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Water Leakage Event Electronic and Mechanical System Damage Mechanisms

All water intrusion events have similar impacts on electronic, electrical and mechanical systems, differing only with the types of secondary contaminants dissolved within the water along its leakage path and the types of metals used in the systems. In many water damage events, where a large volume of city water is involved without passing through ceilings or walls, secondary contaminants are essentially negligible.

The impact of water on metal surfaces is highly dependent on the metal type, contact time, and most importantly whether the metal was powered (directly or indirectly) at the time of the event. Water impact to exposed metallic surfaces may be defined within five categories (in increasing level of impact):

- Water residue deposition
- Hygroscopic dust activation
- Oxidative corrosion
- Galvanic corrosion
- Electrolytic corrosion
- Short-circuiting, heating and arcing

The impact of water residue on a metallic surface, where corrosion has yet to occur, is simply that the deposited material may make the surface more susceptible to future corrosion during a high humidity event, particularly if the deposited materials contain any hygroscopic ("moisture absorbing") salts. Deposited residue should always be removed from metallic surfaces after a water intrusion event, when it is safe and non-disruptive to do so, both to avoid any potential long-term corrosion concern, as well as to easily identify the impact of any future water ingress or condensation problem.

Equipment that is already contaminated with sub-micron particles, deriving from outdoor ventilation air in particular, can experience current leakage and shorts when the relative humidity rises above the deliquescence point of salts contained in the pre-existing “dust” deposited on sensitive electronic circuits, such as those in telecommunications central offices and data centers. This mechanism is commonly referred to as “hygroscopic dust failures”. The hygroscopic dust failure mechanism remains an important concern after a water leakage or high humidity event. The cleaning of electronic circuit boards and backplanes of telecommunication switches and data center computer electronics is often recommended after such events because of this reason. A future EDC white paper will be produced to further discuss this potential, and often un-realized, damage mechanism.

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Oxidative corrosion is the most common impact of water (and moisture) on metallic surfaces, with the rusting of iron (forming ferric oxide) as the prime example. The degree of oxidative corrosion is highly dependent on the time that the water is in contact with the metal, the type of metal (iron is easily oxidized, aluminum is much less susceptible) and the amount of time that the wet surface is exposed to air before complete drying. The impact of oxidative corrosion may be measured by the amount of metal that is oxidized or more simply the depth below the surface that has been oxidized. Of importance to damage assessment is that oxidative corrosion tends to be a self-limiting chemical reaction (as opposed to galvanic and electrolytic corrosion or acidic gas contamination from a fire involving PVC). As a surface becomes oxidized, there are less metal molecules exposed to the air and available for further oxidation. Thus, surface oxidation of some metals (e.g., stainless steel) actually is a beneficial "surface passivation" mechanism that inhibits corrosion deep into the material. In other metals, such as copper, oxidative corrosion may take several different forms. In the presence of common atmospheric pollutants (sulfur oxides), copper will form copper sulfate, providing a "patina" green color that is often a desirable architectural feature. Under other circumstances copper will form cupric oxide ("copper tarnish"), a black non-conductive material that in electrical systems may make it difficult to gain a low resistance connection to copper buss bars. Fortunately, copper tarnish is readily removable by solvent or abrasive cleaning and further tarnish may be prevented through the application of an anti-oxidant coating to the copper surface.

Galvanic corrosion is actually a form of corrosion that may occur without direct water damage but is highly enhanced in the presence of water. Galvanic corrosion is essentially an electrochemical process that causes the removal of surface metal molecules (at the anode metal) when a low level current flow is created by contact between two dissimilar metals. Every metal has a unique electrical potential in the "galvanic series". Contact of dissimilar metals will allow a low level current to flow between the metals, depending upon the difference in potential between the metals. The anode of the metal pair is the sacrificial metal, loosing ions that are deposited on the cathode. The presence of water speeds up galvanic reactions in two ways. First, water may bridge dissimilar metals that are not normally in contact, creating a galvanic cell. Secondly, water contact may act as an electrolyte, enhancing the current flow between dissimilar metals that may already be in contact. The impact of galvanic corrosion often is limited to delicate electronics and occasionally the aesthetics of ductwork and other galvanized surfaces. It is interesting to note that the purpose of "galvanizing" steel surfaces (air duct sheet metal, conduits, and electrical panel encasements) is that the zinc plating is meant to act as a sacrificial anode to protect the underlying steel. For short length of exposures, galvanic corrosion is often not a factor involved in water leakage losses, except as related to the long-term exposure of galvanized conduit, electrical connector boxes and electrical panel interiors.

