ENERGIZED NEUTRAL EFFECTS ON CORRUGATED GAS SUPPLY LINES

Kevin R. Davis, PE, CFEI, CVFI
Goodson Engineering, Denton, TX
and
Michael Shuttlesworth, PE
Goodson Engineering, Denton, TX

ABSTRACT

In the course of performing fire investigations, it is not uncommon to encounter a fire where the ignition source is identified as electrical in nature. Furthermore, we have all likely encountered a situation where the fire occurred as a result of the neutral circuit being energized (short circuited to line potential).

This paper will share what occurred during one particular instance where a home owner witnessed and photographed an energized neutral event. Fortunately, a fire did not occur, but easily could have. The home owner photographed the gas appliance connector connected to a water heater that was glowing red hot during the event.

It is the intent of this paper to share the particulars of this case and explore the effects of an energized neutral circuit as it relates to current flow in a gas appliance connector. The energized neutral circuit was witnessed and documented by the home owner. The glowing gas appliance connector was a real event, not theoretical or staged. The glowing gas appliance connector did not result in a fire; however, it did raise questions regarding the current carrying capability of the gas appliance connector and what level of surface temperatures resulted from the current flow through the short section of gas line. The energized gas appliance connector was duplicated in the lab. The external surface temperature of the gas appliance connector was measured at various current levels and documented.

BACKGROUND

In the spring of 2015, Ms. Adams, a resident of the state of Texas, experienced and documented a case of an energized neutral circuit in her home. The incident occurred on a rainy spring day. From her kitchen window, she witnessed a shower of sparks raining down into the back yard. The sparks were coming from the overhead electrical line which provided power to her home and an unattached garage (with a second floor apartment). Ms. Adams was witnessing a short circuit between two of the electrical wires in the triplex overhead electrical drop. One of the energized power wires was making contact to the adjacent (and uninsulated) neutral wire. While standing at here kitchen sink watching the sparks fly, she notice a burning smell. She left the kitchen window to investigate. Ms. Adams discovered the smell originating from a utility closet located on the first floor of her home. The utility closet contained only a gas operated water heater. She could see the corrugated gas line on her water heater was glowing red in color. Ms. Adams photographed the water heater and gas line with her cell phone (see Figure 1). She immediately contacted the local power utility company and the fire department.

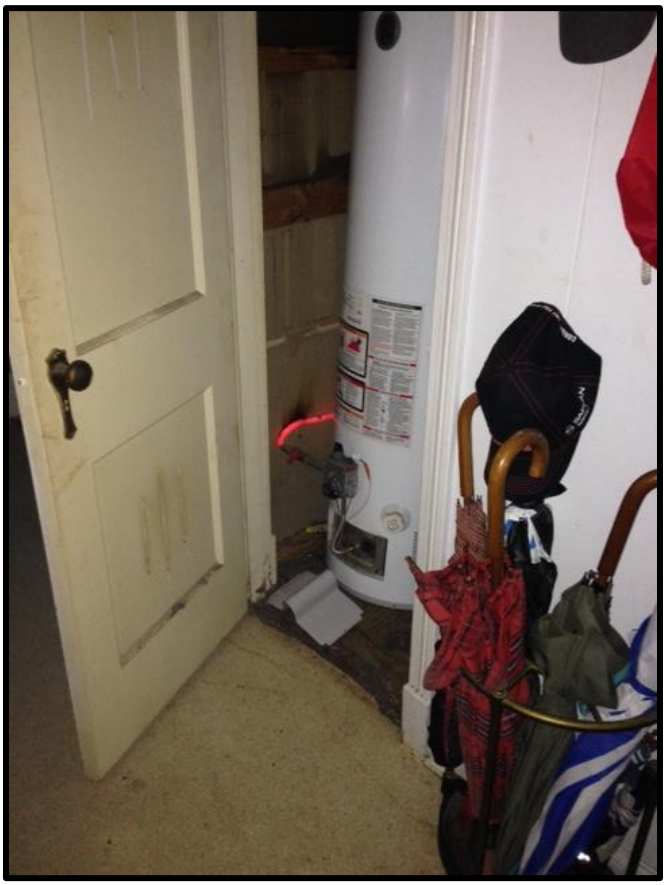

FIGURE 1: The Photograph Of The Glowing Gas Line. Photograph courtesy of Ms. Adams.

