CONTROLS FOR OIL-FIRED HEATING
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CONTROLS FOR OIL-FIRED HEATING

Heating and air conditioning controls are often the most complicated part of a residential heating and cooling system. Some of this complexity comes from the added sophistication needed to incorporate energy conservation features into the equipment. Other increases in control complexity are related to the introduction of new equipment. Your customers are being faced with new control systems all the time and you are one of the people they look to for information on applications and component replacements.

Your job is also complicated by the fact that there are literally thousands of controls that you are expected to know something about. You can be more effective in your job if you can make authoritative recommendations to your customers regarding the replacement controls they need to do their jobs.

This book has been researched and written especially for you. It presents the major families of oil controls used in our industry and gives information on their applications.

Use this book as a reference during your Honeywell Control Pro® training program, and as a continuing resource on your job from now on.
FUEL OIL AND OIL BURNING EQUIPMENT

Fuel Oil Characteristics
Fuel oil is graded based on its physical characteristics. Grades 1 and 2, the lighter grades, are most frequently used for residential applications. Grades 4, 5 and 6 are heavier and are normally used in commercial and industrial burners.

Oil grade is determined by measuring certain physical characteristics of the oil. The most important of these measurements include weight, viscosity, and flash and fire points. The distillation range, water and sediment content, and pour point are also usually measured.

Fuel oil weight can be defined using various scales, but the most common is American Petroleum Institute (API) gravity. API gravities range from 0 to 99 degrees. Lighter grades of fuel oil have higher API gravities. An API gravity of 20 degrees, for example, is equivalent to about 7.77 pounds per gallon of oil; 40 degrees API is equivalent to about 6.87 pounds per gallon.

As the API number increases, the Btu content decreases, so lighter grades of fuel have lower Btu content than heavier grades.

The chart below lists differences in Btu content of the various grades of fuel oil.

<table>
<thead>
<tr>
<th>Fuel Oil Grade</th>
<th>Btu Per Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1 Distillate Oil</td>
<td>137,400</td>
</tr>
<tr>
<td>No. 2 Distillate Oil</td>
<td>139,600</td>
</tr>
<tr>
<td>No. 4 Fuel Oil</td>
<td>145,100</td>
</tr>
<tr>
<td>No. 5 Residual Oil</td>
<td>148,800</td>
</tr>
<tr>
<td>No. 6 Residual Oil</td>
<td>152,400</td>
</tr>
</tbody>
</table>

Viscosity is determined by measuring the amount of time required for a sample of oil to flow naturally through a capillary restriction. The heavier the oil, the longer it takes (and the higher the viscosity). The heavier oils are too viscous to atomize properly at room temperature. Because viscosity can be reduced by raising the temperature of the oil, the heavier oils are preheated before combustion.

The flash point and fire point are determined by heating the oil while exposing it to an open flame. As the oil is heated, oil vapor collects above the surface of the liquid. The oil temperature when flash combustion occurs is called the flash point. The fire point is the temperature at which the surface vapor will continue to burn for at least five seconds. These temperatures indicate the degree of fire hazard present in stored fuel oil. For example, No. 2 oil has a minimum flash point of 110°F (43°C). This means that fuel is unlikely to ignite spontaneously during storage in basement tanks, but outdoor tanks should be placed to avoid temperatures above 110°F (43°C).

The distillation range is determined only for the lighter grades of oil. This test involves heating a sample and recording the temperatures at which various percentages of the initial volume of the sample have been distilled off.

Water and sediment content are determined by whirling a sample of oil in a centrifuge. The water and sediment settle to the bottom where they can be measured. Too much water or sediment in the oil can clog the burner and interrupt the flame. Heavier grades of oil usually contain more of these impurities.

Pour point is the temperature at which the oil can no longer be poured. It is an important factor when the oil must be stored outdoors in a cold climate.

Regardless of grade, fuel oil will not burn as a liquid. It must be vaporized and mixed with air before it will burn. More volatile fuels such as gasoline vaporize readily at room temperature. They therefore ignite easily—unlike fuel oil.

The relative ease with which a fuel oil can be vaporized determines the method used to prepare it for combustion. Since the lighter fuel oils vaporize more easily than the heavier oils, they require less elaborate and expensive equipment to burn the oil. They also have colder pour points, which allow them to be stored outdoors even in cold climates. These characteristics make the lighter fuel oils the fuels of choice in residential oil-fired heating.

Oil Burner Types
Fuel oil combustion requires that the fuel oil be atomized (broken into droplets), mixed with air, and then ignited. There are two basic types of oil burners, which are classified by their methods of preparing fuel for combustion. The two types are vaporizing burners and atomizing burners.

Vaporizing burners depend on natural evaporation to provide oil vapor for combustion. These burners are usually gravity fed and have a standing pilot. They are often manually
controlled and have either a natural or forced draft. The vaporizing burner is suited to low firing rates and light oil only. The only vaporizing burner you are likely to encounter is the pot type burner used in older oil-fired space heaters.

**Atomizing burners** forcibly separate the fuel into tiny droplets and spray it into the combustion chamber. The resulting oil vapor/air is ignited with a spark. Atomizing burners are either rotary or gun burners. The gun burner is much more common. The table on page 6 lists the different types of atomizing oil burners and the appropriate application.

**Rotary burners** use the centrifugal force of a spinning cup and a forced air blower to break the oil into droplets, mix them with air, and propel the mixture into the combustion chamber. This type of burner is used primarily in larger commercial or industrial applications.

**Gun burners** are the most common in residential oil heating. The gun burner uses a fuel pump to deliver oil under pressure (up to 150 psi) to a precision-made nozzle. At the nozzle, the oil is broken into a fine, cone-shaped mist. A blower driven by the burner motor directs a turbulent airstream into the oil mist as it leaves the nozzle. The oil-air mixture sprays out under pressure and is ignited by arcing electrodes that are placed above the nozzle and slightly upstream of the oil spray. The electric arc (or spark) between the electrodes is provided by the ignition transformer. The heat from the gas causes combustion of the oil-air mixture. The illustration on page 6 shows a typical gun type oil burner. See the Ignition Requirements chapter for ignition requirement details.

**Table 2. Atomizing Burner Types and Applications.**

<table>
<thead>
<tr>
<th>Type of Atomizing Burner</th>
<th>Heating Capacity (1000 Btu/hr)</th>
<th>Oil Flow Volume (gph)</th>
<th>Fuel Grade</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>70 to 7000</td>
<td>0.5 to 50</td>
<td>No. 2 (less than 25 gph) or No. 4 (greater than 25 gph).</td>
<td>Boilers, warm-air furnaces, and heating appliances.</td>
</tr>
<tr>
<td>Return-flow pressure or modulating pressure</td>
<td>3500 and greater</td>
<td>25 and greater</td>
<td>No. 2 and heavier</td>
<td>Boilers and warm-air furnaces.</td>
</tr>
<tr>
<td>Air</td>
<td>70 to 1000</td>
<td>0.5 to 70</td>
<td>No. 2 and heavier</td>
<td>Boilers and warm-air furnaces.</td>
</tr>
<tr>
<td>Horizontal rotary cup.</td>
<td>750 to 37,000</td>
<td>5 to 300</td>
<td>No. 2 for smaller capacities and no. 4, 5 or 6 for larger capacities.</td>
<td>Boilers and large warm-air furnaces.</td>
</tr>
<tr>
<td>Steama</td>
<td>12,000 and greater</td>
<td>80 and greater</td>
<td>No. 2 and heavier</td>
<td>Boilers</td>
</tr>
<tr>
<td>Mechanicala</td>
<td>12,000 and greater</td>
<td>80 and greater</td>
<td>No. 2 and heavier</td>
<td>Boilers and industrial furnaces</td>
</tr>
<tr>
<td>Return-flow mechanical</td>
<td>45,000 to 180,000</td>
<td>300 to 12,000</td>
<td>No. 2 and heavier</td>
<td>Boilers</td>
</tr>
</tbody>
</table>

a Register type.

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**Oil-Fired Furnace Types**

The most common residential applications of oil burners are in forced warm air furnaces and hot water boilers.

**Forced warm air furnaces** use the oil burner to raise the temperature of a heat exchanger. When the heat exchanger is hot, a blower starts, pulling cold air from the controlled space and blowing it past the heat exchanger, raising the temperature of the air. The warmed air passes into distribution.
ducts and along these ducts to various rooms in the home. When the thermostat detects that the need for heat is satisfied, it shuts down the system. The system may also be shut down by a high limit that monitors the air temperature in the furnace for overheating.

**Fig. 3. Typical forced warm-air system.**

In **hot water boilers**, also called hydronic systems, the oil burner is used to heat water in a boiler. See Fig. 4. This hot water is circulated to pipes in the controlled space, typically passing through radiators or baseboard units, which distribute heat to the controlled space by convection. When the thermostat indicates that the need for heat is satisfied, it shuts down the system. The system may also be shut down by a high limit that monitors the water temperature in the circulating system for overheating.

**Oil-Fired System Operation**

The illustration (Fig. 5) shows the components of a residential oil-fired heating system. The main components include the burner motor, furnace or boiler, oil tank, stack, draft regulator, oil supply line, oil primary control and ignition system.

On a call for heat, the system goes into the start mode. The fuel pump pushes oil through the burner nozzle and into the combustion chamber in a mist. The oil mist is mixed with air and ignited. Within a set period (varying up to 90 seconds), the flame detector either proves the existence of flame and permits the system to go into run mode or shuts down the system. If the flame goes out at any time during run mode, the flame detector responds with a safety lockout (except in the R8991 and R7997, where it will recycle once before lockout). Manual reset is then required before the burner can be restarted.

**Fig. 4. Typical forced hydronic heating system.**

**Fig. 5. Oil heating system.**
IGNITION REQUIREMENTS

Several conditions are required for the oil-air mixture to ignite in an oil burner system. These conditions include the following:

- Oil-air mixture to sustain ignition.
- Energy to provide a spark between two electrodes.
- Long enough spark pulse rate.
- Fan-out of the spark to reach oil-air mixture.

Oil-Air Mixture

In order for oil to burn, there must be adequate air to support combustion. If there is too much or too little air, the oil will not burn. The range between these two extremes is called the flammable limits of the oil. This is the range in which combustion will be self-supporting. When the oil-air mixture is outside the flammable limits, the flame will go out. It is important to have the appropriate ratio of oil and air for the mixture to burn. If there is excess air, and therefore less oil, it is more difficult to light the mixture because air alone cannot light.

Energy (Heat)

For the oil-air mixture to ignite, the temperature of the oil-air mixture must be raised to its ignition temperature. The ignition temperature of fuel oil is in the range of 600 to 765°F (316 to 407°C). In an oil burner system, the energy to ignite the oil is provided by the spark.

