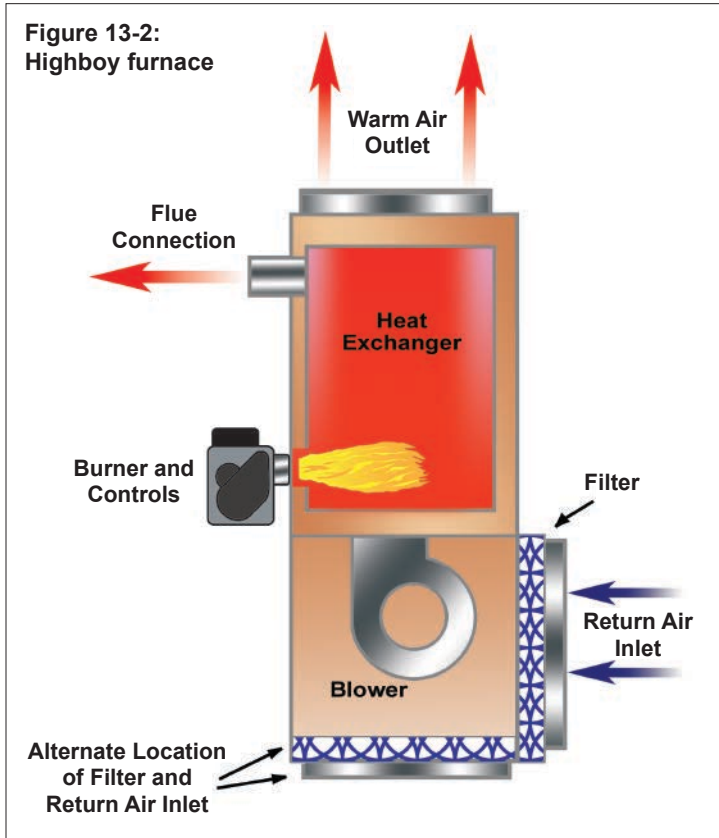


Accompanying audio files are available at Learning.NORAweb.org/manual



Use the time stamp on each page to navigate.

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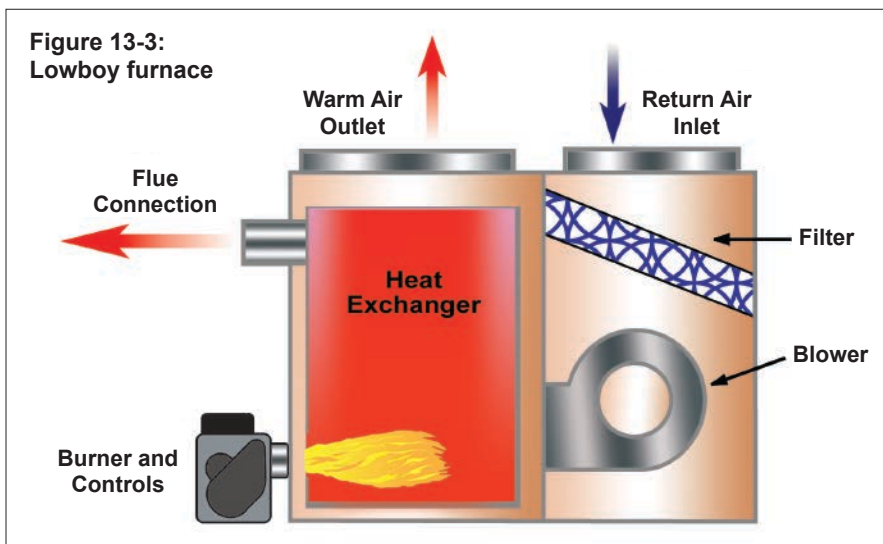


come back on after a minute or two because some residual heat from the combustion chamber and heat exchanger has risen from the furnace to activate the fan control once more.

There are different types of warm air furnaces for different applications. The basic operation of these is similar, but the configurations vary.

Highboy furnace: The most common furnace is the highboy. It gets its name because the heat exchanger sits on top of the blower within the furnace cabinet. Return air is pulled in through the bottom of the unit and circulated upward across the heat exchanger and then out through the top of the unit. See Figure 13-2.

Lowboy furnace: Where height constraints are a consideration, a lowboy furnace is often used. The blower is in a compartment next to the heat exchanger, thereby shortening the overall height of the unit. See Figure 13-3.



Counterflow furnace:

These units are commonly found in slab type construction and mobile homes and look much like a highboy in outward appearance but differ in that the blower is located above the heat exchanger. Return air comes in through the top and is distributed out through the bottom of the unit. In this type of furnace an additional fan control is installed below the heat exchanger. The upper control turns the blower on when it senses the temperature of the air rising in the unit. The lower

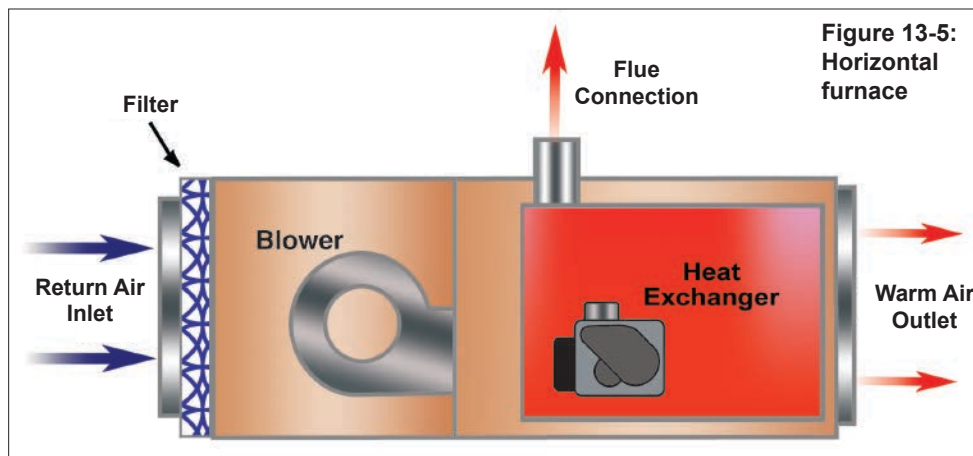
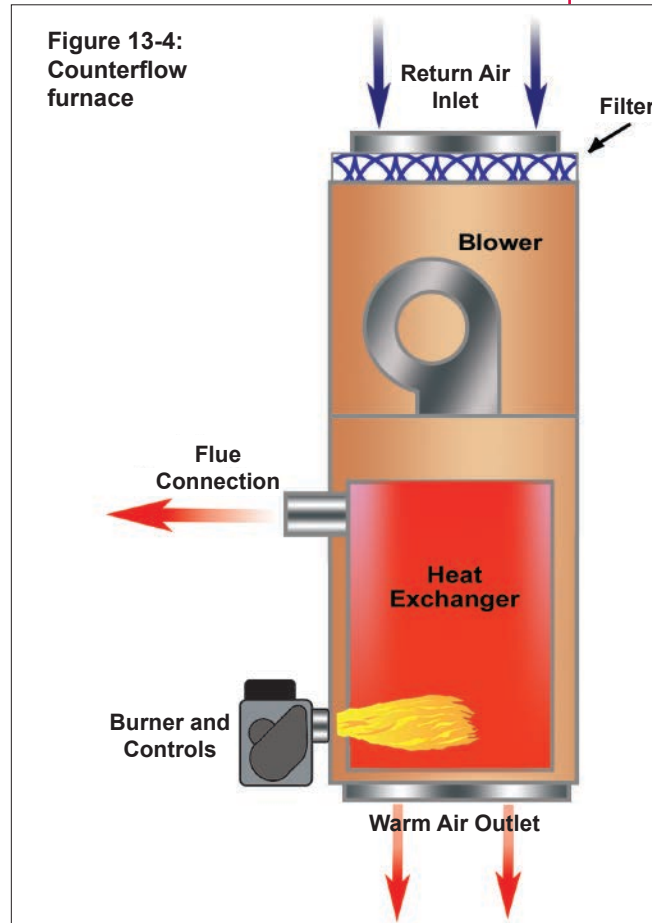
control turns the blower off when it senses a decrease in the temperature of the air being blown down through the furnace. See Figure 13-4.

Horizontal furnace: A horizontal furnace is often described as a highboy furnace on its side. These units are normally used in crawl spaces or suspended from a ceiling. The air travels through these units in a horizontal pattern with return air entering on one side and supply air discharging through the opposite end. See Figure 13-5.

The distribution system

Figure 13-6 (following page) shows the main components and fittings found in a warm air distribution duct system. The distribution or duct system is comprised of three main parts:

Plenums: These are boxlike chambers connected to the furnace. There are two plenums in the modern furnace, one on the supply side and one on the return. The plenum should always be the same size as the opening on the furnace and be at least 14" long or high.



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Trunks: These are usually rectangular ducts that connect to the plenums and are run out through central areas of the house.

Branches: These are smaller ducts, either round or rectangular, which connect the trunk lines to the individual registers. It is a good idea to install locking dampers in an accessible location of each branch to allow for system balancing.

