Controls Principles

Lesson 13 to 20

Unit 4 Preview: Gas and Oil Heating Combustion Controls

Before proceeding with Unit Four, let's pause a moment to take stock of what we have learned so far.

Unit 1 centered on the *Low Voltage Control Circuit*. We reviewed basic electricity, studied the transformer, and learned about basic control circuits and how to trace circuit diagrams.

Unit 2 focused on the main or master controllers - *Room Air Thermostats and Humidistats.*

Unit 3, just completed, considered basics of *Controllers, Relays and Electronic Devices.* In this unit, auxiliary or sub-master controllers were described with emphasis on air and water temperature controllers that start and stop fans and pumps, and also act as limiting devices so that circulating air and water stay within a prescribed temperature range. (One of several safety devices built into a modern control system.)

Now Unit 4. In this unit, emphasis is on *Oil and Gas Burner Combustion Control.* There are six lessons - four dealing with gas burner controls, two on oil burner controls.

You'll learn that the basic functions of combustion controls are to:

1. Provide a *source* of ignition.

2. *Assure* safe ignition.

3. *Start* and *stop* burner on demand.

This unit involves the student with the most common of all control systems. Control technicians are certain to become confronted with gas and oil burner controls on a regular basis. Literally millions of these systems are installed in homes, apartments, shopping centers, and small industrial buildings. These devices cycle many times a day, seven days a week, for some 273 days in a normal heating season. With that kind of work load, even the most rugged device will eventually need servicing. Unit 4 is perhaps the most useful and practical section in your course of study.

Lesson 13: Learning Objectives

To begin our four-lesson discussion of gas burner controls, Lesson 13 presents a discussion of pressure regulation in the gas distribution system from the gas well up to the burner manifold.

Handling a gas automatically places great importance on gas pressure control. The amount of gas that can be made to flow in a pipe is directly dependent on the pressure in the line, and fluctuations in pressure can affect flame characteristics at the burner. This lesson highlights the various types of pressure regulators used to safely and economically bring natural gas to the user.

Studying this lesson should permit you to:

1. Define a pressure regulator.

2. List the basic components in a regulator.

3. Know the three basic types of pressure regulators.

4. Understand the various valve and seat designs available in an appliance regulator.

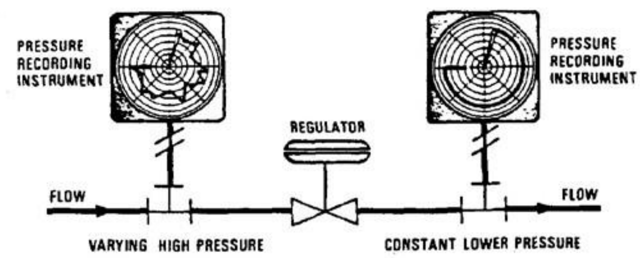
5. List the various burner manifold components.

Now read Lesson 13 which begins on the next page.

Lesson 13: Gas Burner Controls Part I – The Gas Distribution System

Let's begin our discussion of gas heating controls by taking a look at the gas supply piping system. When we do, we find that the most important control in the distribution system is the *pressure regulating* valve.

13-1 GAS PRESSURE REGULATOR usually reduces pressure in a gas line and also stabilizes any fluctuations in supply or inlet pressure.



A gas pressure regulator is a device that maintains a constant downstream (outlet) pressure at some selected value below a higher, and perhaps fluctuating, upstream (inlet) pressure (Figure 13-1).

Gas pressure regulators are relatively simple devices. However, one must know how gas pressure regulators work, and the differences among them, in order to select the *right* regulator for a specific application.

Pressure Regulation in Gas Supply Piping

Gas pressure regulators are commonly classified by *usage.* Figure 13-2 is a diagram of a gas distribution system showing the use *of four basic types* of gas pressure regulators along with a graph showing the pressure reductions at various points in the distribution system.

The regulators at "A" and "B" in Figure 13-2 are *high pressure regulators* or let-down valves. A cutaway view of a typical high pressure regulator is shown in Figure 13-3. These tremendous valves, which often stand 6 to 8 feet high, are constructed to fail safe; that is, to fail in the closed position. Let down valves are also designed as "no leak" devices and provide a tight seal.

The regulator at "C" in Figure 13-2 is an *intermediate "pounds to pounds" regulator.* Intermediate regulators will reduce gas pressure from about 50 to 100 psi down to about 5 to 10 psi.

The regulator at "D" just outside the house in Figure 13-2 is a pounds-to-ounces regulator or *service* regulator. Service regulators reduce gas pressure from several pounds per square inch down to fractions of a pound.

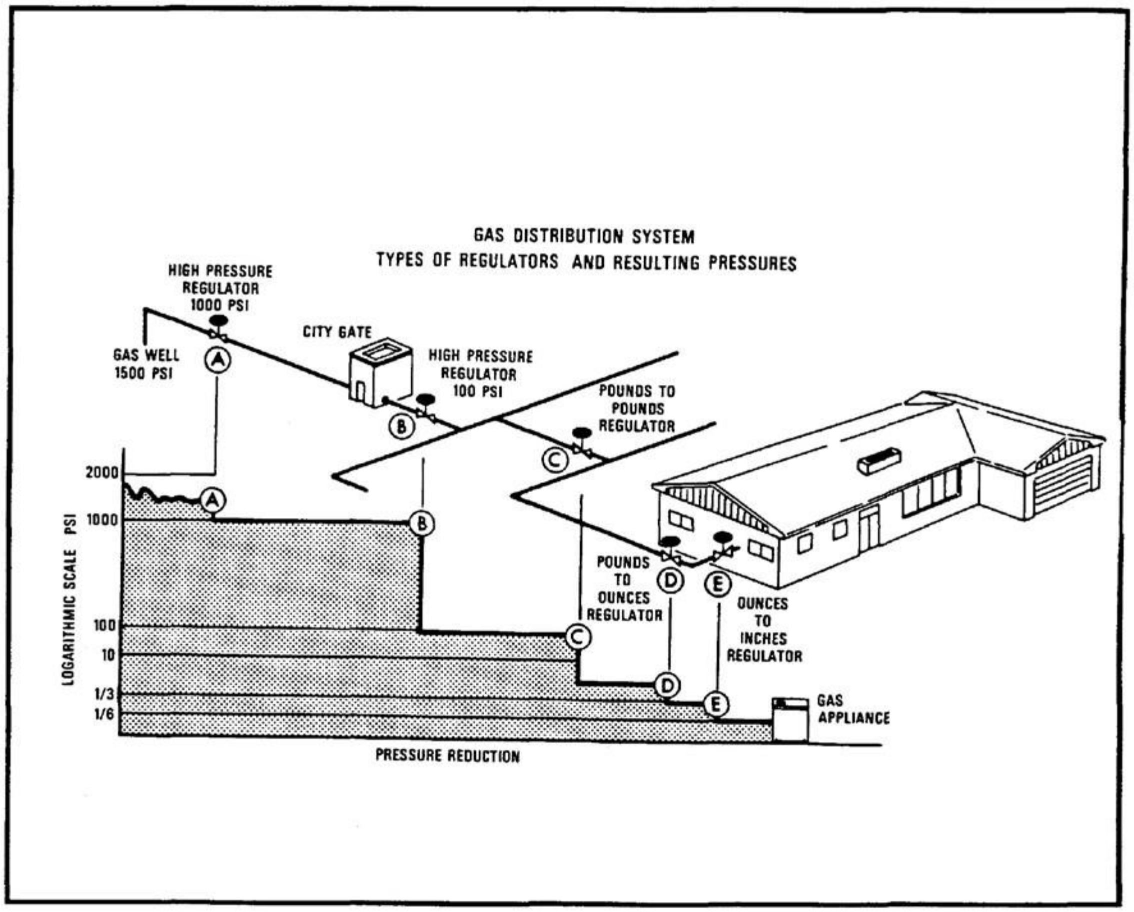


Figure 13-2: Gas piping system shows the four basic types of gas pressure regulators used between the gas well and the homeowner's gas appliance. They are: the high pressure regulator (A & B), the intermediate regulator (C), the service regulator (D), and the appliance regulator (E).

The regulators within the house at "E" in Figure 13-3 are *ounces-to-inches* or *inches-to-inches appliance* regulators. Appliance regulators provide constant pressures for the gas burners on household appliances such as the furnace or boiler, the water heater, and the clothes dryer. The input to each appliance must be controlled separately by an individual gas pressure regulator so that the appliance will operate at designed performance conditions.

Student Note: Pressures under 1 pound per square inch are referred to in "ounces per square inch" or in "inches of water column." 1 pound per square inch (psi) = 16 ounces per square inch (oz/sq. in.) = 27.71 inches of water column (WC), or water gauge (WG). Inches is sometimes abbreviated (in.) or (").

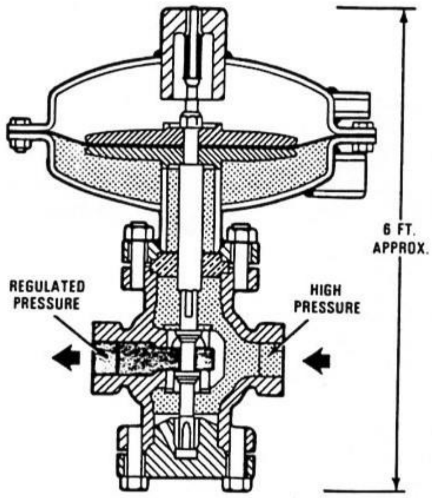


Figure 13-3: High pressure regulator is designed to fail safe; is powered by instrument air imposed on a large diaphragm.

Dead end service regulators are used for house service regulators where pressure in the downstream house piping must not be allowed to build up even under zero flow conditions. A typical dead end service regulator (Figure 13-4) has a small port, a relatively large diaphragm area and a system of levers that provide good pressure control at low flow and tight shut-off at zero flow conditions. Seating pressure is high, therefore these regulators will lock-up under zero flow conditions even if there is some foreign material on the valve seat.

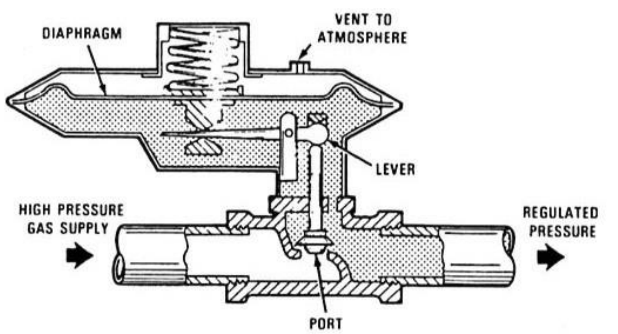


Figure 13-4: Dead end service regulator is usually placed near occupant's gas meter.

Student Note:

1. Convert 3.5 inch - WC into psi.

2. Convert 1/2 psi into inches WC.
(<u>Answers below</u>.)

Dead end service regulators may be used as appliance regulators; however, the cost of a service regulator is many times that of an appliance regulator and the economics involved normally prohibit using dead end service regulators in this fashion. Appliance regulators, on the other hand, cannot be used as dead end service regulators.

Appliance Regulators

Gas appliance pressure regulators are installed on the gas manifold piping of a gas furnace or boiler, a water heater, a clothes dryer, a kitchen range, or other gas burning equipment. In Lesson 15, we'll be concerned with the operating details of the appliance regulator at the burner. At this point, let's review the basic features of the various types of appliance regulators. The essential components of a pressure regulator are shown in Figure 13-5. The three basic types of appliance regulators based on valve configuration are shown in Figures 136, 13-7 and 13-8.

Appliance regulators with *poppet* valves (Figure 13-6) are in common use. The term poppet means a single valve which moves into a seat. The valve and seat are similar to a ball and ring, the valve edges being bell shaped and therefore self-centering. The poppet valve is inexpensive, but effective, providing excellent regulation at nominal pressure ranges and good regulation at low flow conditions. Poppet valves are affected to some extent by inlet pressures and pressure drop conditions. Therefore poppet valves are usually used only when inlet pressures will not exceed 30 in. water column (WC).

Answers to Student Note Problem:

1. 3.5 inches WC = 0.126 psi
2. 112 psi = 13.85 inches WC

(3.5 inches WC is the "typical" natural gas pressure at burner orifice, and low pressure piping is defined as 1/2 psi or less.)

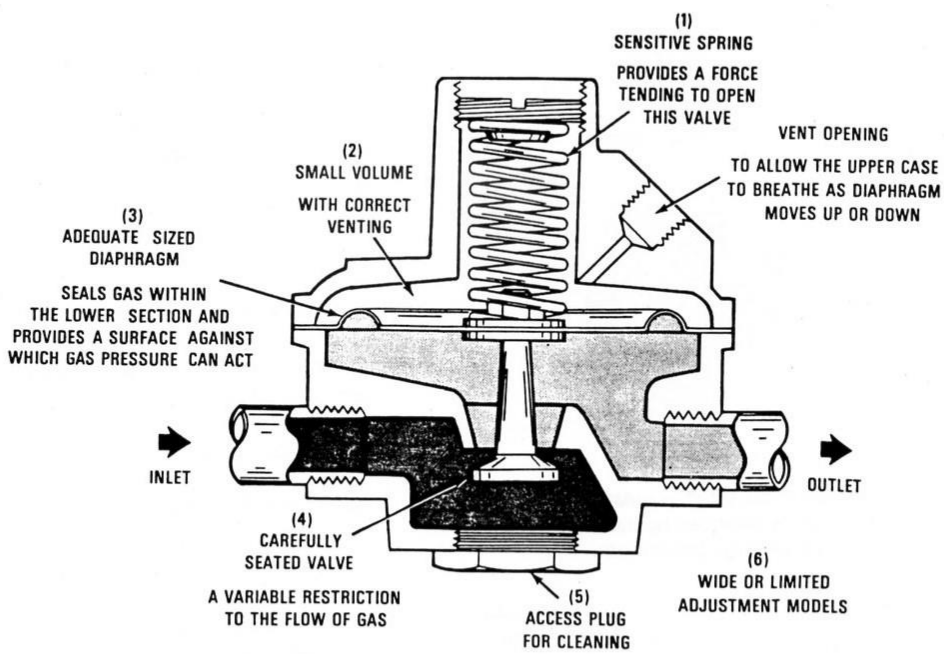


Figure 13-5: Essential components of a pressure regulator.

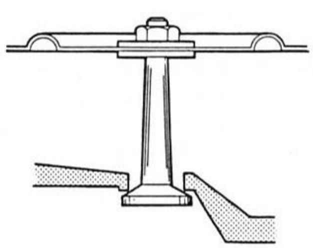


Figure 13-6: Poppet or single valve design.

The conical regulator (Figure 13-7) is a modification of the poppet valve. Essentially, the shape of the poppet is changed to a cone. Conical regulators are more expensive than poppet valves of comparable pipe sizes; however, conical regulators have almost twice the capacity. Conical regulators are usually rated at 3 psi and 5 psi maximum inlet pressure. However, the *inlet pressure should not exceed ten times the outlet pressure. This ratio limitation holds, regardless of the 3 or 5 psi maximum rating of the valve.*

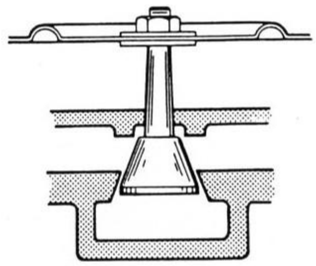


Figure 13-7: Modified poppet or conical valve.

The double-seated balanced regulator (Figure 13-8) is not affected by inlet pressure forces. In the double seated balanced regulator, gas flows through two passages, the upper valve and the lower valve. The upper valve and the lower valve are approximately the same size; and, since the effect of inlet pressure is upward on the
top seat disc and downward on the bottom seat disc, the inlet pressure forces are balanced and cancel each other. The double seated semi-balanced regulator is a high capacity regulator that can handle high inlet pressures and provide constant downstream outlet pressure regardless of fluctuations of inlet pressure.

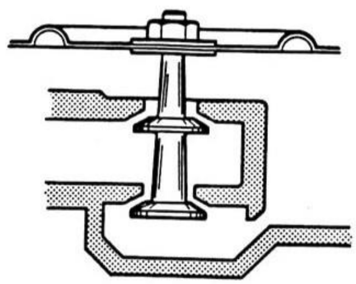


Figure 13-8: Balanced or double-seated poppet valve.

Burner Manifold Requirements

To make safe and effective use of gas combustion, the fuel supply system must be designed so that gas cannot flow to the main burner unless: 1) a proved pilot flame exists to assure the proper ignition of the gas flow to the main burner; 2) all safety controls are operative; 3) there is a demand for fuel burning from the controller (thermostat).

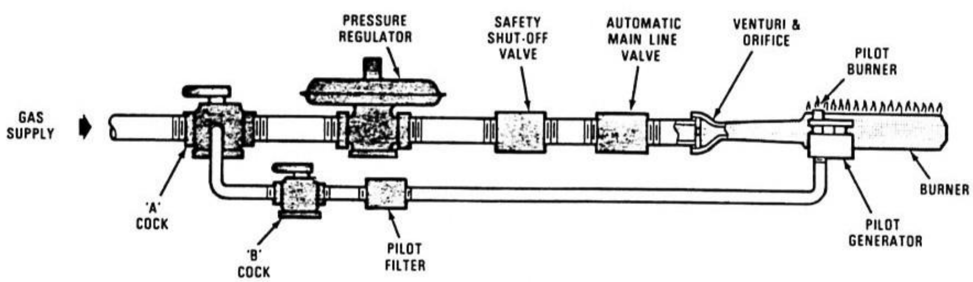


Figure 13-9: Burner manifold components broken down by function.

Therefore, broken down by *function*, a typical gas burner manifold should include the components in Figure 13-9.

“A” Cock - a manual valve for “on” and “off” control of main gas flow.

“B” Cock - a manual valve for “on” and “off” control of pilot gas flow.

Pilot Burner - a constant flame to ignite the main burner and a controlled heat source for a safety device which will not permit the main valve to open unless a safe ignition flame is present.

Pressure Regulator - maintains a constant pressure at burner regardless of pressure fluctuations upstream.

Safety Shutoff - permits main gas flow only when the safety device indicates an ignition flame is present.

Orifice and Venturi Tube - limits the amount of gas flow to the proper and safe limits for the main burner and provides primary air for combustion that is mixed with the gas prior to ignition.

Safety Device (Pilot Generator) - senses the absence of the pilot flame and prevents the flow of gas to the main burner.

Main Line Valve - operates on the demand of the thermostat if all other safety controls are satisfied.

In the lessons that follow, we'll consider each of the components in detail.

By 1960, the burner manifold components of Figure 13-9 had been combined into a single control. Lesson 16 covers the combination gas valve in detail.

Self-Check, Lesson 13 Quiz

You should have read all the material in Lesson 13 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A pressure regulator holds a constant pressure downstream when subjected to fluctuations on the upstream side.

2. T F High-pressure regulator valves are designed to fail in a closed position.

3. T F An intermediate “pounds-to-pounds” regulator reduces gas pressure by about 10%.

4. T F Ounces-to-inches regulators provide fluctuating pressure outside the house.

5. T F The upper and lower valves in the double seated appliance regulator are different sizes.

6. T F There is no similarity between the conical type and poppet type of appliance regulator.

7. T F Because of the effect of inlet pressure, the ratio of inlet to outlet pressure is vitally important in a conical appliance regulator.

8. T F The effects of inlet pressure are minimized by the double-seated balanced type of appliance regulator.

9. T F The poppet-type appliance regulator does not lend itself well to conditions of low flow.

10. T F Dead-end service regulators are the same as appliance regulators.

In the following multiple choice questions, choose the phrase that <u>most</u> correctly completes the statement and circle the corresponding letter in front of the phrase.

11. Let-down valves are usually operated on a large diaphragm by:

a. instrument air. b. electricity.
c. fuel oil. d. none of the above.

12. 14.7 psi (pounds per square inch), which is the standard barometric pressure, is equal to:

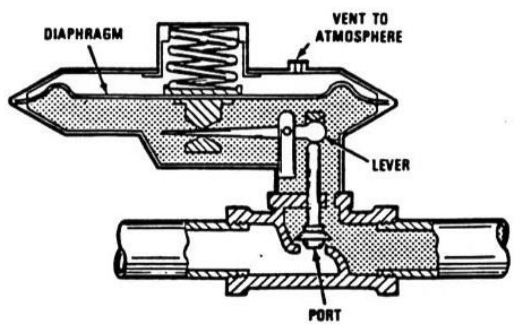
a. 408 in. WC (water column). b. 48 in. WC.
c. 3.8 in. WC. d. 0.38 in. WC.

13. Poppet appliance regulators are limited to use where the inlet pressure does not exceed:

a. 30 psi. b. 3.0 psi.
c. 30 in. WC. d. 3.0 in. WC.

14. The most common classification of gas pressure regulators is by:

a. size. b. shape.
c. manufacturer. d. usage.



15. The figure above shows a schematic drawing of a/n:

a. dead-end service regulator. b. appliance regulator.
c. poppet valve regulator. d. conical type regulator.

16. A regulator with a small port, high seating pressure, and large diaphragm area is a typical:

a. appliance regulator. b. dead-end service regulator.
c. conical regulator. d. poppet-type regulator.

17. One appliance regulator that is quite inexpensive to manufacture and has excellent regulation characteristics is the:

a. poppet valve. b. conical type.
c. double seated semi-balanced. d. all of the above.

18. Intermediate regulators reduce line pressure at 100 psi down to:

a. 10 psi. b. 0 psi.
c. 10 in. WC. d. 100 in WC.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

19. Four basic types of pressure regulators used in a distribution system are:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

20. Three types of appliance regulators are:

1. ______________________________

2. ______________________________

3. ______________________________

21. Let-down valves provide a tight ________________________ in the absence of gas flow, thus preventing downstream pressure buildup.

22. Some limitations to using both poppet and conical regulators are caused by ____________________________ pressure and pressure ____________ through the valves.

23. In a poppet-type appliance regulator, the valve and seat may be compared to a/an _______________________ and a/an ___________________________.

24. The poppet type regulator is one in which a single _______________________ moves into the seat, with valve edges _____________ shaped for self-centering.

25. A typical gas burner contains the following components:

a. ____________________________ b. __________________________

c. ____________________________ d. __________________________

e. ____________________________ f. ___________________________

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

When you are satisfied you understand the questions missed, proceed to your next assignment which starts on the next page.

Lesson 14 Overview

Lesson 14 deals with the automatic pilot used in gas fired heating equipment. While many designs have been used in the past, present day pilots generally rely on the thermocouple principle for dependable operation.

The automatic pilot performs two of the three functions of combustion controls - namely it provides a source of ignition and assures safe ignition.

The automatic pilot is the most important device involving the safe operation of the burner. It is also a frequent cause for complaint and a service call. “The pilot light is out” will be a phrase often heard in your years as a service technician.

In this lesson, be sure you:

1. Understand what a thermocouple is and how it operates.

2. Know the difference between single couple and pilot generator.

3. Can describe the operations in an ignition system when there is a call for heat.

4. Understand the difference between pilot safety valves and pilot safety relays.

Now read Lesson 14 which begins on the next page.

Lesson 14: Gas Burner Controls Part II – The Automatic Pilot

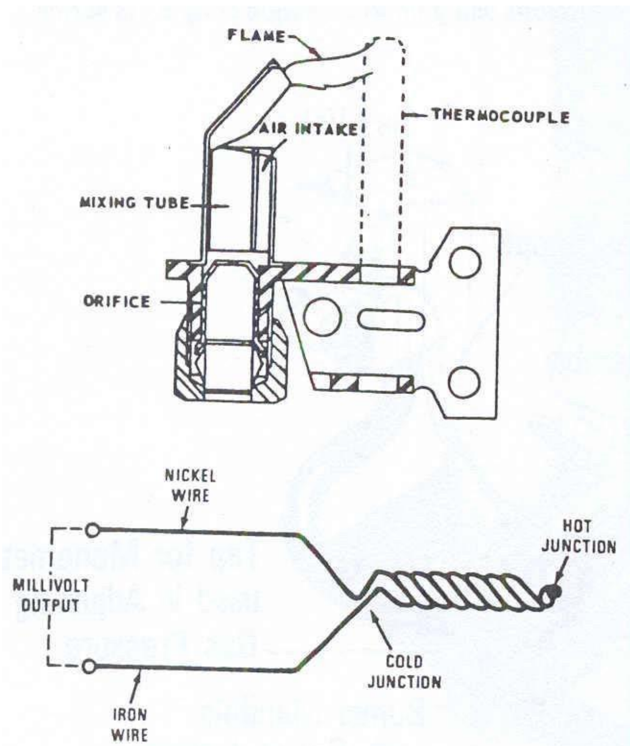


Figure 14-1: Thermocouple converts heat into electricity in sufficient quantities to power safety devices - relays or valves. Photo shows thermocouple mounted next to pilot light.

There have been numerous systems devised to provide fail-safe ignition of a gas burner. Most designs use a tiny "pilot" gas flame to provide:

1) a source of ignition for the main burner

2) a source of power to actuate a safety shutdown device

One design uses a pilot-heated rod and tube sensing element (review Lesson 9) that keeps an electric switch closed. If the pilot flame goes out, the cooling of the rod and tube element opens the switch. The open switch, in turn, interrupts electric power to a magnetic valve, causing it to close, and stopping gas flow to the burner.

Another design does essentially the same job, only using a liquid-filled bellows for a pilotheated sensing element.

But the most common ignition and safety pilot system uses the thermocouple as the sensing element. This is the automatic pilot system we will consider in detail in this lesson.

The Thermocouple

In Lesson 1, we mentioned the two most common ways of producing useful current electricity: 1) by means of a battery, which involves the conversion of chemical energy; and 2) by means of a generator, which involves a combination of mechanical energy and electromagnetic induction.

It is also possible to produce current electricity in small, but still useful amounts, utilizing light energy and heat energy directly. The use of light energy to produce electricity is discussed in Lessons 9 and 18. At this point, let's consider using heat.

The direct conversion of heat energy into electrical energy is called *thermoelectricity,* and involves the use of a thermocouple. A thermocouple is composed of two different wires, such as iron and nickel that are joined together at one end (Figure 14-1). The welded joint is called the *hot junction;* the opposite end is called the *cold junction.*

Thermocouple Operation

When the hot junction is heated, a small electrical potential (voltage) is developed and electrons (current) flow from one wire to the other. The greater the temperature difference between the hot and cold junctions, the greater the voltage output. The voltage output of a thermocouple, which is measured in millivolts (1,000 millivolts = 1 volt), can be very useful in gas controls.

Thermoelectricity can be produced using a single hot-cold junction, or using many couples arranged in ***series*** for voltage amplification. The latter arrangement is called a *pilot generator.*

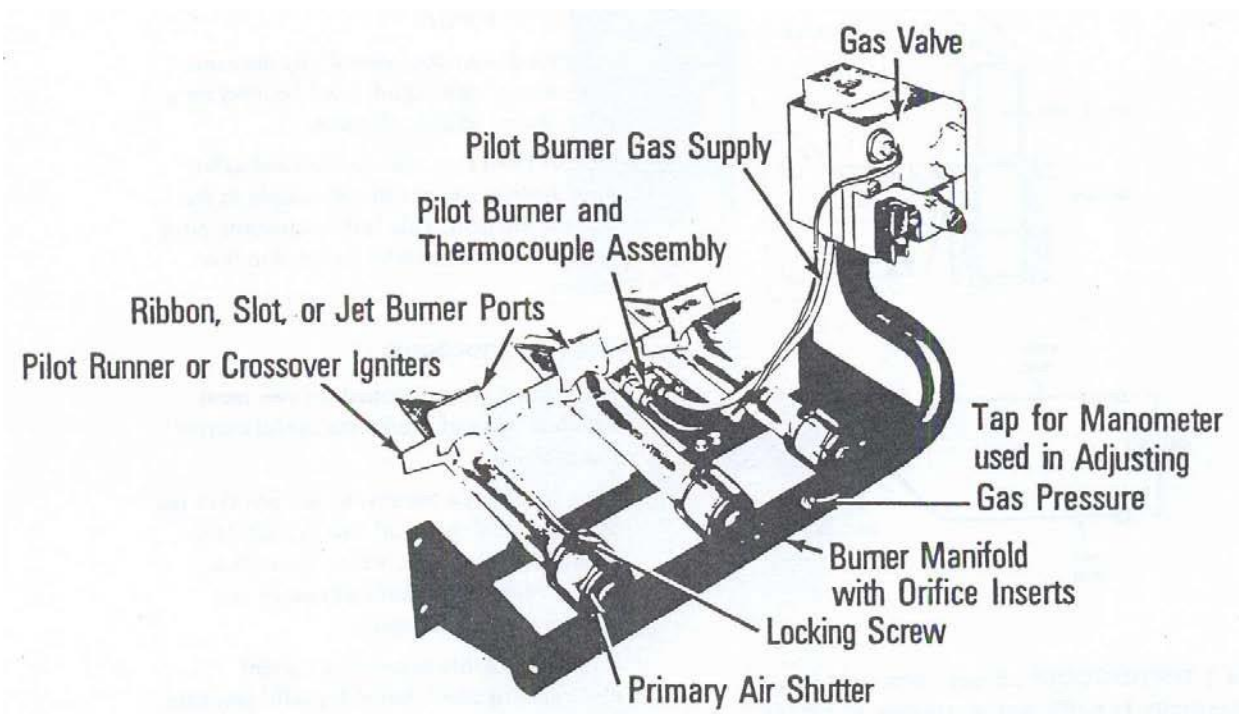


Figure 14-2: Typical automatic ignition system using a single thermocouple as a safety device.

Single couple thermocouples produce approximately 25 to 35 millivolts and are used with circuit components (relays, thermo and electro magnets) that can operate satisfactorily on about 7 millivolts "closed circuit."

The terms "open circuit" and "closed circuit" used in this lesson are defined as follows:

- Closed circuit - all switches in the system are closed and the loads are energized.

- Open circuit - all switches in the system are open and there is no current flow.

Pilot generator thermocouples are classified in two general categories based on the voltage produced.

One category comprises those units using 10 or 15 single thermocouples joined in series to make one generator. Such a unit can produce approximately 250 to 300 millivolts (open circuit) and supply power to systems that operate on 140 millivolts (closed circuits).

The second general category of pilot generators produces a millivoltage output of about 500 to 750 millivolts using up to 27 single couples in series.

This class of generators is generally used in *self-generating control systems* and power all control components, thermostat, main gas valve, limit control, pilot safety valve, etc. No external power source is required. Self-generating systems will be discussed in Lesson 16.

