NATIONAL FIRE INVESTIGATOR

Summer

2017

FIRE RISKS DUE TO UNINTENTIONALLY ENERGIZED METAL STRUCTURES

Take a look at one of the ISFI 2016 papers.

NEW EXCITING CHANGES AT NAFI

Take a look at all the new things happening with NAFI.

2017/2018 TRAINING SCHEDULE

Great upcoming learning opportunities!

The official publication of NAFI,
The National Association of Fire Investigations

TABLE OF CONTENTS

Summer 2017

Follow NAFI on

President's Message

Welcome Members,

It is with great sadness that I write this message to the NAFI members on the heels of our Chairman of the Board, Patrick M. Kennedy's passing. But Patrick wouldn't want us to mourn him, so let's take a minute and reflect on his contributions and influence on the Fire and Explosion Investigation Community.

Patrick was an avid proponent for the proper education and training of individuals in the Fire and Explosion Investigation field, having trained thousands of investigators himself. Along the long list of Patrick's accomplishments are; Patrick was vital in initiating the first certification program (CFEI) for our industry, he was a charter member of the NFPA Technical Committee responsible for NFPA 921 – Guide for Fire and Explosion Investigations and was a well-known and respected lecturer. During his long career, Patrick conducted and presented technical research at conferences like Inter-Flam, Fire and Materials and the International Symposium of Fire Investigation Technology (ISFI). ISFI was a pet project for Patrick, it was an avenue to have fire investigators, fire researchers, manufacturers and engineers come together to present the current research for the fire and explosion community. The list of his accomplishments is endless and his absence will be noticed.

One thing for sure, we lost a great colleague, mentor, investigator, teacher, father, grandfather, husband and friend.

As Patrick would always say "no rest for the wicked" and that holds true for NAFI. NAFI continues to grow in numbers and strength and is moving forward to a productive and vibrant future. I am sure that all of the membership is aware that the NAFI headquarters has moved. NAFI was a long term tenant of John A. Kennedy & Associates and upon Patrick's retirement he made the decision to sell his building which meant that NAFI had to find a new home. The new space is working out wonderfully and we are excited to set some roots down here. I want to extend a heartfelt thank you to the NAFI office staff for making the move seamless.

Sincerely,

Ronald L. Hopkins, CFEI, CFII, CVFI

Meet our New Chairman of the Board

This year has brought about a lot of changes, good and bad, for NAFI. After the passing of our long time Chairman of the Board, Patrick Kennedy, we have had to dry our eyes and keep things going strong. With that said the NAFI Board of Governors has unanimously elected a new Chairman of the Board, Kathryn Smith. The Board of Governors did not have to look far for a new Chairman as Kathryn was our Vice Chairman of the Board. We welcome Kathryn into this new position with years of fire investigation experience, NAFI Board of Director experience and NFPA 921 Committee experience.

"I am humbled and honored to have been elected as the new Chairman of the Board of Governors and am excited to step into this new role. Patrick was a true asset to NAFI and the fire investigation community as a whole, he had a passion for educating/training fire investigators. I am hopeful that I can continue his legacy and play a vital part in growing NAFI, providing first class training programs and helping shape the future of the fire investigation industry.

I am no stranger to the dirty fire scene, I started my career as a full time fire and explosion investigator with John A. Kennedy & Associates over 15 years ago. Through the years I have had the pleasure of working with, learning from, and sitting on committees with some of the best in our industry. Since 2003, I have served as the alternate NAFI representative on the NFPA 921 committee. As I hang up my work boots, I plan on taking all of my technical experience to help drive our amazing organization forward."

Kathryn will be a permanent fixture in the NAFI office and is available for comments and questions at KSmith@nafi.org.

New NAFI Headquarters

Boxes are unpacked, signs are up and we are all settled into our new headquarters. Same great NAFI with a new address. Feel free to stop in and say "Hi". 4900 Manatee Ave. West, Suite 104, Bradenton, FL 34209

You can find NAFI here, at our new office suite.

FIRE RISKS DUE TO UNINTENTIONALLY ENERGIZED METAL STRUCTURES

Michael C. Stern, Ph.D., P.E., CFEI
Exponent, Inc., USA

Sean C. O'Hern, Ph.D., P.E., CFEI
Exponent, Inc., USA

Timothy L. Morse, Ph.D., P.E., CFEI
Exponent, Inc., USA

Justin Bishop, Ph.D., P.E., CFEI, CVFI
Exponent, Inc., USA

Harri Kytömaa, Ph.D., P.E., CFEI
Exponent, Inc., USA

ABSTRACT

Ungrounded electrical equipment can lead to a fire within a home. If electrical equipment in a home is not properly grounded, then an electric fault may cause metal structures (such as HVAC ducts, metal framing, or screws, nails, and bolts) to become energized without triggering an overcurrent protection device. Electrical connections between these energized materials and grounded objects can lead to prolonged self-heating that can cause ignition in combustible materials such as wood framing, cellulosic insulation, and other lightweight combustibles. Alternatively, molten metal that is capable of igniting lightweight combustibles can be ejected if the energized surface contacts a grounded objected. This paper presents results from experiments performed to investigate conditions that cause fires as a result of stray energization of electrically conductive construction items. Resistances, types of nearby combustibles, and other factors were evaluated.

