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CONTROLS COMPANY
Uni-Line North America A SIEBE COMPANY

Control Tips

August 1996

THERMOCOUPLES and PILOT SAFETIES

CONSTRUCTION - OPERATION - TROUBLESHOOTING

BACKGROUND

For over 60 years, thermocouples have been used in the gas heating and appliance industry. Their primary function has been to prove that a standing pilot light is operative so that on a call for heat the main burner gas will be properly ignited.

Thermocouples are one half of a pilot safety system. The other half is the pilot safety. This electromagnetic safety may be a separate device mounted in the main gas line, or an integral part of a combination gas valve.

The purpose of the pilot safety system is to provide for automatic burner ignition when the main gas valve is turned on. The pilot, however, cannot always be observed easily. If the pilot has gone out and the appliance is turned on, there might be a dangerous accumulation of gas before this fact was discovered. Pilots perform two basic functions: 1) they automatically light the gas at the main burner on a call for heat and 2) they also provide the heat energy required to operate the electromagnetic safety system. If the pilot flame is extinguished or reduced to a size which will not successfully light the burner, the safety device will be de-energized shutting off the gas supply at the main burner and, in most instances, shutting off the gas supply to the pilot.

Although many gas heating and appliance systems today incorporate electric or electronic type ignition components, basic thermocouple - pilot safety systems are still very much in evidence and use. Understanding their operation and testing procedures is very important to service technicians.

THERMOCOUPLES

The basic principle of the thermocouple is very simple. If we take two dissimilar metals and fuse them together at one end, then apply heat to the fused end, a small amount of voltage will be generated. (Figure 1.) If the heat source is removed, the voltage will drop to zero. The amount of voltage is very small; it is measured in millivolts. (1 millivolt equals 1/1000 of one volt.)

The two dissimilar metals used in thermocouple construction are stainless steel and copel. This combination provides the right amount of electrical energy necessary for a gas safety system. The stainless steel is used for the outer jacket of the thermocouple. (Figure 2.) Its hardness and other qualities provide for long life and resist the tendency to blister under prolonged heating conditions. The other metal, copel, is a combination of copper and nickel alloys and is a good conductor of electricity. The copel rod is inserted into the stainless steel jacket and fused or welded at the tip. Attached to the base of the copel rod is an insulated copper wire. At the other end of the copper wire is a tin-plated contact button. Between the stainless steel jacket or base of the copel rod and the contact button is a hollow capillary or soft copper jacket. The insulated copper wire is inside this jacket. The contact button is insulated from this outer jacket with a mica washer. This prevents current flow from the contact button to the outer copper jacket (eliminates a shorting condition).

Figure 1

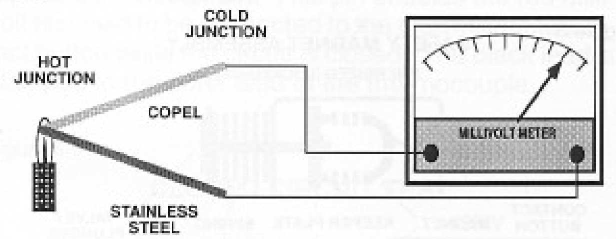
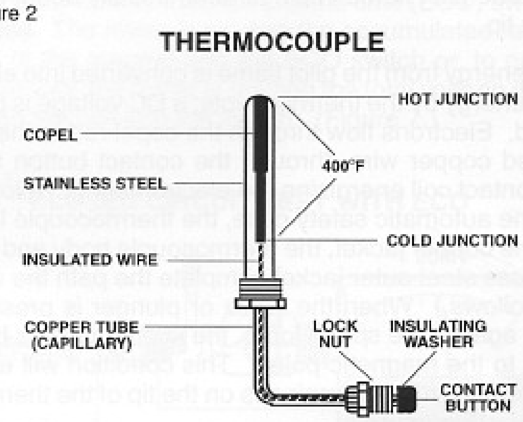