An electric arc (or spark) in an air gap results when the electric field in the gap exceeds a value determined by the shape, material and spacing of the electrodes. When this field intensity (measured by the voltage across the electrodes) is reached, an ionized path is created between the electrodes. The voltage at which this occurs is the breakdown voltage. For a typical residential oil burner application, the breakdown voltage at the electrodes is between 8000 and 10,000 volts. Once breakdown occurs, the voltage across the gap assumes a lower value, which is the voltage required to maintain current through the gap. This is the holding voltage.

When the air surrounding the electrodes is essentially stationary, the holding voltage remains fairly constant. However, if the air is moving, the air carries the ions away from the electrodes. This has the same effect as lengthening the arc gap. The result of an increase in arc length is a gradual increase in holding voltage. Meanwhile, the area around the electrodes is purged of ions by the moving air. As long as current flows in the arc, the arc continues to fan out away from the electrodes, carrying away the heat in the ionized air.

In a conventional iron core transformer, the voltage at the electrodes oscillates between positive and negative polarity at 60 Hz. At this low frequency, the increasing holding voltage exceeds the breakdown voltage before the voltage changes polarity and the current stops flowing. When this occurs, a new arc is formed at the electrodes and the fan-out process begins again. Approximately 12 arcs are produced in each full cycle at 60 Hz.

In a high frequency ignitor such as the R8991 (32 kHz), the voltage changes polarity before the holding voltage has exceeded the breakdown voltage. Current flow stops, and the ionized air begins to dissipate until the voltage across the electrodes is high enough to reestablish the arc. This is the restrike voltage. Because the ions do not have sufficient time to dissipate, this voltage is only slightly higher than the holding voltage. The arc continues to fan out until the restrike voltage is higher than the breakdown voltage, at which time a new arc is formed at the electrodes and the fan-out process begins again.

In an oil burner system, a small portion of the oil-air mixture is raised to the ignition temperature by blowing the hot spark into the edge of a cone-shaped mist of oil-air. The heat of the oil-air ignited by this means is transferred to adjacent unburned oil-air, raising its temperature to the ignition temperature. The unburned oil-air mixture is ignited by the mixture that is burning. This process is known as flame propagation. A flame becomes self-propagating only after it reaches a certain critical size. To ignite oil, a spark must provide sufficient energy within a sufficiently short time to establish a flame of critical size before the heat in the burning oil-air mixture is dissipated to the point that it can no longer ignite the surrounding mixture. There are two aspects of providing the energy—the energy is delivered to the spark and the spark then has the ability to fan out to transfer the energy to the oil-air mixture.

The power supplied to the spark, which is the rate at which energy is expended, is the product of the voltage across the gap times the current through the gap. Neither voltage nor current alone is sufficient to provide energy. From the above discussion on spark formation, it is clear that the voltage across the gap will be similar for any ignitor because the breakdown and holding voltages are determined by the electrodes. As long as the ignitor open circuit output voltage exceeds the breakdown voltage, the ignitor will produce spark at the electrodes. Therefore, measurement of the voltage alone or current alone will not be a good indication of the ability of an ignitor to light oil.

In fact, even measurements of average power are inadequate to predict the ability of a spark to light oil. The power varies over time as the voltage and current vary. Measurements of average power do not predict ability to light oil. To light oil, a lot of energy must be delivered in a very short time. This means that an ignitor that delivers energy at a continuous rate might not light oil as well as an ignitor that delivers energy at a much higher rate for short periods of time at intervals. As long as the spark pulses deliver sufficient energy to establish the critical flame size, they will light oil as well as a continuous spark.

Conventional iron core transformers provide a continuous spark. The R8991, however, provides a continuous spark for the first five seconds of ignition, and then provides five spark pulses per second. The R8991 pulsing spark is able to light oil under adverse conditions. By pulsing the spark, the ignitor life should be extended because the components are energized for less time and do not heat up as much as components would in a continuous spark system.
Spark Fan-Out
Once there is a spark between the electrodes, it is necessary to get the spark to reach the oil-air mixture. The ability of the spark to reach the oil-air mixture depends on the fan-out of the spark and the angle of the spray from the nozzle. See the figure below. Fan-out is the distance a spark will blow downstream under the influence of combustion air flow. Fan-out is important because the electrodes are above the nozzle and outside of the oil spray. If the electrodes are placed in the oil spray, carbon deposits will build up on the electrodes and cause the spark to short out. The combustion air must blow the spark downstream into the fuel spray.

Fig. 6. Electrode location.
OIL BURNER CONTROL REQUIREMENTS

Safe, automatic control of oil-fired heating equipment depends on equipment such as a thermostat, limit and primary control. Also of vital importance is flame detection and a safety switch.

Automatic Control

The control system of a typical oil-fired heating system is composed of certain standard controls and whatever auxiliary controls are required by the specific installation.

Three basic controls must be incorporated in each system—the thermostat, the limit, and the primary control (with flame detector).

The primary control is the heart of the oil burner control system. It has three basic control functions that are summarized in Fig. 8.

3 BASIC PRIMARY CONTROL FUNCTIONS:

1. RESPOND to heating requirements initiated by the thermostat.
2. SHUT DOWN the burner on limit action.
3. SUPERVISE the starting, stopping, and running of the burner including:
   a. PROVING THE FLAME
   b. CONTROLLING THE IGNITION AND OIL VALVE
   c. SHUTTING DOWN ON MALFUNCTION IN THE SYSTEM

Fig. 8. Three basic primary control functions.

First, the primary control must respond to the heating requirements indicated by the thermostat. It must respond to calls for heat and provide heat to satisfy the requirements of the controlled space.

Second, the primary control must shut down the system on limit action. This is accomplished by wiring the limit into the primary's control circuit so that limit action immediately breaks the circuit and shuts down the system.

Third, the primary control must supervise the starting, stopping and running of the burner. This means that it must be capable of proving the presence or absence of flame, controlling the ignition transformer and shutting down the system when malfunctions occur. Examples of some malfunctions include failure to establish flame on start, flame failure during run or power failure.

Oil-fired primary control involves the following terms that describe various kinds of ignition:

Intermittent ignition—The ignitor comes on when the burner is energized and stays on as long as the main burner is firing.

Interrupted ignition—The ignitor comes on when the main burner is energized. It goes off automatically when a flame is established or after a preset time period.

Nonrecycling control—Attempts are made to restart the burner immediately on loss of flame. The ignition attempt continues until the control is locked out by the safety switch.

Recycling control—The burner shuts down immediately on loss of flame, then attempts to restart once before locking out on safety.
Auxiliary controls may be included with the primary control. For example, the R8182D Combination Oil Primary Control and Aquastat® Controller combines in the primary control high limit protection, low limit control, and circulator control. Other auxiliary controls that are available include fan controls, zone valves, air cleaner or humidifier controls, time delay controls, and additional relays.

All flames have the following characteristics:

- Production of heat.
- Expansion of gases.
- Production of combustion products.
- Emission of light (infrared to ultraviolet).
- Ionization of the atmosphere in and around the flame.

Various flame detection systems use these properties of flame to prove flame and allow oil burners to run. But only two properties of flame are important for residential oil-fired heating applications: heat and visible light.

Heat or thermal detectors respond to an increase or decrease in stack temperature through a bimetal element inserted into the stack.

Visual detectors respond to the light emitted by the oil flame through a light-responsive photocell.

The primary control uses the information transmitted to it from the detector to either shut down the burner or allow it to operate. This function is performed by a safety switch.

The safety switch consists of a small bimetal element and a separate safety switch heater. On a call for heat, current passes through the safety switch heater. The heat produced by the heater raises the temperature of the bimetal. If this heater is not turned off within a set period of time (45 seconds is common), the continued heating of the bimetal will break the system control circuit and shut down the system.

It is the job of the flame detector to shut off the safety switch heater and allow the system to run. On detecting flame, the flame detector breaks the safety switch heater circuit, giving the OK TO RUN signal to the control system. If the flame detector does not turn off the safety switch heater, the safety switch breaks the control circuit. This is called safety lockout, a condition that requires manual reset before the system can be restarted.

**Fig. 9. Oil heating system controls.**

One more component worth mentioning is the V4046 Oil Valve. Most residential oil burners do not have a separate oil valve; that function is most often incorporated into the burner unit itself. Larger burners may, however, use an oil valve such as the V4046. The V4046A has a built-in delay feature that keeps it closed almost five seconds after it is energized. This permits the pump to get up to full speed and develop its full rated pressure before the valve opens. This ensures that the oil will be properly atomized by the nozzle when the burner first lights off and that the blower has established a draft.

**Fig. 10. Safety switch.**

**Flame Detection and Safety Switch**

The primary control must prove the presence or absence of flame when the burner starts and during the run cycle. The primary control must also allow the burner to run only when flame is present and must shut it down if flame is not proved.
operate again. If the burner loses flame during a run, the flame detector closes the safety switch heater circuit, causing the heater to start heating again.

The general sequence of flame detection on start is diagrammed in Fig. 11.

Fig. 11. Proving the oil burner flame.

Fig. 12. Stack detector oil primary.

Fig. 12 shows the safety first wiring logic behind the safety switch concept. The load relay and the safety switch heater are wired in series. When the heater burns out, this circuit cannot close and the system cannot start.

Another safety problem that modern equipment has solved is the false flame indication that can result from component failure; that is, indication that there is a proved flame when there is none. Each heat cycle must begin with the burner dark (or cool for thermal detectors). If a flame detection component fails, giving a false flame signal, the system cannot start because the cool or dark condition required for a start is not present.

Safe operation of oil-fired equipment, therefore, requires reliable flame detectors that prove the presence of flame before allowing the system to change from start to run cycle. Both methods of flame detection mentioned earlier are used in oil-fired residential heating equipment.
Thermal detectors are usually mounted on the stack. A bimetal element in the detector signals the presence of flame when it is heated by hot exhaust gases. This type of detector has been typically used in stack relays.

Visual detectors use a cadmium sulfide photocell to optically sense the flame's light output. These flame detectors are typically used in cad cell primaries.

Fig. 13. Thermal flame detector location.
STACK RELAYS

A stack relay is usually mounted on the stack with the detector bimetal directly in the path of hot stack gases. (In some installations with low stack temperatures, the detector may be located directly on the front of the furnace above the combustion chamber.) The stack gases heat the bimetal, which moves a drive shaft, activating control switches.

Stack relays are no longer used in new installations. They are used for replacement of defective units. All new residential oil heating systems use cad cell primary controls.

Stack relays have some built-in limitations. They are slow-acting because of thermal lag in the bimetal. They have to be wired in the field, so they cannot be checked out completely as they are manufactured. They have to be wired to the line voltage, the thermostat circuit, and the oil burner circuit, which requires more work (and field checkouts) than for wiring a cad cell detector. Positioned in the stack as they are, the bimetal is exposed to combustion products, and requires more maintenance than the cad cell detector. Unless the burner is in perfect adjustment, combustion products can clog the unit’s mechanical parts and cause it to malfunction.