DOCUMENTATION OF THE STRUCTURE

The original structure was constructed in the early 1900's. There have been multiple additions to the structure over time. The electrical system varies throughout the structure from knob and tube, to cloth covered conductors, to three-wire non-metallic sheathed cables. The water lines consisted of copper plumbing through-out the structure. The electrical service meter was located on an exterior wall along with the main electrical distribution/circuit breaker panel. There were several smaller electrical panels located throughout the structure indicating the progressive modifications made to the structure over time.

We documented the ground resistance of the following items after the incident (using a FLUKE 1630 Earth Ground Clamp):

- Ground conductor at the utility pole (34 Ω),
- Ground rod for the house (58 Ω),
- Ground rod for the unattached garage/apartment (730 Ω),
- Corrugated gas line on the furnace (7.7 Ω),
- Corrugated gas line on the water heater (9.2 Ω),
- Copper water line supply to the water heater (0.045 Ω), and
- Copper water line for hot water (106 Ω).

The gas lines connected to the gas furnace (located in the attic) and the gas water heater (located in the first floor utility closet) were replaced with all new gas line material at the time of our inspection. The resistance readings may not reflect the actual resistance of the lines at the time of the electrical neutral fault. The remaining electrical grounding connections were undisturbed from the time of the electrical neutral fault.

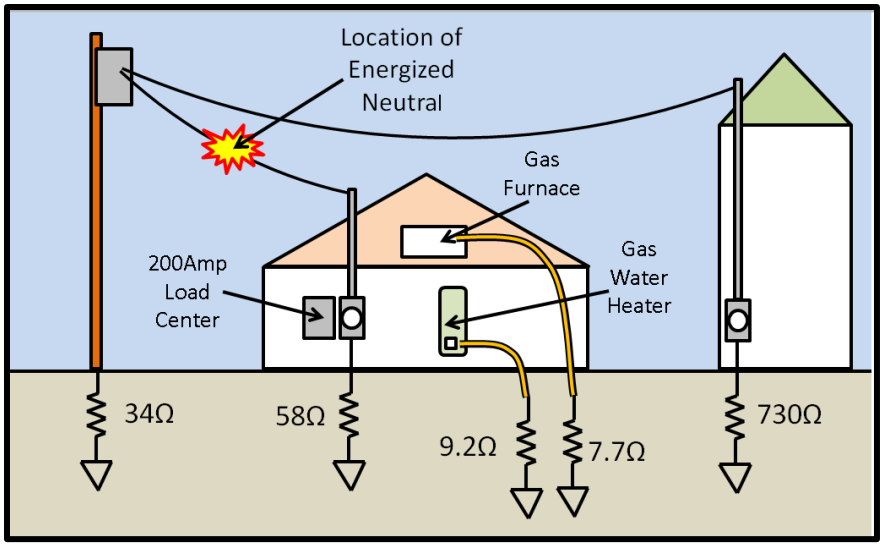

FIGURE 2: Map Of Ground Resistance Measurements.

The insulation failure on the electrical power service drop allowed one of the two power lines to energize the neutral circuit. A failure of this type causes the voltage that normally appears as 120 volts (as measured from Line 1 to neutral or Line 2 to neutral) at a receptacle to either drop to near zero or surge upwards of 240 volts, depending on which circuit is shorted to neutral.

The actual electrical failures in the structure were limited to a few items (such as a computer, television, clock radio, and stereo equipment) and multiple blown light bulbs.

THE TEST SET-UP

We reproduced the energized neutral condition through a new water heater by connecting a constant AC current source, a Lincoln AC welder, model AC-225, between the cold water supply line and the corrugated gas supply line. The current source was held constant while the temperature of the corrugated gas supply line was allowed to reach a steady state. The temperature of the corrugated gas supply line was measured at each coupling nut and at three points along its length using thermocouples.

A thermal camera, FLIR model T400, was also used to duplicate the thermocouple data and determine the maximum temperature and the location where the maximum occurred.

The yellow insulating coating was burned off of the gas line during the set up in order to affix the thermocouples directly to the metallic surface of the corrugated gas supply line (see Figure 3). The data from the thermocouples was collected using a Keithley, 2700 multimeter/data acquision system. The current was monitored using an Extech True RMS AC/DC clamp meter, model EX830. The water heater was not connected to a supply of gas or water at any point during the testing.

FIGURE 3: The Test Set-up. NOTE: The Water Heater Is Not Supplied Gas or Water.

RESULTS

The test data has been represented in figures 4 and 5 below. The corrugated gas line could not be seen to glow until the surface temperature reached approximately 1100℉, as measured on the thermal camera. A current flow of 110 amps was required to observe a slight glow of the gas line. We noted that as the level of current increased, the brightness of the glow also increased, as well as, the maximum surface temperature of the corrugated gas line.

