Reactor Shutdown: Dominion Learns Big Lesson From A Tiny 'Tin Whisker'

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Waterford — During the first 24 hours of a sudden nuclear reactor shutdown at Millstone Power Station this spring, technicians zeroing in on a computer malfunction as the culprit were stumped.

Two technicians for Dominion Nuclear Connecticut and their supervisor, Timothy Reyher, figured out that a computer circuit card had signaled an unsafe drop in pressure in the reactor's steam system, as if there were a break in a steam line. The condition led safety systems to automatically shut down the reactor, as they are meant to do, and brought the electric generator to a halt.

The problem, recalled Reyher, was that the pressure was not, in fact, low. The card, also called a digital logic card, had no obvious signs of wear or damage, like burn spots or discoloration. Yet repeatedly, the card failed tests aimed at replicating the correct electrical signal.

It was then, said Reyher and lead engineer Keith Deslandes, that one of the technicians picked up a magnifying glass and took a closer look.

“They saw something different,” Reyher said, “and they asked themselves, ‘What can this be? A piece of solder? Something's there. Let's take a picture.' ”

Within a few hours, under a high-powered microscope, they spotted a thin filament of metal, barely visible to the naked eye, spanning the card's surface and bridging a line of conductive material, called a trace. That metal fragment, they would soon learn, had single-handedly caused the electrical short that gave a false low-pressure reading and forced an unplanned shutdown.

A day later, after the Unit 3 reactor had accidentally “tripped,” and at a time when the only other operating Millstone reactor was shut down for refueling, Dominion workers realized the problem was due to a tiny “tin whisker” — an anomaly well-known to the electronics and space industries, but not, as yet, familiar to purveyors of nuclear power.

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The tin whisker is a phenomenon the National Aeronautics and Space Administration (NASA) has been tracking since the 1940s. A whisker's tendency to disrupt electrical flow has disabled satellites and interrupted service to companies like DirecTV and National Public Radio, according to information from the Goddard Space Flight Center.

The tin whisker that shorted out at Millstone's Unit 3 reactor on April 17 triggered an automatic shutdown designed to protect the reactor, but that is not what worries the Nuclear Regulatory

Commission. Rather it is that the tin whisker could prevent a safety system from working properly, said NRC spokesman Neil Sheehan, whose agency is responsible for overseeing safe operations in the industry.

Engineering experts at the NRC, including Thomas Sicola, are now studying Millstone's recent brush with the tin whisker and drafting an “informational notice” to alert the industry.

Dominion has already notified reactor owners in the United States and abroad. One owner, whom the company would not name, even borrowed Dominion's high-powered microscope to look for tin whiskers, Deslandes said.

The nuclear power industry has turned to NASA for more answers to questions on the potential havoc that the minute slivers of metal might wreak at a reactor.

According to Sicola and the NASA Web site, the presence of a tin whisker is as unpredictable as it is difficult to detect.

Scientists began to note the phenomenon after engineers and electricians tried to reduce the amount of lead in digital circuitry. They began to make circuit boards and digital logic cards out of pure, or nearly pure metal, the NASA Web site states.

Whiskers can form not only from tin but from other metals such as zinc, gold and cadmium. They might be dormant for years, or grow spontaneously but inexplicably from a micron wide and a few millimeters to 10 millimeters long, the Web site states.

According to Reyher and Deslandes, Millstone's circuit card was 97-percent tin and made by Westinghouse Nuclear, facts ferreted out by the company in conjunction with analysis by

Massachusetts Materials Research Inc. The lab, in West Boylston, has been in business for more than 30 years, said Kevin Pelletier, a sales and marketing manager.

“We've seen tin whiskers before, but never related to a nuclear power plant,” Pelletier said after consulting with Fahmida Hossain, the lead materials engineer at the lab who examined Dominion's specimen.

The lab refused to comment further, saying the analysis was confidential.

On the morning of April 17, the tin whisker was directly responsible, Deslandes and Reyher said, for triggering the shutdown. While it did not cause the problems that followed, those problems ultimately prevented the company from restarting the reactor for two weeks.