Troubleshooting warm air systems

Not enough heat

When responding to a service call for “not enough heat” or certain rooms in the house “not heating,” first see if the burner, controls and blower are set correctly and operating properly, then look to the distribution system. Most issues of these type are air flow related. Some common things to check are:

1. *Temperature rise.* This is the dif-

ference in temperature between the supply air and the return air. To check temperature rise, measure the temperature out of the line of site of the heat exchanger, see Figure 13-7, to be sure that the temperature probe is not affected by radiant heat from the heat exchanger. If the appliance has

Figure 13-6:
Warm air
distribution
system

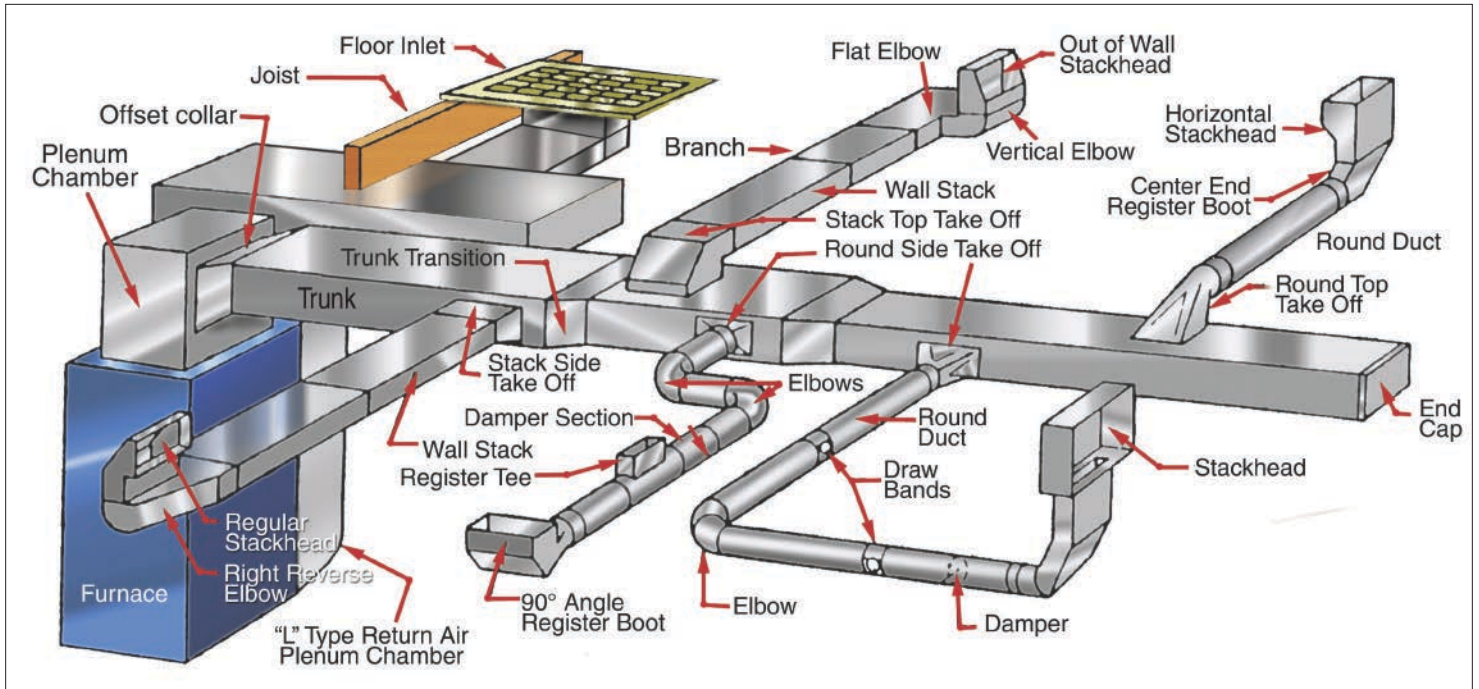
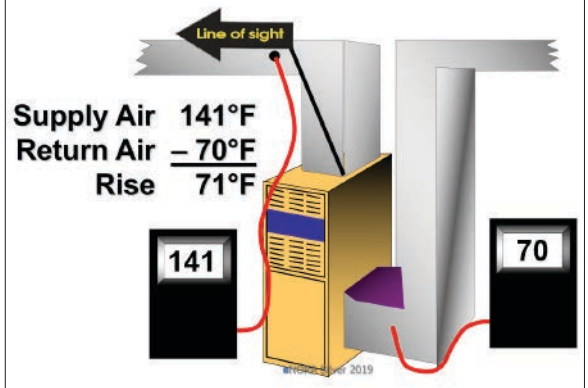


Figure 13-7
Temperature Rise



a bypass humidifier, make sure the bypass is closed or the results will be inaccurate.

Manufacturers specify a recommended temperature rise and the technician should verify that the appliance is operating within these settings. If the rise is too high it could be too little airflow – verify that the air filter is clean, the blower is at the right speed and that the ducts are unrestricted. Figure 13-8



If the rise is too low it could be too much airflow. Check the blower speed and look for openings in the return air ducts or the blower compartment.

2. *Is there adequate return air?* Ideally, there should be an equal amount of return coming back to the furnace as there is going out on the supply side.

As a minimum, the return should never be less than 80% of the supply. (100% is better and with air conditioning 120%.) If the ducts appear to be adequate then 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 the ducts run through “cold” areas?* Sometimes ducts are run through unheated areas such as crawl

spaces, garages or attics. When this situation occurs, the heat loss from a bare duct cools the air coming out of the register. Ducts should always be insulated to prevent this heat loss.

Short cycling

If the burner is short cycling or if the unit is regularly shutting off on high limit, the following should be checked:

1. Are controls set properly?
2. Is blower operating?
3. Is fan belt broken or slipping?
4. Are pulleys slipping?
5. Are air filters plugged?
6. Are return air grills and ducts free of restriction?
7. Are supply registers and ducts free of restriction?
8. Is unit over fired?
9. Is the duct system designed to meet the requirements of the furnace?

Testing for a leaking furnace heat exchanger

A combustion analyzer can be used to find leaks, cracks or holes in a furnace heat exchanger. The high static pressure created by the system blower can pressurize the heat exchanger and force air to leak into the combustion chamber. The reverse of this is also true, high positive pressure in the combustion chamber can allow combustion gases to leak into the space heating side of the furnace and allow CO to be carried into the conditioned space.

O₂/CO₂ or draft readings that change when the blower comes on are indicative of a combustion air, venting or mechanical problem such as a cracked heat exchanger.

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Procedure for testing a heat exchanger by monitoring the O₂ reading:

1. Follow the manufacturer's instructions to properly zero the combustion analyzer. Insert the combustion analyzer probe into the flue pipe.
2. Start the furnace and observe the oxygen reading for stability (1-3 minutes).
3. When the blower starts, watch for a change in the O₂ reading. If the O₂ reading changes, there is a leak.

Corrective action: Attempt to visually find the leak.

A. Sometimes a cleanout door or inspection door can leak air, this is not a heat exchanger failure and only requires that new gaskets be installed and/or the leak properly sealed.

B. If a visible defect can be seen, show it to the customer. See Figure 13-9.

C. On the service invoice, write that the testing indicates a leak in the heat exchanger (Do this even if you cannot find the leak).

D. Inform the customer, in writing, that the heat exchanger has a defect and that it should NOT be operated. Attempting to repair a leaking heat exchanger is not like repairing other system components because a leaking heat exchanger can allow carbon monoxide to enter the living space.

Part II

Hot water boilers and heating systems

A hot water boiler is a heat exchanger that uses the heat from the burner's flame to heat water. This heated water is piped to heat emitters in the building to supply space heating. The cooled water then returns to the boiler where it is reheated. Figure 13-10 shows a basic hot water heating system.

Usually the heated water leaves the boiler at about 160° to 180°F and returns at 140-160°F.

Boiler designs

Boilers are constructed from cast-iron or steel and can be either "wet base" or "dry base."

A wet base boiler has water surrounding the combustion chamber while a dry base boiler does not.

The most common steel boiler is the "fire-tube" boiler in which hot combustion gases flow inside long tubes surrounded by water. These fire-tubes can be arranged vertically or horizontally within the boiler water. As the combustion gases rise through the tubes, heat passes through the wall of the tubes to the water. Figure 13-11 shows a dry base vertical fire tube boiler.

In horizontal fire-tube boilers, the hot gases travel to the back of the boiler and then pass into the horizontal fire tubes where more heat is transferred to the water.

