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FIRES CAUSED BY FRACTURED RESISTANCE HEATING ELEMENTS

The resistance heating element is the mainstay of electric heaters, furnaces, and electric clothes dryers. Resistance elements are found on electric furnaces and on heat pump systems that use resistance heat for backup or emergency purposes. The typical resistance heating element for a heater or furnace consists of a length of coiled resistance wire configured in a 5000 watt configuration. Photo 1 shows such a resistance coil for a furnace. On a dryer, typical wattages for resistance elements are between 5000 and 6000 watts.

The resistance heating element is akin to a light bulb filament, in that electric current is applied and heat is generated. Just as light bulb filaments fail over time, so will the resistance element. Eventually, the heating element will fail with a parting arc; the splattered molten metal, often nichrome, is capable of igniting combustibles that it may land on. We have seen numerous fires caused by the ignition of plastic ductwork, dust accumulations, and air filters. Obviously, filter location and ductwork construction vary with each installation, such that not every failed resistance element will cause a fire.

A second mode of fire causation occurs when the element fails, and then ‘welds’ itself onto surrounding metal. While probably of little concern from a fire standpoint on a 120 VAC appliance, on a 240 VAC appliance the result can be that the element is now welded such that a portion of it is permanently powered. If the safeties are now bypassed in this situation, a fire is almost guaranteed.

In Photo 1, we note that the coils (loops) of this element are relatively uniformly spaced. Such uniform spacing creates a relatively constant surface temperature for the element. At 240 VAC, with a fan blowing (as in actual use), surface temperatures were approximately 470 deg F when measured with a thermocouple. This temperature, however, will lessen as the heater element is used. A nominal 5000 watt heater will drop in wattage (and thus heat output) as a function of time. As with the lightbulb filament, the heater element becomes smaller in diameter over time. On the heater element, this reduction in cross sectional area is due to oxidation. The smaller cross sectional area increases resistance, which thus decreases wattage.

Photo 1

We examined eight 5000 watt heater elements, installed in 3 separate furnaces in the same building. The wattages for the eight elements, which were installed new in 1989, are as follows:

5042, 5114, 5162, 5270, 5148, 5075, 5070, 5221.

As one can see, the wattages are not uniform. They will all decrease over time, until each element catastrophically fails.

MODES OF FAILURE / MODES OF FIRE CAUSATION

There are two modes of failure for the heater elements, both capable of causing fires in two separate ways.

1. NORMAL INSTALLATION AND USAGE—In this mode of failure, the wattages will continue to decrease until the weakest spot in the resistance element fails, causing the element to electrically open. At the moment of failure, a parting arc will be created, with temperatures in the 7,000 to 10,000 degree F range. One way that a fire is created is by the splattering of molten metal particles during the arcing process. Obviously, there must be nearby combustibles that are capable of being ignited by the molten nichrome.

A second manner of fire causation occurs when the failing element welds itself onto the grounded metal frame. Photo 2 shows a furnace heating element where this has occurred. Diagram 1 shows the schematic of this element, before and after failure. On a 240 VAC appliance, because often only one leg is switched, the other leg is continually powered. The now shorted element will continue to heat, without benefit of a high-limit thermostat or Thermal Cut Off (TCO). The heating can go on for hours or days until a fire is created; once again, we do need combustibles for ignition to occur. The heat that is generated from a normally operating heating element will be dispersed by the air from the blower; when the heater has welded and is on continually, the heat flux will accumulate because there are no air currents to remove the flux.

Photo 2

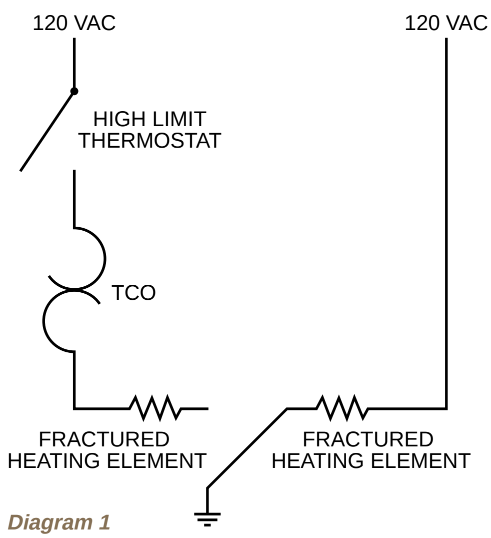


Diagram 1

Lifetime in this mode of failure (normally installed element) is determined by the quality of materials and the applied voltage. If the voltage increases 1 percent above the nameplate rating, we have a roughly 2 percent increase in wattage, which will decrease life. Likewise, any drop in voltage will correspondingly increase element life.

2. IMPROPER INSTALLATION—The failure that occurs because of improper installation is the more common failure that we have noted. Invariably, a heating element that is improperly installed is one that is a replacement or retrofit unit. The replacement units come in a long coil that has not been extended. It is up to the installer to route the heater element, which resembles a coiled spring, through the various ceramic standoffs. Invariably, the spacings on the coils are spaced erratically. We have witnessed some installations where adjacent coils are touching each other, leading to a lessening of overall resistance and increasing heater current (and wattage). A second problem with this lack of uniformity is the concentration of heat flux where adjacent coils are too close together. Both of these factors are what causes the much reduced life on a heating element.

Photo 3 shows a resistance heating element that came from a failed furnace; the furnace had two elements, and this is the one that did not fail. Surface temperatures varied from 460 to 790 degrees F, depending on turns density. This increased temperature results in a severe increase of oxidation rate where the turns are dense, and a corresponding decrease in element life. Photo 4 shows the infrared thermogram of this same heating element when powered.

