

COMBINATION GAS CONTROLS

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INTRODUCTION

Gas is the most popular fuel for heating homes in America. Well over 40 million homes across the country use gas as their source of heat. About 2 million new gas furnaces and approximately 150,000 gas boilers are sold in the U.S. every year. Almost 60% of new single family homes built have gas heating.

While it takes a great variety of equipment to control all the different gases and different applications, the *functions* required for safe, automatic operation are remarkably similar.

GAS BURNER CONTROL FUNCTIONS

The purpose of all gas burner controls is to ensure that the furnace or heater will be safe for the people who depend upon it for comfort and convenience. So we find that there are a handful of basic things or functions that must be accomplished in almost any gas heating appliance. These functions are:

Manual shutoff-- Required in the gas line that feeds the burner. The valve in the main burner is sometimes called the "A cock" as opposed to the pilot gas manual shutoff which is called the "B cock."

Pressure regulation--To maintain the specified firing rate, gas must be delivered to the manifold of the burner at the correct pressure.

Ignition --This function is essential to combustion. There are several methods of accomplishing ignition in modern gas heating equipment:

1. Standing pilot systems have a pilot burner that is on all the time.
2. Intermittent pilot systems light the pilot on each call for heat. After the pilot is proved to be burning, the main burner is lighted.
3. Direct burner ignition control lights the main burner directly without a pilot. This is accomplished by a spark or hot surface igniter.

Safety lockout--If ignition cannot safely occur, or the burner flame fails for any reason, the gas supply to the pilot or burner must be shut off.

Automatic ON-OFF control--Automatic operation is one of the main purposes of most heating control systems. The main burner in a gas heating system must be turned on and off in response to the demand for heat in the home or building.

Over-temperature control--Shuts down the burner when the temperature of the medium (air or water) becomes too high for safe operation.

DEVELOPMENT OF THE MODERN COMBINATION GAS CONTROL

Fifty years ago, the typical residential gas furnace looked much different than what we're used to today. For one thing, there was no combination gas control. All of the gas control functions were done by separate devices. That system might have looked a lot like what you see in Figure 1.

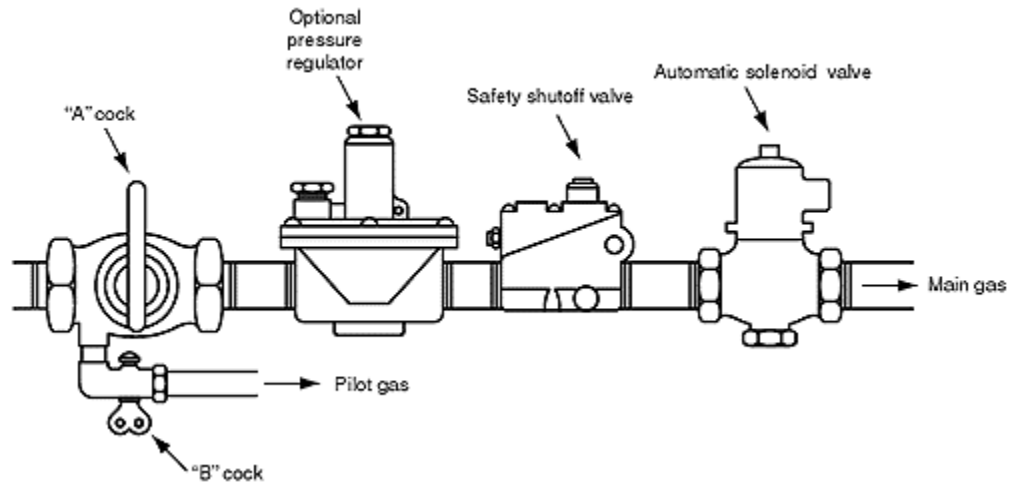


FIGURE 1 — Separate Controls For Each Gas Manifold Function.

The *A Cock* provided manual gas shutoff, and the *B Cock* provided manual pilot gas shutoff.

The *pressure regulator* maintained a fairly uniform outlet pressure to the main burner. Its job was to compensate for variations in supply pressure.

The *safety shutoff valve* is connected to the thermocouple (or thermopile) located so as to use the pilot flame to generate an electrical current. As long as the pilot is lit, the electrical output of the thermocouple holds the safety shutoff valve open, and gas flows to the main burner on a call for heat. If the pilot flame goes out, there is no thermocouple output to hold the valve open, so it closes.

The system shown will not cut off the pilot itself when the pilot goes out as is required on LP gas installations. For LP gas applications, pilot gas must be piped through the safety shutoff valve so that it is also shut off if the pilot burner fails.

The reason behind this difference in requirements relates to the properties of natural gas and LP gas. Natural gas is lighter than air. So the small amount coming from a pilot burner simply vents through the combustion chamber of a natural draft furnace and out the flue. LP gas is heavier than air and will accumulate in the combustion chamber to present a safety hazard.

The *automatic valve* is connected to the thermostat control circuit. When the thermostat contacts close to call for heat, a solenoid type valve permits gas to flow to the main burner. The high limit switch shuts off power to the solenoid if the limit senses too high a temperature.

In the mid-50's we started to see the combination of some of these functions. First the safety shutoff valve and the automatic valve were combined into a single unit. (Figure 2) The resulting combination valve was smaller and less costly. The thermocouple and thermostat connections were made on the combination valve.

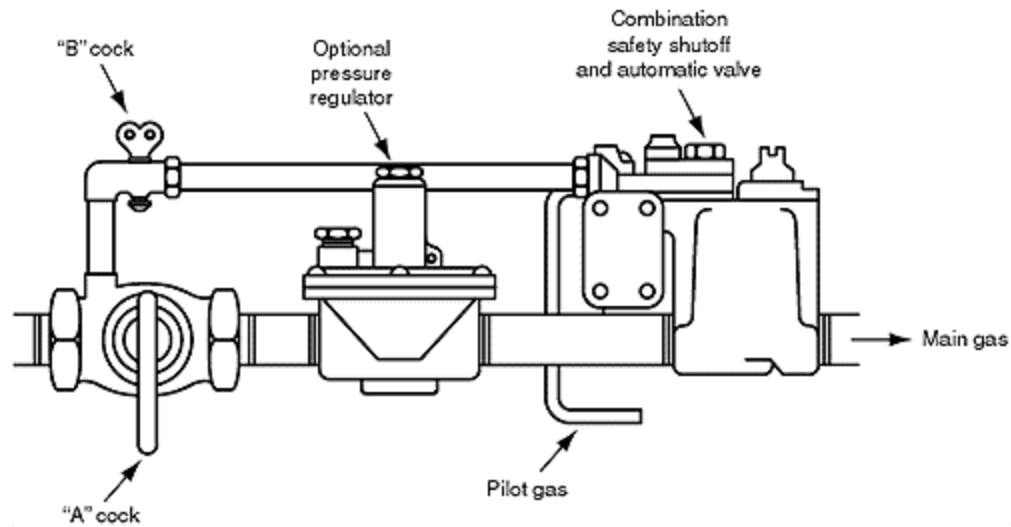


FIGURE 2 — Automatic Valve And Safety Shutoff Valve Combined.

In 1959 the first valve with a built-in pressure regulator valve was introduced. This was the first device that truly merited the name “combination gas control.”

In Figure 3 the functions of the entire manifold were provided by one control. It was made up of a Pilotstat assembly (containing the power unit, pilot gas flow adjustment, and a gas cock), an operator section, the basic valve body, and standard type pressure regulator.

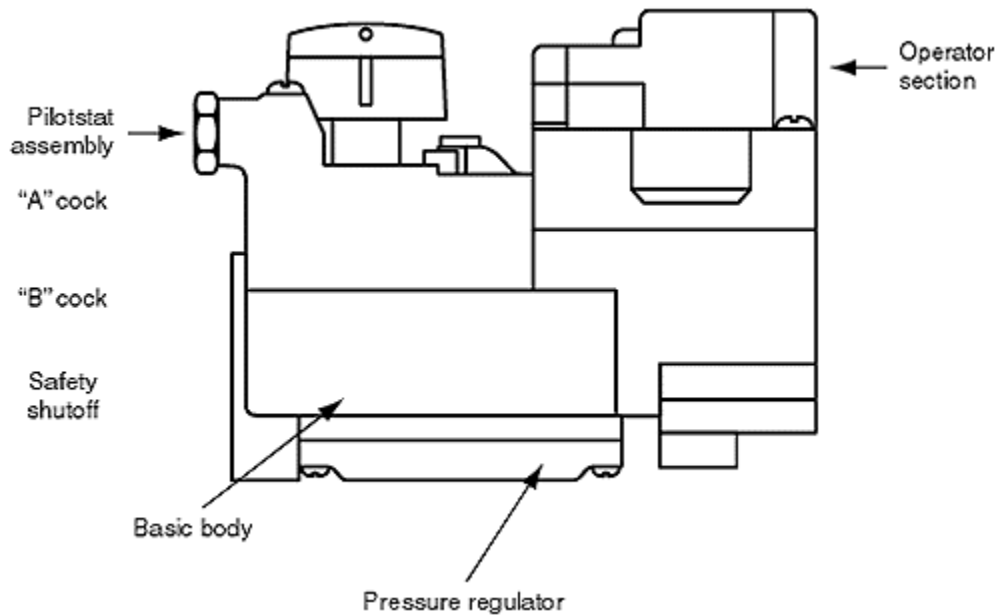


FIGURE 3 — 1959-We Combined In One Control.

