Electrical Fires and the Power Disconnect Issue

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Abstract
This paper will present issues surrounding Class C (energized electrical) central office fires and discuss what works, what doesn't work and what needs more research. The central office from the perspective of a fire responder will be presented. Additionally, the paper will address the thorny question: to disconnect or not to disconnect and offer concepts for micro level power down circuitry. Certainly it is a controversial issue and it rages on nearly ten years after the watershed Hinsdale Illinois (USA) fire. Most telephone people distrust any device which might shut down telephone service. Generally, when a telephone person is in favor of disconnects it nearly always follows that the person is a volunteer fire fighter in his or her private life.

While large devastating central office fires are rare, their impact is expensive and far reaching. Then too, the smoke from even a small fire can cause millions of dollars in contamination damage. Power disconnects are only one approach to the problem and I'm sure that this paper will not resolve that issue. What it will do, though, is explore the many facets of the central office fire potential, with particular attention to the risk of Class C (electrical) fire. It will offer solutions and alternatives to many of the problems and potential risks.

As result of the Montreal Protocol, many common fire extinguishing agents are no longer available as they were fluorocarbon based and caused damage to the earth's atmospheric ozone layer. Replacing them are new more environmentally friendly agents. New findings suggest, however, that when electrical power is the heat source, extinguished fires reignite within approximately thirty seconds. The paper will discuss recent tests and national standards activity centering on extinguishing Class C fires.

As a practical matter, the familiar fire triangle is a graphic representation of physical laws. Each side is necessary for combustion and when all three are present in appropriate measure, the result is fire. Our challenge is to keep the triangle from completing.

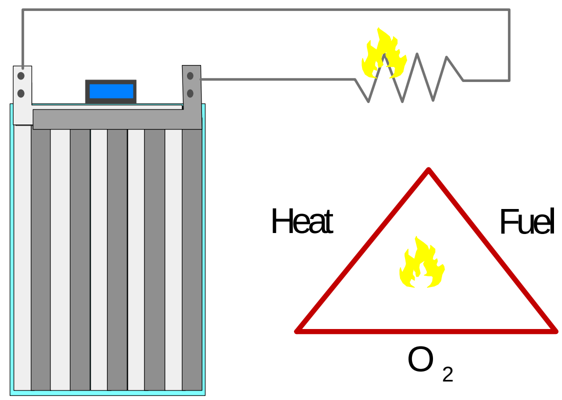


Figure 1 CO_2 extinguishers displace the oxygen needed for combustion. Halon inhibits the reactions of O_2 and flame. HFE agents cool - if only for a short time. With heat (power) and fuel and O_2 still available the fire will reignite when these parameters migrate back towards a normal atmosphere.

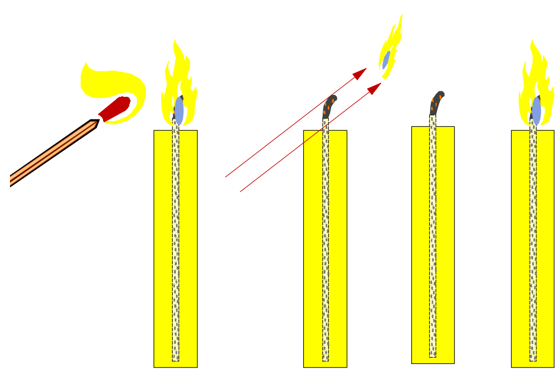
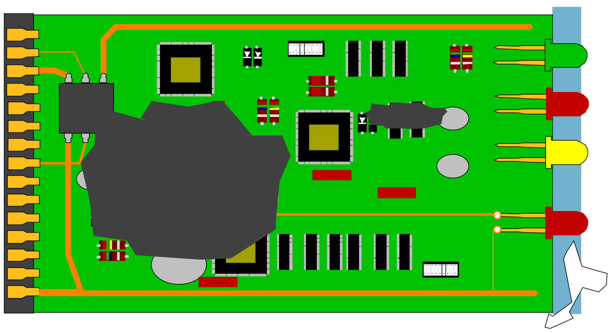


Figure 2 Class C fires are like an electrical version of the "trick" birthday cake candle. As the candle is lit, heat from the match melts wax on the candle wick. The wax heats to a gassification point and then the gas begins burning. When the candle is blown out, the gas is moved away, the wick is cooled and the candle goes out. In a few seconds, heat stored in metal filings impregnated into the wick gassify more wax reigniting the flame. The candle burns again. Unless the heat (power) is removed, electrical fires reignite just as the candle does.