Automatic Ignition System

A typical automatic ignition system for a gas furnace using a single thermocouple as a pilot safety device is shown in Figure 14-2.

First of all, the thermocouple must be properly heated. Therefore, about 30 to 50 percent of the thermocouple element (depending on specific design) should be in the *hot* part of the pilot flame. After lighting, the pilot burner flame should be steady, not lifting or floating, and blue in color.

Once the thermocouple is heated and the millivoltage output is developed to hold open the safety shutdown valve, the pilot gas valve is manually set open to allow pilot gas to flow uninterrupted to the pilot burner. When the thermostat calls for heat, the automatic main gas valve opens, allowing fuel to flow to the main burner where it is ignited by the pilot flame. When the thermostat is satisfied, and its contacts open, the main gas valve closes.

If the pilot burner flame is extinguished for any reason, the thermocouple output will be insufficient to hold the safety and pilot valves open, and all gas flow will stop. The burner will not automatically relight until corrective action is taken.

The operation of an automatic ignition system is dependent on the following factors:

1. **The design of the pilot burner** - The size of the port, the energizing port, and the pilot burner orifice must be properly balanced so that the flames from the ignition port and the thermocouple energizing port are proportioned to perform their respective functions of:

    a) igniting the burner

    b) heating the thermocouple to produce the voltage required to operate the thermomagnet mechanism in the valve or relay

2. **The relationship between the ignition port and the main burner** - The relative position of the ignition port of the pilot burner to the main burner ports is important. The pilot flame is adjusted so that the lowest flame that could be expected in the field will hold the control valve in the “on” position to permit safe ignition of the main burner under all possible operating conditions.

3. **Relationship of the pilot burner assembly to the main burner** - The pilot assembly (pilot burner and thermocouple) should be located so that room drafts, concussions from opening and closing appliance doors, the force of igniting and extinguishing puffs from the main burner, and severe draft conditions will not disturb the energizing flame enough to cause a drop in the voltage output of the thermocouple that would close the pilot safety valve and stop the flow of gas to the main burner.

4. **Dimensional relationship between the pilot burner and the thermocouple** - The thermocouple must be placed so the flame from pilot burner energizing port will produce a temperature differential between its hot and cold junction that will generate the voltage required to operate the thermomagnetic mechanism in the safety control. The temperature difference between the hot and cold junction will vary with the distance between the element and the port and with the nature of the pilot flame. If the element is placed too close to the port, the small head of a flame at minimum flame conditions may be sufficient to hold the control valve in the “on” position even though the ignition flame is too small or too far away to ignite the main burner.

5. **Nature of the fuel supplied** - Pilot burner flame outage can be caused by plugging of the pilot orifice with gum, rust, tar, and dust. Installing protective devices such as filters in the gas distribution lines, in the controls, or in the pilot burner lines reduces this problem.

6. **Pilot burner rate** - The millivoltage output of a thermocouple is ***not a direct function*** of the Btu input to the pilot burner. The Btu input to a pilot burner is determined by the orifice size and the type of gas used. Common pilot orifice sizes (depending on design) are:

Gases	**Size of Orifice (diam.)**
Natural & Mixed	0.018 to 0.021 in.
Manufactured	0.024 to 0.026 in.
LP (Butane and Propane)	0.008 to 0.011 in.

Under any given operating condition, the *maximum* voltage output of the thermocouple can be gained with *various pilot burner* input rates (Btu per hour). Voltage output depends on the gas supply, *the pilot location and the ambient temperature effects* on the hot and cold junctions of the thermocouple.

Pilot Safety Devices

Each control manufacturer offers its own versions of a pilot safety device. Cost, capacity, system characteristics, and code requirements are a few of the variables that foster specific designs. The myriad of products, however, can be grouped into two broad categories - pilot safety *valves,* and pilot safety *relays.*

Under the first category, the thermoelectric energy generated is used to power an electro or thermo magnet that holds a valve open directly. The second group offers a somewhat indirect approach; the thermoelectric energy powers a relay switch that, in turn, is part of the control circuit serving the main gas valve. Specific safety devices in both categories can require a single thermocouple or a pilot generator to supply the needed energy. Let's look at pilot safety *valves* first.

Figure 14-3 represents a typical pilot safety valve. The thermomagnetic assembly is energized from the pilot thermocouple. As long as safe ignition is assured (the pilot is burning), the thermomagnet will hold the valve open. But if the pilot flame is out, or too low for safe ignition, the valve will close, shutting off gas flow to the main burner.

There are several types of independent pilot safety valves available. They often will include manual on/off gas cocks, 100 percent safety shutoff, and safe lighting or flow interruption features. (No main gas flow can occur during lighting of the pilot.)

The valve in Figure 14-4 provides both manual shutoff and automatic 100 percent safety shutoff. If the pilot flame fails, the safety valve shuts off both main flow and pilot flow regardless of the position of the manual control. (100 percent safety shutoff is required with LP gas.)

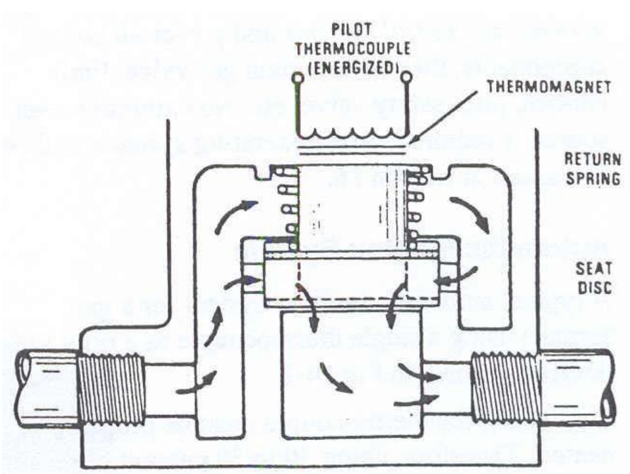
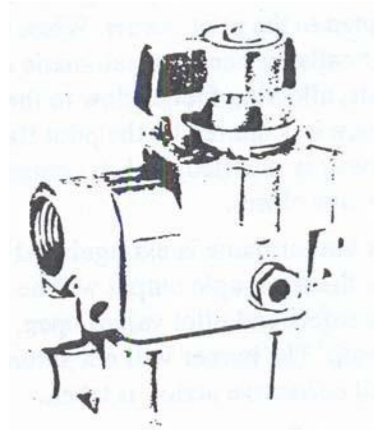
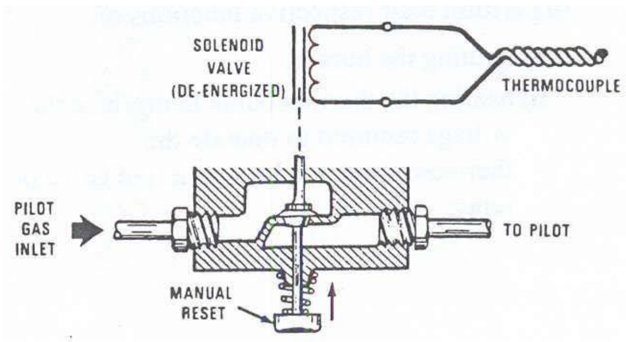


Figure 14-3: Typical pilot safety valve without manual "A" or "B" shutoff cocks (See Figure 13-9, Lesson 13.)

Figure 14-4: Safety valve at right features manual "A" cock and provides 100 percent safety shutoff. See also sketch below (ITT General Controls).





The independent manual reset safety pilot valve shown in Figure 14-5 also provides 100 percent safety shutoff control. On this pilot safety valve, depressing and holding a manual reset button opens the pilot gas valve for pilot ignition. Gas cannot flow into the main burner until the button is released. After the pilot burns for 60 seconds, electric current generated in the thermocouple should be sufficient to hold the valve open.

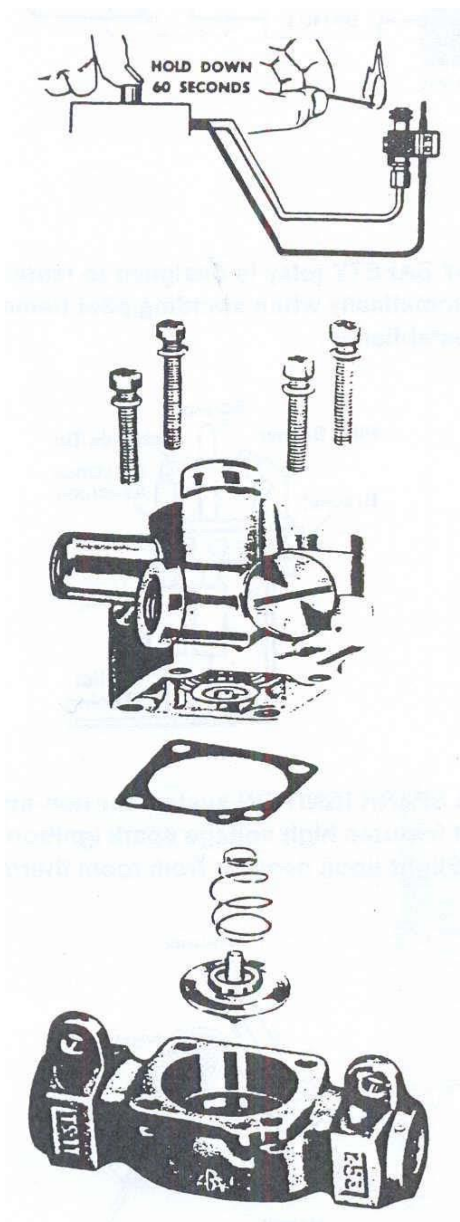


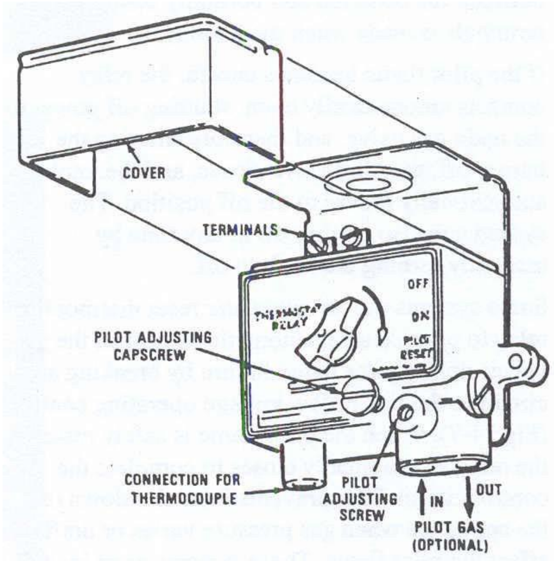
Figure 14-5: Interior components of a 100 percent safety shutoff valve with push button operation for pilot ignition (Robertshaw Controls).

Pilot safety relays, the other category of pilot safety devices, use a thermocouple powered relay to open and close electrical contacts to initiate safety shutdown or other desired actions when a pilot outage occurs. Thermopilot relays are used with 24 V, 120 V, or 240 V control circuits, depending only on contact capacity rating. They can be further categorized as being either manual or automatic reset. Thermopilot relays can also include manual on-off valves, 100 percent shutdown and safe lighting or flow interruption features.

The manual reset safety pilot relay in Figure 14-6 is generally attached to the appliance casing separate from the main control valve. Electrical power for operating the relay is supplied by a single thermocouple. On some models, turning a knob or lever to the “pilot reset” position opens the relay contacts. If a pilot valve is incorporated, gas will flow to the pilot burner only. After the pilot has been burning for about one minute, the thermocouple will produce the necessary power to close the relay contacts and the knob can be released and turned to the on position. Contact between the common and normally open line terminals is made when the knob is on.

If the pilot flame becomes unsafe, the relay contacts automatically open, shutting off power to the main gas valve, and therefore shutting the burner off, the pilot valve closes, and the knob automatically moves to the off position. The system can also be shut off at any time by manually turning the knob to off.

Some systems use an automatic reset thermopilot relay to provide safe, automatic shutoff of the gas valves during pilot flame failure by breaking a circuit to the line or low voltage operating controls (Figure 14-7). When the pilot flame is safely restored, the relay automatically closes to complete the control circuit. This prevents false shutdown of the appliance when gas pressure varies or drafts affect the pilot flame. These systems must include switching for automatic spark ignition for the pilot burner during the pilot flame failure, as might occur with rooftop equipment.



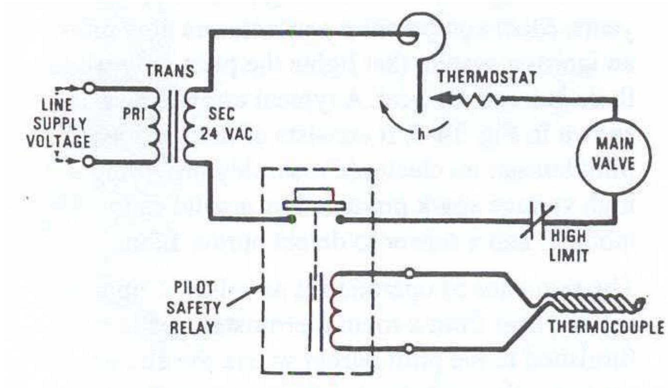


Figure 14-6: Pilot safety relay interrupts power to main burner to provide safety shutdown. This particular design requires manual reset after safety shutoff.

No Standing Pilot

To reduce energy consumption, industry has moved away from the standing pilot in recent years. Most equipment manufacturers now offer an ignition system that lights the pilot only when there is a call for heat. A typical arrangement is shown in Figure 14-8. It consists of the traditional pilot burner; an electrode assembly providing a high voltage spark produced by a solid state module; and a sensor to detect burner flame.

The sequence of operation is as follows: upon a call for heat from a room thermostat, gas is furnished to the pilot burner where the already sparking electrode ignites the pilot gas. When the thermal sensor detects the presence of the pilot flame, sparking stops. When gas enters the main burner, the now burning pilot lights off the main gas supply. When the thermostat is satisfied, both the pilot and main gas supply are shut off.

Another approach is to replace the pilot/spark system with a “hot surface” igniter similar to glow coil ignition used on gas clothes dryers.

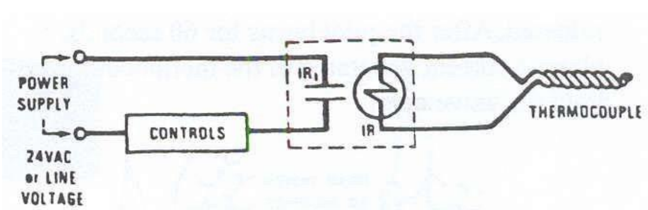


Figure 14-7: Safety relay is designed to restart automatically when standing pilot flame is reestablished.

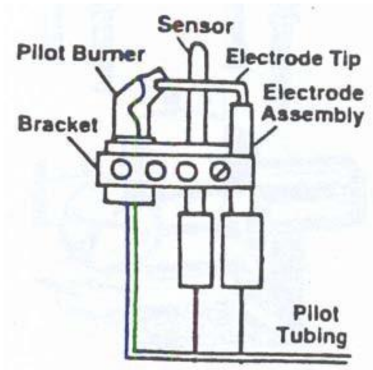
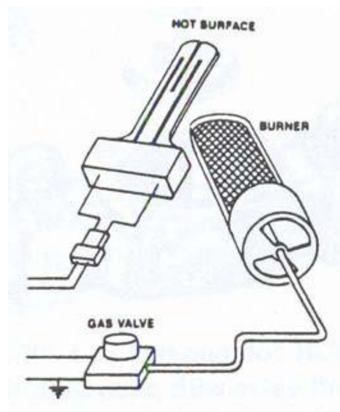


Figure 14-8: Spark ignition system for non-standing pilot features high voltage spark ignition of pilot light upon demand from room thermostat.

Figure 14-9: Hot surface igniter.



Self-Check, Lesson 14 Quiz

You should have read all the material in Lesson 14 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A thermocouple consists of two similar wires joined at both ends.

2. T F Most existing gas burners use a tiny auxiliary flame that burns continuously to provide ignition.

3. T F A pilot flame can be used to actuate a safety shutdown device.

4. T F Most safety shutdown devices use a rod and tube sensor.

5. T F The electric energy generated by a thermocouple can be used to hold a valve open directly or to keep a relay closed.

6. T F Automatic reset is not possible using a pilot light/relay system.

7. T F Millivoltage output increases proportionately with the thermal differential between the hot and cold junctions of the thermocouple.

8. T F An open circuit allows free flow of electrical current.

9. T F Millivoltage output of a thermocouple is not a direct function of Btu input to the pilot burner.

10. T F There is no need to balance the size and positioning of the ignition port, energizing port and pilot burner orifice.

In the following multiple choice questions, choose the phrase that <u>most</u> correctly completes the statement and circle the corresponding letter in front of the phrase.

11. The direct conversion of heat energy into electrical energy is called:

a. electromagnetism. b. osmosis.
c. thermoelectricity. d. thermomagnetism.

12. Pilot burner flame outage can be the result of a pilot orifice plugging with:

a. rust. b. gum.
c. tar. d. dust.
e. all of the above.

13. Pilot generators using 10 or 15 thermocouples are used to power systems that operate on:

a. 140 millivolts closed circuit. b. 7 millivolts closed circuit.
c. 25 to 35 millivolts open circuit. d. 24 volts open or closed circuit.

14. Orifices used in pilot burners are usually listed according to:

a. thickness. b. diameter.
c. surface area. d. circumference.

15. Single component thermocouples produce about:

a. 25 to 35 millivolts. b. 7 millivolts.
c. 25 to 35 volts. d. 7 volts.

16. The most common ignition safety pilot system is:

a. a pilot heated rod and tube. b. a pilot heated liquid filled bellows.
c. a pilot heated thermocouple. d. a spark detector network.

17. One millivolt equals:

a. 1000 volts. b. 100 volts.
c. 0.01 volts. d. 0.001 volts.

18. To increase electrical output, a pilot generator uses many single couples wired:

a. in parallel. b. in series.
c. in combination circuits. d. independently.

19. The term open circuit means that:

a. all switches in system are open - no current flow.
b. all switches in system are closed - no current flow.
c. there's a break in the circuit.
d. the circuit is being tested.

20. As a general rule, that portion of the thermocouple element placed in the hot part of the burner flame should:

a. extend down 10% of element's length
b. include 30 to 50% of element.
c. include just the tip of the element.
d. include all of the element

21. The Btu to a pilot burner depends on the gas used and the:

a. size of the orifice.
b. size of the supply pipe.
c. length of the nozzle.
d. area of the gas valve.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

22. The millivolts produced by a thermocouple can be used to hold a/an ___________ open, or to close, a/an ______________ placed in series with the thermostat and main gas valve.

23. Installing a/an _______________ in the pilot burner gas line helps reduce pilot outage due to ________________ of the pilot orifice with dust, lint, gum, etc.

24. When relighting a pilot, it may be necessary to manually hold open the pilot safety gas valve for _____________ minute(s) until the thermocouple begins to create sufficient power.

25. If the pilot flame becomes unsafe, pilot safety relay contacts automatically open and the _________________ valve closes, thus stopping the flow of fuel to the burner or pilot

26. The two types of thermocouples found in present-day systems are called ______________ and ________________ thermocouples.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

Lesson 15 Overview

Lesson 15 deals solely with one component - the appliance regulator at the gas burner. This device stabilizes gas flow to assure steady flame characteristics despite any fluctuations in pressure in the supply piping.

You briefly encountered the appliance regulator back in Lesson 13 when you studied the gas distribution system. There you learned about regulator valve and seat designs.

In this lesson, you'll learn in detail exactly how the appliance regulator operates under various gas flow conditions. You'll also be offered some important guidelines on installation and service.

After completing this lesson, you should understand:

1. How the appliance regulator operates under the conditions of no flow, normal flow, and pilot flow.

2. How ball check and orifice vent-limiting devices work.

3. The five steps to a good regulator installation.

4. Elements of good testing and adjusting procedures.

Now read Lesson 15 which begins on the next page.

Lesson 15: Gas Burner Controls Part III – Pressure Control at the Burner

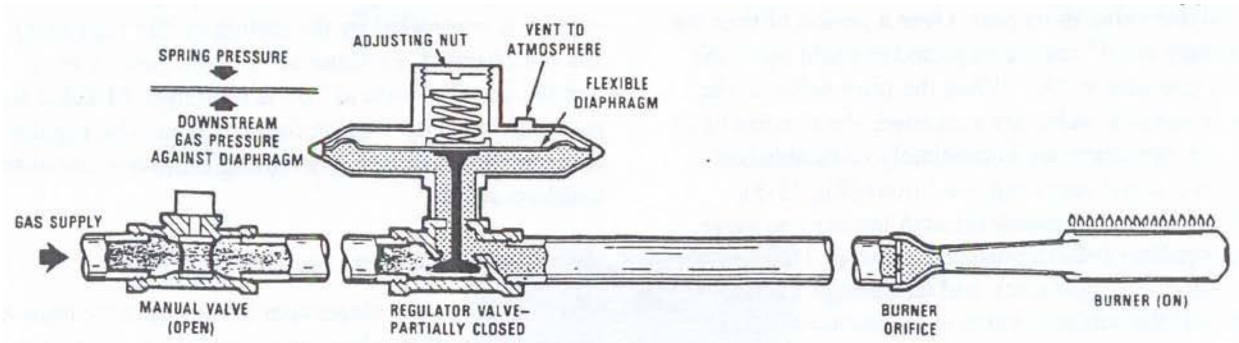
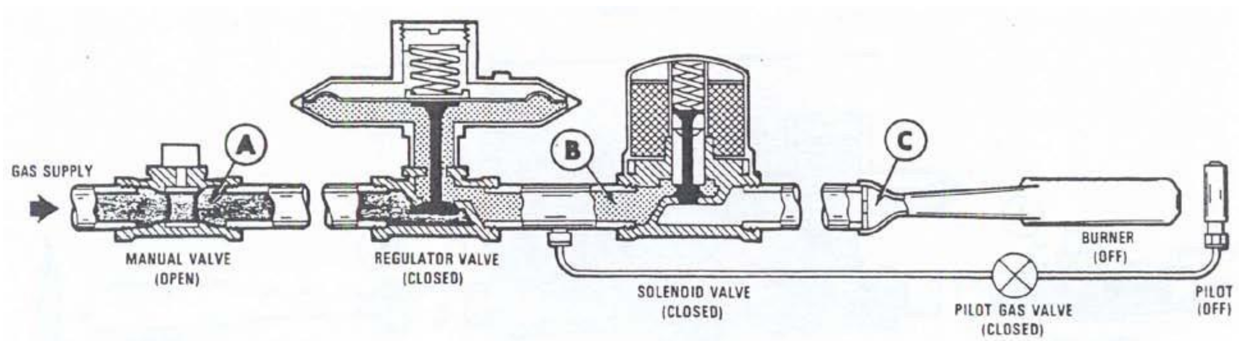


Figure 15-1.

The amount of gas which will flow through a burner *orifice* increases as pressure in the piping to the orifice increases. The burner itself, however, is designed to operate properly with a *constant* gas input. Therefore, gas pressure regulators are used to control pressure variations in the gas piping to the burner.

The operation of gas pressure regulators is based on balancing two forces or pressures (Figure 15-1). The downstream *outlet* pressure exerts a force on the diaphragm. (Back pressure, if you like.) Diaphragm movement caused by a change in outlet pressure will reposition the regulator valve to change the flow rate through the valve. However, the upward movement of the diaphragm is opposed by the force of the spring which tends to hold the regulator valve in the fully opened position. Therefore, the outlet pressure is automatically maintained at the point where the downward spring force is balanced by the upward force of the gas pressure against the diaphragm.

Naturally, an increase or decrease in upstream *inlet* pressure will cause a change in flow through the partially opened regulator valve. There would, therefore, be an immediate change in downstream outlet pressure. A well-designed regulator will respond to this change and reposition the diaphragm and, consequently, the regulator valve, to change the flow rate so that a constant downstream outlet pressure is maintained.



Under zero gas flow conditions (Figure 15-2) the pilot pressure at “A” will be equal to the outlet gas pressure as long as the solenoid gas valve is closed.
The pressure at “C” will be zero since the solenoid valve is closed. Since the pilot valve is also closed, the pressure at “B” will rise until the upward movement of the diaphragm effectively seats the regulator valve in its port. Over a period of time, the pressure at “B” can be expected to build up to the inlet pressure at “A.” When the pilot valve or the main solenoid valve is reopened, the conditions of normal operation are immediately re-established. Under normal operating conditions (Figure 15-3), incoming gas is passing through the manual valve, the regulator (where pressure is dropped to the setting of the regulator), and on through the pilot gas line and the solenoid valve to the burner orifices. The pressure at the burner orifices is held constant by the regulator.

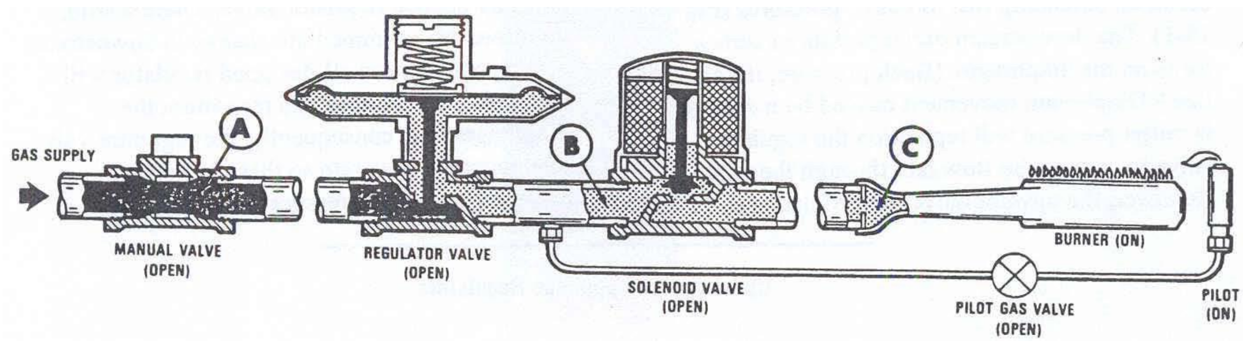


Figure 15-3.

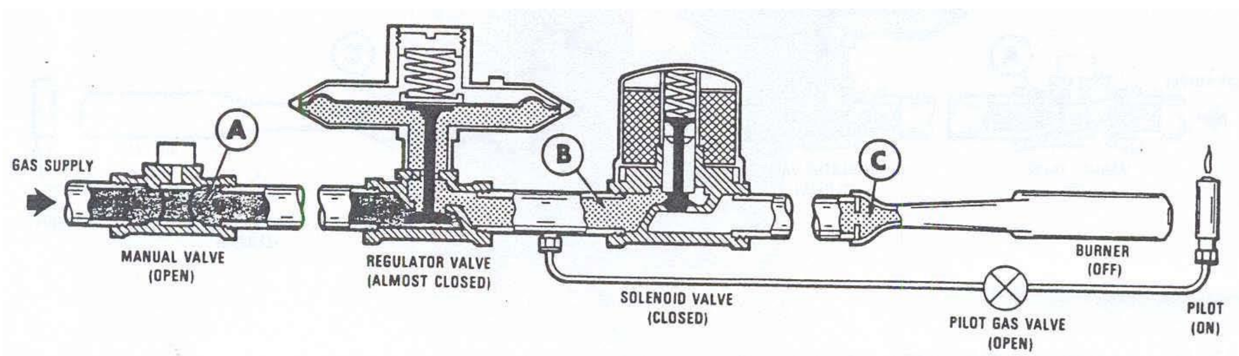


Figure 15-4.

If the flow rate to the main burner is 50 cubic feet of gas per hour and the flow rate to the pilot burner is 1 cubic foot per hour, the total flow through the regulator is 51 cubic feet per hour. The pressure at “B” and “C” is substantially equal and the regulator valve is well off its seat to accommodate this flow rate.

Under pilot gas flow conditions (Figure 15-4), the solenoid valve to the main burner has closed. The pressure at “A” still equals the outlet pressure of the dead end service regulator and the pressure at “B” (which is controlled by the setting on the regulator) has not changed. Pressure at “C” however, is zero; and the gas flow rate at “B” is no longer 51 cubit feet per hour, but only 1 cubic foot per hour. The regulator valve is almost closed, preventing excessive pressure buildup at “B.”

Vent Leak Limiting Devices

The area above the diaphragm in the regulator must be vented to the atmosphere by a vent leak limiting device. Without a vent opening, the air trapped above the diaphragm would restrict the movement of the diaphragm.

The vent leak limiting device is also a safety device, in that it will limit gas leakage if the diaphragm is ruptured. The vent leak limiting device is simply a restrictive orifice that limits the bleed of gas in case the diaphragm is ruptured to an amount that does not exceed one cubic foot per hour of 0.6 specific gravity gas at 7 inches water column pressure.

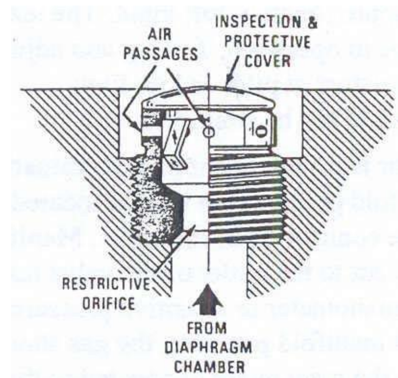


Figure 15-5: Restrictive orifice vent limiting device for small regulators.

The American Gas Association (AGA) and the National Fire Protection Association (NFPA) sanction the use of vent leak limiting devices on all appliances using gas burners. City codes may accept the standards of the AGA and NFPA, or they may require vent tubing. If codes require vent tubing, a vent line must be run from the vent leak limiting device into the firebox, near, but not in, the standing pilot flame. There are two basic types of vent leak limiting devices. The simple restrictive orifice (Figure 15-5) is commonly used on small regulators.

Figure 15-6 is a ball check leak limiting device commonly used on larger regulators. The ball check leak limiting device does not restrict air movement when the regulator valve is moving from the low flow or closed position to the full flow position. However, when the regulator valve moves from the full flow to a low flow or closed position, the ball check seals the air inlet and air must be vented through the restrictive orifice. Regulator response is therefore slightly dampened when going from full flow to low flow, but this does not present significant operating problems. If the diaphragm ruptures, the ball seals the air inlet and the vent flow is reduced below 1 cubic foot per hour by the restrictive outlet.

