PRC.5.0.3

Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

HIGH-ENERGY ELECTRICAL EQUIPMENT

INTRODUCTION

A circuit overheats, and its electrical insulation starts decomposing. As the insulation decomposes, drafts passing through unprotected openings carry the released corrosive contaminants. Damage spreads to nearby areas. This “cold smoke” hovers low and does not trigger smoke detectors at the ceiling. Finally, when the duration of the overcurrent reaches the time delay setting of the protective relay, the power supply circuit breaker opens and cuts off the electric power. This power interruption damages product batches and interrupts production and profits.

This type of loss scenario is not uncommon. Overheating chemically breaks down insulation. Overheating can be caused by contamination, loose connections, short circuits, mechanical overloading and power quality issues. The smoke that results can permeate a building. Smoke from such overheated electric equipment is just as damaging as smoke from a fire.

For the purpose of this section, high-energy electrical equipment is any electrical equipment that can release sufficient energy to break down the insulation on its circuit wiring. This includes most 120 V ac equipment. However, voltage alone does not limit circuit energy. Some 24 V dc batteries can release enough energy to break down insulation.

Effective loss control for electrical equipment involves much more than stopping the spread of a fire and extinguishing it. It also includes preventing fires from occurring through judicious electrical system design and through adequate electrical inspection, testing and maintenance programs.

Individuals involved with loss control for areas containing electrical equipment must analyze smoke and water hazards. Loss control personnel should attempt to respond to electrical incidents before damage spreads to other equipment. Limiting losses may involve using special equipment and building construction, modifying equipment layout and location, expanding fixed protection and maintenance, and implementing special emergency and firefighting responses.

This Property Risk Consulting Guideline introduces some of the construction, protection, firefighting and maintenance concerns affecting any facility that uses high-energy electrical equipment. It discusses smoke and water hazards relating to electrical equipment. Guidance for life safety concerns, such as lock-out tag-out procedures and confined space entry programs, are not provided in this section but are available from OSHA and other sources.

POSITION

Compartmentalize or isolate building areas and equipment as necessary to prevent the spread of fire, smoke and water, and to limit or prevent property damage.

- Provide all openings in firewalls, fire barriers and fire partitions with fire doors, fire dampers, firestops or other acceptable and listed means having a fire rating consistent with the rating of the barrier and meeting the guidance in PRC.2.2.1.
- Firestop all openings around electrical penetrations through fire-rated walls, partitions, floors and ceilings to restore the fire resistance ratings of these barriers. Use “T” rated firestops that seal against the passage of water and smoke for the rated duration of the barrier.
- Provide conduit seals and cable seals between nonclassified and hazardous (classified) areas as necessary to comply with National Electrical Code® (NEC) Articles 501, 502 and 504.
- Provide raceway seals where necessary to prevent the spread of moisture and extreme thermal conditions and to comply with NEC Article 300.
- Block the interiors of conduit and other electrical raceways penetrating walls, partitions, floors and ceilings to prevent the passage of water and smoke. Prevent or delay the spread of smoke and other contaminants into areas housing highly susceptible equipment by using listed putties or similar seals.
- Provide waterproofing, multiple floor drains and curbing, or other reliable devices or construction features to prevent accidentally released liquids and sprinkler discharges from flowing into areas containing high-energy electrical equipment. Features such as drains, curbs and barriers can protect electrical equipment from:
    - Backflows caused by partial blockages or poor design.
    - Water overflows caused by blocked sink drains, storm drains and other mechanical and plumbing fixtures.
    - Unauthorized or accidental discharges of liquids from fixed tanks and piping systems, including lubricating oil, process liquids and fire protection water systems.
    - Accidental release of liquids from the puncturing or rupturing of large storage tanks including tote tanks.
- Avoid or limit the use of electrical equipment in limited-access spaces. Limited-access spaces include vertical shafts; plenum and hollow spaces; ventilation and air-handling ducts; attics; basement crawl spaces; and similar, normally occupied areas. Where these spaces must be used for electrical equipment, select and locate equipment to minimize the potential for fire and smoke spreading to other areas.
- Provide walls, fencing, or other enclosures as practicable to protect electrical equipment from unauthorized entry, including entry by animals.

