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A Failure of Imagination

Roofing, the Canadian Electrical Code, and why the status quo isn't working anymore

Fall 2022

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Burned

In 2008, roofers were engaged in replacing the roof on a Save on Foods store in Victoria when a bank of lights inside the store went out. Staff found a tripped breaker and reset it. When the bank of lights again went off, staff again reset the breaker. This happened several times. Eventually, customers and staff reported smelling smoke. The store was evacuated, and someone called the fire department. Public investigators traced the source of smoke to a wire in a concealed ceiling space, damaged by a roofing fastener. The overcurrent generated by the short circuit had been interrupted by the circuit breaker, but because the circuit was repeatedly re-energized by store staff, arcing threatened to ignite combustibles. Fortunately, a sustained fire was avoided.

In 2010 the roof of a senior's residential complex clubhouse in the Greater Vancouver area unexpectedly caught fire. Asphalt shingles on the roof has been replaced three years earlier. Unknown to anyone, a fastener damaged wiring installed close to the underside of the roof sheathing (deck). The injured wire never tripped a breaker before fire erupted, but an independent cause and origin investigation suggested the injured wire had eventually arced through its insulation, igniting adjacent combustibles. Fortunately, no one inside the senior's building sustained injuries.

These are just two stories. There are more. Are they preventable? Yes, but prevention will require the imagination of new possibilities and the courage to embrace considerable change in construction and electrical design practices. In the absence of such imagination, we risk repeating the mistakes of the Apollo 1 disaster. This article explains why.

What you don't know can hurt you

To understand how roofing, electricity, and fires are related, let's begin with how electricity and electrical systems work. Some of what follows is an oversimplification, but this article is not intended to be a primer on electricity.

The way electricity flows can be likened (with limited parallels) to water flowing through pipes. Pipes are used to convey and control the flow rate of water and where it goes. To flow, the water must be pushed. We call this force *pressure*, commonly measured as pounds per square inch, or *psi* (in metric, it is Newtons per square metre). The flow rate of water through a pipe is also measurable (volume per minute or second).

We can describe electricity using similar concepts. The force of the "push" in electricity is called *volts*. Voltage is often referred to as the *potential* in an electrical circuit; a circuit rated for 120 volts is the maximum force in the circuit. Voltage pushes electrons through *conductors* (usually wire, but also fittings such as a light switch, to which wire conductors are connected). The flow of electrons is called *current*. Just as an increase in water pressure increases the flow rate of water, so an increase in voltage increases the electrical current (measured in *amperes*, or simply *amps*).

The inside diameter and thickness of a pipe naturally limits the amount of water that can flow through it before it will burst. Similarly, electrical conductors have limits on the current they can safely conduct, or they will overheat. Thicker (heavier gauge) wires are able to safely conduct more current. The maximum capacity of a wire conductor circuit is referred to as its *load rating*, measured in amperes (amps). You can see the maximum load rating for a circuit by looking at a circuit breaker in a distribution panel (the rating is marked on the toggle of the breaker). Many residential and light commercial circuits are limited to a range of 15 to 30 amps; heavy commercial and industrial buildings will naturally need more power and so their electrical systems with will accommodate higher load limits, but this is because of the type of electrical services these buildings are designed with, a topic this article cannot explore. The concept of *load rating* is important to remember as we take a look at how electrical conductors can be compromised.

A closed-loop circuit of water pipes ensures that the water that is pushed through the pipes returns to its source; shutting off a valve in the circuit stops the flow in the system. Similarly, electrical current flows through a circuit (called a "closed circuit") but will stop flowing if a switch is thrown to break ("open") the circuit.

Voltage in a wire conductor that is connected only to a power source and to nothing else does not make electricity flow; there must be something that draws it through the conducting circuit – an absence of *potential*. That something is referred to as a *load*. The wire conductor through which electricity flows from its source is called the "hot" or "ungrounded" conductor. Without a pathway back to its source, or a pathway to ground, the electrical circuit is open and the *hot* conductor is relatively harmless; it is said to have "potential", but the potential is not realized. However, touch it while you are grounded (connected to the earth through your body) and you will feel a shock which could be fatal. In electrical circuits, the wire conductor on the opposite side of an eletrical fixture or appliance (the load) is called the "neutral" or "grounded" conductor. A third wire conductor, often a bare (uninsulated) wire, is commonly called the "ground" wire, but is also referred to as the "grounding".

Finally, it's important to understand *resistance*. Resistance refers to anything that slows down the free flow of an electrical current. It can be caused by a wire conductor – every wire produces some resistance – or by a load, such as an electric motor. The most important thing to know about resistance is that it produces heat, and although every wire conductor warms from the heat, too much resistance in a wire conductor can produce heat that is detrimental to the conductor and its insulation[1]. Motors and bulbs are designed to dissipate considerable heat; electrical wire conductors are not.