As Fig. 14 shows, the stack relay uses one set of contacts in Start mode and another in Run mode. When the cold (Start mode) contacts are closed, they close the safety switch circuit, energizing the safety switch heater. When the hot stack gases heat the bimetal, the drive shaft moves, breaking the cold contacts (and the safety switch heater circuit) and making the hot contacts that complete the run circuit.

Stack Relay Operation

Thermal flame detectors may be separate from the primary control (as in the R8189/C550D combination that is continuing to be used although now obsolete) or included with the primary as in the RA117. Whether it is included or separate, however, the very basis of the thermal relay is the Honeywell Pyrostat® Flame Detector. The parts shown above are common to all Pyrostat® Flame Detectors although some details may vary.

The bimetal element is inserted in the stack where it is exposed to rapid changes in the temperature of the stack gases. On an increase in stack temperature, the bimetal straightens, moving the drive shaft outward. This outward movement of the drive shaft is transferred to the hot and cold contacts through the clutch fingers. As the drive shaft continues to move, the cold contacts are opened and the hot contacts are closed.

The clutch fingers ride on the drive shaft and must be free to slide, although there must be enough friction so they will move the contacts. If there is too much friction because of dirt buildup, the clutch fingers will not slide freely and the contacts will not be correctly sequenced.

The RA116 and RA816 Primary Controls and the C550D Detector have only one set of contacts that acts as both hot and cold contacts. The contacts must be closed when cold.

The drive shaft moves the clutch fingers outward until the outer finger strikes the stop arm. The arm may be located either above or below the drive shaft. The stop arm stops the travel of the clutch fingers, although the drive shaft itself must continue to move outward slightly farther for proper sequencing of the contacts.

Stack Relay Location

Although stack relays are no longer placed in new installations, location guidelines are provided here to provide an understanding of the importance of placing a replaced stack in the same location as the old one.

Thermal flame detectors have only a few location considerations. The location must provide sufficient heat to move the drive shaft slightly beyond the stop arm. The maximum temperature at the detector location should not exceed 1000°F (538°C) for most thermal detectors. The detector should be located ahead of any draft regulator. If it is necessary to locate the flame detector in an elbow, the bimetal element should be inserted in the outside curve of the elbow where the hottest gases flow. Installations may be encountered where low stack temperatures make it necessary to locate the detector directly on the front of the furnace above the combustion chamber.
Stack Detector Operation

RA116

The detector contacts in the RA116 are closed when the stack is cold, and open when the stack is hot. Proof of flame is indicated by open detector contacts.

Sequence of Operation: On a call for heat, the thermostat completes a circuit between T and T. The load relay, 1K, is energized by a circuit including the thermostat, the safety switch contacts, the transformer secondary, the safety switch heater and the detector contacts. Before this circuit can work, the detector contacts must be closed, indicating a no flame condition. Also, since the safety switch heater is in the circuit, it must also be working for the burner to come on.

When 1K pulls in, the burner and ignition are energized through contact 1K1. At the same time, contact 1K2 provides an alternative current path around the safety switch heater and the detector contacts. This is called the hold-in circuit.

Now there are two circuits in operation:

- On the left, part of the transformer is powering the safety switch heater through the detector contacts and 1K2.
- On the right, the other part of the transformer is powering the coil of relay 1K through the thermostat, safety switch contacts, and 1K2.

Normal Operation: When the detector feels heat from the burner, the detector contacts open the safety switch heater circuit. The burner will continue to run until the thermostat signals that the need for heat is satisfied.
Flame Fails to Light: If the burner fails to light, the detector contacts remain closed. In 70 seconds, the safety switch trips out, opening its contacts in the thermostat circuit. The burner stops. The safety switch must be manually reset before the burner can be restarted.

Flame Fails During Run Cycle: If the flame goes out during the run cycle, the detector cools off. Its contacts will close, energizing the safety switch heater. The safety switch will trip into safety lockout in about 70 seconds. Again, manual reset is required before the burner will start.

RA117

In the RA117, the load relay is 2K and the ignition relay is 1K. This permits ignition to be interrupted after the flame is proven. The cold contacts are closed when the stack is cold and the hot contacts are closed when the stack is hot.

Sequence of Operation: On a call for heat, the thermostat completes a circuit between W and B on the control. This energizes relay 1K through the safety switch contacts, the transformer, the safety switch heater and the cold contacts. Contact 1K1 powers the ignition transformer.

Relay 2K is energized by the right part of the transformer through the safety switch contacts, contact 1K2, and the thermostat. Contact 2K1 powers the burner motor.

The safety switch heater remains energized as long as the cold contacts are closed. That circuit includes the left part of the transformer, 2K2, 1K3 and the cold contacts.

When the left part of the cold contacts open, the safety switch heater stops heating. When the right part of the cold contacts open, relay 1K1 drops out, stopping ignition. At this time, the hot contacts must be closed to keep relay 2K pulled in. Its hold-in circuit includes the thermostat, the safety switch contacts, the right part of the transformer, contact 2K2 and the hot contacts.

Failure to Light: If the burner fails to light, the cold contacts will not open. The safety switch will continue to heat until it trips and locks out.

Flame Fails During Run Cycle: If the flame fails during the run cycle, the drop in stack temperature causes the detector’s hot contacts to open and drop out relay 2K, shutting down the burner. After two to three minutes, the cold contacts close, energizing the safety switch heater. If the thermostat is still calling for heat, the burner and ignition will come back on to restart the burner. If a flame is not established within 70 seconds, the safety switch will lock out.

Replacement Stack Relays

The RA116 and RA816 are used in intermittent systems. In these models, the burner motor, ignition and oil valve are all powered by a single relay that remains pulled in throughout the normal run cycle. These models also have only one set of Pyrostat® contacts. The contacts must be closed to energize the burner motor, oil valve and ignition.

The RA116 was originally intended for use with 3-wire, series 10 thermostats. However, the RA116 can easily replace the RA816 because wiring instructions on the unit show how to hook it up in a 3-wire or a 2-wire circuit.

The RA117 replaces the RA817. Both of these units provide interrupted ignition. In addition, the RA117 can also be wired to provide intermittent ignition. As the illustration in Fig. 17 shows, the ignition is wired to terminal 4. This provides interrupted ignition. If, however, the burner requires intermittent ignition, wire the ignition transformer to terminal 3. The RA117 can be used to replace any stack relay, enabling stocking of only one unit.
CAD CELL PRIMARY CONTROLS

The cadmium sulfide photocell (cad cell) primary controls are universally applied to new oil burners.

The cad cell is now the industry standard because it offers significant technical advantages. It can be wired in the factory, which means it can be checked out in the factory rather than in the field. In fact, Honeywell cad cell controls are actually checked out on a working furnace in the factory. Cad cells respond faster to flame than stack relays because the visual detector works almost immediately. Except in the R8991, the cad cell location is determined in the factory, so that one-of-a-kind field installations are not necessary. And, because of its out-of-the-way location, the cad cell sensor does not have clogging problems.

Cad Cell Operation

The cad cell is a light-sensitive device that responds to the light produced by an oil flame. The light sensitivity is provided by a chemical called cadmium sulfide.

The cad cell detector consists of a cad cell with a holder and a cord.

Fig. 18. C554 cad cell.

The electrical resistance of cadmium sulfide changes with light intensity. In darkness, its resistance is high, and it acts like an electrical insulator. As light intensity increases, its resistance drops. When sufficient light is present, cadmium sulfide conducts electricity. This property enables it to complete a circuit when it detects the light from the burner flame.

Fig. 19. Cad cell response to light.

This illustration shows the cad cell response to light. Note that as the illumination striking the cell increases, the resistance of the cell drops. Very slight illumination produces a considerable drop in cell resistance, but enough light must reach the cell to lower its resistance to its normal operating range. This is usually 300 to 1000 ohms with a properly adjusted burner; however, it may be as high as 1600 ohms if the burner is not properly adjusted.

The cad cell responds to any light in the visible range, including both daylight and artificial light. The cell does not normally react to gas flames because most of the light emitted by the gas flames is not in the visible range. In certain cases, though not typically, the cell is applied to gas flames by having the cell view a fuel-rich portion of the flame that does not have complete combustion.

When the burner starts, a bimetal-operated safety switch in the primary starts to heat. This switch will break and shut down the burner unless the burner flame is established. If the flame is established, the cad cell’s resistance drops until the current through the cad cell actuates a sensitive relay or electronic network in the primary. The circuit to the safety switch heater is broken, so the safety switch does not trip and break the circuit, and the system runs. If the flame goes out, the cad cell’s resistance goes up, and the circuit containing the safety switch element remakes. The safety switch heater starts to heat the bimetal. The burner will go out on safety unless the burner flame is relit before the safety switch breaks the circuit.

The cad cell itself is a ceramic disk coated with a layer of cadmium sulfide and overlaid with a conductive grid. Electrodes attached to the disc transmit an electrical signal to
the primary control. The conductive grid is shaped like an “S” to fit more grid area into a smaller space. This shape gives the effect of two parallel bare wires a few inches long with cadmium sulfide between them.

In construction, the cell is evacuated and filled with clean dry air. The entire cell is then sealed with a glass-to-metal hermetic seal to prevent deterioration of the cadmium sulfide. Although glass sealing is an expensive process, experience has proven that less expensive potting seals such as plastic or epoxy allow moisture to contaminate the cadmium sulfide. This moisture eventually prevents the relay or electronic network from working properly, resulting in a safety shutdown.

If the burner is properly adjusted, the cad cell resistance will be in the range of 300 to 1000 ohms when the burner is operating. To assure continuous, reliable burner operation, the resistance of the cell should never be above 1600 ohms during the burner run cycle. If the cell’s resistance is greater than 1600 ohms, the cad cell may need cleaning or adjusting, or the burner flame may need to be adjusted. See the Oil Control Service and Troubleshooting chapter for instructions.

**Cad Cell Location and Hookup**

Fig. 21 shows the correct location of a cad cell flame detector in a gun type burner. The detector is positioned to view the flame at the end of the gun without being exposed to clogging by combustion products. The C554 cell shown is supplied in two pieces. The actual detector cell is a plug-in device that can be replaced by unplugging the old detector and plugging in the new one.

The location of cad cells is carefully designed by burner manufacturers to meet the following specifications:

- The cell should view the flame directly.
- Enough light must reach the cell for it to sense the flame. If the burner is properly adjusted, it should be under 1000 ohms.
- The cell must be protected from external light sources. The cell responds to any light source, not just the flame, so it must be protected.
- Ambient temperature should be below 140°F (60°C).
- The cell must have enough clearance so that metal surfaces near it will not affect it by movement, shielding or radiation.