Evaluate areas such as motor control centers, control rooms, cable spreading rooms and other areas of cable concentration to determine the need for detection and/or suppression system(s). Consider the following:

- **Combustibility**: Most electrical insulations are combustible. Keep unnecessary combustibles out of such areas.
- **Impact on operations**: The extent and duration of any shutdown must be weighed against the cost of protecting the area.
- **Vulnerability**: Some areas, such as control rooms with sophisticated equipment, are quite easily damaged by smoke, water or fire.
- **Access for firefighting**: Areas like cable spreading rooms can have extremely limited access for manual firefighting. Redundant detection and suppression systems can compensate for this deficiency.

Provide an air sampling smoke detection system for major electrical service areas including major switchgear and motor control rooms. Design the system to detect insulation breakdown before serious damage or fire develops. Make sure the system will be unaffected by air movement and “dirty” environments. In motor control centers, the detection system will normally provide prompt detection if the sensing points are inside and at the bottom of the unit enclosures and are near a ventilation opening or an unsealed seam. Use only qualified system representatives to design the system.

Effective loss control requires a planned emergency response. Pre-emergency planning includes examining all aspects of firefighting, salvage and restoration of power. Pre-emergency planning and training are important to guide this emergency response.

- Set up a firefighting program with written plans of action.
- Train fire brigade personnel in electrical hazards.
- Conduct annual pre-emergency planning tours with on-site emergency organizations and public fire department personnel to identify electrical hazards and coordinate firefighting activities. Also coordinate actions between the fire brigade and the electric utility response team.
- After completing firefighting tasks and before restoring power:
  - Replace or isolate damaged electrical system components.
  - Immediately remove water from the area, reduce the humidity in the air as quickly as possible, dry wet components, and wash or clean contaminated components. Use corrosion-inhibiting treatments where necessary to prevent corrosion.
  - Test circuits and equipment to verify that conditions are safe.
  - Open switches to circuits powering equipment that are not immediately needed at the time the feeder system is initially energized.

At facilities containing electrical equipment rated over 600 V, provide signs and labels as required by the NEC. These include:

- High voltage warning labels on unlocked doors or at entries to rooms and enclosures containing such equipment.
- Caution signs on such equipment in areas accessible to personnel who might not be aware of the hazards.

Electrical Equipment IR Tests

Initially, scan newly installed and repaired electrical equipment, while under load, soon after being placed in service.

Annually, scan all power distribution switchgear, 480 V ac or higher and all dc, including distribution panels, breakers and their “stabs” or connections, bus structures, transformers and their insulators and connections, fuses and fuse clips, bus ducts, large motors and other large loads and their connections and controllers, and generators or rectifiers and their associated switchgear.

Quarterly, scan all previously listed equipment that is located in or exposed to severe atmospheres. Environments containing heat-insulating chaff, moisture or water, heat-insulating or electrically conducting dusts, oil mist, sunlight, corrosive chemicals, or severe heat can deteriorate equipment. Paper, textile and steel manufacturers typically have such areas.

Weekly, scan severely exposed and heavily loaded electrical equipment, such as arc furnace transformer secondaries.

DISCUSSION

Smoke

Smoke is defined as airborne vapors and particles produced by combustion, but such a definition can be misleading. Fire is not needed to produce smoke. Smoke is also produced by the degradation and chemical breakdown of overheated materials. For example, overcurrent in rubber- or plastic-insulated wire can produce smoke without fire. Another source of smoke is electrical arcing, which heats and vaporizes conductors and forces particles of decomposed conductors and insulation into the air. The terms “smoldering fire” and “electrical fire” do not apply to these nonfire incidents. Insulation breakdown and electrical breakdown, respectively, are more appropriate terms.

