# 4. Controls and safeties

## Overview

### Purpose

All gas burners are under control in some way—either manually or automatically. This Chapter identifies various controls that gas technicians/fitters use to either regulate the medium being heated or ensure maximum safe limits.

### Objectives

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

- describe various controls and safeties.

### Terminology

| Term | Abbreviation (symbol) | Definition |
|---|---|---|
| Aquastat | | Device that controls water temperature in hydronic heating systems |
| Flame roll-out switch | | High temperature limit switch wired to the burner ignition control that de-energizes the gas valve if it sensed flame roll-out |
| Flow switch | | Ensures that the pumps are circulating water in the piping system and the boiler before the main burner can fire |
| Pressure relief valve | | Mechanical valve used on hot water boilers |
| Pressuretrol | | Operating steam pressure switch on a steam boiler |
| Unitrol | | Multipurpose valve typically installed in hot water heaters |

## Various controls and safeties

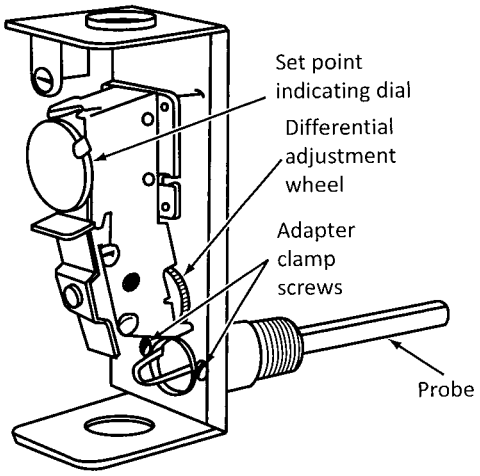
The safety controls described below are wired in the control circuits of various appliances. Changes in temperature, fluid movement, or pressure actuate them.

# Operating aquastat

The *operating aquastat* acts in response to a change in water temperature. It is a normally closed switch (break on rise) that controls the temperature of the water inside a boiler. For example, if you set the aquastat at 180°F (82 °C), the contacts remain closed until the water reaches this temperature. At this point, the contacts open and cut off power to the main gas valve. The water cools several degrees before the contacts close again.

Figure 4-1 shows a direct-mounted operating aquastat with horizontal probe.