The shocking truth about faults

When too much current is drawn through a conductor (for example, when too many appliances are plugged into one circuit), a situation called *overcurrent* may result. Fortunately, each electrical circuit in a residential and commercial building, designed and built to the present electrical Code, is protected from *overcurrent* by a circuit breaker or fuse. Circuit breakers are devices "designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its ratings" (C22.1-20, "Canadian Electrical Code, Part 1; Definitions). Fuses are simpler devices that also open the circuit in an *overcurrent* situation; too much flow will burn the internal conductor in the fuse, which then opens the circuit.

Electrical wiring in buildings is designed for specific load capacities, and wires are manufactured to dissipate the heat normally generated as current flows through the conductor. If a fault occurs, the cause of the fault could generate more than the usual amount of heat. These types of faults are collectively referred to as resistive (resistance) heating faults[2].

Unfortunately, common electrical circuit breakers cannot detect high resistance faults in an electrical circuit. Damage to a conductor is a common cause of a high resistance fault. Either the conductor is severed, or the conductor is damaged (nicked or even sharply bent). Both scenarios are bad and can generate heat at the fault because of electrical resistance. However, severing does not always open the circuit, and it does not always generate *overcurrent*[3]. What is more, it has been shown that severed conductors can sometimes repair themselves, leaving them in a state where *overcurrent* does not occur but the old injury produces heat that can have long-term damaging consequences[4].

Fasteners do not have to damage a conductor to produce a fault; simply making contact with a conductor, or just damaging its insulation, can produce a line-to-ground fault[5]. The latter scenario is quite insidious; when the conductor penetrates insulation but does not contact the conductor, the reduced separation between the electrical circuit conductor and any adjacent conductor (the fastener) creates the perfect conditions for insulation degredation, which in turn can render the insulation conductive, produce an arc

[1] *Insulation* is the protective sheath around a conductor (wire) that dissipates the little heat generated as electrical current passes through it, and which also prevents accidental short circuits with other conductors or adjacent conductive materials.
[2] NFPA 921, "Guide for Fire and Explosion Investigations": 2004, Section 8.9.2, p. 69.
[3] Babrauskas, Dr. V., "How do electrical wiring faults lead to structure ignitions?". 7th International Fire and Materials Conference, San Francisco: 2001 (https://www.interfire.org/features/electric_wiring_faults.asp)
[4] Shea, John J., "Identifying Causes for Certain Types of Electrically Initiated Fires in Residential Circuits". Conference of Proceedings on "Aged Electrical Systems", NFPA, Chicago: October 2006.
[5] "Causes of Electrical Fires: the hidden danger of arc faults", Siemens Industry, Inc., 2018.

fault[6]. Degradation of the insulation is caused by heat, a phenomenon commonly referred to as "carbonization".

Heat

In its most basic terms, *carbonization* means the reduction of a carbon-based material to its essential element, carbon. *Pyrolysis* is the name given to the chemical process that reduces materials to their elemental state, through the application of heat. Many compounds consist of gaseous elements and carbon. Carbon is a solid. Burning wood in a camp fire or fireplace breaks the chemical bonds between atoms, liberating the gaseous compounds and leaving behind carbon.

Common electrical wiring insulation is polyvinyl chloride (PVC), and PVC is also a carbon-based material (Figure 1). If PVC is continously heated it will carbonize, and since carbon is electrically conductive, electrical current may pass through the wiring insulation and jump (arc) to an adjacent conductor, such as a metal roof deck, a length of conduit, or galvanized strapping. This phenomenon is known to fire investigators as "arcing through char". As you can imagine, that can lead to a very bad outcome.

Carbonizing is a slow process. It can take years, depending on how much heat is involved. But, as a material is gradually reduced to carbon, it not only becomes more electrically conductive, it also becomes easier to ignite. This is because in its carbonized state, it takes less heat energy to bring it to combustion.

Why is this a problem for electrical wiring? Because an electrical fault that generates heat but does not generate *overcurrent* sets the perfect stage for a fire. For example, a roofing screw may damage (injure) a wire but not sever it. Resistance created by the fastener elevates heat at the point of injury, and heat then gradually carbonizes the insulation around the conductor. But that heat also will be conducted by the fastener into deck or framing material, and if that material is wood, it too will begin to carbonize (Figure 2). Once the material near the screw has been sufficiently reduced to carbon, it may take only a few arcs through the charred wire insulation to ignite a fire.

In their November 2021 report on residential fires attributed to electrical causes, the NFPA's publicly accessible research paper authored by Richard Campbell identified that in 33% of fires where the cause was an "electrical failure or malfunction", the wire or cable insulation was the first item to ignite. The second item was structural framing (i.e., wood). Given that the mass of structural framing requires a long exposure to heat energy before the wood will ignite (a short but intense exposure to considerable heat will achieve the same result), one can conjecture that in many if not most of those residential fires carbonization was a pre-condition to ignition.

