In the case of a cable tray, the frequent movement of cables being installed or removed from the tray will easily dislodge the tiny metal filaments. This creates an invisible fine metal dust that can become airborne in the high volume of air movement in a data center or even in a plenum ceiling space.

ZINC WHISKERS:

Will Your Cable Support Destroy Your Network?

By Gregory Camburn, RCDD

Electronic circuits started becoming smaller in the early 1940s, and technologists began seeing unexplained equipment failures and searched for causes. In 1946, H.L. Cobb, technical librarian from Aircraft Radio Corporation (ARC), identified cadmium (Cd) whiskers growing up to several millimeters long from Cd-plated surfaces of variable air-spaced capacitors as the source of electrical shorting failures in radios used during World War II. These observations prompted a shift away from Cd toward increased use of tin and zinc coatings for corrosion protection of structural elements used in and around electronics. In 1951, a Bell Labs group reported zinc and tin coatings also sometimes erupt with metal whiskers.[1] Their reports showed metal whiskers growing from a wide assortment of mechanical and electrical components.

Since these initial discoveries, many have documented electronic failures caused by zinc whiskers, tin whiskers and cadmium whiskers, including failures in many private and government data centers, satellites and even heart pacemakers.[2] The world has also seen the data center raised-floor industry redesign its product offering to reduce or eliminate the use of zinc electroplating, which has been identified as a primary source of whiskers in the data center environment (see Figures 1 and 2).[3] An entire industry has sprung up to remediate older raised-floor systems that were built with zinc electroplated stringers, stanchions and tiles in order to rid these facilities of sources for massive zinc

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whisker infestations.[4] Today, however, one significant source of zinc-coated structures remains and is often seen in current data center design and construction—cable supports and cable trays.

What Is a Zinc Whisker?

The zinc whisker is a metallurgical phenomenon where very fine filaments of metal (whiskers) will grow outward from a zinc coating applied over a substrate metal (typically for corrosion protection). These whiskers are metallic; as such, they are good electrical conductors that can induce short circuits if they manage to bridge conductors at different electrical potentials. Zinc whiskers are typically only a few microns in width (less than one tenth to one one-hundreth the diameter of a human hair), and over many months and years, they can grow to several millimeters in length (see Figure 2). The narrow dimensions of whiskers can make seeing them extremely difficult. Proper illumination, angle of inspection and magnification can help improve the chances of seeing whiskers—sometimes even with the naked eye.

In extreme cases, the density of whiskers in terms of number per area can reach in excess of 10,000 whiskers per square centimeter although far less dense whiskering is more common. The growth process involves long-range diffusion of zinc atoms from within the zinc coating. As these atoms arrive at the base of a growing whisker, they may join the growing filament at its root (not the tip) pushing the whisker outward from the surface. The phenomenon occurs with a variety of metals, but it is of particular concern for zinc since it is the most common metal used to prevent corrosion of steel parts.

A raw steel product will oxidize (rust) very quickly upon exposure to air. Even in a climate- controlled atmosphere, such as a data center, raw steel will oxidize within months. A thin coating of zinc may prevent this oxidation for years. In a typical indoor environment, zinc-electroplated parts should last the service life of the building wherein they are used. Given its anti-corrosion effectiveness and low cost prior to environmental regulation, the zinc-electroplated finish has become the most common treatment for steel products in the construction industry, including communications and electrical cabling support systems such as cable tray.

Figure 1: Zinc whiskers growing on bottom of zinc-coated raised floor tile

Whisker Phenomena Threats

Despite nearly 70 years of research by industry, academia and major private and governmental research labs, there have been losses because of metal whiskers estimated to be in excess of a billion dollars in equipment and down time.[5] However, very little is known about the mechanisms of zinc whisker formation. At this time, it is impossible to accurately predict whether any individual zinc electroplated part will grow whiskers or to what extent in terms of the number per area and distribution of whisker lengths over time.

No specific environmental causes have yet been identified as essential for whisker growth (e.g., they will grow in both humid and vacuum conditions; under steady state temperature and temperature cycling). It is known that whiskers can grow from virtually any zinc-electroplated or hot dip-galvanized component at rates of about 1 mm per year (though growth rates are highly variable). Photographs of parts infested with zinc whiskers show them to be almost fur covered in appearance. However, other examples of whisker growth may contain far less dense formations.