**Figure 4-1**
**Direct-mounted aquastat with horizontal probe**

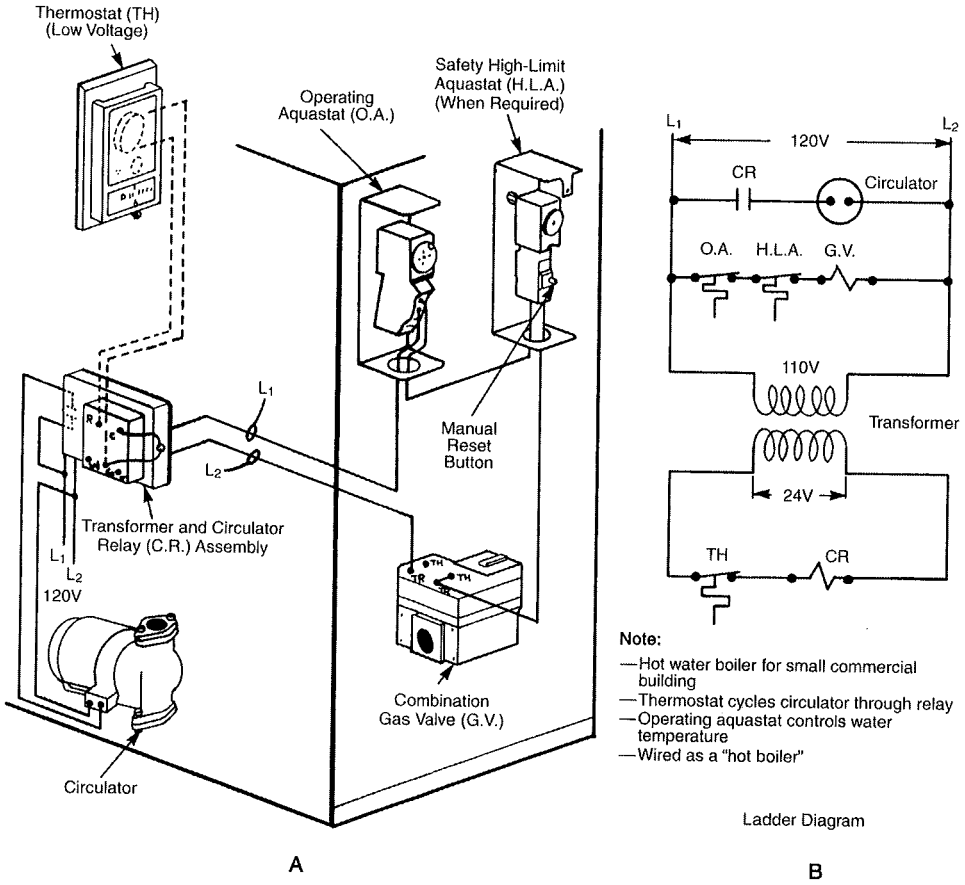



# High limit aquastat

The high limit aquastat is identical to the operating aquastat but is adjusted to a higher water temperature setting (commonly 20°F above the operator). It serves as a backup safety switch in case the operating aquastat fails. You can mount the two aquastats side by side. In some cases, you consolidate them into one component and even make them share a single sensing element.

Some models come with a manual reset device. For example, if the water temperature reaches 200°F (93 °C) and the contacts open, you must manually reset the switch for the contacts to close again.

**Figure 4-2**
**Basic Electrical Control system for a small commercial hot water heating boiler**

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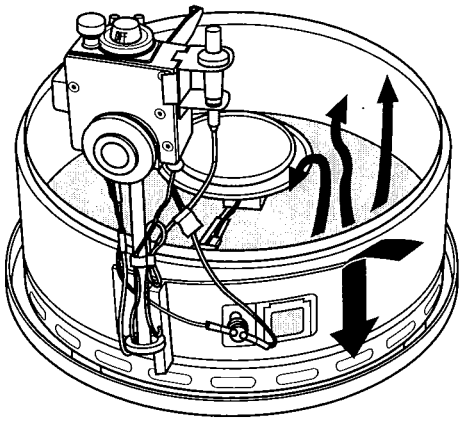
# Unitrol

The Unitrol (see Figure 4-3) is a multipurpose valve that people typically install in hot water heaters. It contains in one compact Unit:

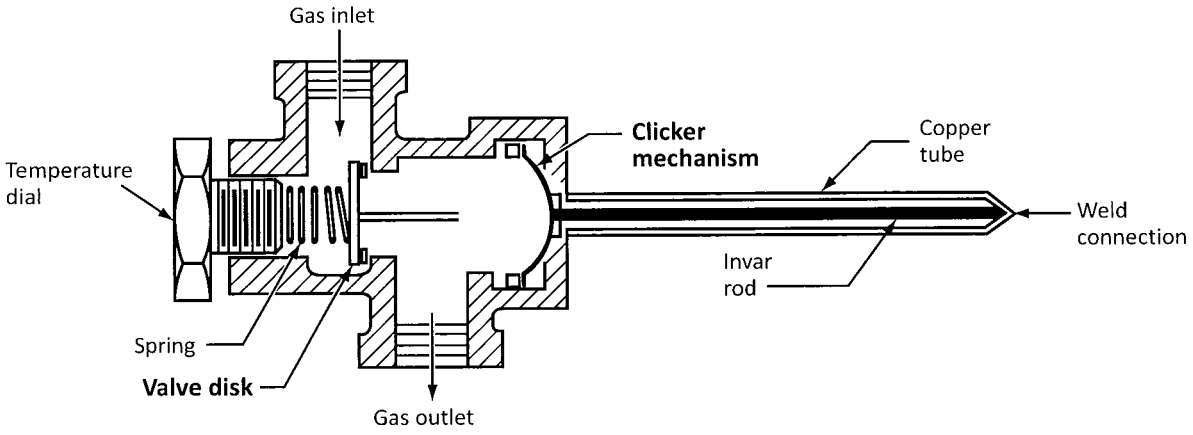
- thermostat;
- automatic gas shut-off valve;
- over temperature energy cut-off (ECO) device;
- main pressure regulator; and
- main and standby gas valve.

**Figure 4-3**
**Unitrol multipurpose valve**



The Unitrol acts in response to changes in water temperature. Its sensing device works on either the rod and tube principle (see Figure 4-4) or the bulb and bellows principle (see Figure 4-5).