If you are reading this and asking why statistics about residential wood-framed fire losses are relevant to the subject of membrane roofing, just look at the increasing popularity of mass timber construction and the ever popular concrete podium/wood-framed buildings typically designed for mixed use occupancies[7]. Wood is a relatively inexpensive material that is easy to erect and, when properly protected, can be

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[6] Heating of the conductor and its insulation may occur when the electrical conductor is taxed by appliance use (for example, when a motor in a circuit draws a higher than normal current). Conductor heating can then degrade the insulation around the conductor, eventually reducing some or most of the insulation to carbon; and, since carbon is conductive, it can eventually permit electrical current to arc between the conductor and the fastener. Arcing may produce an *overcurrent* situation, but by then it may be too late; in the presence of combustibles, a fire may occur before the circuit is opened by a breaker.

[7] Construction Canada News, September 13, 2022, concerning a mass timber building in Edmonton (DIALOG Architects). See also Construction Canada News (September 20, 2022) concerning the tallest mass timber building erected in Milwaukee, WI.

enduring (just look at heritage wood-framed buildings in Vancouver or Victoria to see what I mean). The risk to buildings from resistive heating is real, no matter what part of the Building Code they reflect.

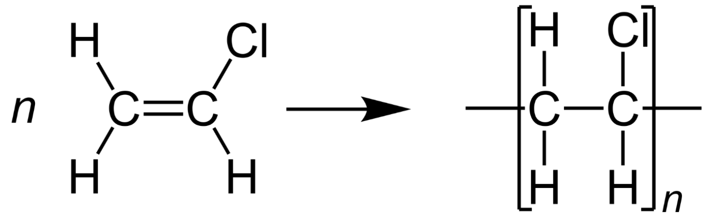

Figure 1: PVC molecule comprised of carbon, hydrogen, and chlorine atoms

I have personally seen the destructive results of carbonization. As a claims adjuster with fourteen years experience handling structure fire claims, I have worked beside both public and private fire investigators, and I can recall at least two fires, both devastating, that resulted from a years-long process of carbonization, the product of injured electrical conductors. One started inside the concealed cavity between the basement ceiling and the main floor. The point of origin was traceable to wiring that had been overstapled[8]. The staple had damaged the conductor, and gradual heating eventually erupted in fire. Fortunately, no one was injured, but the family living in the home lost everything.

A conflict of interests

Membrane roofs are exposed to fluctuating negative pressures generated by wind as it passes over the roof's surface.[9] When a roof is newly built, it must be secured to the structural deck so that it successfully resists those pressures[10]. That is never done with mere guesswork; proven, tested methods are required by the Building Code, because properly securing the roof system to the building is a matter of both public safety and building occupant comfort and health. The Building Code doesn't specify how a membrane roof system must be secured; it only specifies how one can be sure the methods are reliable.

A newly constructed membrane roof system may use screw fasteners, adhesives, or a combination of the two. When screw fasteners are used to secure all or part of the system, their placement must precisely follow a tested or proven pattern, or the roof may fail in a windstorm. One roofing membrane manufacturer I know of tinkered with the number and placement of mechanical fastener on one of their highly successful tested assemblies, to test the viability of an alternate pattern. The test failed miserably.

Subjected to the harshest of conditions, a roof has a limited lifespan. Eventually, at least some of the roof must be renewed. Electrical systems, on the other hand, are permanent. No one ever contemplates renewing their electrical system ever so often; it may be added to, but it will never be removed and replaced because it is worn out.

As a roof system ages, so do the links between each of the materials. When much of an existing roof system is in serviceable condition and it is time to renew the membrane, the designer may find it next to impossible (apart from destructive testing) to assess the integrity of connections between materials,

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[8] NFPA 921, "Guide for Fire and Explosion Investigations", identifies overdriven or misdriven staples as a common cause of electrical faults (Section 8.11.8., page 76: 2004 Edition).

[9] See my article on the subject of wind uplift in Roofing BC, Vol. 18, No. 2 (Summer, 2021)

[10] I use the term "roof" as short-hand for the system of materials that protects a building from the weather. It is not used here to denote the roof structure. I am also using the term to focus specifically on "flat" roofs that are typically waterproofed with a sheet membrane system.

particularly where adhesives were used. In that case, the old membrane can be renewed (left in place or removed and replaced, depending on circumstances) by securing new roof materials with roofing screws and plates. Why use roofing screws? Because regardless of the bonds between materials in the existing roof system, screws fasten the entire *in situ* assembly to the structural deck.

