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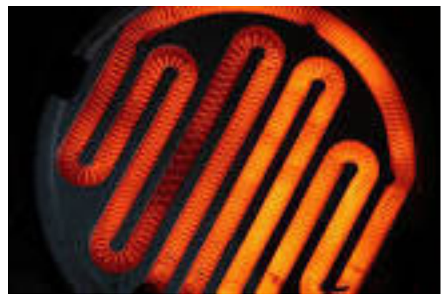
Watts = I^2R Watts = Heat

This I^2R heating takes place in the conductors as in the load.

Useful work would be an appliance such as an electric range, the I^2R heating is needed and is not considered wasted power. Another example of useful work is the light bulb. The wattage or power is a measure of the I^2R heating of the filament of the bulb which depends on the fixed resistance of the filament.





Some home fires have started from people smoking, children playing with matches, lightning, but recently a fire started in an elderly couple's older home at 2 pm in the afternoon. There were no children there to play with fire, the elderly couple did not smoke, it was a bright day with sunshine and no lightning in the area. Then how could a fire start? **Have you heard any noises in the attic lately?**

Residential fire deaths exceed those of any other building classification. More than half of the fire deaths that occur in residential buildings have occurred because a delay in detection ***due to the occupants being asleep at the time of the fire***.

Each unseen cable in the wall or **attic** in your home supplies energy, and each one can potentially fail and cause a fire when you least expect it.

Frayed wiring can produce the heat and sparks necessary to cause a home to be completely destroyed by fire.

The absolute most common cause of attic fires in residential homes is an electrical malfunction.

An **attic** is one of the most common places where a fire can originate in your home. The Federal Emergency Management Administration (FEMA) estimates more than 10,000 residential building attic fires occur in the United States each year, leading to an average of 125 injuries, 35 deaths and $477 million in property damage.

Electrical overloads that overheat in **attic** insulation and other parts of the home are responsible for approximately 43% of all residential attic fires.

An attic fire may occur when wiring has become **frayed or torn**.

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Cable damage from rodent chewing in the attic

Here is an example of the type of chewing rats do. Rats are rodents, and like all rodents, their teeth grow non-stop. They must chew all the time in order to wear down their teeth, similar to the way a cat must wear down its claws. Unfortunately, rats often choose to chew on electrical wires, which can and has caused fires in attics.

Even today you will find **$$ multi-million dollar homes** being wired by the **low bidder** using the #14 size nonmetallic sheathed cable called Romex. Which the rodents in the attic love to chew on.

Here is a photo of rodent chewing on wires. It doesn't happen in every attic, but when it does, it causes several potential problems. The worst problem is the risk of a fire hazard. The next problem is that the chewing often causes a short. I've had customers tell me that all of a sudden half of their house lost power. The other risk is that the rodent is electrocuted and dies, (fries) causing an odor problem.

Rodents seek out a warm place to spend the nights, and so they go in attics. They then seek out things to gnaw on, because that's what rodents do. These disease-ridden critters are nocturnal, and can often be heard scampering up the walls and in the attic at night. They chew on electrical wires, contaminate food, and spread disease.

Rats, mice and squirrels like to munch on electrical wiring routed through attics and inside wall voids.

The problem with the "unseen" wiring in the walls **and the attic** where the rodents have been chewing, **you can't see the wiring.** If the insulation is chewed to where the bare copper would touch another bare wire in the cable, a short-circuit (high amperage) would occur and the circuit breaker or fuse is required to open the circuit immediately.

It generally takes roughly 3 days to one week to get rid of rats with rat poison. Mechanical traps can sometimes take a few days to trap rats because the rodents may be wary of the trap. A pest control professional can remove rats in as little as one day to a few days depending on the size of the infestation.

But, the **hazard occurs** when the insulation is chewed exposing the copper wires but they are **not** touching each other to cause an immediate opening of the circuit by the fuse or circuit breaker.

This encourages the copper wire to react with oxygen in the air. The resulting copper oxides are more resistive than copper. That causes them to heat up more than the surrounding wire, encouraging even more oxidation.

This exposing the wire starts the oxidation and **ohmic heating** which over an **unknown** period of time (*could be years*) starts to smoulder and eventually **reaches ignition** temperature.