**Figure 4-4**
**Non-electric gas valve using rod and tube principle**

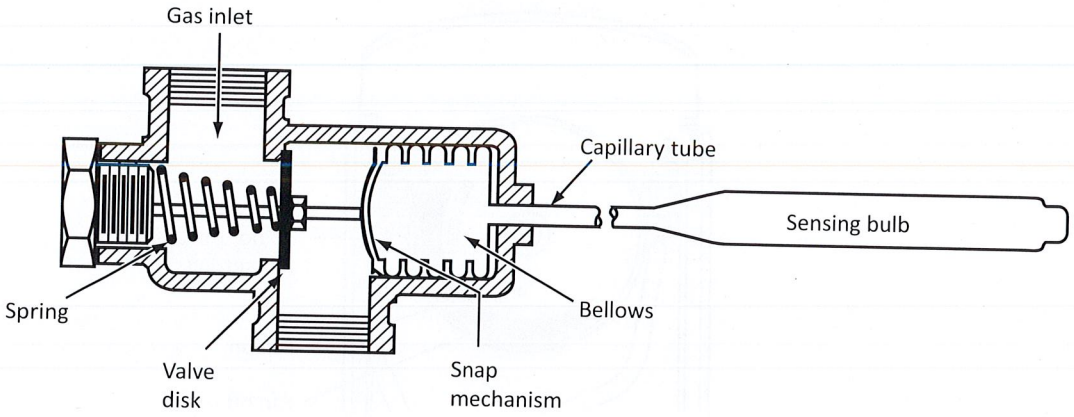



When exposed to temperature change, different metals have different rates of expansion or contraction. The rod and tube thermostat use the expansion differential of a metal rod and a dissimilar metal tube to operate an electrical switch (or mechanism) controlling a gas port.

The rod is inside a tube and the two bond together at one end (see Figure 4-4). Since the tube is made of a metal having a greater expansion rate than the rod, it expands or contracts more when both are exposed to the same temperature changes. As the tube expands or contracts, the rod, which has less of an expansion rate, decreases or increases its tension on a switching device controlling the electrical circuit of the primary control or a mechanism directly controlling the opening or closing of the main burner gas valve port.

You can also employ a bulb and bellows temperature sensor for the same purpose in a capillary-operated gas valve. See Figure 4-5.

**Figure 4-5**
**Capillary-operated gas valve**



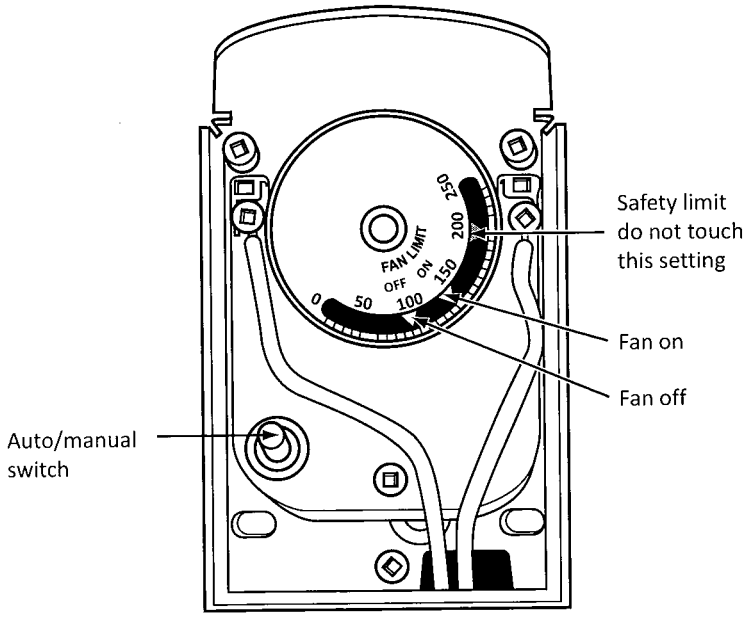

The force that results from the expansion of liquids or gases within a sealed capillary helps operate an electrical switch or a mechanism to open or close a gas port. A bulb at one end of the capillary senses the temperature of the surrounding water or air. At the other end of the capillary, an attached bellows reacts to the pressure within the capillary by expanding or contracting. The action of the bellows is what you use to operate a switching device (completing or interrupting the electrical circuit to the equipment's primary control) or a mechanism that controls the gas valve outlet (opening or closing the valve port supplying gas to the main burner). See Figure 4-5.