The decomposition of polyvinyl chloride (PVC) insulation, which occurs at relatively low temperatures, 212°F (100°C), is well known to produce a toxic smoke that contains hydrogen chloride (HCl) gas. The humidity in the air combines with the HCl to form an acid, which quickly corrodes electrical and electronic components. Insulations containing bromine and fluorine are similarly toxic and corrosive when overheated.

Smoke corrodes most metals, particularly when moisture is present. Corrosion is a chemical reaction between a material and its environment. During metallic corrosion, the metal deteriorates. The rate of metal loss varies. Thinning, which includes rusting and tarnishing, is a form of corrosion. Cracking, loss of strength and loss of ductility are other forms of corrosion.

Noble metals, like gold and silver, usually do not corrode. Aluminum, stainless steel and certain other corrosion-resistant materials develop thin oxide films. The films protect the metals by limiting the rates of the corrosion reactions. However, high temperatures and fire conditions can counteract the protection these films provide. Most carbon-based steels and certain copper-based alloys corrode fairly quickly. The longer a metal is exposed to smoke, the more severe the corrosion.

Corrosion can be reduced if salvage precautions are taken immediately after a fire or an electrical breakdown. Both cleaning and corrosion-inhibiting treatments might be needed, but the longer the delay, the less successful the effort will be.

Smoke not only corrodes, it also contaminates. Smoke can foul the operation of ball bearings, create an objectionable odor in a manufactured product, and bridge electrical circuits to form a short. Smoke can form a nonconductive coating on electric contacts to prevent closure, or to form a high-resistance connection that is likely to overheat. Smoke can create an insulating jacket that blocks the heat transfer process and causes an electric device to overheat. Damage can be minimized by immediately removing electric power from a contaminated circuit and cleaning the circuit,.

The greater the smoke concentration, the higher the potential for equipment to corrode or become contaminated. The quality of combustion often affects smoke concentration; that is, if materials burn poorly, combustion is less complete and can produce more smoke. Smoke concentrations can increase when the fuel-to-air ratio is changed, when materials containing fire retardant additives are burned and when firefighting agents are applied to the fire.

Like fire, smoke cannot always be prevented; but loss control efforts, which include removing or containing smoke, can be very effective in minimizing damage. Removing smoke reduces corrosion and contamination potentials. Smoke containment limits the spread of damage.

Any opening in a wall or ceiling can allow smoke to pass between areas. Drafts caused by pressure differentials sometimes speed up the process. Sealing these openings blocks the passage of smoke. In some cases, further precautions might be needed. For example, porous walls might not stop the spread of contaminants; wall coatings or other measures could be appropriate.

Smoke Detection

Smoke from fast-burning, growing fires normally moves upward in a thermal draft or plume. Thermal plumes are less common from low-heat-release fires and from decomposing electrical insulation. Such incidents produce a “cold smoke” which hangs low, stratifies and disperses with incidental or forced drafts.

Smoke detectors located at ceilings of rooms containing electrical hazards may not be adequate to detect cold smoke. In one instance, a ceiling-mounted smoke detector in a switchgear room failed to detect smoke from overheated insulation below the detector, even though the concentration of smoke was so heavy that the smoke billowed out of the room through an open doorway. However, most standards, codes and listing requirements force users to locate detectors at ceilings. In any case, requirements do not discourage or prevent installing special, supplemental detectors.

In facilities where electrical equipment can malfunction and produce cold smoke, low-level air sampling detectors can improve smoke detection reliability. “Area detectors” designed to be used at ceilings are not tested for cold smoke capabilities, and using them at low levels violates their listing requirements. Sampling detectors draw air from selected locations and can quickly detect insulation breakdown and incipient fire.

Rigorous cold smoke testing programs are needed; however, air sampling and aspirating detectors, which use sampling tubes to sample air at selected points, can reliably detect cold smoke and incipient fire. Vesda,™ a product of Vision Systems; Analaser,™ a product of Kidde-Fenwal Inc; and IFD,™ from SAFE Fire Detection, Inc are three commonly known systems. These detectors are listed, along with area detectors, in the FM Approval Guide. Because air sampling and aspirating detectors are highly sensitive, careful engineering for each application is required.