High resistance creates localized heating, heating **increases oxidation** and creep, the connection becomes less tight, and further heating occurs, until high temperatures are attained. At a certain stage, a poor connection can become a **glowing connection** which shows very high temperatures. At that point, nearby combustibles may be subject to ignition. The process generally appears to be one of **ohmic heating.**

Experienced investigators uniformly cite **high-resistance connections as the most common electrical cause of fires.**

The electrical conductivity is typically deteriorated at elevated temperatures due to the oxidation by forming non-conducting oxides on surface, while enhancing oxidation resistance via alloying is often accompanied by **a drastic decline of electrical conductivity**.

In **120 VAC circuits**, it is not difficult to cause sustained arcing **if there is a carbonized conductive path**.

Carbonization is the degradation of a material in the **absence of oxygen**.

A well-developed oxide can reach **30-40 watts** on a 15-20 amp circuit.

Arcing across a carbonized path

Arcing across a carbonized path is often considered synonymous with "arc tracking," although strictly speaking the latter has narrower scope and refers only to a carbonized path self-created by the flow of electrical current. Carbonized paths may also be created by external means, e.g., heating imposed from an external heat source upon the material. In the extreme case, a fire impinging upon electrical insulation may carbonize it. In any case, arcing across a **carbonized path** is a mechanism which is a common cause of fires, but which has received inadequate study. Arcing across a carbonized path is typically subdivided into two types: wet tracking and dry tracking. Wet tracking may occur if a wet, polluted (**wet tracking does not occur if the water is distilled**) path can be formed across an insulator, spanning from one conductor, to a conductor at a different potential.

Moisture combined with dirt is the greatest deteriorating factor for conductor insulation. Perfectly dry dirt is harmless, but even a small amount of moisture, such as condensation, will result in electrical leakage that leads to tracking and flashovers.

Insulation and insulators must be kept clean and dry. A tracking pattern has been known to develop from moisture droplets in a heavy layer of dust which forms a carbon track which can often be hidden by later deposits of dust.

When I started my electrician apprenticeship in 1956 with the New York Central Railroad, I was taught about keeping insulators clean and dry. As locomotives create a lot of dust as they travel the rails, they are subject to a monthly electrical inspection at which time the traction motors located between the wheels and insulators must be cleaned.

Tracking (worms) is an electrical discharge phenomenon caused by electrical stress on insulation. Tracking develops in the form of arcs on the surface of the insulation. A common sign of tracking is one or more irregular **carbon** lines in the shape of branches.

The one case that remains upmost in my mind that should be included is a fire in a wood framed townhouse where two children were burnt to death.

After the family returned home from an evening dinner party, the two children went upstairs to bed and the parents turned on the TV to watch the news. The father while watching, fell asleep in his recliner. The mother stated in the report that this evening was the first cool weather they have had this autumn and just before she fell asleep in her chair, she remembered she reached back and turned the **thermostat to heat**.

She was awakened by the smell of smoke and witnessed what appeared to be a huge orange ball of fire that went across the living room and fire was everywhere. At that moment, she heard the screams of her children upstairs but could not reach them as the stairway was completely engulfed in flames. The children perished in the fire.

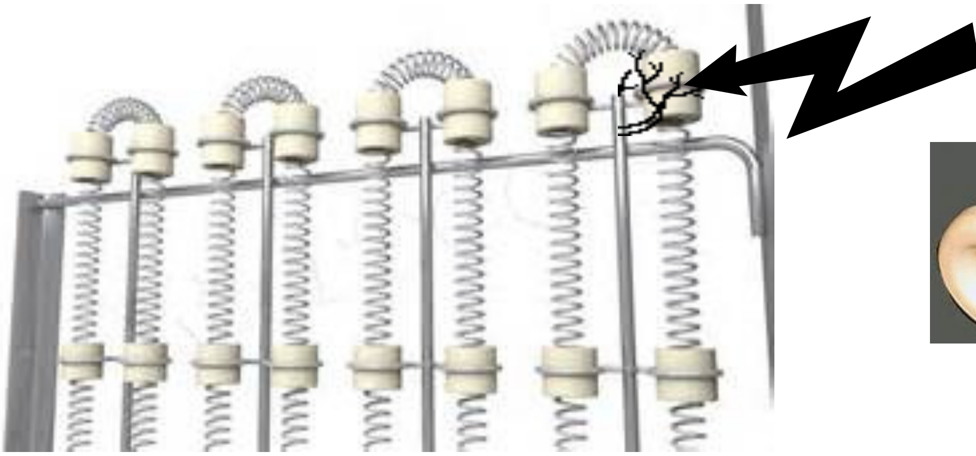
The local fire department gathered the remains of the electrical equipment and properly stored it.