## Combination high-limit/fan control switch

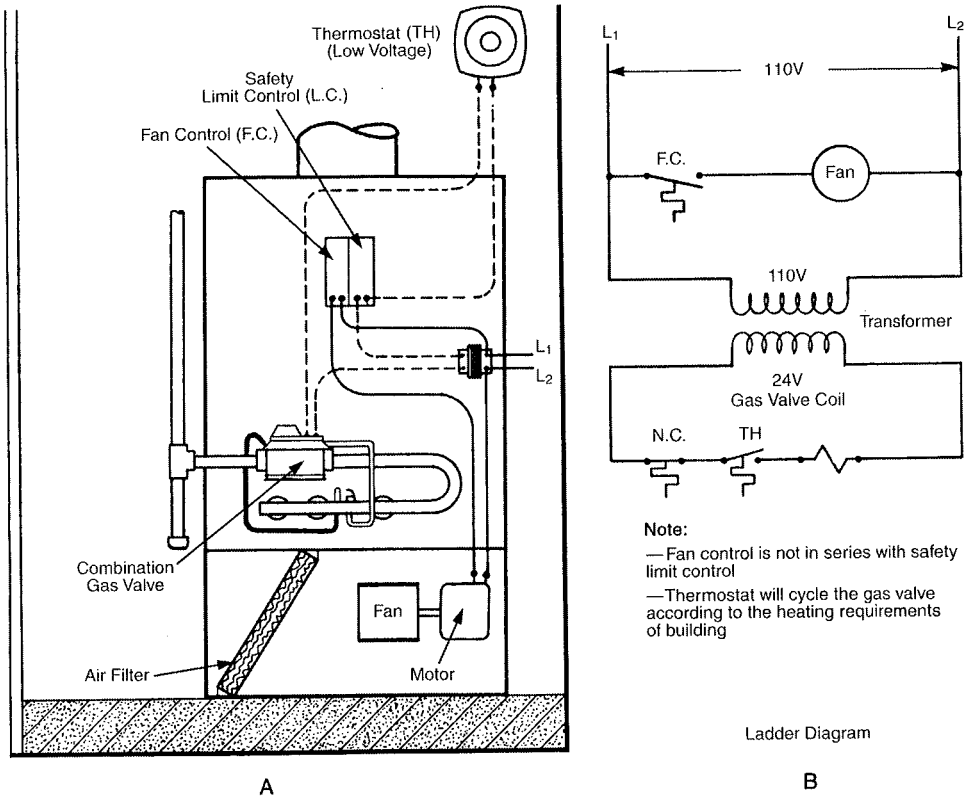
A combination high-limit/fan control switch is what you use on air heating systems to sense air temperature. The combination high-limit/fan control contains a normally open fan switch on the left side and a normally closed high limit switch on the right side (see Figure 4-6). A jumper connects the same power source to the two switches.

As the temperature rises, the bimetal strip first closes the fan switch and start the blower. If an overheating condition occurs, the bimetal strip continues to warp until the limit cut-out temperature is reached (around 200°F) and then opens the limit switch.

## Figure 4-6
## Combination high-limit/fan control add control




## Figure 4-7
## Control Circuits for a residential warm air furnace



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When the limit switch is open, the transformer circuit is interrupted. This de-energizes the control circuit, causing the main gas valve to close. Meanwhile, the fan continues to run until the fan switch cools and opens.

Many fan operations on new equipment are under the control of the electronic control board and operate on a time delay function. Rather than sensing for temperature rise, these Units bring on the circulation blower after a predetermined timeframe anticipating that the furnace is now up to temperature.

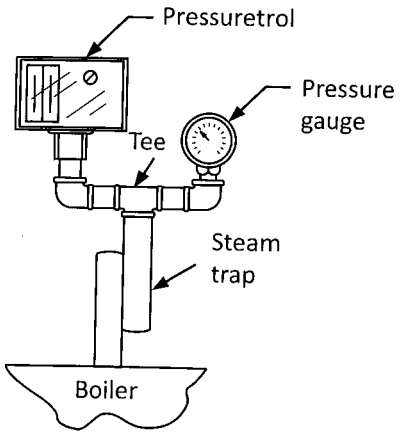
## Operating pressure switch

A pressure switch acts in response to changes in water, steam, air, or gas pressure. You can find it on steam boilers, water boilers, as well as on combustion blowers for gas burners.

Operating steam pressure switches on steam boilers are what you call pressuretrols (see Figure 4-8). As steam pressure in the boiler rises and reaches the set point of the pressuretrol, the switch contacts open and de-energize the power to the main gas valve.

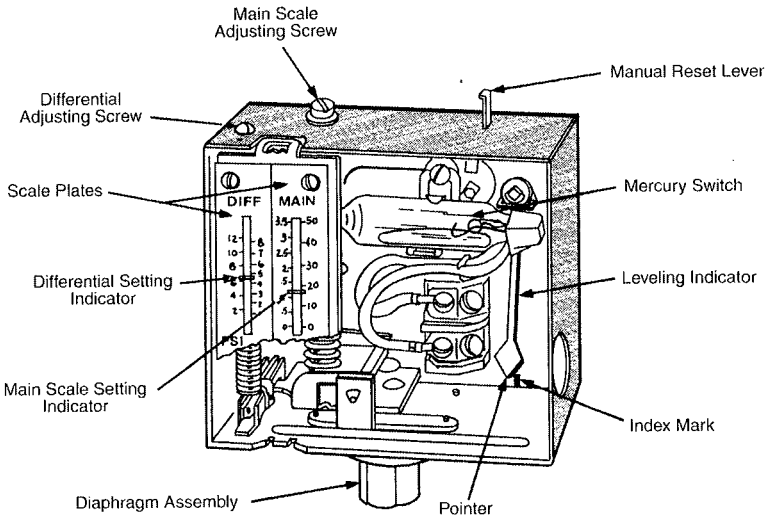
For example, if you set the pressuretrol to 3 psig (21 kPa), the contacts stay closed until the steam pressure reaches 3 psig (21 kPa). Once it has reached this pressure, the contacts open and cut off power to the main gas valve. The contacts close again when the steam pressure reaches the low point setting.