This valve featured shutoff of gas to both the main burner and pilot when the pilot failed. In addition, a few of the first CGC's had an optional pilot gas filter. This CGC could be built with all functions or as few as two functions, allowing equipment manufacturers to order CGC's with only those functions they required.

MODERN COMBINATION GAS CONTROL

Today's version of the CGC provides the same basic functions as the one introduced in 1959. (Figure 4) Today's valve however, is somewhat more sophisticated. In addition to the standard functions provided in the first regulator equipped control, the CGC of today may include all (or many) of the following features:

- *Programmed safe lighting* gas cock. The main burner cannot come on while the pilot is being lighted.
- *Servo pressure regulation* provides much better regulation and makes it easier to use the valve for service work where it must work with quite a wide range of firing rates.
- A choice of different types of valve operators for different operating characteristics.
- *Pilot gas filters and flow adjustments* as standard features.
- *Installation adds* to make replacement of other valves more readily accomplished.

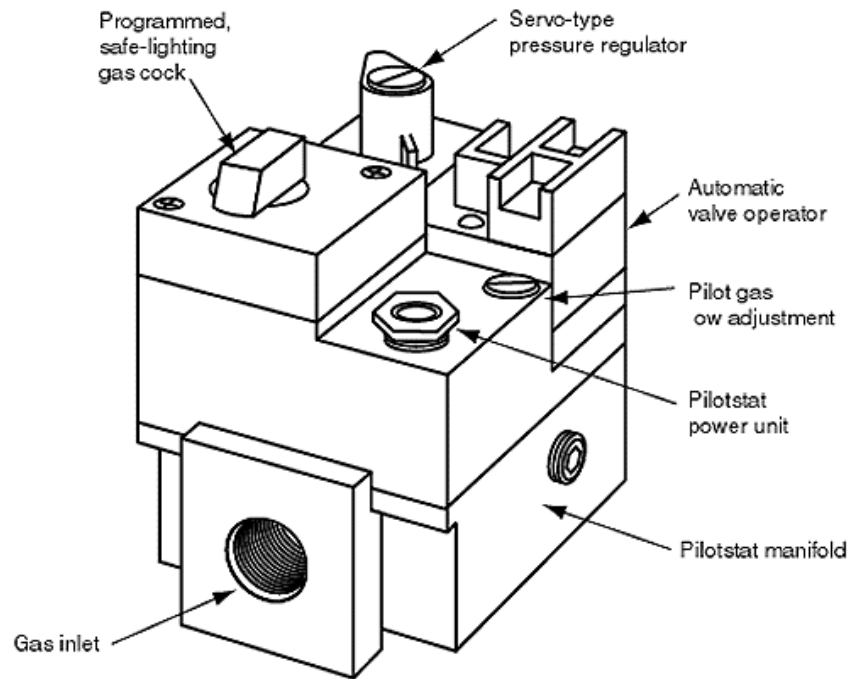


FIGURE 4 — Modern CGC.

A CLOSE LOOK AT THE CGC

The *body casting* is that part of the combination gas control to which components are added to build the complete control. It contains inlet and outlet tappings to connect to the supply and to the burner manifold. The inlet and outlet tappings typically accept pipe sizes from 3/8 to 1 inch. These inlet and outlet sizes determine the maximum CGC capacity.

A *pressure tapping* is included in the valve body for either or both the inlet and outlet. This tapping accepts a manometer fitting for easy adjustment of the main burner's input.

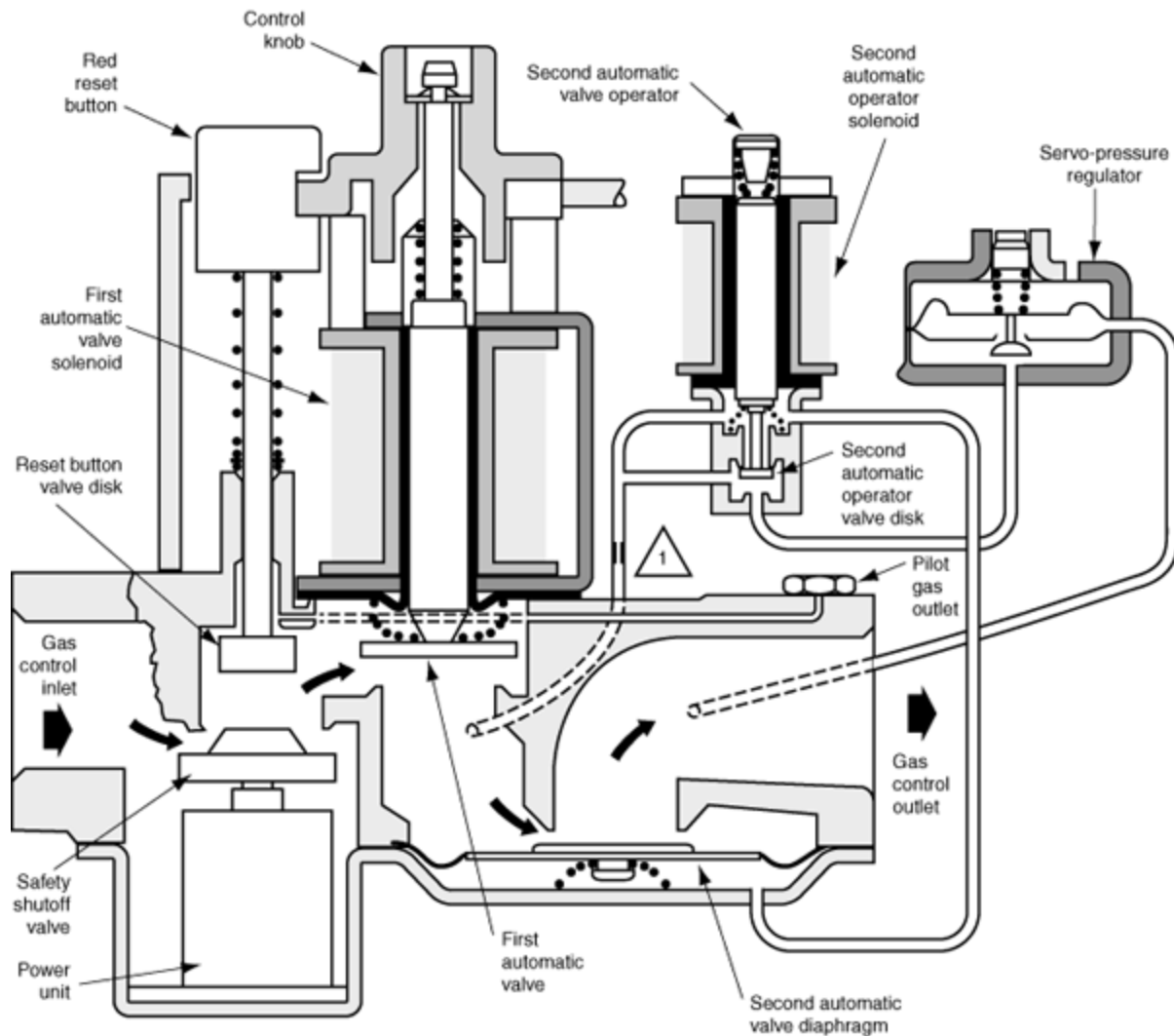
The *safety shutoff* unit, *gas cock knob*, and *pilot flow adjustment* are mounted on the basic body.

PRESSURE REGULATION

Most gas valves manufactured today for use on central gas heating appliances utilize the principle of servo pressure regulation. This design combines the functions of pressure regulation and on-off control.

OPERATION OF A SERVO-CONTROLLED CGC

The schematic diagram (Figure 5) will help to illustrate how a CGC operates.



Note: Second automatic valve operator and servo-pressure regulator shown outside gas control for ease in tracing gas flow.



1 Slow-opening gas control has a gas flow restrictor in this passage.

FIGURE 5 — CGC Operation.

The *gas inlet* is on the left. Valves often have a screen type of filter to prevent debris from being swept into the valve along with the gas supply.

Incoming gas first encounters the *safety shutoff valve* (SSOV). It is shown in the open position. Note that this valve can be held open manually by pushing down on the red reset button.

To light the pilot the red reset button is held down to permit gas to flow to the pilot. After the pilot is lit and the thermocouple starts generating electricity, the power unit is able to hold the SSOV open against spring pressure. A mechanical interlock in the *gas control knob* only permits the reset button to be pushed when it is in the “pilot” position. And the first main valve can only open when the gas control knob is in the “on” position. That’s how the safe lighting feature works.