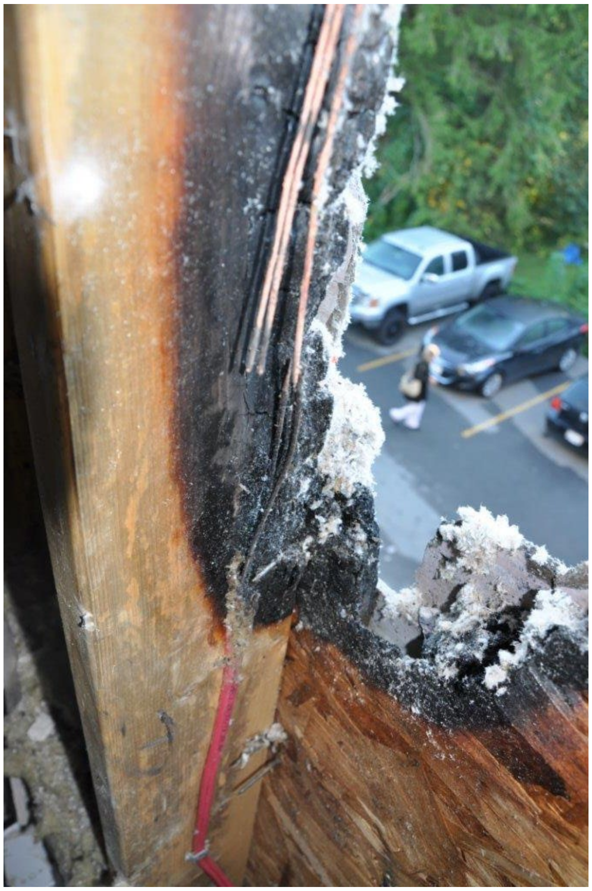


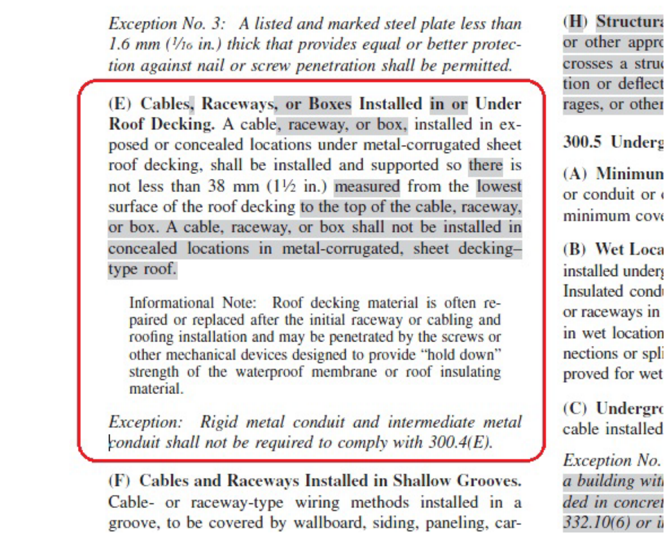
Figure 2: An example of probable carbonization and arcing through char. The fire that burned this wall ignited several years after the siding was installed on the building exterior. The fire was attributed to the combination of long siding nails and improper wiring practices.
(Credit: Fredericton Fire Department)

Roofing screws are made to be self-drilling, and they are very effective at drilling through wood or sheet steel. For a screw fastener to work, it must penetrate into or through a structural deck at least 19 mm (3/4"). However, electrical conduit, junction boxes, or light fixtures often are installed directly beneath or even inside the roof assembly, sometimes before the first roof system is installed[11]. Because the precise placement of screws is essential for the performance of a roof system (new or renewed), the installation of electrical systems beneath the structural deck can conflict with the building code or the specified roof design. When electrical systems are concealed inside spray insulation or obscured behind ceiling materials, roofing renewal becomes challenging and may even be dangerous.

Some who espouse the practice of locating electrical installations inside or immediately beneath a roof assembly argue that electrical wiring can be protected with Rigid Metal Conduit (RMC). Certainly, the NEC took this view in 2008 when they permitted the use of RMC and IMC (Intermediate Metal Conduit) (see Figure 3). But self-drilling screws can easily penetrate either; like smart bombs guided to a target, screws driven through the dense insulation in a conventional roof system will run true no matter how theoretically tough the conduit is.

Others propose protecting conduit installed inside the flutes of steel decking with protective steel plates. Once upon a time, the RCABC also thought that was a sufficient response[12]. But then the British Columbia Building Code changed in 2018, and suddenly roof assemblies had to be designed and built using those tested or proven patterns of securement I mentioned earlier. Screw fasteners formed the backbone of two principal tested assembly types – Mechanically Attached Roof Systems (MARS) and Partially Adhered Roof Systems (PARS). In each

[11] Installation inside the roof assembly is no longer permitted by the Canadian Electrical Code, Part 1 (Rule 12-022), but this has not yet been adopted by the Province of British Columbia.
[12] Technical Safety BC, Information Bulletin NO: IB-EL 2015-05.



Exception No. 3: A listed and marked steel plate less than 1.6 mm (1/16 in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(E) Cables, Raceways, or Boxes Installed in or Under Roof Decking. A cable, raceway, or box, installed in exposed or concealed locations under metal-corrugated sheet roof decking, shall be installed and supported so there is not less than 38 mm (1½ in.) measured from the lowest surface of the roof decking to the top of the cable, raceway, or box. A cable, raceway, or box shall not be installed in concealed locations in metal-corrugated, sheet decking–type roof.