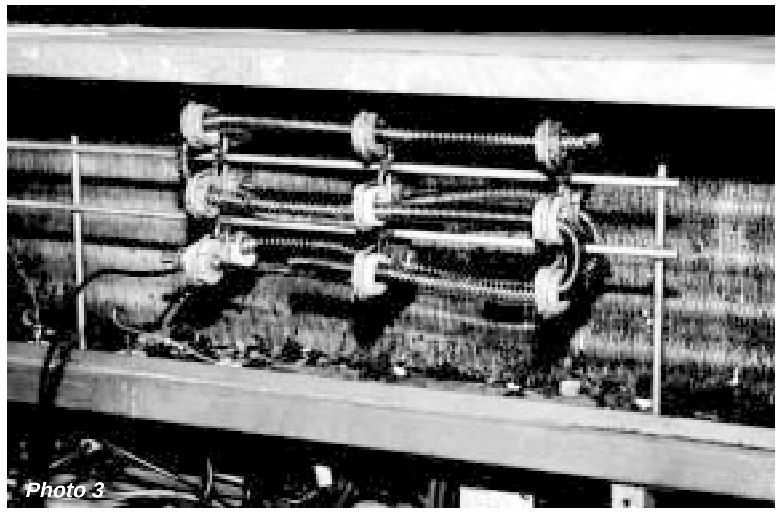


Photo 3

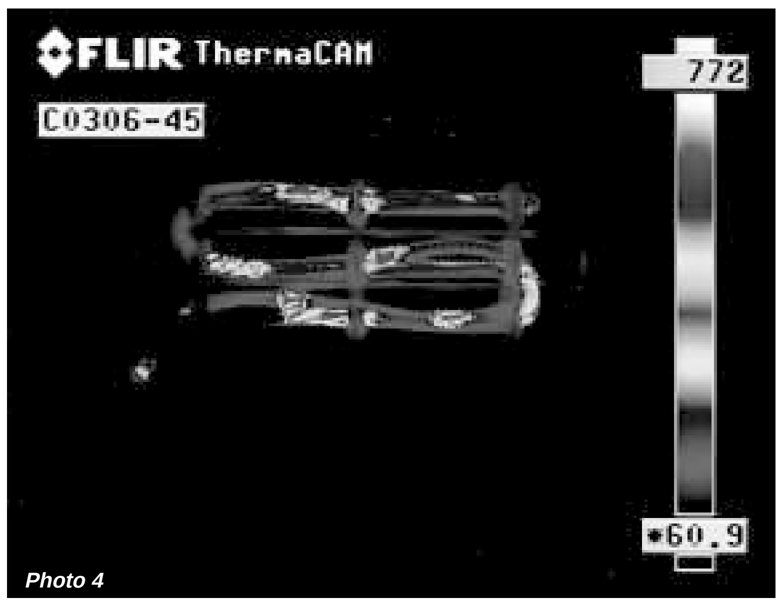


Photo 4

The element depicted in photos 3-4 came from a furnace that had a second element, with the second element being the one that caused the fire. The failed element is depicted in photos 5 and 6. Photo 5 is a photomicrograph of the element in portions that are appropriately spaced. Photo 6, shows the increased turn density that was responsible for the failure. Also note that there are ‘balls’ of splattered metal from the heating element’s base material, these having been generated in the arcing process. It is these balls that caused ignition of nearby combustibles.

Photo 5

Photo 6

Nichrome is an alloy, often 80 percent Nickel and 20 percent Chrome, that melts at about 2550 deg F. As the heating elements are enclosed in steel cabinets, it is doubtful that the heating elements melted in the fire. In our 18 years of experience, we have never seen a resistance element melt from thermal exposure. If the heating element is open, it is necessary to show that the 'splatter' had nearby combustibles which it could ignite, and that the combustibles then spread the fire.

If the element is instead shorted to ground on a suspected furnace, one should determine if there were safeties that were bypassed by virtue of the welding. The usual safety system consists of a high limit switch and a TCO. If the welding took these safeties out of the circuit, then the fire may well have been caused by the accumulation of heat flux from a constantly powered element. Because these elements and the ceramic standoffs are robust, the lack of fire damage will make it possible to test the elements after a fire by the application of the appropriate voltage.

While the increased watt density from poor installation results in premature failure, the failure can once again cause fires in two ways. The furnace we examined caused a fire by splattering. It also could have caused a fire if the element had welded itself to ground, bypassing the safeties and being permanently powered.

The authors have purchased many replacement elements for furnaces. Not one set of packaging instructions told the user to uniformly space the resistance coils, or to insure that the TCO was installed in the leg opposite of that of the high limit thermostat. It is of no surprise, then, that poor installation is often a cause of these fires.

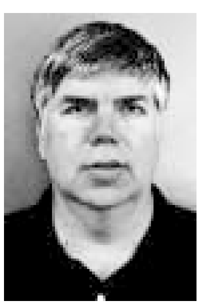
FIRE INVESTIGATION

When investigating a fire where a heater element may be suspect, one logically starts with a competent O&C investigation. If a furnace fire is indicated, one should carefully check the resistance coils.

SUMMATION

Correct diagnosis of the fire caused by a fractured heating element requires both a competent O&C exam and engineering analysis of the fractured element. Elements which have coils uniformly spaced will have failed from normal usage, while elements with erratic spacing suggest an element which has been replaced and prematurely failed due to increased wattage density. The fractured element may create a fire by splattering molten material, or by welding itself to ground such that it is continually powered. Either possibility is easy to see even after an intense fire, due to the high melting point of the base material.

ABOUT THE AUTHORS



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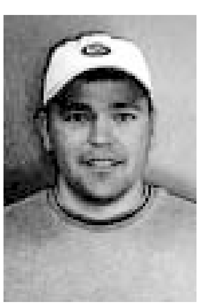

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