After gas gets past the safety shutoff valve it comes to the *first automatic valve*, which is directly operated by an electrical solenoid. This valve opens against the pressure of the flowing gas, and it is also spring loaded to close when unpowered. That is an inherently safe design feature that adds to the overall safety of the complete device and the entire system. The first automatic valve opens on a call for heat from the thermostat.

The *second automatic valve* is a much different type of device. It is a servo-operated valve. By that we mean it's position is controlled by the pressure of gas admitted to a chamber beneath a diaphragm that drives the valve disk open and closed. More pressure under the diaphragm closes the valve and less pressure opens it.

SERVO PRESSURE REGULATION

During the ON cycle, the servo pressure regulator provides close control of outlet pressure, even if inlet pressure and flow rate vary widely. Any outlet pressure change is immediately reflected back to a diaphragm in the servo pressure regulator, which repositions to change the flow rate through the regulator valve and thus changes the pressure under the diaphragm that operates the second main valve. Here's how that works (Figure 5):

Gas is tapped out of the area below the first automatic valve. This working gas can either go through a passage to, and push up on, the second automatic valve diaphragm, or be bled off to the outlet of the CGC by the servo pressure regulator. In this way the servo pressure regulator controls the pressure under the second automatic valve diaphragm, and the position of that valve.

If outlet pressure begins to rise, the servo pressure regulator diaphragm moves slightly higher, allowing less gas to bleed out of the regulator to the CGC outlet. That, in turn, increases the pressure under the second main valve diaphragm and tends to close the valve, reducing outlet pressure.

If outlet pressure begins to fall, the pressure regulator diaphragm moves slightly lower allowing more gas to bleed out to the CGC outlet. The servo regulator diaphragm repositions lower and decreases pressure in the area under the main valve diaphragm-- the valve opens wider, increasing outlet pressure.

It's a self-balancing system that is quite independent of flow rate and can regulate over a wide range of gas capacities. This is important to the servicing technician because it's unknown what size or type of equipment will need to be repaired next. This type of valve typically works in a wide variety of applications i.e. 30,000 to 300,000 Btuh burner inputs.

REGULATORS

The function of gas pressure regulators is to maintain relatively constant outlet pressure despite changing inlet pressure. There are many regulators used in the gas distribution system before the gas is finally burned in a residential heating system:

High pressure regulators are used in applications where pressures range from 50 psi to 1,000 psi. Examples of this type of regulator are found in transmission lines which serve city distribution systems.

Intermediate pressure regulators are used in applications where the pressure range is 1 psi to 50 psi. Regulators of this type are usually found in city distribution systems and in commercial and industrial burners.

Service regulators reduce street main pressure to pressures usable in residential applications.

Appliance regulators further reduce the gas pressure required by a gas-fired residential appliance, such as a kitchen range or a furnace.

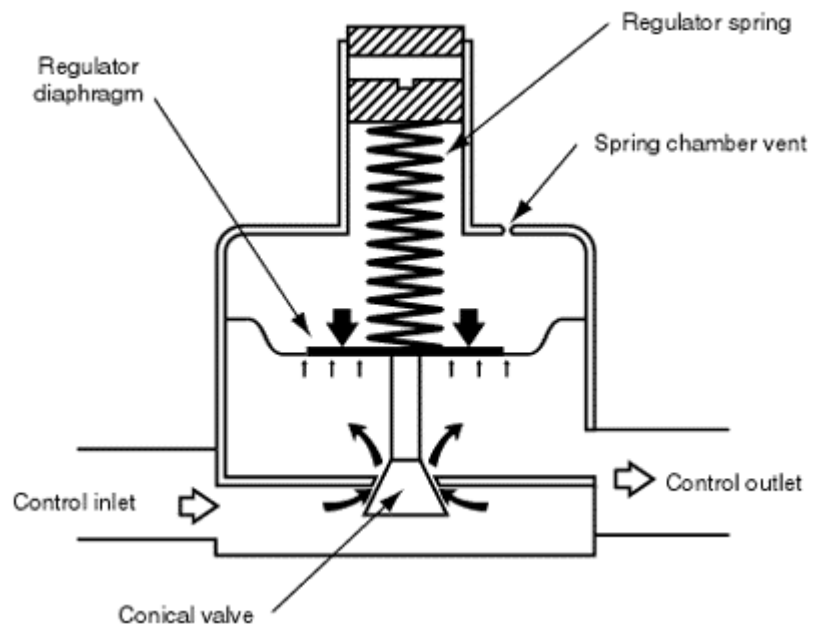


FIGURE 6 — Standard Pressure Regulator.

Standard regulators act as a variable orifice, which is made smaller or larger in response to changes in inlet pressure. These changes in inlet pressure are sensed by the regulator diaphragm. Figure 6 shows a typical standard regulator.

The components of the standard regulator are a *flexible diaphragm* which, in operation, has two forces working on it: (1) outlet pressure of the gas, and (2) an *opposing force*, usually a spring. The diaphragm connects to a valve disk which controls the flow of gas into the chamber of the regulator. A vent in the top of the regulator body allows air displaced by diaphragm movements to be vented to the atmosphere.

When inlet or supply pressure increases, pressure builds up on the bottom of the diaphragm. The diaphragm and the valve move up until the force of the gas pressure in the chamber and the spring force are equal. This positions the valve so that it maintains the desired outlet pressure.

If the inlet pressure decreases, the diaphragm and valve move down until the forces on each side of the diaphragm are equal, opening the valve further to compensate for the drop in inlet pressure.

Conventional regulators were used for many years to provide regulation in combination gas controls, and in some cases are still used today. They only provide effective regulation, however, when the inlet supply pressure and the gas flow rate are relatively stable. For other applications in the gas distribution system this type of regulator is standard and it works just fine. But to regulate the input to a residential size gas burner, it has been found over the years to have some limitations.

As the inlet supply pressure or the flow rate of the gas changes, the actual regulation control point deviates from the desired point of control. Figure 7 and the following examples demonstrate the problems with conventional regulators.

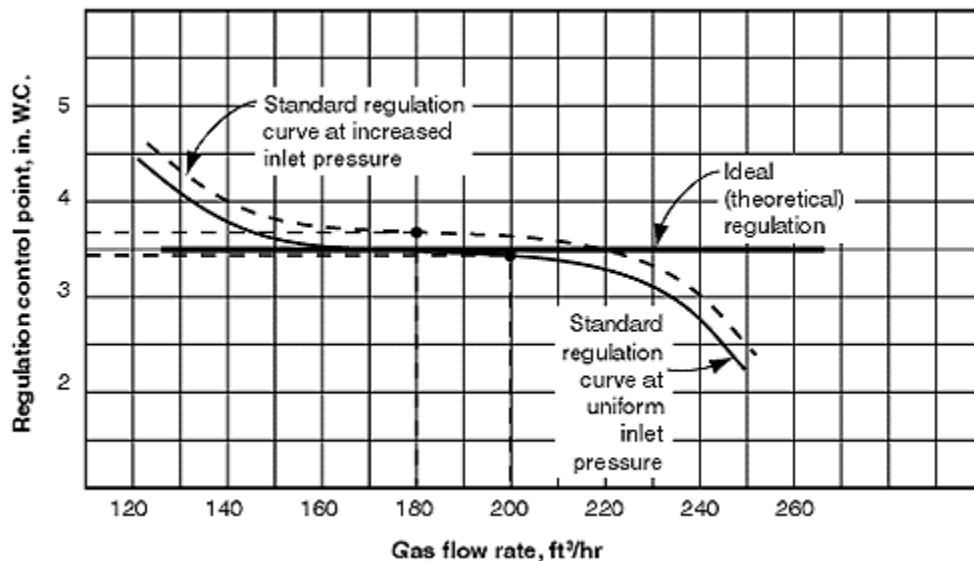


FIGURE 7 — Pressure Regulation.

Consider the situation where an appliance regulator is set to deliver 3.5 inches water column (wc) outlet pressure at an inlet pressure of 7 inches wc and a 180 cfh flow rate. It controls the outlet pressure at 3.5 inches wc (solid line) if the inlet conditions are constant.

If the inlet pressure increases to 9 inches wc (with the regulator setting and flow rate staying the same), the regulation curve shifts upward (broken line), and the outlet pressure goes above the setting of 3.5 inches wc.

Assume the inlet pressure is controllable at 7 inches wc. The regulator setting remains the same, but the rate of consumption increases from 180 to 200 cfh. The control point shifts to the right along the solid curve to provide less than 3.5 inches wc outlet pressure.

SERVO PRESSURE REGULATORS

Because conventional regulators could not maintain even outlet when inlet pressures or consumption rates change, an improved servo type of regulator was developed for combination gas controls. Unlike the conventional regulator, the servo regulator provides almost constant outlet pressure over the entire range of inlet pressures and consumption rates. Further, because of its unique design, the servo regulator can be used on CGC's with a broad range of capacity ratings.