Circuit Packs

Many small central office fires are a result of burning components on circuit packs. Usually, they begin with overheating which can result from a variety of causes such as aging, transient voltages, overvoltage, undervoltage, ESD, Hydroscopic dust bridging, external short circuit and other malfunctions. Often, solid state components such as diodes or transistors are the first to short and overheat. Flaming components often are capacitors and other components with plastic parts - often because they were near superheated plasma from the carbon arc of a burning resistor.



Although they rarely cause major fires, circuit packs can cause collateral damage to nearby packs. Smoke from even small fires can result in costly decontamination expenses, particularly where lead, mercury, cadmium or other toxic metals are smoke-borne contaminants.

Often such small fires are discovered by technicians responding to equipment alarms, who pull the smoking pack, and extinguish the fire. Increasingly, however, network equipment sites are unattended so no such technicians are on site. Also, the government is taking smoke more seriously. Burning plastics can release lethal concentrations of cyanide and other deadly chemicals. Some years ago, a US fireman fell dead of cyanide poisoning minutes after wheeling a burning typewriter out of an office rather than make a mess while extinguishing the blaze inside. Technicians are required by law to evacuate if the fire alarms sound.

Montreal Protocol

Since 1974, when scientists hypothesized that chloro-fluorocarbons (CFCs) were reaching the stratosphere, and being broken into chlorine atoms by solar radiation, the condition of the Earth's ozone layer has become an issue of increasing concern. Today, we know that the ozone layer is being depleted rapidly.

The ozone layer is the Earth's natural protection from the sun's rays. Ozone is created and destroyed naturally in the stratosphere by ultraviolet (UV) rays from the sun Natural destruction balances ozone creation so that the ozone layer is maintained at the correct thickness. Ozone depleting substances contain bromine and chlorine, which reach the stratosphere and collide with ozone, thereby destroying ozone molecules.

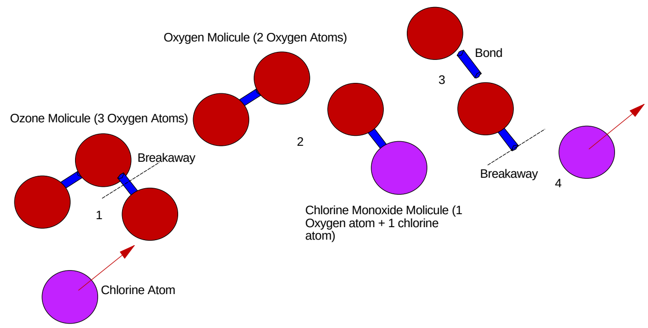


Figure 3 Molecular Bumping Cars: 1- Chlorine atom strikes an Ozone molecule, taking away one Oxygen atom. 2 - This leaves a new Oxygen molecule and creates a Chlorine Monoxide molecule 3- the Chlorine Monoxide molecule then combines with an Oxygen atom forming another Oxygen molecule as the Chlorine atom breaks away to continue the process through potentially thousands of Ozone molecules.

Basically, the developed and developing nations had to come to grips with the fact that each time we've discharged an air conditioner, used a fire extinguisher or even a can of hair spray we were stomping on the earth's sunglasses, putting ourselves at increased risk of skin cancer, global warming, and perhaps flooding from arctic melt. Politically, there were questions of who could afford to change, who was willing to help developing nations buy-into the expensive production of alternative chemicals, and timetables.