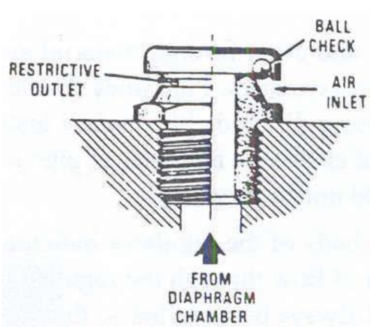


Figure 15-6: Ball check leak limiting device is used on many larger regulators. See diagrams at right and left.

Restrictive orifice vent leak limiting devices should be used with smaller regulators (less than ½" iron pipe size IPS) and ball check devices should be used with larger regulators (½" or larger) to maintain service free performance. The ball check device can be used on smaller regulators, but the higher cost is not offset by improved performance.

Installation Guidelines

Dirt, pipe chips, and other foreign materials are the regulator's greatest enemies. Pipe lines should be blown out to remove dirt and chips before installing the regulator, and excessive amounts of pipe joint compound should not be used.

An arrow on the body of the regulator indicates the correct direction of flow through the regulator. The regulator should always be installed so that gas will flow in the direction of the arrow. Some (but not all) regulators can be mounted in any position. If in doubt as to correct positioning, the regulator should be installed in a horizontal pipe run with the diaphragm level and above the pipe.

The ambient temperature surrounding the regulator must not exceed 175° F.

Regulators are generally factory-set to the appliance manufacturer's specifications. If resetting is necessary, a manometer or pressure gauge should be connected to the downstream pressure tap. After removing the seal cap, a screwdriver should be used to turn the adjustment nut. Clockwise rotation of the nut (screw-in) will increase pressure; counterclockwise rotation of the nut (screw-out) will decrease the pressure. Adjustments must be made with the gas flowing. On limited adjustment regulators, the adjustment is limited to plus or minus ½" water column (wc) pressure to prevent over firing.

The regulator vent orifice must be open to the atmosphere. Vent passages usually terminate in a 1/8" iron pipe size thread. If a vent line is required by local code, it should be run into the combustion chamber *below* the pilot flame, because heat from the flame may fuse the line.

Student Note: Proper tools and test instruments are "half the job." A good controls technician should use the proper tools to do the job quickly, easily and effectively - and keep all test instruments in good repair and proper calibration.

Field Testing, Adjustment, and Service

The *outlet pressure adjustment of* appliance regulators is pre-set at the factory. Typical settings are 3" wc, 3½" wc and 4"wc. The outlet pressure setting is stamped on the regulator.

The gas input of the appliance is governed by both the size of the burner orifices and the gas pressure at the manifold. Therefore, if the gas flow is in question, the burner should be checked for proper orifice size before the regulator is tested to determine whether or not the pressure setting is at the appliance manufacturer' specifications. When testing the pressure setting, the test tapping should be as close to the regulator as possible. Regulator outlet pressure must be tested with the appliance operating at approximately full input. The main burner must be in operation. Testing and adjusting appliance regulators at pilot or low flow conditions should not be attempted.

If the regulator is a component of a combination valve, a manifold pressure tap will be located at the outlet pipe connection of the valve. Manifold pressure adjacent to the outlet of the valve may be tested with a manometer or sensitive pressure gauge. To test manifold pressure, the gas should be turned off, the manometer connected to the pressure tap, the gas turned on, the pilot turned back on and re-established, and the main burner turned on. The pressure reading on the manometer should be within ¼" wc of the appliance manufacturer's specifications.

Field servicing of appliance regulators is generally limited to assuring that vent lines and passages are clean and possibly cleaning the regulator valve. A clogged vent opening will restrict diaphragm movement, causing sluggish regulator operation.

If a regulator must be replaced, the new regulator must have a capacity equal to or greater than the regulator being replaced, and it must be preset or adjusted to the appliance manufacturer's specifications.

An ounce of prevention is worth a pound of cure.

Blowing down gas piping before connecting the controls, selecting the proper control for the job, keeping controls clean, and handling them carefully during original installation can prevent many service calls later on.

Self-Check, Lesson 12 Quiz

You should have read all the material in Lesson 12 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F The pressure at Point B rises to move the diaphragm upward to seat the regulator valve (See Figure 1 below).

2. T F The volume of gas at Point B is large and dangerous.

3. T F In Figure 1 below, the pressure at point "A" is controlled by a dead end service regulator probably installed at the meter.

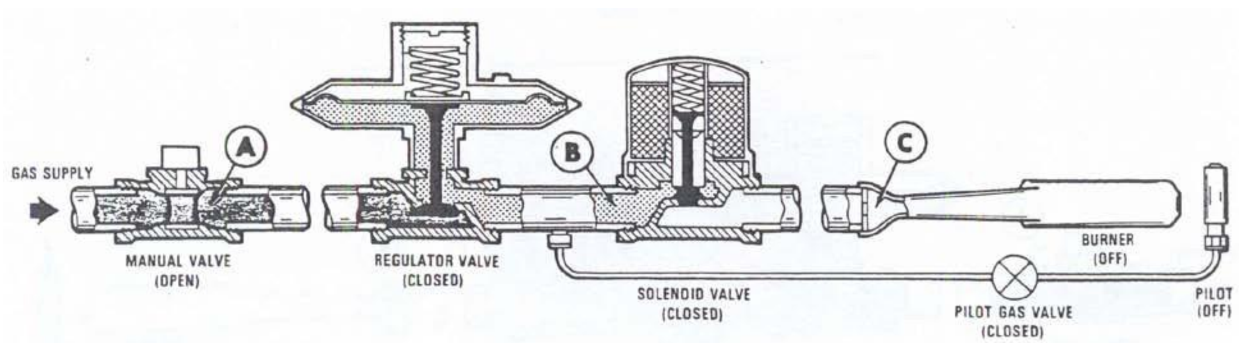


Figure 1 for True-False questions 1-3.

4. T F The vented area above the diaphragm in a gas pressure regulator allows for normal and free movement of the diaphragm.

5. T F The regulator vent orifice must not be open to atmosphere.

6. T F Proper burner orifices operating at a specified manifold pressure determine the gas input of an appliance.

7. T F Gas must be flowing through a regulator while it is being adjusted.

8. T F Some city codes require the regulator to be vented back below the pilot burner flame.

9. T F The purpose of the vent leak limiting device is to limit the escape of gas in event of diaphragm rupture.

10. T F The restrictive orifice type of vent leak limiting device is more commonly used on large pipe size regulators.

In the following multiple choice questions, choose the phrase that <u>most</u> correctly completes the statement and circle the corresponding letter in front of the phrase.

11. The possibility of diaphragm rupture or breakdown in an appliance regulator is:

a. small. b. great.
c. average. d. alarming.

12. Increasing spring force in a regulator:

a. increases manifold pressure. b. decreases manifold pressure.
c. changes upstream line pressure. d. damages diaphragm.

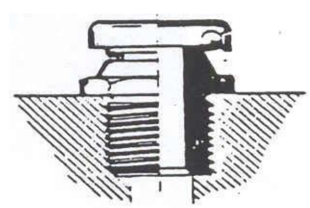
13. Under zero flow condition, the pilot and solenoid gas valves are:

a. open. b. closed.
c. controlled by the pressure. d. none of the above.

14. The proper direction of gas flow through a regulator is indicated:

a. by differences in pipe inlet and outlet sizes.
b. using inside and outside threads on opposing flanges.
c. by an arrow stamped on the body.
d. using color coded flanges.

15. The figure to the right illustrates:



a. pilot gas flow.
b. appliance regulator under zero condition.
c. restrictive orifice vent leak limiting device.
d. ball check type vent leak limiting device.

16. To prevent over firing, the adjustment range on limited adjustment regulators is limited to plus or minus:

a. ¼” water column. b. ½” water column.
c. 1” water column. d. 2” water column.

17. If a vent opening is dirty, the regulator will:

a. act sluggishly. b. respond quickly.
c. show no change in operation. d. pose an explosive hazard.

18. The outlet pressure adjustment of appliance regulators is preset at the factory, usually at:

a. 3” WC. b. 3½” WC.
c. 4” WC. d. any of the above.

19. Ambient temperature surrounding a pressure regulator should not exceed:

a. 100° F. b. 125° F.
c. 150° F. d. 175° F.

20. The ball check vent leak limiting device seals the large opening in the event of:

a. reaching maximum pressure. b. reaching minimum pressure.
c. diaphragm rupture. d. explosion.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

21. The vent leak limiting device limits gas bleed to less than one cubic foot per hour of ________ specific gravity gas at _______________ inches WC pressure.

22. Two basic types of vent leak limiting devices are:

a. _________________________

b. _________________________

23. Under normal flow conditions, incoming gas passes through the _____________________ valve through the ____________________ then through the pilot gas and solenoid valves to the _________________________ of the burner.

24. The gas pressure regulator is designed to control ________________ __________________ in the gas piping to the burner orifice.

25. To reset a regulator, remove the ___________ _____________ and turn the adjustment nut clockwise to ___________________ pressure, counterclockwise to ________________ it.

Check Your Answers!

Lesson 16 Overview

The main line gas valve is the device actuated by the room air thermostat that starts and stops the main gas flow to the burner. This combination, a thermostat and gas valve, is the classic example of a basic control system - a controller and a controlled device.

Lesson 16 offers a comprehensive analysis of how the basic types of simple shut-off gas valves operate but also contains a very detailed explanation of the various operations of the combination gas valve which has become more popular today.

There's also a section devoted to the millivolt gas valve that is used in self-generating control circuits (No external source of power is required to operate these controls).

Finally, installation and service procedures for both 24 volts and millivolt systems are detailed.

This lesson is of equal practical significance to Lesson 14 on the automatic pilot.

There are many important details in this lesson. You should:

1. Know the two basic types of shut-off gas valves and how they operate.
2. Be able to identify the four jobs performed by a combination gas valve and explain how it performs these functions.
3. Be able to describe a millivolt system and the type of main gas valve used in the system.
4. Know how to install and adjust gas valves used in the system.
5. Be able to name the most common servicing problems and their solutions.
6. Know how to use a millivoltmeter and how to test millivolt circuits.

Now read Lesson 16 which begins on the next page.

Lesson 16: Gas Burner Controls Part IV – The Main Gas Valve

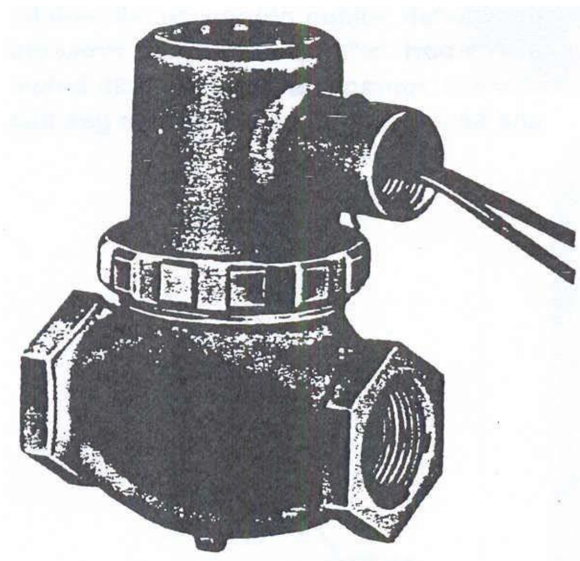
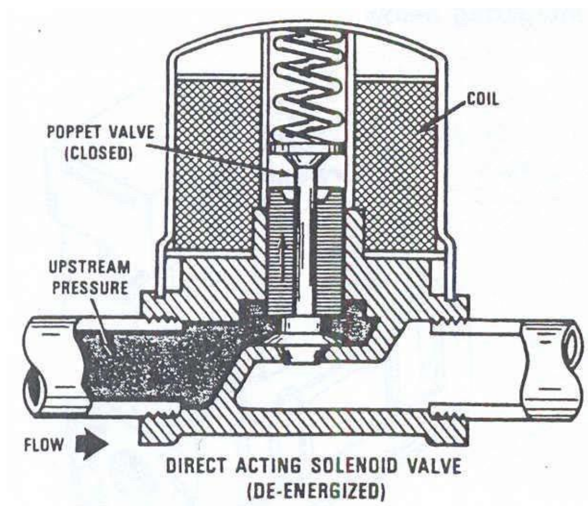


Figure 16-1: Solenoid type main gas valve is opened and closed by thermostat switching on and off a magnetic coil that lift a plunger. Spring pressure closes valve (White-Rodgers). Cut-away schematic below shows typical components.



At this point, we have considered all the important aspects of supplying and regulating gas to and in the home, with the exception of the controlled device known as the *main gas valve.* This valve is directly controlled by the room thermostat, and is the means by which the gas input, hence the heat output, is normally regulated to offset the building's heat loss. To begin, let's briefly return to a figure in Lesson 13.

Single function main line manifolds, similar to the burner manifold in Figure 13-9 in Lesson 13, uses one of two basic types of main line gas valves --- either a *solenoid* or a *pressure differential* valve.

A direct acting solenoid valve is opened by a magnetic field generated by a solenoid coil. If the coil is energized, a plunger is lifted into the solenoid core opening and permits main gas flow to the burner (Figure 16-1).

A pressure differential valve (Figure 16-2) has two compartments separated by a diaphragm and seat disc. Both sides of the diaphragm are exposed to upstream pressure through port "A" when the valve is in the de-energized position. The equalized pressure above and below the diaphragm and the weight of the seat disc seals off gas flow to downstream piping to the burner.

When the thermostat calls for heat, the solenoid is energized, opening port "B" (Figure 16-3) and closing port "A." The pressure on top of the diaphragm is vented to the downstream piping and a pressure differential is created above and below the diaphragm, This pressure differential permits the inlet pressure to move the diaphragm and seat disc up and the main orifice to the flow of gas opens.

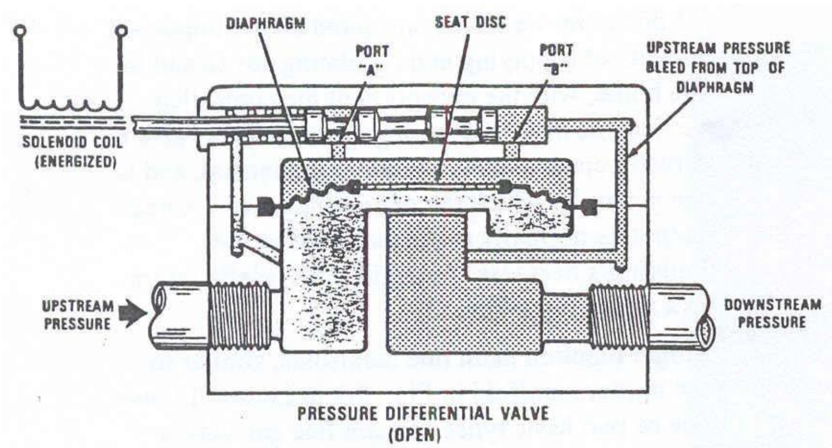
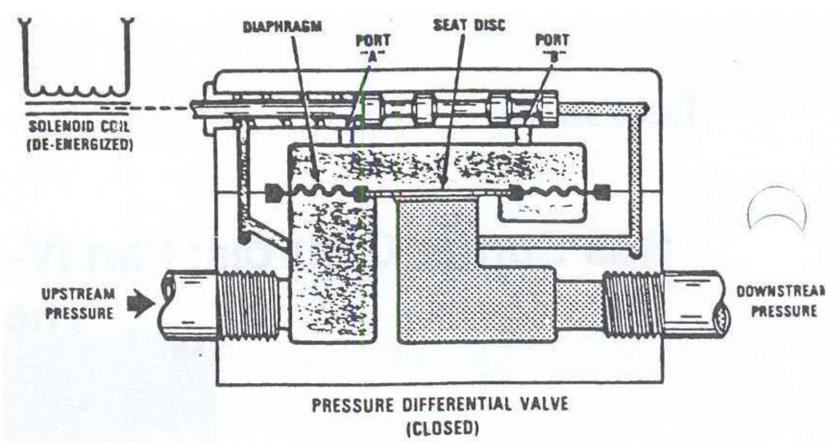


Figure 16-2: Pressure differential main gas valve also uses solenoid action but utilizes gas pressure to do the actual job of opening and closing the main valve. This permits use of a much smaller, quieter coil and plunger. In this diagram, port "A" is open and "B" is closed. Pressure above and below diaphragm is equal --- hence valve is closed.

When the thermostat is satisfied, it breaks the circuit to the solenoid coil, the solenoid returns to its original position, closing port "B" and opening port "A." Gas pressure then builds up above the diaphragm and the seat disc closes, sealing off gas flow to the burner.

Combination Valves

The combination valve (combination gas valve, safety pilot, pressure regulator, and gas cock all in one body) has greatly simplified manifold arrangements. (Compare Figure 16-4 with Figure 13-9 in Lesson 13.) Almost all residential gas fired systems installed today use combination valves. A combination gas valve performs four major functions: 1) manual shutoff, 2) safety shutoff, 3) pressure regulation, and 4) automatic on/off control of the burner.



Integrated or "smart" gas valves may also include ignition-safety functions within the gas body.

Figure 16-3: Solenoid plunger is now energized in this sketch pulling plunger to the left which opens port and closes "A." Pressure above diaphragm is now less than below and seat disc lifts, opening main gas line flow.

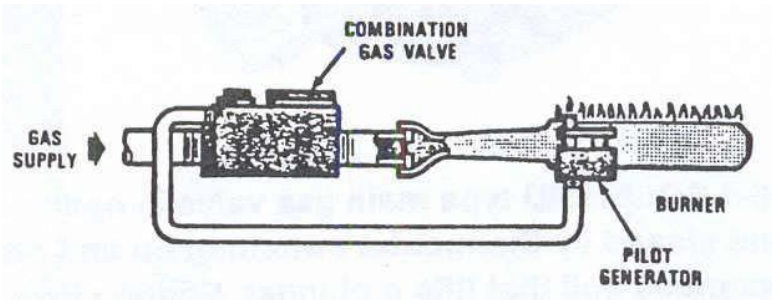
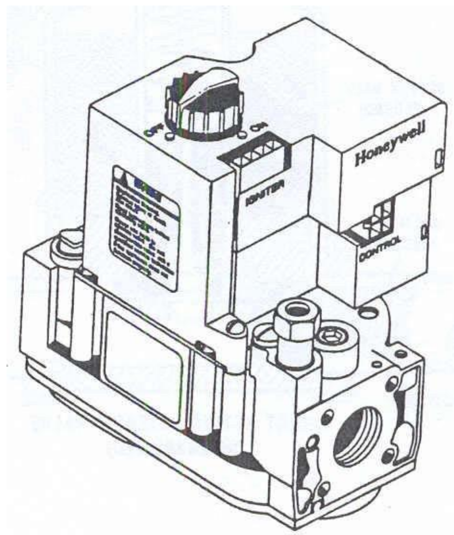


Figure 16-4: Traditional combination valve above, integrated below.



Combination Valve Operation. (Refer to Figure 16-5 next page.)

Manual Shutoff and Safety Shut-off: The manual control (on/off) and the safety shut-off functions are performed in the same section of the valve. When gas is supplied to the valve, the manual control at “J” must be depressed and turned to the pilot position before the pilot burner can be lit. After the pilot flame is established, the safety shutoff valve at “K” will open (usually after a delay of about 20 seconds), since the electromagnetic section of the safety shut-off valve has been energized by the thermocouple in the pilot flame.

If the pilot flame fails or is too low for safe ignition, the thermomagnetic section of the safety valve will be de-energized, and the spring force will close the shutoff valve.

After the pilot flame is established and the safety shut-off valve opens, the manual control can be released and turned to the “on” position. The fact that the manual control must be depressed to light the pilot burner and then released and turned to the “on” position for main burner gas flow prevents full burner gas flow while the pilot is being lit.

The manual control is turned to the “off” position to shut off gas flow through the combination valve.

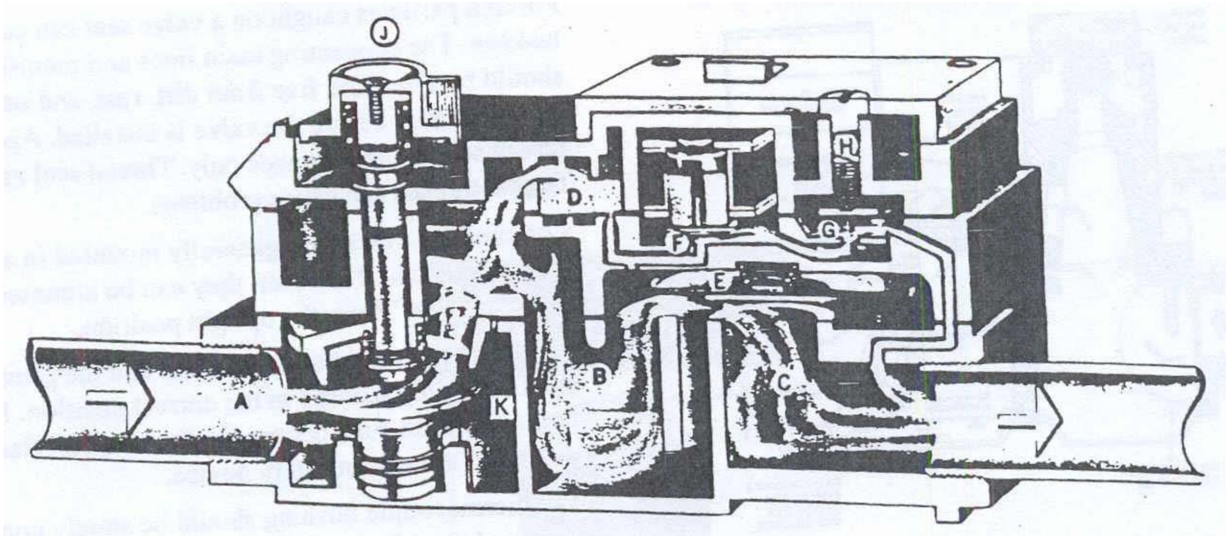


Figure 16-5. Cutaway of typical combination gas valve (ITT General Controls).

Pressure Regulation: Gas under supply pressure enters the combination valve at "A." (Figure 16-5.) When the main valve is energized, the gas will flow through the safety shut-off valve at "K," into the chamber at "B," over the main valve seat into the chamber at "C," and out to the burner. The main diaphragm at "E" functions as both a pressure regulating diaphragm and as an automatic on/off main line valve.

When the burner is operating, gas also flows through the filter at "D" and into the area above the main regulator diaphragm at "E." It also goes up through the seat of the servo-relay at "F" to an area below the servo-regulator diaphragm at "G" and on to the outlet of the combination valve.

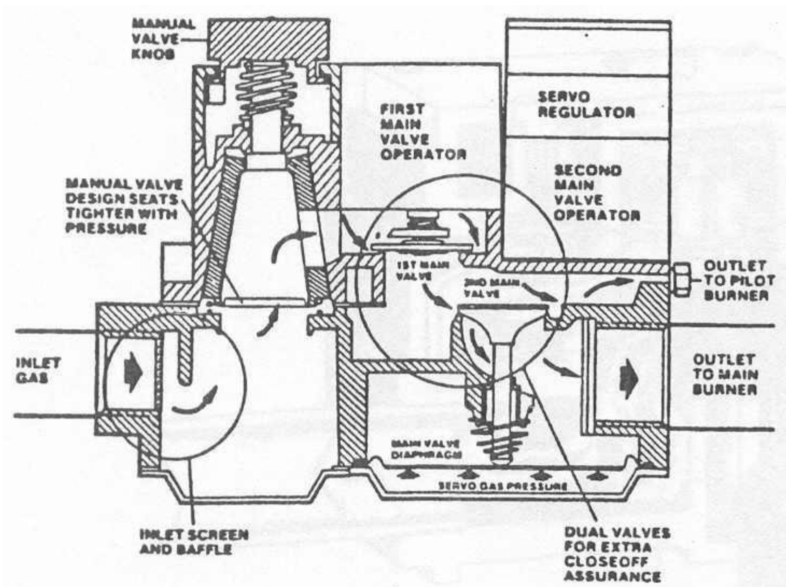
Main burner pressure regulation is achieved by balancing the flow through the servo-regulator and the pressure above the main diaphragm at "E." For example, an increase in pressure at the furnace manifold imposes a higher pressure at "G." This increased pressure lifts the servoregulator diaphragm, reducing flow through the servo-regulator valve. As the flow through the servo-regulator valve is decreased, pressure builds up at "E," causing the main diaphragm to move toward its seat. This reduces the flow of gas between areas "B" and "C," bringing manifold pressure back to design level.

If there is a decrease in manifold pressure, the valve will compensate automatically, since decreased pressure below the servo-regulator increases flow through the servo-regulator valve and drops the pressure above the main regulator diaphragm at "E." In this case, the pressure below the main diaphragm would force it upward, increasing mainstream flow.

The pressure control point of the valve can be adjusted by turning the manifold pressure regulator screw at "H" which controls the spring force on the servo-regulator diaphragm.

Automatic On/Off Control of the Burner:

Automatic on/off control of the main valve is achieved through a 24 volt (or a millivolt) control circuit connected to the servo-relay at “F.” When power is applied to the servo-relay which is actually a solenoid valve, the plunger will lift off its seat and gas will flow to the main burner. Opening the power circuit to the solenoid valve allows the plunger to close, preventing any gas from leaving the area at “E” above the main diaphragm. The pressure above and below the main diaphragm equalizes, and flow to the burner is shut off.



Increased risk of gas leaks through combination gas valves has fostered the dual valve design shown above. Since 1980, all gas furnaces are now fitted with combination valves featuring two main valves in series (Honeywell, Inc.).

Installing Combination Valves

Combination gas valves should be installed on a regulated line which does not exceed the maximum pressure rating of the valve. Combination valves are normally designed to operate on lines with supply pressures between 2 and 14 inches wc.

Foreign particles caught on a valve seat can cause leakage. The connecting main lines and manifolds should be clean and free from dirt, rust, and other foreign matter before the valve is installed. Apply thread sealant to the male threads only. Thread sealant applied to female threads can cause problems.

Combination valves are generally mounted in an upright position. However, they can be mounted in any plane up to 90° from the upright position.

Pilot tubing should be blown clean and the pilot burner must be rigidly secured in the correct position. Main burner ignition must occur with the smallest flame that will hold in the pilot safety device.
The thermocouple bushing should be snugly connected to the valve with a small wrench. Pilot adjustments can be made by removing a cap screw on the top of the valve (usually located beside the manual control) and turning an adjustment screw. The pilot flame should be a nonblowing blue flame which covers the top 1/4 to 3/8 inch of the thermocouple tip, depending on design. After pilot adjustments are made, the cap screw should be replaced.

Wiring connections should be clean and tight. All start/stop safety controls are in series with a transformer or millivolt pilot generator and the valve terminals. Thermostat heat anticipation should be set to the amperage value of the heating circuit.

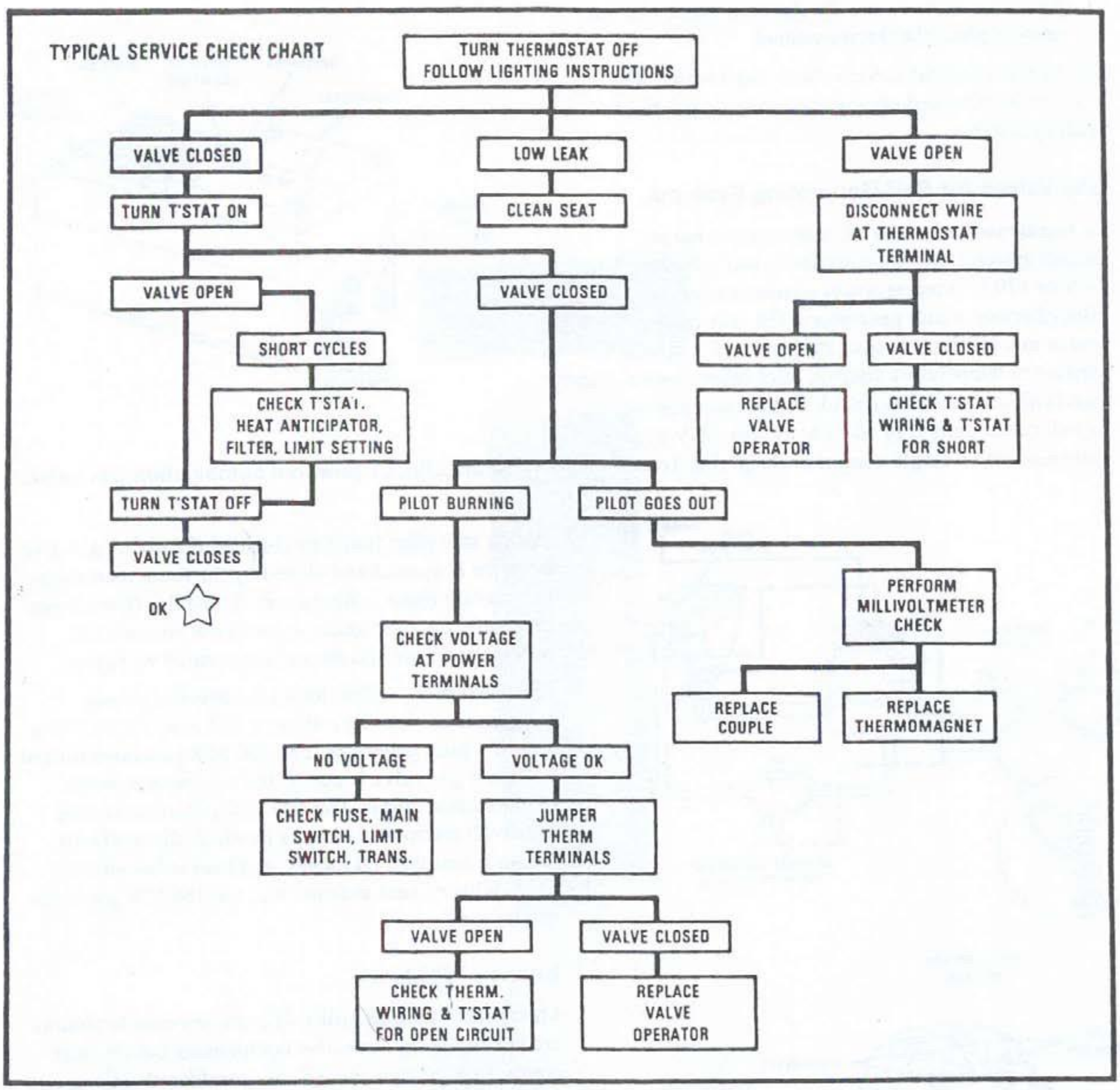


Figure 16-6: Service procedure chart.