Under normal circumstances, the location of the cad cell should never be changed.

Even though the cell is properly located, cell operation can be adversely affected by dirt buildup or external light interference. Dirt buildup in the burner tube can cause repeated safety lockouts if it is bad enough to block the cad cell’s view of the flame. In some applications, the cell views the flame through a hole in the static disc. This hole must be free of dirt for the cell to work properly.

The cad cell is generally not sensitive to stray ambient light. The light from an uncovered light bulb would have to be reflected almost directly onto the cell face to cause a malfunction. But intense ambient light will keep the burner from starting.

Ambient temperatures above 140°F at the cell location will harm the cell. Heat, like moisture, deteriorates cadmium sulfide. The cell is usually located in the back of the burner to protect it from high ambient temperatures. It may, however, be located farther forward in the blast tube where it can be cooled by blower air.
The C554 Flame Detector assembly consists of a two-piece socket and receptacle that can be easily mounted in the fan housing or the rear of the burner blast tube. The receptacle can be permanently mounted to the housing with screws. The receptacle is usually factory-installed by the burner manufacturer. Do not change its location unless it is apparent that the cell is not properly sighting the flame. The plug-in assembly, which contains the cell, can simply be unplugged from the receptacle for cleaning or replacement (part no. 130367).

The leadwires on the C554 are color-coded yellow to provide separate identification from other commonly used colors.

The cad cell hookup is very simple. Simply connect the leadwires to the F-F terminals on the primary control. Note that F terminals are designated S on older controls. Also, note that the cad cell leads are now yellow, while many cells in the field have blue wires. The change to yellow was made to comply with a recent NEMA standard.

The Flame Sensing Circuit

Since the cad cell can only carry very small currents, the flame sensing circuit in the primary control must be designed to operate reliably on very little power. Honeywell cad cell primaries have met this requirement two different ways: by using an spdt sensitive relay and, recently, by using an equivalent solid state circuit.

Sensitive Relay

The sensitive relay uses a set of forked contacts that provide the best possible electrical contact for the very low power levels in cad cell circuits. This method of construction provides point-to-point contact, maximum force per unit area, the smallest surface area on which dust can settle, and a sloping surface that will not hold dust. However, a dust cover over the entire relay is included as an added insurance.

Although the clear dust cover makes the contacts inaccessible, the contacts are still visible. As shown in Fig. 23, the relay is pulled in when the bottom contacts are made and is dropped out when the top contacts are made.

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Although the clear dust cover makes the contacts inaccessible, the contacts are still visible. As shown in Fig. 23, the relay is pulled in when the bottom contacts are made and is dropped out when the top contacts are made.
The bilateral switch is frequently used to trigger a triac. When only terminals 1 and 2 are used, it acts as a resistor until a certain voltage called the breakover voltage is reached. This voltage is very small (approximately 8V). When the breakover voltage is passed, the resistance of the switch collapses and current flows. When the bilateral switch is used as a 3-terminal device, current is applied to the gate terminal to change the breakover voltage.

The resistors and the capacitor in the cad cell primary are not actually solid state devices, but are used extensively in solid state circuits. A resistor simply opposes the flow of current. A capacitor in a dc circuit blocks the flow of current. In an ac current, the capacitor stores current on one half-cycle and releases it on the reverse half-cycle. Resistor 1 determines the voltage drop across the F-F terminals, and resistor 2 protects the solid state components from abnormally high voltages. The capacitor provides an extra burst of current each half-cycle to assure the triac is triggered when necessary.

The solid state flame sensing circuit is less affected by ambient light hitting the cad cell than is a comparable sensitive relay.
Sequence of Operation: Cad Cell Primary Control

Fig. 26 shows the schematic of an intermittent ignition model of a cad cell primary control (in this case the R8184G). This model is used as the example because it performs only the basic control functions and does not include additional functions such as interrupted ignition, boiler water temperature control, etc.

When the line switch is closed, the internal transformer is powered, whether or not the thermostat is calling for heat. A line voltage thermostat can be used with this control when terminals T-T on the primary are jumpered. In this case, the primary and cad cell will not be powered until the thermostat calls for heat.

The solid state flame sensing circuit is designed so that the triac will conduct current only when cad cell resistance is very high, indicating no flame. If cad cell resistance is high, the voltage across the bilateral switch exceeds the breakover voltage, causing it to conduct and trigger the triac. The capacitor provides a current pulse each half-cycle to make sure the breakover voltage is exceeded.

If the triac is in the conducting mode (cell resistance is high) on a call for heat from the thermostat, the 1K relay will be energized. Contacts 1K1 and 1K2 close and the burner motor, oil valve and ignition are energized. If the flame is established, cad cell resistance decreases, voltage across the bilateral switch drops below the breakover value, and the signal to the triac stops. The triac then stops conducting, dropping out the safety switch heater. The 1K relay remains powered through its 1K1 contact, and the burner runs.

On flame failure, cad cell resistance increases until the triac is energized. The safety switch heats until the bimetal warps enough to break the circuit and stop the burner. The primary control must be reset before the burner can be restarted.

Overview: Cad Cell vs. Stack Relay Primary Systems

Regardless of the type of detector and primary control used to supervise the burner, there are basic similarities in the general operation of the primary control. In all systems, a call for heat energizes the burner and starts the safety switch heater. If flame is established, the flame detector (either thermal or visual) acts to bypass the safety switch heater and allows the burner to run.

The steps taken by the cad cell to bypass the safety switch heater and allow the burner to run are comparable to the steps taken by the stack detector. The cad cell sighting of the flame and lowering the flame resistance is matched by the thermal detector bimetal element "feeling" the change in stack gas temperature and moving the drive shaft outward. The pull-in of the sensitive relay or electronic network is matched by the opening of the stack relay contacts.

The actions of both detectors when flame is proven have the same result—the safety switch heater circuit is broken.

Compare the parts of a thermal flame detector to the cad cell detector. The electronic network replaces the Pyrostat® contacts, and the light-sensitive cell replaces the heat-sensitive bimetal element.

The cad cell detector has certain advantages over the thermal detector. The cad cell response time is faster than the bimetal response time. On exposure to light, the cad cell resistance drops almost immediately, while the bimetal reacts slowly to a relatively slow change in stack temperature. Because of this faster response, the cell is better suited to modern installations. The cad cell is also well-suited to the package concept because it and its associated primary control can be completely installed and wired by the burner manufacturer.
Fig. 27. Basic primary control function.
CONTROLS FOR OIL-FIRED HEATING

OIL PRIMARY CONTROLS

The R8184 Oil Primaries

All R8184 controls provide intermittent ignition and solid state flame detection. The R8184 also locks out if the burner fails to light or if the flame goes out and does not relight. After lockout, it must be manually reset.

The R8184G is a primary control for intermittent ignition applications, and is available with 15, 30 or 45 second safety switch timing. R8184G models include an improved safety switch with a minus 40 to plus 130°F (minus 40 to plus 54°C) ambient temperature range (up to 150°F (66°C) on some models), a lockout alarm light with remote lockout indication available, and a lightweight, tamper-resistant cover.

The R8184M is much the same as the R8184G but has a bigger transformer and includes cooling hookups. The R8184M provides central wiring and a low voltage power source for both air conditioning and oil-fired heating.

The R8184P adds timing delays for nonsafety rated purge timing applications to the list of R8184M features. To help establish draft and reduce oil after drip-related problems, the R8184P includes a fixed 15 second valve on delay and a selectable blower off delay (up to 30 minutes on select models).

Fig. 29 below shows how the R8184P is hooked up in a typical warm air application.

---

**TYPICAL R8184P CONTROL CIRCUIT IN WARM AIR APPLICATION**

- **L1** (HOT) BLACK
- **L2** (LINE) WHITE
- LIMIT RED
- OIL VALVE ORANGE
- AIR FLOW SWITCH VIOLET
- SWITCH WHITE
- BURNER MOTOR ORANGE
- IGNITION TRANSFORMER RED
- VENTER MOTOR VIOLET
- CAD CELL
- CAD CELL
- PROTECTORELAY®
- WARM AIR CONTROL
- WARM AIR CONTROL
- COOLING TRANSFORMER
- COOLING CONTACTOR
- FAN RELAY
- FAN RELAY

**NOTE:** USE COPPER CONDUCTORS ONLY

- POWER SUPPLY. PROVIDE DISCONNECT MEANS AND OVERLOAD PROTECTION AS REQUIRED.
- IGNITION TRANSFORMER CAN BE CONNECTED TO VALVE OR BURNER MOTOR.
- OMIT ON SYSTEMS WITHOUT POWER VENTING.

---

Fig. 29. Typical R8184P control circuit in warm air application.
The R7184 Interrupted Electronic Oil Primary

All the R7184 models are line voltage, safety rated, interrupted ignition oil primary controls. They are used in residential applications that include boilers, forced air furnaces or water heaters. The primary ignites the fuel oil, senses the flame, controls the ignition spark and notifies a remote alarm circuit (select models) when lockout occurs.

Depending on the system, an Aquastat® controller (hydronic system) or a low voltage thermostat (forced air system) is used to provide the initiation and termination of the combustion sequence. Sometimes it is necessary to have a valve-on delay (no oil flow when the burner motor runs prior to combustion) or burner motor-off delay (burner motor runs after combustion) during initiation or termination of combustion. Select models of the R7184 offer these delay features, but they are only intended to help establish draft and reduce oil after-drip related problems. The delay features are not designed to meet the safety requirement as defined in UL 296.

There are four R7184 models with the R7184U being the most universal. All the models have limited recycling, pump purge cycling and interrupt function features. Limited recycling allows the R7184 three recycle trials to satisfy a call for heat or it enters lock out. The pump purge cycling is used to help with the purging of air from the oil line and filter. You press and release the reset button during certain modes and the safety switch timing is extended to 45 seconds. Finally the interrupt function is used to stop any function at any time. When you press the reset button the mode is stopped until the reset button is released.

Each R7184 model has thermostat terminals (T-T), but the R7184U also includes selectable valve-on and burner motor-off delay along with alarm contacts. For added flexibility, the valve-on and burner motor-off delay features can even be disabled in the field if desired. This model can be used in the majority of systems.

Sometimes an application doesn't warrant all the R7184U features so there are three more models to meet these system requirements. The R7184A has no delay features so it has the fewest features. The R7184B has the valve-on delay feature, but does not include the burner motor-off delay feature. Finally, the R7184P includes valve-on delay and selectable burner motor-off delay so if an application doesn't need alarm contacts this would be the model to consider.

Fig. 31 and 32 show a typical R7184 control circuit and how the R7184 is mounted.

Fig. 30. R7184 Electronic Oil Primary.

