Are unexplained short circuits plaguing electronic equipment? If it's operating in a raised-floor data center, zinc whiskers growing from the floor tiles could be the cause.

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Zinc Whiskers: Hidden Cause of Equipment Failure

During a one-month period, a NASA data center experienced at least 18 catastrophic power supply failures in newly installed mass memory storage devices. The ensuing failure investigation determined that the causes of failure were electrical short circuits. But what had prompted such repeated short circuits in modern, typically reliable systems? The investigation concluded that for many years small metallic filaments, practically invisible to the unaided eye, had been growing from the underside of the raised floor tiles and floor support structures. Maintenance activity to install the new equipment dislodged many of these conductive filaments, which were then distributed throughout the data center by the forced-air cooling systems. Many of these particles were drawn into the equipment power supplies, where they bridged exposed conductors, causing electrical failures. Only then did the data center managers become acquainted with the phenomenon scientists call *zinc whiskers*.

If you manage a data center, especially one that sits on a raised floor, zinc whiskers might eventually have an impact on your operations.

Inside

WHAT ARE ZINC WHISKERS?

Zinc whiskers, as the name implies, are tiny hair-like filaments of zinc that actually grow from certain zinc-coated metal surfaces. Figure 1 shows zinc whiskers, which are typically less than a few millimeters long and only a few thousandths of a millimeter wide. Because of their miniscule dimensions, zinc whiskers can be extremely difficult to see without magnification and proper illumination.

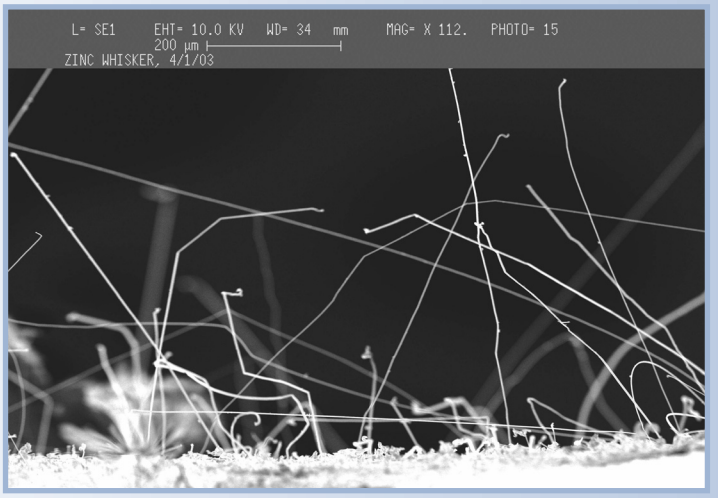
The whisker formation process consists of an unpredictable incubation period—typically lasting months or even years without any growth at all—followed by a period of growth at rates as high as 1 mm/year. Many zinc-coated surfaces may never grow whiskers. Unfortunately, accelerated techniques do not currently exist to predict if, when, and to what extent a zinc-coated surface will produce zinc whiskers.

Despite the first identification of zinc whiskers in the 1940s, their precise growth mechanism remains unknown today. In the decades since, research aimed specifically at the zinc whisker phenomenon has been limited. However, during this same time, researchers have written more than 100 reports or studies about tin whisker formation, a process that many agree is closely related to the zinc whisker phenomenon. Even with the large effort to study tin whiskers, identification of their growth mechanism(s) has also remained elusive. The NASA Goddard Tin Whisker (and Other Metal Whisker) Web site (http://nepp.nasa.gov/whisker) lists many of the available reference materials on the subject of tin and zinc whisker formation.

1520-9202/04/$20.00 © 2004 IEEE

Published by the IEEE Computer Society

Figure 1. Zinc whiskers (here, magnified 100×) growing on the underside of a raised-access floor tile.



Many of these whiskers are 1 mm or more in length.