INTRODUCTION

Electrical fires represent a significant fraction of residential fires in the United States each year. In 2011, the National Fire Protection Association (NFPA) estimated that 47,700 fires responded to by fire departments were related to electrical failures or malfunctions.[1] The NFPA estimated that many more than this, potentially more than ten times this number, occur but go unreported.[2] Electrical fires represented 13% of residential fires from 2007 to 2011. While the ignition mechanisms related to high resistance connections, arc flashes, or electrical sparks are generally understood, especially in the context of common electrical equipment such as breaker panels or outlets, less study has been conducted on the details of these mechanisms in unintentionally energized metal structures that are not intended to carry current.[3]

This paper considers the effects of energized metal structures, such as HVAC ducting, steel structural items, and metal piping, that are not intended to become energized. Generally, these components can become energized due to improper electrical installations and grounding and can also occur if the insulation of electrical wiring becomes compromised in the proximity of metallic construction materials.[4]

In the event that such a metal structure does become energized, both a fire hazard and a shock/electrocution hazard are created. The risk of a fire is dependent on several factors including the mechanisms by which the energized structure may interact with nearby grounded conductors, the circuit resistances involved, and the nearby fuel packages. Unintended electrical connections can be generated between conductors in a multitude of ways resulting in, for example, very small contact areas or high resistance connections through corroded surfaces.

In this paper, two types of unintended electrical connections that can occur in homes are evaluated both in the context of an energized HVAC duct. In the first configuration, a grounded nail directly contacts an energized steel HVAC duct. Nails can become grounded in homes through contact with grounded objects, for example through a support strap for a water or gas pipe In a second configuration, an energized HVAC duct interacts with a grounded junction box through a metal strap and a drywall screw that secures it. The fuels considered for these scenarios were common lightweight combustible materials representative of what commonly exists in attics, basements, or joist spaces where these electrical faults are likely to occur.

The last parameter that was investigated was the resistance of the overall circuit. This resistance is the sum of the resistance of the conductive path that energizes the unintended conductor, the resistance to ground of the grounded object that interacts with the unintended energized conductor, and the resistance between the energized and grounded object. In cases where both the unintentionally energized conductor and the grounded conductor are connected directly to the branch circuit wiring through the house, this resistance can be around an Ohm or less. If, however, one of the connections is through an electrical load, such as a set of lights, the resistance of the circuit can be significant. For this reason, we considered resistances of near zero and six Ohms to represent both potential circuits.

EXPERIMENTAL METHOD

Two experimental setups were used in this testing. Both setups were supplied by 20-amp circuit breakers.

Energized Duct / Grounded Nail Test Setup

In these tests, a grounded bright common 4d 1-1/2” nail was placed in contact with a section of HVAC ducting which, through a high current (60 amp) switch, could be energized with standard household 120 VAC electricity through a 20-amp breaker. A lightbulb was installed in parallel in the circuit to indicate when the circuit was energized. This test was performed in three configurations:

- With minimal resistances in the circuits (i.e. just the low resistance inherent in the wiring and connections)
- With a 6 Ohm of resistance in the circuit between the nail and the ground (i.e, representative of an electrical load)
- With minimal resistance and a parallel minimal resistance path to ground on the HVAC duct (i.e., not through the nail)

A circuit diagram showing the electrical setup for the three configurations can be seen in Figure 1. A photograph of the setup can be seen in Figure 2.