On 16 September 1987, Canada became the first country to sign the Montreal Protocol, an agreement to cooperate to protect the ozone layer. Other nations soon followed. The Protocol, and the London and Copenhagen Amendments to the Protocol set dates for the phase-out of ozone depleting substances (ODS). Under the Copenhagen Amendment to the Montreal Protocol, the following dates were set for the phase-out of consumption of ODS:

1994

- 75% reduction of CFCs
- **Halons phased-out**
- 50% reduction of MCF

1995

- Freeze MB at 1991 level

1996

- CFCs eliminated
- MCF eliminated

- CTC eliminated
- Hydrobromofluorocarbons eliminated
- Freeze HCFC consumption at base level
- Limit HCFCs to uses where a more acceptable alternative does not exist

2004

- 35% reduction of HCFCs

2010

- 65% reduction of HCFCs

2015

- 90% reduction of HCFCs

2030

- HCFCs eliminated

Fire Suppression

Halon fire suppression systems typically employed bromochlorofluorocarbons that extinguished fire through a catalytic cycle in which the chemical chain reaction of fuel and oxygen are inhibited. As a fire suppressant, Halon was used because it was an effective fire fighter and people did not suffer the potentially deadly effects of oxygen displacement as they did when large carbon dioxide extinguishers were used. Also, delicate equipment did not receive the extreme thermal shock often experienced when the icy blast of expanding CO_2 landed. As a practical matter, however, Halon, wasn't quite all it was hoped to be. Electronic circuits frequently sustained damage from the corrosive effects of bromine.

Going forward, now that Halon is eliminated as an ozone depleting substance, the industry is learning that environmentally friendlier halon alternative chemicals, based primarily on hydrofluoroethers (HFE'S), have operational drawbacks also. HFE's suppress fire by removing heat. This works acceptably well on class A (wood & paper) and B (oil etc.) fires, but in Class C fires <u>power</u> is the heat source. Tests by 3M Corporation have shown that, depending on the gas concentration, after approximately 30 seconds, power has reheated the fuel to another ignition point, and the fire begins anew. The 30 second interval can be increased somewhat by pouring staggeringly expensive concentrations of HFE's into the space and find a way to contain it there. Or, we can find a way to depower burning equipment.

Professional Fire Response

When fire "First Responders" arrive on site a number of factors come into play. In the US, the burning property is now under the legal jurisdiction of the Fire Commander and he or she will make whatever decisions are needed to handle the fire based on certain priorities:

1. Protection of life and safety

2. Protection of nearby buildings

3. Extinguishing the fire

4. Protection of the burning building

Equipment in a building is the fire responder's lowest priority. Further, while the central office is a very inviting and familiar place to a telephone technician, it is a fearsome hell-hole to a fire responder.

Much of the material in a central office is Polyvinyl Chloride (PVC) because PVC is fairly flame resistant and is self extinguishing <u>once the heat source</u> (usually power) is removed. PVC burns with a dense black smoke which is both toxic and corrosive. During a fire it quickly, it becomes impossible to see and a fire responder gropes his or her way around.

Because he or she is wearing bulky protective clothing and Self Contained Breathing Apparatus (SCBA) the relatively narrow central office equipment aisles are tough to navigate. Cable support brackets, knobs, cord hooks, shelves, wires etc. all snag the fire responder.

A central office fire confronts fire responders with a set of unique conditions that conflict with his or her training and tend to inspire confusion and fear.

In fire school they teach that a fireman's "Turn-out jacket" (the big coats fire fighter's wear) will protect them from fire, water and chemicals. In the central office, burning PVC forms a fine white ash which penetrates the turn-out jacket and other garments. On the skin, this ash combines with perspiration to form hydrochloric acid which burns the skin causing a minor rash. What the fire-responder <u>experiences</u> is burning skin and the nagging feeling that something is very wrong because the condition runs counter to their training. From a commander's viewpoint, it also means they require huge amounts of manpower and equipment because the fire responders and their gear must be decontaminated (washed down) each time they leave the structure.