Water

Water is commonly used as an extinguishing agent for electric and electronic equipment fires. Automatic sprinklers are used where they can be effective in controlling losses involving combustible construction, combustible occupancy, high values or concentrations of values. Sprinklers are normally provided if a room contains grouped cables or other significant combustibility, including clusters of circuit boards or plastic components.

Usually, equipment is not kept energized when firefighting operations are in process; electric power is shut off in the early stages of firefighting. Using water-based firefighting agents assumes that an overcurrent or other automatic protective device, or as a minimum, a planned emergency response will disconnect the power.

However, electric power to protective equipment, including electric fire pumps and critical equipment, must be maintained for as long as possible during emergency situations. Reliable and safe power can be maintained during emergencies if the construction and power system designs provide adequate compartmentalization and isolation, and if emergency response is adequately planned and coordinated.

The belief that most electronic equipment will be damaged by contact with water is incorrect. Sprinkler protection limits fire, smoke and heat damage. Equipment wetted by sprinklers is more likely to be salvageable than equipment burned by fire. A sprinkler discharge scrubs and cools the air, and stops the spread of fire and contaminants. Furthermore, spraying such equipment with warm, soapy water, and rinsing and drying it, is a common cleaning practice. Equipment soaked by floodwaters or by storm damage can usually be washed and dried in the same manner.

Sometimes, noncombustible hoods or shields are installed to prevent water from contacting energized equipment. These hoods and shields must not obstruct sprinkler discharge or otherwise interfere with the primary function of the sprinkler system, which is to extinguish fires. Hoods and shields might not be effective against hose stream water, which can be directed from many angles. Electric system instrumentation and controls can be used to interrupt power quickly when failures and sprinkler discharges occur and may be more effective in preventing water from contacting energized equipment.

Specially designed electric equipment enclosures also protect energized equipment from water damage. NEMA 250, NEMA MG-1, and PRC.5.13.1 describe these enclosures.

Also, building construction features and equipment arrangement can limit or spread water damage. It is not good practice to drill a hole in a floor or wall to run cable, and not seal the opening with a watertight seal. Rain, sprinkler water spray or some other liquid discharge can seep, splash or flow through the opening and follow the cable to equipment where electrical breakdown and arcing can result. Construction features such as seals and equipment arrangements can control water damage. Equipment arrangement might include putting a deliberate sag in a cable run.

Drains aid firefighting. Damage caused by the spread and weight of firefighting water is limited or avoided by draining the water away. Curbs and liquid-tight seals may also be needed to control runoff. Containment and drainage systems should respond to other liquid discharges. These systems can include oil separation and other equipment necessary to protect the environment.

Automatic sprinklers discharge less water than hose streams when used to extinguish fires. Furthermore, when sprinklers operate, the environment is already hot enough to damage electrical components. Even though water should not contact some electrical equipment, water discharging from automatic sprinklers does far less damage than a serious fire. No one should doubt the value of sprinklers in areas containing electrical equipment.

Manual Firefighting

Safety is an important consideration when using firefighting agents. Water and foam fire extinguishing agents are electrically conductive. Trained personnel using proper safeguards can safely apply water to some energized equipment. But de-energizing equipment before applying firefighting agents is preferred unless the equipment is necessary for loss control.

NFPA 15 describes electrical clearances for fixed water spray systems. These are presented as equipment clearances, not as “safe” distances for manual firefighting.

Typical nozzle designs allow firefighters to use water spray systems and hose streams on 120 V electrical systems. One suggested standard requires a minimum nozzle clearance of 6 ft (1.8 m) when the nozzle is discharging a freshwater water spray or fog nozzle hose stream into equipment energized up to 34 kV. That standard requires a minimum clearance of 11 ft (3.4 m) for equipment up to 220 kV. However, the electrical protection designed into the system is a factor in setting “safe” distances.