Informational Note: Roof decking material is often repaired or replaced after the initial raceway or cabling and roofing installation and may be penetrated by the screws or other mechanical devices designed to provide "hold down" strength of the waterproof membrane or roof insulating material.

Exception: Rigid metal conduit and intermediate metal conduit shall not be required to comply with 300.4(E).

(F) Cables and Raceways Installed in Shallow Grooves. Cable- or raceway-type wiring methods installed in a groove, to be covered by wallboard, siding, paneling, car-

(H) Structura or other appro crosses a struc tion or deflect rages, or other

300.5 Underg

(A) Minimun or conduit or minimum cove

(B) Wet Loca installed underg Insulated cond or raceways in in wet location nections or spli proved for wet

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Figure 3: Excerpt from the NEC (NFPA 70), Rule 300.4(E)

assembly type, precise fastener placement is critical; vary the location of screws even a few centimetres and the roof may not survive the largest predicted gusts. Protective metal plates suddenly lost their appeal. There had to be a better way, and there is. But before we talk about a better way, we need to be completely honest about the real consequences of not doing things the better way.

Where there's heat, there's fire

Sometimes, roofing screws unavoidably damage the electrical system. Occasionally, the damage is obvious; a fastener bisects an energized conductor and the lights in the building go out. As you can imagine, it's an expensive proposition to repair the damage. I was told of one instance where a screw penetrated an electrical junction box and its cover. The fastener tripped the overcurrent protection device (not before wiring inside the box had burned), but because the junction box cover could not be removed to access the wiring for repairs, the electrical repair contractor was forced to dismantle and replace the entire circuit.

At times, a screw simply nicks the wire, creating a high-resistance fault and resistive heating[13]. This is the type of damage that is most insidious because, I said earlier, it cannot be detected by overcurrent protection devices. Resistive heating causes more electrically generated fires than one might think. A 2008 report by the Ontario Electrical Authority (ESA) suggested that "29% of the electrical fires from 2002 to 2007 were caused by Arcing and 40% from Resistive Heating", but the actual number of fires caused by resistive heating might be higher, as high as 58%.[14] Of course, the data does not imply that the majority

[13] NFPA 921 states that while "conductors that are reduced in cross section by being nicked or gouged are sometimes thought to heat excessively at the nick...calculations and experiments have shown that the additional heating is negligible" (NFPA 921, "Guide for Fire and Explosion Investigations", Section 8.11.8., page 76: 2004 Edition). However, this is contested in a 2018 publication by Siemens Industry Inc. ("Causes of Electrical Fires"). It is also, by inference, contested by John J. Shea in his paper to the NFPA in 2006, "Identifying Causes for Certain Types of Electrically Initiated Fires in Residential Circuits". In his paper, Shea suggests that broken wires can generate *series arcing* which, inside wire insulation, can lead to high heat or a "glowing contact" that, in turn, "can result in copper wire temperatures that exceed the insulation melting point". Eventually, through the generation of char, Shea contends prolonged high heat of this kind can "initiate a fire".

Also see the excellent online article by Marin Coles, P. Eng., CFEI, "Finding Fault: Electrical Installation Failures" (Origin and Cause magazine; May 30, 2019). Coles is a seasoned fire investigator and a specialist in electrical engineering.

[14] Montgomery, Steve. "Required Technology to Prevent Electrical Fire Ignitions", IAEI Magazine: September/October 2011 (https://iaeimagazine.org/2011/september2011/required-technology-to-prevent-electrical-fire-ignitions/)

Figure 4: Mechanical fasteners penetrating the underside of a "corrugated" steel roof deck. The circle indicates a fastener that has penetrated the electrical conduit branch near the junction box.
(Photo: RCABC files)

of fires caused by resistive heating were attributed to damage from fasteners (roofing or otherwise), but it is clear from more than a decade of changes to the US National Electrical Code (NEC) that roofing fasteners pose a serious concern. Canadians should be paying attention to those concerns.

In 2008 the NFPA introduced Rule 300.4(E) to the National Electrical Code (USA, NFPA 70). The rule prohibited the installation of cables or raceways "in exposed or concealed locations under metal-corrugated sheet roof decking" and instead required a separation space of 38 mm (1-1/2") between the electrical installation and the roof deck. Rule 300.4(E) was adopted after significant input from the International Association of Electrical Inspectors (IAEI) because data collected by the IAEI indicated roofing fasteners were damaging wiring and generating both shock hazards and fires. The issue was not blamed on the roofing industry; it was simply understood to be necessary because of shifting methods in building construction to which the NEC had to adapt[15].

Since 2008, the NEC has amended Rule 300.4(E) to include the prohibition of electrical boxes (2011) installed directly beneath the roof deck (Figure 4). A further proposed change to include the prohibition of luminaires (light fixtures) directly beneath the roof deck was on the books for the 2017 NEC but evidently did not receive approval.