Service Procedure

Adjusting the Pressure Regulator. Not all combination valves have pressure regulators. Some valves used with LP gas (propane) may have the regulator placed on the LP tank outside. On those valves that do have regulators, the regulator has been factory adjusted to the pressure stamped on the valve.

If the pressure regulator requires adjustment:

1) Remove the 1/8" pipe plug usually located near the valve outlet.

2) Install a pressure-measuring device.

3) Remove the cap screw normally installed over the regulator adjustment screw.

4) Adjust pressure regulation by turning the adjustment screw clockwise to increase pressure and counterclockwise to decrease.

Testing the Safety Shutoff Section.

To test the thermocouple output:

1) Unscrew the thermocouple from the valve and screw in an adaptor.

2) Attach a millivolt meter test clip (see section on using meter) to the side of the thermocouple and the other to a button on the adaptor.

3) If the millivolt meter moves to the left of zero or if there is no reading (with the pilot burning), reverse the meter leads.

4) Read the 0 to 50 millivolt scale on the millivoltmeter (use a higher scale if testing a millivolt pilot generator.

5) If testing a thermocouple, and the millivolt reading is less than 7 millivolts:

    a) adjust pilot gas

    b) clean pilot burner primary air holes and orifices

    c) replace the thermocouple if the reading is still less than 7 millivolts

6) If the reading, when testing a thermocouple, is 7 millivolts or more and the thermomagnet will not open, replace the thermomagnet.

Figure 16-6 (previous pages) is a typical service check chart which will help you in troubleshooting and servicing gas fired heating systems.

Gas Valves for Self-Generating Systems

As mentioned in Lesson 14, there are gas burner control systems that are completely self-powered. No 24 V or 120 V external power source is required. A pilot (thermocouple) generator is the only power source in a millivolt control system. Such a system is capable of temperature control, pilot safety control and high limit temperature control. System components can be individual units (Figure 167) or as with 24-volt systems, combined into a single control package (Figure 16-8).

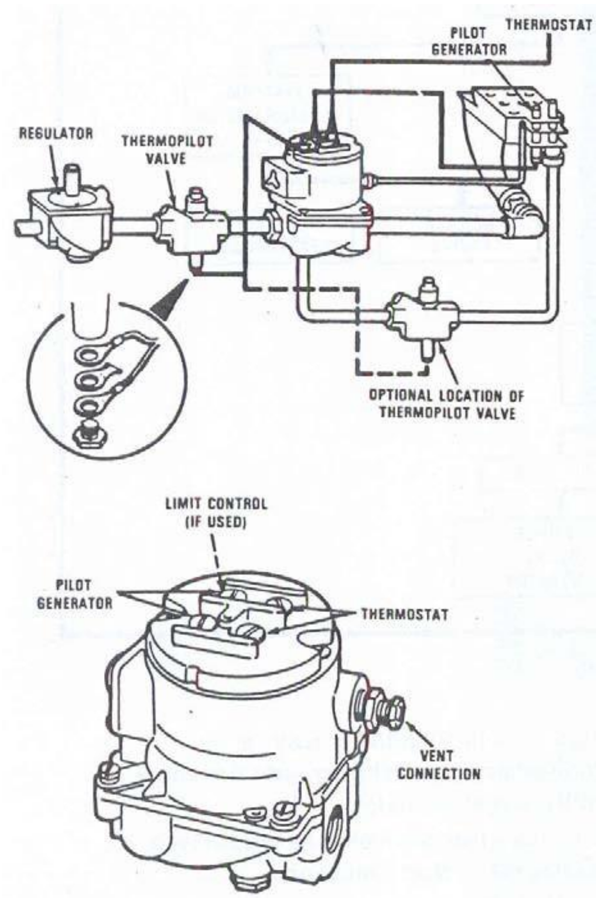


Figure 16-7: Components of a self-generating (millivolt) control system.

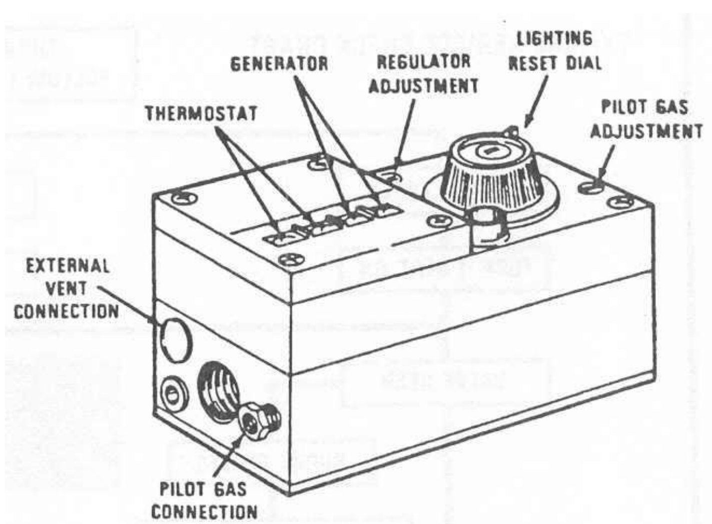


Figure 16-8: Millivolt powered combination gas valve.

With a safe pilot flame established, the main gas valve operator is opened and closed by the room thermostat to maintain room temperature. If the pilot flame is out or unsafe, the pilot generator will not produce the necessary power and the main gas valve will close. Electric power (millivoltage) for operating these systems is produced by either a 750 MV, 500 MV or a 250 MV pilot generator. The 750 MV generator is used when the gas valve is connected to a remote, wall mounted thermostat. The 500 MV generator is used only with thermostat circuits in which the total wire length is less than 60 inches, and heat anticipation is used. Without heat anticipation, the 250 MV generator can be used.

Service Problems

Most problems with millivolt or thermocouple circuits are not caused by defective components but by loose connections, dirty connections, unsoldered splices, etc. When a pilot outage occurs, the following steps should be taken:

1. Check the pilot flame to see if it is high enough.
2. Check the millivoltage output of the thermocouple.
3. Check to be sure the thermocouple connection is tight (this is a common problem when the pilot burner flame cannot be established).

Using Millivoltmeters

A typical *dedicated only* millivoltmeter has three scales --- 0-50 millivolts d.c., 0-500 millivolts d.c., and 0-1000 millivolts d.c. Millivoltmeters should be used only on millivolt circuits. They should never be used on line voltage or low voltage (24 volt) circuits. All tests should be made under closed circuit conditions where the load is powered by a thermocouple or pilot generator and the controls are calling for heat (See Figure 16-9).

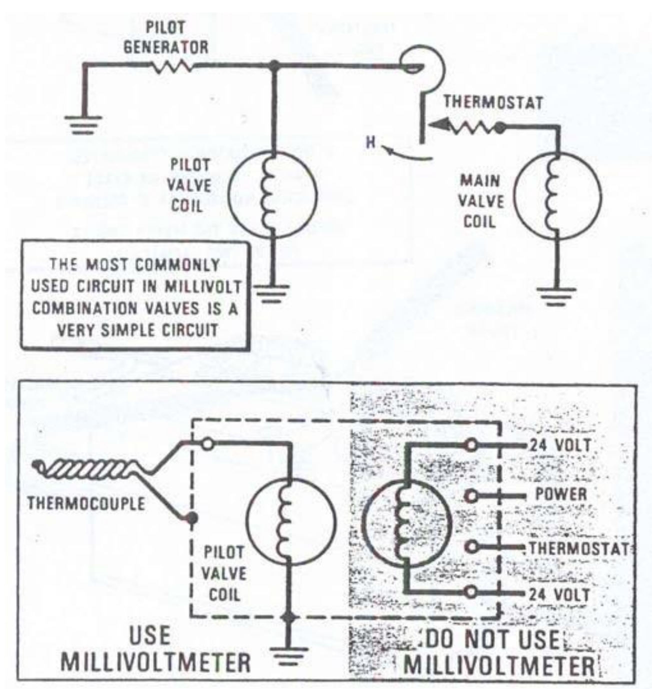


Figure 16-9: Use millivolt meter correctly.

When checking out a system, first look at the equipment that is on the unit to determine the voltage range then, select the appropriate scale on the millivoltmeter by plugging the leads into the plug jacks. On a simple millivoltmeter there is usually a common jack marked "-" or negative. One lead always remains in the common jack. The other lead is plugged into one of the three range positions. If the needle on the dial or scale moves to the left of zero, the leads on the device being tested should be reversed.

In some cases, special adaptors may be required to check millivoltage output. The thermocouple lead at the valve or relay must be disconnected and the proper adaptor inserted into the bushing (the adaptor should be finger tight). Connect the thermocouple to the adaptor and light the pilot. Connect the meter leads as shown in Figures 16-10A and 16-10B to test millivoltage output.

If the pilot generator is terminated in spade connectors, adaptors are not required. Simply touch the meter probes to the two terminals to check millivoltage (Figure 16-11).

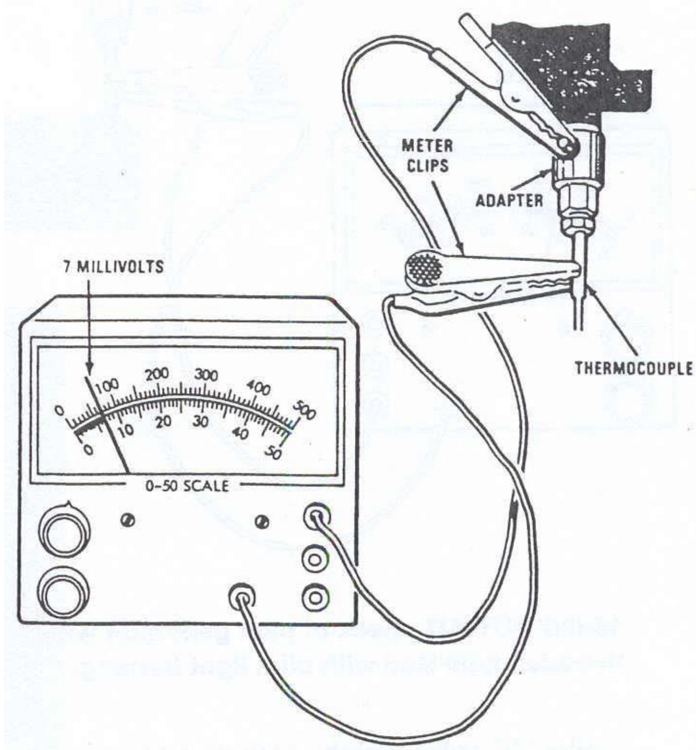


Figure 16-10A: Output test of single thermocouple threaded type lead at relay or valve using adapter and with pilot "on."

Testing Single Thermocouples

Controls used with a single thermocouple require a minimum of 7 millivolts to operate. Use the 0-50 scale on the millivoltmeter to check the thermocouple output. If the output is less than 7 millivolts, make the following checks:

1. Check the pilot gas. The pilot flame should be blue in color. If the flame is extremely large and yellow, check the size of the pilot burner orifice - it may be too large. If the size of the flame is satisfactory, but the flame is yellow, clean the pilot burner. If the pilot burner has been in operation for a long period of time, you may have to blow out the pilot orifice with compressed air.

2. If the pilot burner flame is lifting and floating, (the control cover and jacket doors should be in place), screw in the pilot adjustment screw or close the pilot "B" valve slightly. After making any adjustments, check the pilot burner to be sure it is properly heating the thermocouple and that there is sufficient ignition flame to light the main burner.

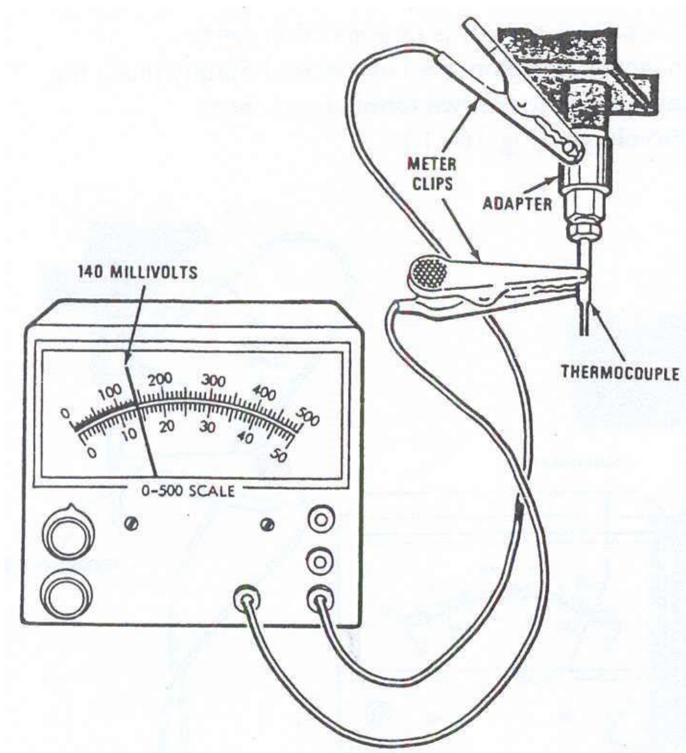


Figure 16-10B: Output check of pilot generator with threaded type lead with pilot light burning.

Replace the thermocouple if the above procedures fail to bring the millivolt output of the thermocouple up to at least 7 millivolts.

Testing Pilot Generators

Use the 0-500 millivolt or the 0-1000 millivolt scale on the meter to check pilot generators. Pilot generator output should be at least 140 millivolts. If the generator output is less than 140 millivolts, make the following checks:

1. Adjust the pilot gas as described above:

2. Clean the pilot burner orifice and make sure correct orifice is in the pilot burner for the fuel provided.
3. Replace the pilot generator if the above procedures fail to bring the millivoltage output to 140 millivolts.

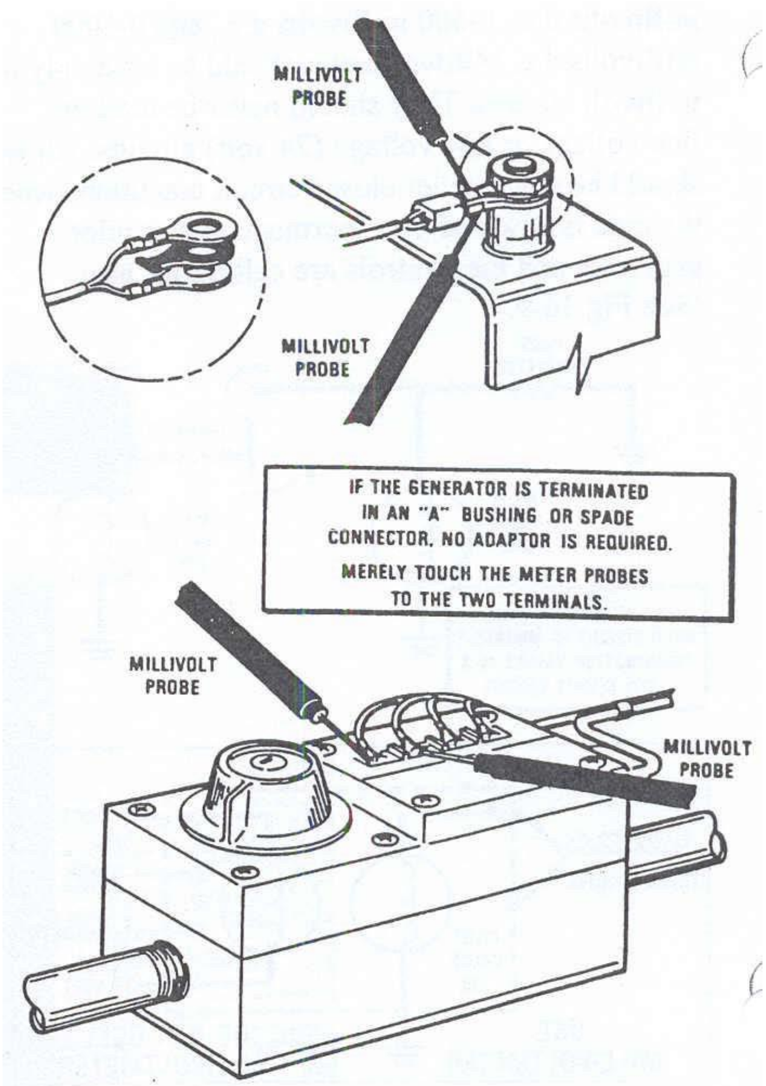


Figure 16-11: Output check for thermocouple leads using "A" type terminals (above) or spade connectors (below).

If the generation is over 140 millivolts (closed circuit) and the control will still not operate, replace the control.

The output of pilot generators used as the main power source or as the power source for the pilot safety circuit may vary. Always follow the equipment manufacturer's detailed instructions for *test and checkout.*

Self-Check, Lesson 16 Quiz

You should have read all the material in Lesson 16 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F The main gas valve is controlled directly by the room thermostat.

2. T F Manual shut-off and pilot safety take place in different sections in a combination gas valve.

3. T F Pilot flame should be a constant blue flame covering ¼” to ⅜” of the tip of the thermocouple.

4. T F Leakage can be caused by dirt particles caught on a valve seat.

5. T F There is no way to incorporate a high temperature limit control on a generator type thermocouple system.

6. T F A direct acting solenoid valve is opened by energizing a magnetic field.

7. T F A pressure differential valve uses solenoid action, but not to open and close the valve directly.

8. T F Using a combination valve saves installation time and conserves space.

9. T F Combination valves can be mounted in any plane up to 90 degrees of the upright position.

10. T F All stop/start safety controls are in series with the gas valve and the room thermostat.

In the following multiple choice questions, choose the phrase that most correctly completes the statement and circle the corresponding letter in front of the phrase.

11. In testing thermocouple output, adjust the pilot gas and clean burner holes and orifice if the reading is less than:

a. one millivolt.
b. three millivolts.
c. five millivolts.
d. seven millivolts.

12. A 500 millivolt control system limits a heat anticipating thermostat circuit to a total wire length of:

a. 60 feet. b. 6 feet.
c. 6 inches. d. 60 inches.

13. One of the most common yet simplest problems with millivolt circuits is:

a. thermocouple failure. b. pilot repairs.
c. defective gas valves. d. dirty or loose connections.

14. Pilot name should be steady and:

a. yellow in color. b. blue in color.
c. orange in color. d. clear.

15. An extremely large and yellow pilot flame indicates:

a. orifice may be too large. b. gas quality is poor.
c. too much primary air. d. bent burner tips.

16. A typical dedicated only millivolt meter has:

a. one scale. b. two scales.
c. three scales. d. four scales.

17. Tests with a millivoltmeter should be made:

a. under open circuit conditions. b. under closed circuit conditions.
c. with thermostat off. d. with burner off.

18. A 750 MV pilot generator must be used:

a. when there is no heat anticipation used on the thermostat.
b. some 24 volt power is also used.
c. when the furnace is 100,000 Btu/h or larger.
d. when a remote wall-mounted thermostat is required.

19. If a thermocouple produces 7 millivolts and safety shut-off fails to stay open, replace the:

a. combination valve. b. thermomagnet in combination valve.
c. pilot burner. d. pressure regulator in combination valve.

20. One of the most important installation requirements is to:

a. place main gas valve in an upright position.
b. adjust thermostat anticipator to match gas valve's current draw.
c. pressure test lines and valves.
d. time cycle rates.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

21. Three basic checks on a pilot outage complaint are:

a. ____

b. ____

c. ____

22. The two single-function main line gas valves used today are the ___________________ and the __________________________valves.

23. Thread sealant (pipe dope) should be applied to _________________ threads only when installing a combination valve.

24. The four functions of a combination gas valve are:

a. ______________________________________

b. ______________________________________

c. ______________________________________

d. ______________________________________

25. Four steps to follow in adjusting a gas pressure regulator are:

a. ______________________________________

b. ______________________________________

c. ______________________________________

d. ______________________________________

Check Your Answers!

Check Your Answers!

Lesson 17: Overview

In the last two lessons in Unit 4, we switch our attention from gas to oil and consider oil burner combustion controls.

While nationally, gas has replaced oil in popularity as a domestic heating fuel, oil-fired equipment can still be counted in the millions of installations. And in some areas of the U.S., oil is still the most widely used domestic heating fuel.

Both Lessons 17 and 18 deal with the same family of combustion controls. The family has come to be popularly referred to as oil burner primary controls. These devices are sometimes classified according to where the sensing element is located. In Lesson 18, burner-mounted primaries are discussed. In this lesson, we'll take up stack-mounted primaries in detail.

Lesson 17 should help you achieve the following goals:

1. Be able to list the four types of oil burner primaries and the method of sensing used.
2. Know the four functions of a primary control.
3. Know the difference between single-piece and two-piece stack-mounted primaries.
4. Explain the operation of the stack switch transducer.
5. Understand the construction and function of the ignition switch.
6. Know the difference between recycling and non-recycling primaries.

Now read Lesson 17 which begins on the next page.

Lesson 17: Oil Burner Controls Part I – Stack-Mounted Primary Controls

Oil-fired heating equipment uses a controller that embodies several functions in one package. Because of its multiple duties, it has come to be known as the oil burner primary control. As might have been expected, there are several variations - of primary controllers. The device can be either: 1) Single-piece, stack-mounted, temperature sensitive; 2) Two-piece, stack-mounted, temperature sensitive; 3) Two-piece, burner-mounted, temperature sensitive; 4) Two-piece, burner-mounted, light sensitive. Examples of each of these devices are shown in Figure 17-1.

Role of the Primary

The primary control is used to:

1. Start and stop the oil burner at the command of a room thermostat, operating control, or limit control.

2. Initiate automatic ignition of the burner.

3. Shut down the burner in the event of ignition failure or flame failure during the burner cycle.

4. Detect any malfunctioning of either the burner or of the control components within the oil burner primary control itself.

All of these functions are either sensing functions or switching functions and are performed by the two basic parts of the primary control – the sensing element and the transducer or switching element.

This lesson will cover the first two types of primary controls. The following lesson will consider burner mounted designs.

Single-Piece Stack-Mounted Primary
Temperature Sensitive

The single-piece, stack-mounted temperature sensitive oil burner primary control is installed in the stack or smoke pipe that connects the furnace to the chimney. It combines a thermal sensing element in one unit. This control should be installed between the barometric draft regulator and the furnace or boiler (Figure 17-2). On boilers or furnaces that have integral draft regulators, the thermal sensing element should be in the direct path of the hot combustion gases and located so cold air from the draft regulator cannot influence the operation of the thermal element to prevent false safety shut downs.

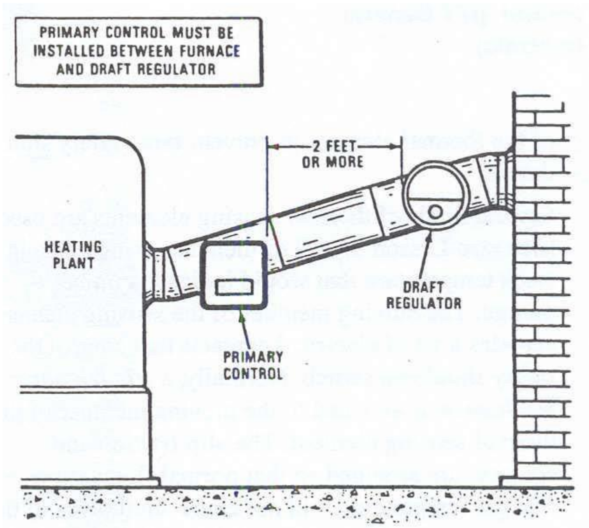


Figure 17-2: Location of stack-mounted primary.

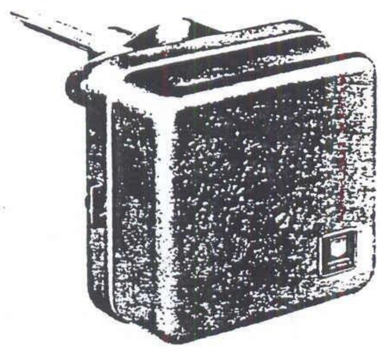


Figure 17-IA: Single piece, stack-mounted, temperature-sensitive oil burner primary control (ITT General Controls).

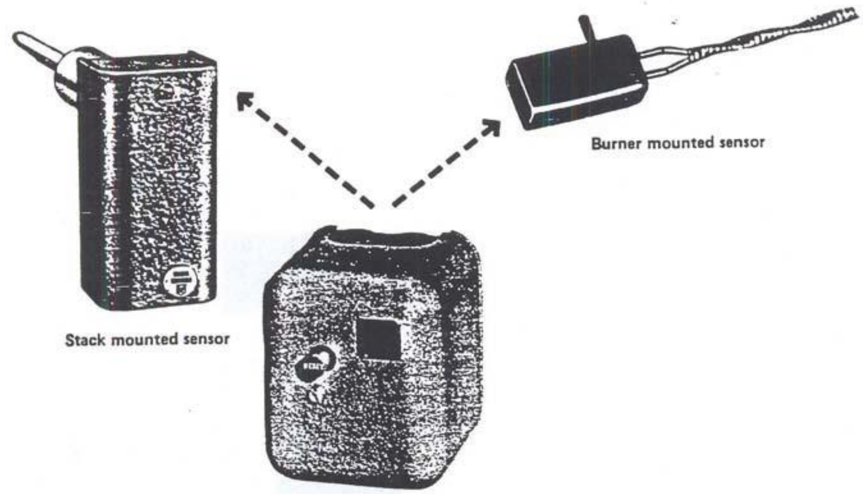


Figure 17-1B: Two-piece temperature sensitive primary with either stack mounted (left) or burner mounted (above) sensors (ITT General Controls).

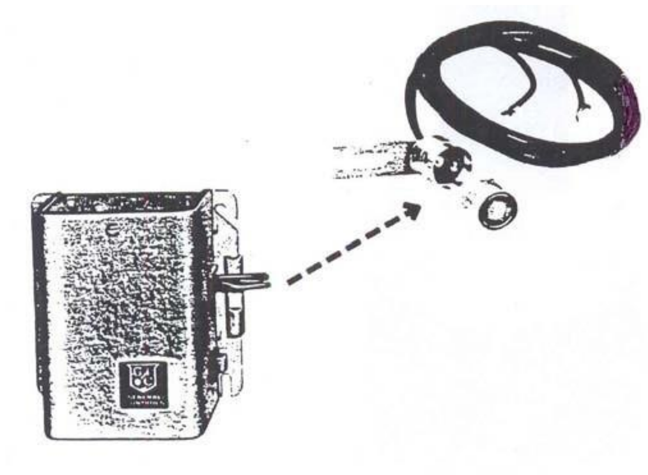


Figure 17-1C: Two-piece, light sensitive primary using cad cell burner mounted sensor (ITT General Controls).

Several kinds of thermal sensing elements are used (See also Lesson 9). All of them sense a change in stack temperature that would indicate a flame outage. The moving member of the sensing element actuates a set of electrical contacts that control the safety shutdown switch. Normally, a *slip friction mechanism is* attached to the moving member of the thermal-sensing element. The slip friction and contacts are arranged so that normal fluctuations of flue gas temperature will not cause shutdowns of the burner. Some of the more widely used slip friction mechanisms for thermal elements and contacts are shown in Figures 17-3, 17-4 and 17-5.

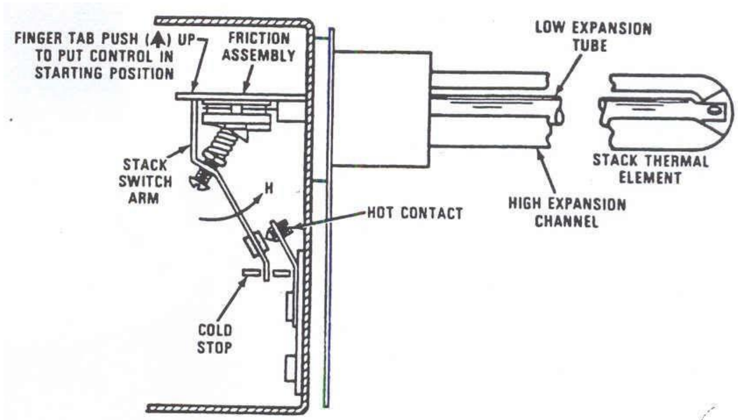


Figure 17-3: Tube and channel stack sensor.

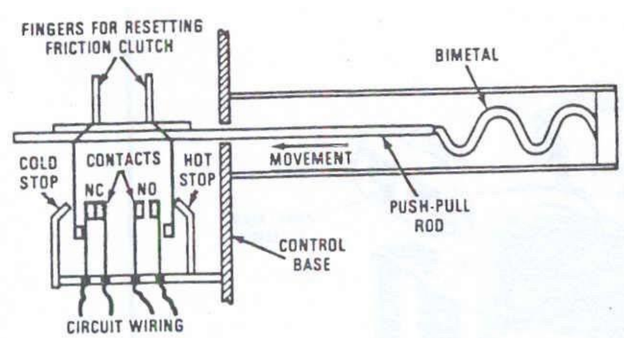


Figure 17-4: Rod and tube stack sensor.

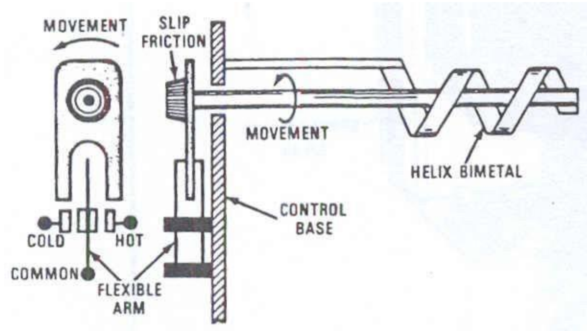


Figure 17-5: Helix type bimetal stack sensor.

Thermal Element Operation

In its starting position, the stack switch arm must rest against the cold stop. The room thermostat calls for heat by energizing the ignition relay through the safety switch heater and cold contacts. After the burner starts, the rise in stack temperature causes the stack element to open the cold contacts in the stack switch, opening (bypassing) the circuit to the safety switch. The stack arm then travels to the hot stop. The burner will continue to run until the thermostat contacts open, shutting down the burner. The drop in temperature after burner shutdown decreases stack temperature and the thermal element returns the stack switch arm to its original position. In fact, any prolonged drop in stack temperature will result in a burner shutdown, irrespective of thermostat demand.