Fig. 31. Typical R7184P, U control circuit with a 24 Vac thermostat.
Fig. 32. Mounting R7184 on the junction box.

The R7184 is a microprocessor-based control with an indicator light that provides diagnostic information for lockout, recycling and patented cad cell status. The control includes a reset button that moves the control from the lockout state to the idle state. Refer to the following table for an overview of the control's operation sequence.
Table 3. R7184 Operation Sequence.

<table>
<thead>
<tr>
<th>External Action</th>
<th>R7184 Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power applied to control.</td>
<td>Internal safety check conducted. If no light or flame is detected and all internal conditions are correct, control enters Idle Mode.</td>
</tr>
</tbody>
</table>
| Thermostat or Aquastat® Control calls for heat. | 1. Shorts across T-T terminals in warm air system provides power to black/red leadwires in hydronic system.  
2. Safety period (2 seconds) internal and external check for flame or light. If flame or light is detected, control remains in idle mode.  
3. When flame or light is not present:  
   a. R7184A,U (if zero valve-on delay is selected) will apply power to the burner motor, ignitor and valve.  
   b. R7184B,P, U (if valve-on delay is selected) will apply power to the burner motor and ignitor, enter/complete valve-on delay period and then apply power to the valve.  
4. Control enters trial for ignition period.  
   a. Monitors burner for flame.  
   b. When flame is not detected:  
      (1) Enters lockout state (after lockout time of 15 or 30 seconds).  
      (2) Shuts off valve, ignitor and burner motor.  
      (3) Indicator light flashes at 1 Hz (1/2 second on, 1/2 second off).  
      (4) Depress reset button to return to power-up sequence.  
   c. When flame is detected:  
5. Control enters ignition carry-over period (continues to spark for 10 to 30 seconds).  
   a. Turns indicator light on.  
   b. If flame is lost and lockout time has not expired, R7184 returns to trial for ignition period.  
   c. If flame is lost and lockout time has expired, R7184 enters recycle mode.  
6. Carry-over time expires; ignitor turns off.  
7. Enters run mode:  
   a. Flame is monitored until call for heat ends or flame is lost. If flame is lost:  
      (1) Control enters recycle mode.  
      (2) Recycle time starts (60 seconds).  
      (3) Burner and valve are turned off.  
      (4) Indicator light flashes at 1/4 Hz (2 seconds on, 2 seconds off).  
      (5) Returns to idle state at end of recycle time.  
| Call for heat is satisfied. | 1. R7184A (if burner motor-off delay is set for zero):  
   a. Burner motor and oil valve shut off.  
   b. Indicator light turns off.  
2. R7184B,P, U (if burner motor-off delay is set for more than zero):  
   a. Oil valve shuts off.  
   b. Burner motor runs for selected burner motor-off delay.  
   c. Burner motor turns off.  
   d. Device returns to idle state.  
| Reset button pushed three times without device entering run mode. | 1. R7184 enters restricted mode.  
2. Indicator flashes at 2 Hz.  
3. Reset device by pressing and holding reset button for a minimum of 30 seconds.  

The indicator light provides lockout, recycle and cad cell information as follows:

- Flashing at 1 Hz (1/2 second on and 1/2 second off): system is locked out.
- Flashing at 1/4 Hz (2 seconds on and 2 seconds off): control is in recycle period.
- On: cad cell is sensing flame.
- Off: cad cell is not sensing flame.

When the cad cell is working properly there is a resistance of below 2500 ohms. The resistance can be checked by pressing and releasing the reset button when the control is in the run mode. The indicator light flashes between one and four times. Table 4 shows what the resistance is in relation to the number of flashes.

Table 4. Cad Cell Resistance/Indicator Flash Rate.

<table>
<thead>
<tr>
<th>Flashes</th>
<th>Cad Cell Resistance in Ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Less than 625.</td>
</tr>
<tr>
<td>2</td>
<td>Between 625 and 1250.</td>
</tr>
<tr>
<td>3</td>
<td>Between 1250 and 2500.</td>
</tr>
<tr>
<td>4</td>
<td>Between 2500 and 5000.</td>
</tr>
</tbody>
</table>
The R8182 Combination Oil Primary/ Hydronic Controller

When an oil burner is used to fire a hydronic system, the control system can be simplified by combining the functions of the oil primary with the hydronic controls. (The functions performed by the oil primary part have been described.) The hydronic control functions include high limit and low limit/circulator control, making the R8182 suitable for installations requiring domestic hot water. Because hydronic heating systems often incorporate some type of zoning, the R8182 is also designed to accommodate either multiple-valve or multiple-circulator zone equipment.

With zone valves, the end switch in each zone valve is connected to the thermostat terminals on the R8182. When the zone thermostat calls for heat, it activates the valve; the valve end switch then activates the burner and central circulator pump.

With multiple circulators, a relay such as the R845 is used for each zone to switch the circulator and the thermostat circuit of the oil primary.

Fig. 33 and 34 show how the zone thermostats are hooked into the R8182.

Remember, the zone valves control the primary through the end switches, and in multi-circulator systems, the thermostat is connected through a relay.

![Diagram](image-url)
Several models are designed to mount directly on the boiler, and other models are equipped with a five-foot armored capillary and bulb for remote installations.

A call for heat by the thermostat pulls in relays 1K and 2K to turn on the burner. The safety switch heater of the oil burner controller starts to heat. If the burner ignites within the safety switch timing, the cad cell sees the flame and the safety switch heater is bypassed. The burner operates until the call for heat ends. The circulator operates when relay 1K pulls in only if R-W in the Aquastat® controller is made.

When low limit contacts R-B are made by a drop in water temperature below setpoint, it acts as a call for heat, pulling in relay 2K to turn on the burner. The circulator cannot operate.

The relay for each zone is connected to the Aquastat® controller through terminals ZC and ZR. The R845A Relay and thermostat for each zone can energize the zone circulator only if R-W in the Aquastat® controller is made. If R-B is made, the zone thermostat energizes the burner.
Overview: Primary Oil Burner Control Function Comparison

The basic primary oil burner control function remains the same (start, detect, maintain and shutdown), the added functions are provided by adding sensors, relays or components to the basic control. The following is a matrix of past and present controls and their functions. Refer to the TRADELINE® Catalog Cross Reference, form number 70-6910, for a complete list of products.

**Fig. 35. R8182 Aquastat® Controller switching.**
CONTROLS FOR OIL-FIRED HEATING

Table 5. Matrix of Past and Present Primary Oil Burner Controls and Functions.

<table>
<thead>
<tr>
<th>Control</th>
<th>Ignition</th>
<th>Thermostat</th>
<th>Description</th>
<th>Safety Switch</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C550</td>
<td>N/A</td>
<td>N/A</td>
<td>Pyrostat® flame detector</td>
<td>N/A</td>
<td>Bimetal type flame detector</td>
</tr>
<tr>
<td>C554A</td>
<td>N/A</td>
<td>N/A</td>
<td>Cad cell assembly</td>
<td>N/A</td>
<td>Sensor for all cad cell primaries</td>
</tr>
<tr>
<td>R49A</td>
<td>Intermittent</td>
<td>Line voltage</td>
<td>Stack relay</td>
<td>~80s</td>
<td>Original one-piece stack relay</td>
</tr>
<tr>
<td>R866, R867, R868, R969</td>
<td>Low voltage, S80</td>
<td>Protectorelay®</td>
<td>Older relay for C550, C551 Pyrostats®</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA116</td>
<td>Intermittent</td>
<td>Low voltage, S10, S80</td>
<td>Stack relay</td>
<td>~70s</td>
<td></td>
</tr>
<tr>
<td>RA117</td>
<td>Interrupted(^a)</td>
<td>Low voltage, S10, S80</td>
<td>Stack relay</td>
<td>~70s</td>
<td>May be wired for interrupted or intermittent ignition</td>
</tr>
<tr>
<td>RA816</td>
<td>Intermittent</td>
<td>Low voltage, S80</td>
<td>Stack relay</td>
<td>~70s</td>
<td></td>
</tr>
<tr>
<td>RA817</td>
<td>Interrupted(^a)</td>
<td>Low voltage, S80</td>
<td>Stack relay</td>
<td>~70s</td>
<td>May be wired for interrupted or intermittent ignition</td>
</tr>
<tr>
<td>R4118</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>First generation cad cell primary</td>
<td></td>
</tr>
<tr>
<td>R4184</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>Older cad cell primary</td>
<td></td>
</tr>
<tr>
<td>R4166A</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 45</td>
<td>Older cad cell primary with water low limit</td>
<td></td>
</tr>
<tr>
<td>R4166B</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 45</td>
<td>Older cad cell primary with low and high limits</td>
<td></td>
</tr>
<tr>
<td>R7184A,B,P,U</td>
<td>Intermittent or intermittent</td>
<td>Low voltage or line voltage</td>
<td>Cad cell primary 15, 30</td>
<td>Valve-on delay and burner-off delay models available</td>
<td></td>
</tr>
<tr>
<td>R8118</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>First generation cad cell primary</td>
<td></td>
</tr>
<tr>
<td>R8119</td>
<td>Interrupted(^a)</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>First generation cad cell primary</td>
<td></td>
</tr>
<tr>
<td>R8142, R8143, R8189</td>
<td>Low voltage, S80</td>
<td>Protectorelay®</td>
<td>Older relay for C550, C551 Pyrostats®</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R8182D-J</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 45</td>
<td>High and low limit, circulator control</td>
<td></td>
</tr>
<tr>
<td>R8184G-L</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>Manual shutdown lever</td>
<td></td>
</tr>
<tr>
<td>R8184M</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>Cooling terminals, tie-points</td>
<td></td>
</tr>
<tr>
<td>R8184P</td>
<td>Intermittent</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>Cooling terminals, purge, oil delay</td>
<td></td>
</tr>
<tr>
<td>R8185E</td>
<td>Interrupted(^a)</td>
<td>Low voltage</td>
<td>Cad cell primary 45</td>
<td>Manual shutdown lever</td>
<td></td>
</tr>
<tr>
<td>R8404A</td>
<td>Interrupted(^a)</td>
<td>Low voltage</td>
<td>Cad cell primary 15, 30, 45</td>
<td>Older cad cell primary, terminals for remote alarm.</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Most interrupted ignition primaries can also be wired as intermittent ignition by wiring the ignition transformer in parallel to the burner motor.

This comparison matrix indicates the control of or sometimes the delay of an oil valve. Some burners depend on the oil pump integral to the burner motor instead of an oil valve to control the oil flow. Also in some cases it is desirable to have a separate oil valve to positively and redundantly control the flow of oil to the combustion chamber and delay the flow of oil until the burner is up-to-speed (the oil pump and draft).