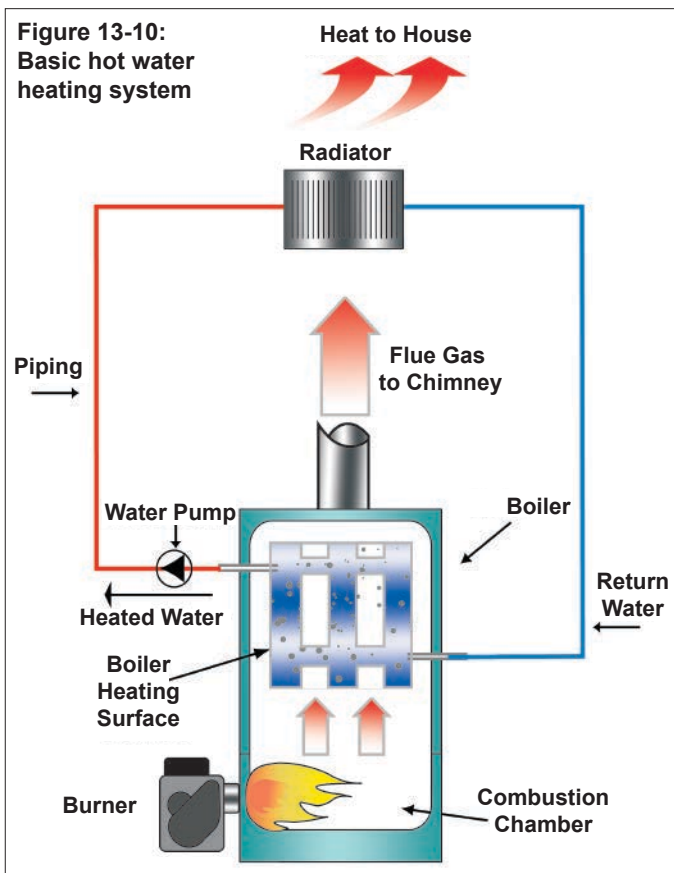
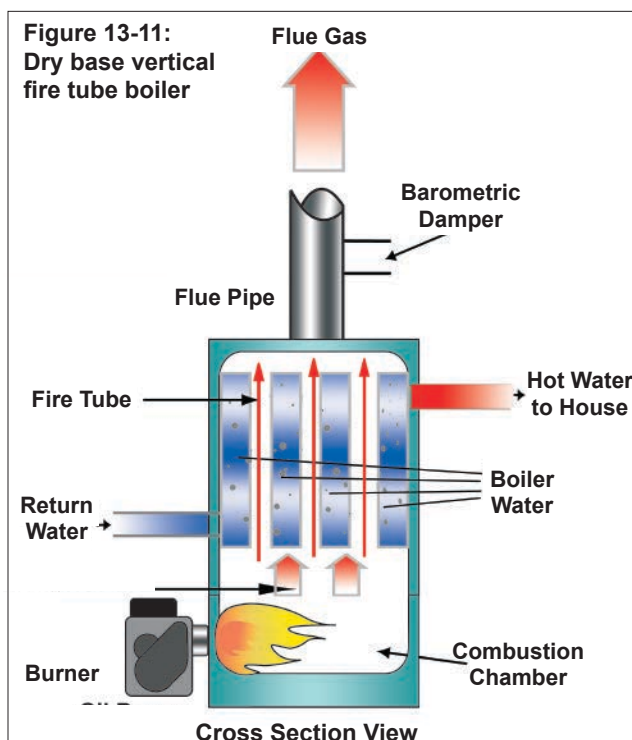
Figure 13-9:
Visible defect to show customer



This design is called a “two-pass” boiler because the gases go front-to-back in the first pass, and back-to-front in the second pass, before they are transported by the flue pipe to chimney.

Some steel boilers include a third pass through fire-tubes for increased efficiency. Some features of these boilers include low mass construction and reduced water storage for lower heat loss.

Cast-iron boilers are narrow sections of cast iron that are joined together. Each section contains boiler water on the inside, while hot gases pass in channels between the sections. The cast sections are joined together with either metal push nipples or non-metallic “O” rings.



Some cast-iron boilers have “wet-legs” or “wet-backs” so that the combustion chamber is partly surrounded by boiler water.

Water is supplied to each section through a common header at the bottom and top of each section. The water flows upward and it is heated by the hot inner surfaces of the cast-iron sections. The heated water leaves the boiler through the outlet fitting and then it is piped to the radiation.

Extra attention is needed when assembling or servicing sectional boilers to be sure that there is no way for air to leak into the boiler between the sections. These must be sealed tightly to prevent the entrance of secondary air that lowers operating efficiency.

Firebox and combustion chambers

The burner is fired into a combustion area that may be lined with a refractory

material that reflects radiant heat back to the flame. The reflected heat helps to stabilize the flame by vaporizing the fuel droplets more quickly.

Dry-base boilers require a combustion chamber made of an insulating material such as ceramic fiber to reduce the heat loss through the base of the boiler and to prevent burning out the base. In wet-base boilers the insulating properties of the chamber are less important because the surrounding boiler water recovers the heat.

Heating surface or heat exchanger

The heating surfaces of the boiler are exposed to the hot combustion gases on one side and to the boiler water on the other side. Heat is conducted through these boiler surfaces from the hot gases to the water. Larger surface areas give better heat transfer. Many surfaces are designed with contours, fins, pins or surface projections to increase the outer area and improve the gas-side contact.

The heat transfer surfaces must be kept clean so that good heat exchange can take place. Soot deposits on the heating surfaces act as an insulator.

Baffles or turbulators

Baffles and turbulators are objects placed in heating passages to redirect the gas flow for better heat transfer.

Fire-tube boilers use turbulators to prevent the flow of hot gases up through the center of the tube. Some turbulators are long narrow strips of metal that are twisted into a spiral to give a spinning motion to the hot combustion gases. Turbulators should always be put back into the tubes after the

Figure 13-12:
Boiler Baffle



boiler is cleaned. If they are damaged or badly corroded, they should be replaced with new ones. Figure 13-12.

Insulation

Boilers and furnaces have thermal insulation on the outside of the heat exchanger to reduce heat loss from hot surfaces. The outer jacket or casing must be securely fastened to minimize heat loss.

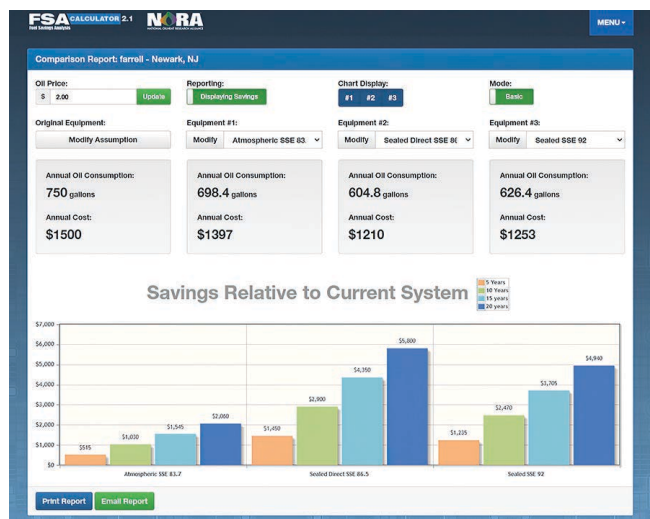
Boiler ratings

Cast-iron and steel boilers are tested to verify heating capacity and efficiency. The Air Conditioning Contractors of America (ACCA) publishes boiler ratings in its *I=B=R Residential Hydronic Heating Guide*. Listings provided in the guide show the boiler's Btu output and its Annual Fuel Utilization Efficiency (AFUE). The AFUE is calculated based on a testing procedure specified by the US Department of Energy. The Gross Output is the total heat delivery in BTUs per hour that the boiler will deliver.

The NET RATING deducts a "piping and pick-up factor" equal to 15 percent of the gross output for hot water boilers. This factor takes pipe heat loss and boiler warm-up time into account. This is important to assure that the boiler will deliver adequate heating at the coldest times of the year. The NET RATING should be used for selecting a boiler.

NORA has taken the next step and has developed an on-line calculator which allows technicians to compare the efficiency of boilers by inputting the amount of energy to heat the home and provide domestic hot water, Figure 13-13.

Figure 13-13: Image from FSA Calculator on NORA's website: noraweb.org/fsa



Piping systems

One of the features of hot water heat is its flexibility. There are a wide variety of different hot water piping systems in the field. Each is designed for specific applications and has its advantages and disadvantages. The following is a brief description of some different hot water piping systems a technician is likely to encounter.

Series loop

The most common is the Series Loop. It is the least expensive and easiest to install. See Figure 13-14 (following page) for three examples of Series Loop systems. Series loop systems feature a single pipe that goes from the boiler outlet through each piece of radiation and back to the boiler inlet. One of the series loop's biggest advantages is that it will supply heat to each of the heat emitters with a minimum of pipe and fittings. No special valves or fittings are required. The disadvantage of this system is that heat delivered to the last heat emitter is less than that delivered to the first.

One pipe system

This system also features single pipe that

connects the boiler supply to the return while supplying the radiation. What makes it different from the series loop is all of the sections of radiation are connected to the single pipe main by the use of a standard tee and a special tee that form a “branch” of the main circuit. See Figure 13-15, on following page.

The special tee is called by many names including “One-pipe”, “Venturi”, “Mono-Flo” and “Jet” and it serves the purpose of directing the flow of water so that each section of radiation is supplied with water at approximately the same temperature. Figure 13-16 shows the special tees required for single pipe systems.