Servo type pressure regulators operate on the *working gas* principle. They use outlet gas pressure to sense the need for regulation. This need is transmitted to the main valve diaphragm, and the main valve disk is positioned to maintain the desired outlet pressure.

SAFETY SHUTOFF VALVE

All gas appliance safety systems have some way of proving that an adequate ignition source is available before gas is allowed to flow into the combustion chamber through the main burner. The unsafe condition that must be guarded against is the uncontrolled flow of gas into the combustion chamber without being able to light it promptly.

The oldest method of providing this safety function is the standing pilot. The burner system is engineered so that any time the pilot is burning well enough to keep the safety valve open, the pilot will reliably light the main burner. Heating appliances are tested extensively to make sure this is true.

THERMOCOUPLE SENSES PILOT FLAME

A thermocouple is two wires of different metal welded together at one end. When this welded "junction" is heated while the other end remains relatively cool, a small electric voltage is generated and, if it is connected to a circuit, a small current can be made to flow.

The heated end of the thermocouple is called the "hot junction" and the cool end is called the "cold junction." (Figure 8) A single thermocouple generates about 30 millivolts. (.030 volts).

Note that the cold junction need not be a common junction. The load shown is the power unit coil. The copper leads shown are the thermocouple-to-power unit connection. These leads do not alter the thermocouple effect but simply complete the electrical circuit between the power source (thermocouple) and the load (power unit coil).

It is possible to connect a number of thermocouples in series, greatly increasing the available power. This is illustrated in Figure 9 below. This series of thermocouples is called a thermopile. It is installed in a pilot burner and is used to power a temperature control circuit including a thermostat and limit control.

A single thermocouple is capable of producing about 25 to 30 millivolts dc. Thermopiles are designed to produce 750 millivolts. Other voltages commonly

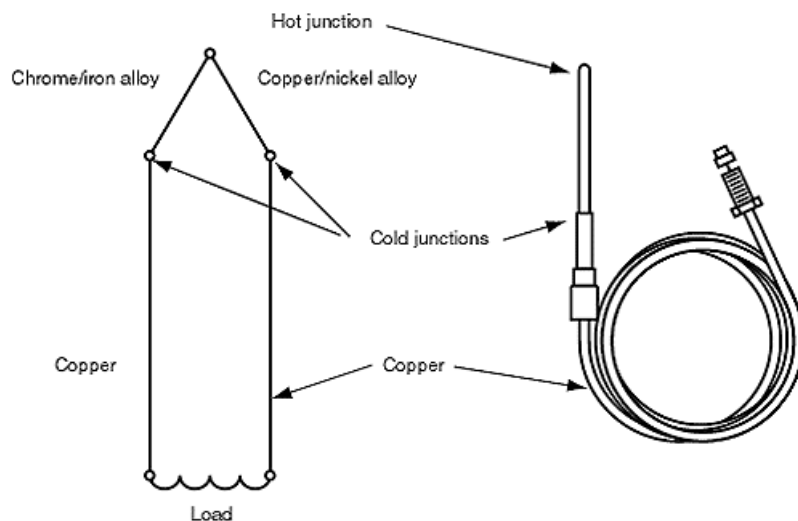


FIGURE 8 — Typical Thermocouple Construction.

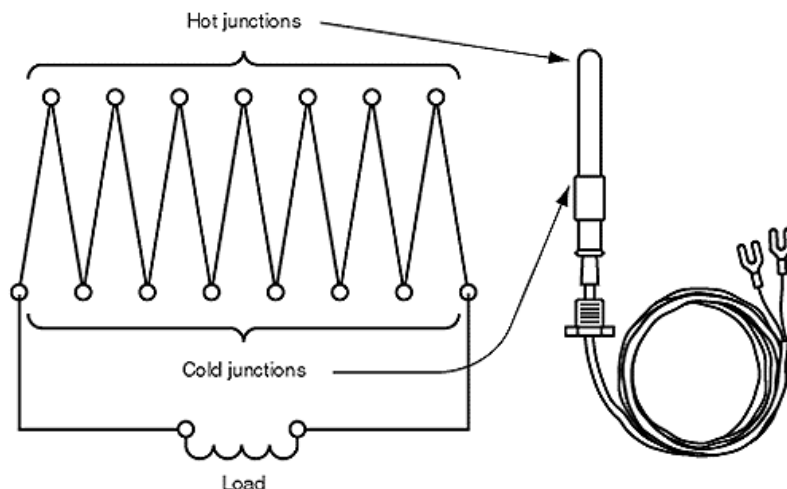


FIGURE 9 — Basic Thermopile Construction.

used in the past include 250 and 500 millivolt systems.

SAFETY SHUTOFF VALVE

The *safety shutoff valve* is controlled by a *Pilotstat™ power unit*.

Figure 10 shows how a Pilotstat power unit works. The actual mechanical form of this device varies depending on how it is used in a particular combination gas control, but the operation is always very similar.

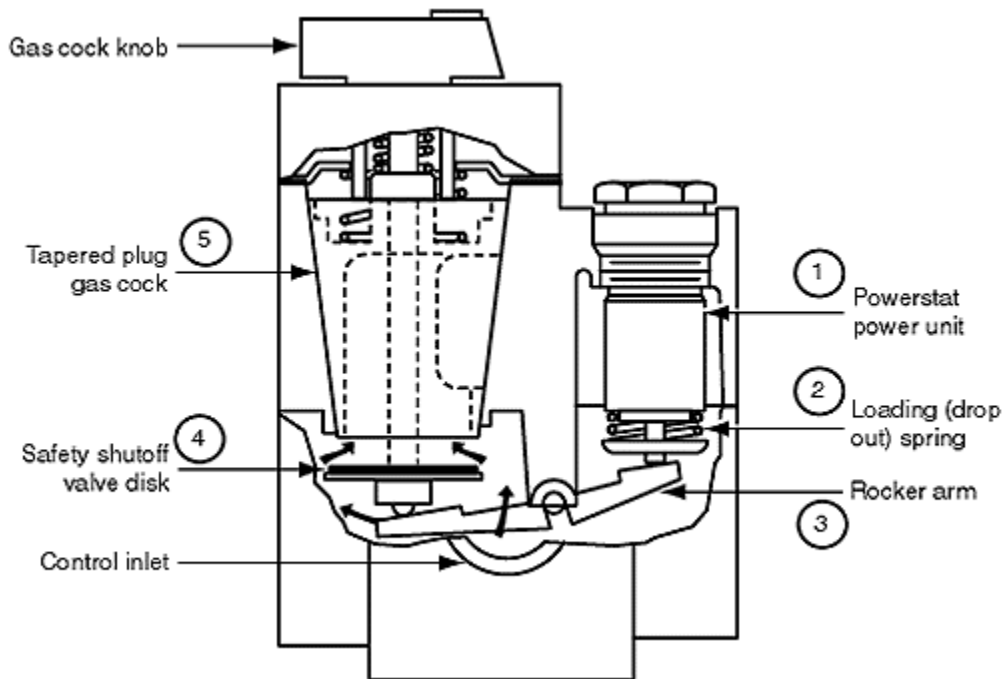


FIGURE 10 — Safety Shutoff.

The electrical power generated by the thermocouple (or thermopile) energizes the electromagnet. However, this is not sufficiently strong to pull the spring-loaded plunger assembly into contact with the magnet. The power unit must be manually reset. This is what you are doing when you push the red reset button on the combination gas control to light the pilot. With a normal pilot flame, good thermocouple or thermopile, the electromagnetic holding force exceeds that of the dropout spring so that contact is maintained and the plunger is held in the inward position.

SAFETY SHUTOFF CIRCUIT

A basic thermocouple safety shutoff circuit is shown in the Figure 11.



FIGURE 11 — Safety Shutoff Circuit.

In the circuit shown, the thermocouple is represented as a battery to emphasize the fact that it is the source of power for the safety shutoff circuit. The load, or user of electricity, in this circuit is the electromagnet coil in the Pilotstat power unit. Figure 12 is a typical circuit for a basic gas heating control system showing the relationship of the safety shutoff circuit and the temperature control circuit.

