NEON TRANSFORMER ELECTRIC ARCS AS VIABLE IGNITION MECHANISMS FOR WOOD STRUCTURAL MEMBERS

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ABSTRACT

The fire investigator conducting investigations involving fires at facilities where neon signs and neon transformers are present should include consideration of the potential ignition mechanisms associated with this type of transformer. This paper presents test results for neon transformers that were available for installation through the early 1990's, which demonstrate that secondary output voltages ranging from 3,000 to 15,000 volts are produced that can start fires in wood structural members. The voltages were found to be capable of initiating and sustaining arcs over distances of up to 1 inch in air, and arc tracking on a damp surface of a foot or more, for extended periods without tripping a circuit breaker. Arcing was found to be easily initiated for a variety of commonly occurring grounding points in neon sign installations. Ignition and burn-through of wood structural members such as 2" X 6" and 7/16" thick oriented strand board (OSB) were demonstrated using neon transformer arcs. Neon transformer and sign wiring issues are discussed. A commercial structural fire attributed to neon transformer ignition is presented along with photographs of the burn patterns found in the area of origin and at the point of origin of the fire.

RESTAURANT FIRE INVOLVING NEON TRANSFORMERS

On March 24, 2004 at 8:26 PM, a witness observed smoke coming from the roof of a restaurant and called 911. When the fire department arrived about 8:33 PM, they indicated that they observed heavy smoke on the south and east sides of the building. Using forcible entry through the front doors on the east side of the building, they noted that the inside of the building was clear of smoke and no signs of the fire were visible. They turned to the left, into a dining room near the front of the restaurant and observed smoke and fire seeping out of the suspended ceiling tiles. When they started to pull down some ceiling tiles, heavy smoke, heat and debris began to come down on them. It was reported that at 8:47 PM, due to heavy air conditioner units and steel on the roof above them, the firefighters were ordered out of the structure and fire fighting tactics changed to a defensive mode.

The fire continued to burn and by about 10:20 PM the entire roof had collapsed. Fire extinguishment activities continued until around 3:41 AM the next morning.

A spectator with a video camera started taping the fire beginning around 8:45 PM, about the time that the firemen made entry through the front doors of the restaurant. At the beginning of the tape, the video confirmed the absence of burning below the ceiling within the restaurant early in the fire, and contained images of a large plume of flame erupting from the roof of the building near the southeast front of the restaurant.

Investigation indicated that the fire was largely confined to the area above the suspended ceiling and below the flat roof, and that it had spread throughout the 7300 square foot building at that elevation. The structure was wood framed with gypsum board interior and wood orientated strand board (OSB) exterior walls, wood roof trusses, and stucco on the exterior wall surface. The building included a large central metal covered arched roof area with laminated wood arch beam supports, and a metal structural framework positioned over the front entry way.

During their investigation, the fire department recovered two neon transformers from the southeast room of the restaurant. One of the neon transformers was found on the floor near the southeast corner of the room close to the east wall, while the other remained attached to the east wall just below roof level and about 20 feet from the southeast corner of the building. Their investigation led them to conclude that the area of origin of the fire was in this southeast room where they identified two V-shaped burn patterns on the east wall that represented the lowest burn areas in the building (see Figure 1).