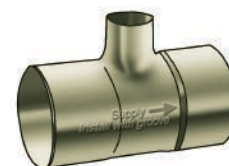


Figure 13-16:
Monoflow tees

Two pipe system

This system incorporates the use of a separate supply and return pipe from the boiler to each heat emitter. The preferred way to pipe this: the first piece of radiation to be taken off the supply is the last returned to the boiler. Likewise, the last supplied is the first returned. This produces a uniform and balanced design that requires no special valves or fittings. See Figure 13-17 on following page.

Components of hot water heating systems

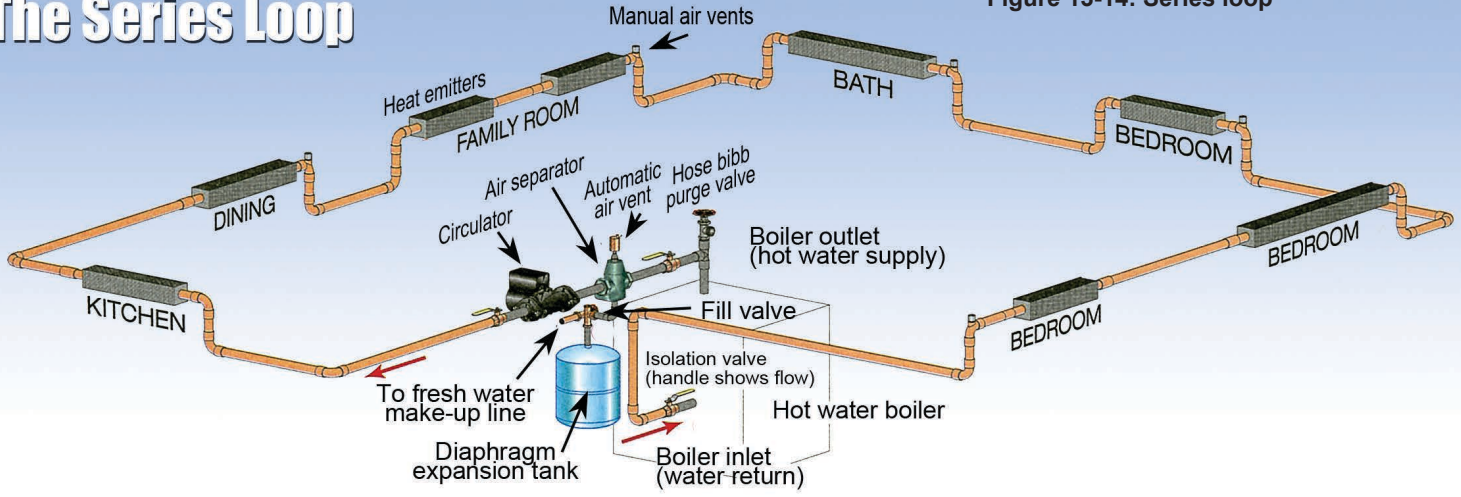
Heat emitters aka radiation

Hot water is an easily adaptable and transportable medium that lends itself to all sorts of radiation. The five most common types of heat emitters are the conventional radiator, the convector, the fan-coil unit, baseboard and radiant panel.

- **Conventional radiator:** usually made of cast iron sections that either rest on the floor or mount on the wall. Radiators are normally found in older systems

The Series Loop

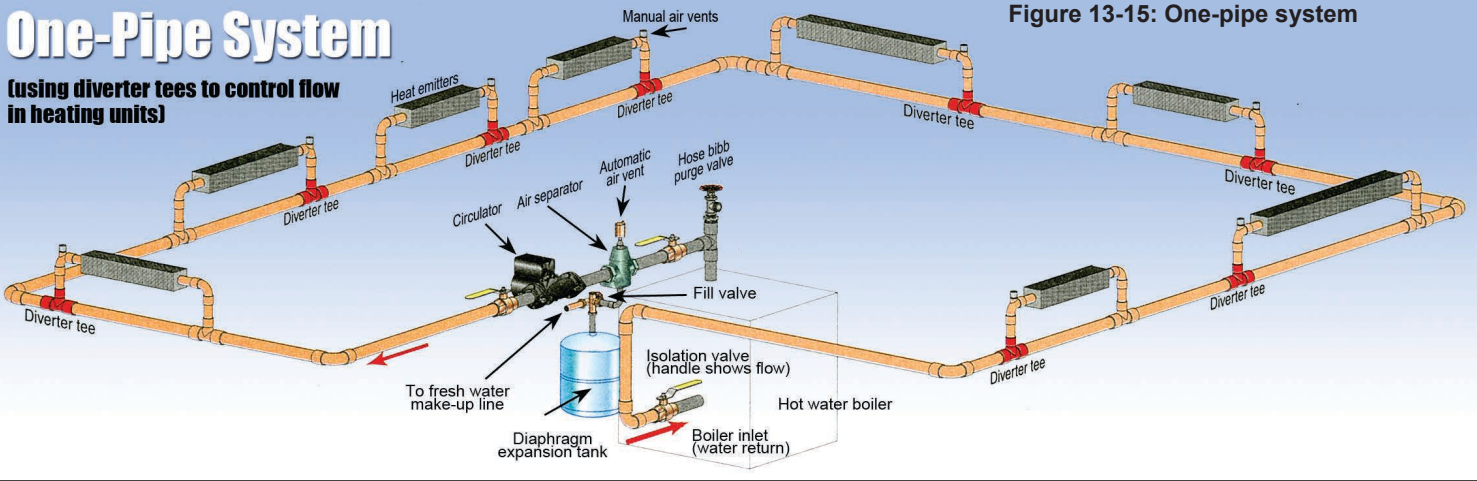
Figure 13-14: Series loop



One-Pipe System

(using diverter tees to control flow in heating units)

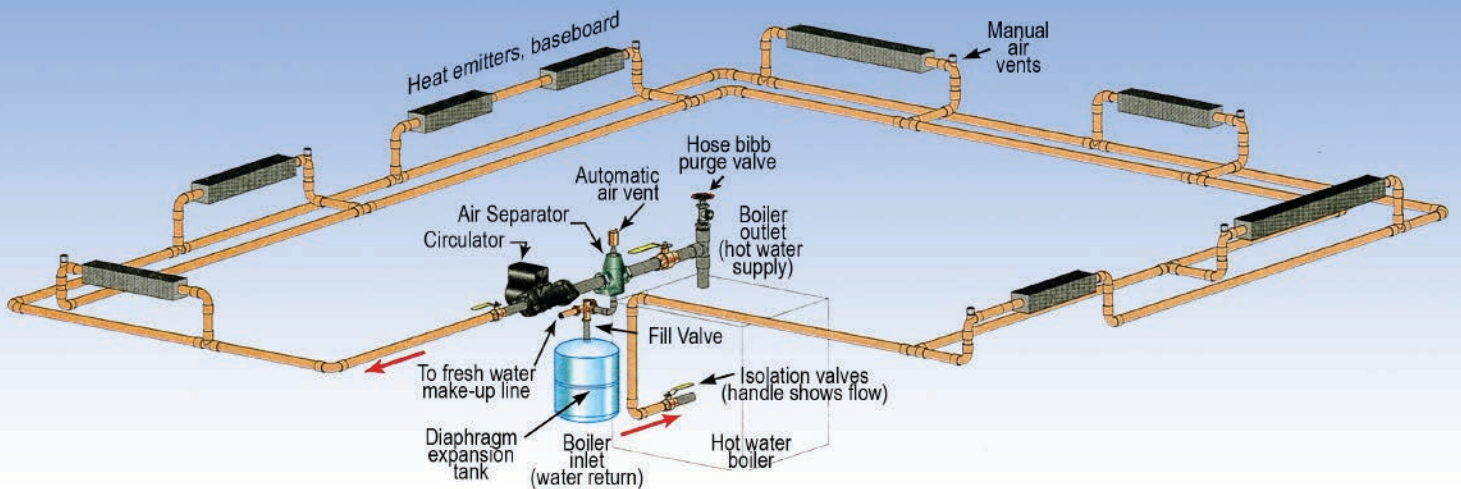
Figure 13-15: One-pipe system



Two-Pipe System

(reverse-return—closest supply unit has longest return)