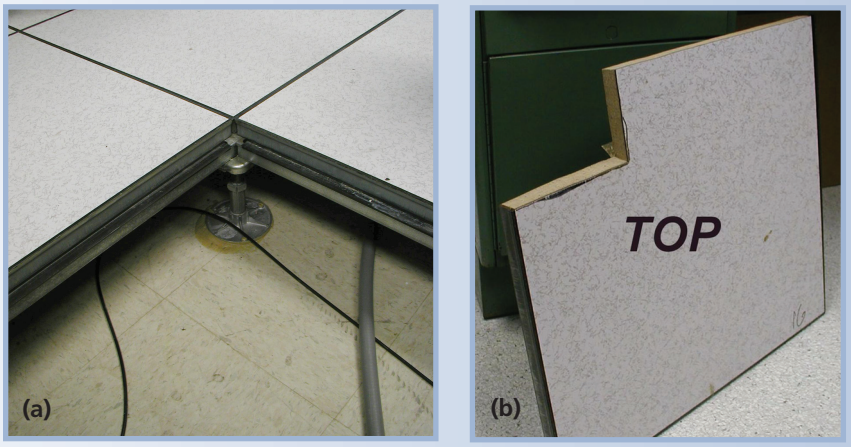
WHERE DO ZINC WHISKERS GROW?

Zinc whisker growth has been documented on a wide range of zinc-coated materials including electrical components (such as electromagnetic relays) and mechanical hardware (such as nuts, bolts, washers, equipment racks, housings, and rails). Recently, however, the most frequently reported source appears to be the zinc-plated underside of the raised-access floor tiles and the support structures (pedestals and stringers) commonly used in computer data centers. Figure 2 shows a typical raised-access floor system.

Raised-floor tiles, pedestals, and stringers are often constructed from steel to provide adequate strength. A thin zinc coating—from electroplating or hot dip galvanization (HDG)—is commonly applied to protect the steel from corrosion. This thin zinc film is at risk for forming zinc whiskers over time. Figure 2b shows one type of access floor tile known to form zinc whiskers. Figure 3 shows the tile's underside; a high-intensity light held parallel to the surface reveals what appear to be fuzzy dust-like formations. Closer examination reveals that the dust-like appearance is actually millions of zinc whiskers shown magnified in Figure 1.

Investigators have reported many cases of zinc whiskers growing on zinc-electroplated structures, and some report that HDG coatings are immune to the whisker phenomenon. However, we have recently seen one report citing evidence of zinc whiskers (some as long as 0.3 mm after one year in service) growing on floor tiles and support structures that the manufacturer advertised as HDG. So we recommend caution when using any zinc coating in applications where zinc whiskers could pose a hazard.

Figure 2. Typical raised-access floor system.



A data center floor system with one tile up, permitting a view of the supporting pedestals and stringers; such a raised-floor arrangement facilitates underfloor cable routing. The subfloor space also serves as an air plenum (a). In this top and side view of one type of floor tile (b), cutting a tile reveals a vinyl top surface attached to a 1 inch thick wood fiber core. The core has a thin sheet of zinc-electroplated steel attached to its bottom and sides.

In the case of the NASA data center, investigators observed whisker densities on the order of millions per single floor tile (each with an area of 4 square feet). At the time of the equipment failures, these zinc-electroplated floor tiles were approximately 10 years old.

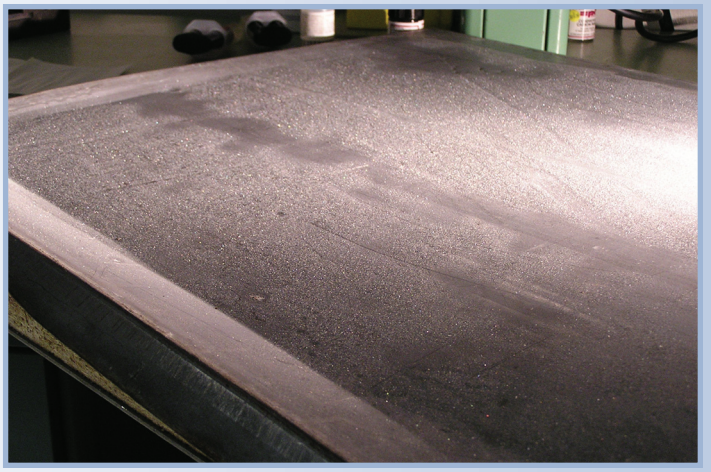
Zinc whiskers on the underside of raised-floor structures might seem to be a long distance from electronic systems that operate above the floor. However, the NASA review determined that routine maintenance activities in the data center—including the lifting, sliding, and reinstalling of access