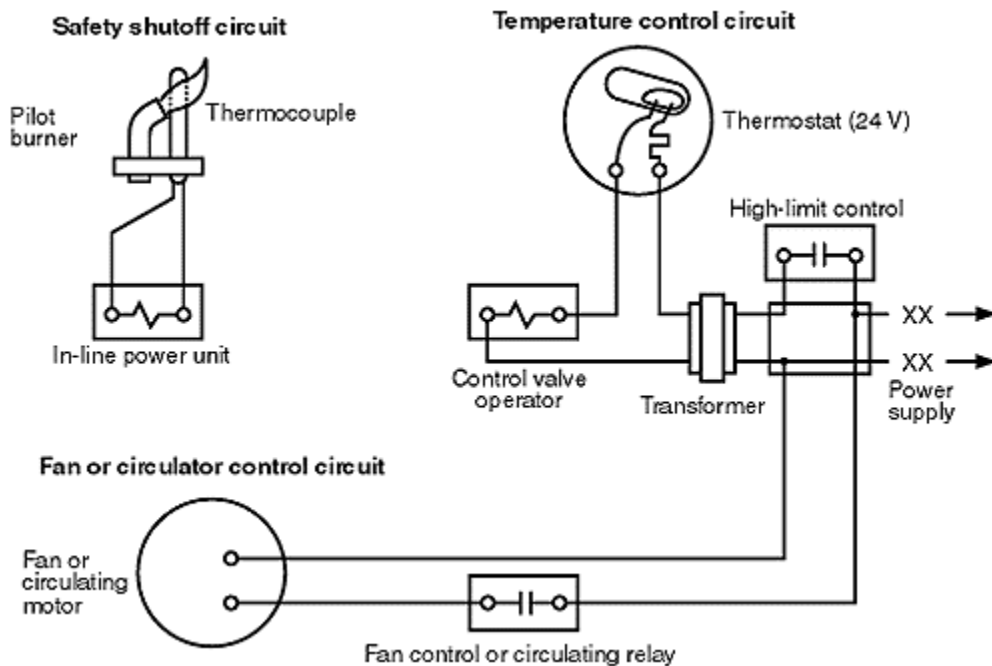


FIGURE 12 — Typical Heating Control System.

The *safety shutoff circuit* includes the pilot burner, thermocouple, and the Pilotstat power unit. The function of this circuit is to monitor the condition of the pilot flame and to insure that the gas valve does not open if the pilot is not safe, or if a component fails in the safety shutoff circuit itself.

Another system of providing pilot safety is to have a bimetal-operated pilot switch that is wired in series with the control valve operator. If the pilot goes out the bimetal moves, the switch opens and the temperature control circuit opens, preventing gas valve operation.

TYPES OF AUTOMATIC VALVE OPERATION

Several methods have been used to provide the automatic operation function of a combination gas control. The basic requirement is that some device like a thermostat sense medium or space temperature and through electrical, hydraulic or mechanical means cause the valve to open and close to fire the burner intermittently. The most common methods used are:

1. Magnetic operator
2. Bimetal operator
3. Remote bulb operator

Magnetic operators (Figure 13) use an electromagnet or solenoid to open the valve, or open a servo valve that in turn opens the valve. Current flowing in the temperature control circuit as the result of thermostat switch closure energizes the solenoid and opens the valve. Most valves in use today use magnetic operators.

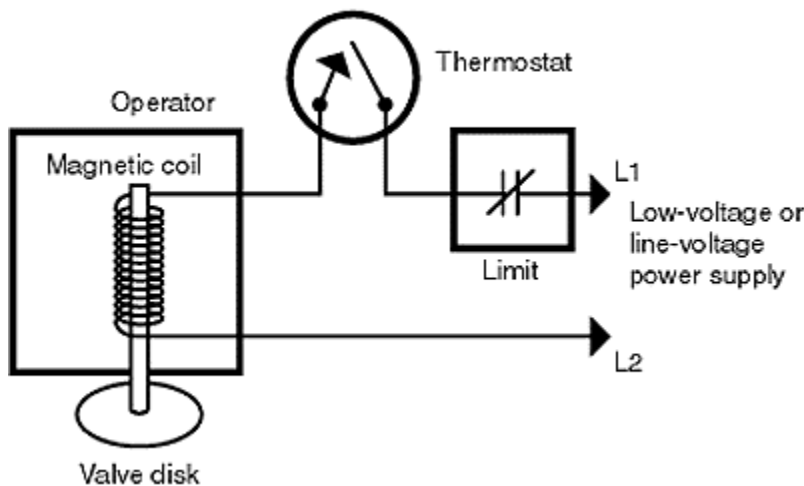


FIGURE 13 — Magnetic Operator.

Bimetal operators (Figure 14) open a valve by heating a bimetal, which warps and provides motion to open the valve in the servo operator. On a call for heat, current flows through the resistance wire which heats the bimetal. There is a short delay for the heater and the bimetal to reach operating temperatures. This delay causes this type of operator to be referred to as a delayed-opening operator.

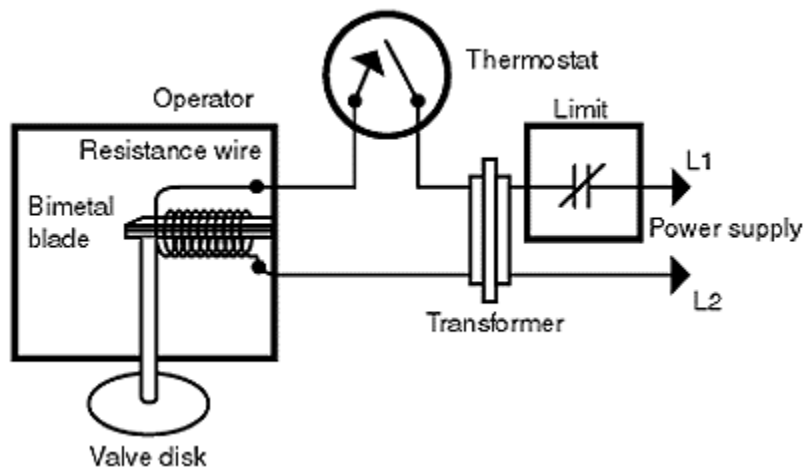


FIGURE 14 — Bimetal Operator.

Bulb Type Operators(Figure 15) use the expansion of the fill in a remote sensing bulb to activate a bellows on the valve stem. This type of operator contains a mechanism to translate the expansion of the fill into snap action. Obviously this type of operation is very useful where there is no electricity available to run the control circuit. So this control system is found in recreational vehicles, construction heaters and similar appliances.

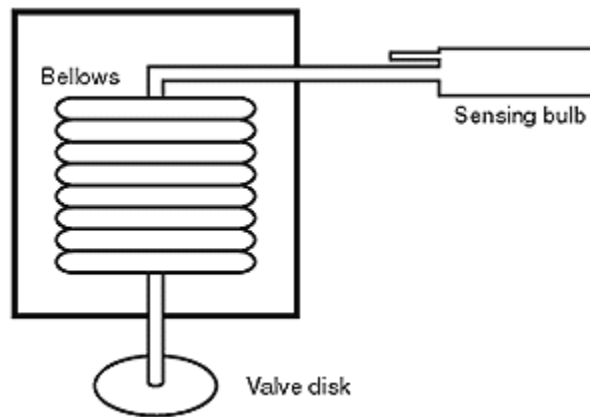


FIGURE 15 — Bulb Type Operator.

VARIATIONS ON THE BASIC COMBINATION GAS CONTROL

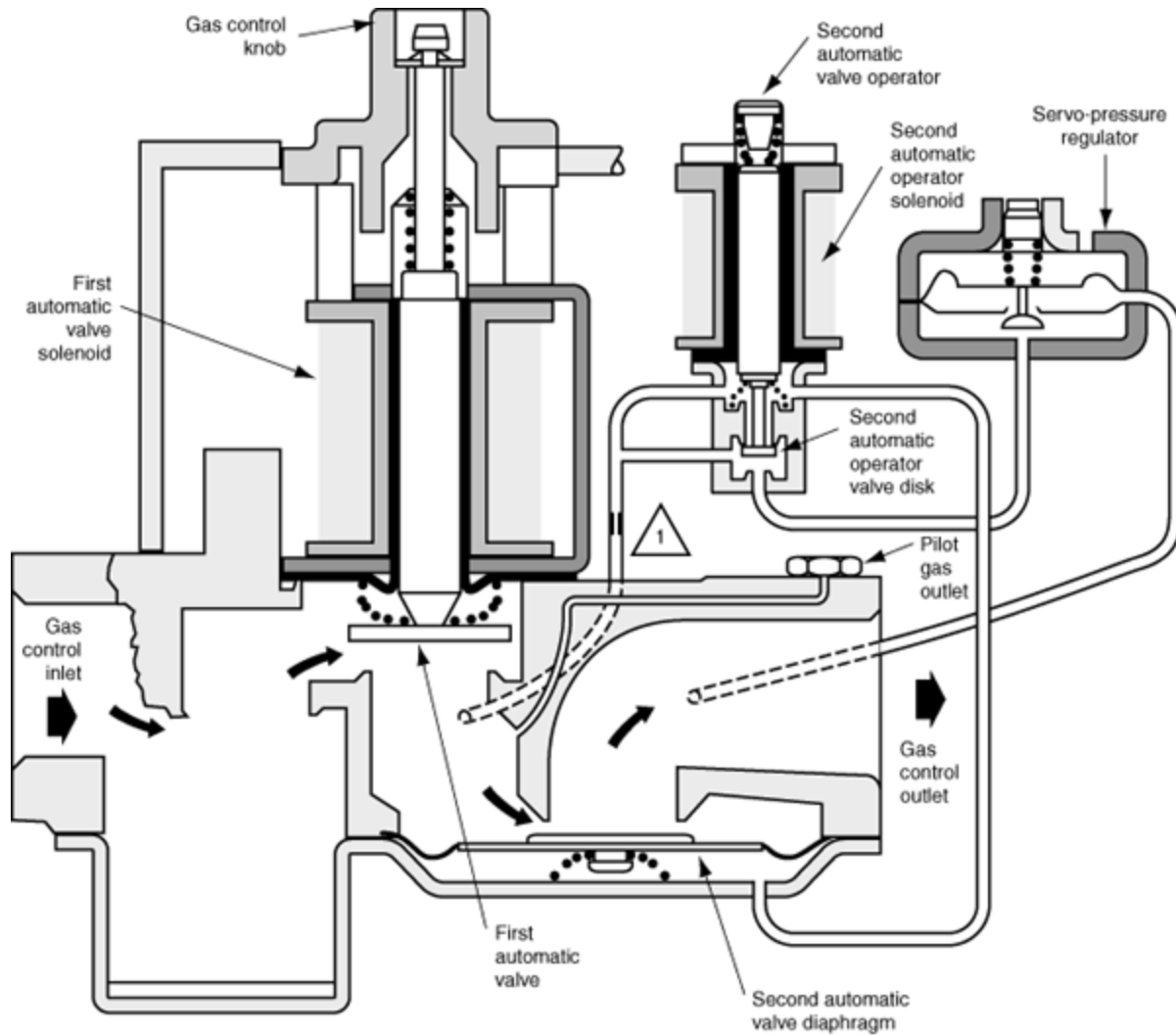
New developments in gas heating controls have resulted in different (and usually more sophisticated and therefore more complicated) types of combination gas controls. This is particularly the case where electronic ignition is applied to gas furnaces and boilers in place of the standing pilot system. Intermittent pilot and direct burner ignition systems require some different functions from the combination gas control.

