ELECTRIC COOKTOP FIRES

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BY MARK GOODSON, PE AND GLENN HARDIN, PE, DENTON, TEXAS—One of the cardinal rules about fire investigations is that an open mind must be kept. We must state, however, that we have a difficult time in being completely open when investigating fires believed to have been caused by electric cooktops. Our 'usual' pre- investigation advice to the client is to the effect that the unit was probably left unattended and thus caused the fire. We can also state that cooktops with conventional 'infinite' controls do not turn on by themselves. Outlined herein we show how cooktops work, as well as their modes of failure.

THEORY OF OPERATION

In analyzing a cooktop, one must first realize that this appliance is unlike most other cooking appliances. In a conventional oven, the temperature is set, a recipe followed, and baking takes place for a predetermined time. In this regard, an oven requires minimal attention from the user. A cooktop, however, often requires much supervision, in that the user is part of a 'control' and 'feedback' system. In its simplest form, cooking is merely a heat transfer issue—it is desirable to transfer sufficient heat flux Q to the mass of food such that the mass will rise in temperature to a desired point. The variables, however, include:

- Available heat from the burner
- Mass and shape of the vessel (pot or pan)
- Vessel material (copper, aluminum, steel, iron)
- Mass of food, as well as shape
- Heat capacity of food
- Amount of water present
- Cooktop burner surface material
- Rate of heat transfer from the burner.

When cooking, the user (chef) must consider all of these variables (with some dependent upon others), and adjust the burner heat output until the desired result is achieved. This is a very complex control system, with the user providing feedback. Taste, smell, and visual sensations received by the chef allow him/her to adjust the cooktop setting until the food is cooked properly—this is the feedback that is taking place. If the cooktop is unattended and the burner is on low, the food may never reach the right temperature—here, the feedback system can be considered 'open', but with 'gain' less than 1. The result is under cooked food. If the cooktop is unattended but the burner is too high, the food will burn—here, we have open loop (zero) feedback with gain greater than 1—such a system is 'unstable' (an engineering term) and results in disaster. For both the engineer and non-engineer, this long explanation is the reason that cooktop knobs (unlike an oven) do not have temperature settings present. Rather, the cooktop relies on feedback (user attention and control) in order to insure that the overall system works properly.

There are predominantly three types of electric cooktops in use—heater element, coiled heaters, and halogen lighting (we are ignoring the rare inductive type of cooktop). The heater element is simply a metal tubing (such as copper) that houses an insulator (typically Magnesium Oxide (MgO) and a resistance heating wire such as nichrome. General Electric invented this type of heating element, and it is often referred to as a 'Calrod;' we will refer to it as a 'sheathed heating element.' The pot or pan sits directly on these elements. These same types of sheathed heating elements are also used on electric water heaters, in dishwashers, and in hot tub heaters.

The next two types of cooktops often make use of a glass-ceramic (Ceran®) that is made by the Schott company. The glass-ceramic is very rugged, and is transparent to infrared energy. A coiled nichrome wire heater or a halogen lamp is placed beneath the glass-ceramic in each of the burner positions. When the element is powered, heat is transferred upwards to the pan, and heating takes place. The desirability of these Ceran® glass-ceramic types of cooktops comes from the flat surface they present—they are easier to clean.

Regardless of the type of heating element, however, all of them are typically controlled by what is known as an infinite control. The infinite control is a two pole thermostat, and is called 'infinite' because (in theory) there are an infinite number of settings between LOW and HIGH—it is strictly a matter of how finely one can adjust the control knob. Photo 1 shows a picture of the infinite control.

Photo 1—External view of infinite control.

The infinite control has two sets of contacts, one for each side of the 120/240 VAC system (we are assuming a 240 VAC cooktop). The infinite control has a detent system present, such that it must be pushed in order to rotate and turn ON. When turned on, one contact set is closed, applying one leg of 120 VAC to the heating element. The second set of contacts, however, are controlled by an internal bimetallic element, which causes the contact set to cycle off and on.

The ratio of ON time to (ON plus OFF time) is referred to as the 'duty cycle.' When multiplied by 100, we have the percentage duty cycle. In its lowest setting, the infinite control may have the burner on for 1 second, and off for 9. The percentage duty cycle is thus 10 percent. If the heating element is a 2200 watt element (as an example), the element is 'transformed' into a 220 watt element. At 100 percent duty cycle, the 2200 watt element will provide 2200 watts of power.