Electrolytic corrosion occurs as a result of water contacting powered metallic surfaces. The presence of water on powered equipment results in the creation of a continuous leakage pathway from the powered surfaces to ground. In a DC current system, this electrical leakage occurs from the battery providing continuous DC current, resulting in the immediate start of electrolytic corrosion. Electrolytic corrosion or "electrolysis", which produces a metal-carbonate (e.g., the blue-green colored copper carbonate), will continue until the power is eliminated. The continued creation of electrolytic corrosion for even a few minutes often results in non-repairable damage to circuitry and components of powered DC systems (e.g., fire and security alarm panels).

In AC powered systems, electrolytic corrosion is much less rapid and often results in much less damage due to the voltages involved and the thickness ("bulk") of the metals used in common AC powered building applications (e.g., switchgear, electrical panels, cabling and connectors). While electrolytic corrosion is devastating to microelectronics, since it often irreparably removes protective surface metals exposing base metals to rapid corrosion, it is often easily removable from AC electrical systems through simple abrasion of the corroded surface. This assumes that the corrosion product is fully removed, that the power was removed shortly after the system was impacted by water, and that no arcing damage has occurred as a result of shorts to ground. If the corrosion product is allowed to remain on powered surfaces, particularly within connectors where it is difficult to see, the surface will continue to corrode.

If left unattended, electrolytic corrosion will result in electrical failure due to high electrical resistance that develops at connectors. This resistance promotes heating at connectors or even within the current carrying member itself. Under worse case conditions, this heating can result in a fire. It is for this reason that electrolytic corrosion must be removed from all current carrying surfaces.

A more common concern with water intrusion into powered electronic systems that can occur at the time of the event is hard failures due to electrical short-circuiting. Short-circuits form when water bridges normally isolated conductors. Continued current flow produces electrolytic corrosion products that may also result in the bridging of isolated conductors. This can lead not only to electrical failure but also to arcing and fire if the current draw remains below the fusing current, causing excess heat to be generated.

It should be noted that electrical systems, electrical connectors, wires, conduit and most metallic and polymeric surfaces will not be damaged by non-condensing moisture in the air even at high relative humidities, assuming the lack of significant dust contamination. Clean electrical systems require condensed phase water to cause electrolytic corrosion. Galvanized metal, such as used for electrical conduit, is a specifically chosen material for high humidity conditions. The one concern with electrical systems in the presence of a moist environment is when they have been heavily soiled with airborne contaminants that are hygroscopic (water absorbing) in nature. Such contaminants often are deposited on indoor surfaces and derive from insufficiently filtered outdoor air used for ventilation. Such dust could impact systems that have been in place for numerous years. However, for new installations that have only been exposed to construction and renovation related dust (wallboard, concrete and common soil particles), damage to such surfaces would not be expected to occur solely due to high humidity.

For an environment that contains steam, such as within boiler rooms, condensing moisture is a significant corrosion issue for electronics and electrical systems. The degree of corrosion associated with such a steam environment would be significant (up to 2.2 mm depth per year for unprotected low carbon steel), making discrimination between water leakage or flood loss related and long-term ambient corrosive damages difficult to determine. However, there are several methods or pieces of evidence that makes this discrimination possible. For iron containing materials (sheet metal panels, screws, pipe, etc.), the color of the surface oxidation layer (i.e., rust) is often a distinguishably different color (more orange) for more recent water exposure than for rusting from the normal environment. For submergence events, we also look for evidence of standing water in unsealed electrical (e.g., light fixtures or electronic components such as relays). This evidence may include remaining standing water or an obvious water line within the components. A final piece of evidence often evaluated is the presence of electrolytic corrosion, indicting direct water contact while under power (as discussed above). Although electrolytic corrosion may be pre-existing to some extent, there is again color discrimination between recent (green) and longer term exposures (blue-green).

Interestingly enough, the National Electric Code (NEC) does not provide specific guidance for electrical equipment unintentionally exposed to water. The NEC only addresses the types of components (cables, enclosures, etc.) that may or may not be installed in potentially damp environments. However, the National Electrical Manufacturer's Association ("NEMA") provides the document "Guidelines for Handling Water Damaged Electrical Equipment". In this document, they state that in molded case circuit breakers and switches, direct water exposure can affect the overall operation of the mechanism through corrosion, through the presence of foreign particles, and through removal of lubricants. The condition of the contacts can be affected and the dielectric insulation capabilities of internal materials can be reduced. Also, some molded case circuit breakers are equipped with electronic trip units and the functioning of these trip units might be impaired. For fuses, the water may affect the filler material. A damaged filler material will degrade the insulation and interruption capabilities. These components are listed as required replacement when submerged in water. The same holds true for motor control switches.

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