Switching Relay Operation

Figure 17-6 shows the interior of a stack-mounted oil burner primary control. The job of each component is as follows:

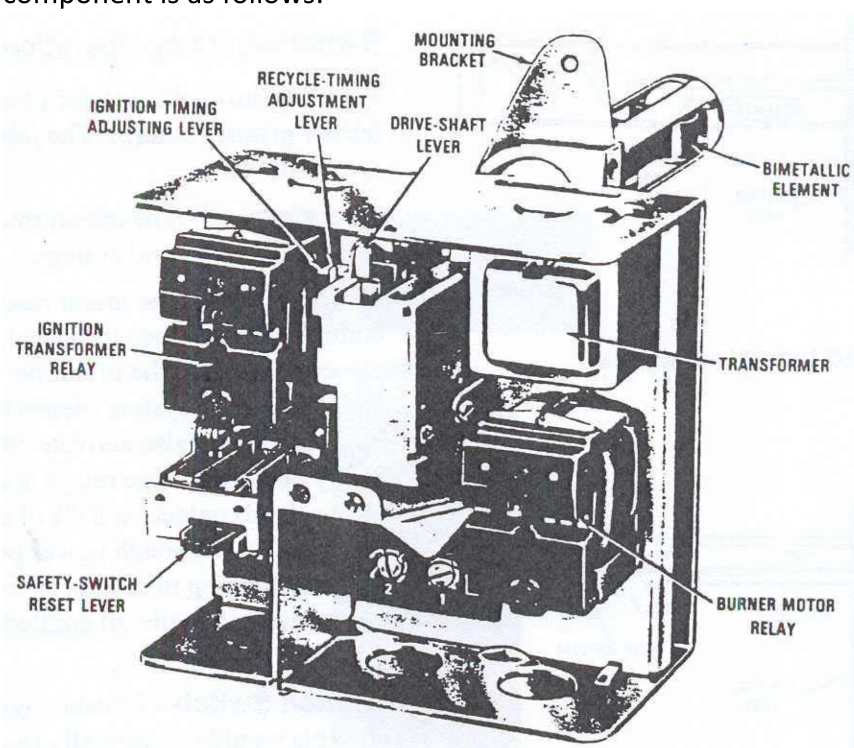


Figure 17-6: Interior of a common single piece, stack mounted oil burner primary. Major components are identified. In two-piece primary, transformer, relays and timer are in one package, sensor and hot and cold contacts in another (Honeywell, Inc.).

Transformer - The transformer provides 24 volt power for the control system.

Motor Relay - The motor relay responds to the control action of the thermostat. When energized, it closes contacts to the oil burner's pump/fan motor and the ignition system (depending on internal circuitry, it may also activate other contacts). For safety purposes, these relays are calibrated to "pull in" or close contacts at 85% of the rated voltage so there is always enough power present when the motor is running to sustain an arc across the ignition electrodes and ignite oil emitted by the running pump.

Ignition Switch - Constant ignition primary controls would not normally use an ignition switch or relay, since the ignition circuit on these systems is energized throughout the call for heat. Intermittent ignition primary controls break the ignition circuit after the ignition time has elapsed. Standard timings for ignition periods are 15, 30, 45, 60, 90 or 120 seconds, depending on the size, type and operating characteristics of the burner.

The ignition switch contacts are usually wired in series with the motor relay so that the relay will not pull in unless the ignition switch has closed the circuit to the ignition transformer. Some control manufacturers use a separate ignition relay and depend on stack switch contact action for ignition timing. Others use an ignition switch with a dual bimetal. One bimetal is activated by a heater controlled by the motor relay contacts. The other bimetal acts as a compensating bimetal, counteracting variations in ambient temperature to provide consistent ignition timing.

Primary controls may be either *recycling* or *non-recycling.* Non-recycling primaries will shut down the system on ignition failure (or if the flame fails during the burner run) and lock out the safety switch. The primary must be manually reset before burner operation can be returned.

Recycling primaries will generally shut down the system on ignition failure and lock out the safety switch. However, if the flame fails after the ignition period has elapsed, the primary will stop burner operation as soon as the thermal element senses the temperature drop. After either a sufficient stack temperature drop is sensed or after the ignition timer has cooled and closed (depending on design characteristics), a restart will be attempted. If satisfactory ignition and firing occur, the burner will operate normally. If not, the primary will lock out on safety switch and manual resetting is required.

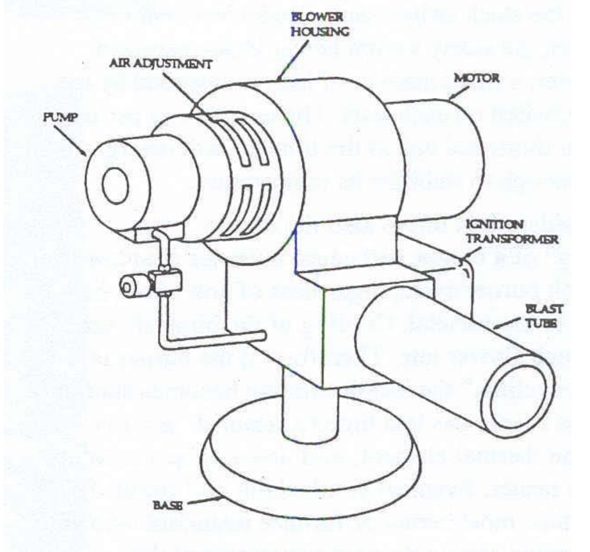
Multiple recycles can and do occur before the safety switch lockout occurs; however, there will seldom be more than three such cycles before the switch lockout occurs.

Safety Switch - The safety switch in an oil burner primary control has only one function, to electrically shut down the oil burner if either ignition failure or burner flame failure occurs. The safety switch mechanism usually consists of two bimetals, an ambient or compensating bimetal, and an active bimetal. The active bimetal warps whenever the artificial heat of the safety switch heater is imposed on the bimetal through the action of the stack switch contacts. The ambient bimetal compensates for any variation in ambient temperature and always keeps the interface distance between the bimetals constant when burner operation is normal, to provide consistent safety lockout timing.

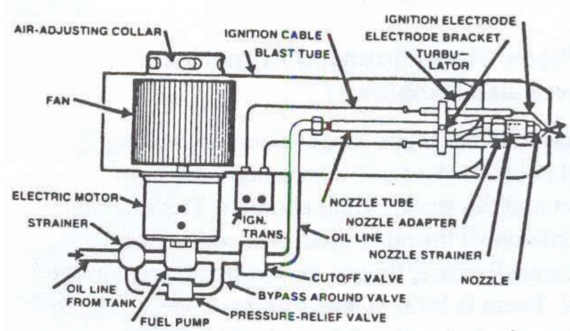
All lockout timings of oil burner primary controls (period from first call for heat, until safety switch opens) are usually checked from a cold start condition. Lockout timings should not be checked after the unit has been operating for any length of time. This is because the primary control must be in a "cold check" condition at the start of each cycle. That is, the safety switch must be energized on a call for heat to initiate lockout if ignition does not occur. When the stack switch senses sufficient heat to prove ignition, the safety switch heater is de-energized. However, a small amount of heat is absorbed by the safety switch on each start. The next timing period will be shortened unless the bimetal is de-energized long enough to stabilize its temperature. It is evident that this is also the reason "short cycling" of a burner will cause nuisance shutdowns. On each burner cycle, regardless of how short, heat is added to the bimetal. Cooling of the bimetal occurs at a much slower rate. Therefore, if the burner is "short cycling," the lockout timing becomes shorter and the burner has less time to establish ignition, heat the thermal element, and de-energize the safety switch heater. Eventually, a lockout will occur. To avoid this, most burner or furnace manufacturers will recommend setting the heat anticipator of the thermostat to assure a minimum of dime to five minutes burner "on time."

Two Piece Stack-Mounted Primaries
Temperature Sensitive

One unit of a two piece, stack-mounted primary control contains the stack temperature sensing element and the stack switch contacts. The second unit contains all the other electrical components, relays, transformers, timers, and switches used in the control. There is little, if any, difference between the components of a single piece and a two piece primary control, and the operating characteristics are similar. However, the two-piece unit is a more versatile control, since the switching unit can be remotely mounted. Either the switching unit or the sensing unit can be replaced independently, and these two pieces are widely used.



High Pressure Oil Burner



How a High Pressure Atomizing Oil Burner Works: This unit is frequently referred to as a "gun burner." A pump on this burner takes oil from the tank, builds it up to a pressure of approximately 100 pounds per square inch, and squirts this oil through an atomizing nozzle, from which it leaves as a fine mist. Since the effectiveness of combustion in the "gun burner" depends on the degree of oil atomization and on the mixing of the oil and air, special turbulator heads are used to swirl the air which is mixing with the atomized oil. Electrodes near the nozzle create a 10,000 volt spark for automatic ignition. Depending upon the type of primary control used, the ignition spark is either constant or intermittent; when intermittent, the spark is supplied only for ignition. This type of burner fires into a firebox that is lined with refractory material or stainless steel.

Self-Check, Lesson 17 Quiz

You should have read all the material in Lesson 17 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A burner with short times (short cycling) cannot cause a lockout or cause the primary to "go out on safety" (safety switch opens).

2. T F A stack sensor should be placed in the smoke pipe between the draft regulator and the chimney.

3. T F Two-piece and one-piece stack-mounted primaries are essentially the same.

4. T F A sufficient drop in flue gas temperature can cause a safety shutdown of the oil burner.

5. T F Constant ignition primaries do not use an ignition switch or ignition relay.

6. T F The safety switch is usually a single bimetal element.

7. T F The ignition switch is wired in parallel with the oil burner motor relay.

8. T F Manual resetting is required if a recycling type primary senses flame failure after ignition period.

9. T F It is wise to test the safety switch on the single-piece stack-mounted control when the control is in a cold start position.

10. T F Lockout timing is the time interval in minutes between first energizing a cold safety switch heater until the safety switch snaps open breaking the power to the oil burner.

In the following multiple-choice questions, choose the phrase which <u>most</u> correctly completes the state and circle the corresponding letter in front of the phrase.

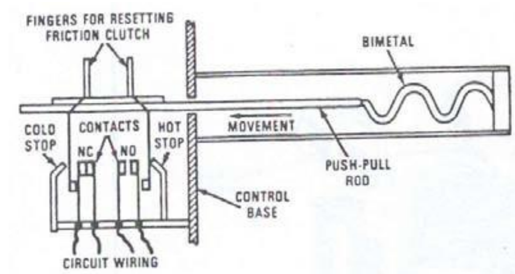
11. A stack-mounted single piece primary should be installed in the smoke pipe of the furnace, between the furnace and the:

a. barometric draft regulator. b. boiler.
c. flue. d. chimney.

12. One reason why two piece stack-mounted controls are widely used is that:

a. they have superior operating characteristics.
b. they're not as expensive as single piece controls.
c. the two piece unit is more accurate
d. the switching unit and the sensing unit can be replaced independently.

13. The figure at right illustrates a:



a. push-pull bimetal element.
b. rotary bimetal element.
c. thermal transformer.
d. switching relay.

14. Even recycling primaries require manual resetting after:

a. 1 to 3 attempts at automatic restart. b. 4 to 6 attempts at automatic restart.
c. 5 to 7 attempts at automatic restart. d. no more than 10 attempts at restart.

15. The motor relay in a single piece stack-mounted burner is calibrated to close contacts at _________ % of the rated voltage.

a. 40. b. 65.
c. 70. d. 85.

16. In a single-piece stack-mounted primary, the ignition switch is usually wired in series with the:
a. motor relay. b. bimetal.
c. thermostat. d. furnace.

17. Non-recycling primary burners shut down the system when:

a. the safety switch fails. b. flame ignition is initiated.
c. ignition or flame failure occurs. d. none of the above.

18. A drop in stack temperature after burner startup will cause the:

a. safety switch to open. b. safety switch to close.
c. firing rate to increase. d. transformer to disconnect.

19. While a stack-mounted primary senses a change in flue gas temperature, its primary job is to detect:
a. flame outage. b. overheated supply air.
c. excessive boiler temperature. d. flame temperature.

20. Many ignition switches use a dual bimetal, one is activated by a heater, the other is referred to as a/n:

a. inactive bimetal.
b. compensating bimetal.
c. limiting bimetal.
d. reserve bimetal.

21. The safety switch in an oil burner primary has just one job:

a. to limit flue gas temperature.
b. to shut off the furnace blower or boiler pump.
c. to shut down the oil burner.
d. to prevent startup in the summertime.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

22. Four common functions of the four types of oil burner controls are:

a. ___________________________________

b. ___________________________________

c. ___________________________________

d. ___________________________________

23. The switching section of a stack-mounted oil burner primary control contains four major components. These are:

a. ___________________________________

b. ___________________________________

c. ___________________________________

d. ___________________________________

24. The ___________________ or _____________________ element should be installed in the direct path of the hot combustion gases so that the cold air from the _____________________ regulator cannot influence the operation of the thermal element.

25. The ____ mechanism and control contacts are arranged so that temperature drops caused by normal fluctuation of flue gas temperature will not result in safety shutdown of the burner.

26. Most burner or furnace manufacturers will recommend setting the heat anticipator of the thermostat to assure a minimum of ______________ to __________________.

27. The safety switch in an oil burner primary will electrically shut down the oil burner operation in case of ____________________ failure or a lack of _______________________.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

When you are satisfied you understand the questions missed, proceed to your next assignment which starts on the next page.

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Lesson 18: Overview

Lesson 18 is a continuation of Lesson 17, in that it is concerned with oil burner primary controls. But in this lesson, burner-mounted primaries are discussed, and while the previous primaries considered were all temperature sensitive devices, we will now be concerned with both temperature and light sensitive primaries. (Light is referring to the light from the burner flame.)

As you will soon discover, stack-mounted primaries are not without problems and shortcomings. Burner mounted devices were developed specifically to overcome these problems.

For this lesson, consider these objectives:

1. Learn the basic disadvantages of the stack-mounted primary.

2. Understand how the combustion thermostat senses radiant heat.

3. Learn the service peculiarities of the combustion thermostat.

4. Know how the light sensitive cad cell (CdS) operates.

5. Learn how solid state electronics has improved the cad cell primary.

6. Know the service suggestions for the solid state burner primary.

Now read Lesson 18 which begins on the next page.

Lesson 18: Oil Burner Controls Part II – Burner-Mounted Primary Controls

There are some **disadvantages** to using oil burner primary controls which *sense flue gas or stacktemperature* as discussed in Lesson 17. They are:

1. Soot accumulates on the sensors, which slows response, causing nuisance safety lockouts or delayed starts.

2. High stack temperatures and wide temperature variations (70 -100° F) cause sensing element deterioration and require the use of special and expensive materials.

3. Variations in stack temperatures that occur during normal burner operation require careful calibrations to avoid unnecessary burner shutdowns.

4. Installation is critical and improper location of the control on the burner equipment causes poor control performance.

5. Any component failure requires expensive replacement and rewiring of the entire control.

6. Slow speed of response and monitoring the combustion temperature rather than the combustion flame itself provides only marginal safety control.

Burner-Mounted Primaries Temperature Sensitive

Burner-mounted primaries are used to overcome these problems. The first of the burnermounted controls used a temperature sensitive element (combustion thermostat) which was mounted on the nozzle adaptor in the blast tube of the burner (Figure 18-1). The combustion thermostat monitored the main flame by sensing the radiant heat of the flame and therefore was not affected by variable temperatures. The relay or switching components (except for some miniaturization), remained relatively unchanged from the stack-mounted primary control.

The combustion thermostat is hermetically sealed; therefore, it cannot be repaired. If a malfunction occurs, the thermostat must be replaced. The proper location of the combustion thermostat in the blast tube is determined by the burner manufacturer. Any other location will cause a malfunction of the equipment and/or unsafe operation.

External Wiring: The hot line (through a limit control) is connected to Terminal #1, (Figures 182A and 18-2B). Incoming power should come through an adequately fused line. The grounded line (neutral or white wire) is connected to Terminal #2. The common neutral line from the ignition transformer and the oil burner motor is connected to the extra Terminal #2. On constant ignition models (18-2A), the motor and ignition leads are connected to Terminal #3. On intermittent ignition models (18-2B), the motor is connected to Terminal #3 and the ignition is connected to Terminal #4. The combustion thermostat leads are connected to the “Det” terminals. The 24 volt room thermostat is wired to the “Therm” terminals.

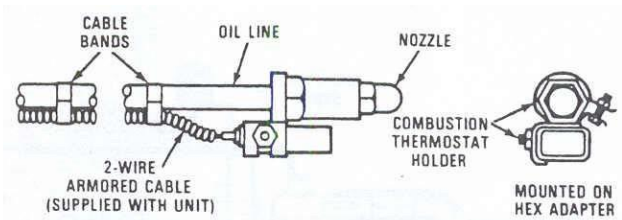


Figure 18-1: Combustion thermostat (switch) mounts in burner.

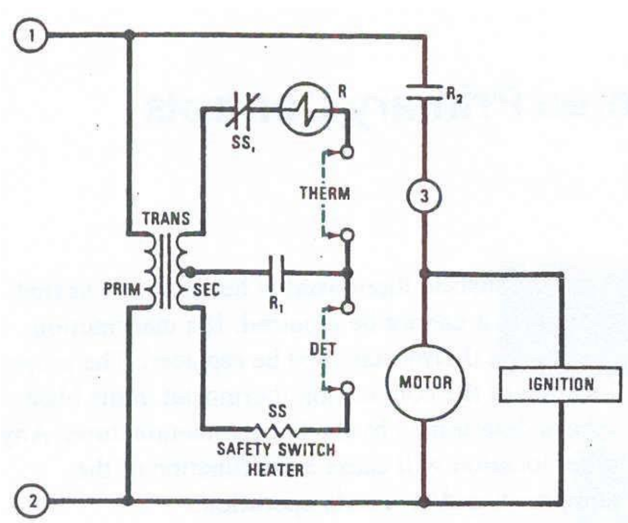


Figure 18-2A: Constant ignition wiring hookup. With motor relay contact R2 closed, ignition is on throughout the call for heat.

Changes in temperature which affect the combustion thermostat are transmitted to a bimetal SPST Switch (Figure 18-3) to energize or de-energize the safety switch heater (SS) located in the relay unit (Figure 18-2). A temperature rise of approximately 25° F will cause the combustion thermostat contacts to open, de-energizing the safety switch heater for normal burner operation. A temperature drop of approximately 70° F indicates flame failure or improper combustion. In either of these circumstances, the combustion thermostat contacts will close, energizing the safety switch heater. The safety switch (SS1) will break contact and safety shutdown of the burner will result.

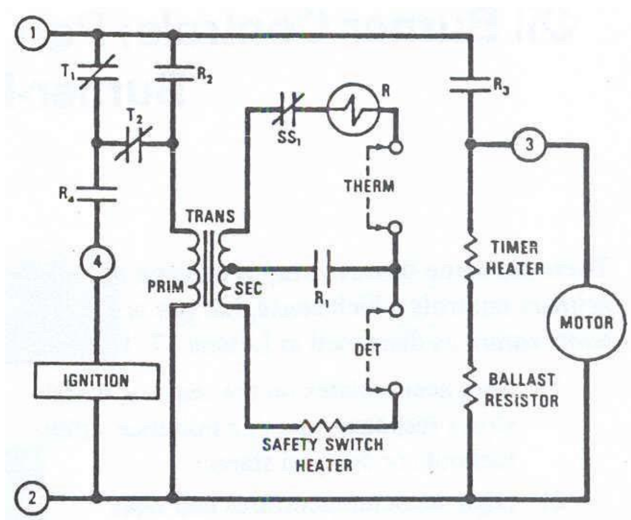


Figure 18-2B: Intermittent ignition wiring hookup. Timer heater opens T1 contacts and stops ignition after several seconds of successful burner operation.

If proper ignition is not established upon a call for burner operation, the combustion thermostat contacts remain closed. The safety switch heater stays energized, and the safety switch opens, causing a burner shutdown.

Service: Repeated safety shutdowns may be caused by slow flame detector response. The slowest response will usually occur after a short burner "off" period which has been preceded by a long run. A first step in diagnosing is to check the "recycle" time of the combustion thermostat. Recycle time is checked by momentarily pushing the manual reset button while the burner is running. The ignition timing armature should be held in the closed position (Figure 18-4). The relay will pull in when the combustion thermostat contacts close. The "off" period is the "recycle" time. The most critical burner "off" period for slow heating response is 3 to 8 times this "recycle" time.

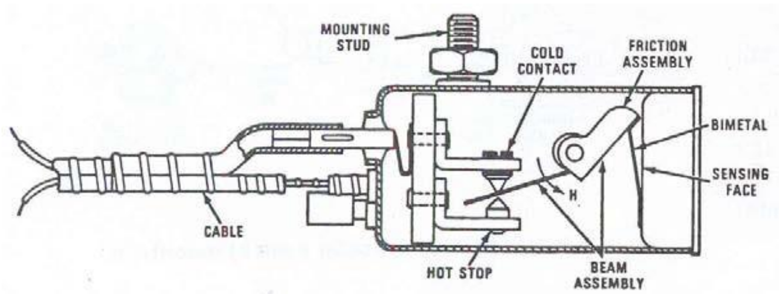


Figure 18-3: Combustion thermostat reacts to radiant heat of burner flame. Switch opens on successful burner ignition and de-energizes the safety switch heater and keeps safety switch contacts closed.

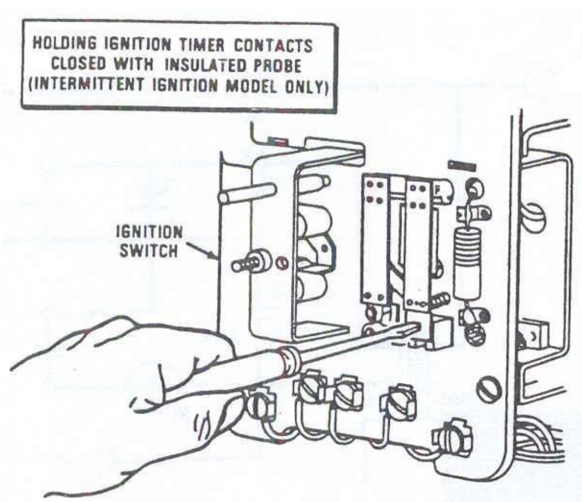


Figure 18-4: Recycle time of combustion thermostat (i.e., time contacts go from open to closed) can be checked by holding in contacts T1 (see Figure 18-2B) and timing when motor relay pulls in.

The heating response time of the combustion thermostat can be checked by using an ohmmeter (Figure 18-5). Disconnect one of the combustion thermostat leads from the detector terminals. Connect an ohmmeter across the disconnected lead and the remaining wired terminal. Start the burner by momentarily shorting across the "Det" terminals. Check the time for the combustion thermostat to open as indicated by the ohmmeter response. This is the response time. Slow response may be caused by:

1. Excessive amounts of burner air which push the flame away from the nozzle. Adjust the burner for a more efficient flame.

2. Incorrect positioning of the combustion thermostat. Check the thermostat mounting against the manufacturer's instructions. The detector holder should be positioned so that the sensing face of the combustion thermostat is pointing toward the center of the nozzle spray --- not toward the choke ring or other nearby parts of the blast tube.

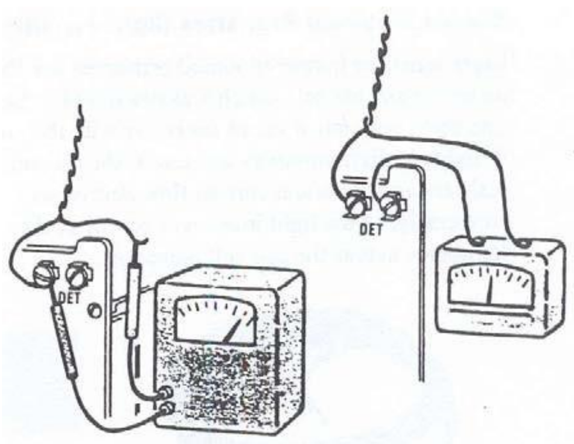


Figure 18-5: Response time of combustion thermostat (i.e., time contacts go from closed to open) can be determined using an ohmmeter (left). When contacts open, ohmmeter will register infinite resistance. Ammeter in series (right) is an alternate test method.

3. Excessive temperature buildups in the choke ring and other parts of the blast tube after the burner stops. These temperature buildups may be caused by low over fire draft. Adjust the barometric draft regulator for slightly more draft.

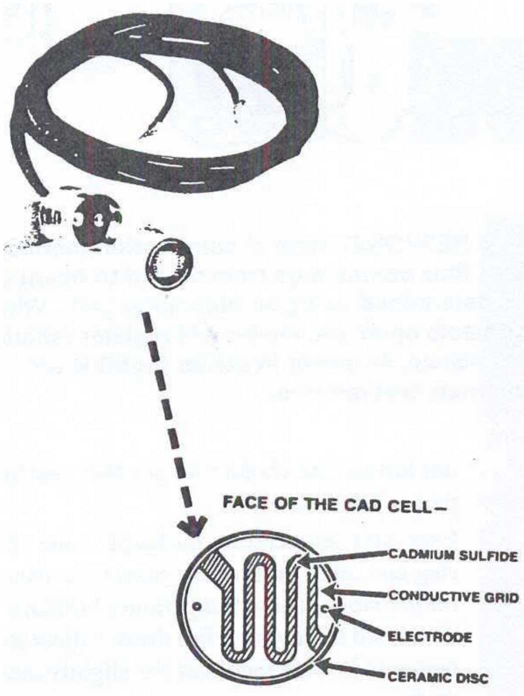
4. Spalling or breaking away of firebox refractory around the blast tube, which causes excessive temperature buildups in the blast tube. Repair the firebox; or, if this cannot be done immediately; move the burner back so the choke ring does not project past the spalled part of the firebox.

5. An oversized blast tube opening in the firebox, which also causes excessive temperature buildups in the tube. Oversized openings may be filled with cast-set refractory material.

If the relay will not pull in to start the burner even though power is present at the power terminals and the auxiliary limits are closed, check the contact position for proper “phasing.” Contacts in the detector must be closed before the operating control can initiate a burner cycle. Momentarily jump the ‘Det” terminals on the relay portion to start the burner. If repeated “phasing” is required, replace the detector.

Burner-Mounted Primaries (Light Sensitive)

Light sensitive burner-mounted primaries use the cadmium sulfide cell which was discussed in Lesson 9. The cell’s resistance varies *inversely* with the amount of light. As light intensity *increases,* the cad cell’s resistance to electrical current *flow decreases;* conversely, as the light intensity *decreases,* the resistance across the cad cell *increases.*



Early versions of light sensitive primaries used a very sensitive dc relay to open or close the circuits to the safety switch (Figure 18-6). If the registered light on the cad cell indicated a safe flame, the resistance across the detector would be low enough to permit sufficient voltage on the sensitive relay to allow the relay to pull in and de-energize the safety switch heater. If light intensity was low, cell resistance was high and there was not enough voltage available to energize the relay. In this case, the safety switch energized or remained energized, causing a safety lockout.

The principal operating problem encountered in these early units was maintaining a preset calibration pull-in point and a clean contact condition on the sensitive relay contacts. Technological advances in *solid state components* eliminated the need for a dc relay to energize the safety switch. Control functions remained unchanged; but a *trigger diode,* a *silicon controlled rectifier* (SCR), and a *variable resistor* (Figure 18-7) were used to construct a simple solid state circuit to take over the functions of the sensitive relay. (Compare the circuits in Figures 18-6 and 18-7.)

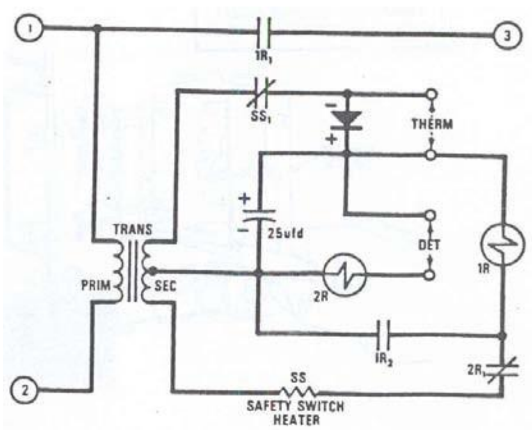


Figure 18-6; One type light sensitive primary uses a voltage sensitive relay (2R) that opens safety switch contacts 2R1 when cad cell resistance decreases (hence voltage increases) in presence of burner flame.

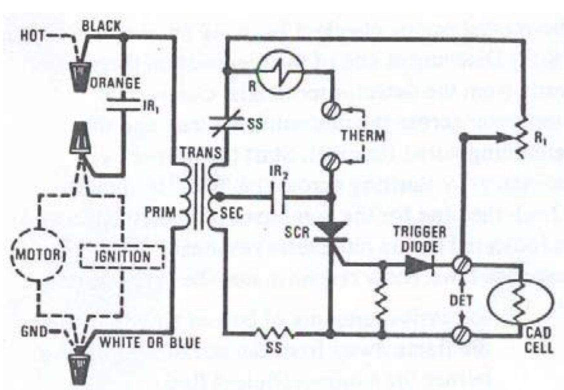


Figure 18-7: Replacing sensitive relay 2R (in Figure 18-6) with an SCR, trigger diode and variable resistance R1 provides a more rugged modified solid state version of a light sensitive primary.

The diode and rectifier are among the simplest of solid state components. The only difference between a diode and a rectifier is the current rating, and this is not well defined. Usually a component with under a 1 ampere rating is called a diode, and above this the component is called a rectifier. Therefore, the word *diode* indicates that the component is frequently used as a small signal device and a rectifier is commonly used as a power device.

A silicon-controlled rectifier is used as a solid state switch, a device that can switch electric current without moving parts or contacts.

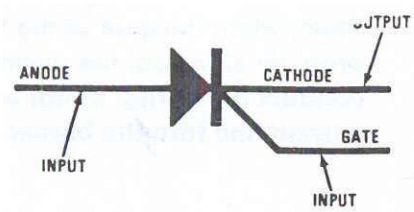


Figure 18-8: Circuit symbol for SCR. A positive signal applied to gate "starts" SCR. Lowering anode voltage shuts SCR off.

The electrical components of an SCR are the cathode, the gate, and the anode. An SCR will conduct current in only one direction (from the anode to the cathode); and, further more, it will not conduct current until a specific minimum voltage is applied at the anode and the gate to create a "high" conduction condition. Once the SCR is conducting, the current flow through the component is independent of the gate current. The "high" conduction will remain until the anode to cathode voltage is reduced to decrease the current through the SCR to a value called the holding current. Therefore, the SCR is a switch that is energized "on" by applying a gate current and de-energized "off" by removing the voltage difference between the anode and the cathode. (For a more detailed discussion, review Lesson 12.) Figure 18-8 shows the circuit symbol for an SCR. Figure 18-9 diagrams the conducting pattern of a trigger diode. As the minimum voltage is applied to the gate and the anode (12 volts), the diode or rectifier becomes conductive. As voltage is decreased to almost 0, it becomes non-conductive and remains non-conductive until it again receives the necessary voltage to regain its conductivity.