**Figure 4-8**
**Pressure switch senses change in steam pressure**




The high and low set points on the operating pressuretrols are adjustable, as are the differentials.

**Figure 4-9**
**High-Limit Pressure Control with manual reset lever**



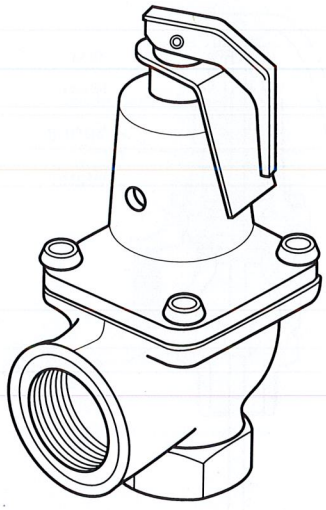

## High-limit pressure switch

A *high-limit pressuretrol* works exactly like an operating pressuretrol, except that you adjust it to a higher-pressure setting. Some models come with a manual reset device.

## Pressure relief valve

The pressure relief valve is a mechanical valve that controls pressure on hot water boilers. If pressure in the system rises above the set point, the valve opens and dumps water until the pressure drops to an acceptable level.

**Figure 4-10**
**Pressure relief valve**

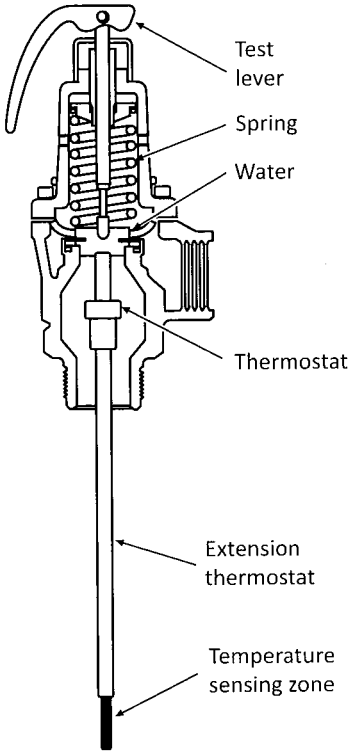


**Source:** *OCB Supplement*

## Combination pressure–temperature relief valve

Some local and national codes require the installation of storage water heaters with a combination pressure-temperature relief valve (see Figure 4-11). The sensing stem of this valve extends into the water within the top six inches of the tank. It opens to dump water if the tank pressure or water temperature is excessively high. Whenever a water heater is replaced, you should install a new valve and discard the old valve.

**Figure 4-11**
**Combination pressure-temperature relief valve**




*Note that you must pipe the discharge of relief valves without restrictions or reductions in diameter to an air gap as per local Building Codes. It must also be of a material suitable of withstanding the potential discharge temperatures.

## Low water cut-off switch

The low water cut-off switch is what you use on all steam boilers and hot water boilers over 400 000 Btu/h or where any part of the heating system is below the boiler and it acts in response to fluid loss. If the water level in the boiler falls below the minimum level, the low water cut-off switch opens its contacts and cuts off power to the main gas valve.

There are two types of low water cut-off switches:

| Type | Description |
|---|---|
| Float type | This is a normally open switch that the float on top of the water (see Figure 4-12) holds close.<br><br>If the water level falls below a predetermined point, the float mechanism lowers and breaks the electrical contact. |
| Probe | This is a normally open switch. It has an electronic circuitry that uses boiler water to conduct current between the terminals on the end of the probe. See Figure 4-13. |

| Type | Description |
|---|---|
| | If the water falls below the level of the probe, the electronic circuit between the terminals is broken. In response to no circuit, the low water cut-off switch opens, cutting off power to the main gas valve. |