Where water is used for firefighting, water runoff must also be controlled. Rubber boots can protect firefighters against unexpected water runoff. Effective firefighting training must examine all such features.

Some carbon dioxide and dry chemical extinguishers are listed for use on Class C fires. But even these agents have their disadvantages. Consider the effects of thermal shock and contamination potentials. Qualified personnel trained in using extinguishers suited to the hazard can safely discharge these extinguishers on energized equipment.

Stopping Fire, Smoke and Water

The UL Online Certificate Directory contains classification listings for Through-Penetration Firestop Devices (TPFD) and Through-Penetration Firestop Systems (TPFS). Qualification tests for listing purposes investigate the complete penetration assembly including the integrity of the component passing through the opening. Using listed firestops to prevent the spread of a fire is more reliable than simply filling an open space around a penetrating object with an untested patch of “like construction.”

Firestops are not always installed by experienced personnel, nor are installations limited to any one trade. Plumbers, insulation contractors, waterproofing contractors, mechanical contractors and electrical contractors all install firestops. Supervision of contractors can assure that manufacturer’s instructions are followed.

TPFD and TPFS are similar in several ways. Both:

- Must be used with an appropriate conductor fill. NEC identifies acceptable percentages of conductor fill for conduits, cable trays and other raceways.
- Must be used in rooms maintained at temperatures suitable for normal occupancy unless otherwise stated in the listing. Heat and air-condition these rooms as necessary.
- Are intended to be used only once.
- Must resist the spread of fire from either direction through a wall opening, unless otherwise indicated by the listing.
- Must resist the spread of fire through a ceiling (floor) opening from the underside.
- May require derating the conductors passing through a firestop. Many have not been investigated for this requirement.
- May be rated with an “F” or “T” rating stated in minutes or hours. To receive either an “F” or “T” rating, a firestop must also resist damage during a hose stream test. Penetration seals not

qualifying for "F" or "T" ratings may not be effective in preventing firefighting water and smoke penetration.

An "F" rating, which signifies the effective duration of firestopping during tests, is the length of time the firestop blocked the passage of flames. A "T" rating is the shortest duration of two measurements: the time for flames to penetrate the firestop or the time for the temperature on the unexposed side of the firestop to rise 325°F (181°C). The "T" rated firestop passes the more severe test and is more likely to limit damage during severe fires.

The TPFD and TPFS are not tested for their effectiveness against the spread of smoke or moisture. Some devices may require special seals. Consult the manufacturers.

TPFD (UL Classification #XHCR) are complete, factory-built, mechanical, "bolt-in" type assemblies installed to resist the spread of fire through openings of floors, walls or both, as stipulated by the classification. Electrical and mechanical system components that pass through the TPFD include electrical cable, conduit, pipe and cable trays. These components must be rigidly supported and be independent of the TPFD on both sides of the opening.

TPFS (UL Classification #XHEZ) are field-erected firestops. The specified components are installed to achieve specified ratings. Components are listed in four categories:

- Through Penetrating Products (UL Classification #XHLY) - Cables, conduits, pipes and tubing.
- Fill, Void or Cavity Materials (UL Classification #XHHW) - Mastics, mortars, putties, caulks, gaskets, sealants, wraps, batts, pillows and similar materials. Some are intumescent. Intumescent materials expand and char to form a tight seal when exposed to fire or intense heat.
- Forming Materials (UL Classification #XHKU) - Formboards, batts and sheets shaped to fit the opening to form and seal the fill during installation. These materials remain in place following the installation.
- Firestop Devices (UL Classification #XHJI) - Collars, frames, couplings and other fittings, some lined with intumescent material, designed to fit with specific TPFS applications.

PRC.5.5.4 provides additional information.

National Electrical Code® Construction Requirements

The NEC encourages the use of water spray systems and other loss control measures. The code allows the fire resistance ratings of walls and roofs of transformer vaults to be reduced from 3 hours to 1 hour if fixed automatic sprinkler protection is provided. The NEC describes barriers and other construction requirements for buildings, vaults and rooms housing electrical hazards.