Central office fires conflict with a fire responder's training and experience in electrical design and the National Electric Code. Electrically, fire responders are trained to deenergize the commercial power so they can safely use water to put down the fire. In the central office, this only means that the standby generator will start. Stopping the generator does little to kill power because the battery plant continues on. Modern fire responders are somewhat used to Uninterruptible Power Systems, however those have Emergency Power Off (EPO) functions. Most telephone plants do not. So, a fire responder is faced with the task of dragging a hose line through a narrow electrically charged environment, while slogging through water in dense smoke, perhaps with sparks falling from cable racks somewhere up in the smoke.

If the Main Distributing Frame (MDF) or line card frames are burning another circumstance comes into play. The burning terminals may emit a soft blue flame. It's caused by PVC wire insulation heated to the gassification point by office battery potential and then burning. A fire responder is taught that a soft blue flame indicates gas. The fire responder has every reason to suspect that a gas pipe has broken and is adding potentially explosive fuel along the frame, even though most US central offices do not use gas. Given that many urban MDF's are 3 meters wide, nearly five meters tall and more than 50 meters long, a fire responder may feel less than comfortable if he or she perceives it as a humongous broken gas burner full of electrical wiring.

When a fire is large or safety conditions vague, fire commanders often will opt for the relatively safe attack strategy called "Surround and Drown." This is exactly what it implies, they surround a building, knock out its windows and pour on water from every available hose line until:

1. the fire is out and the structure deemed safe to enter; or,

2. all the world's water is used up.

Though effective and safe as a fire suppressant, the surround & drown tactic is tough on central office equipment. It makes good business sense to try to make central office fire safety and suppression more automatic, faster acting and more approachable for the emergency response community because we don't want them to surround and drown us. Obviously, the first order of business is prevention. Central office fires are most likely to begin with administrative spaces, burning circuit packs, and burning cable racks.

Administrative Spaces

Administrative spaces are the most likely of places to catch fire. With people come the inevitable PCs, printers, coffee pots, radios, curling irons, toaster ovens and all manner of appliances which migrate into the space. Companies are losing their long held wavers and grandfathered zoning and building code exclusions where local codes require water sprinkler systems - particularly in administrative spaces.

Obviously when sprinkling, the use of a dry-type pre-action system is desired, because there normally isn't water in the pipe so that accidental leaks, freezing etc. are not issues. Because most concrete floor slabs leak, it is prudent to invest in waterproof membranes along floors and, perhaps, 6" (15 CM) above the floors at walls and cable hole sheathings. As a practical matter only reenterable membrane systems should be used. Also, water must go somewhere so appropriate drains, scuppers etc. must be provided.

From a system reliability and fire safety viewpoint, it makes good business sense to place a fire-rated partition wall between switching systems and their maintenance and administration areas. This places those "people" things most likely to catch fire out of the equipment space and also removes several equipment contaminants such as printer toner, paper dust and ESD from the equipment area. Keeping the space free of unneeded combustibles such as boxes and packing materials is a very inexpensive yet effective fire prevention policy.

Figure 4 A partition between switching systems and Maintenance & administrative area improves reliability and fire safety by isolating several heat, fuel and contamination sources.

Depowering

Depowering an office makes good business sense when the office circuitry will become wet by fire hoses, leak or flood. Depowered equipment which becomes wet can usually be decontaminated by cleaning with deionized water and then dried, tested, and returned to service. Equipment which is kept powered while wet begins a destructive corrosion cycle which usually means replacement. Since the Hinsdale IL central office fire some ten years ago, the subject of power disconnects simply won't go away. The big objection is that a malfunction or malicious act would take a switching system out of service needlessly. I believe that, with mass production, power disconnects could become cheap enough to build-in overheat detection and power down on the circuit boards. Disconnected from heat at this micro level, fire is prevented or minimized, and a malfunction can touch only a limited amount of circuitry.

Two such concepts are proposed. In the first, a protection module consisting of a resistive sense tape and a detector/shutoff would control power to the pack's dc bus.