Figure 2

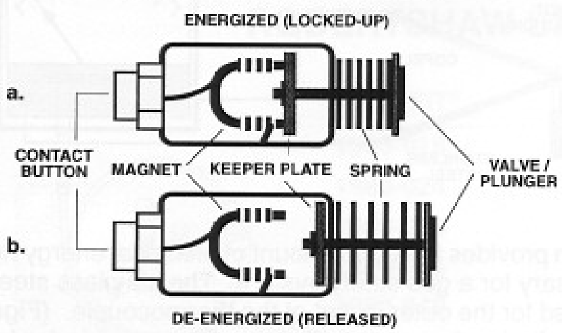


PILOT SAFETIES

We know through studies of electricity that a magnetic field surrounds a conductor when a voltage is produced. The basic principle of the electromagnet is: a metal bar, bent into a u-shape, upon which a wire is wound into a coil. If a voltage is applied to the wire, a magnet will exist. (Figure 3.)

Thermocouples are used to generate the voltage necessary to create an electromagnet. A constant flow of electricity proves the presence of a pilot flame, and the metal bar will retain its magnetic characteristics as long as current flows through the wire.

Figure 3



A typical electromagnetic safety device common to the industry is shown in Figure 3. The metal bar is installed in a device which includes a spring-loaded gas valve or plunger rod that is normally in an extended position. Inside the chamber a keeper plate is attached to the base of the valve stem. When the electromagnet is energized and the valve pushed downward, the keeper plate is securely held against the poles of the magnet as long as voltage is present in the coil.

To place the safety into operation, the thermocouple contact button is inserted into the base of the magnet and the locking nut is tightened finger tight, and then only one quarter turn with a small wrench.

The thermocouple tip is installed into a pilot burner. The tip is positioned in such a manner as to provide for adequate pilot flame impingement; usually about 3/8" of the tip.

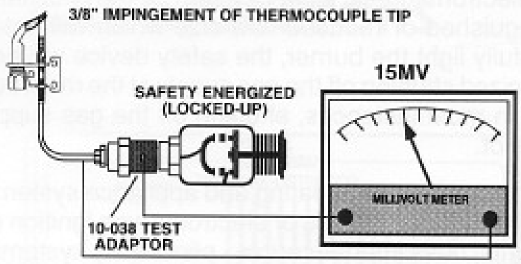
Heat energy from the pilot flame is converted into electrical energy by the thermocouple; a DC voltage is produced. Electrons flow through the copel rod to the insulated copper wire, through the contact button and the contact coil energizing the electromagnet. (Notice that the automatic safety case, the thermocouple lock nut, the copper jacket, the thermocouple body and the stainless steel outer jacket complete the path the current follows.) When the valve or plunger is pressed down against the spring force, the keeper plate is held firmly to the magnetic poles. This condition will exist as long as the flame impinges on the tip of the thermocouple. (Figure 4.)

OPERATION

The purpose of the thermocouple is to prove the presence of a pilot flame used to ignite a gas burner on a demand for heat. If the pilot flame is not present, the keeper plate will be released by the diminishing magnetic force. The spring will force the valve or plunger outward placing the valve onto a seat, or pushing a lever, shutting off the potential gas flow to a burner. If a main gas valve is opened, no gas will flow.

As noted, the materials used in thermocouples are copel and steel. A characteristic of these two metals is that there is an increased resistance to current flow when they are heated. A thermocouple generates only a tiny amount of voltage. Therefore, any adverse heat conditions anywhere other than on the tip of the thermocouple (3/8"), or the hot junction, will cause a diminishing electrical output due to high resistance caused by this heat. In order to achieve a maximum output from a thermocouple, there must be at least a 400 degree temperature difference between the hot junction and the cold junction. A thermocouple generates its maximum output under these ideal conditions: a good, stable blue pilot flame, and proper flame impingement on the thermocouple tip. Heat applied lower than this point, narrows the temperature difference between the hot and cold junction and causes a diminishing output of electricity. Another adverse condition may be excessive heating due to routing the thermocouple lead near the burner from the pilot to the gas valve. The safety magnet housing may also be subjected to excessive

Figure 4



heat in certain applications. This will cause higher resistance through the magnet coil. These heat conditions may be separate from the magnet and a "false" shutdown of a safety system may occur. A false shutdown is a condition caused by something other than pilot outage. Usually these conditions occur while the main burner is operating.