There are two standard oil valve types in the industry, quick opening and the delay opening valves. The quick-opening valve (V4046A) opens as soon as it is powered. When the valve is wired in parallel with the burner motor, it opens when the burner starts. A delay opening valve (V4046B) delays powering up for a period of 3 to 8 seconds (depending on the valve). If the valve has its own delay-opening terminal, it does not open until that terminal is powered and the period of delay is determined by the oil burner primary. When the delay opening valve is wired in parallel with the burner motor, the delay allows burner oil pump and draft to get up-to-speed.

Another way to delay the oil valve is to install a draft-proving switch in series with the oil valve. The switch keeps the oil valve from opening until a draft is proven and the oil pump is up-to-speed.

When zoning is part of either a hydronic or forced air oil fired system, refer to Residential Hydronic Zone Systems and Residential Forced Air Zone Systems for complete information about the controls to use and circuitry. The following illustration shows a typical zoning installation.
Aquastat® Controller

The L7124U is an Electronic Aquastat® Controller that is designed to replace many older and current electro-mechanical (bulb and capillary) Aquastat® temperature controllers, including models of the L8124A,C and L8184A controllers, as well as models by other manufacturers.

Electronic means an electronic faster response temperature sensor wired to the controller. Electronic means that now an Aquastat® controller can meet UL Limit-rating requirements. Electronic now means more functions may be included within the control for ease of application, such as diagnostic LEDs, dial-type setpoints, and differentials. The L7124 is physically the same size as the L8124 and it has replaceable relays and a power supply fuse.
OIL CONTROL SERVICE AND TROUBLESHOOTING

To develop an analytical, systematic approach to oil system service, it is necessary to:

1. Understand the function of each part in the oil system and the relationships between the parts.
2. Separate problems into specific categories.
3. Develop a specific approach for each type of problem based on your knowledge of the whole system. Fig. 38 reviews the relationships in the control system. It may help to refer to it as you read through this chapter.

The information in this chapter is organized as a narrative, which you should read as part of your course of instruction. For additional troubleshooting information (and a handy reference chart), use the Oil Controls Service Handbook.

**Tools and Equipment**

Oil burner service requires the standard tools required by all service professionals—screwdrivers, line and low voltage test lamps, etc. In addition, you should also have a voltmeter, a supply of hard surface cards for cleaning contacts, and an ohmmeter for servicing cad cell systems.

**Basic Control Circuits**

There are five basic control circuits external to the primary control, with these exceptions—the ignition circuit is separate only on interrupted ignition controls, and the flame detector circuit may be an internal circuit (i.e., one-piece stack relays).

**Trouble Areas**

Three basic service complaints include no heat, too much heat and not enough heat. No heat calls make up a large proportion of all service calls. A no heat condition is caused by a burner not starting on a call for heat or the burner starting up but locking out on safety. Other service calls are in the category of the system either overheating or underheating the house, or other miscellaneous complaints.

**Troubleshooting Sequence**

When troubleshooting any oil burner system, first assume that the primary control and the flame detector are operating correctly. Start troubleshooting by first checking the parts of the oil burner and ignition systems that could be causing the difficulty. Next check the thermostat and the thermostat circuit. Then check the primary control and the detector as described later in this chapter and in the Oil Controls Service Handbook.

Before attempting to check the primary control, review the control operating sequence. Make sure you know the safety switch timing, recycle timing if applicable, and ignition cutoff timing if applicable. For most Honeywell controls, this information is listed in the Oil Controls Service Handbook. It may also be located on a cover insert or on separate instructions that may be mounted near the furnace.

**No Heat Complaint.** Certain obvious checks should be made before proceeding with specific troubleshooting procedures on a no heat complaint.
1. Make sure the system is powered.
   a. Check the main switch.
   b. Check the burner motor fuse.
   c. Make sure all limit switches are closed.
   d. Check the remote burner on-off switch, if provided. If the switch is off, make sure the burner is free of unburned oil or oil fumes; then turn it on.

2. Make sure the burner is getting fuel.
   a. Check the oil tank.
   b. Make sure the oil line is not clogged.
   c. Check the oil filters.
   d. Make sure any hand valves are open.

3. Make sure the thermostat is calling for heat.

After completing these checks, try to start the burner as follows:

1. Make sure the combustion chamber is free of unburned oil or oil vapor.

2. Push in and release the red safety switch button. This resets the safety switch. If a thermal detector is used, make certain the Pyrostat contacts are in step. This is necessary because the detector contacts are actuated by a friction clutch that is mounted on the drive shaft. To put the clutch and the contacts in step, remove the cover, pull the lever outward about 1/4 inch (6mm) and then slowly release the lever.

3. With the oil supply hand valve open and the thermostat calling for heat, close the line switch. The burner should start. If the system fails to operate properly, note the point at which the sequence fails. This is a starting point for specific troubleshooting procedures.

   **If the Burner Motor Did Not Start.** First check the primary control power supply and the thermostat circuit. The procedure is the same for all types of detection used.

   1. Check for power at the primary control. Check voltage at terminals 1 and 2 (or at the black and white leadwires) as shown in Fig. 40. If the line voltage is normal at terminals 1 and 2, the power supply to the primary is OK. If the voltage at 1 and 2 is zero, there is an open circuit in the power supply line. A quick continuity check with the voltmeter or test light will locate the open circuit. If a line voltage thermostat is used, it must be calling for heat when the voltage is checked. Check the line switch, overload protection and the limits.

   **Fig. 40. Checking power at the primary control.**

   2. Check the thermostat circuit. Jumper the thermostat terminals (T-T or W-B) at the primary control or switching relay. If the burner runs, the trouble is in the thermostat circuit. Some of the troubles in the thermostat that could prevent operation are (1) dirty contacts, (2) too low a setting, (3) defective anticipation heater, or (4) damaged thermostat. Check the wiring from the thermostat to the primary control or switching relay. For more complete thermostat troubleshooting, refer to the appropriate technical documents.

   **Fig. 41. Checking thermostat circuit.**
So far, the procedures for checking the primary control are the same whether flame detection is visual (optical) or thermal. However, the procedures that follow vary depending on whether visual or thermal detection is used. These procedures will be described separately.

**Visual Detection Systems**

1. Disconnect one cad cell lead. This causes the primary to “see” high resistance.
2. Reset the safety switch by pushing the red reset button. The primary control should now be in the proper starting condition.
3. Jumper the thermostat terminals to simulate a call for heat. If the burner starts, the primary is OK. The trouble is in the cad cell. If the burner does not start, either there is a loose wiring connection somewhere or the primary is bad.
4. To recheck the primary, disconnect the power, check the wiring, and tighten any loose connections. Try to start the burner again. If it still does not start, replace the primary.
5. To check the cad cell, reconnect it to the F-F terminals on the primary. Then shield it so there is no possibility that ambient light can reach the cell face. Jumper T-T to start the burner. If the burner starts, the shield must be permanently installed to keep stray light from reaching the burner and simulating a proved flame. If the burner did not start, the cad cell is shorted and should be replaced.

**For Visual Detection Systems**

1. First check the operation of the primary control. Reset the safety switch and then disconnect the cad cell leads from the primary. Connect the leads to an ohmmeter. With the cad cell leads disconnected, start the burner by placing a jumper across the T-T terminals. Before the control locks out, the F-F terminals are jumpered, preferably with a 1600 ohm resistor. If the control locks out with the terminals jumpered, it must be replaced.

   The advantage of using a 1600 ohm resistor instead of a jumper wire to jumper F-F is that the resistor will show up a flame sensing circuit when the resistance of the cell drops to 1600 ohms. That is the minimum pull-in value for dependable operation.

2. If the burner runs with the F-F terminals jumpered, the problem is in the cad cell. With the burner running, check cad cell resistance on your ohmmeter. Then check Fig. 44 below to determine the proper action.

---

**CAD CELL TROUBLESHOOTING**

<table>
<thead>
<tr>
<th>OHMMETER READING</th>
<th>CAUSE</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 OHMS.</td>
<td>SHORT CIRCUIT.</td>
<td>CHECK FOR PINCHED CAD CELL LEADWIRES.</td>
</tr>
<tr>
<td>LESS THAN 1600 OHMS BUT NOT 0.</td>
<td>CAD CELL AND APPLICATION ARE OPERATING CORRECTLY.</td>
<td>NONE</td>
</tr>
<tr>
<td>OVER 1600 OHMS BUT NOT INFINITE.</td>
<td>DIRTY OR DEFECTIVE CELL, IMPROPER SIGHTING, OR IMPROPER AIR ADJUSTMENT.</td>
<td>1. CLEAN CELL FACE AND RECHECK. 2. CHECK FLAME SIGHTING. 3. REPLACE CELL AND RECHECK. 4. ADJUST AIR BAND TO GET GOOD READING.</td>
</tr>
<tr>
<td>INFINITE RESISTANCE.</td>
<td>OPEN CIRCUIT.</td>
<td>CHECK FOR IMPROPER WIRING, LOOSE CELL IN HOLDER, OR DEFECTIVE CELL.</td>
</tr>
</tbody>
</table>

---

Fig. 42. Burner won’t start—visual detection systems.

Fig. 43. Burner won’t start—thermal detection systems.

Fig. 44. Cad cell troubleshooting.
3. If you do not have an ohmmeter, remove the cell and clean its face with a soft cloth. Then replace it and check the sight alignment. Reconnect the cell to the F-F terminals and try to start the burner. If it locks out again, the problem may be an open circuit in the socket assembly or in the cad cell wiring. If you cannot find an open circuit, replace the cad cell and try again. If the problem persists, check the flame adjustment. If necessary, replace the socket assembly.

Visual Detector Problems. Because cad cell resistance varies with exposure to light, an accurate check of cell performance requires using an ohmmeter.

Fig. 46 shows the procedure for checking the cell. Remove the cad cell leadwires from the primary controls. Start the burner, and jumper the F-F terminals before the control can lock out on safety. If the terminals are jumpered before the start is attempted, the burner cannot start. The jumper bypasses the safety switch, allowing the burner to run.
After checking the cell in light, check dark cell resistance to make sure the cell is not being affected by external light. Stop the burner and remove the F-F jumper. (If the jumper remains in place, the burner cannot be started.) The resistance of the cell in the dark should be more than 100,000 ohms.

If the flame detector circuit is open, check the seating of the cell in its receptacle. It may have vibrated loose.

Clean the cell surface with a soft cloth to remove any soot or dust that may impair its view of the flame.

To replace the plug-in part of the cell, just remove the old cell and plug the new one into the old receptacle. If you replace the cell, check its operation before assuming you have solved the problem.