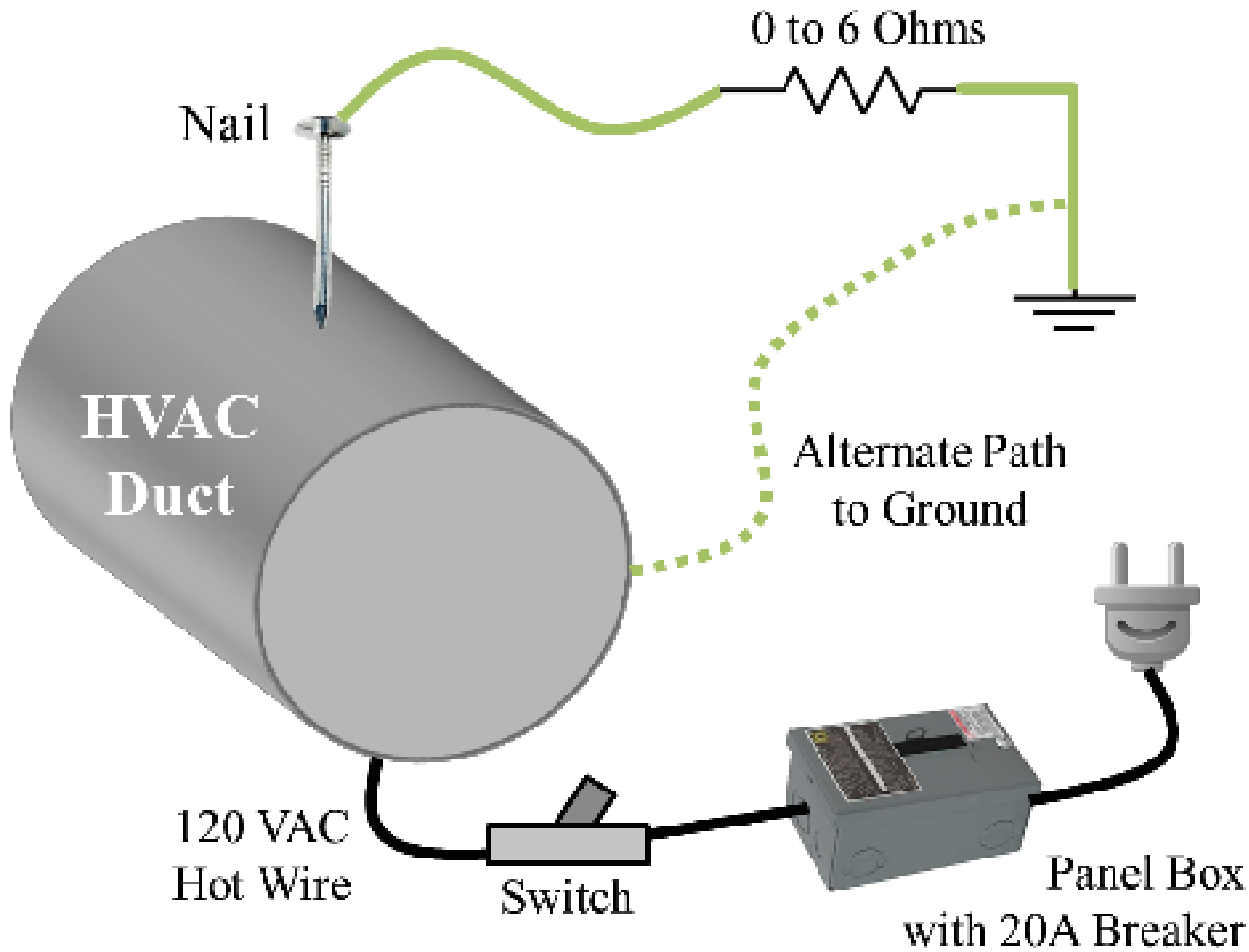


Figure 1 – Simplified electrical circuit diagram for the Energized Duct / Grounded Nail test setup.

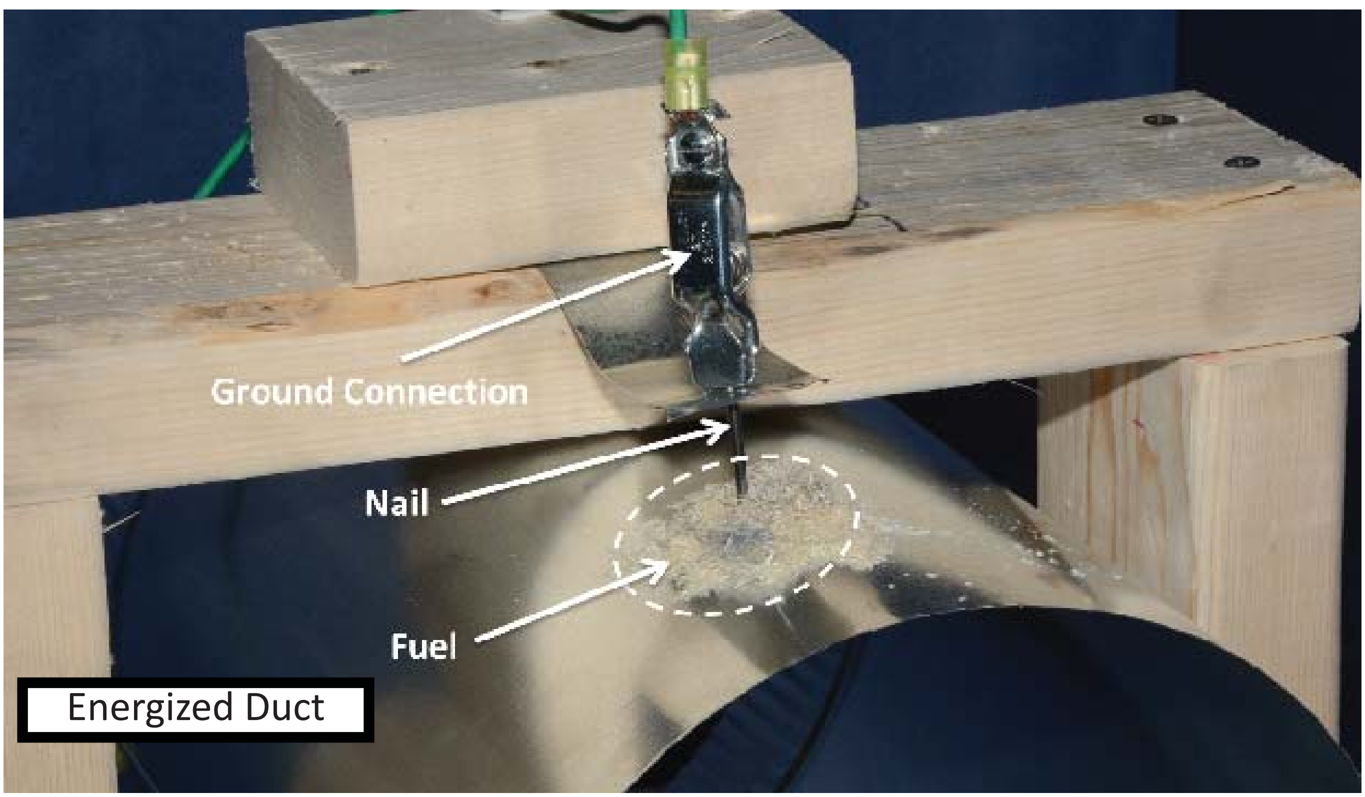


Figure 2 – Annotated photograph of the Energized Duct / Grounded Nail test setup. Energized connection to the HVAC duct is not shown.