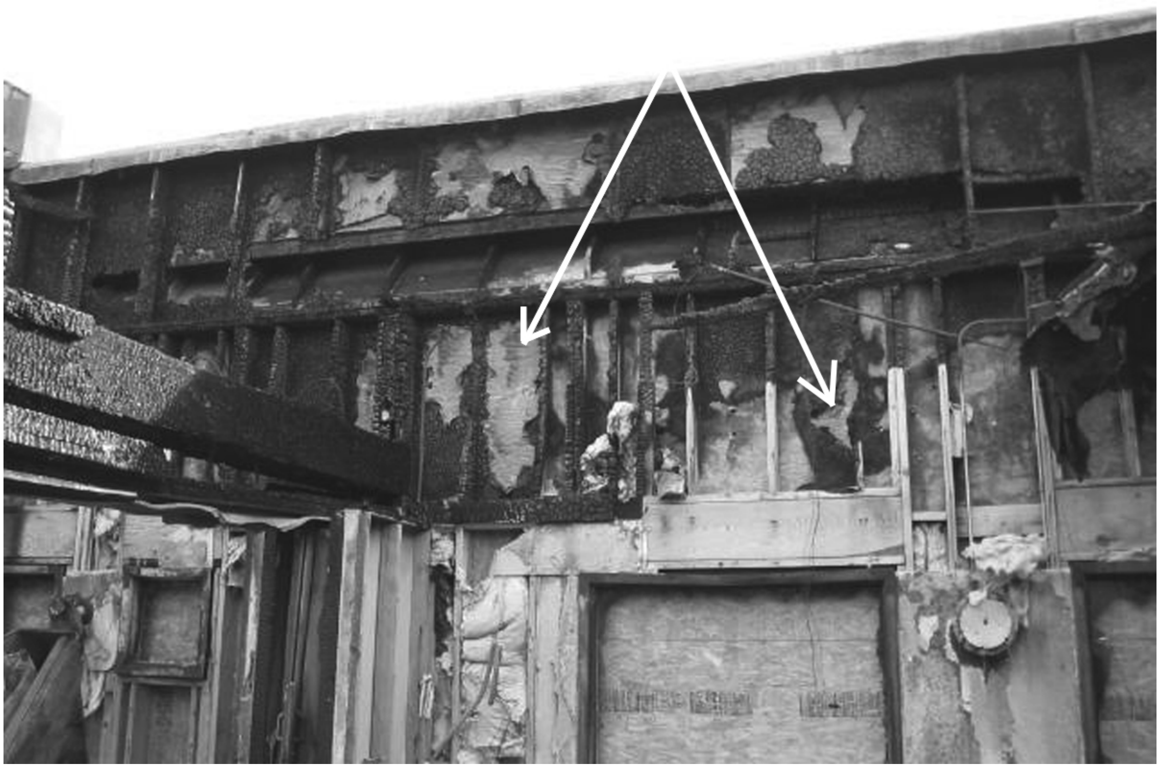

Figure 1 - Two v-patterns in area of origin

Subsequent investigation identified two additional neon transformers on the floor next to the east wall. One of the transformers was found about 13 feet from the southeast corner of the building, and the other on the floor along the northern portion of the east wall. It was then determined that of the four neon transformers that were recovered from the east wall area, two of them had been used for neon outline lighting on the exterior east wall, and two had been used for block channel letters, which spelled out the name of the restaurant on the east wall near the south end of the building. It was further determined that the block letters had recently been removed, and the high voltage wire (commonly called GTO wire) and flexible conduit, which had supplied power to the neon channel letters, had been pushed back through the holes in the exterior stucco wall, and the holes subsequently patched with stucco patch.

Investigation then determined that the neon transformers that supplied power to the block channel letters had not been disconnected from the primary power source when the letters were removed. Additionally, it was discovered that the new occupant leaseholder had turned on electrical power to the circuits that supplied the primary power to those transformers the day before the fire. A timer limited power to the transformer circuits during the hours of 5:00 PM to 12:00 PM on the evening before the fire and on the evening of the fire.

Investigation concluded that the fire patterns indicated that the point of origin of the fire was at the V-pattern which was approximately 13 feet from the southeast corner of the building, where two of the secondary output high voltage GTO wires from the neon transformers and their aluminum flexible conduits, would have been located after they were disconnected and pushed back into the wall from outside the building.

Close inspection of the V-pattern at the point of origin indicated burn-through of the OSB on the inside surface of the exterior wall and scorching of the stucco, all the way through the wall. Signs of scorching were observed on the internal and external surfaces of the stucco at this location (see Figure 2 and Figure 3). Additional photographs are available at www.wendellhull.com.