Although NEC Rule 300.4(E) is seriously flawed[16], it has significantly paved the way toward a future with fewer shock and fire incidents attributed to damaged electrical installations. Canada has been slow to mirror that progress. In part, this is because the CSA Committee on the Canadian Electrical Code, Part 1 isn't yet satisfied that the issue has enough supporting data to warrant a parallel code change in Canada[17].

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[15] Keith Lofland, IAEI Director of Education (USA), in his October 2017 submission to the Section 12 Subcommittee (Committee on the Canadian Electrical Code, Part 1) stated the NEC changed because "fastening devices used to hold down roofing materials are typically driven through the metal decking as a normal part of their installation", and as such, "where cables and raceways are installed on the underside of the decking and spacing is not maintained between the decking and the wiring, they are vulnerable to damage by roof material fastener…"

[16] Rule 300.4 (E) permits the use of Rigid Metal Conduit and Intermediate Metal Conduit in or directly beneath the roof deck; the erroneous assumption is that RMC and IMC are impervious to self-drilling roofing fasteners, which the NRCA has shown to be false.

[17] In their 127th meeting held in June 2019, the Committee on the Canadian Electrical Code, Part 1 met to vote on regulatory matters. On the agenda was Subject 4007, a submission by the RCABC to introduce a new rule in the CE Code that would provide for a physical separation between roofing assemblies and electrical installations, similar to NEC Rule 300.4(E). The RCABC's proposal was voted down, in part because the Section 12 subcommittee remained

But there is also another reason; CE Code development falls under the jurisdiction of the CSA Group, and although the CSA Committee includes liaison members from the National Research Council, electrical code requirements are somewhat siloed and insulated from the model code process under the CCBFC.

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stalled behind panels designed to allow access, shall be supported according to their applicable articles.

(D) Cables and Raceways Parallel to Framing Members and Furring Strips. In both exposed and concealed locations, where a cable- or raceway-type wiring method is installed parallel to framing members, such as joists, rafters, or studs, or is installed parallel to furring strips, the cable or raceway shall be installed and supported so that the nearest outside surface of the cable or raceway is not less than 32 mm (1¼ in.) from the nearest edge of the framing member or furring strips where nails or screws are likely to penetrate. Where this distance cannot be maintained, the cable or raceway shall be protected from penetration by nails or screws by a steel plate, sleeve, or equivalent at least 1.6 mm (1/16 in.) thick.

Exception No. 1: Steel plates, sleeves, or the equivalent shall not be required to protect rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

Exception No. 2: For concealed work in finished buildings, or finished panels for prefabricated buildings where such supporting is impracticable, it shall be permissible to fish the cables between access points.

Exception No. 3: A listed and marked steel plate less than 1.6 mm (1/16 in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(E) Cables, Raceways, or Boxes Installed in or Under Roof Decking. A cable, raceway, or box, installed in exposed or concealed locations under metal-corrugated sheet roof decking, shall be installed and supported so there is not less than 38 mm (1½ in.) measured from the lowest surface of the roof decking to the top of the cable, raceway, or box. A cable, raceway, or box shall not be installed in concealed locations in metal-corrugated, sheet decking–type roof.

Informational Note: Roof decking material is often repaired or replaced after the initial raceway or cabling and roofing installation and may be penetrated by the screws or other mechanical devices designed to provide "hold down" strength of the waterproof membrane or roof insulating material.

Exception: Rigid metal conduit and intermediate metal conduit shall not be required to comply with 300.4(E).

(F) Cables and Raceways Installed in Shallow Grooves. Cable- or raceway-type wiring methods installed in a groove, to be covered by wallboard, siding, paneling, carpeting, or similar finish, shall be protected by 1.6 mm (1/16 in.) thick steel plate, sleeve, or equivalent or by not less than 32-mm (1¼-in.) free space for the full length of the groove in which the cable or raceway is installed.

mediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

Exception No. 2: A listed and marked steel plate less than 1.6 mm (1/16 in.) thick that provides equal or better protection against nail or screw penetration shall be permitted.

(G) Insulated Fittings. Where raceways contain 4 AWG or larger insulated circuit conductors, and these conductors enter a cabinet, a box, an enclosure, or a raceway, the conductors shall be protected by an identified fitting providing a smoothly rounded insulating surface, unless the conductors are separated from the fitting or raceway by identified insulating material that is securely fastened in place.

Exception: Where threaded hubs or bosses that are an integral part of a cabinet, box, enclosure, or raceway provide a smoothly rounded or flared entry for conductors.

Conduit bushings constructed wholly of insulating material shall not be used to secure a fitting or raceway. The insulating fitting or insulating material shall have a temperature rating not less than the insulation temperature rating of the installed conductors.

(H) Structural Joints. A listed expansion/deflection fitting or other approved means shall be used where a raceway crosses a structural joint intended for expansion, contraction or deflection, used in buildings, bridges, parking garages, or other structures.