NAFI's 2017 & 2018 Training Schedule

2017	2018
2017 International Fire Investigation Training Program: NFPA 921 and 1033 Tampa, FL July 31 - August 3, 2017	**2018 International Fire, Arson and Explosion Investigation Training Program** Dallas, TX March 12 - 16, 2018
2017 Vehicle Fire, Arson, Explosion Investigation Training Program Lexington, KY September 18 - 21, 2017	**2018 International Fire Investigation Training Program: NFPA 921 and 1033** Charlotte, NC July 16 - 19, 2018
Register for NAFI training programs at www.NAFI.org/learn	**2018 International Symposium on Fire Investigation - ISFI** Itasca, IL (Chicago area) September 24 - 26, 2018

The 2017 Annual NAFI Membership Meeting will be held Tuesday, August 1, 2017 at 7PM in the Ballroom of the Hilton-Tampa Airport Westshore, 2225 North Lois Ave, Tampa, FL, 33607. All NAFI members are welcome.

Great Sources of Fire Investigation Training

NAFI
Live Training Events
http://www.nafi.org/learn

International Association of Fire Investigators (IAFI)
Recorded webinar training
http://www.i-a-fi.org

PATC – Public Agency Training Council
Live and webinars training courses.
http://patc.com/
http://www.fsti.com/

Eastern Kentucky University - EKU
College credit courses in Fire Investigation
http://fireandarsoninvestigation.eku.edu/

National Fire Protection Association - NFPA
Online and live training
http://www.nfpa.org/training-and-events/by-type/online

Fire & Emergency Services Training Institute - FESTI (Canada)
Live Training
https://elearning.festi.ca/festi/views/cart/search/fieldsearch.html?field=productcategory&productcategory.value=fireprevention&operation=exact

CFI Trainer
https://www.cfitrainer.net/
Recorded webinar training

University of Maryland
College courses in FPE
http://www.fpe.umd.edu/home

Voltages across important elements of the circuit were recorded using a high speed Graphtec GL-900 datalogger at a sampling rate of 1000 Hz, sufficient to observe the 60 Hz AC waveforms. Tests were recorded with video and photographs. Because the current during a 6 Ohm test would take a long time to trip the 20-amp breaker, if ever, testing with the 6 Ohm resistor was limited to 20 minutes. The fuel packages in these tests were a mixture of coarse wood particles (saw dust) and lint.

Energized Duct / Grounded J-Box Test Setup

In these tests, a small assembly was fabricated to represent a joist space that is common in an attic or basement setting. In this space an HVAC duct was secured using metal strapping that was attached to 2" x 4" wooden members using 2" drywall screws. The screws passed through the wood, and contacted a grounded junction box. Six inches of cellulosic insulation was then added to the setup to represent a typical insulated joist space.

Similar to the previously described test setup, the HVAC duct was energized through a high current switch connected to standard household 120 VAC electricity through a 20-amp breaker. A resistor bank was used to create a 6 Ohm resistance in the circuit between the junction box ground connection and the ground of the circuit. A lightbulb was installed in parallel in the circuit to indicate when the circuit was energized.

A circuit diagram showing the electrical setup for the test system can be seen in Figure 3. Photographs of the setup can be seen in Figure 4.