**Thermal Detection Systems**

1. Step the Pyrostat® contacts.
2. Now reset the safety switch by pushing and releasing the red safety switch button. Jumper the T-T terminals to start the burner.
3. If the burner still does not start, check the detector contacts and timer contacts (if any). Jumper the contact blade supports as shown in Fig. 48, which shows RA117 and RA817 contacts. Some detectors have only one set of detector contacts. If a separate detector is used, jumper the R-B terminals on the detector. If the burner can now be started, check the contacts using a hard surface business card. Check the timer contacts as you would the cold contacts by jumpering the contact blade supports. Fig. 49 shows the timer contact supports on the RA117, which must be jumpered from behind the panel. If the relay pulls in when the timer contacts are jumpered, the contacts are dirty or defective. Clean timer contacts in the normal manner. Some of them (as on the RA117) are difficult to access.
4. If the burner still does not start, and the primary is the combination type, replace the control. If a separate detector is used, perform one additional check. Jumper R-B on the primary and attempt to start the burner. If it starts, check the wiring to the detector. If there is no fault in the wiring, replace the detector. If the burner still does not start, replace the primary.

**If the Burner Motor Starts but the System Locks Out on Safety After the Burner Motor has Started.** It is either because flame is not established or because the detector-primary control combination is not properly sensing and responding to the burner flame.

**If Flame is Not Established or if it Goes On and Off.** The problem could be faulty wiring between the primary and the ignition transformer. If servicing an interrupted ignition system, the problem could also be dirty or faulty ignition contacts. Step 1, then, is to check the wiring between the primary and the ignition transformer. Make sure the connections are clean and tight, and that there are no breaks in the wire.
Fig. 50. Checking power at terminals 2 and 4.

On interrupted ignition systems, check the ignition contacts by checking for power at terminals 2 and 4 as follows:

1. Open the line switch, and then allow time for the escape of unburned fuel in the combustion chamber. (On an ignition failure, the burner may pump a lot of fuel into the chamber. Take care to allow this fuel to escape. You may have to remove it by hand.) Allow sufficient time for any timer contacts to return to starting position (recycle timing). With the line switch open, disconnect the burner and ignition leads from terminals 3 and 4. Be sure the thermostat is calling for heat.
2. Close the line switch. Check the voltage at terminals 2 and 4. If this voltage is zero, clean the ignition relay contacts. If this does not put power at terminal 4, replace the control. If there is normal line voltage at terminals 2 and 4, check the ignition system and fuel delivery system as applicable. Possible ignition failures are caused by bad transformers, bad insulators, improper spacing or shorting.

Flame Starts but Primary Control Locks Out. Whenever the primary control locks out on safety, first make sure there is no defect in the burner system that is causing the lockout. If you find no problem in the burner or ignition systems, check the detector-primary control combination. The procedures for visual and thermal detection systems are different.

Fig. 51. Burner locks out on safety.

For Thermal Detection Systems

1. First, clean and step the detector contacts. Clean the timer contacts (if any). Reset the safety switch and try to start the burner with a jumper across the T-T terminals.
2. If the burner locks out, clean the drive shaft and the bimetal element. Restart the burner and watch the drive shaft movement. If it does not move far enough, the detector contacts will not sequence properly and the primary will lock out. If this seems to be the problem, too little heat might be reaching the bimetal. Make sure the detector is fully inserted into the stack. If necessary, relocate the detector closer to the combustion chamber.
3. If the system still does not operate properly, replace the detector. On a two-piece control, replace just the detector first, then replace the primary if necessary.

Too Much Heat Complaint. Most control defects that cause overheating are centered at the thermostat. The thermostat should be located about five feet from the floor on an inside wall where it will not be affected by drafts or dead air spots like those behind doors or in hallways. A defective or incorrectly set heat anticipator may cause too long a burner-on time or fail to accelerate the shutdown of the burner. This will result in wide swings above the temperature setting.

To make heater settings more consistent, all new Honeywell cad cell primaries and Aquastat® controllers have settings at 0.2A. Stack primaries have settings of 0.4A. Short circuits in the low voltage wiring or a thermostat stuck in the ON position will cause excessively high temperatures. Too high a setting on the limit control may also cause overshooting of the setpoint. Hydronic limits must be located where there is room for water to circulate freely around the sensing element.

To make sure the primary control is not at fault, start the burner and disconnect one thermostat lead at the primary. The burner should stop. If it does not, the primary control is defective and should be replaced.
Burner defects that cause overheating are not common. High pressure will raise the gph rate, or the gph rate may be high due to too large a nozzle being used. Other possibilities include leaks, defective oil valves, or loose nozzles.

Distribution problems are also a possible cause of overheating. The ductwork may be closed to the area where the thermostat is located. The hot water control valve (hydronic) may be stuck ON. The circulator may be stuck ON. These problems can be corrected by opening the ductwork, repairing or replacing the valve, and by checking the circulator circuits and repairing or replacing the circulator switching device.

**Not Enough Heat Complaint.** Underheating is a more common complaint than overheating, and a more serious one if the condition is excessive. If the system has been carrying a normal load but delivers too little heat on very cold days, check first for low input (low fan speed, sooted heat exchanger, etc.). If there is no obvious cause, check the entire system.

Control system defects that cause underheating are also centered at the thermostat. (The trouble is almost never in the primary control except when the cad cell is receiving intermittent external light.) The thermostat location considerations are the same as for overheating, except the house will be underheated if the thermostat is in a hot spot rather than a cold spot. A hot spot might be caused by appliances, cooking or wiring in the wall behind the thermostat. If a clock thermostat is used, it may be 12 hours out of phase. Loose wiring or dirty contacts may cause the thermostat to make only part of the time. Check the limit controller for too low a setting, which would cause the system to cycle off the high limit, or for slowness in returning to the closed position after limit action. If an Aquastat® limit is used, check it for too close a differential setting.

Distribution system defects that cause underheating will become more apparent the colder it is outdoors. A low fan speed, for example, may be OK at moderate heating loads, but in very cold weather it may cause the system to cycle off the limit. Dirty air filters can have the same effect. Extreme underheating will result if the circulator is not operating. If the problem of underheating cannot be corrected, carefully study system sizing.

Burner system defects in underheating fall into a single category—not enough fuel is being burned. The problem may be in the nozzle or fuel lines. Or there may be inadequate pressure. Follow the burner manufacturer instructions to troubleshoot burner problems.

**Thermal Detector Problems.** The next illustration shows the actual contact locations on the RA117 and the RA817. The Pyrostat® detector failure to properly sense flame may be caused by any of the following:

- Impaired clutch operation. Carefully observe the Pyrostat® detector in operation as the burner operates. If the detector contacts are bad, they will appear to make and break properly. If the bimetal is poorly located or the clutch is not working properly, the contacts will not make or break in proper sequence.

Not Enough Heat Complaint. Underheating is a more common complaint than overheating, and a more serious one if the condition is excessive. If the system has been carrying a normal load but delivers too little heat on very cold days, check first for low input (low fan speed, sooted heat exchanger, etc.). If there is no obvious cause, check the entire system.

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Burner system defects in underheating fall into a single category—not enough fuel is being burned. The problem may be in the nozzle or fuel lines. Or there may be inadequate pressure. Follow the burner manufacturer instructions to troubleshoot burner problems.

**Thermal Detector Problems.** The next illustration shows the actual contact locations on the RA117 and the RA817. The Pyrostat® detector failure to properly sense flame may be caused by any of the following:

- Bad contacts (dirty or burned).
- Not enough heat reaching the bimetal.

If the contacts make but do not conduct, check the condition of the contacts. Badly burned or pitted contacts require replacement of the unit. Clean dirty contacts with a hard surface card such as a business card. Apply gentle pressure to the contacts as you clean them. Never use abrasives such as sandpaper for cleaning contacts.

If the contacts do not make, first reset them. By carefully observing their performance, you should be able to determine whether or not the bimetal is moving far enough to move the contacts, or whether the clutch fingers are binding on the drive shaft. If the drive shaft does not move enough, the bimetal is not getting enough heat. On a newer installation, this might indicate a badly located detector. On an older installation that has been working OK, this probably means that the bimetal has too much soot on it.

If the clutch fingers are binding, it is probably caused by dirt on the shaft. Pulling the drive shaft lever several times may correct the problem. If that does not correct the problem, you may have to clean the drive shaft.

**R7184 Troubleshooting Sequence**

The R7184 uses an indicator light to show lockout, recycle and cad cell resistance. Review the following table for a complete troubleshooting description.
**Table 8. R7184 Troubleshooting sequence.**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Status</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condition: Burner does not start when there is a call for heat.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Check that limit switches are closed and contacts are clean.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2. Check for line voltage power at the oil primary control. Voltage should be 120 Vac.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>3. Check indicator light with burner off, no call for heat (no flame).</td>
<td>Indicator light is on.</td>
<td>Cad cell or controller is defective, sees external light or connections are shorted. Go to step 4.</td>
</tr>
<tr>
<td></td>
<td>Indicator light is off.</td>
<td>Go to step 5.</td>
</tr>
<tr>
<td></td>
<td>Indicator light stays on.</td>
<td>• Replace cad cell with new cad cell and recheck.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If indicator light does not turn off, cut leadwires near cad cell bracket and recheck.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If indicator light turns off, replace cad cell bracket assembly. Refer to TRADELINE® catalog for bracket part number.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If indicator light does not turn off, then replace controller.</td>
</tr>
<tr>
<td>5. Jumper thermostat (T to T) terminals on R7184.</td>
<td>Burner starts.</td>
<td>Trouble is in thermostat circuit. Check thermostat wiring connections.</td>
</tr>
<tr>
<td></td>
<td>Burner does not start.</td>
<td>• Disconnect line voltage power and open line switch.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Check all wiring connections.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tighten any loose connections and recheck.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• If burner does not start, replace R7184.</td>
</tr>
<tr>
<td><strong>IMPORTANT:</strong> First, remove one thermostat lead.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condition: Burner starts then locks out on safety with indicator light flashing at 2 Hz rate (1/4 second on, 1/4 second off).</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indicator light continues to flash at 2 Hz.</td>
<td>Replace R7184.</td>
</tr>
<tr>
<td>7. Listen for spark after burn turns on (after a 2-second delay.</td>
<td>Ignition is off.</td>
<td>Replace R7184.</td>
</tr>
<tr>
<td></td>
<td>Ignition is on.</td>
<td>Go to step 8.</td>
</tr>
<tr>
<td></td>
<td>Ignition is on, but no oil is being sprayed into combustion chamber.</td>
<td>Wait for purge to complete (R7184P). Check oil valve, oil valve wiring, pump and oil supply.</td>
</tr>
<tr>
<td>8. Check indicator light after flame is established, but before oil primary control locks out.</td>
<td>Indicator light is on until the control locks out and starts flashing during lockout.</td>
<td>Replace R7184.</td>
</tr>
<tr>
<td></td>
<td>Indicator light stays off.</td>
<td>Indicator light does not turn on. Go to step 9.</td>
</tr>
</tbody>
</table>
Table 8. R7184 Troubleshooting sequence. (Continued)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Status</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Disconnect line voltage power and open line switch.</td>
<td>Burner keeps running.</td>
<td>Check all wiring connections; cad cell is okay. Replace R7184.</td>
</tr>
<tr>
<td>• Unplug cad cell and clean cad cell face with soft cloth. Check sighting for clear view of flame. Replace cad cell in socket.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reconnect line voltage power and close line switch. Start burner.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Disconnect line voltage power and open line switch.</td>
<td>Indicator light is off.</td>
<td>Go to step 11.</td>
</tr>
<tr>
<td>• Remove existing cad cell and replace with new cad cell.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Disconnect all wires from thermostat terminals to be sure there is no call for heat.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reconnect line voltage power and close line switch.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Expose new cad cell to bright light such as a flashlight.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Check cad cell bracket assembly.</td>
<td>Indicator light is off.</td>
<td>Replace cad cell bracket assembly. Refer to TRADELINE® catalog for bracket part number.</td>
</tr>
<tr>
<td>• Disconnect line voltage power and open line switch.</td>
<td>Indicator light is on.</td>
<td>Replace R7184.</td>
</tr>
<tr>
<td>• Cut leadwires near cad cell bracket and leave control leadwires open.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Apply power to device.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9. L7124 Troubleshooting Sequence.