One typical process for zinc whisker-induced failure of electronic systems involves the (unwitting) detachment of copious numbers of whiskers by human activity. In the case

Figure 2: Width of a human hair (60 to 100 microns) versus zinc whiskers (submicron to tens of microns)

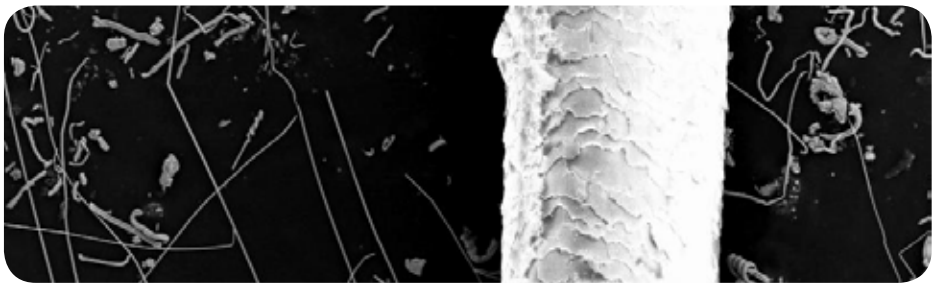

Figure 3: Relay destroyed by whisker-induced metal vapor arc

of a cable tray, the frequent movement of cables being installed or removed from the tray will easily dislodge the tiny metal filaments. This creates an invisible fine metal dust that can become airborne in the high volume of air movement in a data center or even in a plenum ceiling space. These whiskers are too small to be filtered by anything other than high efficiency particulate air (HEPA) filtration systems. Without such a system, the whiskers quickly find their way inside electronics enclosures. As loose conductive debris, the metal whiskers can bridge a pair of electrical conductors at differing electrical potentials and induce a variety of electrical shorting events, ranging from permanent and/or intermittent resistive shorts to extremely destructive metal vapor arcs that can cause either intermittent or complete system failure (see Figure 3).

Although we have explored the concept of zinc whiskers and the threat they pose to electronic devices, there is an additional factor which is even less known. The effect on human health because of aspirating zinc whiskers has not yet been directly studied. The Occupational Safety and Health Administration (OSHA) has studied other forms of zinc ingestion and found mixed results.[6] Zinc oxide and zinc chromate are toxic with the chromate falling into the category of hexavalent chromium.[7] Plain zinc granules, however, have much less restrictive regulation although they do have some MSDS restrictions.[8]

Another area of concern is the physical shape of the zinc whisker, which closely resembles the legal definition of asbestos—any inorganic substance with a length-to-width ratio of 100:1 or greater.[9] The end result is a substantial potential danger from exposure to zinc whiskers. This should be of special concern for installers and maintenance workers whose job may entail frequent whisker contact. It should also be a concern in environments where health is already compromised such as healthcare facilities.

Mitigating the Risks

Virtually all manufacturers of cable tray systems, whether steel wire basket, aluminum or steel ladder type, offer epoxy powder coat corrosion protection for their products. However, these powder-coated finishes are often applied after zinc electroplating. Some NASA research has shown that zinc whiskers can grow through a polyurethane adhesive coating if the coating is not sufficiently thick.[10] It is unclear whether this will also happen with epoxy powder coatings. It appears that the ideal finish would be an epoxy powder coating over bare carbon steel using stainless steel for electrical bonding. Because of EPA regulation on US domestic electroplating shops, from a manufacturing standpoint, the powder coat process is the same or lower cost as electroplating. Epoxy powder coat finishes have been shown to be as or more durable than zinc electroplating from a corrosion standpoint while eliminating the toxic waste that is a byproduct of the electroplating process.[11]

A powder-coated tray with electroplated bonding points has a good balance of risk mitigation versus cost. The vast majority of zinc-electroplated material is eliminated (or encapsulated with powder coat) with no cost penalty. For greater assurance, a powder-coated tray with stainless steel bonding points should virtually eliminate whisker-related risk. However, there is some added cost estimated at 10 to 20 percent because of the small amount of more expensive stainless steel versus carbon steel. In the most sensitive or mission critical environments, the small additional expense of stainless steel for exposed bonding points makes sense. Considerably more expensive options like using entirely aluminum and/or stainless steel trays are also available, but they do not appear to provide additional benefit versus powder coating and stainless steel bonding hardware. However, given the nearly 70 years of research and data we have on the risks associated with zinc whiskers, there is very little excuse for continuing to ignore the problem. ■

FOOT NOTES

[1] "A History of Tin Whisker Theory: 1946 to 2004", Dr. George Galyon, IBM eSG Group

[2] NASA GSFC Tin Whisker Investigation Team, http://nepp.nasa.gov/whisker/failures/index.htm

[3] http://www.asmproducts.com/zinc_whiskers.htm

[3] http://www.tateaccessfloors.com/pdf/technical_bulletin277_zincwhiskersrev1.pdf;

[4] http://www.dataclean.com/zinc-whiskers.htm

[4] http://www.wes.net/zincwhiskers.htm;

[5] http://www.calce.umd.edu/lead-free/tin-whiskers/TINWHISKERALERT.pdf

[6] http://www.osha.gov/SLTC/healthguidelines/zincoxide/recognition.html

[7] http://www.osha.gov/SLTC/healthguidelines/zincchromate/recognition.html

[8] http://cheville.okstate.edu/photonicslab/Safety/safety/MSDS/zinc_msds.htm

[9] http://www.michigan.gov/documents/cis/iv_routine_analysis_chapter2_cim_2006v042_175833_7.pdf

[10] http://nepp.nasa.gov/whisker/reference/slides/tw_study/index.htm

[11] http://www.epa.state.il.us/small-business/electroplating-shops/