floor tiles and the pulling of electrical cable in the subfloor space—could dislodge whiskers. Because of a whisker's small size and weight, the subfloor, forced-air cooling system can easily redistribute whiskers throughout the facility.

For efficient cooling, the forced-air system typically pressurizes the subfloor space with chilled air. Perforated floor tiles and air vents provide channels through which the cool air—and along with it, zinc whiskers—can pass into the above-floor space. Ultimately, many whiskers can pass into the electronic hardware through vents and fans on the equipment. Once inside the equipment, zinc whiskers can cause various electrical failures, ranging from intermittent to permanent short circuits.

Whisker debris can also become a physical impediment to moving parts or obscure optical surfaces and sensors within some equipment (such as disk or tape drives). Figure 4 shows a graphical representation of this zinc whisker failure mechanism.

Figure 3. Underside of the zinc-electroplated-steel floor tile in Figure 2b.



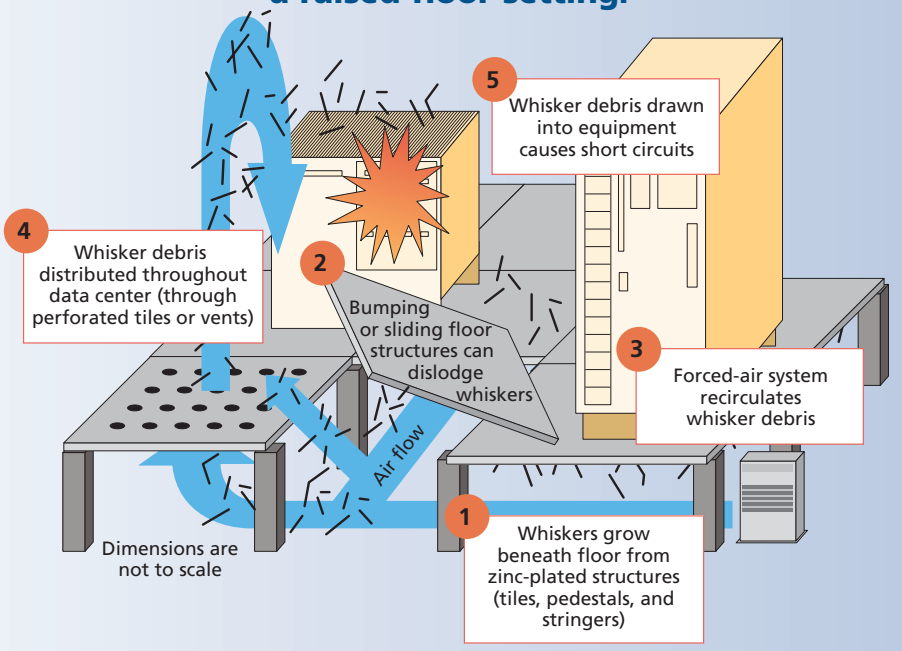
The sparkling dust-like surface is actually millions of zinc whiskers shown magnified in Figure 1.