**Figure 4-12**
**Float-type low water cut-off switch**

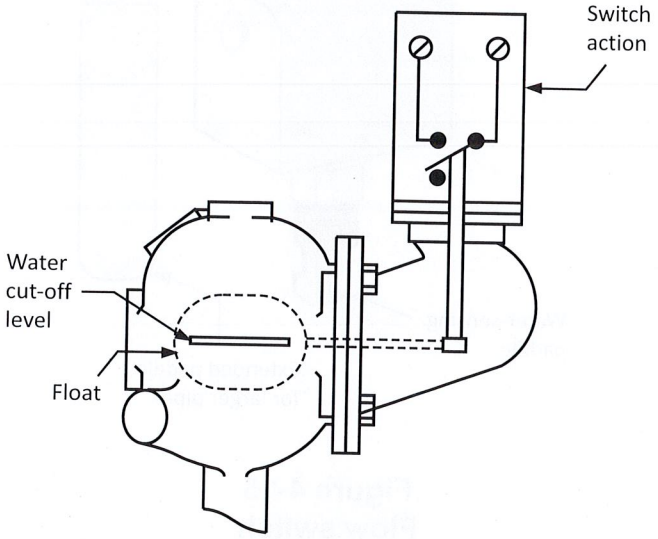
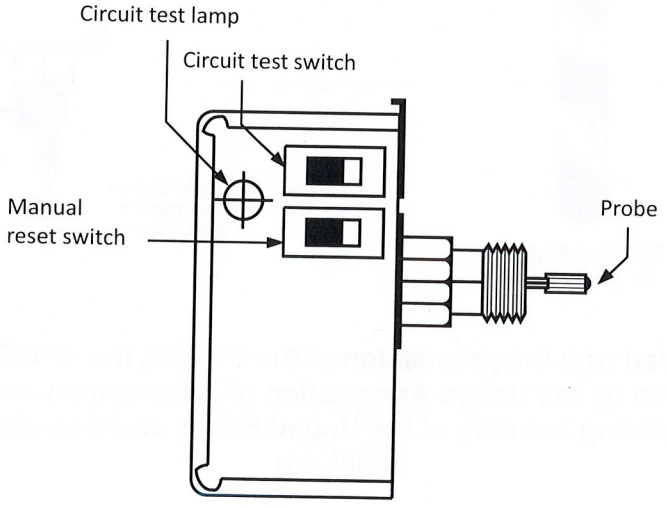



**Figure 4-13**
**Probe-type low water cut-off switch (top view)**




## Flow switch

Flow switches act in response to water movement (see Figure 4-14). They ensure that the pumps are circulating water in the piping system and the boiler before the main burner can fire. Boilers

that require flow switches have small water capacities and their water may turn to steam if the flow of water is inadequate.

**Figure 4-14**
**Flow switch that senses water movement**

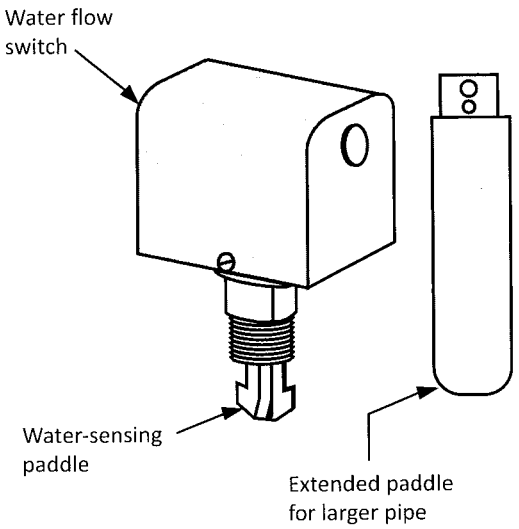
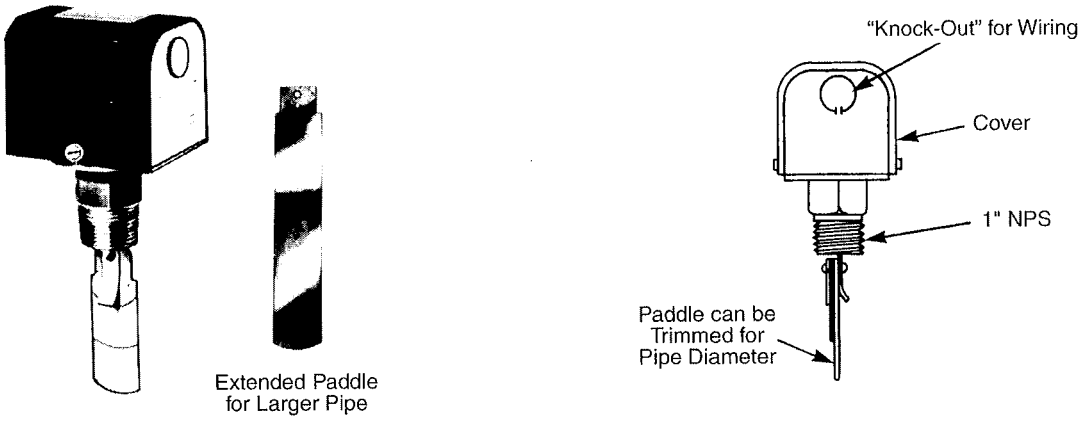