INTERMITTENT PILOT VALVES

To control gas flow to a burner with an intermittent pilot ignition system we need to have automatic, independent control of gas flow to both the pilot and main burner. The pilot is turned on and lit on each call for heat, and the main burner is only fired after the pilot has been proved to be burning properly.

VALVE OPERATION

Figure 16 the valve is shown in the open (energized) position. Note that there are two automatic valves--one with a solenoid operator and one with a servo operator. Also note that there is a small passage for gas to flow to the pilot and that it starts between the two main valves.



Note: Second automatic valve operator and servo pressure regulator shown outside gas control for ease in tracing gas flow.



Slow-opening gas control has a gas flow restrictor in this passage.

FIGURE 16 — Intermittent Pilot Valve.

When the valve is off the first automatic valve is closed. The second automatic valve operator is de-energized, closing the channel to the pressure regulator, and opening a channel to the underside of the second automatic valve diaphragm. The combination of spring pressure under the second automatic valve diaphragm and lack of outlet pressure hold the diaphragm firmly closed. Pilot burner gas flow is prevented by the first automatic valve and flow to the main burner is blocked by both main valves.

CALL FOR HEAT

When the thermostat calls for heat, the trial for pilot ignition begins. The first automatic valve solenoid is energized by the module and opens, allowing pilot burner gas flow. Gas also flows to the second automatic valve operator, but is mechanically blocked at the operator.

After the pilot lights and the pilot flame is sensed by the igniter-sensor, the second automatic valve operator is energized by the electronic ignition module. Through the servo operation system, it causes the second main valve to open.

The pilot burner and the main burner both remain on until the call for heat ends. When the thermostat stops calling for heat both automatic valves are closed, shutting off the pilot and main burner.

SLOW OPENING FEATURE

It is possible to incorporate a slow opening feature into a combination gas control by special design characteristics. Slow-opening gas controls function the same as standard-opening models except that when the thermostat calls for heat, the second automatic valve opens gradually.

Opening is slowed because a gas flow restriction in the passage to the second automatic valve operator limits the rate at which gas pressure builds up in the servo operation system. That, in turn, limits the opening speed of the main valve.

Outlet pressure increases gradually from 0 to rated outlet pressure in about 5 or 6 seconds.

STEP - OPENING FEATURE

Step-opening gas controls actually combine two pressure regulators, one for the low pressure and one for the full-rate pressure. When the thermostat calls for heat, the automatic operator opens the valve and regulates at the step rate for several seconds. At that point the regulator goes to the full rate and regulates the output at the rated output. For a natural gas valve with a full rated output of 3.5 inches wc, the step might be somewhere between .7 and 1.7 inches wc.

Something worth noting is that it takes step opening valves about 60 seconds to “reset” after they are de-energized. If it is re-energized within 60 seconds, it may bypass or shorten the length of the low pressure step. The burner would then light off at the full rate.

Slow opening and step opening valves are used to provide a more gentle burner light-off characteristic.

DIRECT BURNER IGNITION

In a direct burner ignition system there is no pilot. The ignition source--either a spark or a hot surface igniter--directly lights the main burner. Because of this mode of operation, combination gas controls intended for this purpose must operate differently

DIRECT BURNER IGNITION OPERATION

When the thermostat calls for heat the module simultaneously energizes both first and second main valve operators, as well as the ignition. There is no pilot. Gas flows to the main burner. Ignition must occur within a relatively short time (4 to 11 seconds compared to 90 seconds trial for pilot in an intermittent pilot system) or the CGC is de-energized and shuts off gas flow to the main burner.

In many cases the valves for standing pilot, intermittent pilot and direct burner ignition are very similar in appearance and may be mainly differentiated by model number. Obviously it's very important the right valve get used in each application. This needs to be checked carefully in service situations.

POWER SUPPLIES FOR GAS HEATING CONTROL SYSTEMS

Electric control systems for gas heating systems principally are powered by 24 volt a.c. transformers. Other power sources sometimes found are line voltage and millivoltage. Figure 17 shows a typical low voltage control system for a gas warm air furnace.

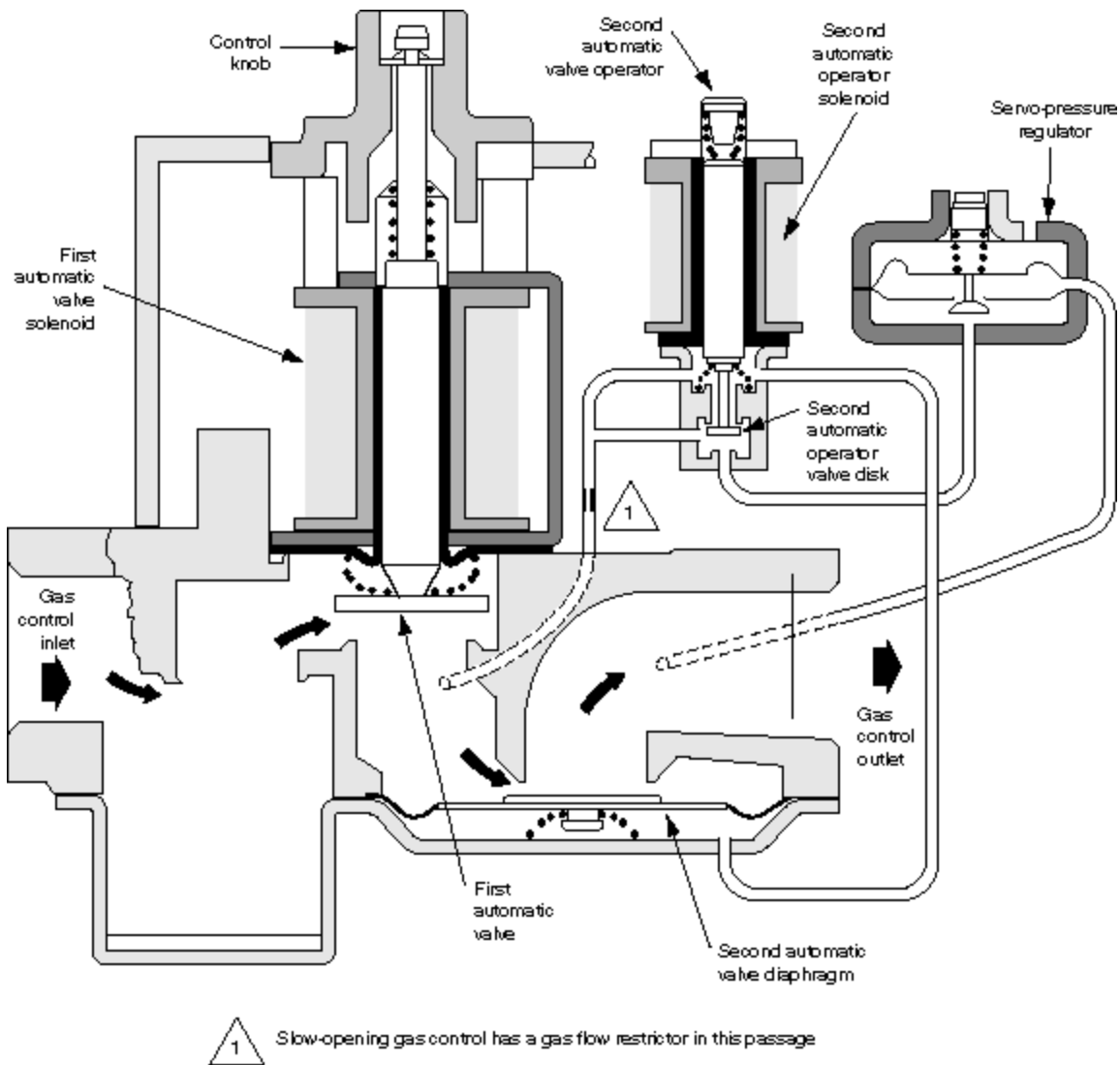


FIGURE 17 — Direct Burner Ignition Valve.