The on/off cycle is adjusted by changing the mechanical bias in the infinite control. The infinite control generates heat internally proportional to current flow. Photo 2 shows (by way of a thermogram) the internal heat generated by the infinite control. The heat is what causes the bimetallic element to cycle the control off and on. Photo 3 shows the two sets of contacts, with the 'fixed' contact being on the left hand side and the cycling contact being on the right hand side. With the control on fully HIGH, the cycling contact will not cycle but will be fully ON.

Photo 2—Thermogram of thermostat in the infinite control.

Photo 3—Internal view of infinite control showing contacts.

Wattages on the heating elements vary between about 1500 watts for small elements, and 2500 watts for large ones. Bosch has a cooktop that has five elements, as follows: 1200, 1500, 1700, 1900, and 2500.[1] The sum of all these wattages (8800 watts) would require about 37 amperes if each burner were fully ON.

Energy efficiency among various types of cooktops has been determined as follows:

Induction	90%
Halogen	58%
Electric	47%
Gas	49%[2]

The appliance industry has several standards that are useful. The reader is referred to the following:

UL 858—Household Electric Ranges
ASTM F1521—Standard Test Methods for Performance of Range Tops
BS EN 60335-1—Household and Similar Electrical Appliances—Safety.

There is also a 'black wall' test used in Europe, outlined in EN60335-2-6.[3] For this test, the wattage of a rear burner is increased by 24 percent over nominal by increasing the voltage to the element. Thereafter, the temperature is measured on a black wall located immediately behind the burner. Obviously, 'drop-in' type cooktops are of particular interest here, with the rear burners being key. Per this standard, a temperature rise of 150° K (270 R) is allowed on the black wall behind the cooktop.

Note that absent in our discussion of cooktops is the answer to the question, "How hot does it get?" While this seems to be a logical question, the answer is very dependent upon the 'loading' on the cooktop—what is present to take the heat from the burner. Because pots and pans are so varied, and likewise their contents, temperature measurements of an open burner are not very helpful.

EXAMINATION

We outline here failure modes and ways of diagnosing a cooktop fire.

1—PHANTOM OPERATION:

The 'usual' claim that we have heard is that the cooktop somehow turned itself ON. Mechanically, we have never seen this happen in analyzing about 80 electric cooktop fires or 'thermal events.' (A thermal event is what occurs when there is thermal damage and pyrolysis, but no true fire in the sense of flame being produced or self sustaining chemical reaction taking place) The controls on cooktops all have 'flats' on their shafts, such that it is easy to see if all the 4 controls 'line up' or if one (or several) are in the ON position. We make it a practice when examining a cooktop to first mark the shaft position of each control with a paint marker. If the control housings (thermoset plastic) are destroyed, it is still possible in many cases to find the flat and how it lines up. Another technique is to look at the contact faces—if the faces are well covered with soot, but have bare spots in the center, it appears as if the faces were touching and the controls ON.

We have on two occasions seen instances where unattended simmering was taking place, but a fire still resulted. In both of these cases, the 'cycling' contacted welded itself to its mate, resulting in a roughly 10 percent duty cycle jumping to 100 percent. These cases are easy to diagnose, but the manufacturer of the stove and/or control should be present when the control is disassembled. There is, of course, a human factors question present here—should the stove have been left unattended? The same question can be asked a different way: Is it reasonable for a person to put a large pot of stew on simmer for the day without having to constantly check on it to see if the control failed? Reasonable persons can disagree on these issues.

Occasionally, a cooktop is so badly damaged that the controls yield nothing meaningful when examined. At this point, it is necessary to examine the pairs of wires that run to each burner. The wires are covered with a high temperature fabric (glass) insulation. The insulation is very rugged, and not prone to failure in the same manner as common PVC is. If wiring on the load side of controls shows arcing, it is reasonable to assume that the wire was energized and thus the controls were ON. We have never seen this type of wiring fail from normal use and cause a fire by arcing. The reader will readily appreciate, however, that many cooktops are laden with grease in the control area, and thus such a fire is not out of the realm of possibilities.

In examining the phantom issue, the 'thermal event' is easy to analyze. For the thermal event, there is no self sustenance of an exothermic chemical reaction; rather, the heat continues to flow from the burner. Ergo, the destruction of combustibles will be seen to be a result of heat from the burner. A pot may melt, nearby control knobs may melt, or a cooking mitten may heat up and smolder; regardless, the damage will all point back to the burn as the heat source.