**Figure 4-15**
**Flow switch**

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## Air flow switch

Two common types of air flow switches are:

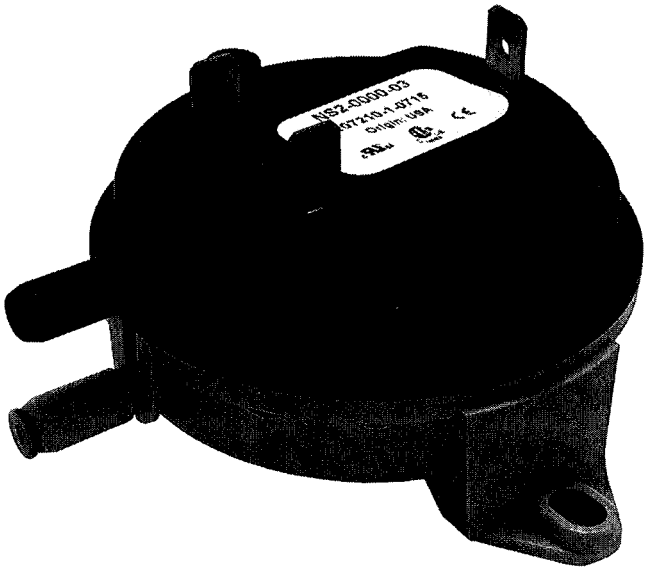
- the sail switch, which works similarly to a flow switch, except that it acts in response to the movement of air rather than water; and

- the pressure differential switch senses air flow by the differential of pressure across its sensing mechanism.

You use these switches in applications that require proving of air flow, e.g., for sensing combustion air or flue gas flow on any appliance that incorporates a fan or blower or in the case of the pressure differential switch, for sensing the venting action of a high-efficiency furnace (see Figure 4-16).

A blocked vent, faulty heat exchanger or even a blocked drain tube could cause the pressure switch to activate and shut furnace operation down.

**Figure 4-16**
**Differential air proving pressure switch**
**Image courtesy of Terry Bell**

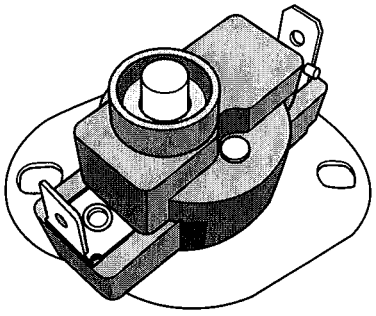


## Flame roll-out switch

The flame roll-out switch (see Figure 4-17) is a high temperature limit switch wired to the burner ignition control. If it senses flame roll-out, it opens and de-energizes the gas valve. This is a manually reset switch.

A failure to vent the flue products from the combustion chambers or a heat exchanger failure usually causes flame roll-out. If the burner flame is trapped or disturbed in the heat exchanger, the flame may flash back or roll outside of the combustion chamber area, potentially causing a CO or fire hazard.

**Figure 4-17**
**Bimetal roll-out switch**



## Blocked vent shut-off system

When furnaces have draft hoods, you may equip them with a shut-off system that automatically cuts out the main burner when the vent is totally blocked. These shut-off systems are commonly —and incorrectly—referred to as *spill switches*. Furnace certification standards specify test methods for these systems. Similar to the flame roll-out switch, they are temperature sensing, manual reset switches wired in series to the gas valve function.