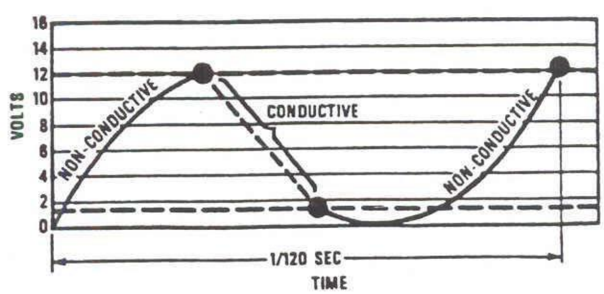


Figure 18-9: Volts vs. time shows conduction pattern of a trigger diode.

Referring again to Figure 18-7, which is a typical semi-solid state circuit for a light sensitive oil burner primary, we can follow a typical burner cycle:

1. The thermostat calls for heat.

    a) The anode of the SCR is energized.

    b) The cad cell's resistance (since it is dark) is greater than R1 resistance. Therefore, 1 volt plus is imposed on the trigger diode and the SCR becomes conductive.

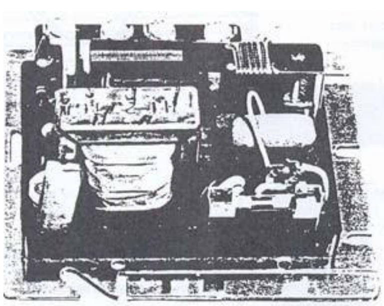
2. With the SCR conductive, the safety switch heater is energized and the motor relay pulls in and starts the burner operation.

3. If a failure to ignite occurs, the SS heater will remain energized and the heat will cause the SS switch to open, dropping out the relay and stopping burner operation.

4. If ignition is successful, the cad cell will sense the light and its resistance will decrease. This decrease in resistance will permit the current to return to the transformer through the trigger and anode of the SCR, through the now closed I R2 holding contact and thus bypass the SS heater. The heater not being energized will permit the SS contact to remain closed and a normal burner cycle will result.

Servicing Solid State Primaries

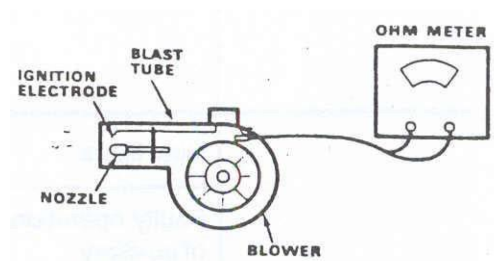
To check detector response with an ohmmeter, disconnect the detector leads from the “Det” terminals and connect them to an ohmmeter. Start the burner and then jump the “Det” terminals to prevent a lockout. Detector resistance measured on the ohmmeter should not exceed the manufacturer’s specifications. Higher resistance may be caused by incorrect positioning of the flame detector in the blast tube or by a defective detector. Check the burner manufacturer’s recommendations for locating the flame detector in the tube. After performing the check and taking corrective action, if needed, remove the jumper and reconnect the detector leads to the “Det” terminals. Figure 18-10 shows a handy service guide for burnermounted primaries. See also “Testing Cad Cell Controllers.”



Adding an SCR and other components eliminates sensitive relay (see Figure 18-7). Another design adds a triac to eliminate the motor relay. A triac is a special kind of SCR that operates irrespective of voltage polarity. Thus, when the gate of the triac is properly signaled, the device can conduct full burner motor ac current and turn the burner on.

Testing Cad Cell Controllers

Here are a few simple tests (and what they indicate) that can be made on a CdS oil burner controller using an ohmmeter and an inexpensive 2,000 ohm resistor that you can purchase at any Radio Shack® store.



Before you begin a test, always check the calibration of your ohmmeter by measuring the resistance of the test resistor. It should read 2,000 ohms plus or minus five percent. Also, be sure to follow all the instructions provided by the instrument manufacturer.

To begin: disconnect the thermostat leads at the primary; depress the reset buttons on the burner motor and primary; remove the cad cell leads from the primary.

Next, connect the ohmmeter to the cad cell leads and set the meter to read ohms times (x) 1,000. Also, jumper the cad cell terminals on the primary using the 2,000 ohm resistor, and jumper the thermostat terminals using an ordinary jumper wire. Now the test begins. Loosen the connection on one side of the resistor in order to momentarily break contact. When the burner starts (make sure it does start) retighten the terminal screw quickly. At this point the ohmmeter pointer should immediately move to the right. Now:

1) If the meter reads between 0.3 and 2 (x 1,000) the CdS cell is O.K.

2) If the meter reads above 2,000, the following problems might be occurring:

    a. There's a partially plugged burner nozzle.

    b. Cad cell is dirty.

    c. Cad cell is misaligned - it doesn't "see" enough light.

    d. There's a defective cad cell.

3) If the meter pointer indicates less than 300 ohms:

    a. There could be insufficient combustion air.

    b. Cad cell could be misaligned - now "sees" too much light.

Following three minutes of operation, remove the resistor jumper. The primary should lock out on safety within 25 seconds. If it doesn't, the primary is obviously defective.

After the primary locks out, the ohmmeter should move past the 50 (x 1,000) mark on the meter scale. If the meter indicates less than 50,000 ohms, then the cad cell is either defective or there is stray light entering the burner housing.

Trouble	Cause	Check	Remedy
REPEATED SAFETY SHUT DOWN	Inadequate combustion detector response	Check detector response with ohmmeter.	If no response, replace detector. Adjust burner for more efficient flame. Increase draft slightly. Check flame pattern and nozzle condition.
	Low line voltage	Use voltmeter. Check voltage before, during and after burner run.	New wiring, or contact power company.
SHORT CYCLING OF BURNER	Dirty filters		Clean
	Faulty operation of auxiliary controls	Check for differential adjustments or other faults in auxiliary controls.	Reset, repair or replace auxiliary controls.
	Incorrect thermostat anticipation	Check thermostat anticipator.	On plug type thermostat, replace anticipator with one of higher ampere rating. On adjustable models, set at higher ampere rating. Normal setting is 0.4 amperes.
RELAY WILL NOT PULL IN	No power. Open power circuit.	Check fuses, line switch and limit controls.	Reset, repair or replace.
	Open thermostat circuit.	Jumper “THERM” terminals. Burner should start.	Check “THERM” wiring.

Figure 18-10: Service guide for burner mounted primaries.

Self-Check, Lesson 18 Quiz

You should have read all the material in Lesson 18 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A burner-mounted combustion thermostat is a normally open device that closes upon sensing radiant heat from a burner flame.

2. T F The combustion thermostat is not affected by variations in stack temperature.

3. T F The switching section of a burner-mounted primary using a combustion thermostat is essentially unchanged from that used in a stack-mounted primary.

4. T F Repeated safety shut-down may be caused by slow combustion thermostat response.

5. T F A voltmeter can be used to check the response time of a combustion thermostat.

6. T F A cad cell's electrical resistance decreases as light intensity increases.

7. T F Solid state devices are not substituted for a dc relay in the light sensitive oil burner primary.

8. T F An SCR acts like a switch to stop and start the safety switch heater.

9. T F One cause for repeated safety shut downs is high line voltage.

10. T F Slow hot start response may be due to incorrect positioning of the detector in the blast tube.

In the following multiple-choice questions, choose the phrase which <u>most</u> correctly completes the statement and circle the corresponding letter in front of the phrase.

11. A combustion thermostat will open on a temperature rise of about:

a. 25° F.
b. 70°F.
c. 35° F.
d. 40°F.

12. A combustion thermostat will close when temperature decreases about:

a. 70° F.
b. 25° F.
c. 35° F.
d. 40° F.

13. Slow detector response caused by temperature buildup in the choke ring can be remedied by adjusting the:

a. barometric draft regulator. b. thermostat.
c. pilot flame. d. fire box.

14. On light sensitive burner mounted primaries, if light intensity is low, cad cell resistance is:

a. low. b. high.
c. constant. d. non-existent.

15. The sensor in a combustion thermostat is connected to a/n:

a. invar SPST switch. b. bimetal DPST switch.
c. bimetal SPST switch. d. low voltage relay.

16. The response time of a combustion thermostat can best be determined using:

a. a voltmeter. b. an ohmmeter.
c. a continuity checker. d. a signal lamp.

17. Before using solid state components, early cad cell primaries required frequent:

a. cleaning of CdS detectors. b. changes in lead-in wires.
c. transformer repairs. d. calibration of dc relay pull-in voltage.

18. The burner sensor is usually connected to leads in the switching section marked:

a. SS. b. CT.
c. DET. d. THERM.

19. An SCR is energized (switched on) by:

a. applying a minimum current at the gate.
b. changing from ac to dc.
c. keeping voltage levels high across the cathode and anode leads.
d. reversing current direction.

20. A SCR is de-energized (switched off) by:

a. removing voltage potential between anode and cathode.
b. using a high gate current.
c. changing polarity.
d. removing voltage difference between anode and gate.

21. High resistance in a CdS cell may be caused by:

a. long lead in wires.
b. incorrect positioning of flame detector in blast tube.
c. loose connections.
d. dirty contacts.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

22. If ignition does not take place in an oil burner, combustion thermostat contacts stay ___________________________, the safety switch heater is kept _____________________ and safety switch _____________________ causing the burner to stop.

23. The combustion thermostat is _______________________ sealed and therefore it ________________ be repaired.

24. SCR stands for ____.

25. The three main components of the solid state primary circuit that replaced the dc relay are:

a. _______________________________

b. _______________________________

c. _______________________________

26. List six operational disadvantages found in the use of “stack-mounted” oil burner primary control:

a. _______________________________

b. _______________________________

c. _______________________________

d. _______________________________

e. _______________________________

f. _______________________________

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

When you are satisfied you understand the questions missed, proceed to your next assignment which starts on the next page.

Preview to Unit 5: Year-round Air Conditioning Control Systems

The theme of the last unit in your course of study is *Year-round Air Conditioning Control Systems*. For this purpose, the unit is divided into two lessons.

Lesson 19 offers an overview of compressor motor characteristics and how the compressor must be controlled and protected. How to safely start and stop a compressor is a logical progression following the lessons you have just concluded on how to safely start and stop oil and gas burners.

Lesson 20, entitled *Troubleshooting Control Systems*, details what to do to find and repair a control malfunction.

In addition to the material in these two lessons, your last examination will also include questions dealing with material found in the Appendix and Lesson 3 --- *The Control Circuit*. So in studying for the unit exam, be sure to read the *Common Control Terminology, Wiring Symbols*, and *Low Voltage Terminal Designations* sections of the Appendix and re-read Lesson 3.

No single text on a subject as broad as controls could possibly detail every facet of control systems and components to the extent that each may deserve or that any one student may desire. For this reason, your textbook includes a list of supplemental references.

Finally, no one can truly be a control technician unless he is also thoroughly familiar with heating and cooling system design. Air flow in ductwork, water flow in pipes, the types of systems and their characteristics, and building loads must all be understood as well as how a thermostat and gas valve works. What is thought to be a control problem is quite often a result of a design error, not a control malfunction. So be certain to include heating and cooling system design in your future studies.

Lesson 19 Overview

The hermetic motor-compressor, where the electric motor and refrigerant compressor are combined in one sealed compartment, was introduced to eliminate the potential leakage problem around a rotating shaft when a separate motor and separate compressor are joined together.

The hermetic motor has its own distinctive characteristics and problems. Every year, roughly 8 million unitary air conditioning and heat pump units are produced. It's estimated that there are now 60 to 70 million central units in service in North America. It's easy to see why a lesson on how a compressor is controlled can be so important and must also include a discussion of motor characteristics.

Lesson 19 focuses on the compressor power and control circuit, motor characteristics, motor protection, and motor starting techniques.

Specifically, you can expect to learn:

1. The four jobs that a power-control circuit must do.

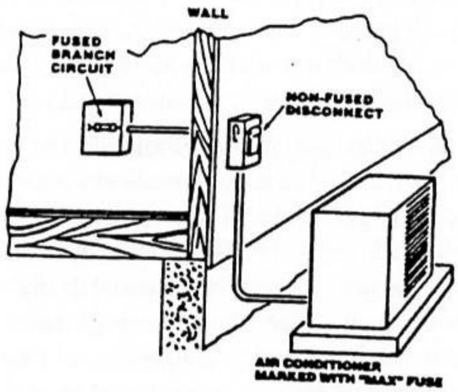
2. How PSC and CSR single phase motors are started.

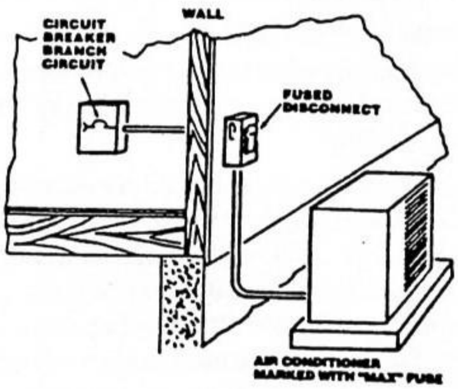
3. The two most popular methods of protecting motors from the effects of overheating.

4. How the two basic types of motor starters work and why they are necessary.

Now read Lesson 19 which begins on the next page.

Lesson 19: Air Conditioning Controls Part I – How the Compressor is Controlled





Electric Power supply to an air conditioning unit must comply with the National Electric Code (N.E.C.) that requires a disconnect (switch) near the unit. Also, Underwriter Laboratories (UL) safety tests require that if an equipment manufacturer specifies fuses for over current protection, then circuit breakers cannot be substituted. Circuit breakers are only acceptable when equipment has been tested and is listed for use with circuit breakers. The sketches at left show two acceptable arrangements for equipment needing fused protection.

Starting and stopping an air conditioning compressor is a control function that's equivalent to starting and stopping a gas or oil burner for heating. And as in the case of gas and oil burners, there is a family of compressor control and safety devices to assure that the job is done correctly and safely.

Basic Circuit Functions

Compressor power and control circuits usually must provide the following:

1) A means to disconnect the compressor from the power supply.

2) A means to protect the branch electric circuit from over current.

3) A means to protect the compressor from overheating.

4) A means to stop and start the compressor.

Figure 19-1 illustrates a simplified compressor control circuit in which either a single-phase, capacitor start, capacitor run motor, or a permanent split capacitor motor drives the compressor. The circled numbers refer to the four necessary circuit functions listed above.

Compressor Motor Characteristics

The problems of safely starting and stopping the compressor are for the most part, of course, the problems of starting and stopping an electric motor safely and efficiently. As a result, before considering the circuit in Figure 19-1 in more detail, let's briefly review some basic motor characteristics.

The most common electric motor used in air conditioning systems is the alternating current *induction* motor. For this type of motor, alternating current is connected to one set of windings mounted inside the periphery of the motor housing. Then, by transformer action, a voltage - hence a magnetic field - is induced in another set of windings surrounding a shaft. The two windings develop opposing magnetic fields, causing the shaft to rotate. Such a motor can be designed to operate on single phase or three-phase alternating current power.

Because of inherent electromagnetic relationships, a three-phase induction motor is selfstarting. Once connected to a source of electric power, its shaft will begin to turn unaided. Such is not the case for a *single-phase* induction motor. Only after rotation has been initiated do the proper magnetic forces interact to sustain rotation. It's like trying to start a single cylinder steam engine with its piston on dead center. You must give the flywheel a spin to get it going. For this reason, *phase or starting* windings must be added to give single-phase motors that initial "spin" automatically. Single-phase motors are then identified or classified according to their specific "self-starting" technique.

Currently, the most common single-phase induction motors are: shaded pole, split-phase, permanent split capacitor (PSC), capacitor start (CS), and capacitor start/capacitor run (CSR).

The shaded pole motor is a comparatively new development. To provide magnetic pull on a stationary rotor (shaft), each of the main poles of the frame windings have a heavy, but much smaller, auxiliary winding - usually a copper strap wrapped around a portion of the main pole - that magnetically lags the main field. This lag provides sufficient pull to get the rotor to turn provided the load on the motor is small, say a tiny direct connected fan.

The split-phase motor is the oldest type of single phase induction motor. In this design, there are two distinct stator (frame) windings, termed the main and starting windings. The starting winding is made of smaller wire to increase its resistance to reactance ratio above that of the main winding. The starting winding is placed in electrical parallel with the main winding. The strength of the magnetic fields in each winding occurs at different times, thereby causing a type of "rotating" field similar to a polyphase motor circuit, and capable of initiating pull. As the motor approaches full speed, the starting winding is disconnected automatically to avoid "burning out" the highly resistive starting winding.

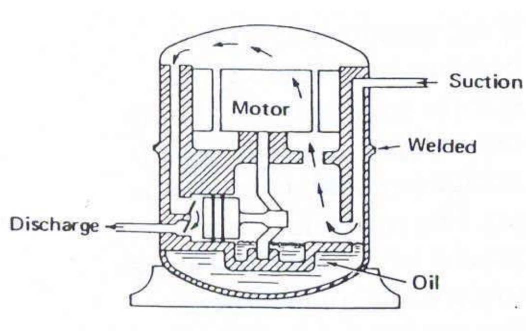
A refinement made to the split-phase motor is to add a capacitor in the starting circuit to create an even larger phase displacement between main and starting winding field strengths. This increases the starting torque or pull of the motor. This type of motor is called a capacitor start, induction run motor. Both the capacitor and starting winding are disconnected as the motor reaches full speed.
Capacitance in a motor circuit also improves running as well as starting characteristics. It can lower current draw, for example; however, the same size capacitor is not required to optimize both starting and running situations. One approach is a capacitor start/capacitor run (CSR)

motor. Two capacitors are used for starting; then by a suitable switching action, only one capacitor remains in the circuit as the motor reaches full speed.

A compromise design that eliminates the switching circuit is referred to as a permanent (one value) split capacitor (PSC) motor. The one capacitor (run) stays in the circuit at all times. The PSC motor does not have starting torque characteristics equal to that of a CSR motor because of the compromising nature of the capacitor sizing, but the complexity of a switching circuit is eliminated, and a potential servicing problem.

In both the CSR and PSC motors, the auxiliary winding is designed to be kept in the circuit, and is sometimes referred to as a phase winding rather than a starting winding.

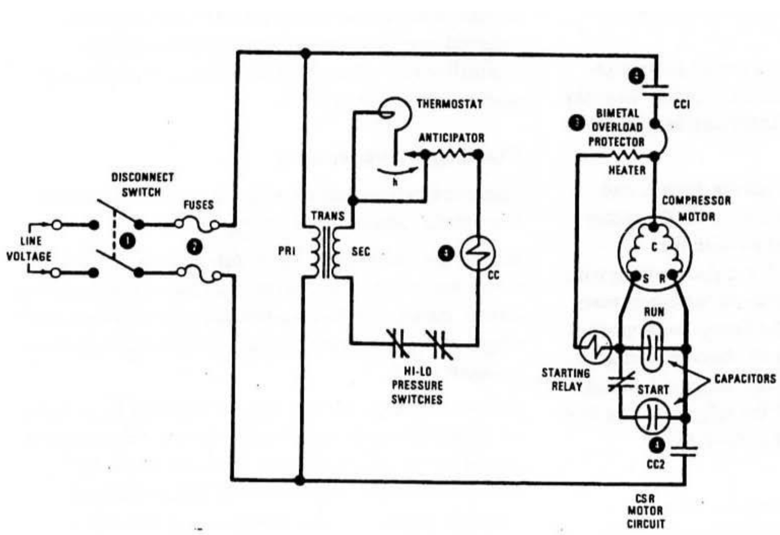
Because of their stronger torque characteristics, PSC and CSR motors are used to drive compressors in single-phase air conditioning units. Currently, single phase air conditioning units come in sizes up to 6 hp, or roughly up to 72,000 Btu/h cooling capacities. (Three-phase motors are used exclusively above this size, but, in addition, some three-phase equipment is available in sizes down to 2 hp.)



Schematic cutaway of hermetic unit shows a typical motor-compressor arrangement. Motors for hermetic units are specially designed.

Capacitor start, capacitor run motor driven compressors usually use a normally closed voltage relay called a starting or potential relay to disconnect the starting capacitor from the circuit after the compressor reaches about 85 percent of normal running speed. (Refer to Figure 19-1.)

The starting relay is connected in parallel with the phase winding. When power is applied to the compressor, the relay does not operate because it is calibrated to operate on a higher voltage. As the compressor comes up to speed, the voltage across the phase winding and relay coil increases in proportion to the motor speed. At a pre-selected voltage (and speed), the relay opens its contacts, and thereby opens the circuit containing the starting capacitor. The relay keeps the contacts open until the compressor is shut off.



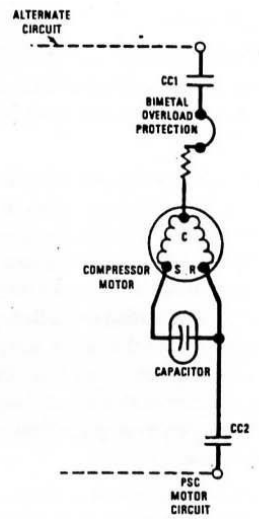


Figure 19-1: Basic compressor power and control circuit for a single-phase capacitor start, capacitor run (CSR) motor compressor. Numbered elements are discussed in text.

Figure 19-1A: Alternate circuit for providing single-phase power to a permanent split capacitor (PSC) motor compressor.

Providing Running Protection

Now that we've reviewed compressor motors and starting techniques, let's consider the control diagram in Figure 19-1 from the beginning - right at the power leads.

The disconnect (1) can be a pull handle knife switch, and the branch over current protection can be ordinary fuses (2), or a HACR circuit breaker switch can be used to perform both functions.

Fuses or circuit breakers sized to protect the branch circuit lines and components for over current or short circuits will inherently be too large to protect the motor from a current draw that could prove damaging while the compressor is running.

This stems from the fact that motors momentarily draw up to 5 times their normal running current at start up. This high, brief current inrush is what causes lights to flicker, momentary TV shrinkage, etc. Now, motors can safely absorb these brief surges, but exposure to prolonged over current could cause overheating and motor burnout.

Fuses (and branch conductor wires) must obviously be sized to meet the large startup current draw. As a result, a current flow somewhat less than starting draw would not blow the fuses and could proceed to damage a running motor.

To protect a compressor directly, a motor protection device (3) in the form of an overload relay, or inherent protector is used. (The latter is illustrated in Figures 19-1 and 19-2.)

The overload relay is a current sensing device, and consists of a bimetal contact in series with the motor contactor coil, and a heater in series with the compressor. It's usually mounted in a panel along with the compressor's contactor. Whenever the compressor motor is overloaded or stalled, the heavy continuous current through the heater warps the bimetal contact until it opens the motor low voltage relay coil circuit. With no current flowing through the relay coil, the load contacts open to stop the flow of current to the compressor.

An inherent protector is both a *current* and a *temperature* sensing device. It is installed inside the motor or on the compressor's hermetic casing, and is basically a thermostat invoking the snap action of a bimetal disc. The bimetal is affected by the temperature of the motor windings and also by the motor current draw which flows through a heater. This dual sensitivity gives the protector quick response which is crucial in protecting hermetic compressor motors, because motor cooling is dependent solely on the flow of refrigerant gas over the windings; and if any interruption of the flow of refrigerant occurs, a motor can burn out quickly without rapid sensing.

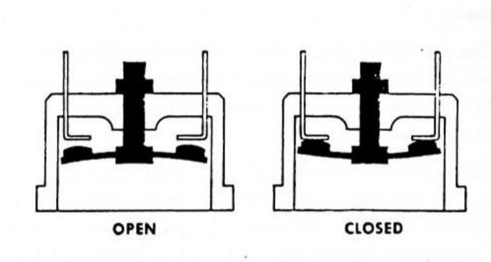


Figure 19-2: External type (mounts on housing) snap disc line break overload. Some designs fit inside motor winding (Klixon-Texas Instruments, Inc.).

Inherent protectors are used in hermetic compressors up to about 10 hp. Overload relays are used in larger sizes.

To actually stop and start the compressor, a thermostat-operated contactor is used (4). If the contactor houses an overload relay, the device is referred to as a motor starter - or even a motor controller. (Don't confuse the terms contactor, motor starter and starting relay.)

Starting Compressors

There are two classes of motor starters - across the line starters and reduced voltage starters.

Across the line starters apply *full* line voltage to motor stator windings, permitting *full* starting current inrush. Across the line starters are typically used with single and three-phase motordriven compressors up to about 10 hp.

Reduced voltage starting may be required by utilities for larger hp equipment in order to minimize current inrush and its effect on other services on the line. There are several methods of providing reduced voltage starting - consequently reduced starting current draw. Resistors, reactance coils or autotransformers can be added to the starting circuit. As a motor comes up to speed, these voltage reducers are bypassed.

There is also a *part winding* starter. Many electric motors are built with stator windings made in sections so that by connecting the sections in series or parallel, the motor can have a dual rating, say operate on 240 or 480 volts. The part winding starter uses two contactors, one for each winding section. The motor is started in effect using only “half” the motor windings and then the second contactor closes and connects the remaining stator windings.

The remaining elements in our simplified compressor control circuit are the room air thermostat and the high pressure/low pressure refrigerant cut-out switches. These latter devices are bellows-actuated low voltage switches placed in series with the cooling contactor relay coil. The bellows sense refrigerant discharge and suction pressure.

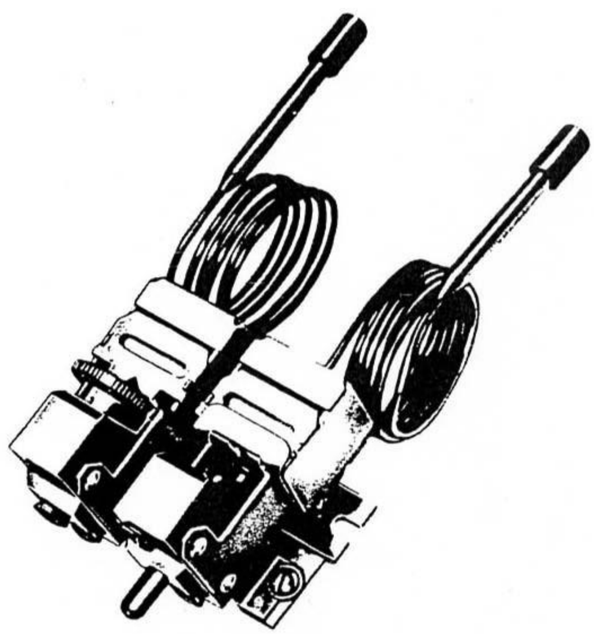


Figure 19-3: High pressure-low pressure controls sense refrigerant suction and discharge pressures and de-energize contactor coil in emergencies.

A too high “head” pressure or too “low” suction pressure causes the switches to open, thereby stopping the current flow to the contactor coil and thus shutting down the compressor. (See Figure 19-3 above.)

To review: in a normal sequence, with the disconnect switch closed, a call for cooling by the room thermostat energizes the contactor relay (CC) that closes load contacts CC1 and CC2. Power is applied through the overload protector through the two capacitors to the motor windings. After reaching about 85 percent of full speed, the starting relay opens its contact to take the starting capacitor out of the circuit. The running capacitor remains in the circuit to improve the power factor of the motor. Should the motor become overheated, the overload protectors would open and interrupt the power supply to the compressor.

In our next lesson, we’ll consider some refinements to this basic compressor control circuit and also consider some basic troubleshooting procedures.

Self-Check, Lesson 19 Quiz

You should have read all the material in Lesson 19 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F The most common electric motor used in heating and cooling equipment is the AC induction motor.

2. T F A single-phase induction motor is inherently self-starting.

3. T F Inductance added to a motor circuit improves starting characteristics.

4. T F Capacitor start, capacitor run, and permanent split capacitor motors drive almost all three-phase AC units.

5. T F A potential relay is used to disconnect the starting capacitor as the CSR motor comes up to speed.

6. T F Line fuses are too large to protect a running motor from excess current.

7. T F Motors can draw up to five times their running current at start-up.

8. T F A motor overload relay is a voltage sensing device.

9. T F An overload relay disconnects power to the compressor directly.

10. T F An inherent protector is really just a specialized snap action bimetal thermostat.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement and circle the corresponding letter in front of the phrase.

11. The shaft windings of an ac induction motor are “energized” by:

a. means of commutator brushes.
b. direct leads to contactor.
c. transformer action.
d. slip rings.

12. CSR is an acronym for a:

a. shaded pole motor.
b. split phase motor.
c. capacitor start, induction run motor.
d. capacitor start, capacitor run motor.

13. Single-phase AC units are generally only available in sizes up to:

a. 2 hp.
b. 3 hp.
c. 6 hp.
d. 10 hp.

14. Starting capacitor in a CSR motor is disconnected when motor speed approaches:

a. 55 percent of running speed.
b. 65 percent of running speed.
c. 85 percent of running speed.
d. full running speed.

15. The potential relay in a CSR motor is connected in parallel with the:

a. motor starter.
b. start capacitor.
c. phase winding.
d. run capacitor.

16. A PSC motor that normally draws 12 amps while at full speed is likely to draw:

a. 6 amps when starting.
b. the same amps when starting.
c. 48 amps when starting.
d. 96 amps when starting.

17. Across the line starters are used on AC equipment in sizes up to:

a. 5 hp.
b. 10 hp.
c. 15 hp.
d. 25 hp.

18. Reduced voltage starting on large equipment is required by utilities in order to:

a. use smaller starters.
b. avoid sparks.
c. minimize current inrush.
d. conserve energy.

19. One method of providing reduced voltage starting is to:

a. add resistors to start circuit.
b. open switch only part way.
c. turn two units on at same time.
d. use smaller wires.

20. Motors started using only half the motor windings require a/n:

a. autotransformer starter.
b. reactive coil starter.
c. part winding starter.
d. resistor starter.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

21. An inherent protector is both a/an ______________ and a/an _____________ sensing device.

22. A/an ______________ ___________________ is a contactor fitted with an overload relay.

23. The two most common classes of motor starters are:

a. ___________________

b. ___________________

24. High/low pressure cut-outs which are really specialized sub-master controllers, are placed in _____________ with the cooling contactor's ____________.

25. List the four basic functional requirements of a compressor power and control circuit.

a. __________________________ b. _______________________

c. __________________________ d. _______________________

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

Lesson 20: Overview

Lesson 20, *Troubleshooting Control Systems,* is intended to be a very practical and useful guide on how to test a year-round control system in order to first locate the “trouble” in a circuit- and then proceed to resolve the problem.