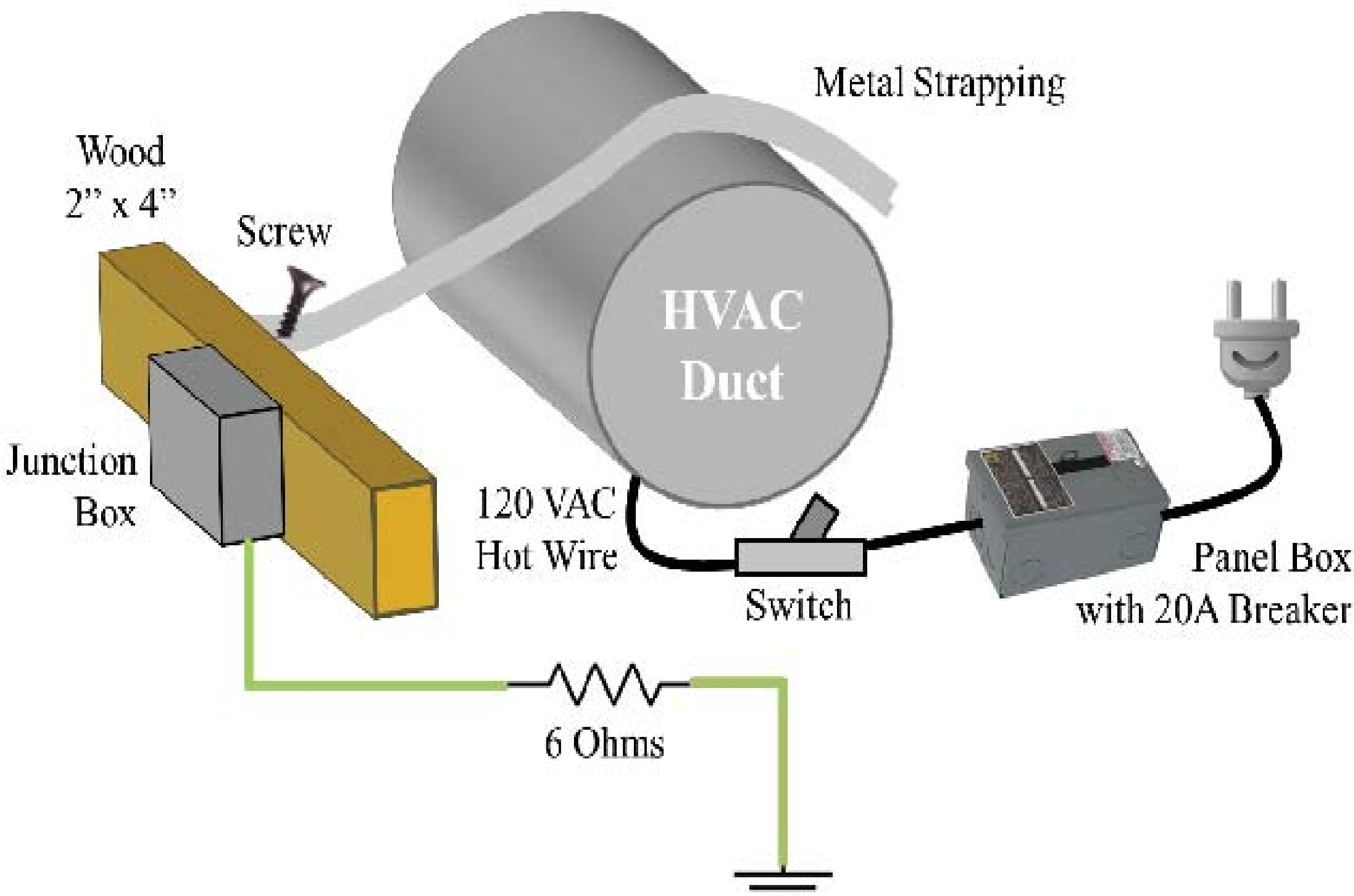


Figure 3 – Simplified electrical circuit diagram of the Energized Duct / Grounded J-Box test setup. Six inches of cellulosic insulation that cover the test setup are omitted from the schematic.

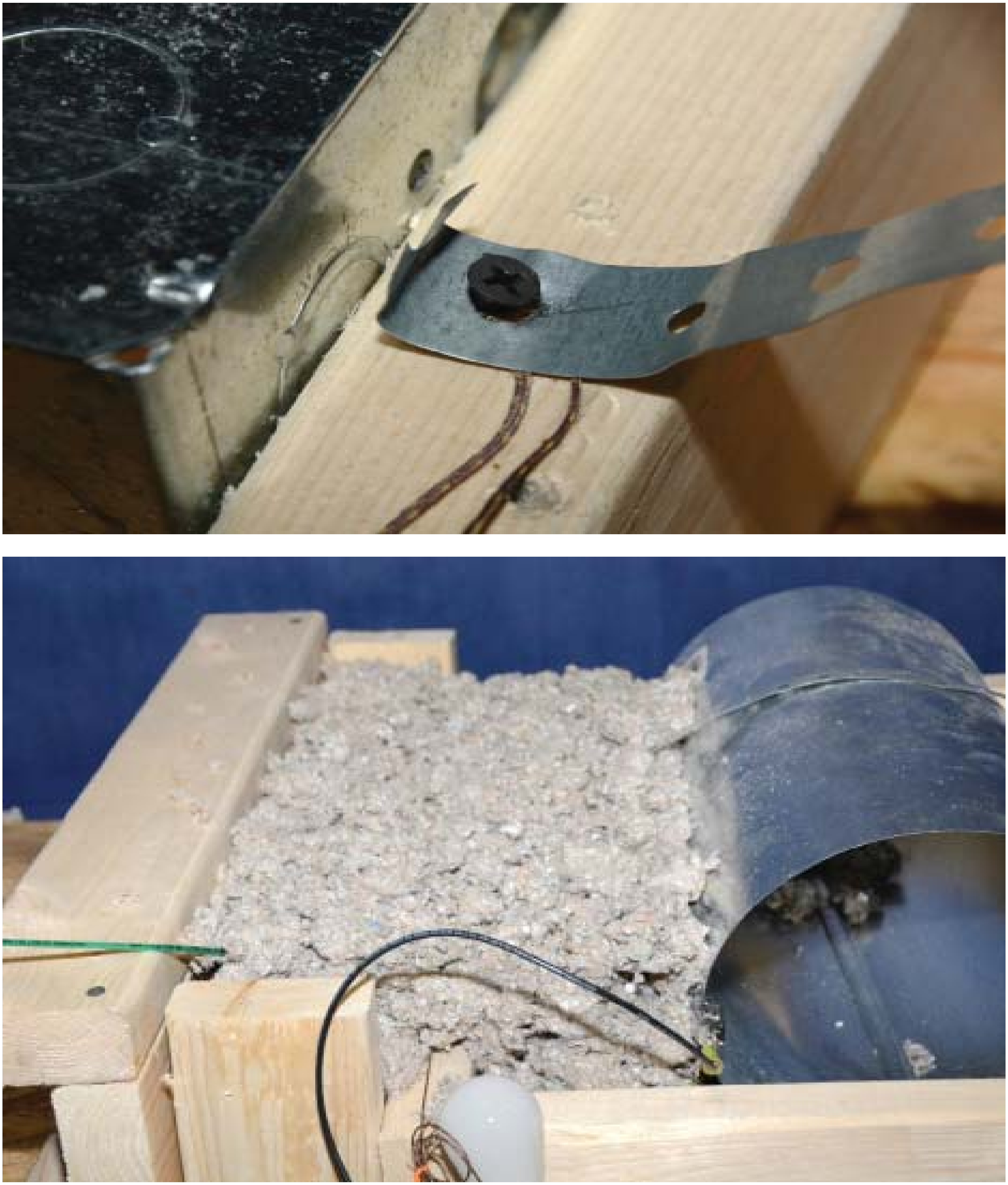


Figure 4 – Photographs of the Energized Duct / Grounded J-box test setup showing the connections between the metal strapping, screw, and J-box (top) and the setup after addition of the cellulosic insulation (bottom).