Figure 13-17: Two-pipe system



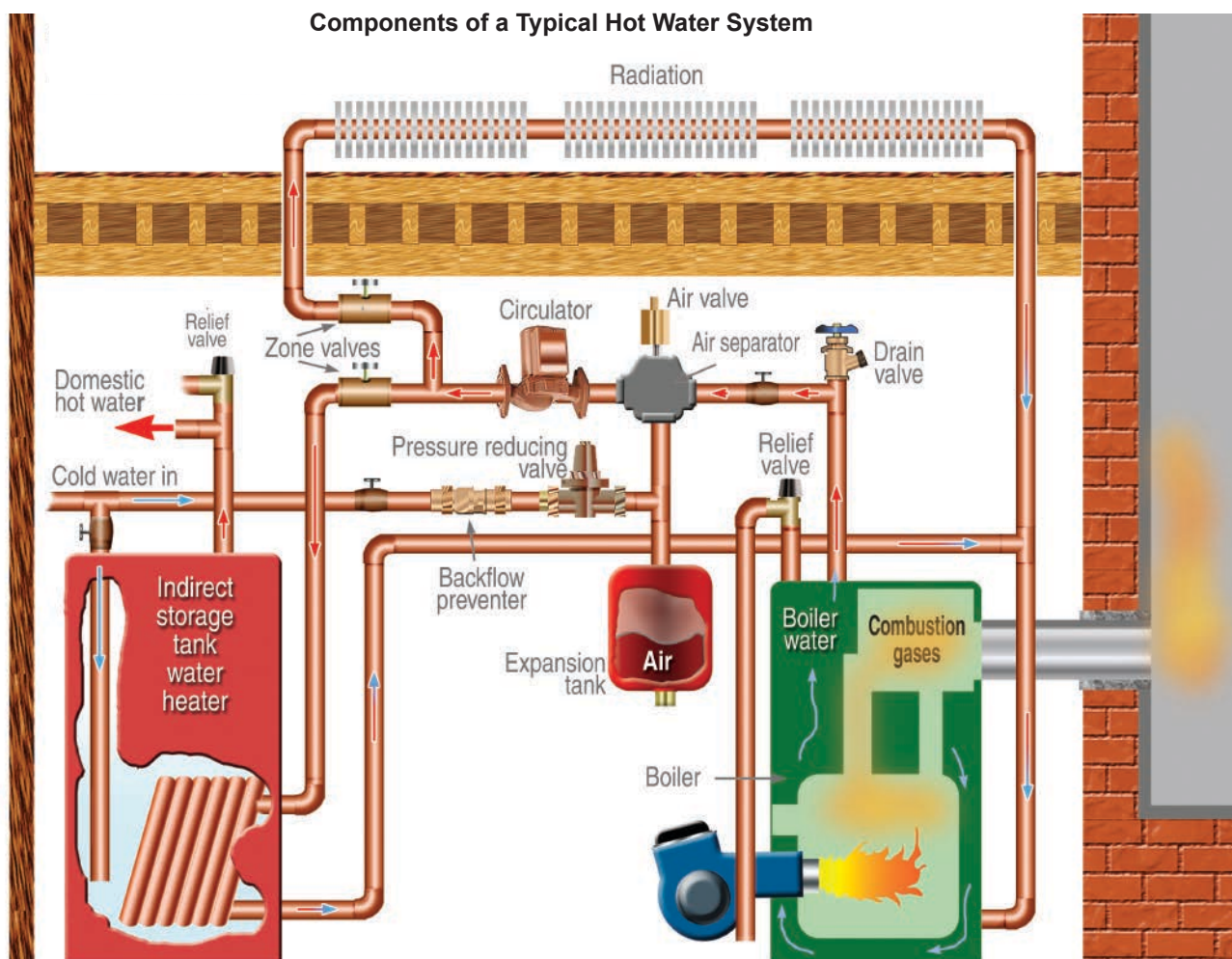
- **Convectors:** a series of finned-tube sections enclosed within a cabinet. They are constructed of either cast-iron sections or steel
- **Baseboard radiation:** constructed of cast-iron panels or copper pipe covered with aluminum fins that create surface area for heat transfer. In larger system applications, the pipe and fins can be constructed of steel
- **Fan-coil or unit heaters:** coils of finned-tube element with a fan that blows air over the coils. They are especially suited to rooms where there is little wall space available, such as kitchens and baths. They are also popular in

garages and commercial applications

- **Radiant or panel heating systems:** serpentine loops of non-finned pipe in floor, walls, or ceilings that circulate low temperature water. Residential radiant heat systems are becoming very popular in new homes. The piping can be filled with anti-freeze and run from a separate heat exchanger or boiler for heating garages, driveways and sidewalks

Circulator

The circulator is the key to the proper function of today's hot-water heating system. Circulators create a pressure differential in the piping that produces flow in



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the system. The circulator motor rotates an impeller that pushes heated water outward into the piping. As the water is pushed away, cooler water is pulled from the system into the impeller. This movement of water creates “head pressure,” Figure 13-18.

Hot water systems work best when the circulator is located on the supply line and located so it “pumps away” from the expansion tank as shown in Figure 13-19. Unfortunately, some systems, especially old-

er ones, often have the circulator on the return piping. Figure 13-20.

Expansion tank

All hot-water heating systems need an expansion tank. As water is heated, it expands. Water cannot be compressed. In a closed system it has nowhere to expand as it is heated, so the pressure increases instead. If nothing is done to address this, every time the burner came on the relief valve would open.

The expansion tank solves this problem. It is a tank full of air with a flexible diaphragm installed in the system. When the burner fires, the water expands, pushes against the diaphragm and compresses the air in the tank. When the burner shuts off, the water cools and the compressed air expands and pushes the water back out of the tank.

Originally, all tanks were hollow steel cylinders. These tanks worked on the principle that as the system was filled with water, a cushion of air was trapped in the tank and as the system water expanded, the

Figure 13-18:
Pump resistance,
TACO “00”
circulator

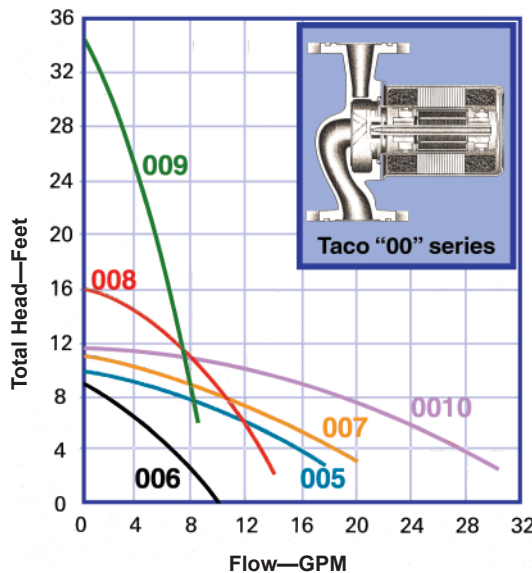


Figure 13-19: Circulator located on supply line



Figure 13-20: Circulator located on return line



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air compressed. On cooling of the system, the water would contract and the air would decompress. Unfortunately, every time the water cooled it would absorb some air from the tank and carry it to the system. Eventually all the air would be removed and the tank would become waterlogged and require service.

The steel tank has been replaced by the flexible diaphragm design, Figure 13-21. These tanks are pre-pressurized to 12 pounds per square inch and have advantages over the older design:

1. Smaller size. About 1/3 to 1/2 the size of the older tank.
2. The flexible diaphragm keeps the water and air separated so the cooling water cannot absorb the air from the tank. It cannot become waterlogged, unless the diaphragm leaks.

Pressure reducing valve

Hot water systems must be pressurized to push water out of the boiler and up in the system. The pressure reducing valve allows for the automatic filling and maintenance of heating system water pressure. This valve is adjusted by the technician to reduce incoming service water pressure (>80 PSI) to the pressure required by the system.

It takes one PSI of water pressure to push water 2.3 feet up a pipe. Typical residential systems operate at 12 pounds pressure because that much pressure will push water up 27.6 feet (sufficient height to heat a radiator up in the attic of a two story home). The factory

Figure 13-22:
Pressure
reducing valve

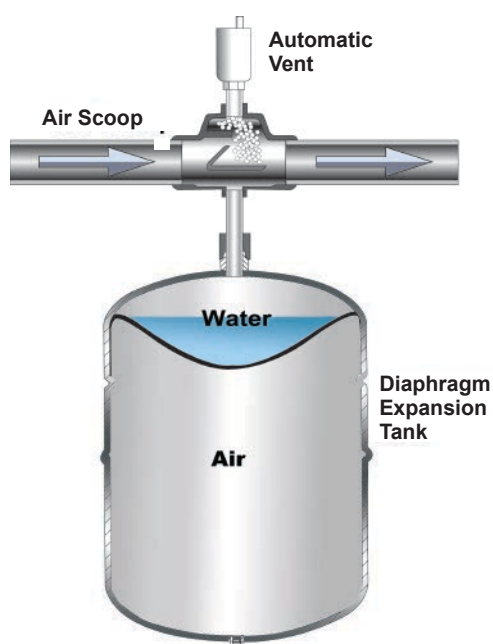
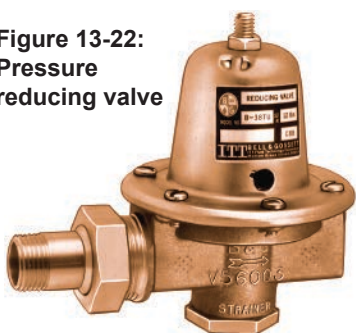


Figure 13-21:
Expansion tank

setting of 12 PSI is almost always adequate for residential applications. Figure 13-22.

Pressure relief valve

The pressure relief valve protects the boiler and system from high pressure conditions. Its discharge should be piped to an area where the released water will not scald the occupants. Relief valves should always be sized to boiler manufacturers' specifications. Residential hot water boiler relief valves are set to open at 30 PSI.