<table>
<thead>
<tr>
<th>Action</th>
<th>Normal System Response</th>
<th>Fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermostat calls for heat.</td>
<td>Circulator starts if water temperature is above low limit setting.</td>
<td>If not, check wiring, check power.</td>
</tr>
<tr>
<td></td>
<td>Burner starts if water temperature is below high limit setting.</td>
<td>If not, check B1 and B2 output. Check if control is in Error Condition (open sensor, bad control).</td>
</tr>
<tr>
<td>Circulator continues to run without call.</td>
<td>Circulator should stop if no call under normal conditions.</td>
<td>If control is in High Limit, or in Error Condition, circulator will continue to run until limit or error condition is rectified.</td>
</tr>
</tbody>
</table>
GLOSSARY

API (American Petroleum Institute) gravity. A scale from 0 to 99 degrees used to measure the weight of oil. A higher API gravity represents a lighter grade of fuel oil and a lower Btu content.

Atomizing burners. Oil burners that forcibly separate the fuel into tiny droplets and spray it into the combustion chamber. The resulting oil vapor/air is ignited with a spark.

Auxiliary controls. Controls included in a system other than the thermostat, limit and oil primary control. May include fan controls, zone valves, air cleaner or humidifier controls, time delay controls, additional relays, etc.

Bilateral switch. One of two solid state switches in a solid state circuit. Frequently used to trigger a triac.

Blower-off delay. The burner motor runs after the combustion which helps to reduce oil after-drip related problems.

Boiler. The component of an oil-fired hydronic system where the water is heated.

Breakdown voltage. The voltage at which an ionized path is created between the electrodes, resulting in a spark that ignites the oil.

Bilateral switch. One of two solid state switches in a solid state circuit. Frequently used to trigger a triac.

Breakover voltage. A small voltage that needs to be passed, resulting in the resistance of a bilateral switch collapsing, and the current flowing.

Cad cell. Abbreviation for cadmium sulfide cell. A photocell of cadmium sulfide used in a cad cell detector or primary.

Cad cell detector. A type of visual detector consisting of a cad cell with a holder and cord (i.e., C554).

Cad cell primary. An oil primary control that uses a cadmium sulfide photocell (cad cell) to optically sense the flame light output (i.e., R8184).

Cadmium sulfide. The compound used in a cadmium sulfide photocell (cad cell) to optically sense the flame light output.

Capacitor. A component that, in a dc circuit, blocks the flow of current. In an ac current, it stores current on one half-cycle and releases it on the reverse half-cycle.

Circulator control. This device prevents the circulator pump from coming on when the burner is operating in response to the low limit.

Combination oil primary control and Aquastat® controller. A single device that provides high limit and low limit/circulator control for oil-fired hydronic heating systems (i.e., Honeywell R8182).

Distillation range. Determined only for lighter grades of oil. Involves heating a sample and recording the temperatures at which various percentages of the initial volume of the sample have been distilled off.

Electronic ignitor. A microprocessor-based (as opposed to an electromechanical-based) ignitor (i.e., R8991).

False flame indication. The indication of a proved flame when there is none.

Fire point. Of oil, the temperature at which the surface vapor will continue to burn for at least five seconds following the flash point.

Flame detection. The process of proving a flame, allowing the oil burner to run.

Flame propagation. A process by which the unburned oil-air mixture is ignited by the oil-air mixture that is burning.

Flammable limits. Of oil, the range of air in which combustion will be self-supporting. If too much or too little air, the oil will not burn.

Flash point. Of oil, determined by heating the oil while exposing it to an open flame. It is the temperature at which flash combustion occurs.

Glass-to-metal hermetic seal. The type of seal used on Honeywell cad cells to protect the cadmium sulfide from deterioration due to humidity. The cell is filled with clean, dry air and sealed.

Grades. Of fuel oil, determined by measuring the physical characteristics of oil. Grades 1 and 2 are lighter; grades 4, 5, 6 are heavier.

Gun burner. A type of atomizing burner that uses a fuel pump to deliver oil under pressure to a precision-made nozzle.

Heat detector. See thermal detector.

Hold-in circuit. An alternative current path around the safety switch heater and the detector contacts.

Holding voltage. Following breakdown voltage, the voltage required to maintain current.

Hydronic system. A heating system that works using the circulation of hot water through pipes.

Ignition circuit. One of the basic control circuits on interrupted ignition controls only.

Ignition temperature. The temperature at which the oil-air mixture will ignite.

Ignition transformer. A component in an oil system that is most often controlled by the flame detector.

Indicator light. A light included in the R8991 that provides lockout and cad cell indication.

Intermittent ignition. The ignitor comes on when the burner is energized and stays on as long as the main burner is firing.

Interrupted ignition. The ignitor comes on when the main burner is energized. It goes off automatically when a flame is established or after a preset period of time.
**NEMA standards.** Specifications adopted as standards by the National Electrical Manufacturers Association, an organization of manufacturers of electrical products.

**Nonrecycling control.** Attempts are made to restart the burner immediately on loss of flame. The ignition attempt continues until the control is locked out by the safety switch.

**Oil-air mixture.** In a gun-type atomizing burner, oil is delivered under pressure to a nozzle, where it is broken into a fine mist. A blower driven by the burner motor directs an airstream into the oil mist as it leaves the nozzle, creating an oil-air mixture.

**Oil primary control.** In an oil-burning system, supervises the operation of the burner under the control of the thermostat and the high limit.

**Oil tank.** One of the major components of an oil-fired system; the place where the oil is stored.

**Oil valve.** A component in an oil system that controls the flow of oil from the oil tank to the pump. It is most often controlled by the room thermostat.

**Optical detector.** See visual detector.

**Photocell.** Abbreviation for photoelectric cell. A cell that has electrical properties that are affected by light.

**Pot type burner.** The most commonly seen type of vaporizing burner; used mostly in older oil-fired space heaters. Also see vaporizing burners.

**Pour point.** Of oil, the temperature at which the oil can no longer be poured.

**Proving flame.** The process of the flame detector proving the existence or absence of flame, which would either permit the system to run or shut down.

**Pyrostat contacts.** Contacts on stack relays that must be closed to energize the burner motor, oil valve and ignition.

**Recycling control.** The burner shuts down immediately on loss of flame, then attempts to restart once before locking out on safety.

**Restrike voltage.** The voltage across the electrodes high enough to reestablish the spark if current flow has stopped. Slightly higher than the holding voltage.

**Rotary burner.** A type of atomizing burner that uses the centrifugal force of a spinning cup and a forced air blower to break the oil into droplets.

**Safety lockout.** A condition requiring manual reset before the system can operate again. The flame detector does not detect flame, making the safety switch heater circuit, breaking the control circuit.

**Safety switch.** In an oil primary control, either shuts down the burner or allows it to operate, using information from the flame detector.

**Safety switch heater.** One part of the safety switch, along with a small bimetal element. On a call for heat, current passes through the safety switch heater. The heat produced by the heater raises the temperature of the bimetal. If this heater is not turned off within a set period of time, the continued heating of the bimetal will break the system control circuit and shut down the system.

**Sediment content.** Of oil, determined by whirling an oil sample in a centrifuge. The sediment settles to the bottom where it can be measured.

**Semiconductors.** Solids that conduct electricity better than ceramic insulators but not as well as a metal conductors.

**Sensitive relay.** In a flame sensing circuit, a spdt device that, using forked contacts, provides the best possible electrical contact for the very low power levels in cad cell circuits.

**Short cycling.** The thermostat cycles the heating system on and off excessively for short time periods. Is most often caused by an anticipator that is set too low.

**Solid state circuit.** In a flame sensing circuit, the manipulation of semiconductors to perform functions in the circuit.

**Solid state switches.** A bilateral switch and a Triac in a solid state circuit.

**Spark fan-out.** The distance a spark will blow downstream under the influence of combustion air flow.

**Stack relay.** Stack-mounted, oil primary control that uses thermal flame detection (i.e., RA117).

**Tester.** A troubleshooting tool used to provide easy, convenient testing of cad cell primary controls or oil primary/ignitor units.

**Thermal lag.** The occurrence of the surrounding air being colder than the bimetal when the temperature is dropping, and hotter than the bimetal when the temperature is rising. This happens due to the air temperature changing faster than the actual bimetal temperature.

**Thermal detector.** A type of flame detector that responds to an increase or decrease in stack temperature through a bimetal element inserted into the stack.

**Triac.** One of two solid state switches in a solid state circuit. A normally open switch that will conduct alternating current between terminals A and B after a triggering current is applied to the gate terminal.

**Triggering current.** See bilateral switch, triac.

**Valve-on delay.** The burner motor runs prior to combustion which helps to establish a draft.

**Vaporizing burners.** Oil burners that depend on natural evaporation to provide oil vapor for combustion. They are usually gravity fed and have a standing pilot. Also see pot type burner.
**CONTROLS FOR OIL-FIRED HEATING**

**Viscosity.** Of oil, determined by measuring the amount of time required for a sample of oil to flow naturally through a capillary restriction. Heavier oil has higher viscosity.

**Visual detector.** A type of flame detector that responds to the light emitted by the oil flame through a light-responsive photocell (i.e., C554 Cad Cell).

**Water content.** Of oil, determined by whirling an oil sample in a centrifuge. The water settles to the bottom where it can be measured.

**Weight.** Of oil, defined using API gravity scale. See API (American Petroleum Institute) gravity.

**Zone valves.** Primary controls used to control individual zones in a zoned heating system.