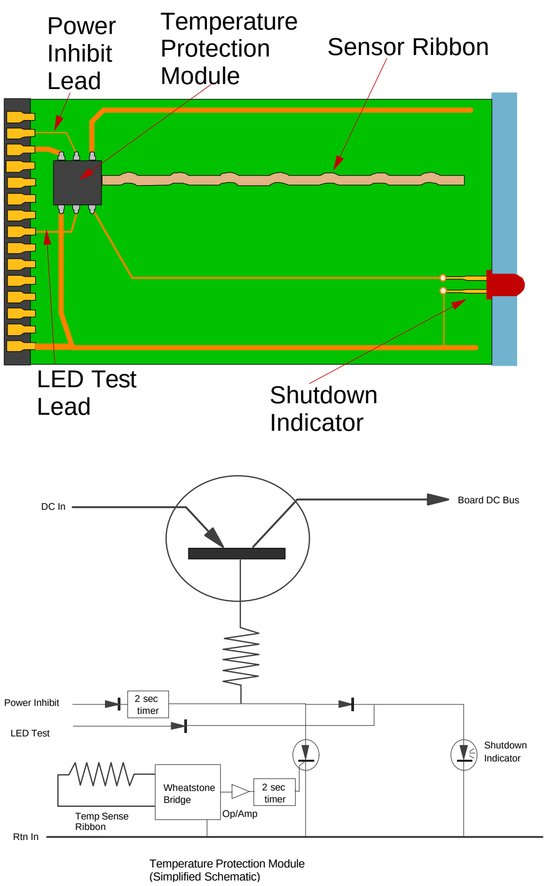


Figure 5 The overheat shutdown protects by determining hot spots on the circuit pack.

The sensor tape would be routed over likely overheat components. A heat proportionate voltage from the wheatstone bridge would route via a 2 second delay (to prevent transient operation) and gate an SCR which would drive the transistor into cutoff until the board is removed or completely depowered. The inhibit lead permits external systems to hold power down until the lead is released providing a sequenced restart capability. The LED indicates a shutdown and can interface with LED test circuits via diode isolation.

In the next circuit I'm thinking that most circuits which overheat enough to burn are probably drawing more current than designed. A small wire wound resistor or even a fixed foil on the board's foil pattern could serve as a tiny ammeter shunt. The voltage dropped across the shunt could be amplified and used to drive the transistor to cutoff if the current exceeded a threshold. As in the previous design, a transient delay, LED test and Power inhibit functions are provided.

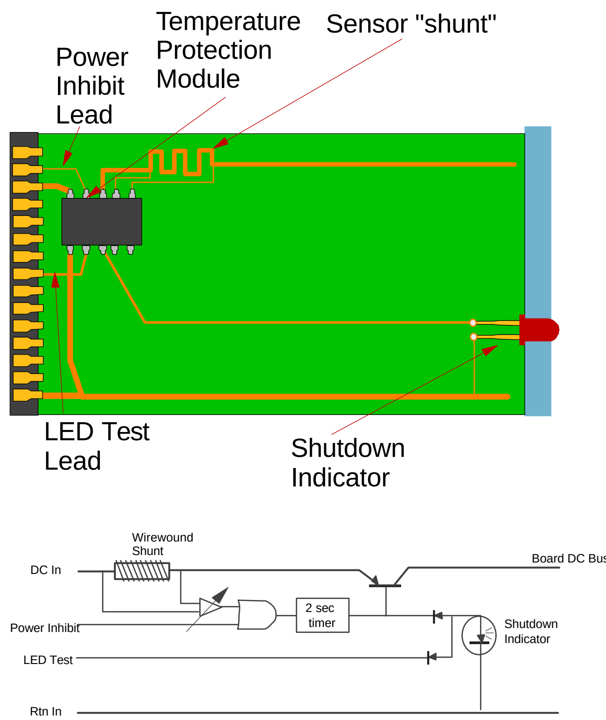


Figure 6 This circuit is basically an on-board current monitor/threshold unit designed to cutoff the transistor switch on overload.