Figure 2 - Stucco scorching inside at point of origin

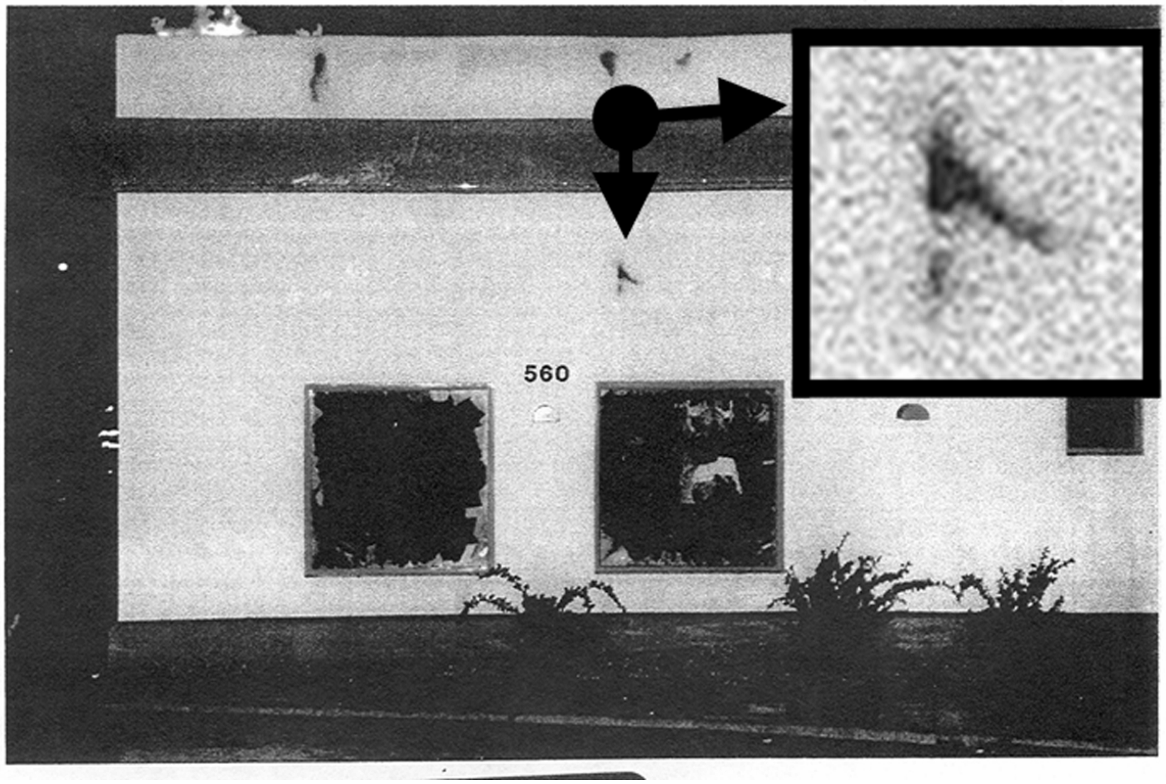

Figure 3 - Stucco scorching outside at point of origin

Further investigation indicated the second larger V-pattern (see Figure 1), which was approximately 19 feet from the south corner of the east wall, was primarily caused by the asphalt which ran out of the neon transformer that had remained attached to the wall, but had tipped on its side, spilling the asphalt down the wall during the fire.

NEON TRANSFORMER APPLICATIONS

Neon transformers produce high voltages that are necessary to cause gases, such as neon and argon, to give off visible light that can be used for signs and for outline lighting on portions of buildings. They are widely used for signs that identify businesses. The typical application has neon tubes that are formed into letters or object shapes, some of which are contained inside block channel letters. The latter commonly have colored lenses that cover the external surface of the letters and provide for the creation of letters with a multitude of colors. The length of neon tubing a neon transformer can adequately power depends on the diameter of tube and the type of gas used in the tubing. Tables are provided by neon transformer manufacturers that can be used as a guide in evaluating a given installation. They also provide guidelines on how best to arrange a sign layout with respect to the transformer for optimum operation. The guidelines point out that the neon tube load on the transformer should be balanced, and that there is a need to limit flexible metallic conduit to no more than 20 feet total and flexible non-metallic conduit to 100 feet in the secondary circuit of a sign installation. The conduit is normally connected to facility ground (via the wire with green insulation or bare wire). Figure 4 shows a typical neon transformer installation.