Voltages were measured across the connection between the duct and the junction box and across the resistors to measure the current flow using the high speed GL-900 datalogger at 1000 Hz. High definition video was recorded during the tests along with photographs and IR thermal images. Thermocouples were located 1/4 inch and 1/2 inch from the screw in the 2" x 4" wooden member and used to record the temperature throughout the testing.

RESULTS

Energized Duct / Grounded Nail Test Results

The results for these tests are presented in Table 1. Ten tests were performed with no added resistance in the circuit; five of these tests were performed with an alternate path to ground. Two additional tests were performed with no alternate path to ground and 6 Ohms of resistance in the circuit.

Table 1 – Results from Energized Duct / Grounded Nail testing

TEST NUMBER	ADDED CIRCUIT RESISTANCE	HVAC GROUNDED?	OBSERVATIONS
1	NONE	NO	METAL EJECTION, FLAMING COMBUSTION
2	NONE	NO	LIGHT OBSERVED NEAR NAIL TIP
3	NONE	NO	METAL EJECTION, NO FLAMING COMBUSTION
4	NONE	NO	METAL EJECTION, FLAMING COMBUSTION
5	NONE	NO	METAL EJECTION, SMOKING, NO FLAMING COMBUSTION
6	NONE	YES	NO OBSERVED METAL EJECTION OR COMBUSTION
7	NONE	YES	NO OBSERVED METAL EJECTION OR COMBUSTION
8	NONE	YES	NO OBSERVED METAL EJECTION OR COMBUSTION
9	NONE	YES	NO OBSERVED METAL EJECTION OR COMBUSTION
10	NONE	YES	LIGHT OBSERVED NEAR NAIL TIP
11	6 OHMS	NO	TEST STOPPED DUE TO CONNECTION ISSUE
12	6 OHMS	NO	NO OBSERVED METAL EJECTION COMBUSTION

In the tests performed with no alternate path and no added resistance, the ejection of molten metal was observed when the circuit was energized and the 20-amp breaker tripped quickly enough that the lightbulb in the circuit never appeared to turn on. In 2 of the 5 tests with no alternate path and no added resistance, the ejected molten metal ignited the fuel package causing flaming combustion that continued until the fuel package was consumed. Figure 5 shows still images of the metal ejection and subsequent ignition observed during testing.

Figure 5 – Still images taken during Test Number 1 with no added resistance and no grounding of the HVAC duct.

Figure 6 shows two voltage versus time plots measured around the duct-to-nail connection for a test without grounding of the HVAC duct (Test 4) and a test with grounding (Test 6). As can be seen in the figure, significantly lower voltages are observed in the presence of an alternate grounding path.

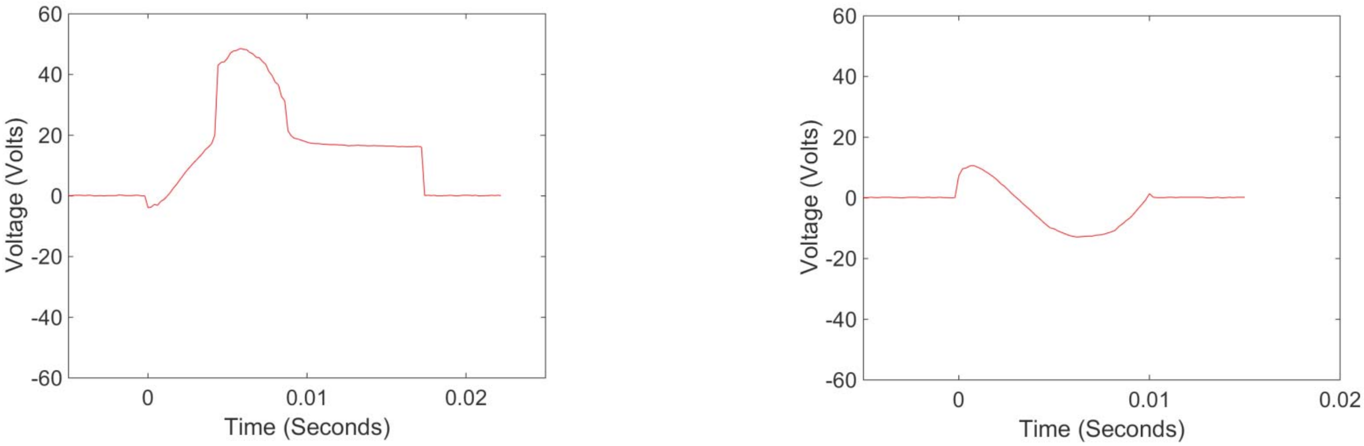


Figure 6 – Voltage versus time plots of the voltage across the duct-to-nail connection without the HVAC duct grounded (left) and with the HVAC duct grounded (right).

In tests where an alternate path to ground existed, no metal ejection or ignition were observed and the breaker tripped quickly enough that the lightbulb in the circuit never appeared to turn on. In Test 12 where 6 Ohms of resistance was added to the circuit, current flowed through until the circuit was intentionally interrupted after 20 minutes as the breaker did not trip. No metal ejection or combustion were observed.

Energized Duct / Grounded J-Box Test Results

In both tests of this type, significant heating at the connection between the metal strapping and the screw was observed. In the first test, the heating lasted 80 minutes but ceased when the connection between the screw and the junction box was lost. In the second test, the connection was intentionally interrupted after 6 hours.

