Risk Solutions

Electrical and Electronic Equipment— Non-Thermal Fire Damage

Non-thermal fire damage, excluding water damage, to electrical and electronic equipment is caused by smoke and corrosive products generated from the combustion of materials, particularly plastics. The frequency and severity of losses due to non-thermal fire damage have increased in recent years, due to the increased use of thermoplastics in building materials and furnishing. Further, modern electronic equipment is sensitive to corrosive smoke produced by some thermoplastics. Because of this corrosiveness, telecommunication companies have initiated major research in the prevention and mitigation of non-thermal fire damage. This report examines non-thermal damage and discusses the fundamentals of non thermal damage, restoration technologies, and methods of prevention.

Non-Thermal Damage

Generally, non-thermal damage can be divided into two types: corrosive damage and non-corrosive damage. Corrosive damage results when the by-products of combustion combine with moisture, condense, and form acidic compounds on the surface of equipment. Electrical circuits and electronic components are at the greatest risk from this type of non-thermal damage. Non-corrosive damage, from soot and smoke, can cause a loss of product, cosmetic repair costs, and damage to electrical components by conductivity (i.e., shorting of circuits).

Corrosive Damage

The increased use of thermoplastics in the construction industry has brought complications to the fire protection field. Plastics account for a significant percentage (app. 10%) of the total building and construction materials used in the United States per year, with polyvinyl chloride (PVC) accounting for almost half of all the construction plastics used. Depending on the specific occupancy, it is not uncommon to find more than 25 percent of buildings' furnishings manufactured from PVC or similar compounds. PVC is a thermoplastic compound that softens when heated. In its solid form, PVC can be difficult to ignite and generally will self-extinguish when the heat source is removed. However, when PVC burns, it releases hydrogen chloride that is both toxic and corrosive. When hydrogen chloride combines with moisture, it can form hydrochloric acid (HCl). There are a number of other materials that when burned produce potentially corrosive gases, including Teflon (TFE). However, these materials typically produce hydrogen fluoride (HF), not HCl.

HCl has been found to cause corrosive damage to electrical equipment at relatively low concentrations. HF and other potentially

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corrosive gases do not corrode electronics until much higher concentrations are reached. The specific concentrations vary based on the relative humidity (RH), type of circuit exposed, and the concentration of corrosive material present. Typically, for corrosion to occur, the relative humidity (RH) must be greater than 30 percent at 68°F (20°C). Corrosive gases (i.e., chlorine ions) require water or another electrolyte at the metal's surface before corrosion can occur. Rapid corrosion occurs at between 70-80 percent RH.

Since corrosive hydrochloric gas at lower concentrations does not have a significant smell or optical density, the presence of HCl may not be noticed until after substantial equipment damage has occurred. The amount of these corrosive gases produced and the spread of contamination will be proportional to the volume of plastic-based products present and the intensity of the fire. The greater the volume of plastic materials involved in combustion, the higher the volumetric concentration of corrosive gases produced.

Non-Corrosive Damage

Non-corrosive damage includes the effects of relatively cool smoke and soot that condense on electronic equipment. The type of smoke and soot produced depends on the type of fire. Smoldering fires are typically low-temperature fires that produce particles heavily laden with non-conductive organic compounds. These particles, while not corrosive, condense and may cause insulating films that impair the contacts of electrical equipment. High-temperature fires produce particles that include vaporized metals and highly conductive graphitic soot. A continuous film of this soot causes electrical shorting.

Restoration

Restoration of electronic and electrical equipment typically provides cost savings of 80-85 percent over the replacement of the same equipment. Furthermore, sensitive equipment that may not be available for several months is typically back in service faster with restoration, reducing losses associated with business interruption.

Evaluation of Contamination

To determine which equipment has been contaminated, two methods may be employed. The quickest method is a chloride strip test. The second method employs wiping the surface of the equipment and dissolving the debris in solution. This solution is then titrated with silver nitrate. Any chloride ions would precipitate out as silver chloride. From the precipitate, the concentration of the contaminants can be determined. Once the concentration of the surface is known, appropriate measures may be taken.

Mitigation and General Salvage

Once the level of contamination has been determined, the following salvage strategy should be followed. These steps will also help to mitigate current and potential future damage from corrosive causes.

Secure Contaminated Equipment as Soon as Possible

The corrosion process does not stop when the fire does. Therefore, to stop the corrosion, equipment should be removed from the post-fire environment and placed into desiccated storage at a relative humidity less than ten percent. Corrosion is a function of time, and the more time that elapses before the equipment is either restored or secured to a controlled environment, the greater the damage.

Prevent the Contamination of Clean Equipment

After contaminated equipment has been secured, uncontaminated equipment must be protected. Protection can range from covering the equipment with plastic sheeting during cleanup and rebuilding, to removing the equipment and placing it in storage. Protection of uncontaminated equipment is essential to prevent corrosion problems from equipment that initially tested clear, and then was contaminated during overhaul.

Remove All Damaged Construction Parts

All building materials affected by the fire should be removed. Even charred materials can diffuse contaminants into the environment for extended periods of time.

Clean All Affected Areas

A high-pressure water spray can be used to reduce the contaminants present in a post-fire condition.

Start Rebuilding and Repainting

Charred surfaces should be replaced or painted to prevent the small, but continued evolution of corrosive fire gases.

Ensure Cleanup of Any Heating Ventilation and Air Conditioning (HVAC) Equipment

During a fire, the ventilation system, even if programmed to automatically shut down in alarm conditions, may get contaminated with corrosive compounds. Tests should be performed to ensure no recontamination of cleaned spaces when the HVAC equipment is turned back on.