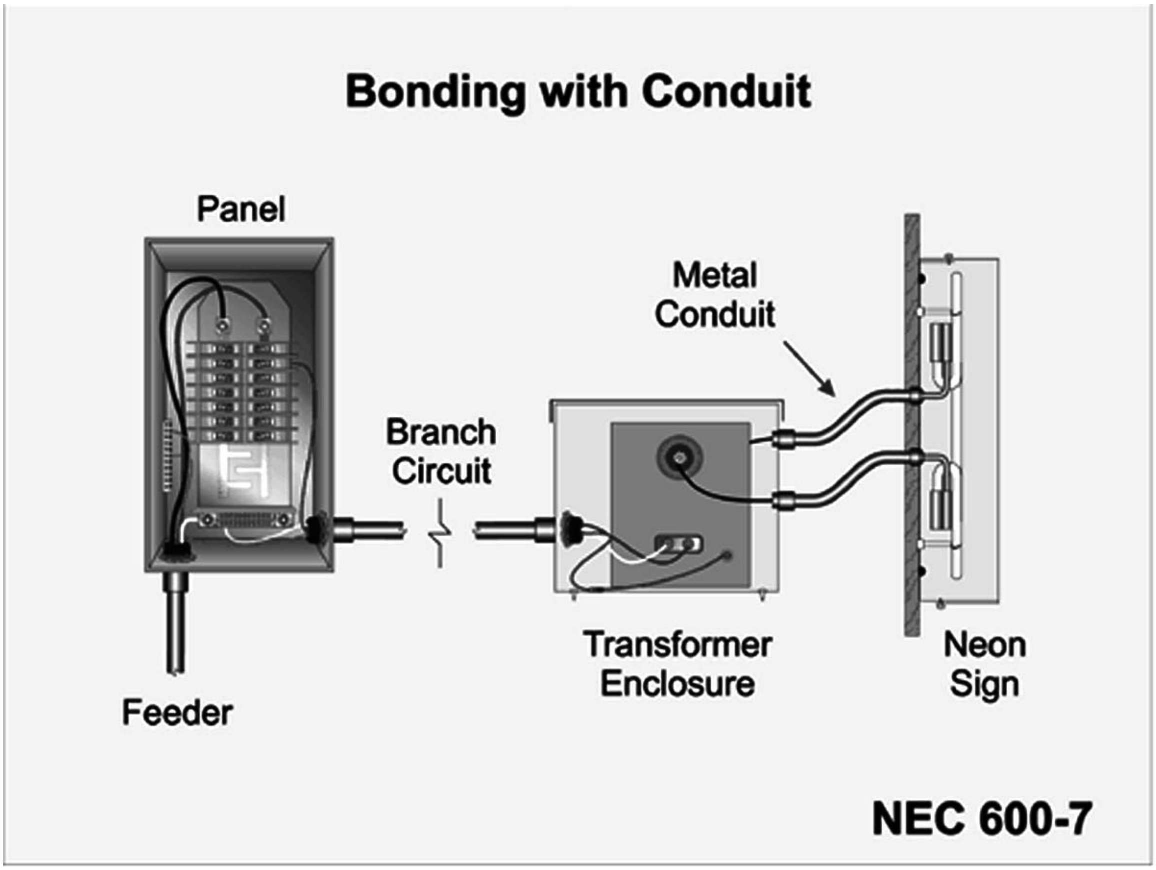

Figure 4 - Typical neon transformer connections

NEON TRANSFORMERS

A photograph of one of the recovered neon transformers from the subject fire and an exemplar new transformer is shown in Figure 5. Typical neon sign transformers range in size from approximately 3”x 6” x 8” to 5” x 8” x 12” and weigh up to about 25 pounds. Part of their weight is associated with the asphalt with which they are filled. The asphalt serves as an insulator, a heat sink, and for the purpose of muffling noise produced by the transformer windings.