Flow control valve

The flow control valve is used to prevent gravity circulation on a forced hot water heating system. It is a check valve opened by the circulator's force so the heated water can travel through the system. See Figure 13-23 on following page.

Air elimination or control

Water holds a great deal of air in suspension. Cold water holds more air than warm water and as water is heated, the air

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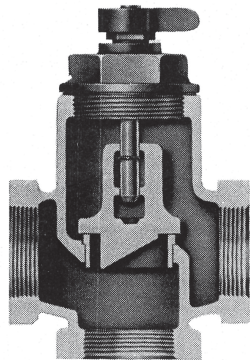


Figure 13-23:
Flow control valve

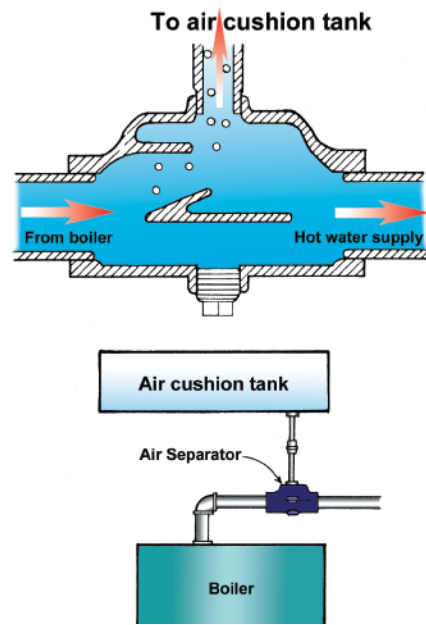
is released. If air gets trapped in the system, it can stop the flow of water to that part of the system and cause a no heat call. Air vents release air from the system and are often installed at the highest point to keep air from accumulating. In

addition, most systems, with the exception of the series loop, have air vents installed in each piece of radiation. Series loop systems typically have air removed through “purge valves” located in the return piping.

Air separators remove the air from the water being pumped from the boiler and should be located in the supply piping.

Figure 13-24 shows the cross section of an air separator and the installation of one on a steel expansion tank system.

Figure 13-24: Air elimination

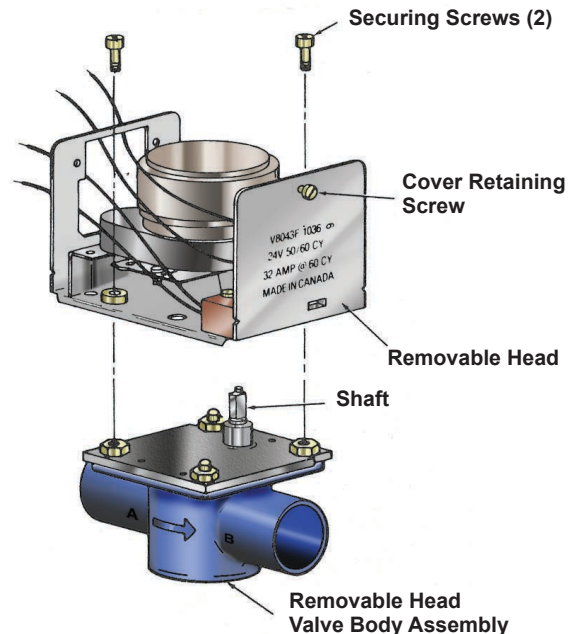


System zones

Hot water systems are easy to zone or break into separate heating circuits or areas. The two primary ways to provide for zone control are multiple zone valves with one circulator or individual circulators for each zone.



Figure 13-25:
Electric zone valves



Zone valves are 24 volt valves that provide control to either a circuit or piece of radiation. Figure 13-25 shows zone valves. They can also be of the nonelectric type installed on each piece of radiation. Combinations of these two types can be very effective and provide positive, efficient and inexpensive total comfort control.

For more information on hot water heating systems, see NORA's publication *Advanced Hydronics*, available at noraweb.org/advanced-study-manuals

Part III

Steam heating systems

Just like hot water boilers, steam boilers are heat exchangers that use the heat from the flame to heat water. A key difference is that steam boilers are only partially full of water, so that when the water is heated it turns to steam and expands by 1,700 times. It is this expansion that pushes the steam into the heating system. All that needs to be done, is to get the air that is in the system out of the way and the steam will rush in.

Steam pressure

The job of steam pressure is just to overcome the friction that steam meets as it works its way around the system. Enough steam pressure must be supplied by the boiler to overcome the system piping friction. The pressure needed is remarkably low, less than 2 PSI in a typical residential system. Raising the pressure higher than 2 PSI will cause problems.

Steam is compressed when pressure is raised. When steam is compressed, it takes up less space. It also begins to move more slowly. It takes longer for high-pressure steam to get out to the heat emitters than it does for low-pressure steam. Also,

high-pressure steam, since it's more tightly packed, will take more water out of the boiler than low-pressure steam. This can lead to low-water problems back at the boiler.

Steam travels through a system because of a subtle difference in pressure. Besides friction, the condensing of the steam in the heat emitters also leads to a difference in pressure throughout the system. Since all the air vents are open when the system is idle, the inside of the piping system is at atmospheric pressure and steam begins to move from the higher pressure in the boiler to the lower pressure in the system.

As soon as steam begins to move, it also begins to condense into water. When steam condenses it leaves a partial vacuum in its place. Since steam occupies about 1,700 times the volume of water, when it condenses it shrinks to 1/1700th of the space it occupied as steam. This creates a partial vacuum that makes the steam travel to the heat emitters. This is why circulators aren't needed to move steam. The boiler's job is simply to get steam (a gas) out to the last heat emitter before it condenses into water (a liquid.)

The importance of the piping around the boiler

Today's replacement steam boilers typically contain much less water than the boilers they replace. As boilers became smaller, the piping around them became more and more important. For a replacement boiler to work properly, careful attention must be paid to the boiler manufacturer's piping instructions.

Here are a few of the things the boiler manufacturers generally specify:

- Allow at least 28 inches between the center of the gauge glass and the bottom of the steam header

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- Use full-size risers to the header
- Pipe the system take-offs at a point between the last riser to the header and the equalizer
- Pipe swing joints into the header
- Use a reducing elbow to connect the header to the equalizer

The dimension labeled “A” in Figure 13-26, represents the distance that must be maintained between the center of the gauge glass and the bottom of the lowest dry return in the system.

Dimension “A”

In one-pipe systems “Dimension A” must not be less than 28 inches. “Dimension A” provides the force that puts the condensate back in the boiler. Without it, water will back up into the horizontal piping and block the take-offs to the heat emitters.

New steam boilers must be skimmed

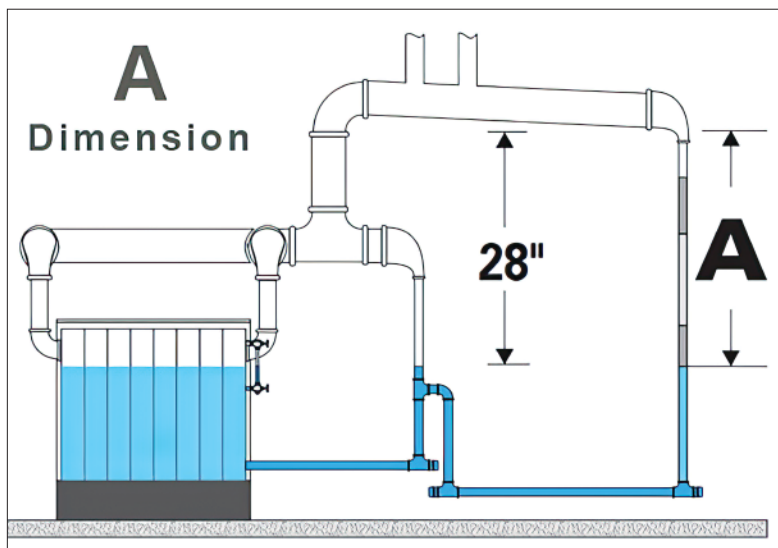
The waterside of steam boilers must be cleaned after installation to remove substances that can cause foaming and surging of boiler water. It often pays to let the system run for a few days before cleaning to let the

cutting oil and dirt have a chance to settle on the surface of the water, Figure 13-27. Skimming the boiler is the best way to remove cutting oil, grease, sludge, etc., from the system. It includes:

- Using (or inserting) a 1¼" or larger nipple into a horizontal tapping above the waterline
- Raising the waterline to the level of the nipple
- Draining water slowly until it runs clear and clean



Figure 13-26:
One-pipe system
“Dimension A”



Before skimming or cleaning any boiler, check the manufacturer’s instructions for their recommendations.

One-pipe steam system

One-pipe steam takes its name from the single pipe that connects each radiator to the steam main. Both steam and condensate travel in this pipe, but in opposite directions. This is what often makes one-pipe steam so difficult to manage. When steam and condensate travel in opposite directions, close attention must be paid to the size and pitch of the pipes; the pitch must be at least one inch for every twenty feet.

See Figure 13-28 for the layout of a one-pipe steam system.