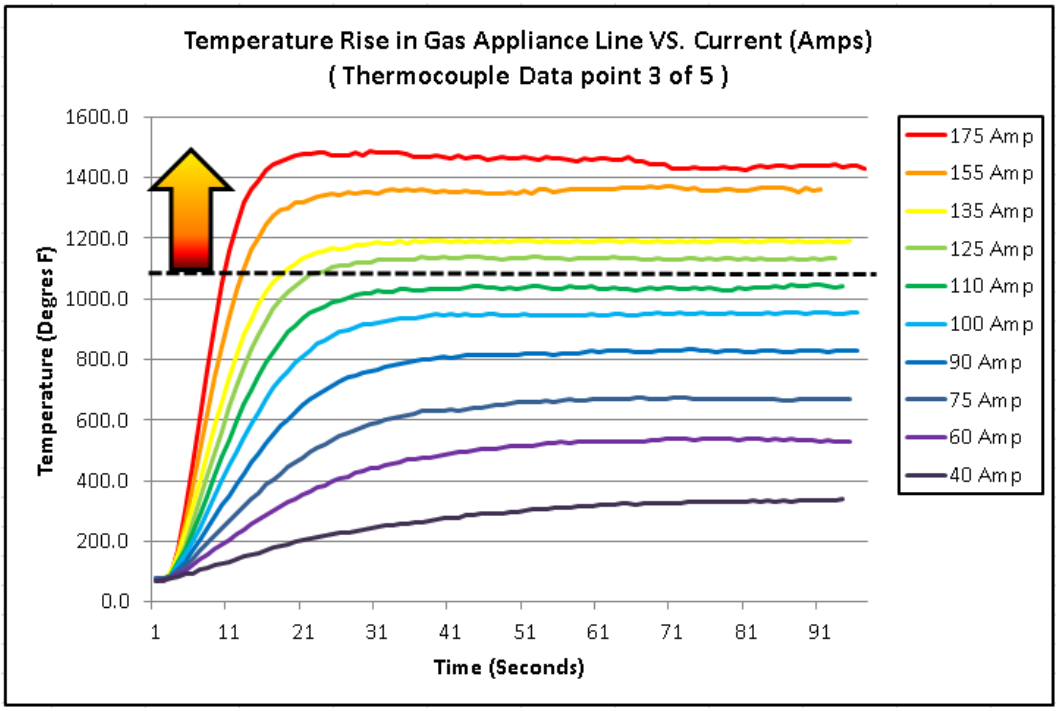

FIGURE 4: Graph Of Current Vs. Time At Multiple Current Levels. NOTE: Dashed Line Indicates The Approximate Temperature When The Gas Line Begins To Glow.