WHEN TO SUSPECT A ZINC WHISKER ATTACK

A review of the published literature and discussions with several other affected organizations have revealed the following common attributes of most zinc-whisker-caused failures in data centers:

- Inexplicable system failures began concurrent with (or within weeks of) maintenance activities requiring the handling of or impacts to floor tiles. Power supply failures are the most obvious because of the impact they have on system operation. However, failures of other electronic systems (logic cards, motherboards, memory devices, and so on) can also occur with less obvious but potentially serious effects.
- Newer equipment seems to be more susceptible to failure than older equipment.
- Equipment located adjacent to floor vents seems more susceptible to failure.
- Users might not thoroughly investigate periodic or intermittent system failures unless permanent hardware failures begin to occur or substantial system downtime occurs. Invoking service contracts and warranties sometimes means that problem investigation stops as soon as the vendor supplies replacement equipment.

Figure 4. Zinc whisker failure mechanism in a raised floor setting.



Resources

- "Are Zinc Whiskers Growing in Your Computer Room?" R. Hill, Data Clean Corp.; http://www.dataclean.com/pdf/zincwhiskers3.pdf.
- "Testing Your Mettle: Zinc Whiskers in the Data Center," B. Brown, Network World, Nov. 2004, http://www.nwfusion.com/news/2004/110104widernetwhiskers.html
- "Pesky 'Whiskers' Zap PCs in Secretary of State's Office," Aldo Svaldi, *The Denver Post*, 1 July 2004, pp. C-01.
- "Precautions Against Zinc Whiskers," Compaq Corp., *Power Requirements for Non-Stop Himalaya Servers—429905-001*, http://h71033.www7.hp.com/TechPubs/PDF/Power_Requirements/TPSEC05.pdf.
- "What Nasty Little Things Are Lurking Inside Your Data Center?" S. Tucker, *Unisys World Monthly*, Nov. 2002; http://www.unisysworld.com/monthly/2002/11/whiskers.shtml.
- "Zinc Whisker Abatement," Worldwide Environmental Services; http://www.wes.net/field_engineering_services-zinc_whisker_detail.htm.
- "Zinc Whiskers: Could Zinc Whiskers Be Impacting Your Electronics?" J. Brusse, Apr. 2003; http:// nepp.nasa.gov/whisker/reference/tech_papers/Brusse2003-Zinc-Whisker-Awareness.pdf.
- "Zinc Whisker Contamination: A Paper on the Effect and Abatement of Zinc Whiskers in Data Processing Centers," D. Loman, HP Services; http://www.dataclean.com/pdf/ZincWhiskerWhitePaper.pdf.
- "Zinc Whiskers Growing on Raised Floor Tiles are Causing Conductive Contamination Failures and Equipment Shutdowns," The Uptime Institute; http://www.upsite.com/TUIpages/tuiflashzinc.html.
- "Zinc Whiskers on Floor Tiles," Infinite Access Floors; http://www.accessfloors.com.au/zincwhiskers.htm.
- "Zinc Whisker Induced Failures in Electronic Systems," ERA Technology, Winter 2003, http://www.era.co.uk/news/rfa_feature_06.asp.
- "Whisker Alert," Japan Electronics & Information Technology Industries Association (JEITA), Jan. 2002; http://it.jeita.or.jp/infosys/info/whisker/ (in Japanese).

- Failure investigations (and corrective action) frequently consider electrical power spikes or inadequate cooling as the problem sources before identifying zinc whiskers as a suspect. Techniques for investigating these other causes might involve significant handling of floor tiles and can actually generate additional whisker-induced problems.
- Most data center managers have never heard of zinc whiskers until the problem affects their systems.

CAUSES FOR RENEWED INTEREST

During the course of this problem investigation, engineers supporting NASA Goddard Space Flight Center learned that numerous organizations (financial, engineering, educational, governmental, and so on) have experienced problems with zinc whiskers, as the "Resources" sidebar indicates. Several factors appear to contribute to the apparent increase in reported failures:

- *Continuous miniaturization of electronic components.* Technological advances have led to more densely packed circuitry and tighter spacing between conductors. As a result, smaller conductive particles can now cause short circuits.
- *Reduction in circuit voltages and currents.* Many newer electronic systems operate at lower voltages and currents. Energy available from these components might not be sufficient to melt a zinc whisker, resulting in increased risk for permanent shorts.
- *Age of existing floor structures.* Many facilities have zinc-electroplated floor structures that are 10, 20, or 30 years old or more. Thus, where zinc-electroplated floor structures are in use, whiskers have had time to grow to lengths capable of bridging exposed conductor spacings in most modern electronic systems.
- *Increased maintenance and upgrade activity in raised-floor facilities.* Any activity in the raised-floor facility that involves handling or moving floor structures can potentially dislodge zinc whiskers, if the structures are already infested with these growths. In today's high-technology environment, it is more commonplace for computing facilities to undergo regular maintenance activity to perform tasks such as adding or removing hardware; repositioning or reconfiguring the equipment; or general troubleshooting.

Other concerns, such as those we discuss in the "Potential Health Hazards?" sidebar could also become a problem.

REMEDIATION

The affected NASA data center implemented some short-term corrective actions while evaluating long-term solutions to its zinc whisker problem. The short-term corrective actions included replacing the affected power supplies; the new power supplies came with a protective insulating compound that coats most of the exposed electronic circuitry. This coating will minimize (not necessar-

ily prevent) the risk of future power supply short circuits from zinc whisker debris.

The affected data center also reduced activities that require the significant handling of floor tiles.

For long-term solutions, NASA is evaluating proposals from industry professionals that include, but are not limited to

- the carefully planned and controlled removal of all affected or suspicious tiles and support structures, while protecting equipment and personnel;
- thorough cleaning of the data center environment, using vacuums with HEPA (high-efficiency particulate air) filters to remove as much whisker debris as possible; and
- the installation of replacement floor structures that are not prone to zinc whisker formation, including all-aluminum or steel structures with conductive epoxy powder coatings or paints instead of zinc for corrosion protection.

Simply washing whisker-infested materials is not an effective long-term remedy. Whiskers can grow back. And though cleaning and then coating whisker-prone surfaces might work, whiskers could possibly grow through some conformal coatings, depending on their properties and thicknesses. Long term testing is certainly needed to validate such remediation approaches.

Data center managers should take zinc whisker identification, detection, and mitigation seriously. Improper procedures could produce additional hazards and failures. Rather than attempt to conduct these activities alone, organizations at risk for zinc-whisker-related problems should seek expert advice. Possible information sources include the suppliers of electronic hardware; the original supplier of the floor structures; professional data center cleaning or disaster recovery companies; and professionals in medicine, or occupational health and safety.

We encourage data center managers to review equipment maintenance records as well as the equipment self-diagnostic fault logs for abnormally high failure rates. Such trends, especially if concurrent with floor-handling activities, could indicate an active zinc whisker problem.

Unfortunately, this zinc whisker failure mechanism appears to be quite widespread, while awareness by facility or data center management personnel appears to be rather limited. We hope this report will help other organizations to identify a potentially serious hazard *before* they experience problems. ■

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Potential Health Hazards?

Our investigation of the NASA data center raised concerns about potential health hazards from zinc whisker exposure. NASA is still reviewing this issue, but our initial research did not identify any specific studies or published guidance.

Several sources discuss the toxicity of zinc in other forms, particularly zinc oxide in the form of granules, powder, fumes, and dust. In these forms, zinc seems generally benign when inhaled or swallowed, except in very high concentrations. Inhalation of zinc fumes can have more serious effects. Various informal reports on zinc whiskers suggest no health implications from exposure; however, these reports lack cited references from medical or occupational-health professionals.

Other research suggests that the shape of airborne fibers can be an important factor regarding the potential pathologic effects on the lung, specifically a length-to-width ratio of 100 to 1 or greater. Zinc whiskers commonly exceed this ratio.

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We acknowledge the NASA EEE Parts Assurance Group (NEPAG) for its support in investigating tin and zinc metal whisker formations. We also thank Henning Leidecker (NASA Goddard) and Jong Kadesch (Orbital Sciences Corp.) for their invaluable participation on our metal whisker investigation team at the NASA Goddard Space Flight Center.