VESDA and cabinet level sensing and disconnect

As mentioned numerous times herein, just before the ignition point, heated materials outgas. The particles from this outgassing is what Very Early Smoke Detection and Alarm (VESDA) systems detect. VESDA is an improvement over conventional ceiling mounted ion type smoke sensor heads. Because the power density of modern switching and transport is so high, it requires large airflow systems for cooling. Often the cooling airflow is such that smoke from overheating equipment cannot reach the ceiling because the air resisters simply blow it by. Eventually, sensors in the return air system pick up the smoke and alarm but valuable time is lost. VESDA employs air pipes as sensors by using an air pump to draw air from locations near the equipment and then pulling it into a centralized chamber where a laser counts particles. Particles of dust and smoke are indistinguishable to VESDA but the gross amount of contaminant is the key. Threshold counts are set after the office ambient dust baseline is established. High counts register as a potential fire. When working properly, VESDA detects long before there is visible smoke.

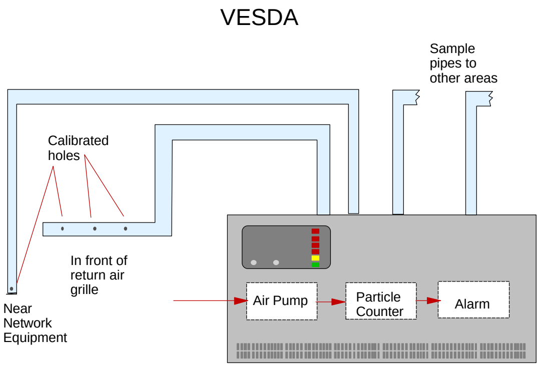


Figure 7 VESDA System performs a particle count on air samples drawn from equipment spaces and air retruns to detect incipient fire.

There is discussion in the industry which suggests that the next generation VESDA may use a gas sensor "chip" to replace the relatively expensive laser counter presently employed. In the telephone industry Gas sensor chips are presently used to monitor safety in Controlled Environmental Vaults, (CEVs) cable vaults, and similar structures which might accumulate methane, sewer gasses or other explosive atmospheres. Generally, electronics at the chip level have a way of becoming inexpensive through mass production. It may become cost-effective to build component out-gas sensing and power down into cabinets at the system level.

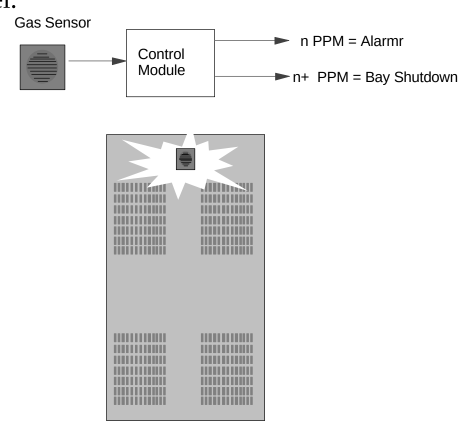


Figure 8 Gas sensor chips could provide in-cabinet detection of pre-fire component outgassing and alarm or powerdown based on the threshold level of detected gas.

Cable Trays

In a story told and retold, nearly as often as Pinochio and the whale, the tragic and expensive fire at the central office in Hinsdale, Illinois is believed to have occurred when a length of paralleled 750,000 CM copper cable became damaged by cold flow and short circuited to the grounded armor of a piece of BX cable sharing the rack. The armor became incandescent, burning a polyethylene optical fiber inner duct which dribbled burning plastic onto a tub of paper file cards improperly stored in the switch room.

As a result of this event, many telephone companies no longer use plastics in the central office unless they have a rating of 0 or 1 in the UL 94V vertical flame test. They self extinguish when the heat source is removed, and will not dribble burning material.

Additionally, companies have become more stringent about engineering standards - segregating cable types on a rack, carefully loading the racks, downsizing feeder fuses, etc. Still, though, there are many cable rack fire events - arcing faults - every year. These occur for a variety of reasons. Most of them relate to insulation cold flow and cabling which pinches against the cable rack, its retaining horns or other grounded steel structures. Additionally, some fires are a result of cable "taps" which are overheated due to improper sizing or poor crimping. Because the cable racks are may be close to the ceiling it makes discovery of the overheating difficult using infrared thermography or other tools. I believe it's time to rethink central office power cable racks.