300.5 Underground Installations.

(A) Minimum Cover Requirements. Direct-buried cable or conduit or other raceways shall be installed to meet the minimum cover requirements of Table 300.5.

(B) Wet Locations. The interior of enclosures or raceways installed underground shall be considered to be a wet location. Insulated conductors and cables installed in these enclosures or raceways in underground installations shall comply with 310.10(C). Any connections or splices in an underground installation shall be approved for wet locations.

(C) Underground Cables and Conductors Under Buildings. Underground cable and conductors installed under a building shall be in a raceway.

Exception No. 1: Type MI cable shall be permitted under a building without installation in a raceway where embedded in concrete, fill, or other masonry in accordance with 332.10(6) or in underground runs where suitably protected against physical damage and corrosive conditions in accordance with 332.10(10).

Exception No. 2: Type MC cable listed for direct burial or concrete encasement shall be permitted under a building without installation in a raceway in accordance with 330.10(A)(5) and in wet locations in accordance with 330.10(A)(11).

70–144 NATIONAL ELECTRICAL CODE 2014 Edition

Figure 4: Excerpt from the NEC (NFPA 70), 2014 Edition

In June 2019 the Committee on the Canadian Electrical Code, Part 1 voted to adopt Rule 12-022[18]. Rule 12-022 (now part of the 2020 CE Code) prohibits the installation of high-voltage cables or raceways inside a roof system (that is, above the deck and concealed within roofing materials). However, the rule permits concealed installations for "embedded trace heat" wiring and "Class 2 circuits" with an open circuit voltage not exceeding 30 Volts. It also still permits the installation of "exposed cables or raceways" immediately below the roof deck, although the non-binding language in Appendix B to the rule also says that this should not be done "until substantial completion of the roof decking system". Rule 12-022 is replicated below for reference.

Ironically, these various exceptions result in a rule that appears to fall well short of aligning with the first functional statement in the National Building Code of Canada, that a building or its elements must "minimize the risk of accidental ignition" (Div. A, Article 3.2.1.1.).

Rule 12-022 assumes a "corrugated" steel roof deck and does not contemplate organic wood decks which now are coming into vogue in Ontario and Alberta. Furthermore, Rule 12-022 does not contemplate roof system renewal. While a stronger rule would clearly separate every type of electrical system from the roof assembly, critics of that position argue that the lifespan of a roof does not concern the CE Code and that it is up to others to exercise Due Diligence when and if a roof had to be replaced using screw fasteners.

Although Rule 12-022 appears to ignore the consequences of fastener contact with energized conductors and lacks the ambition behind related changes to the NEC (USA), there are some ways designers, owners, and roofing contractors can step up now to design and build safer buildings for the future.

focused on the apparent lack of substantiation behind the RCABC's assertion of fire hazard. Yet their own inquiries with US counterparts indicated the NFPA had substantiated concerns about a fire risk, which was the rationale for their own code change.

[18] In 2015, the RCABC made application to the Committee on the Canadian Electrical Code, Part 1, to change the CE Code and introduce a mandatory separation space between the roof assembly and electrical wiring, boxes, and luminaires. The Code Change Request (CCR) was assigned to the Section 12 Subcommittee as Subject No. 4007. Rule 12-022 was adopted after years of work by the RCABC but is very different from what the RCABC recommended to the Committee on the Canadian Electrical Code, Part 1.

Legally separated

Roofing screws must penetrate through steel decks at least 19 mm (3/4”) and must penetrate into or through wood decks at least 25 mm (one inch, nominal). This is required by screw manufacturers to ensure maximum pull-out resistance. The operative word is “through”, which is measured from the underside of the deck.

> **Rule 12-022** Cables or raceways installed in roof decking systems (see Appendix B)
>
> 1) Cables or raceways installed in accordance with this Section shall not be installed in locations concealed within a roof decking system where the roofing systems utilize screws or other metal penetrating fasteners.
>
> 2) Notwithstanding Subrule 1), the following circuits shall be permitted for installations in locations concealed within a roof decking system:
>
> a) Class 2 circuits in which the open-circuit voltage does not exceed 30V; and
> b) embedded trace heat.
>
> 3) Where wiring is concealed within the roof decking system in accordance with Subrule 2), a warning label shall be affixed
>
> a) at all permanently installed roof access points, where provided; and
> b) in a conspicuous location in the roof area where the wiring is installed.

Often, electricians affix conduit and junction boxes directly beneath a roof deck. Can you spot the problem? Of course. The roof assembly and electrical systems each by themselves have good things to offer, but they make terrible marriage partners[19].

Since fasteners that contact energized electrical conductors can produce resistive heating, and resistive heating can eventually produce a fire, they should be separated. The RCABC’s Guarantee Standards require a vertical separation space at least 38.1 mm (1-1/2”) deep. That will allow for adequate fastener penetration and yet accommodate variation in screw length.