It is sometime difficult to observe these conditions. One thing is certain: if a safety system continues to shut down, something is wrong. The pilot flame may be lazy or yellow (not hot enough), or is no longer impinging on the thermocouple tip. The thermocouple may not be generating enough electricity.

The first problem is the pilot flame condition. This can be checked visually. The pilot can be cleaned, gas pressure can be set, pilot gas flow can be adjusted, and this problem can be solved. The second problem can be observed or felt by touching the thermocouple lead or the safety magnet while the burner is on. If they are hot to the touch, then certain steps should be taken to shield them from the heat source.

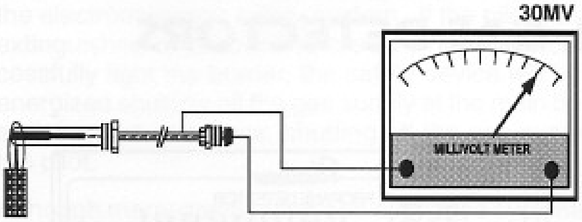
The best way to determine whether or not a thermocouple/magnetic safety is functioning properly is to use a test meter designed to read voltage in millivolts. The testing of a thermocouple and magnet with a test meter is sometimes misunderstood or confusing. There are two tests that are usually performed: 1) the open circuit test, and 2) the closed circuit test.

TESTING PROCEDURES

To determine the voltage output of a thermocouple only, an open circuit test can be made. Using an accurate millivolt test meter with a test lead plugged into the 50 millivolt socket allows you to read up to 50 millivolts (50MV). Connect the red wire to the contact button of the thermocouple and the black wire to the outer lead or capillary of the thermocouple. Light the pilot or hold the thermocouple tip in a pilot flame. The needle on the meter will begin to move upward on the scale until the maximum voltage potential is reached. This will usually be between 25 and 30 millivolts.

Figure 5

OPEN CIRCUIT TEST



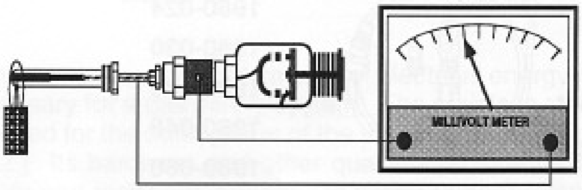
The length of the thermocouple lead will have a small effect on the output of the thermocouple. All thermocouples are made the same at the tip and the only difference is their length. A thermocouple 18" long has a lower resistance and higher electrical output compared to a 72" thermocouple which has a higher resistance (longer wire) and, therefore, lower electrical output. This is the main reason for the differences in the output of thermocouples. Remember, this reading is obtained across an open circuit or an infinite resistance gap. The readings would normally be between 25 and 30 millivolts. This test proves the potential of the thermocouple. The meter reads the voltage generated by the thermocouple base on the flame impingement on the thermocouple tip. Another way to look at this is, the meter is reading the voltage drop across an infinite resistance gap. (Figure 5.)

A closed circuit test is not the same as an open circuit test. The open circuit test measures the voltage (approximately 30MV) generated by the thermocouple across an infinite resistance gap. A closed circuit test measures resistance between the contact button of the thermocouple and the outer lead of the thermocouple. This represents the amount of resistance through the coil of the electromagnet, or the voltage drop through the coil.

To perform a closed circuit test, remove the thermocouple from the base of the electromagnet. Install a test adaptor (10-038) into the magnet base and install the thermocouple into the test adaptor. The test adaptor has a connector pin. This pin enables the red millivolt test lead to be connected to the thermocouple contact button while the circuit is closed. The black lead is clamped to the outer lead of the thermocouple.