In addition to the four general service procedures that tell you how to approach every troubleshooting job, specific circuit analysis procedures are described.

Before you begin the lesson, however, please study the wiring symbols and low voltage terminal designations listed in the Appendix. If you don’t know the symbols and wiring code, you will not be able to follow the lesson examples.

In Lesson 20, you’ll learn how to troubleshoot:

1. The cooling circuit.
2. The fan circuit.
3. The heating circuit.
4. The pressure control circuit.
5. The changeover relay.
6. The reversing relay.
7. The impedance (lockout) relay.
8. The thermal delay relay.
9. The defrost controls for heat pumps.

Now read Lesson 20 which begins on the next page.

Lesson 20: Air Conditioning Controls Part II – Troubleshooting Control Systems

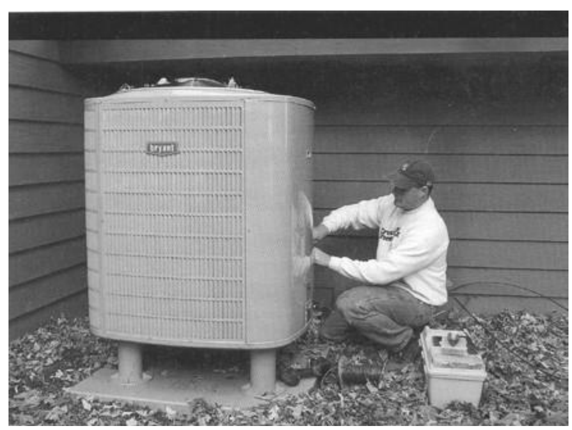
The knowledge we have acquired in our study of comfort conditioning controls will be used in this summary discussion of commonly encountered control systems. The operation and service checkout procedures pertaining to electrical components will be covered. You should review the servicing sections of prior lessons, and the wiring symbols and wiring code given in the appendix.

General Service Procedures

There are certain fundamental procedures which should be followed whenever servicing electrical equipment. The procedures described below should be followed whenever you troubleshoot a control system.

First - Inspect and set the room thermostat for the checkout. Set the thermostat "System" switch to the "Off" position. Set the "Fan" switch to the "Auto" position. If there are no switches on the thermostat, set the "cool" temperature adjustment dial as high as possible above the room temperature. Set the "heat" temperature dial well below room temperature.

Second - Check the power being delivered to the equipment. Use a voltmeter to check these line voltages.



Warning: *Air conditioning units are powered by* ***high voltage electricity.*** *Common voltages are 120 volts, 208 volts, 240 volts, and 480 volts. A shock at any of these voltages can be deadly.*
Don't touch anything inside a master control panel or wiring compartment of an air conditioning unit until you have checked across every power terminal and each terminal to ground to be positive all power is off. Use test meters with well insulated probes and leads to test circuits and components. And use JUMPERS with great discretion. Components can be readily damaged by misconnected jumper leads. Be alert and cautious at all times.

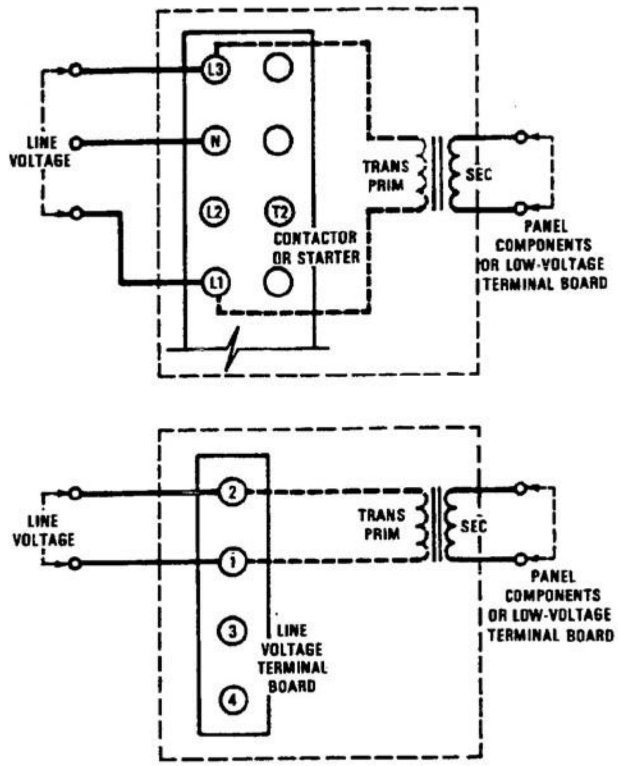


Figure 20-1: Control panels (typical). "L" or numbered terminals indicate incoming power; "T" terminals, switched power load connections.

1) Place the voltmeter probes on terminals 1 and 2 or L1 and L3 (Figure 20 1).

a) If the meter readings match the panel and equipment nameplate ratings, power is present. (If the meter readings fluctuate more than plus or minus ten percent from the rated voltage for 230/240 volt service or more than plus ten or minus five percent for 208 volt service, check with the utility company. Voltage fluctuations beyond these limits could be caused by inadequate building electric service or by inadequate wiring.)

b) If the voltmeter readings indicate no power, check the fuse box and wiring connections for an open circuit and correct it.

Third - Take voltmeter readings at the transformer.

1) To test for power at the transformer primary, attach the voltmeter to the power supply leads as shown in Figure 20-2. (See student note.)

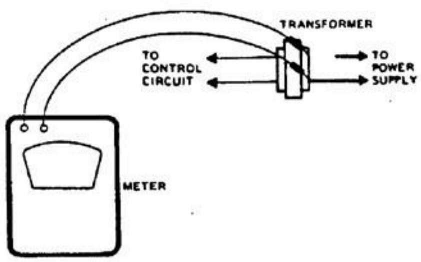


Figure 20-2: Primary test.

a) If meter reading matches the equipment rating, power is present at the transformer primary.
b) If the voltmeter readings indicate no power, check the connection and the power circuit.

Note: 208/240 volt transformers have three lead wires on the primary side. For 230 and 240 volt operation, the black and yellow (or white) leads should be connected to the line voltage terminals. The remaining red lead should be taped.

2) To test for power at the transformer secondary, disconnect one side of the load and attach a voltmeter or trouble lamp to the transformer as shown in Figure 20-3.

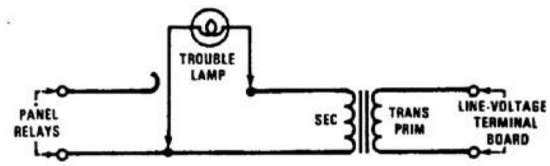


Figure 20-3: Secondary test.

a) If the light glows or the meter reading is approximately 24 volts, power is present at the transformer secondary.

b) If the light does not glow, the transformer or wiring has an open circuit. Check the wire and transformer and repair or replace the defective component.

Fourth - Proceed with the checkout procedures that follow. In troubleshooting electrical control systems, you may need to test for power through a relay coil. The two tests required to check the power through a coil are shown in Figures 20-4 and 20-5. Only one coil and a power supply are shown in these figures; however, the testing procedures remain the same if other components are wired into the circuit.

1) Attach a lamp (or voltmeter) to one of the power supply leads as shown in Figure 20-4.

   a) If the lamp (or voltmeter shows no voltage) does not light, the circuit is open or shorted.
   b) If the lamp lights, the circuit is complete continue with the test.

2) Attach the trouble light (or voltmeter) as shown in Figure 20-5.

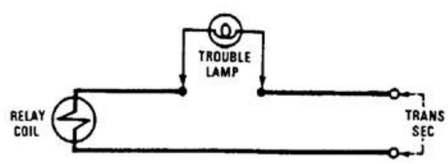


Figure 20-4. RELAY test 1.

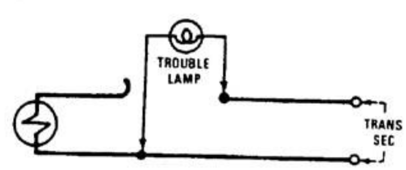


Figure 20-5 RELAY test 2.

a) If the lamp lights (or voltmeter shows voltage), there is power to the coil. If the lamp did not light in the first test, but now lights, there is a defect in the coil and the entire relay must be replaced.

b) If the lamp does not light, check for an open circuit between the transformer and the relay coil.

Troubleshooting Circuits

A typical cooling circuit is illustrated in Figure 20-6. When the thermostat calls for cooling, the cooling contactor is energized through the high-low pressure control and the overload relay. The contactor's contacts close to start the cooling equipment.

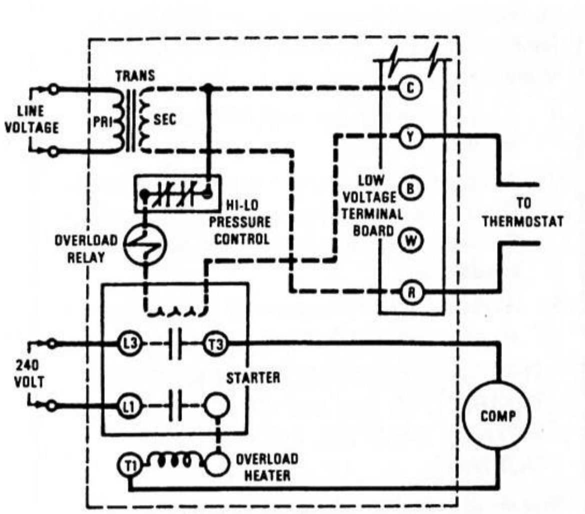


Figure 20-6: Cooling circuit in typical panel.

To troubleshoot the cooling circuit:

1) If a high-low pressure cutout or overload cutout is used, check to be sure they are reset.

2) Jumper terminal R to Y.

a) If the cooling contactor does not pull in, the trouble is in the transformer, the contactor coil, or the pressure switch for the overload.

- Jumper the pressure switch and overload one at a time to make certain they are not open. If the cooling contactor pulls in, replace the pressure switch or overload which is defective.

- Use a test light or voltmeter to check the transformer secondary. If the light does not come on, the transformer is burned out and must be replaced.

- If the contactor has not pulled in, the coil is burned out and must be replaced.

b) If the cooling contactor pulls in and the compressor starts, the trouble is in the thermostat or the low voltage wiring between the thermostat and the panel.

c) If the cooling contactor pulls in, but the compressor does not operate, jumper terminals LI to TI and L3 to T3 on the cooling contactor. Be careful - this is line voltage (240 volts).

- If the compressor starts, the trouble is in the contactor contacts and they should be replaced.

- If the compressor does not start after jumping the contacts, the trouble is at the cooling equipment (capacitors. motor, etc.) or in the wiring to the equipment. These should be checked out to determine which component is defective.

The Fan Circuit

A typical fan circuit is illustrated in Figure 20-7. The fan relay is energized on the thermostat's call for heating or cooling if the fan switch on the thermostat is in the "Auto" position. The fan circuit will also be energized whenever the fan switch is turned to the "On" position.

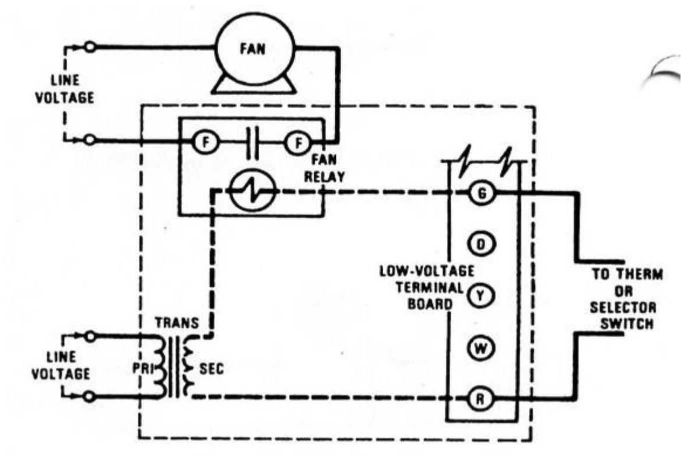


Figure 20-7: Fan circuit in typical panel.

To troubleshoot the fan circuit:

1) Jumper terminal R to G.

a) If the relay does not pull in, the trouble is in the relay coil - replace the fan relay, or the transformer. Check transformer with test light as in cooling circuit procedure.

b) If the relay pulls in and the fan starts, the trouble is in the thermostat or the low voltage wiring between the thermostat and the panel.

c) If the relay pulls in but the fan does not operate, jumper the fan contacts. Be careful, these terminals are line voltage. If the fan starts, the trouble is in the relay contacts - replace the fan relay. If the fan does not start, the trouble is in the fan motor or in the wiring to it. Check for open circuits in the wiring and the fan motor.

Heating Circuit

The typical heating circuits in Figure 20-8 show that on the thermostat's call for heat, the coil in the heating relay is energized through the R and W low voltage terminals. The normally open contacts in the relay close to energize the panel powered or externally powered heating equipment. (Some systems may operate the primary control directly from the thermostat using the R and W terminals only for connections.)

To troubleshoot the heating circuit:

1) Jumper terminals R and W.

a) If the relay does not pull in, the trouble is in the relay coil and it should be replaced.

b) If the relay pulls in and the burner starts, the trouble is in the thermostat or the low voltage wiring between the thermostat and the equipment. Check for open circuits or a defect in the thermostat.

c) If the relay pulls in but the burner does not start, jumper terminals R to V (panel powered) or T to T (externally powered).

- If the burner starts, the trouble is in the relay contacts and the relay should be replaced.

- If the burner does not start, the trouble is at the furnace or boiler. (Check wiring and connection, the voltage output of the furnace transformer, if used, the pilot flame and/or flame safety controls, the limit switch, and the gas valve.)

Note: The R terminal always acts as the transformer power supply for the heating current. When a selection switch is used, the panel B terminal is connected to the selection switch B terminal on the thermostat.

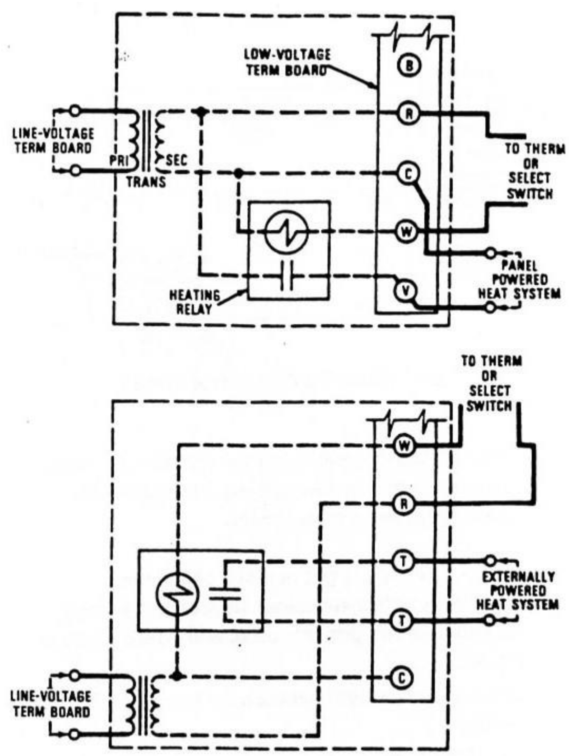


Figure 20-8: Two common heating circuits found in panels.

Pressure Control Circuit

Pressure controls are one or two SPST switches which are used to protect the equipment if the system pressure goes above or below a preset level. The normally closed pressure switch contacts are wired in series with the coil in the cooling contactor and break the control circuit to stop the compressor if system pressures are not within acceptable limits (Figure 20-9).

If the cooling system is not operating, check to make certain the pressure switch contacts have been reset by checking gauges for automatic reset pressure controls or pushing the reset button on manual reset pressure controls.

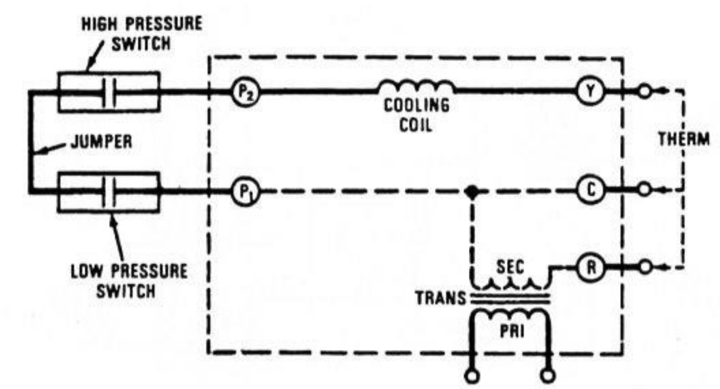


Figure 20-9: Pressure control circuit.

To troubleshoot the pressure control circuit:

1) If the system operates after the pressure switches are reset, a switch was opened (cut out) when pressure limits were exceeded.

2) If the system does not operate, check the manufacturer's instructions for troubleshooting procedures, components used, and type of control circuit.

3) Place a trouble light between the terminals P2 and R.

    a) If the light glows, the pressure switch contacts are closed; check the remaining components of the control circuit.

    b) If the light does not glow, jumper the individual switch terminals until the light glows. This indicates open contacts. If the system pressure is correct, replace the switch.

Troubleshooting Relays

The changeover relay usually has two sets of normally open contacts. These relays are used in heat pump control circuits to control a remotely mounted changeover (solenoid) valve. The changeover valve controls the direction of refrigerant flow for heating or cooling operation of the heat pump. The relay coil is connected in series with the heating contacts of the room thermostat. One set of relay contacts is connected in series with the changeover valve coil and the power supply. The other set of contacts is used in the low voltage control circuit to energize the compressor. To troubleshoot the changeover relay:

1) Jumper terminals Rand O in Figure 20-10. (Only the high voltage relay contacts are shown.)

   a) If the relay pulls in, the trouble is in the thermostat or its connections. Check the wiring and the thermostat for open circuits and repair or replace if necessary.

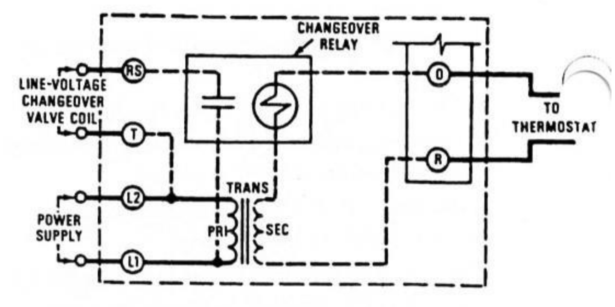


Figure 20-10. HEAT PUMP heat-to-cool changeover relay circuit.

   b) If the relay does not pull in, the trouble is in the relay coil. Check the connections for an open circuit. If no open circuit exists, the trouble is in the coil and the entire relay must be replaced.

2) Jumper the line voltage terminals RS to LR.

   a) If the valve operates, the trouble is in the relay contacts and the entire relay must be replaced.

   b) If the valve does not operate, the trouble is at the valve or the wiring to it. Check for an open circuit.

Reversing Relays

A reversing relay is used in some control circuits to provide reverse switching so a single-pole, single throw thermostat can control both the heating and the cooling equipment. The reversing relay has two sets of contacts that form an interlock to prevent the cooling system from operating when the selection switch is set for heating and the heating system from operating when the selection switch is set for cooling. The 1R1 (heating) contacts in Figure 2011 close when the thermostat actuates the relay coil. When the relay is de-energized, the 1R2 (cooling) contacts are made. The cooling system is energized from the “O” terminal which is energized on cooling and the heating system is energized from the “B” terminal which is energized on heating.

To troubleshoot the reversing relay:

1) Jumper terminals W to R.

   a) If the relay does not pull in, the trouble is in the relay coil. Check the wiring to the coil. If the wiring is not broken, the coil is defective and must be replaced.

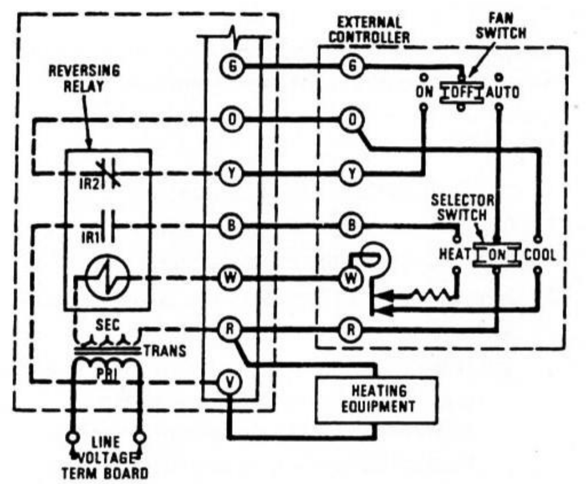


Figure 20-11: Heat cool system interlock circuit.

   b) If the relay pulls in, the trouble is in the thermostat or the wining between the thermostat and the equipment. Check for an open circuit or a defect in the thermostat and repair or replace if necessary.

   c) If the relay pulls in, but the heating equipment does not operate, jumper terminals B to V.

- If the heating equipment starts, the trouble is in the relay contacts and the entire relay should be replaced.

- If the heating equipment does not start, the trouble is in the heating equipment or the wiring to it.

Impedance Relay

The impedance relay (lockout relay) is used to lock out the circuit to the cooling contactor coil after a system shutdown due to a high pressure, low pressure, or overload cutout. The relay's high impedance coil is connected in series with the contactor coil (Figure 20-12). The relay may use SPST or SPDT switching. The SPST normally closed contacts complete a control circuit around the impedance coil. If the overload cutout or the pressure switch breaks their contacts, the control circuit is broken, the impedance relay coil is energized, and the impedance relay contacts open. The resistance of the impedance coil, which is now in series with the contactor, is so high that the contactor cannot hold in its contacts. After the automatic reset overload or pressure switch contacts have re-made, the circuit must be reset by interrupting the current through the impedance relay coil. This is done by moving the system switch on the room thermostat from “cool” to “reset” or “off” and back to “cool”. This de-energizes the impedance relay coil to complete the original control circuit and permit the contactor contacts to make when the thermostat calls for cooling.

Student Note: When troubleshooting the cooling circuit contacts (1R2), jumper terminals O and Y. These contacts are made only when the relay is de-energized.

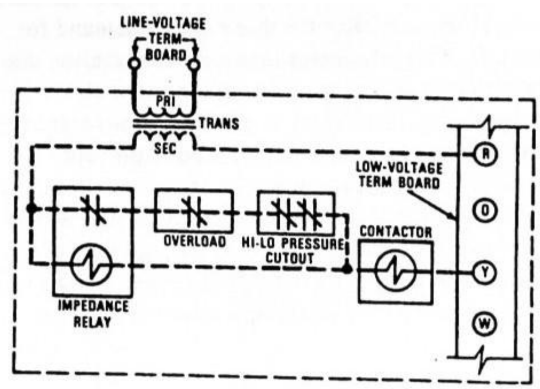


Figure 20-12: Lockout or reset circuit.

When SPDT contacts are used, the normally open contacts energize a warning or check light when the system shuts down. To troubleshoot the impedance relay circuit:

1) Jumper terminals R to Y in Figure 20-12.

   a) If the contactor makes, the trouble is in the thermostat or the wiring to it.

   b) If the contactor does not make, jumper the overload, high-low pressure cutout contacts and the impedance relay contacts. Remove the jumper from the R terminal and reattach (breaking the current flow).

If the contactor pulls in, the trouble is in one or more sets of contacts:

a) Remove the jumper from the overload; if the contactor drops out, the overload is defective and must be replaced.

b) If the overload is not open, remove the jumpers from the high-low pressure controls (one at a time). If the contactor drops out, the control is defective and must be replaced.

c) If both the overload and high-low pressure cutout are not open, remove the jumper from the relay contacts. If the contactor drops out, the contacts are defective and the entire relay must be replaced.

2) If the unit short cycles, the impedance relay coil is not breaking the relay contacts when the overload or high-low pressure cutouts open the circuit. Check for a burned out coil or a loose connection. If the coil is burned out, replace the entire relay.

Thermal Delay Relays

The thermal delay relay is used to prevent short cycling the system by delaying the compressor start several seconds after the thermostat's demand for cooling. This eliminates intermittent operation due to vibration or momentary changes in room air temperature. If the relay is used in a multi-stage (two compressor) system, it can be used to prevent excessive inrush current when two compressor motors are started simultaneously. The relay heater, wound on a bimetal element, is energized through the cooling contacts of a room thermostat (Figure 2013). The relay contacts close several seconds after the heater is energized to complete the control circuit through the contactor coil to start the compressor. The contacts open several seconds after the thermostat is satisfied.

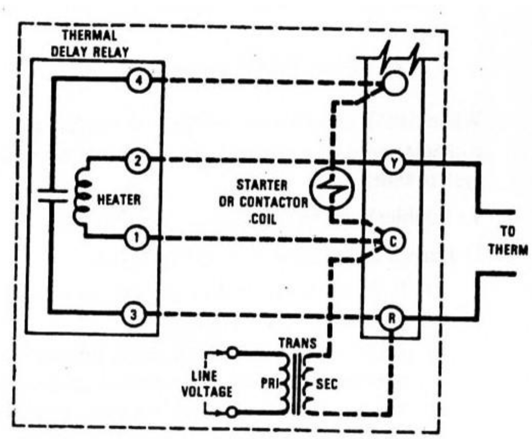


Figure 20-13. COMPRESSOR delay circuit.

To troubleshoot the thermal delay relay:

1) Check for transformer power across R and C. If there is none, replace transformer.

2) Jumper terminals 2 to R in Figure 20-13 and wait 30 to 60 seconds.

   a) If the contactor pulls in, the trouble is in the thermostat, the wiring between the thermostat and the equipment, or in the thermal delay relay heater. Check these components for open circuits.

   b) If the contactor does not pull in, jumper terminal 4 to R.

If the contactor pulls in, the trouble is in the thermal relay heater or intermediate wiring. Replace the relay or correct wiring.

If the contactor does not pull in, the trouble is in another component. Check the wiring and the control circuit.

Defrost Controls for Heat Pumps

During the heating cycle, the outdoor coil of a heat pump is at a lower temperature than the outdoor air and the coil temperature is well below freezing. Moisture in the outside air condenses on the coil causing frost and ice buildup on the coil. As ice accumulates on the coil, heat transfer decreases and some means of defrosting the coil must be provided. There are various types of defrost control circuits used; such as, time initiated, time terminated; pressure initiated, temperature terminated; time initiated, pressure terminated; pressure initiated, temperature terminated, etc. Normally, on circuits with pressure or temperature termination of the defrost cycle, an overriding time termination is provided in case the defrost cycle for some reason is abnormally prolonged.

A low voltage defrost control system using a pressure initiated, temperature terminated defrost cycle is illustrated in Figure 20-14.

During the heating cycle, the fan relay coil and the low voltage reversing solenoid valve are energized through the normally closed contacts of the defrost temperature control (identified as Defrost Terminating) and are “held in” by the fan relay holding contact (FR3) and the normally closed contact of the differential pressure control identified as Defrost Initiating in Figure 20-14.

Electric Shock

Electric shock may cause instant death or may cause unconsciousness, cessation of breathing and burns of all degrees. If a 60 cycle alternating current is passed through a person from hand to hand or from hand to foot, the effects when current is gradually increased from zero are as follows:

1. At about 1 milliampere (0.001 ampere), the shock can be felt.

2. At about 10 milliamperes (0.01 ampere), the shock is severe enough to paralyze muscles so that a person is unable to release the conductor.

3. At about 100 milliamperes (0.1 ampere), the shock is fatal if it lasts for one second or more.

IT IS IMPORTANT TO REMEMBER THAT CURRENT IS THE SHOCK FACTOR RATHER THAN THE AMOUNT OF VOLTAGE.

You should clearly understand that the resistance of the human body is not great enough to prevent fatal shock from a voltage as low as 120 volts. In some cases, voltages less than 120 volts are fatal. When the skin is dry, it has a high resistance. The resistance may be high enough to protect a person from a fatal shock even if one hand touches a high voltage while another part of the body touches the chassis or another ground.

Contact resistance decreases when the skin is moist and body resistance may drop to as low as 300 ohms. With this low body resistance, it can be seen that a very low voltage could supply enough current to cause death.

Immediate action must be taken in cases of electrical shock. Seconds count. They can mean the difference between death and recovery. Artificial respiration is the fundamental first aid measure for this emergency.

A person coming in contact with a “live wire” is the usual cause of electric shock. If a disconnect switch is nearby, turn it off – but don’t waste time looking for it. Remove the person from the wire by using a dry wood pole, dry clothing, rope or any non-conductor. BE SURE NOT TO TOUCH THE WIRE OR THE VICTIM WITH YOUR BARE HANDS, or you’ll end up a victim too.

Artificial respiration should be started immediately after freeing the accident victim.

In addition, if two people are available to give aid, closed chest cardiac massage can be administered at the same time. Closed chest heart massage is the rhythmical compression of the heart using the heel of your right hand on the breastbone (only) of the patient doing about 60 thrusts or depressions per minute.

Red Cross training in first aid is invaluable to anyone who must work on hazardous equipment and is likely to be confronted with an emergency.

When the temperature of the outside coil decreases to the cut-out setting of the defrost temperature (terminating) control, the control’s contacts open. The fan relay coil and the low voltage reversing solenoid valve remain energized, however, because the circuit through the normally closed contacts of the differential pressure control and the FR3 contacts has not been broken.

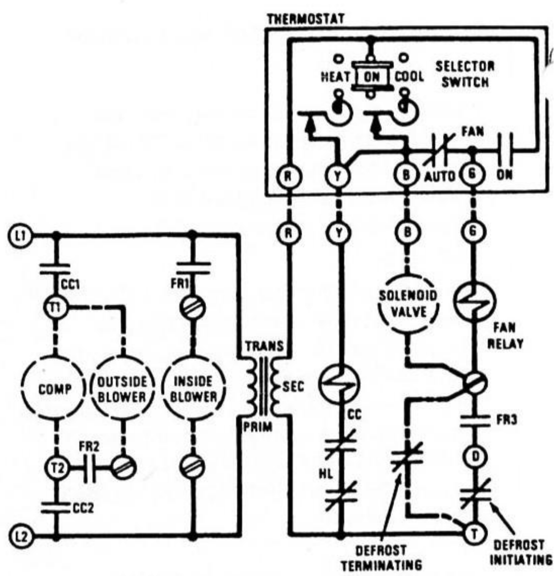
When the outside coil ices, the differential pressure control senses a change in the differential pressure (the difference in air pressure between the inlet and the outlet side of the coil). When this pressure differential increases to the cutout setting of the control, its contacts open. The fan relay coil and the low voltage reversing solenoid are de-energized. The refrigerant cycle then reverses and high pressure, high temperature refrigerant goes to the outdoor coil to melt the frost and ice. Since the fan relay coil is now de-energized, the outdoor and indoor fans stop to prevent cooling of the conditioned space during the defrost cycle. The compressor continues to run as long as the thermostat is calling for heat.