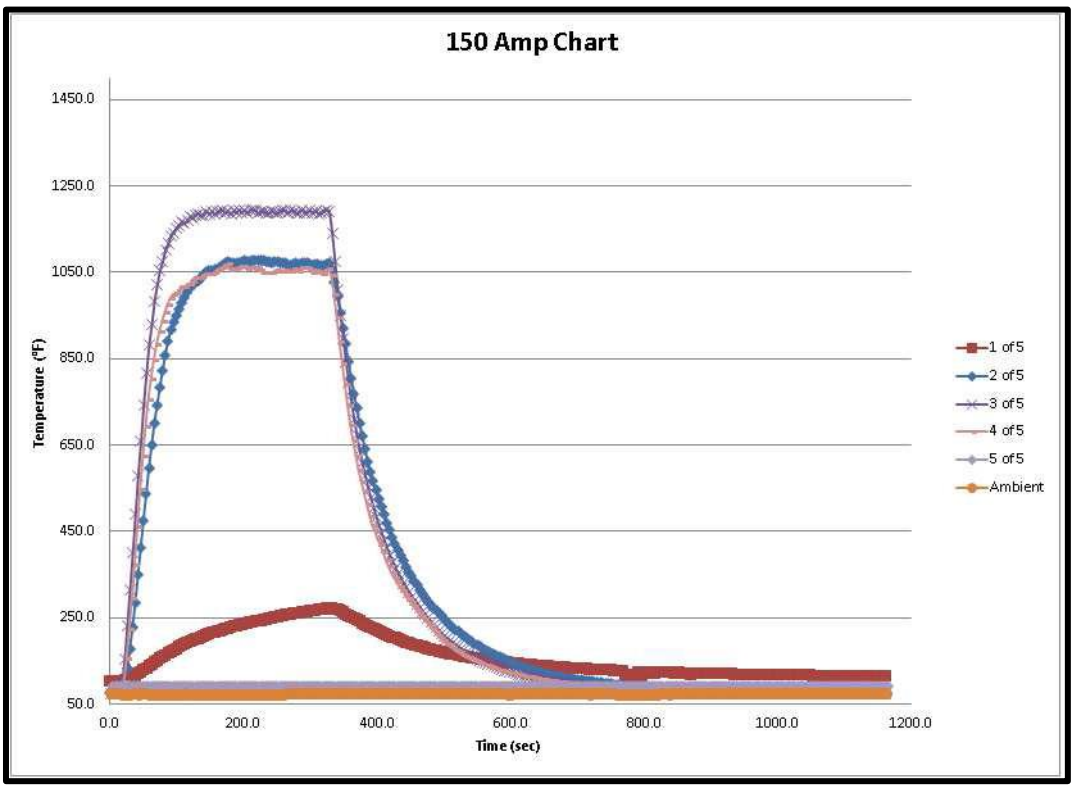

FIGURE 5: Temperature Profile Along The Length Of The Gas Line Was Also Collected At Each Current Level. NOTE: The Thermocouple Located In The Center Of The Length Of Gas Line Reached The Highest Temperature. The T_{rise} and T_{fall} Times Were Short.

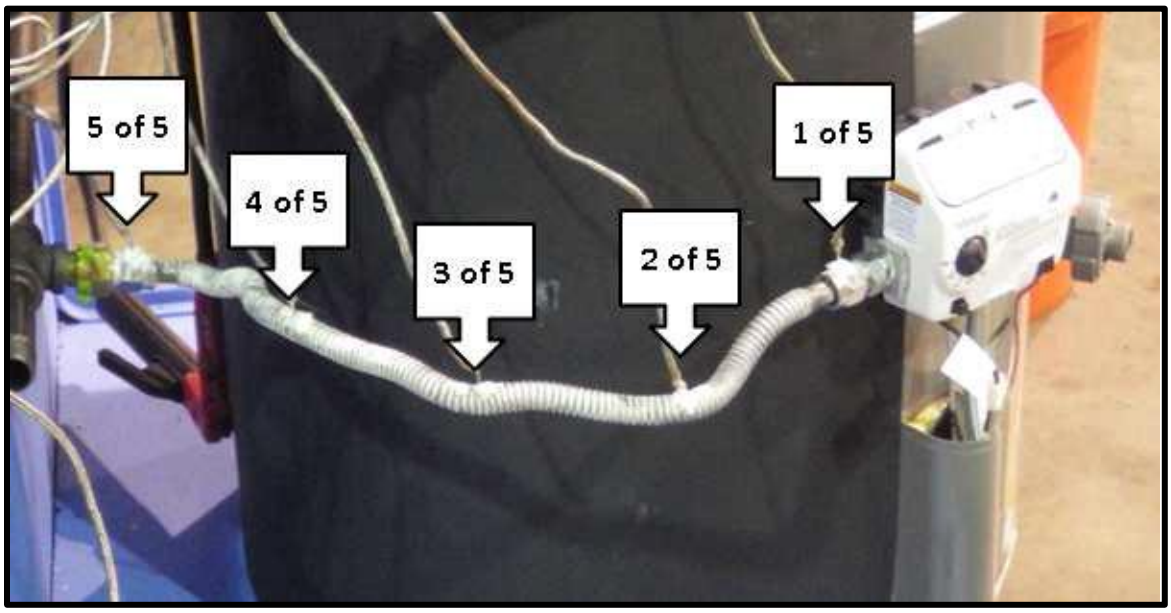

FIGURE 6: Locations Of The Thermocouples On The Corrugated Gas Line And End Nuts.

TABLE I - Temperature Comparison Between Thermocouple and FLIR

Welder Setting	Actual Current	Thermocouple (Point 3 of 5)*	FLIR (Maximum reading)
40	40 Amps	342 °F	374 °F
60	60 Amps	533 °F	583 °F
75	75 Amps	667 °F	725 °F
90	90 Amps	775 °F	868 °F
105	100 Amps	953 °F	1003 °F
120	110 Amps	1036 °F	1092 °F
135	125 Amps	1133 °F	1179 °F
150	135 Amps	1190 °F	1245 °F
175	155 Amps	1360 °F	1417 °F
200	175 Amps	1433 °F	1497 °F

*Average of the last 44 measurements

CONCLUSION

By comparing the luminosity of the corrugated gas line as seen in the photo provided my Ms. Adams (FIGURE 1), we can estimate the current flowing through the gas line was approximately 125 – 135 amps. We can also estimate that the surface temperature of the corrugated gas tubing was approximately 1150°F – 1200°F. It was very fortunate that a fire did not occur at the home of Ms. Adams.