Power for low voltage circuits is provided by a transformer which steps down the line voltage to 24 volts a.c. Transformer output is rated in volt-amperes (VA). VA is a measure of power available from the transformer. The more loads connected to a transformer the more power it must be capable of supplying. A typical heating system transformer might be capable of supplying 40 VA.

A transformer should keep its output voltage as stable as possible over the range of demands or loads placed upon it. Its key components are two coils of wire called windings. The primary winding is hooked to the line voltage power source and the secondary winding to the control circuit.

A transformer's voltage changing ability is determined by the ratio of its number of primary windings to the number of secondary windings. For example, if the ratio of primary to secondary is 5:1, and the voltage on the primary is 120 volts, the output of the transformer will be 120 divided by 5, or 24 volts. A transformer that has a maximum capacity of 1.66 amps current flow at 24 volts would be rated as a 40 VA transformer.

size

To determine what size (VA rating) transformer you need, add up the VA requirements of all the accessories that can be powered in the system at the same time. This figure will give you the size of the smallest transformer for the job.

If you need a minimum of 30 VA to power all the devices on a circuit you can easily use a 40 VA transformer, but you could not successfully use a 20 VA model. Keep in mind that when you add accessories to an existing control circuit you will be putting an additional load on the transformer. You may need to replace the transformer with a larger one to be able to supply enough power.

SAFETY

Most residential heating and cooling systems have 24 volt control systems. They require what the Underwriters Laboratories (UL) calls Class 2 transformers. There are two types of Class 2 transformers: component recognized and general listed. Component recognized transformers with their exposed wiring, can be used only when safely enclosed in a UL-approved wiring box. On the other hand, general listed transformers have no exposed wiring, require no special enclosure, and are suitable for most add-on and replacement applications.

PERFORMANCE

Last and most important, you need to consider how well the transformer maintains it's rated output voltage as the demand of load on it increases and decreases. All transformers are not created equally; one 40 VA transformer may perform quite differently from another.

As the load on a transformer increases, it's output voltage decreases. For example, the larger the load, the more a transformer's voltage output will drop below it's open-circuit rating.

Most systems will work over a voltage range that varies some from the rated input voltage. But the more constant the voltage output, the better the system will perform.

Some systems are more sensitive to voltage fluctuations than others. Electronic controls, for example, are much more sensitive to voltage variations than are electromechanical controls. An electronic control can be burned out by excessive voltage.

ASSURING RELIABILITY

A consistent performance standard for all Class 2 transformers has been developed by the National Electrical Manufacturer's Association (NEMA), the nation's largest trade organization for manufacturers of products used to generate, transmit, distribute and control electricity. If a transformer meets the NEMA Standard (ST2-1986), it's performance lies within tight limits and you can be confident of it's voltage output characteristics.

TROUBLESHOOTING GAS HEATING SYSTEMS

The majority of heating service calls are "no heats" complaints. Others are "poor performance" complaints such as overheating, under heating, wide swings in temperature, rapid cycling, noise, and odors. All customer service problems are important to solve, but problems with the combination gas control or it's associated circuitry are most likely to cause no heat complaints.

We can divide the possible problems into a few basic categories:

1. Safety shutoff circuit
2. Temperature control circuit
3. Electronic ignition

TROUBLESHOOTING THE SAFETY SHUTOFF CIRCUIT

“No heat” complaints can always be approached in the same general way; in other words they lend themselves to a logical troubleshooting procedure.

Before you begin troubleshooting the system, ask the customer to explain the problem. Pay close attention; the customer may have a very good idea as to what the problem is, or they may say something that will remind you of a past problem and make the job a lot easier and quicker to handle.

If, after talking to the customer, you have no clear idea as to the exact nature of the problem, take a good look at the system and the components that make it up. Get in the habit of identifying what the system is supposed to do and what it is doing now. Work on the difference.

To troubleshoot a “no heat” complaint, use the following guide:

1. Make certain that the thermostat function switch is set at HEAT. Some people forget to change the switch at the end of the cooling season.
2. Check the furnace switch to make sure the system has electrical power.
3. Set the thermostat to call for heat:

-If the main burner starts, observe the system through one cycle and check miscellaneous complaints as required.

-If the main burner does not start, make sure there is voltage to the combination gas control, then check the safety shutoff system and pilot flame, the temperature control circuit and the fan or water circulator circuit.

SAFETY SHUTOFF -- TROUBLESHOOTING

Early combination gas controls had replaceable and interchangeable components such as servo pressure regulators, main valve operators, and pilotstat power units. This meant that a troubleshooting procedure needed to isolate system problems to a very specific part of the system. We had a procedure for determining whether the thermocouple or the pilotstat power unit was causing a problem.

In cases where you are unable to get the pilot to remain lighted when you let go of the start button or gas cock knob, the problem is almost always a dead thermocouple. After all, we know the thermocouple is going to fail sometime--that's the way it operates. So our current troubleshooting procedures just call for replacing the thermocouple when the pilot safety circuit doesn't hold in the safety shutoff valve. In almost all cases, this solves the problem. Also, installing a new thermocouple gives some assurance that you are not unnecessarily condemning a gas valve when a bad thermocouple is the real problem.

In a standing pilot system the pilot is the key to troubleshooting the safety shutoff circuit. So when checking the safety shutoff system, always start by looking at the pilot burner. It should envelop 3/8 to 1/2 inch of the thermocouple and be blue and steady.

Some of the pilot problems that prevent proper operation are described below:






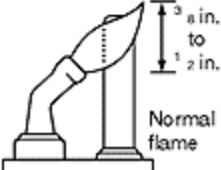
If the flame is *too small*, adjust the pilot gas flow screw on the CGC and check for a clogged pilot orifice. If there is a pilot gas filter, it could be clogged, or the supply pressure to the CGC may be too low. (Figure 20)

A *lazy, yellow flame* means a lack of air. This problem may come from an overly large orifice, a dirty lint screen, or a dirty primary air opening. (Figure 20)

A *waving, blue flame* means an excessive draft at the pilot location. Install a shield to protect the pilot. (Figure 20)

A *noisy, lifting flame* means high gas pressure. Relieve this situation by checking the supply gas pressure and adjusting the pilot gas flow adjustment. (Figure 21)

A *hard, sharp flame* may mean the orifice is too small. However, this flame is normal for manufactured, butane air or propane-air fuels. (Figure 22)

Flame types	Possible causes	Flame types	Possible causes
 <p>Light blue Yellow Lazy yellow flame</p>	<ol style="list-style-type: none"> 1. Dirty lint screen or primary air opening 2. Starving due to excessive input to main burner 3. Orifice too large 	 <p>Noisy lifting blowing flame</p>	<p>High gas pressure</p>
 <p>Waving blue flame</p>	<ol style="list-style-type: none"> 1. Excessive draft at pilot location 2. Recirculating products of combustion 	 <p>Hard sharp flame</p>	<ol style="list-style-type: none"> 1. Characteristic of manufactured, butane-air, and propane-air 2. Orifice too small
 <p>Small blue flame</p>	<ol style="list-style-type: none"> 1. Adjusting screw closed off 2. Low gas supply pressure 3. Clogged pilot burner orifice 4. Improper orifice (too small) 5. Clogged pilot-line filter 	 <p>Normal flame 3/8 in. to 1/2 in.</p>	<p>Proper installation</p>

FIGURES 20, 21 and 22

It is possible to check thermocouples with a meter. Typical resistance values for different types of thermocouples and thermopiles are published by some of the manufacturers. The problem with doing this is that the expected values are very small and often difficult to interpret unless a very high quality meter is used. For instance the proper resistance for a 30 mV thermocouple is .02 ohms -- and most meters used in field service probably can't distinguish between .02 ohms and a dead short.

At one time it was also recommended that thermocouples be checked by measuring the voltage and current they produce, and it's certainly possible to do this. (The lowest acceptable open circuit output of a 30 millivolt thermocouple is 18 mV.) But it usually isn't worth it. Compared to the cost of a service person being at the location, the cost of a new thermocouple is quite small.

The main factor that determines thermocouple life is the temperature of the flame it is in. The *maximum* temperature for the tip (or hot junction) of the thermocouple is 1,400 degrees Fahrenheit, with 1,200 degrees being a better limit in most applications. The hotter it is the shorter it's life. However if the temperature is too low there are likely to be reliability problems. Again it is usually difficult to measure temperatures of this range in service work so the best policy is to adjust the pilot burner by looking at it.