The voltage across the connections between the duct and the junction box for both tests can be seen in Figure 7. The large spikes in the data from the first test indicate losses in contact between the screw and the junction box. In the second test, the voltage across the connections slightly increases over time.

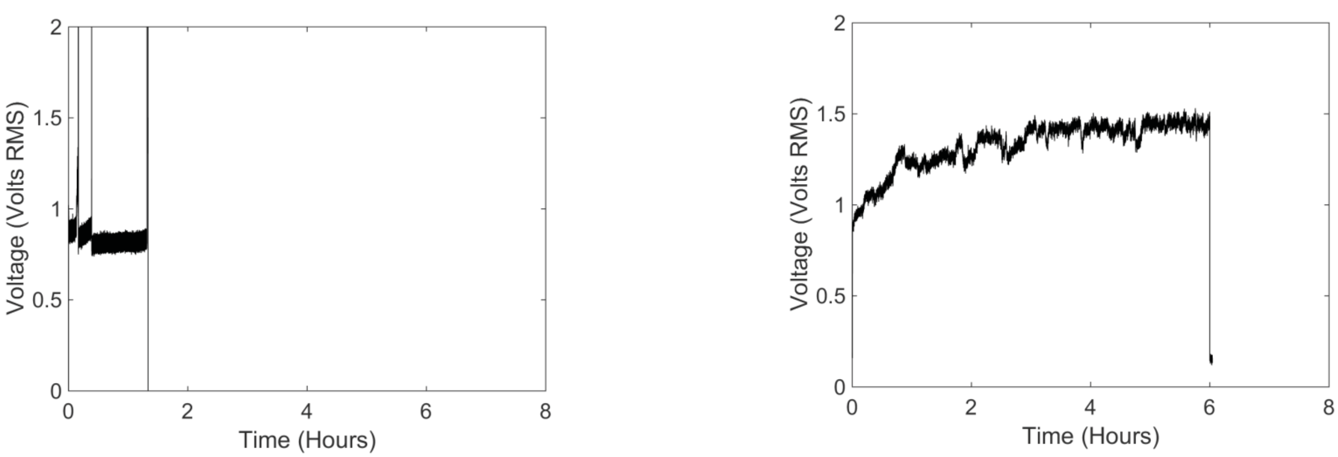
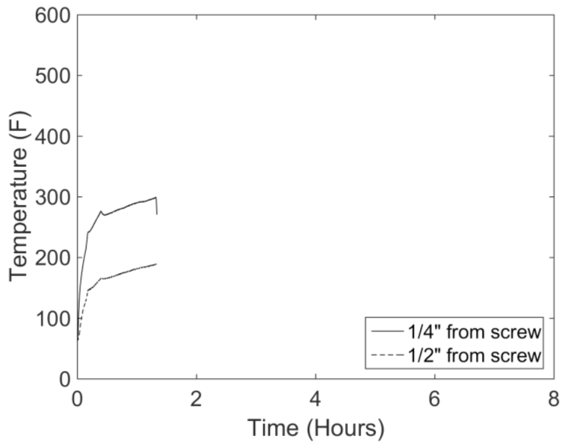


Figure 7 – Voltage versus time curves for Test 1 (left) and Test 2 (right).

The temperatures measured at the thermocouples for both tests can be seen in Figure 8.



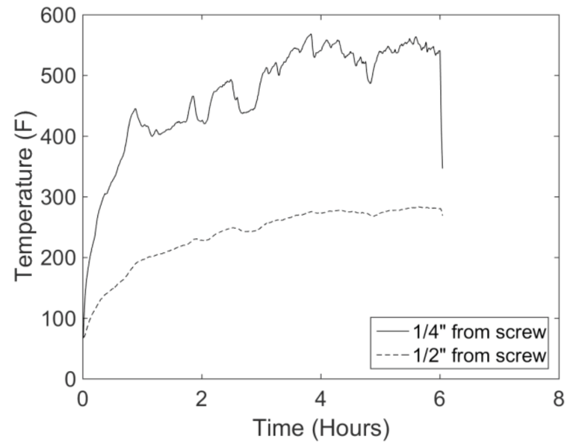


Figure 8 – Measured temperatures during Test 1 (left) and Test 2 (right).

After each test, the cellulosic insulation around the connections between the duct and the grounded junction box was removed to allow for examination of any hot spots. Photographs of the observed thermal damage can be seen for the first and second test in Figure 9 and Figure 10, respectively.

Figure 9 – Photograph of thermal damage to the wood around the screw head taken after the end of the first test.

Figure 10 – Photograph of the thermal damage, evidence of combustion, and consumption of the wood and cellulosic insulation taken after the end of the second test.

DISCUSSION

Electrical fires represent a significant fraction of home fires. The cause of the electrical fault that leads to the fire can be either an improper electrical installation or a flaw in the equipment that existed when it was installed or developed after installation. The testing performed in this paper addressed a specific type of electrical failure: a failure that occurs when an structure that was never designed or intended to carry electrical current does carry current.

In both test setups, ignition occurred at a connection that possessed contact resistance, and therefore generated significant heat locally. In the first test setup, the tip of a bright finish nail possessed a high enough contact resistance relative to the rest of the circuit that sufficient heat was released at its contact point with the HVAC duct to melt the nail tip and eject molten metal. In testing, these molten metal particles landed on nearby combustible materials and were sufficiently hot to ignite them.