When the outside fan stops, the pressure differential across the coil drops to zero and the differential pressure control contacts close. However, the reversing valve solenoid and the fan relay coil cannot be energized, since the FR3 contacts were opened at the beginning of the defrost cycle and can only be reenergized when the defrost (terminating) temperature control on the coil reaches the cut-in setting (about 60° F). When the defrost temperature control contacts close, the heat pump system reverts back to the normal heating cycle.

It should be obvious at this point that:

1) Compressor operation is not affected by the defrost controls.

2) The operation of both the indoor fan and the outdoor fan is controlled by the fan circuit. And the defrost controls do affect the operation of this circuit. If the indoor and outdoor fans do not operate, jumper R to G.



a)If the fan relay *does not* energize, jumper the defrost termination switch terminals. Now if the fan relay *does* energize, the trouble is in the defrost termination switch terminals.

Figure 20-14: Typical pressure initiated, temperature terminated heat pump defrost control circuit.

If the fan relay does not energize, check for an open circuit in the fan relay coil or the wiring to it.

b) If the fan relay does energize, the trouble is in the thermostat or the wiring between the thermostat and the panel.

c) If the relay pulls in but the fan(s) does not operate, jumper the fan contacts L1 to terminal between FR1 and inside blower). Be careful, these terminals are line voltage!

- If the fan starts, the trouble is in the relay contacts - replace the fan relay.

- If the fan does not start, the trouble is in the fan motor or in the wiring to it. Check for open circuits in the wiring and the fan motor.

3) If the fans operate but the coil is iced, disconnect one wire from the pressure (initiating) differential control terminal.

a) If the fan relay and solenoid valve de-energize and the unit defrosts, the trouble is in the pressure differential control. Check the air probes for obstructions; if the probes are clear, replace the control.

b) If the fans continue to run and the reversing valve remains energized, there is a short circuit in the wiring to the pressure differential control.

c) If the fans stop but the reversing valve does not shift, the problem may be due to malfunctions in the solenoid, the wiring to the solenoid, valve damage, or an undercharge of refrigerant.

4) There is no changeover relay in this system. If cooling operation is satisfactory, jumping R to B should energize the solenoid reversing valve. If the valve does not operate, check the valve, the coil and the wiring to it.

Develop Safe Work Habits

When working around moving machinery, do not wear gloves, avoid ties, loose clothing, long hair, etc., that may get caught in the machine and cause you severe injury. Finger rings are dangerous, and should not be worn when a man is at work. Do not stick fingers or tools into moving machinery, nor into automatic machines or fans that may start suddenly. Do not use extension cords or connection cords, the insulation of which is frayed or damaged. Tape up the damaged section with a layer of rubber tape or plastic electrician's tape. If the wires are damaged, reconnect them and, if possible, solder them or use an approved solderless connector --- then re-tape them.

Never unnecessarily touch bare electrical wires or connections that are known to be "hot", that is, carrying electric current. If possible, pull the switch, turn off circuit breaker or pull the fuses serving the equipment so that the line is dead before working on it. If it is necessary to work with "hot" lines or equipment, use every care ----

1. Do not work on "hot" parts or lines unless you understand them.

2. Do not stand on wet floors or earth.

3. Keep your hands or gloves dry.

4. Do not put hands on live parts at the same time.

5. Do not lean against damp walls or grounded machines.

6. BE VIGILANT.

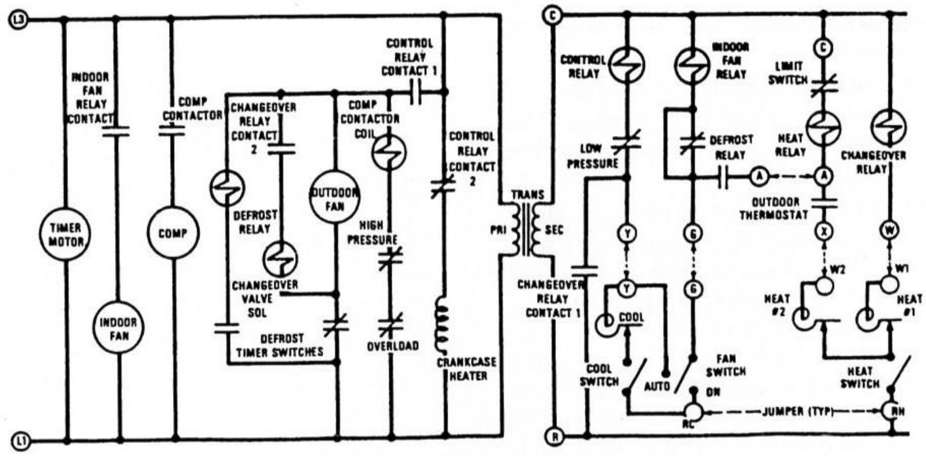


Figure 20-15: Typical line voltage terminated heat pump defrost control circuit.

A line voltage, time initiated, temperature terminated defrost cycle is illustrated in Figure 2015. The defrost control used initiates the defrost cycle at an adjustable, pre-selected time interval (30, 45, or 90 minutes), providing the outdoor coil is below a preset initiation temperature (about 28° F). The defrost cycle is terminated as soon as the outdoor coil rises to a preset temperature (about 60° F) or after a preset length of time (about 10 minutes). If the outdoor coil cannot reach the preset termination temperature, a “time-safe” termination will occur.

The wiring diagram (Figure 20-15) includes a relay which is identified as a control relay. This relay is similar to a reversing relay. It contains two sets of contacts for SPDT switching. When the thermostat calls for heating or cooling, the coil of this relay is energized - its normally open contacts close to make a circuit to the outdoor fan and the *compressor contactor* (starter) coil, while its normally closed contacts open to break the circuit to the crankcase heater.

Field wiring from R on the transformer provides 24 volt power to RH on the thermostat. With the thermostat’s heating cycle switch and heat #1 bimetal contacts closed, the circuit from W1 to W energizes the changeover valve relay coil. When the changeover relay coil is energized, the contacts on the relay complete two circuits - one through the low pressure switch energizing the control relay; the other through Y on the panel to Y on the thermostat, through the “auto” position on the fan switch to G to G on the unit and through the defrost relay contacts, energizes the fan relay.

An additional heating contact, heat #2, on the thermostat bimetal which makes on a temperature fall to a point about 2° F below “heat #1,” is connected between the “heat” selector switch and terminal W2.

Field wiring connects W2 to X on an auxiliary electric heater. This heater is used to supplement the heating capacity of the heat pump at low outside air temperatures and to warm indoor air when the unit goes into “defrost.” To prevent the operation of the supplementary heaters above a minimum predetermined outside temperature, an outdoor thermostat can be installed between terminals X and A. From terminal A, the circuit is completed through an auxiliary heating relay coil and limit switch to C on the transformer.

A field-installed jumper provides power from terminal RH to RC and from that point to both the “cool” selector switch and the “fan” switch. Field wiring completes the circuit from G on the thermostat to G on the panel through the normally closed contacts of the defrost relay, the indoor fan relay coil and to C. A jumper is provided around the normally closed contacts of the defrost relay and the normally open defrost relay contacts are connected to terminal A. When the defrost relay is energized, it closes a circuit to A on the auxiliary heater to turn it on. If an auxiliary heater is not installed on the unit, the jumper should be removed and the defrost relay will turn off the indoor fan so that the inside space will not be cooled during the defrost cycle. A 240 volt timer motor, a part of the defrost control, runs continuously. It drives a timer cam which actuates the defrost switch every 30, 45, or 90 minutes (depending on the frequency desired). The defrost control will function at the selected time interval only if the outdoor coil refrigerant temperature is below about 28° F.

The circuit from L1 to the defrost timer switch, through the normally closed contacts of the switch, the outdoor fan motor and the control relay is made when the control relay coil is energized. The parallel circuit energizing the changeover valve solenoid when the changeover valve relay contacts close is energized through the heat #1 contact. However, when the defrost timer switch is actuated by the timer cam, the normally closed timer switch opens, the normally open contacts close, and a circuit is completed through the defrost relay coil and the control relay contacts to L3. When the defrost timer switch’s normally closed contacts open, the changeover valve solenoid coil is de-energized and the outdoor fan motor stops. The refrigerant cycle is reversed and high pressure, high temperature refrigerant goes to the outdoor coil to melt frost and ice accumulations.

The defrost relay simultaneously energizes the auxiliary heater, or stops the indoor fan, as described above.

The defrost cycle is terminated when coil temperature rises to about 60° F, or after about 10 minutes if the outdoor coil cannot reach the preset termination temperature.

If the outdoor coil is iced:

1) Check the timer motor.

Note: It may be possible to visually check the timer motor by temporarily interrupting power to the motor and observing rotor movement when the power is reconnected. If the motor cannot be checked visually:

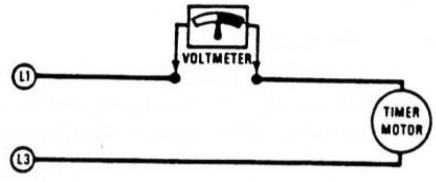


Figure 20-16: Defrost timer motor test 1.

a) Connect a voltmeter to the motor as shown in Figure 20-16. If the meter reading indicates no power, check the wiring for an open or shorted circuit.

b) If the meter reads 240 volts, the circuit is complete. Continue with the next test.

c) Attach the voltmeter to the motor terminals as shown in Figure 20-17.

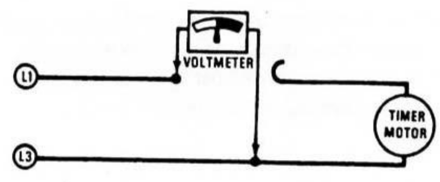


Figure 20-17: Defrost timer motor test 2.

If the meter reads 240 volts, there is power to the motor. If the meter indicated no power in the first test, there is a short in the motor and the timer motor must be replaced. If the meter reads 0 volts, check for an open circuit.

2) Check the timer switch and the charge in the sensing bulb by packing the sensing bulb with ice and manually turning the timer cam (check manufacturer's instructions). The defrost relay should pull in, the outdoor fan should stop, and the reversing valve should cycle.

a) If the above actions take place, the trouble is not in the timer switch and the sensing bulb is correctly charged.

Note: Initiation of the defrost cycle can only occur if the outdoor coil temperature is below the initiation temperature of about 28° F. If the initiation temperature has "slipped" to a lower point, the control may never initiate a defrost cycle. Since it is almost impossible to check the initiation temperature setting in the field, the defrost control may have to be replaced to "prove" this malfunction.

b) If the defrost relay does not pull in, the outdoor fan continues to run and the reversing valve does not cycle, replace the defrost control.

If the house is cold, but the heating operation is normal:

1. Manually initiate a defrost cycle as above.

a) If the outdoor fan drops out and the reversing valve cycles, but the indoor fan continues to run (no auxiliary heat) or the auxiliary heaters are not energized, the problem is in the defrost relay coil, the defrost contacts, or the timer switch.

b) Jumper L1 to the defrost control terminal as shown in Figure 20-18.

If the indoor fan stops, the trouble is in the timer switch (the normally open contacts are not closing when the defrost cycle is initiated). Replace the defrost control.

If the indoor fan continues to run, the problem is in the defrost relay coil or its contacts:

a) If the defrost relay coil does not pull in, check for power across the relay coil using the procedures described previously. Be careful, and use a voltmeter - this is a line voltage (240 volt) circuit.

b) If there is power across the coil, the problem is in the contacts. Replace the defrost relay.

The student is encouraged to write to individual control manufacturers for their respective service manuals describing proprietary circuits and continue developing his circuit analysis know-how.

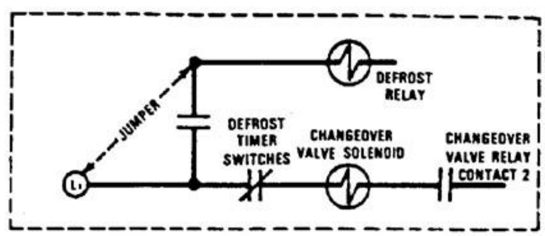


Figure 20-18: Test on poor heating complaint.

Self-Check, Lesson 20 Quiz

You should have read all the material in Lesson 20 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1 T F There is no shock hazard in air conditioning control circuits.

2. T F The first step in any electric test is to determine if the power is “on” or “off.”

3. T F A plus or minus 10 percent variation in rated voltage in all power services is acceptable.

4. T F Ammeters are always connected in series with the load and voltmeters are always connected in parallel (across) the load when taking meter readings.

5. T F A test light can be placed in series or parallel with a load.

In the following multiple-choice questions, choose the phrase that most correctly completes the statement and circle the corresponding letter in front of the phrase.

6. A changeover relay is used to:

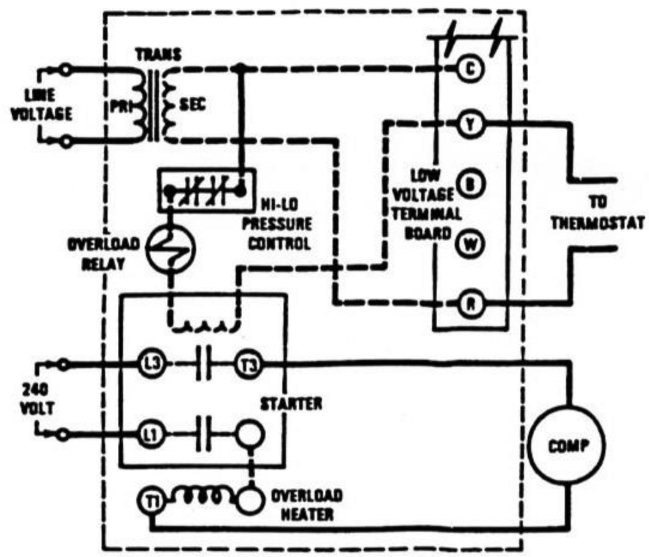
a. switch from summer cooling to winter heating.
b. switch solenoid valve and refrigerant flow in heat pump.
c. start a heat pump on the cooling cycle.
d. protect the compressor between cycles.

7. A reversing relay is used in some circuits:

a. to reverse solenoid valve and refrigerant flow in the heat pump.
b. so that a SPST thermostat can control both heat and cool equipment.
c. to prevent compressor from running backwards.
d. to keep starting contactor from opening on low power.

8. An impedance or lockout relay coil:

a. is connected in parallel with the contactor.
b. is connected in series with the fan contactor.
c. impedes the start of a fan.
d. delays the start of a compressor.



9. Refer to cooling circuit in Figure A above. On a no cooling complaint, you begin your test by jumpering R to Y and compressor starts. The trouble has to be in the:

a. overload relay.
b. contactor coil.
c. thermostat or wiring to thermostat.
d. hi/low pressure cutout.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

10. Line voltage circuits and components should be checked with a/an ____________________.

11. ________________________ should not be used indiscriminately.

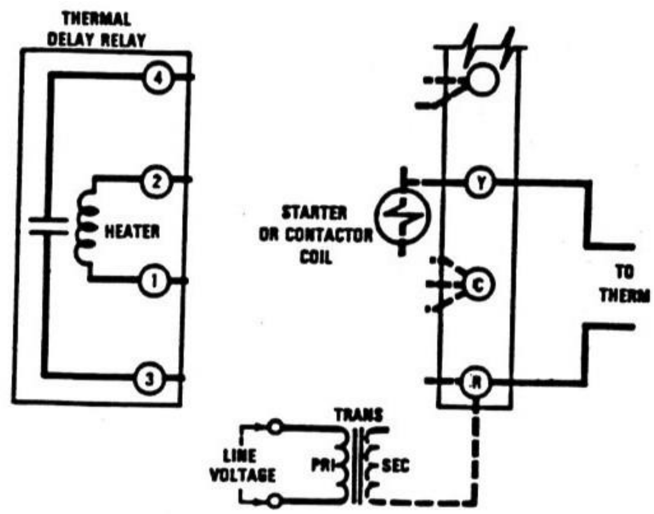
12. In setting the thermostat for system checkout, the SYSTEM switch should be __________, the FAN switch placed in the ____________ position, the COOL temperature adjustment turned ______________________ and the HEAT temperature adjustment turned ___________________.

13. 208/240 volt transformers have three lead wires on the primary side. For 230 or 240 volt operation, the _____________ and ___________ leads should be connected to the line

voltage terminals. For 208 volt operation the ___________ and _____________ leads should be connected.

14. Wiring diagrams always show switches in the _______________ condition.

15. If a voltmeter reading indicates no power at the equipment, check the __________ and wiring _______________ for an open circuit.



16. Figure B above shows the components in a thermal delay circuit. Show how components are electrically connected by drawing the 24 volt wiring.

17. In Figure C above, sketch how you would connect a test light to the relay to check for power through the coil.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

YOU ARE NOW READY TO TAKE

YOUR ONLINE UNIT

EXAMINATION, EXAM #3.

GOOD LUCK!

Self-Check Lesson 13

1. T
2. T
3. F
4. F
5. F
6. F
7. T
8. T
9. F
10. F
11. a
12. a
13. c
14. d
15. a
16. b
17. a
18. a
19. high pressure/intermediate/service/appliance
20. poppet/conical/double seated
21. seal
22. inlet/drop
23. ball/ring
24. valve/bell
25. A cock/manual on-off gas valve/B cock/manual pilot gas valve/pilot burrier/pressure regulator/safety shutoff/orifice and venturi/pilot generator/main line gas valve

Self-Check Lesson 14

1. F
2. T
3. T
4. F
5. T
6. F
7. T
8. F
9. T
10. F
11. c
12. e
13. a
14. b
15. a
16. c
17. d
18. b
19. a
20. b
21. a
22. valve/relay
23. filter/clogging
24. one
25. main gas
26. single/pilot generator

Self-Check Lesson 15

1. T
2. F
3. T
4. T
5. F
6. T
7. T
8. T
9. T
10. F
11. a
12. a
13. b
14. c
15. d
16. b
17. a
18. d
19. d
20. c
21. 0.60/7
22. orifice/ball check
23. manual/regulator/orifices
24. pressure variation
25. seal cap/increase/decrease

Self-Check Lesson 16

1. T
2. F
3. T
4. T
5. F
6. T
7. T
8. T
9. T
10. T
11. d
12. d
13. d
14. b
15. a
16. c
17. b
18. d
19. b
20. b
21. a. Check if pilot flame is high enough
b. Check millivolt output of thermocouple
c. Check that thermocouple connection is tight
22. direct acting/pressure differential
23. male
24. a. manual shutoff
b. safety shutoff
c. pressure regulation
d. on/off control
25. a. Remove plug in manifold pipe
b. connect manometer
c. remove cap seal
d. adjust set screw

Self-Check Lesson 17

1. F
2. F
3. T
4. T
5. T
6. F
7. F
8. F
9. T
10. T
11. a
12. d
13. a
14. a
15. d
16. a
17. c
18. a
19. a
20. b
21. c
22. a. start and stop burner at thermostat command
b. initiate burner ignition
c. shut down burner in case of ignition or flame failure
d. detect burner or component malfunction
23. a. transformer
b. relay
c. safety switch
d. ignition switch
24. thermal/sensing/draft
25. slip friction
26. three/five
27. flame/ignition

Self-Check Lesson 18

1. F
2. T
3. T
4. T
5. F
6. T
7. F
8. T
9. F
10. T
11. a
12. a
13. a
14. b
15. c
16. b
17. d
18. c
19. a
20. a
21. b
22. closed/energized/opens
23. hermetically/cannot
24. silicon controlled rectifier
25. SCR/trigger diode/variable resistor
26. a. soot on sensors

b. special and expensive sensor materials
c. wide variations normally occur in stack temperature
d. installation of sensor critical
e. expensive to replace
f. slow speed of response

Self-Check Lesson 19

1. T
2. F
3. F
4. F
5. T
6. T
7. T
8. F
9. F
10. T
11. c
12. d
13. c
14. c
15. c
16. c
17. b
18. c
19. a
20. c
21. current/temperature
22. motor starter
23. across the line/reduced voltage
24. series/relay coil
25. a. disconnect

b. protect branch circuit

c. protect compressor

d. stop and start compressor

Self-Check Lesson 20

1. F
2. T
3. F
4. T
5. T
6. b
7. b
8. b
9. c
10. voltmeter
11. jumpers
12. off/auto/as high as possible/well below room temperature
13. black/yellow/black/red
14. de-energized/no power
15. fuse box/connections
16. See Fig. 20-13
17. See Fig. 20-4

Appendix B: Glossary

AMBIENT TEMPERATURE: The Temperature surrounding or in the vicinity of a control.

ANTICIPATOR: Small resistance heater placed inside thermostat housing to help thermostat lead or “anticipate” room heating and cooling needs by artificially warming thermostat’s sensing elements.

AUTOMATIC PILOT: Refers to the system that provides ignition and safety shutoff for gas burners using a tiny “pilot” flame.

BIMETAL: Sensing element made of two metals with different coefficients of expansion rigidly joined together to cause useful mechanical motion due to heating or cooling of the bimetal.

CdS CELL: Acronym for photo resistance cell made of Cadmium Sulfide. This solid state device changes its electrical resistance when exposed to light. Use: Oil burner safety shutdown.

CHANGEOVER RELAY: Control element is used in heat pump systems to activate refrigerant reversing valve for heating or cooling operation. Not to be confused with reversing relay.

COMBINATION FURNACE CONTROLS: A common controller that combines the functions of the fan switch and high limit safety control into one device.

COMPENSATED CONTROL: The set point of a controller is adjusted up or down as conditions elsewhere change (e.g., set point of room thermostat is raised as outdoor temperature decreases).

CONTACTOR: A magnetic relay of suitable high capacity that can switch large motorcompressor electrical loads.

CONTACTS: The switch side of a relay or contactor.

CONTROL AGENT: The medium regulated by a controlled device. It may be air or gas flow, steam or water, or even electric current.

CONTROLLED DEVICE: A device in a control system that responds to the signals sent by a controller to start and stop or otherwise vary the operation of conditioning equipment (e.g., a gas valve that starts or stops fuel input).

CONTROLLED VARIABLE: The variable condition, temperature, humidity, or pressure that must be held constant.

CONTROLLER: Principal device, say a thermostat, in a control system that measures some variable condition that must be held constant (e.g., room air), and then activates a second device to regulate a medium (e.g., fuel) that affects the variable condition.

CONTROL POINT: The pressure, temperature or humidity actually being maintained as distinguished from the controller's set point which may be higher or lower.

CSR: Acronym for capacitor start, capacitor run indication motor.

DIODE: An electronic device (vacuum tube or solid state) that conducts electricity in only one direction. One use is to convert ac to dc current.

DROOP: The difference between a controller's set point and the actual control point (e.g., room thermostat set at 75° F, but room air stays at 73° F). Also called drift, deviation or offset.

FACTORY WIRING: Control circuit diagrams presented in functional arrangement using symbols and other shorthand notation.

FAN SWITCH: A controller that features a switch and sensing element inserted in a furnace that turns blower on or off at present leaving air temperatures.

FIELD WIRING: Control circuit diagrams presented in a pictorial or "as installed" fashion.

FINAL CONTROL ELEMENT: Last component in control chain. That portion of the controlled device that regulates control agent—valve, damper, etc.

HIGH LIMIT CONTROL: A controller that features normally closed switch and sensing element inserted in a furnace (or boiler) that shuts down burner (or electric heater) regardless of room thermostat demand when circulating air (or water) exceeds present limits.

HUMIDISTAT: A controller designed to sense changes in moisture levels in air. Uses nylon or hair sensor to open and close low voltage switch.

IMPEDANCE RELAY: Prevents compressor startup after a high or low refrigerant pressure shutdown, until a manual reset is performed. Sometimes called a lockout relay.

INHERENT PROTECTOR: A temperature and current sensitive device placed in a hermetic compressor to provide motor overload protection.

LINE VOLTAGE: Full voltage available for use. Usually 110 or 220 volts.

LOW LIMIT CONTROL: A controller that features a switch and sensing element used in heating boilers that also provide domestic use by activating burner regardless of heating thermostat demand.

LOW VOLTATE: Voltage that is 30 volts or less. Usually provided by means of a step-down transformer.

MODULATING CONTROL: Differs from simple on-off or two position control action in that control agent can be regulated from fully on down to fully off in continuous or discreet steps.

MOTOR STARTER: A magnetic contactor that also contains a current overload relay to protect motor.

NEC: Acronym for National Electrical Code published by the National Fire Protection Association.

NEMA: Acronym for National Electrical Manufacturers Association.

OPERATING DIFFERENTIAL: The overall swing (high point minus low point) of a controlled variable that's necessary to activate a controller.

OPERATOR: One of two functional components in a controlled device. The operator converts signal from controller into a useful local action (e.g., motor that converts electric signal into rotating mechanical motion). See also final control element.

PHOTOCELL: A special vacuum tube that generates small electric current when exposed to light.

PILOT GENERATOR: Refers to pilot burner/thermocouple side of automatic gas pilot system, and is usually applied to systems using other than just a single couple.

PF: Acronym for power factor, the correction factor to be applied to the product of volts times amps in ac circuits to account for voltage and current phase differences.

POTENTIAL RELAY: Sometimes called starting or voltage relay. This device cuts out starting circuit in CSR motor driven compressors.

PRIMARY CONTROL: Used most often in reference to an oil burner controller whose functions include starting and stopping burner, ignition, and safety shutdown.

PSC: Acronym for permanent split capacitor motor.

RELAY: An electric switch that permits low voltage controllers to operate equipment powered by high voltages.

REVERSING RELAY: Permits SPDT thermostat to control heating and cooling equipment by forming an interlock that prevents mutual operation.

SAFETY DEVICE: A control that is added to detect a dangerous condition and stop an action or take a new action to remedy problem.

SCR: Acronym for Silicon Controlled Rectifier. It is, in effect, a solid state or electronic switch with no moving parts that can turn current on and off.

SENSING ELEMENT: One of two recognizable components in a controller. Sensing element measures any change in the controlled variable. See also transducer.

SET POINT: The value of the controlled variable (e.g., room air) at which the controller (e.g., thermostat) is set and represents the desired or idealized value to be maintained.

SOLENOID: An electric device for converting electric energy into a mechanical displacement. Usually consists of a magnetic coil and plunger that can move short back and forth distances as the coil is energized or de-energized.

SOLID STATE DEVICE: A group of electronic components that perform jobs similar to vacuum tubes, but unlike tubes they are not electrodes enclosed in glass but rather specifically prepared solid matter.

SWITCHING ACTION: The term pole and throw in combination with the terms single and double are used to describe the action or electric switches. A single-pole switch has functionally one movable "blade" contact. A double=pole switch has two. A single-throw switch can connect to only one circuit or one fixed contact. A double-throw switch can connect a common lead to either of two circuits or two different fixed contacts. These features are usually abbreviated SPST—single-pole, single-throw; SPDT—single-pole, double-throw, etc.

THERMAL DELAY RELAY: Prevents short cycling of compressor by delaying thermostat's call for cooling for several seconds.

THERMISTOR: A solid state sensing device whose electrical resistance varies dramatically with changes in temperature.

THERMOCOUPLE: A means to directly convert heat into small amounts of useful electric current. One end of two dissimilar wires connected together is heated, producing a small voltage across the other ends.

THERMOSTAT: Once a trade name, it has become a standard term for a temperature controller, but particularly in reference to a room air temperature sensing device.

TIMER MOTOR: Electric motor drives a cam that actuates defrost switch at specific time intervals to begin defrosting of outdoor coil when heat pump is on heating cycle.

TRADE NAMES: Because of pioneering development, or merely common usage, some control devices are referred to by their manufacturer's marketing names. The new control technician should not let this become confusing.

TRANSDUCER: Current amplifying solid state device that's equivalent to a triode vacuum tube.

TRANSFORMER: An electrical device that efficiently converts high voltage power to low voltage power (or vice versa).

TWO POSITION CONTROL: A mode of control action that can only turn equipment fully on or fully off.

Wiring Symbols and Abbreviations

Schematic or factory type wiring diagrams are used most often to illustrate electrical component functions. It is essential that the student become thoroughly familiar with the standard symbols and circuit abbreviations used in the heating and air conditioning industry.

Line Voltage Terminals	**Function**
L1, L2, L3	Incoming power connections
T1, T2, T3	Switched power load connections
(4) (5) (6)	Auxiliary switched load connections

Load Designations	**Component**
CC	Contactor Coil
CC1, CC2, CC3	Contactor Contacts

FR	Fan Relay Coil
FR1, FR2, FR3	Fan Relay Contacts
SR	Solenoid Relay or Reversing Valve
SR1, SR2	Solenoid Relay Contacts
TD	Time Delay Device
TD1, TD2	Time Delay Contacts

Low Voltage Terminal Designations

Two distinct systems of low voltage terminal designations have been used in the heating and air conditioning industry. One was based on the function of the specific load to which the terminal was connected—“F” for fan circuit, “C” for cooling circuit, etc. The other system was based on a color code. In this system, “G” was used for the fan circuit, “Y” for the cooling circuit, “W” for the heating circuit, and “R” for the power supply. Using color-coded cable—green for the fan circuit, yellow for the cooling circuit, etc.—simplified system hookup and troubleshooting.

The existence of both systems caused some confusion; and for a period of time, a combination terminal marking system was used. In the combination system, terminal designations for a fan circuit were marked “F/G” and terminals for a cooling circuit were marked “C/Y.” At the present time, only the color code method is used for low voltage terminal designations.

Low Voltage Code

Color **Function**

R V Hot switched leg of 24 volt ac power used on heating only thermostats and heat/cool thermostats with a common power supply
W H Heating single stage
Y C Cooling—single stage
G F Fan circuit
B Z Heating circuit—constant energization through a manual switch
O D Cooling circuit—constant energization through a manual switch
RH M Isolated power terminal for heating circuit used on heat/cool thermostats with isolated circuits—jumper supplied
RC V Isolated power terminal for a cooling circuit used on heat/cool thermostats with isolated circuits—jumper supplied
W1 H1 Heating—first stage of two-stage units
W2 H2 Heating—second stage of two-stage units
Y1 C1 Cooling—first stage of two-stage units
Y2 C2 Cooling—Second stage of two-stage units
X L Warning light (dirty filter, electric