If so many cables are ground-faulting to the racks why not consider non-conductive racks and eliminate the problem? In the past 30 years composite materials are making inroads into aerospace, automotive and many other places where metals predominated. And, they're doing a superior job. The National Electric Code already recognizes nonmetallic cable trays (Article 318) and they are enjoying increasing use in the electrical industry.

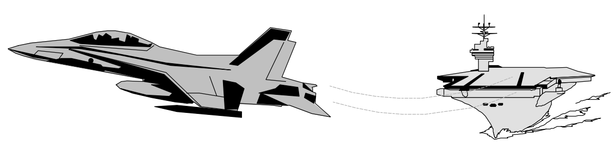


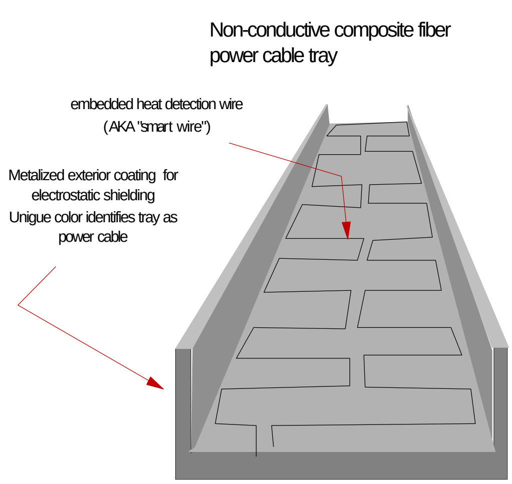
Figure 9 If fiber-based composites are strong enough to manage the stresses imposed on combat aircraft, yet "light enough to fly" and cheap enough to make children's toys and play gym equipment perhaps they are suitable for power cable trays.

From a weight density perspective, the central office battery is perhaps the heftiest item in the central office and we've used fiber/polyester battery stands for more than twenty years. Using nonmetallic ventilated trough type cable trays for power cables could:

- Eliminate cable tray arcing ground faults
- Reduce the overall weight
- Reduce installation cost
- Make power cable runs easier for emergency responders to identify (unique color/construction)
- Embedded "Smart wire" (see text) could detect and locate hot spots in the cable tray

The fire detection industry is developing a form of heat sensing wire sometimes called "Smart wire." It's intended use is to be embedded into the concrete structure of buildings and detect heat. Further, the system is capable of determining approximately where along a length of the wire is the hot spot. If such wire was cast into nonmetallic power cable troughs, it could detect and locate hot cables or overheating cable taps. This would be more reliable and less expensive than periodically scanning the area with an infra red camera or other device.

Increasingly, electrical noise immunity is a factor in central office service reliability. Power cables on open racks are a low impedance path to circuitry. From an EMI immunity viewpoint, the exterior of nonmetallic troughs could be vapor-metalized or metallic-spray painted during manufacture. Top covers are another possibility - both to contain fire if it occurs and to provide improved EMI immunity. Such a step would improve circuit reliability with little added cost.



Follow the Yellow Brick Road

If a central office is experiencing a significant fire, the Fire Chief will probably order the building powered down. Legally, telephone people cannot enter the building, and fire responders may have little or no knowledge of that facility. Some questions come to mind regarding the fire responders:

- What does he or she power down and how?
- How do they find it?
- How much time is lost sorting it all out?
- And, finally, how do they get back outside? To a fire responder low on SCBA air, the hoseline he or she hauls in is often the lifeline that leads the way out if smoke density precludes walking erect.

It is very prudent to have up-to-date floor plans and emergency information in a book near the front door so the Fire Chief can use this information to minimize damage to telephone company facilities. Some companies are taking the additional steps of color coding their central offices to facilitate an organized power down in the event of fire. This is especially useful for large multi-switch entity offices. A number of vendors offer such marking and documentation services. To a fire responder the various switching and transport systems all look the same - electrical "stuff."