Figure 5 - Recovered and new neon transformers

The primary 120 volt input to the transformers is boosted to output voltages that range from 3,000 to 15,000 volts. The output current from the transformers are magnetic shunt limited and normally limited to output currents of 30 or 60 milliamperes. This current limiting of the secondary circuit makes it possible to have a sustained short of the secondary circuit for an extended period of time without damage or tripping a primary circuit breaker for transformer models that do not have secondary ground current interruption protection. These transformer configurations, referred to as secondary ground center tap neon transformers, come in both self contained and the non-self contained models. The non-self contained model requires the transformer to be mounted inside a metal box (see Figure 6).

Figure 6 - Non-self contained neon transformer in metal box

Internal electrical characteristics of these neon transformers have varied over the last decade, partially as a result of efforts to reduce their propensity to start fires. The changes were initiated starting with the 1996 National Electrical Code (NEC), and subsequently in the 1999 and 2002 NEC. Underwriters Laboratory (UL) introduced a new standard in 1996 UL 2169, which replaced their earlier standard UL 506, and redefined the requirements for neon transformers that reflected the changes made in the applicable portions of the NEC. The NEC change incorporated a Secondary-Circuit Ground Fault Protection (SGFP) requirement for neon transformers. The SGFP's primary function is to prevent excessive current flow from the transformer secondary to ground, a condition that has been known to cause fires associated with neon signs in the past.[1] The SGFP does this by interrupting primary power to the transformer when it senses a ground fault current on the secondary circuit of the transformer. Analysis of the electrical circuitry in some of the SGFP systems understood to be in use has led to the conclusion that a secondary short that produces a balanced load, e.g., both outputs arcing to ground simultaneously, may not trip the SGFP feature. The investigator should consider the potential implications of this observation in those instances where the neon transformer was located near an area of origin of the fire, even though the neon transformer appears to be equipped with the SGFP feature.

The new NEC and UL requirements, however, did not make it mandatory to replace neon transformers that were previously installed. They also allowed earlier models which did not have the SGFP, that were currently in the manufacturing, warehousing, and marketing pipeline, to continue to be installed in the United States through October 31, 2002. The new requirements were also not imposed on transformers that were destined for foreign markets.

It is understood that the SGFP has resulted in significant reductions in neon transformer associated fires, however many of the earlier model transformers remain in service. The fire investigator should therefore take particular notice of the presence of neon transformers when they are found in or near an area of origin of a fire, and consider their potential as an ignition mechanism in the fire.

The NEC requirements prescribe installation practices and dictate the type of connections that sign installers should use between the neon transformer and various components of the neon sign or neon outline lighting system. It also requires that the various components of the transformer, the transformer containment box (if one is used), and the metallic components of the sign system be grounded. Failure to follow these requirements and good installation practices can lead to a fire. It is of interest that sign installers are many times not required to be licensed.

Particular installation precautions are needed for sign systems that are subject to wet conditions. The need for the latter is due to the strong tendency for arc tracking to occur in the presence of the high voltage outputs of neon transformers.[2]

NEON TRANSFORMER TESTING

In an effort to evaluate the viability of the neon transformer and its secondary leads as an ignition mechanism for combustible materials that are common to structural fires, exemplar transformers were obtained and a test mock up built for fire testing. The mock up included 2” x 6” structural components with 7/16” OSB external paneling covered by black paper, wire furring and stucco. The mock up wall section was similar to the construction at the restaurant fire discussed earlier. The transformers used for the tests were rated at 12,000 and 15,000 volts.

During the early testing of the transformers, it was noted that arcs were readily created between a large number of potential points. These points included the opposing lead from the opposite end of the transformer, the leads from two different transformers, grounded nails, grounded stucco furring, grounded staples, previously charred wood surfaces, grounded channel letter boxes, and moist surfaces in the conductive path. Since these sites are common to many locations where neon sign transformers are used, the potential for inadvertent circumstances arising that could bring about sustained arcing and ignition of combustible materials becomes readily apparent.