When replacing a steam boiler be sure to maintain the pitch of all the piping. If the piping is improperly pitched heat emitters/piping can bang and air vents can spew water and steam.

Relief valve

The relief valve protects the boiler against damage caused by high pressure. On steam boilers the relief valve is set to open at 15 PSI.

Gauge glass

The gauge glass shows where the water is in the boiler. Expect to see some minor movement in the water line. Anything between a half and three-quarters of an inch of up-and-down movement is normal.

Automatic water feeders

An automatic water feeder is sometimes installed to maintain a safe minimum water level. While it is not essential to the system's operation, an automatic water feeder is a useful back-up safety device.

Main vents

Install main vents near the ends of every main so steam will travel very quickly to every radiator in the building. If the main vents are working properly, steam will arrive at each radiator at about the same time.

For more information on steam heating systems, see NORA's publication *Advanced Steam*, available at noraweb.org/advanced-study-manuals/

Part IV

Domestic hot water

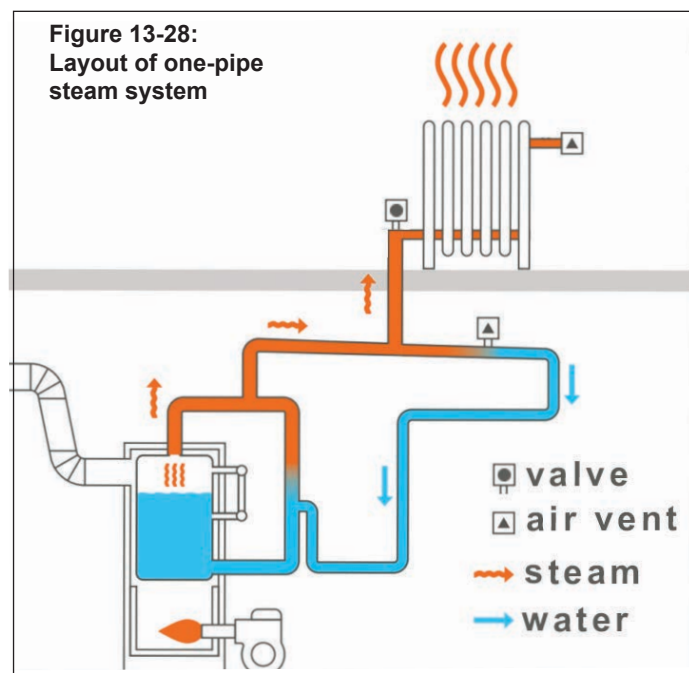
Fuel-fired appliances offer an excellent way to heat domestic hot water for use in showers, baths, lavatories, clothes washing and dishwashers. The production of reliable, inexpensive and efficient domestic hot water provides for the health and comfort of customers and is one of our industry's strong points.

Domestic hot water systems fall into two major groups, direct and indirect.

A direct system is one in which the water is heated directly by the heat from the flame. There is combustion gas on one side of a heat exchanger and domestic water on the other.

With indirect systems boiler water is used to heat domestic water.

There are two types of indirect systems: the storage system, where the water is heated and stored for later use in a tank and the instantaneous or tankless system, where the water is heated as it is drawn to the fixtures.



Audio
34:42

Direct fired water heating

Direct fired water heaters use a tank, which sits over a combustion chamber and is surrounded by insulation and an outer casing. A burner fires into the combustion chamber under the tank and the hot combustion gases heat the water in the tank.

There are two designs of water heaters: the *rear flue heater* where the gases pass around the tank and vent out the back of the heater, as shown in Figure 13-29, and the *center flue heater* where the gases pass through a freeway in the center of the tank and vent off the top of the heater as shown in Figure 13-29.

Oil-fired direct water heaters are typically glass lined steel tanks that are constructed of steel and coated on the inside with a ceramic material. This coating helps protect the tank from rusting and corrosion. However, the ceramic material is not impervious to water and an anode or “sacrificial” rod

made of magnesium is immersed into the tank water. This rod will break down and give itself up to protect the tank from the corrosive properties of the air and chemicals present in the water. These anode rods should be checked routinely and replaced when necessary.

Indirect fired water heating

There are a variety of indirect water heating systems:

Tankless coils. There are two types of tankless coils used to generate domestic hot water. They offer the least initial expense, and least efficient, means of generating domestic hot water with a fuel fired appliance.

1. Internal tankless coils are made of thin copper tubing attached to a steel mounting plate. The coil is placed into the water and/or steam jacket of a boiler, and the coil plate with a gasket is then bolted to the boiler shell. This system requires that boiler water temperature be maintained high enough to heat the water as it passes through the coil. There is no storage capacity in this system, and during heavy draw it is unable to provide enough hot water due to its limited capacity. See Figure 13-30.

2. External tankless coils are steel tanks with a coil inside. See Figure 13-31. Boiler water is piped to the tank and it is kept hot by gravity or forced flow circulation.

Tankless coil with a storage tank

This system, often called an aqua-booster, is a combination of a storage tank and an internal tankless coil. It provides much more domestic hot water than a tankless coil alone.

Figure 13-29

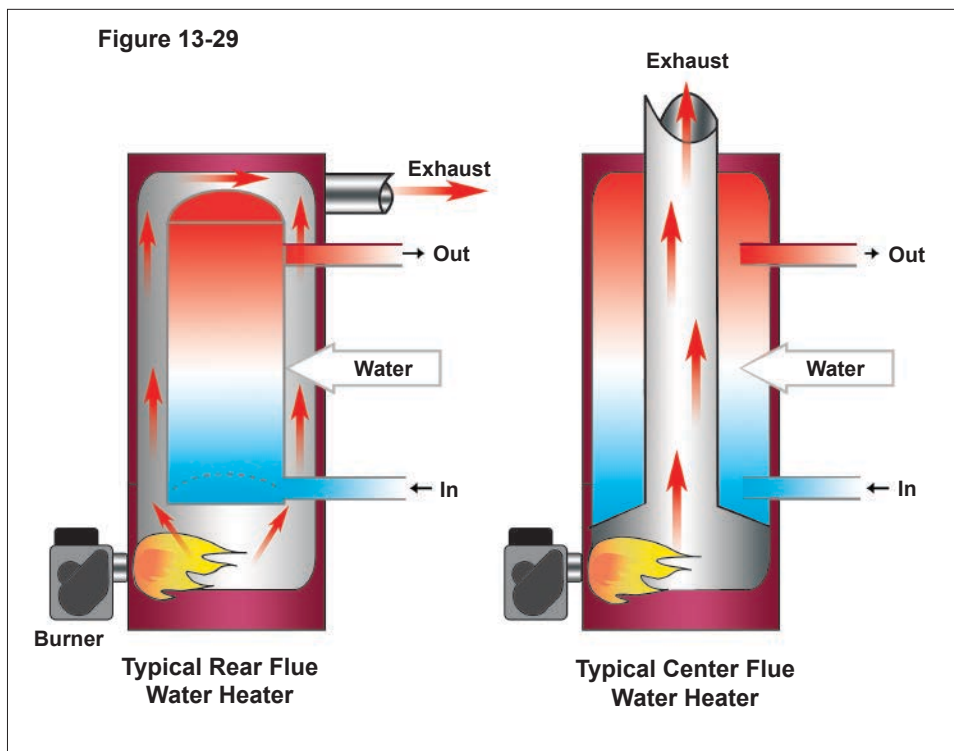
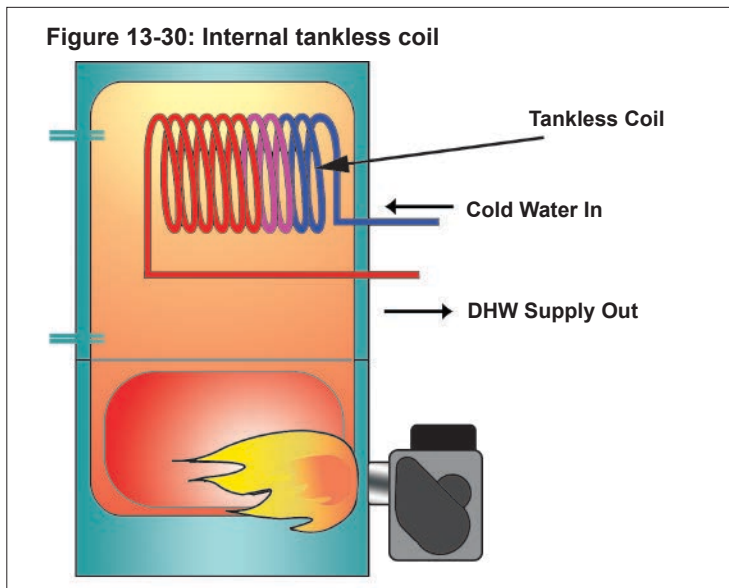