Figure 6

CLOSED CIRCUIT TEST

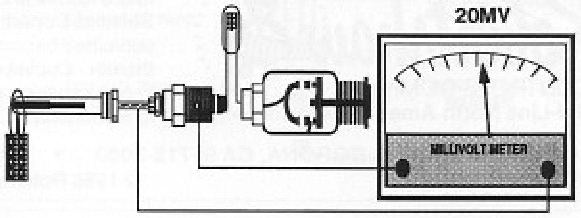


With the pilot flame impinging on the tip of the thermocouple, the reading on the meter will be about half that of the open circuit. This means that the coil of the electromagnet resists the flow of about half the voltage (approx. 15MV) generated by the thermocouple. The meter is reading the voltage drop. (Figure 6.)

In gas water heater controls, as well as many of the heating systems produced in the last 15 or so years, there is usually a switch wired in series between the thermocouple and the magnet. This is called an energy cutoff (ECO) switch. This switch adds a small amount of resistance to the circuit. With the pilot flame impinging on the thermocouple and the test meter connected to the adaptor, the reading on the test meter will now be approximately 5 or 6 millivolts higher (approximately 20MV) than without the limit (ECO) switch installed. The meter is reading the accumulated resistance of the magnet and the ECO switch or, to put it another way, the meter is reading the total voltage drop through the coil and the switch. (Figure 7.)

Figure 7

CLOSED CIRCUIT TEST WITH ECO



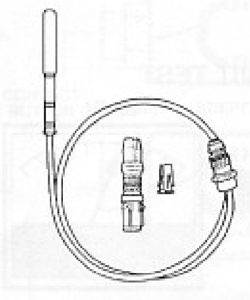
Based on the information presented, it should be readily noted that a thermocouple with an open circuit output of less than 20 or 21 millivolts would not be capable of meeting the resistive requirements of the exampled system. And any minor fluctuations (voltage drop / resistance increase) due to ambient conditions when the main burner is on will further aggravate the situation.

Remember: *with pilot flame on the thermocouple -*

1. The voltage drop (open circuit) across an infinite resistance gap should be 25 to 30 millivolts.
2. The voltage drop through the coil of the magnet may be 12 to 15 millivolts (closed circuit).
3. The voltage drop through the limit switch (ECO) and the magnet may be as much as 20+ millivolts (closed circuit).

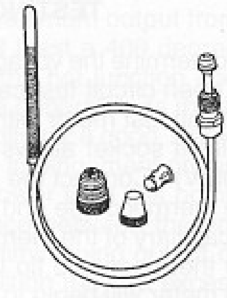
Therefore: As noted in 1; anything less than 25 millivolt output may cause false shutdown of a system if the resistance (or voltage drop) increases due to high ambient temperature or other conditions.

ROBERTSHAW UNI-LINE THERMOCOUPLES



1980 SERIES

SNAP-FIT®	LENGTH	UNI-COUPLES®
1980-018	18"	1970-018
1980-024	24"	1970-024
1980-030	30"	1970-030
1980-036	36"	1970-036
1980-048	48"	1970-048
1980-060	60"	1970-060
1980-072	72"	1970-072



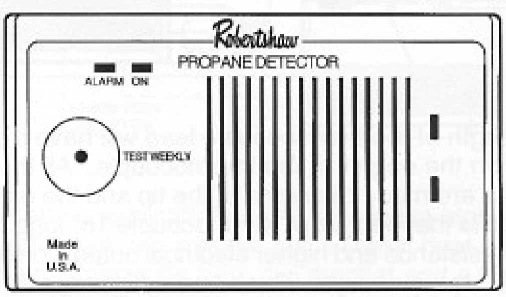
1970 SERIES

7605-411 and 441

PROPANE / NATURAL GAS DETECTORS

7605-411 120 VAC Line Cord

7605-441 12 VDC Hard Wire



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