When a true fire takes place, analysis is much more difficult—did items (combustibles) degrade from heat from the fire or heat from the cooktop? In investigating the cooktop fire, one must identify the first combustible ignited. Identifying this first combustible may tell whether the problem is a result of human error (someone left a paper bag on the hot cooktop) or a control problem—the control stuck in the HIGH position and ignited a rear wall.

2—SHEATHED HEATING ELEMENT FAILURES:

In regards to sheathed heating element failures (Calrod type failures), we should note that we have never seen a sheathed heating element fail (melt) from a fire—this includes heating elements from cooktops, ovens, commercial coffee makers, and hot tubs. Conversely, every instance in which we have found a failed sheathed heating element we have found a fire or thermal event. (Note: we are specifically excluding here failures caused by corrosion, such as in a water heater) The MgO has a melting point of 4100° F, the NiCr has a melting point of 2552° F, and the copper sheath a melting point of 1980° F. These MPs are high enough that most fires will never cause the heating element any harm—after all, the heating elements were intended for high temperature generation. Photo 4 shows a portion of a failed sheathed type element—note the arcing that is present. When these elements fail, a fire is brought about by the spewing of molten products onto combustibles.

Photo 4—Failed sheath heating element.

3—HEAT TRANSFER FROM ADJACENT BURNERS:

The glass cooktops we have tested all show very localized heating. That is to say, a burner that is ON and serves the right rear burner position is not going to ignite a rag or cloth accidentally left on the right front burner. Photo 5 shows a thermogram of a cooktop with the left rear and right front burners on HIGH, and the other two burners OFF. It is obvious that there is little heat conduction to adjacent burner sights.

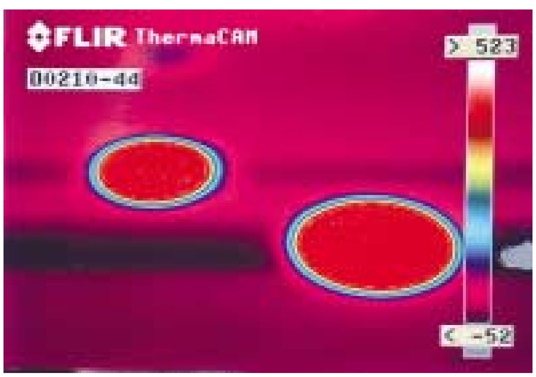

Photo 5—Thermogram of 2 burners on a glass cooktop, showing a lack of heat transfer to other burner locations.

4—FRACTURED GLASS:

The practical experience that we have had with Schott brand (Ceran®) glass-ceramic has been very positive. In cooktops we have used, we have never experienced a breakage problem. The glass is capable of effectively transmitting light, and must be impervious to fractures caused by differential expansion from spilling liquids. When a pot boils over, it is not acceptable for the glass cooktop to shatter. Similarly, it is rare that all 4 burners will be on and/or set at the same power setting, once again creating large heat differentials on the glass. Per the Schott website, thermal expansion of Ceran® type glass-ceramic (made by Schott) is almost zero. Likewise, the heat loss of Ceran® is also very low. All of these factors work together to establish that a fire caused by a shattering glass cooktop is a rare event. We have seen a 'thermal event' on only one occasion from Ceran® glass-ceramic. The cooktop was in use, and the glass shattered. The glass particles landed on an indoor/outdoor type of carpet, bringing about thermal degradation (melting and smoking) but no fire.

5—CONNECTIONS:

There should be no 'wire nutted' connections on a cooktop, other than at the incoming power connections. The presence of other connections possibly indicates repairs or modifications. Overheating connections are beyond the scope of this paper, but the experienced engineer should have little difficulty in diagnosing them.

SUMMATION

We have presented here the 'common' types of failures. Engineering examination of the controls will usually show that human error is involved with the fires or thermal events. The designs of these cooktops, from a fire standpoint, is such that misuse is much more likely that cause of a fire than is a malfunction. ●

REFERENCES

1.) Robert Bosch Appliances, NEM 930 36" 5 Burner, 2002. Brochure
2.) Cooktek, "What's Cooking," Spring 2002, Page 2
3.) EN60335-2-6, "Particular Requirements for Stationary Cooking Ranges,

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