I was called by a law firm to investigate this fire as a suit was filed. As with law suits, depositions are taken from persons involved in the case. The owner that had purchased the apartment complex just a few years before was asked if the building was inspected prior to his purchasing it. His reply was he had the **roof inspected**. There was no electrical inspection.

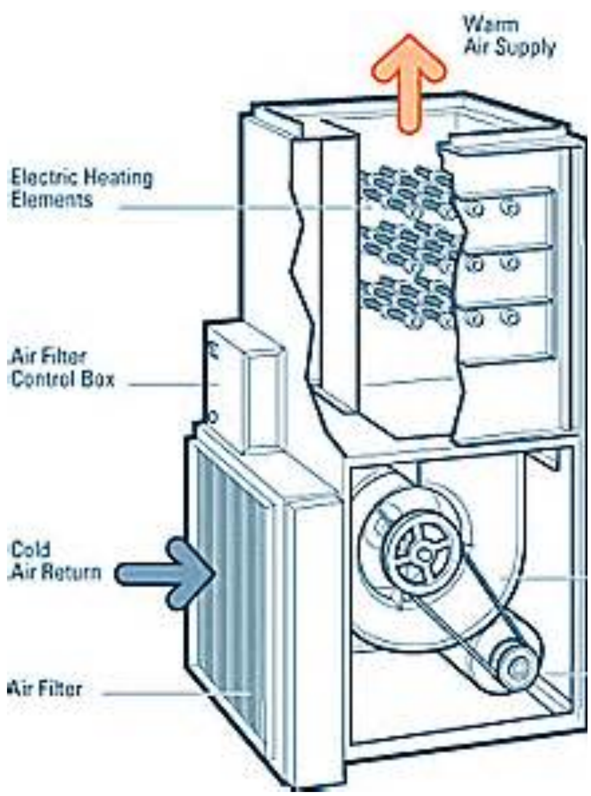
The apartment complex office maintains a file of reported complaints from the renters which are passed on to the maintenance department for the necessary corrections to be made.

The records showed that the apartment that caught fire had several reports of the lights blinking on and off, air conditioning problems, the air handler closet **carpet was reported wet several times** even to mention that presents left there on the floor had become saturated from water.

My investigation continued with the inspection of the remains of the equipment in the fire. What kept going through my mind was the "orange fireball" and the air conditioning closet floor being very wet. After viewing the remains of the wiring and the panelboard with the circuit breakers still in place, I observed the air handler and the angle iron frame that holds the electric heating coils.



What still appeared was a "worm" on one insulator on the frame to the heating coils. Now my mind started to spin back to the 1950s when I was taught what a "worm" was electrically. An insulator must be maintained and kept clean and dry, if not the dust, dirt or moisture over a period of time will start a tracking path for electricity to follow.