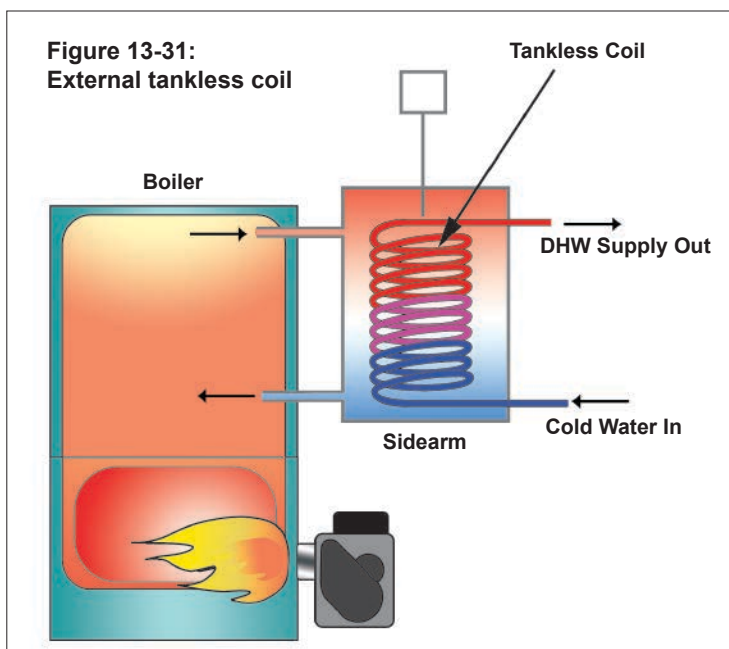
Figure 13-30: Internal tankless coil



Water is heated by the coil and stored in the tank. The tank temperature is maintained by a recirculation loop that allows the water to go back to the coil by forced circulation. Forced circulation is maintained by a non-corrosive circulating pump usually made of bronze or stainless steel. The temperature in the tank is controlled by an aquastat installed in the tank. See Figure 13-32, following page.

External flat-plate heat exchangers. Many new systems feature an updated, much more efficient version of the external tankless coil called a flat plate heat exchanger. It is made of a series of wafers or plates with internal porting. The plates alternate between boiler water and domestic water. See Figure 13-33. These devices can be used either stand alone or in conjunction with a storage tank.

Figure 13-31:
External tankless coil

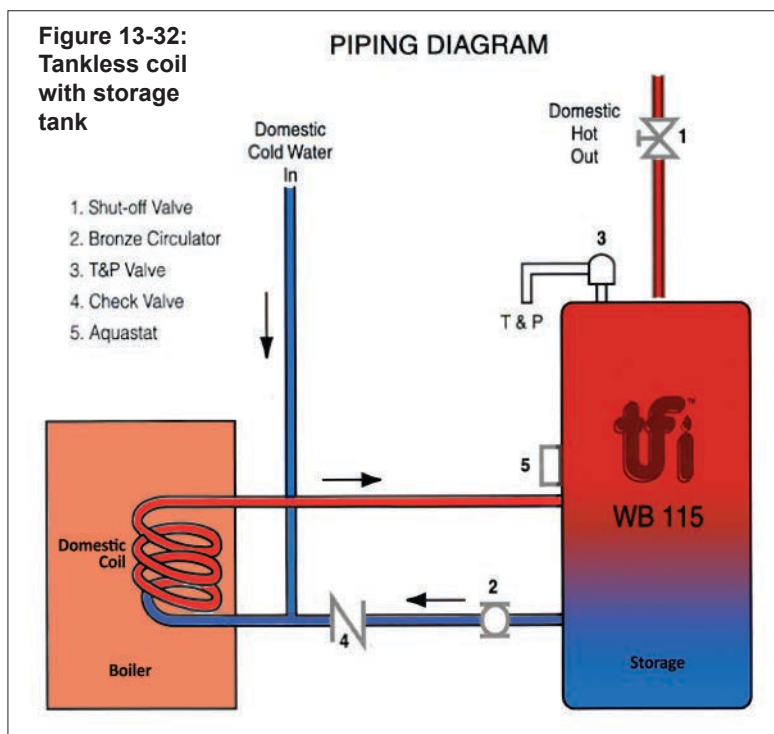


Indirect-storage type water heaters

The indirect-storage type heater also called a “coil-tank” or “indirect fired unit” is a storage tank with a coil of copper inside. The domestic water surrounds the coil and is heated by the boiler water that is circulated through the coil. They are piped and controlled the same as an additional zone to the heating system and may be used on both hot water and steam systems.

Figure 13-33:
External plate heat exchangers





Relief valves: All water heaters with storage capability must have a temperature/pressure (T&P) relief valve that is spring loaded, which will discharge water (relief) if the temperature and/or pressure in the tank become too high. The valve must be installed into the tank water directly so it will adequately sense the temperature in the tank.

There should never be any type of shut-off devices installed on either the inlet or outlet side of the valve. There should also be a blow off line installed on the outlet side of all pressure type valves to direct the hot water to a safe location, 6" off the floor, to avoid injury to anyone nearby.

Since boiler water is circulated, a standard circulator can be used rather than a more expensive non-corrosive one. The domestic water temperature is controlled by an aquastat that turns the circulator and burner on and off. Although these units are more expensive than tankless coils, their excellent warranties, improved efficiency, and high recovery rates make them very popular. Figure 13-34 shows an indirect storage type water heater.

Water heater components

A water heater is a closed vessel, filled with water, normally under city water pressure. When the tank is heated, the tank must contain and store two forms of energy: heat and pressure. If the city water pressure is lost, the tank must also be protected against excess vacuum.

Vacuum relief valves: Some manufacturers and local authorities require protection from a vacuum being exerted onto the tank. If a vacuum occurs, the vacuum relief valve automatically vents the closed system to the atmosphere and allows air to enter and prevent conditions that could damage the water heater.

A mixing (aka tempering) valve is used to control the temperature of the water being delivered to the fixtures. In tankless coil applications, the temperature of the water that has been sitting in the coil immersed in hot boiler water has the potential to scald on an initial hot water draw at the fixtures. As a hot water draw continues, the temperature of the water that has passed through the coil will not be as hot. In order to avoid

the potential for scalding and to balance the temperature of the water supplied during a draw, a mixing valve is used.

A mixing valve has three ports for piping connections, one for the hot discharge side of the water heater, one for a cold water connection, and one for the hot water supply to the fixtures in the house.

The mixing valve is a simple device that contains an element that senses the temperature of the water being supplied from the water heater and then mixes an appropriate amount of cold water to provide domestic hot water at the desired temperature.

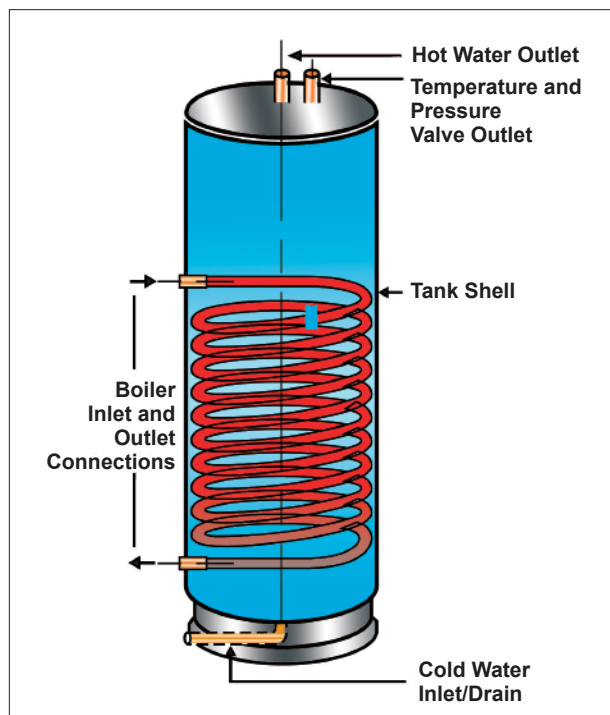
These valves are adjustable so the temperature of the water may be regulated to satisfy individual preferences.

The elements in these valves are susceptible to liming from the minerals in fresh water and require periodic replacement. Rebuilding kits are readily available. When installing a mixing valve, follow the manufacturers instructions. Some mixing valves may need to be installed at a level of 8"-12" inches below the heater so that they will be protected from a heat build-up while not in use.

The dielectric fitting protects the water heater or storage tank against the galvanic reaction caused by the use of dissimilar metals and stray current corrosion. These fittings come in many sizes, materials and types and can also be used in place of “pipe thread to solder” adapter or union.

Backflow preventers, pressure reducing valves and thermal expansion tanks. Although these items are not always

Figure 13-34: Indirect storage type water heater



present they may be required by local codes or manufacturer specifications. Since the domestic water heater or storage tank is a closed system when a backflow preventer or pressure reducing valve is installed, it should be protected by an expansion tank specifically designed for the purpose. These expansion tanks should always be installed on the cold water line, before the tank but after all service valves and pressure reducing devices.

The use of these tanks will prevent nuisance relief valve discharges and premature water heater failures due to excess pressure build-up.

Chapter 13: Additional Resources

NORA has compiled a library of additional technical resources for your continued education. Scan the QR code or go the the web address. Check back often as NORA will continually add content as it becomes available.



You will find:

- Videos
- Technical Bulletins
- Instructions
- and More

https://Learning.NORAweb.org/heating_systems