Nicknamed "Follow the yellow brick road," using floor tapes to color code the aisles or groups of aisles associating them with the power plant they're served from is a first step. Then, the DC Breakers or switch & fuse units on that power plant are color coded with tape or decals. Floor tapes lead the way from the front door to that power plant discharge/distribution bay, engine stops and other critical items. Exit and other warning decals are placed both at eye level and just above the floor to facilitate those crawling beneath smoke layers.

Floor tapes and door decals leading the fire responders to the power room will also lead him or her back out safely - or will do the same if our employees must crawl out of a smoky room.

In this way, fire responders can determine which color coded zone is affected and then depower that zone first, and perhaps minimize the impact on the network by leaving viable systems in service. Perhaps they will need to depower additional zones later, but it's better than a full power down at the first effort. Remember that with switching systems inoperative, affected customers can't call for emergency services if needed.

Accordnigly, an effort to minimize the power down effort pays off. Fire Chiefs usually respect the fact that most of their "customers" call for help on the phone and will proceed gingerly if they have the information to allow them to do so without undue risk to their people.

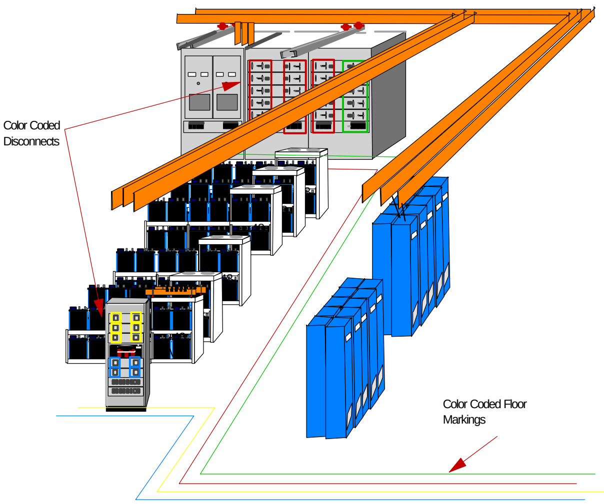


Figure 10 Color Coding permits an organized power down should it become necessary. It also shows an egress path.

Conclusions

While the telephone industry has enjoyed a fairly good track record for equipment losses due to fire - when incidents do occur they tend to be very dramatic.

- The fire triangle is a set of physical laws that aren't going away ever. If there is heat fuel and oxygen in the correct proportions, there will be fire. When equipment burns, we're going to have to find suitable ways to depower it or a lot of things above or along side it are going to burn too.
- There is a compelling need for research into more effective CFC-alternative extinguishing agents.
- There are too many arcing cable faults which could be eliminated by improved installation craftsmanship and the use of nonmetallic cable trays.
- "Smart wire" could help trace heat in cable trays
- Telephone companies need to do a better job of removing unneeded combustibles from switching centers.
- Sprinklers are coming whether we like it or not.

Glossary of terms

Class A fire. A fire involving ordinary combustible materials such as paper, wood, cloth, and some rubber and plastic materials.

Class B fire. A fire involving flammable or combustible liquids, flammable gases, greases and similar materials, and some rubber and plastic materials.

Class C fire. A fire involving energized electrical equipment where safety to the employee requires the use of electrically nonconductive extinguishing media.

Class D fire. A fire involving combustible metals such as magnesium, titanium, zirconium, sodium, lithium and potassium.

Halon 1211. A colorless, faintly sweet smelling, electrically nonconductive liquefied gas (chemical formula CBrC1F2) which is a medium for extinguishing fires by inhibiting the chemical chain reaction of fuel and oxygen. (also known as bromochlorodifluoromethane)

Halon 1301. A colorless, odorless, electrically nonconductive gas (chemical formula CBrF3) which is a medium for extinguishing fires by inhibiting the chemical chain reaction of fuel and oxygen. It is also known as bromotrifluoromethane.

Acknowledgments

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