In the aftermath, NRC inspectors told the regional Nuclear Energy Advisory Council at a public meeting on May 18 that they want to know why a sealant, called packing, around two valves in the reactor's cooling system, leaked, and why a fastener on a tool that acts like a shock absorber to protect against a seismic event, was missing.

The inspectors also said they are looking into Dominion's training practices, because the way workers and supervisors communicated about the source and extent of the problem during the shutdown led to a public alert that, in hindsight, was not necessary. NRC inspectors told NEAC they are reviewing their findings and Dominion's analysis of those complications, and could cite the company for violations.

“We have not seen a ‘tin whisker' cause this much of a system response,” said G. Scott Barber, the NRC team leader and a senior project engineer.

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The chance, however remote, that a tin whisker could disable electronic safety features and keep backup systems, like those that cool the reactor, from operating properly is a chance federal regulators and companies like Dominion are not willing to take, said Sheehan at the NRC and Dominion spokesman Pete Hyde.

In a way, the April 17 shutdown was “a good thing,” Sheehan said, because the electrical short induced a variety of systems to shut down and, thus, protect the reactor.

“You want the system to detect problems at the very initial stages rather than later,” Sheehan said, “so the system functioned as it should.”

That said, Sheehan and David Lochbaum, an engineer with the Union of Concerned Scientists, an independent nuclear watchdog, agree that the tin whisker phenomenon is one the industry ignores at its peril.

“On the plus side,” Lochbaum said, Millstone's experience “shows that, in most cases, the nuclear power plant is designed to shut itself off if a failure occurs. We call it the fail-safe option. The bigger concern would be if you had a tin whisker that prevented a safety function from occurring, like finding out the air bag is broken after you've hit another car. That's not the time to find out.”

In addition to writing up an informational notice, NRC officials at headquarters in Maryland are considering issuing a letter on

requirements for the industry to prevent and deal with tin whiskers, said Sicola.

“The nuke industry is one of the only industries that actually shares information as broadly as possible,” Hyde said. “It doesn't matter if it's a competitor; that's part of the reason the industry is doing better.”

Dominion officials have already reacted to the lessons of April 17. The company removed, photographed, cleaned and inspected 103 computer monitoring circuit cards at Unit 3 and replaced four that showed signs of tin whiskers, Hyde said. They took similar steps for two comparable safety systems at Unit 2, Deslandes said.

Dominion has also started a new preventative program to require thorough inspections for whiskers during every refueling outage — about every 18 months. Up to 50 technicians in Millstone's instrumentation and control department are being trained to spot the whiskers, Reyher said.

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Reyher has worked in the industry for 30 years — 10 of those at Millstone — while Deslandes has been at Millstone for his entire 23-year career.

In all that time, neither had come across a tin whisker.

Despite the substantial research by NASA, scientists still don't know exactly how whiskers grow or when they are most prone to sending electric current to ground in circuit boards, relays and other electrical equipment.

“If I could describe how tin whiskers develop,” said Sicola, who is working on a master's degree, “I'd be getting a PhD.”

What's more, Deslandes said, a tin whisker can vaporize after shorting out, leaving no clues whatsoever.
That did not happen on April 17.
“In this case — if you want to call it lucky — the whisker was still there,” Deslandes said.
NASA research has recorded the fastest tin whisker growth at 9 millimeters a year, Sheehan said, and whiskers can take up to two years to grow long enough to do damage. So inspections for tin whiskers every year and a half — at refueling outages — seems reasonable, for now, he said.
And once the cards are cleaned, Reyher said, the growth rate is more predictable.
Lochbaum, who is often critical of Millstone and nuclear proponents, praised Dominion's initiative in dealing with the problem.
“I think they went beyond what the NRC's expectations were,” he said. “I would not have expected the average nuclear power plant owner to do all of those steps. Many of them would have stopped at replacing a bad card and that would have been it.”
The NRC's warning to the industry will do a lot of good, Lochbaum said.
The tin whisker “needs to be on the list of things you ask and answer. Right now it's probably not on most people's list. Two years later, it's kind of going to be tough to say you didn't know about it.”
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For more information on the tin whisker, visit: (http://nepp.nasa.gov/ whisker/index.html).

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