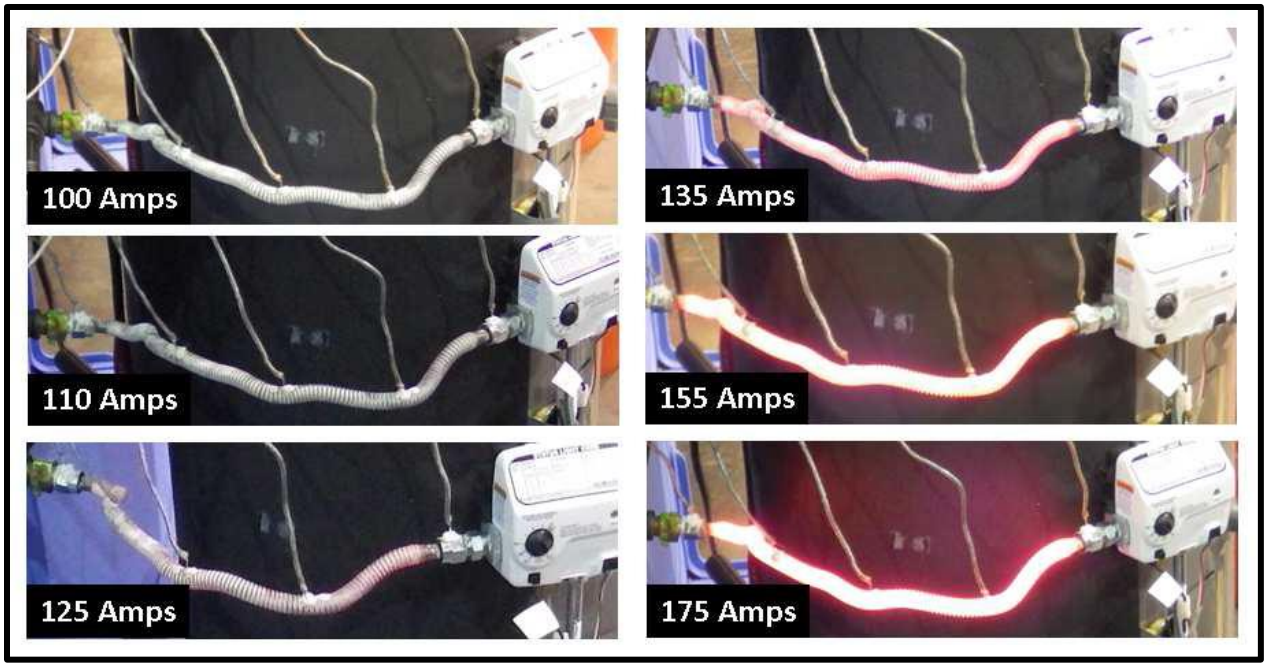

FIGURE 7: Photographs Of The Luminosity Of The Gas Appliance Connection Vs. Current Flow.

The energized neutral, as experienced by Ms. Adams, clearly demonstrates that it is possible to have current flow in a corrugated gas line. Furthermore, this current flow can cause the surface of the corrugated gas line to reach temperatures capable of igniting nearby combustible materials. The ignition of nearby combustible materials can occur without creating a gas leak or pin-hole in the corrugated gas line material. It is therefore possible for an energized neutral to be the source of ignition when a fire origin has been identified near a corrugated gas tube, particularly when it has been determined that the gas line does not have any leaks in the origin area.

It is our sincere desire that the results expressed in this paper may aid in identifying the root cause of a fire that may have otherwise been labeled as undetermined.

ABOUT THE AUTHORS

Kevin R. (KR.) Davis, PE, CFEI, CVFI: An Electrical Engineer that received as BSEE from the University of Missouri-Rolla, and is licensed to practice engineering in numerous states. Mr. Davis has nearly 20 years of product design and development experience while working for Delco Products, Ford Motor Company, Harley-Davidson, Peterbilt and Hatteras Yachts. He has been certified in marine electrical systems by the ABYC and currently works for Goodson Engineering performing failure analysis on electrical systems.

Michael Shuttlesworth, PE: A Mechanical Engineer who is a licensed Professional Engineer. His BSME degree was received from Oklahoma Christian University. He works for Goodson Engineering performing failure analysis on residential appliances and plumbing systems. He also serves as the Lab Manager for Goodson Engineering maintaining and operating the failure analysis instrumentation.