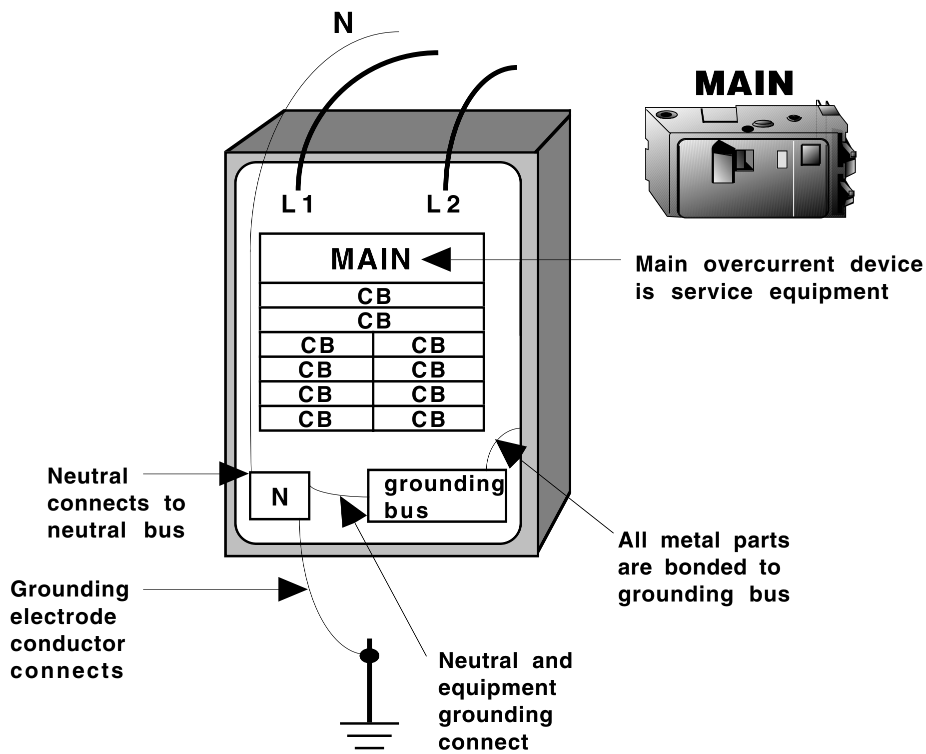


After further investigation of the electrical components and resistance calculations of the wiring involved in the circuit, I came to the conclusion that the drip pan on the air handler had been plugged up for a long period of time and as the fan blower ran, **it kept moisture on the insulators** on the frame to the heating coils and over a period of time with the dust and moisture, **a "worm" was formed to the metal frame providing a path for electrical current to flow to the frame at which point the circuit breaker should have opened the circuit immediately.**

But, the circuit breaker didn't open immediately and a heavy current fault occured and resulted in an explosion and vaporization of the #4 aluminum conductors thus causing the "orange ball" of fire that exploded through the wall of the living room.

THE JURY

The investigation also showed the grounded and grounding conductors were connected together at a ***subpanel****. This is only permitted at the main service equipment*. In the courtroom when presenting a case to a jury which generally is not that familar with electrical terms, I relate electricity to them as the **flow of water**.



EFFECTIVE GROUNDING PATH

The Code states the path to ground from circuits, equipment, and metal enclosures for conductors shall:
(1) Be permanent and continuous.
(2) Have capacity to conduct safely any fault current likely to be imposed on it.
(3) Have sufficiently low impedance to limit the voltage to ground and to ***facilitate the operation of the fuse or circuit breaker****.*

When a fault occurs in a circuit, it is only during the time period while the fault exists that a potential hazard is present. That is why it is so important to clear the fault as **quickly as possible** by providing an equipment grounding circuit of the **least resistance** to trip the circuit breaker or blow the fuse.

The equipment grounding conductor is *not* designed to carry current continuously, but to provide a low impedance path **for fault current** for a *short time* until the breaker opens.

The electrical resistance of an electrical element measures its opposition to the passage of an electric current measuring how easily electricity flows along a certain path. Electrical resistance is similar with the mechanical notion of friction. The unit of electrical resistance is the ohm (Ω).

Water Analogy

The resistance of a given piece of wire depends on three factors: the length of the wire, the size of the wire, and the resistance of the material composing the wire. To understand how this works, **think of water flowing through a river.** The amount of water flowing through the river is similar to the current in the wire. Just as more water can pass through a large river than a smaller river, a large wire can carry more current than a small wire. For a wire, the larger the size, the lower the resistance; the smaller the size, the higher the resistance. Now consider the length. It is harder for water to flow through a very long hose simply because it has to travel farther. As it is harder for current to travel through a longer wire, a longer wire will have a greater resistance.

Relate a river and the dam to a circuit breaker. You want **ALL** the high fault current to go directly to trip the breaker as quickly as possible.

You want **ALL** the water to hit the dam and blow it open as quickly as possible. But, if the resistance slows the current to where the breaker doesn't open quickly we will have heat damage. It's the same as if the river had pipes or branches to **allow the water to flow elsewhere** instead of hitting the dam with ALL the water force.