Designers should be aware of the science behind resistive heating and fires and should specify a separation between a building’s electrical system and the roof. Owners clearly have a stake in the issue. No one wants their asset vaporized by a non-detectible high-resistance fault. Instructing your designer to provide for a separation space means peace of mind for the serviceable life of the building.

[19] Assembly refers to the roof system in combination with the structural deck that supports it.

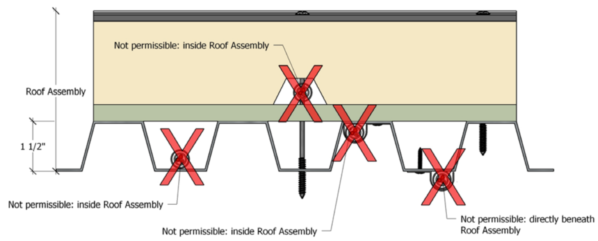

Figure 5: An example of electrical installations that must be avoided.
(RCABC Roofing Practices Manual)

Roofing contractors also have a role to play. A separation space makes a difference only when screws are suitably selected for the depth of the roof system; screws that are too long will damage even appropriately separated electrical wiring. This is especially critical on roofs with tapered insulation packages. Make a fastening plan based on the slope of the roof, select appropriate fastener lengths and sizes, and then ensure the installation conforms to the plan.

Some opponents to a separation space have argued that the cost would be prohibitive to owners and that more roofs should simply be switched to adhered systems. One estimate by an Ontario electrical contractor suggested a separation space would increase the cost of an electrical system installation by thirty percent[20]. But switching a roof system from mechanical fasteners to adhesives is no panacea. Sometimes, adhesives will not achieve the wind resistance necessary to satisfy building code requirements, in which case using fasteners is the better alternative. Furthermore, adhesives typically cost more than fasteners, adding anywhere from twenty-five to forty percent to the cost of a mechanically fastened system; in real dollars, this will be more than a cost increase to the electrical contract. And then there is the issue of future roof renewal; if no separation space is provided, and fasteners are concealed by ceilings or in sprayed-on insulation, future roof renewal will likely add costs for an owner, including the potential cost for electrical system repairs. A separation space brings the lasting benefits an owner will be grateful for.

Figure 6: Junction boxes and conduit installed directly to the underside of a plywood roof deck.
(Photograph by the author)

A Better Tomorrow

In 1967, an electrical short ignited a fire inside the Apollo 1 spacecraft command module during a live test on the launch pad. Gus Grissom, Ed White, and Roger B. Chaffee died in their seats. In the months that followed, an investigation led by fellow astronaut Colonel Frank Borman revealed a number of failures in the design of the capsule, including Velcro that could be ignited in an oxygen-rich environment, and a hatch that could not be opened by the astronauts inside the module because it swung into the module, rather than out. During the inquiry that followed, Borman was asked if he could

[20] Submission to the Section 12 Subcommittee for Subject No. 4007 (July 30, 2018) (Presented as part of the agenda for the 127th meeting of the Committee on the Canadian Electrical Code, Part 1.

summarize the investigation findings. In reply, he said that the fire on board Apollo 1 occurred because of a failure of imagination. No one imagined a fire could even ignite inside the capsule, or that the hatch would be impossible for astronauts to open in a hurry. Had anyone imagined these things years earlier, he said, the three astronauts might still be alive.

Climate change is on everyone's mind and Canada's national model codes are pivoting to imagine new, effective strategies that address energy efficiency and resilience for new and existing buildings. Unfortunately, Canada's electrical code seems somewhat out of step with the direction of Canada's other model codes. That has to change. But we need more than a better electrical code; we need a unified, collaborative national model code development strategy that pulls together all the principal codes under one roof – fire, plumbing, electrical, building, and energy – to ensure our buildings and their critical systems are designed and constructed to be safe, durable, accessible, and efficient. It's time to imagine a new arrangement. We owe it to the generations coming after us. In the meantime, let's be better informed about the risks and hazards when roofing and electrical systems get too close to each other, and design and construct buildings for a better tomorrow.

We've authored the book on great roofing design and construction standards. Learn more about our ***RoofStar Guarantee Program*** at https://www.rcabc.org/roofstar-guarantee, or visit our Roofing Practices Manual at rpm.rcabc.org.

About the author:

James Klassen is a RoofStar Technical Advisor and staff writer with the **Roofing Contractors Association of British Columbia**. As a keen proponent of vegetated roofs, James contributes to education and policy development for sustainable 'green roof' design and is involved on behalf of the RCABC in a collaborative work with Green Roofs for Healthy Cities to develop green roofing professional curricula. He also writes for and manages the online Roofing Practices Manual, participates in numerous CSA task groups responsible for several roofing standards, and is a voting member of the CSA-A123 Technical Committee on Roofing. He is an experienced roofing estimator, a former Occupational Health and Safety professional and independent insurance claims adjuster, and has extensive experience managing facilities and transportation for a large private school in British Columbia's Fraser Valley.