Temperature Control Circuit

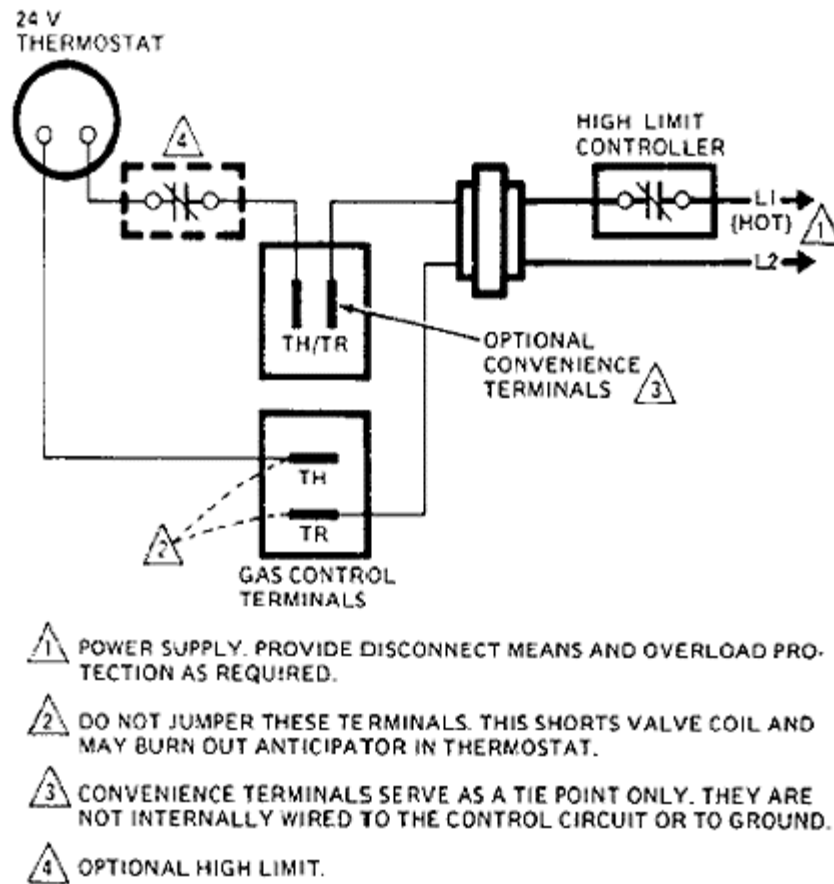


FIGURE 24

TEMPERATURE CONTROL CIRCUIT

The time to start troubleshooting the temperature control circuit is when the pilot is burning properly and the safety shutoff valve in the combination gas control is being held open by the pilotstat power unit—but the main burner won't come on.

Here's the basic temperature control circuit:

The power source is typically a transformer running on the 120 volt line and supplying 24 volts for the control circuit. The limit can be in either the line as it is shown here, or it may be in the low voltage circuit in series with the thermostat. The thermostat controls current flow in the valve circuit.

In other versions of this circuit the control circuit may run on line voltage, in which case the thermostat and valve would be rated for 120 volts (or possibly 240 volts), and there would be no transformer.

Another version of the temperature control circuit operates on 750 millivolts put out by a thermopile generator.

Checking the temperature control circuit involves basic electrical troubleshooting and logical deduction.

1. Set the thermostat to call for heat -- main burner should light.
2. If the burner doesn't light, check for power to the control circuit (transformer output and input; or proper line voltage or millivoltage for those systems). This will diagnose a failed transformer or lead you to other checks.
3. Temporarily jumper the thermostat (at the thermostat sub-base is probably the best place to do this even though this does mean a trip upstairs or to another part of the house).

If the main burner lights, you know the valve and power supply are good.

If the main burner does not light you should suspect the thermostat or the wiring to it. Another possibility is the high limit control, since it may be in the same low voltage circuit as the thermostat.

4. The final check to determine if the valve itself is good is to ascertain that there is indeed 24 volts (or whatever voltage the system is designed to operate on) present at the valve terminals. The valve is bad if it will not open with the proper voltage applied.

There may be circumstances where it is difficult to determine if the valve is opening or not. Especially in noisy field environments, you may not be able to hear the valve open. It may be necessary to check gas pressure into and out of the valve to determine if the problem is the valve or the gas supply.

Another method of troubleshooting gas control systems is to use a "symptom-cause" chart like the one on the next page. This chart (Figure 25) points out the most likely causes for a number of typical symptoms.

ALTERNATIVE POWER SOURCES

While the majority of combination gas controls get used on residential heating equipment where the control system is powered by a 24 volt transformer, there are other systems in use for other applications.

LINE VOLTAGE CONTROL

Some equipment such as unit heaters and some infrared heaters typically utilize a line voltage power source and a line voltage thermostat. This does not materially change your troubleshooting procedure with the exception that you are looking for line voltage when doing checks and there are the obvious safety implications of dealing with line voltage vs. 24 volts.

MILLIVOLTAGE CONTROL

Some heating systems utilize a self-generating thermopile energy source to power the temperature control circuit. Millivoltage control is currently used only on swimming pool heaters and a few other specialized applications. However, in the past, manufacturers used this system for a number of applications such as wall furnaces and floor furnaces.

In a millivoltage powered heating control circuit the power source is a thermopile generator placed in the pilot burner instead of a thermocouple. Its output is somewhere between 1/4 and 3/4 of a volt depending on the system used--250, 500 and 750 millivolt systems were common. This voltage opens the gas valve on a call for heat.

When troubleshooting a millivoltage system the most important thing to remember is that your power source is very small. So it is important to make sure all wiring connections are clean, tight and corrosion free. Any additional resistance in the circuit can prevent the gas valve from getting enough voltage to operate. An important check to make is measuring the voltage available to operate the gas valve. You'll need a meter that reliably reads up to one volt dc.

Thermostat Service Analysis Chart

CONDITION							T/S INDICATES ROOM THERMOSTAT	POSSIBLE CAUSES
T/S jumpered; system won't work	T/S jumpered; system works	Room temp overshoots T/S setting	Room temp doesn't reach T/S setting	T/S cycles out of calibration	T/S doesn't cycle often	Room temp swings excessively		
x							T/S not at fault; check elsewhere	
	x						T/S mounted on cold wall	
	x						T/S wiring hole not plugged	
	x						T/S exposed to cold drafts	
	x			x	x		T/S not exposed to circulating air	
	x	x	x				T/S not mounted level (mercury switch type)	
	x	x	x				T/S not properly calibrated	
		x		x			Heating plant too small or underfired	
x		x					Limit control set abnormally low	
		x					T/S exposed to direct rays of sun	
		x					T/S affected by heat from fireplace	
		x					T/S affected by lamp, TV or appliances	
		x					T/S affected by stove or oven	
		x					T/S is mounted on warm wall	
		x					T/S mounted near register or radiator	
	x			x	x		T/S heater set too high	
				x			T/S heater set too low	
	x				x		Heating plant too large or input excessive	
	x			x	x		T/S does not have heater	
x		x		x			T/S contacts are dirty	
x							Low voltage control circuit open	
x							Low voltage transformer burned out	
x							Main valve operator is bad	
x		x	x				Bad terminals, staking, splicing or soldering	
	x						T/S damaged	
		x	x				Clogged filter in forced warm air system	

Another important factor is the resistance of the wire used in the thermostat circuit. Installers should always use 18 gauge solid copper wire for the thermostat circuit, for either 24 volt or millivolt systems. However in actual practice much wire sold as thermostat wire” is No. 20 or 22.

This smaller wire is not good in 24 volt circuits and is very harmful in millivoltage circuits. In millivoltage circuits No. 18 wire may be run up to 30 feet. If the thermostat is farther away from the valve than 30 feet larger wire should be used (16 gauge up to 50 feet and 14 gauge up to 80 feet). This larger wire has less resistance and will thus deliver more of the supply voltage to the gas valve.

ELECTRONIC CONTROL

In heating systems with electronic controls, such as intermittent pilot or hot surface ignition controls, the overall system troubleshooting becomes more complex, but the checkout of the combination gas control itself remains largely the same. We look for correct voltage supply to the valve and observe it's operation. Complicating factors include the fact that in some ignition sequences, particularly for direct burner ignition systems, the trial for ignition is very short and checks must be made in a very few seconds while the valve is powered before lockout occurs.

SUMMARY

There have been some changes in combination gas control design and application that affect troubleshooting and service, but in large part, the basics remain the same. At one time manufacturers recommended replacing individual components on or in the CGC itself, where now we treat it as a single component that is diagnosed and, if necessary replaced as a unit. Newer ignition systems on gas heating equipment are likely to incorporate some type of electronic control, but troubleshooting the valve itself follows the same principles we've used in the past.

The key elements in servicing gas controls remain careful observation of symptoms and application of logic to come up with system problems. The skills of the individual service person are the key element. Willingness to utilize a systematic, step-by-step approach to troubleshooting is the best guarantee of effective, profitable troubleshooting.