In the second test setup, the heat generated at the contact between the strapping and the screw generated sufficient heat over only six hours to consume parts of the wooden 2” x 4” and the cellulosic insulation. Had this heating been allowed to continue over time (days, weeks, or months) in a full home environment, significantly more damage could occur. The energy release rates of the strapping-to-screw contact did appear to be increasing over time based on the increase in voltage across the connection and the slow rise in temperature over time. Temperature accelerated corrosion could further increase the resistance of such connections, which may increase the heat release rate over time.

The elements of this scenario are possible in regular homes. The prevalence of electrical fires indicates that failures of the electrical system can and do occur. Metallic nails, strapping, and other hardware not designed or intended to carry electrical currents are installed ubiquitously throughout homes as are combustible construction materials. Similarly, lightweight combustible debris is almost always present either as insulation material, or build-up in concealed spaces either from construction or build-up of dirt over time.

CONCLUSION

The results of both sets of testing indicate that under certain conditions, electrical interactions involving an unintentionally energized metal structure such as an HVAC duct can become a competent ignition source even in circuits protected by functional circuit breakers. Fires can occur as a result of molten metal particles created and ejected by a high current electrical discharge or through slow heating at a local point of contact with localized electrical resistance. The risk of fires due to slow heating are reduced in areas that are uninsulated and where connections have lower resistances.

Further testing could be performed to identify additional conditions (in terms of resistance load, level of insulation, and resistance of the high resistance connection) in which ignition scenarios are possible. In practice, however, the resistances of the connection and circuit are often difficult to determine due to the damage caused by the fire; therefore, such specific information would likely be difficult to implement effectively. Understanding the possibility and mechanism of electrical fires that occur between conductors that are not intended to be energized, however, may be informative to fire investigators in situations where the origin does not appear to be near energized electrical equipment and improper electrical installations are observed.

Testing results also showed that using proper installation techniques, i.e., bonding and grounding conductors that could become energized, greatly reduces the risk of fires from these scenarios.

ABOUT THE AUTHORS

Dr. Michael Stern is a senior engineer at Exponent where he uses his chemical engineering expertise for the investigation, mitigation, and preventing of accidents, fires, and explosions in residential and industrial settings. He received his Bachelor's degree from Lehigh University and his Master's and Ph.D. from MIT, where he developed advance chemical separation systems for the energy industry. Dr. Stern participates on the NFPA Committee on Electrical Equipment in Chemical Atmospheres and is a member of the ASTM Committee E27 Hazard Potential of Chemicals.

Dr. Sean O'Hern's background in mechanical engineering includes machining, experimental design, and laboratory testing, with particular interest in nanoscale materials fabrication and characterization. He has experience in engineering analyses involving fluid mechanics, heat and mass transport processes, ion transport processes, thermodynamics, electrokinetics, reaction kinetics, and interfacial phenomena. Dr. O'Hern has utilized these skills to investigate ion and mass transport in membrane separation processes, interfacial polycondensation reactions, layer-by-layer growth of metal oxides on two-dimensional substrates, and focused ion beam irradiation of two-dimensional materials.

Dr. Timothy Morse specializes in the engineering analysis and experimental testing of thermal and flow processes and equipment. His project experience has included turbines, compressors, valves, heat exchangers, boilers, furnaces, autoclaves, heat transfer systems, flammable liquids, cryogenic liquids, and medical devices. Dr. Morse has performed engineering analysis for the oil and gas industry, ranging from natural gas extraction facilities to retail motor fuel stations. He also has experience with offshore facilities. Dr. Morse has performed analysis on wind farms and investigated wind turbine failures and wind turbine fires.

Dr. Justin Bishop applies his knowledge of electrical/electronic system failure modes and electrical codes to the analysis and investigation of marine, residential, commercial, and industrial incidents and fires; alleged product and equipment failures; electrical work practices; and hazard studies. Additionally, he applies his knowledge of simulation and measurement techniques associated with electric and magnetic fields, charged ion densities, and charged aerosols to characterize the environment around high voltage DC transmission lines.

Dr. Harri Kytömaa specializes in mechanical engineering and the analysis of thermal and flow processes. He applies his expertise to the investigation and prevention of failures in mechanical systems. He also investigates fires and explosions and their origin and cause. He consults in the utilities, oil and gas, and chemical industries. Dr. Kytömaa's project experience includes consumer products, intellectual property matters, automobiles, aircraft, turbines, compressors, boilers, steam generators, pneumatic and hydraulic systems, instrumentation, nuclear waste management, heat transfer systems, fuel distribution, delivery and storage systems, including LNG facilities.

REFERENCES

[1] J.R. Hall Jr., Home Electrical Fires. National Fire Protection Association, April 2013.

[2] L. Smith and D. McCoskrie, Residential Electrical Distribution System Fires, CPSC, 1987.

[3] National Bureau of Standards, Analysis of Electrical Fire Investigations in Ten Cities, NBSIR 83-2803, 1983.

[4] L. Smith and D. McCoskrie, What Causes Wiring Fires in Residences?, Fire Journal, Vol. 84, 1990.


FLEXIBLE | 8-WEEK COURSES | RESPECTED DEGREES
100% ONLINE
ACCREDITED DEGREES
to fit your life.
• study at your OWN PACE
• 8-WEEK courses
• RESPECTED degrees
Fire, Arson & Explosion Investigation
Fire Protection & Safety Engineering Technology
Fire Protection Administration
LEARN MORE
go.EKU.edu/NAFI
EKU
ONLINE