## Electronic control module

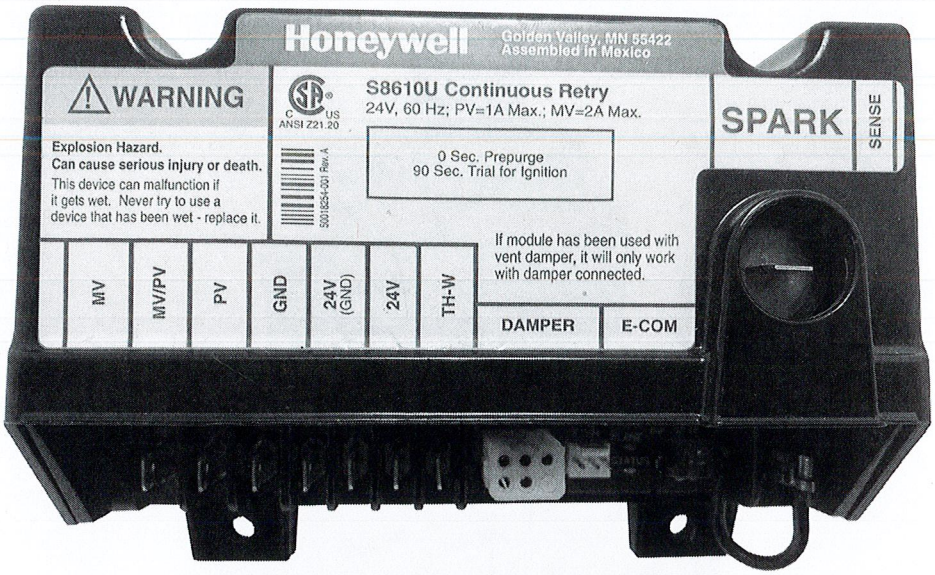
The brain of most modern furnace electronic ignition systems uses an integrated circuit board to control many sophisticated processes. These integrated controllers can also perform self-diagnostics providing various failure codes.

The integrated circuits continuously monitor the furnace's operation and the operation of the integrated control module itself. If a failure occurs, LEDs can indicate a failure code. The Owner's Manual and the furnace door provide the codes.

You always find these integrated controllers on higher efficiency furnaces that rely on many sophisticated design features to reach their high AFUE ratings of over 90%.

The control module monitors furnace operation and, if the safety circuits are open, the gas furnace control board detects this and locks the system out for a specific amount of time. After this time delay, the control board tries again for ignition unless the safety circuit is open. The board stays in lock-out mode until a gas technician/fitter resolves the problem.

**Figure 4-18**
**Control module**
**Image courtesy of Terry Bell**



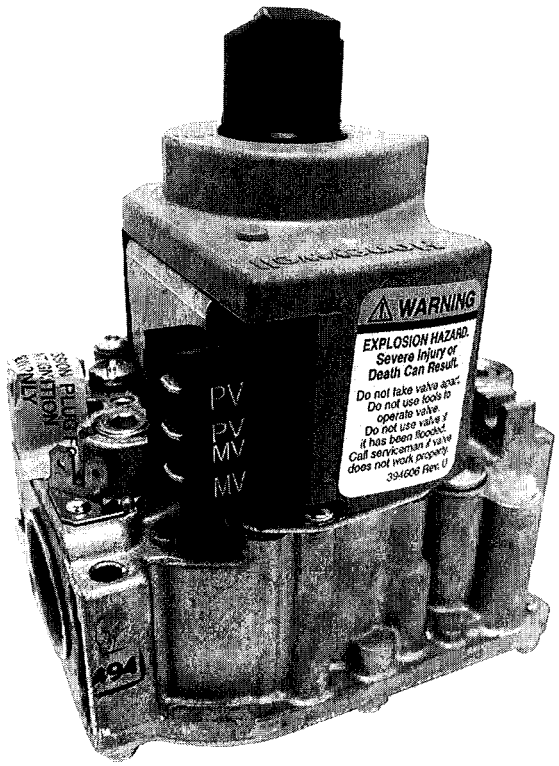

## Gas control valve

Gas control valves come in many different models for many differing applications. Constant pilot, intermittent pilot, and direct ignition models provide the control of pilot and main burner gas to appliances to allow for safe ignition and controlled delivery of gas to burners.

The gas control valve (see Figure 4-19) consists of:

- a regulator or zero governor to reduce gas pressure or control gas flow;
- one or two automatic gas shut-off valves;
- a manual shut-off valve that may direct gas flow only to the pilot line (if so equipped);
- a means of controlling the flow rate to the pilot line (if so equipped)—usually by means of a needle valve; and
- tests ports to measure inlet and outlet pressure.

**Figure 4-19**
**Gas control valve**
**Image courtesy of Terry Bell**




## Wireless controls

Hard-wired connections between thermostats and furnaces have many limitations that you can now overcome with the use of wireless technology. Wireless thermostats allow for temperature control in one or more locations during retrofits or new construction projects.

Most wireless systems include a remote sensor thermostat and sensor along with the option of multiple remote controllers.

# Assignment Questions – Chapter 4

1) What is the purpose of an operating aquastat?
   a) To maintain water pressure in a boiler system.
   b) To ensure water flow.
   c) To energize or de-energize the main gas valve in response to the water temperature.

2) Is the temperature setting of a high-limit aquastat higher or lower than the setting of the operating aquastat?
   a) Lower
   b) Higher
   c) The same