In conjunction with the observations of the potential for multiple arcing opportunities, as noted above, it was observed in early testing that arcs could be initiated through air over substantial distances. It was found, for instance, that a 12,000 volt rated transformer could initiate and sustain an arc between its two GTO output wires over a distance of ¾” without great difficulty (see Figure 7), while a 15,000 volt rated transformer could initiate and sustain an arc in air over a distance of 1”. Surprisingly, this far exceeds the commonly accepted 75,000 volts per inch rule of thumb for arcing in air. It is thought that the difference is potentially associated with the shape of the pointed GTO wires compared to arcing between relatively large spherical electrodes believed to have been used in the test configuration for the classic rule of thumb testing.

Figure 7 - Three quarter inch long arc from a 12,000 volt neon transformer

Another characteristic observed during the testing, was that once an arc was struck, the arc length could be extended to a greater length by simply moving the two objects that were arcing away from each other. An interesting aspect of the long arc lengths that these transformers can create is that a greater opportunity exists for a nearby combustible material to be ignited. This is true due to the extended exposure surface area that an ignitable fuel would have in terms of where the fuel would need to be with respect to where the arc is located. It is also of interest that temperatures of 4,000 to 6,000 degrees Fahrenheit within the extended arc would be continued for a long period of time since the low current (30 or 60 mA) arc would not trip the primary circuit breaker that would be supplying power to the transformer nor would the transformer be significantly overheated since it is operating within its designed current delivery rating. In the testing that was conducted, a variety of grounding conditions which resulted in sustained arcs were investigated. These arcs were, in turn, positioned against or close to wood structural components, such as 2” x 6” pine lumber and 7/16” thick OSB. It was found that with sustained exposure of these wood components, particularly for locations where the heat produced by combustion of the wood was relatively contained, the wood would ignite and a sustained fire could be initiated from the output of the neon transformer. Figure 8 shows an example of burning resulting from the tests.