Restoration Techniques

Soot composition changes over time. Therefore, the restoration process is as much of an art as it is a science. Before the disassembly of complicated equipment, photographs should be taken to ensure proper reassembly. Cleaning should be in accordance with the manufacturer's instructions. Disassembly should be extensive enough to reach surfaces contaminated by smoke. With computers, this may mean the removal of motherboards to reach the contaminated computer case, as well as the cleaning of fan blades of the power supply.

Basic Procedures

The most basic procedure for restoration is an eight-step process.

1. Use high-pressure air to blow off dust and soot.
2. Submerge equipment in an alkaline solution, such as methylene chloride, methyl isobutyl ketone, and methyl ethyl ketone, at a raised temperature. This serves to neutralize the corrosive attack, as well as dislodge soot particles.
3. Scrub the equipment and brush contaminants away.
4. Rinse the equipment with tap water.
5. Rinse the equipment with de-ionized water.
6. Perform a final inspection of the equipment for dislodged or damaged parts.
7. Reassemble the equipment as per the pictures and the manufacturer's literature.
8. Refurbish the outer casing of the equipment if required.

Modifications to Basic Procedures

There are a number of modifications to the basic restoration procedures above, which may be employed, including:

- As a substitute for using high-pressure air to blow off dust and soot; wiping, vacuuming, or lightly brushing may be used.
- Instead of submerging equipment in an alkaline solution, cleaning with steam/water blasting and detergents at 2,000 psi (137.9 bar); high-pressure sprays and solvents at 1,000 psi (69.9 bar); low-pressure sprays and solvents at 50 psi (3.4 bar), or detergents at 50 psi (3.4 bar).
- Vapor degreasing and ultrasonic cleaning may also be used as a substitute for submerging equipment in an alkaline solution.

An experiment by the Swedish Institute of Production Engineering compared three techniques: manual brushing, immersed high-pressure spray, and manual brushing with ultrasonic cleansing. The methods tested in the experiment, those that employed manual scrubbing as part of the technique, were able to remove all of the visible soot deposits. Only the scrubbing plus ultrasonic agitation removed chlorine ions down to the 0.1-micron range. Manual brushing is essential for the removal of soot particles, while ultrasonic cleansing is an effective treatment to get equipment back to a like-new condition.

Professional Resources

Modern electronic equipment often uses very sensitive components, which could be affected by temperature extremes and cleaning agents. While the above procedures are generally accepted, property owners should always consult with the equipment manufacturer for specific instructions. Because of the complex and time-consuming nature of the cleaning process, many property owners utilize third-party professional cleaning firms.

While using a professional cleaning firm is highly recommended, the property owner should evaluate the reputation of the company as well as any concerns for data security. Allowing disk drives, memory storage devices, etc., to be handled by a third party could expose the company to unauthorized release of sensitive or personal information. Property owners should request references and background checks and require that the service provider sign a non-disclosure agreement to limit the exposure.

Prevention of Non-Thermal Damage

While the cost of restoring non-thermally damaged equipment can be much less than purchasing new equipment, the cost of preventing non-thermal damage may be even more cost-effective. There are two main methods used to prevent non-thermal damage during a fire: prevent corrosive smoke and manage corrosive smoke's impact. Both of these methods not only reduce the damage from corrosive compounds produced during a fire, they aid in reducing non-corrosive contamination, as well.

Preventing Corrosive Smoke Generation

One method for preventing corrosive smoke generation is controlling the type of corrosive smoke evolved by the use of other materials for the manufacture of cabling (e.g., computer, telephone, and electrical wiring), building components, and furnishings. Alternate materials may include:

- Installing fire-retardant cabling using flame-retardant phosphate plasticizers in combination with chlorinated materials. These flame retardants volatize upon heating and help to prevent ignition, as well as limit the spread of chlorinated materials.

- Using ethylene vinyl acetate (EVA) cables. EVA cabling is made with low-smoke, non-halogenated materials that upon burning, emits low levels of smoke and corrosive gas.
- Eliminate PVC as a construction material. PVC is the source of most HCI evolved during a fire.
- Limit furnishings to materials having a Class A flame-spread rating.

Managing the Impact of Corrosive Smoke

Managing the impact of corrosive smoke is a difficult task. This is partially due to the immediate concern with the source of the corrosive smoke—the fire. This prioritizing of hazards makes the use of passive protection a reasonable alternative to active fire protection measures. Passive fire protection methods include the use of surface treatments, such as acid-neutralizing coatings, encapsulation, and smoke filters. Additionally, limiting smoke travel during and after a fire can significantly reduce the amount of contamination. Methods to reduce smoke travel include:

- Large areas should be subdivided or compartmentalized. By compartmentalizing a large, open structure, horizontal smoke spread is reduced.
- Ensure firewalls and fire barrier walls are properly installed and free of unsealed penetrations (i.e., holes). Properly-installed walls can provide effective means of protection against the spread of smoke and fire.
- Utilize self-closing fire doors between individual smoke compartments.
- Completely enclose all vertical openings in fire-rated walls and partitions to prevent smoke and fire spread.
- Provide mechanical smoke and heat vents. Smoke and heat roof vents are designed to operate manually or automatically through the fusing of a fusible link or a plastic dome that shrinks and falls from place when exposed to fire.

Telecommunication companies have put into practical use organic removal filters and reduced sulfur gas filters. Another technology makes use of an integrated filtration process, within the HVAC system, that removes vapors, soot, and corrosive gases. These types of systems could be activated in the event of a fire and provide the necessary environmental controls that would reduce potentially catastrophic non-thermal damage.

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