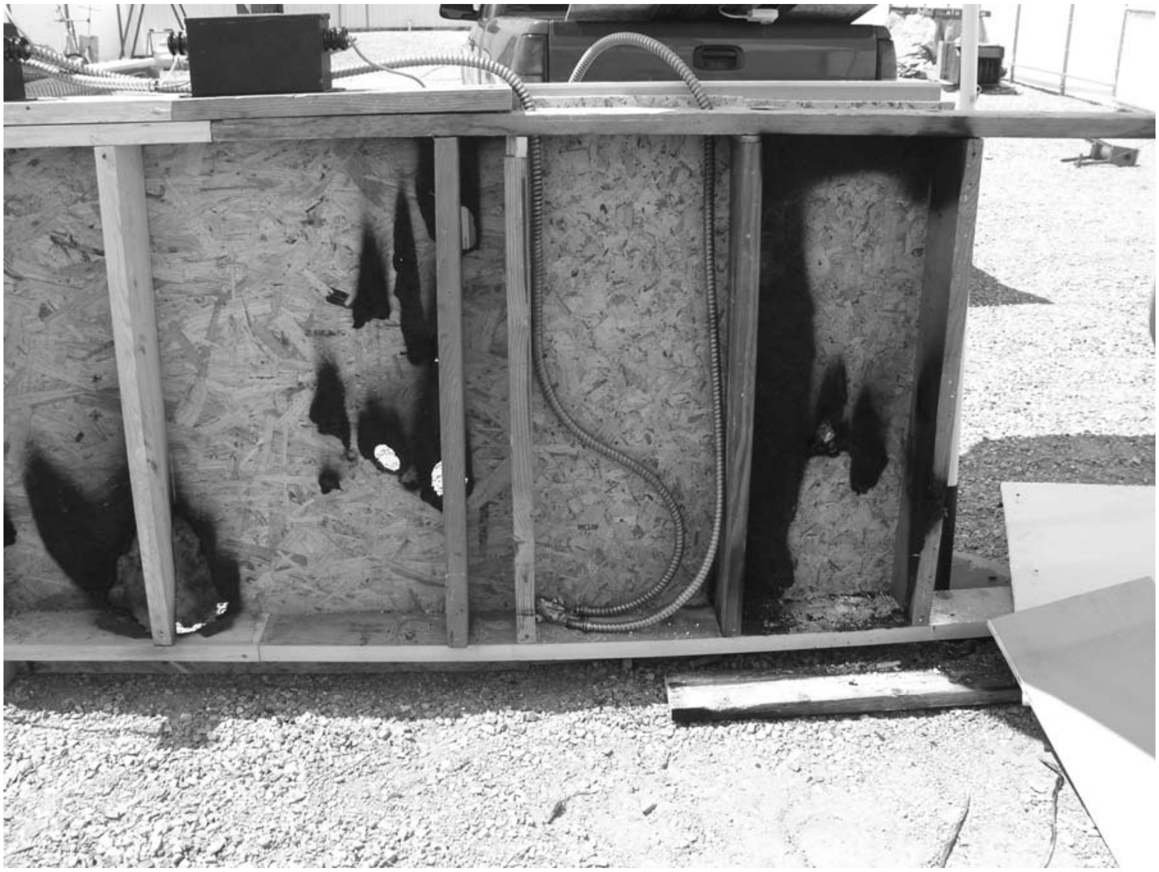

Figure 8 - Neon transformer testing burn patterns

Additional testing on wet wood surfaces indicated that long arc tracks can be produced from the high voltage output of neon transformers. Arc tracks of over one foot were readily created with the exemplar transformers (see Figure 9).

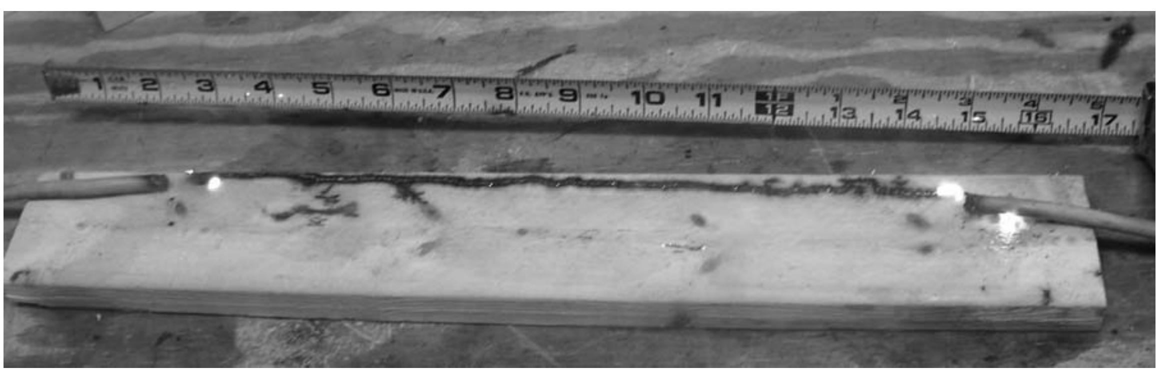

Figure 9 - Arc track on wet wood surface

CONCLUSIONS

Investigation of a building fire using standard fire scene analysis methods led to the conclusion that a neon sign transformer initiated the fire. Careful observation of the fire patterns and evidence from the scene provided sufficient data to draw this conclusion. Characterizing individual exemplar transformers, and initiating fires using them on simulated fire scene structures, verified the conclusions drawn from the fire investigation. Subsequent testing of exemplar neon transformers confirmed that the high voltage secondary output of these transformers, particularly those which do not have the SGFP feature, can create sustained arcs which can, in turn, ignite wood structural members as the first fuel in a fire. They can also cause arc tracking in wet conditions, which has been attributed as the cause of many fires in the past.[2]

ABOUT THE AUTHORS

Wendell C. Hull is a forensic engineer with 30 years experience in the field. He owns a forensic engineering and testing business in Las Cruces, New Mexico. Wendell taught mechanical engineering for 10 years at New Mexico State University. His company, Wendell Hull & Associates, Inc., provides forensic and testing services throughout the United States and in many foreign countries.

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ENDNOTES

[1] Kilgore, W. Ronald, “Neon Lighting Fires”, Fire Findings VOL. 11 NO.3, (2003)
[2] Kilgore, W. Ronald, “Neon Signs as a Fire Cause”, Fire and Arson Investigator, (1994)